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International Biological Program
Canadian Committee for IBP
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International Union for Conservation of Nature and Natural Resources
Commission on Ecology of IUCN

The University of Alberta

Proceedings of the Conference
on

Productivity and Conservation in Northern Circumpolar Lands

Edmonton, Alberta

15 to 17 October 1969

Published with the assistance of the Atlantic Richfield Company.

International Union
for Conservation of Nature and National Resources
Morges, Switzerland, 1970

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Edited by W. A. Fuller and P. G. Kevan

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Preface

Much of what normally would be placed in a preface is covered by Dr. Fuller's opening address. The Conference on Productivity and Conservation in Northern Circumpolar Lands was planned as a 'working conference of experts' to discuss the arctic environment in terms of its potential in terrestrial biotic productivity and how best this can be maintained, and perhaps augmented, by reasonable conservation and management practices. These considerations are immediately important in the light of the present economic potential, particularly from non-renewable resources, in all arctic regions. The discussions resulted in recommendations to government and industry through which it is hoped a maximization of all the benefits (in the broadest sense) offered by the arctic can be achieved. The preparation of these proceedings is intended to make the workings, discussions, recommendations, and resolutions of the conference available to the public so that people whether directly or indirectly involved in the north can better understand the need for care, thought and caution when considering the exploitation of anything in the arctic.

The sequence in which these papers are presented here differs slightly from that of the Conference sessions. We have accommodated the affinities between contributions, the overlap of material, and the presentation of additional and substitute papers. This volume is intended as a unit demonstrating the integration of the arctic ecosystem, with and without man.

The volume starts with greetings, opening addresses and introductions. The stage is then set in terms of climate, permafrost, biotic communities, and the importance of the fauna and flora. The subject of productivity is next broached with discussions of plant productivity and associations. This leads into considerations of animal population fluctuations and the importance of small mammals in tundra ecosystems. Then the economic values and the biologies of arctic-foxes, polar bears, reindeer and birds are discussed. With man's exploitation of animals come problems in their conservation. These are aired in a series of papers dealing with endangered species, and the problems of fauna conservation generally and in specifc areas.

The next six papers (numbered 24 to 29) deal particularly with the direct effects of man on the tundra. These point out what has happened and what is happening to specific tundra areas, and what should be done and what is being done to prevent further degradation of the land. These discussions mesh with earlier papers on permafrost, as well as falling into perspective under general conservation.

From the effects of man on the tundra the course of presentation continues with Dr. A. W. R. Carrothers talk on human resources, which he delivered as guest speaker at the Conference banquet. Four specific papers on human resources (numbered 31 to 34) consider Northern people as conservationists and the establishment of natural areas and parks to augment northern economy through tourism.

The next two presentations (35 and 36) are particularly important as they deal with the legislative and governmental problems, short-comings and projections. These constitute the legal workings and thus the effectiveness (actual and potential) of conservation measures in the North.

The resolutions which follow, were synthesized from many submissions solicited during the Conference including one which is included as an appendix. There was little dissension, as they represent well the views and concerns of the participants.

Dr. F. Fraser Darling's concluding summary, drawing on all aspects of productivity and conservation, demonstrates the close inter-relationships of all the subjects discussed throughout the Conference.

We would like to thank all the contributors to this volume for their assistance, patience with questions and promptness in replying. Special thanks are due to Mrs. Vivian Field without whose industriousness and perseverence the completion of this volume would have been considerably delayed, and to IUCN and Sir Hugh Elliott, secretary of IUCN's Commission on Ecology, for help in publication.

Editors: W. A. Fuller,
Conference Organizer
Peter G. Kevan,
Conference Co-ordinator

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Paper No. 1

Opening Address

W.A.FULLER[1]

Ladies and Gentlemen:

This is primarily a meeting of biologists and more particularly of ecologists. That is, people whose profession is understanding the natural world in which we live.

Until recently ecologists have been hesitant to speak out on issues that involve us all. There have been some outstanding exceptions—William Bogt and Fairfield Osborn in 1948, a few lonely voices in the 1950's,Rachael Carson early in this decade, and now a considerable out-pouring. It is encouraging that books like Paul Ehrlich's 'Population Bomb' become best sellers and that environmental pollution is now on everybody's mind. Before going farther I should expose to you some of my own biases. I am a zoologist and for the past ten years I have been an academic. Prior to that, for twelve years, I lived in the North as a civil servant.

I am not an Arctic specialist. My interest in Arctic conservation began in 1963 when I observed cat tracks on the north slope of Alaska west of Point Barrow. Dr. Peter Lent, who is here today, and who at that time was a graduate student at this University, pointed out to me that those tracks were up to twenty years old and were still getting wider! That was my first introduction to the fragility of permafrost. As I watched exploration increase in tempo I was concerned that great areas of the Arctic could be rapidly altered, probably for the worse, by exploration parties either through ignorance or outright carelessness. Accordingly, I began to work within the International Union for the Conservation of Nature to stimulate interest in the Arctic. I suppose the fact that it has taken nearly five years to mount this conference is a commentary on how little the world's biologists knew or cared for the Arctic. The discovery of oil in Prudhoe Bay suddenly focused the spotlight of world attention on the Arctic. I am still undecided, in my own mind, whether it would have been better to hold the conference *before* Prudhoe Bay or not. At any rate, we are now gathered here to assess what we *do not* know about the Arctic ecosystems and the probable results of human impact on them unless we proceed with great care.

We have among us academics from the U.S.S.R., four Scandanavian countries, and Great Britain as well as Alaska and Canada. We also have civil servants charged with a responsibility for promoting northern development without permanent unnecessary damage to the countryside. We have representatives of several major oil companies actually working in the Arctic, and we have ordinary citizens; especially, I am pleased to say, several representatives of the indigenous people who are most directly affected by Arctic development.

We are not here to condemn but neither are we here to whitewash. My personal philosophy is that development is inevitable but I feel very strongly that total destruction of the environment must not accompany that development. There must be ecological cost/benefit studies as well as economic ones.

The conference was planned from its inception as a *working* conference of experts. The discussions are expected to result in specific recommendations and resolutions to government and industry. To this end a Resolutions Committee is being formed under the Chairmanship of Professor Cragg and the resolutions will be discussed on Friday afternoon.

Now for some announcements. First, it is a pleasure to thank publicly all of our sponsors. You have seen the names of our initial sponsors on the letterhead used in correspondence with you. These are: The University of Alberta, the International Union for the Conservation of Nature and Natural Resources, the Department of Indian Affairs and Northern Development of the Canadian Government, the Canadian Committee for the International

[1] Department of Zoology, University of Alberta, Edmonton.

Biological Program and the International Biological Program. Well after the letterhead was printed we received from Atlantic Richfield Company, through the good auspices of Professor S.Dillon Ripley, a further contribution which I am particularly happy to acknowledge now in public.

I must also express my thanks to a number of helpers. Mrs. Vivian Field has handled the correspondence and many details of bookkeeping and the arrangement of transportation for speakers and various other things, too numerous to mention, in a most capable manner. We are indebted to Mr. Andrei Raszewski, a graduate student in the Department of Zoology, for translation of several papers by our Russian colleagues that were submitted initially in the Russian language. We are also indebted to Dr. Emil Kucera for the translation of one paper and to Dr. Roland Beschel for undertaking the translation of Dr. Alexandrova's paper. I wish to offer special thanks to Roland Beschel because the correct translation of a botanical paper would be a considerable problem for us simple zoologists. Mr. Raszewski and Dr. Kucera have also offered their services as interpreters for our Russian guests during the conference. Finally, there are half a dozen students in the Zoology and Botany Departments who have stuffed envelopes and acted as welcoming committee and drivers. These activities have been admirably co-ordinated by Mr. Peter Kevan who has also done much of the last minute arranging.

I would like to ask the speakers to look over the preprinted version of their paper and make any corrections they would like to make in the text and return to us one initialled copy of their paper that we could use for publication. This can be done anytime during the three days of the conference.

It is also necessary for us to know how many of you will attend the banquet at the Faculty Club for which a separate charge is being made. There will be an information desk just outside the door of this room and I would ask you to inform the people there of your intention to attend the banquet.

I would also like to draw to your attention that all delegates to the Conference may become temporary members of the Faculty Club of the University of Alberta. To do this it is only necessary to show your badge to the girl at the entrance to the Club and complete a temporary membership form. She will then issue you a temporary card with a number on it which is to be used when making purchases at the Club.

On Wednesday evening, at the Coachman, there will be a film program. A number of delegates have brought films or slides and arrangements have been made for projectors of various kinds. Also on Wednesday evening, for those who are interested, there will be a professional hockey game on television. I know from talking to some of our Soviet colleagues yesterday that they, at least, are interested to see professional hockey as it is played in North America.

Now at this point we were to have a welcome to the Province of Alberta from the Lieutenant Governor. However, a few moments ago we received a telephone call from his office pointing out that he had gone to the Coachman Inn and found no conference in progress. He is also required to attend a funeral at 10: 00 this morning and there is now no time for him to get over here and bring his official greeting to us. I have not yet had an opportunity to find out just where the failure in communication has occurred but I hope that this is not an omen for the way in which the rest of the conference will proceed.

Sometime ago I also made an attempt to have the Minister of Indian Affairs and Northern Development present for this opening meeting. His schedule did not allow him to be present but he has sent an opening message which was received by telex and with your permission I will now read this opening message.

Paper No. 2

Statement from the Honourable Jean Chrétien, Minister of Indian Affairs and Northern Development[1]

I regret very much that previous commitments have made it impossible for me to accept the kind invitation of the organizers to participate in this conference. I am grateful, however, for the opportunity of having my remarks read to you.

What you will be discussing over the next three days is of great importance to Canada and to Canadians. Indeed, all people interested in northern environments and in the application of a broad spectrum of knowledge to solving resource development problems will be following your deliberations closely.

All of you are aware of the many-sided attractions of Arctic and Sub-Arctic environments. To some, they are sources of endless intellectual wonders and pursuits, to others, they are sources of great potential or actual wealth; to still others, they are lands of infinite variety and beauty—a vast reservoir of wilderness experience for present and future generations to enjoy. All such attractions and the human fulfilment of them are legitimate characteristics of our society, but realization often brings conflict into focus.

This audience doesn't need to be told of the often fragile nature of northern ecosystems and of the serious problems which can arise if man is thoughtless in how he uses those ecosystems. Governments, industry, and the public have a responsibility to consider very carefully the particular characteristics of our northern lands before embarking on activities which may destroy them.

My Department is responsible for nearly all phases of management of natural resources in Canada north of 60°. The richness of those resources is becoming apparent and the means of transporting many of them south has been revealed by the SS Manhattan. Such developments are exciting and challenging. One of the greatest challenges to the federal government and to my department is to achieve the right balance between resource development and protection of the northern environment. Such a balance requires deep ecological insight coupled with appreciation of the practical realities of industry. I am determined that we shall achieve that balance.

Last week I announced that I will take three important steps to protect the northern environment to the best of our ability. Those steps are to:

(1) Establish regulations governing entry into northern lands under authority of a land use permit for exploration and development purposes, the permit to carry stipulations which will seek to reduce or eliminate damage to the environment and to provide for protection of the landscape in certain areas.

(2) Present to Parliament as soon as possible proposals for water conservation, use and quality control. To establish the principle that rights to the use of water for beneficial purposes are dependent upon the user accepting responsibility for maintaining the quality of the water or restoring its quality after use to acceptable standards before discharging it.

(3) Sponsor a broad program of hydrological and ecological research in co-operation with universities. To identify clearly and assess the environmental effect of current land use practices and, where necessary, devise and test alternative methods or control measurements.

The three steps I have outlined above give only the barest essentials of the action I intend to take. The problems that face us are critical but we have an almost unparalleled opportunity to exercise an ecological conscience in how we develop our northern resources. Laws and regulations, after all, are only tools to achieve a desired objective. They are important, of course, but so is the objective of wise stewardship of the land and the resources it supports. We also have an obligation to exercise wise stewardship for the

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[1] Department of Indian Affairs and Northern Development, Government of Canada, Ottawa, Ontario, Canada.

benefit of indigenous peoples, who presently depend on wildlife and fishery resources, and for future generations of all Canadians who will want to study and to enjoy the northern environment.

It is difficult to predict what Canada will be like 100 years from now. What is predictable, however, is that our human population will be far greater than it is today. Demands for outdoor recreation will be such that what we do now will determine in large measure the quality and nature of outdoor recreation then. Apart from the rather general environmental protection I have been discussing above, I plan to increase the number of land reserves in the north for a variety of purposes. National parks are part of our Canadian scene and I hope to be able to establish northern parks which will be representative of the Arctic and Sub-Arctic landscape. Long term research on northern ecology requires land that is undisturbed by human activity. Such land need not be large in area but it is important that such areas are set aside and I propose, after careful study has been made, to do that. The Arctic has a rich history. Significant historic sites must be preserved and such land will therefore be protected. Through research on wildlife of the north by the Canadian Wildlife Service of my Department, and other research by universities and other agencies, a substantial body of knowledge has been obtained about northern ecology. Much more must be obtained, however, if our activities as land managers and resource developers are to reflect a true understanding of the impact of what we do to northern ecosystems. In addition to the ten year program of broadly-based hydrological and ecological research to be carried out through arrangements with four Canadian universities which I announced last week, the Canadian Wildlife Service will be expanding its research activities in the north to meet ecological problems.

Forums such as yours are an essential part of informing society about the facts needed for intelligent decisions on resource and environmental quality control. I wish you a most successful conference and look forward to hearing the results of your proceedings.

Signed: Jean Chrétien, Minister of Indian Affairs and Northern Development.

Dr. John S. Tener, Canadian Wildlife Service.

Paper No. 3

A Climatic Perspective of Tundra Areas

G. A. McKAY, B. F. FINDLAY and H. A. THOMPSON[1]

INTRODUCTION

The Arctic is a paradox. Its desolation and interminable, harsh winters have resisted inroads by modern society, yet the barrens provide a habitat for animals and plant life of remarkable variety. This paradox is explained, at least in part, by the complexity of the climate, and the cunning of nature in adapting to it.

Pettersen (1962) has listed the biologically effective physical and chemical factors of the atmosphere, (Table 1). The list contains many factors which cannot be treated as yet on a climatological basis for want of basic information. Only those more commonly measured are discussed there.

The tree line, the permafrost, the polar ice pack, the arctic desert, the polar night and other features of the north are evidence of the orderliness and effectiveness of the major

[1] Meteorological Service of Canada, Ottawa, Ontario

TABLE 1. Biologically effective physical and chemical factors of the atmospheric environment

A. Known to act on organisms	G. Presumed to act on organisms
Temperature	
Moisture (in all phases)	
Air Motion	
Natural radiation	Natural radiation
a. Gamma radiation	a. Radio waves
b. Ultraviolet radiation	b. Sferics (long-wave radiations)
c. Visible light	
d. Infrared radiation	
Air Composition	
a. Dust	
b. Smoke	
c. Vapors	
d. Gases	
e. Organic particulates	
Ionizing wave and particle radiation, including fallout	
Atmospheric electricity	Atmospheric electricity
a. Ionization	a. Space charge
	b. Electrostatic fields
Atmospheric pressure	Atmospheric pressure
a. Partial pressure of constituent gases	a. Pressure waves
	b. Total pressure

climatic controls at work within the Arctic. These controls, similar to those operating in temperate latitudes but quite different in impact, are described below in terms of the climate they produce. Much of the data are depicted on circumpolar charts.

It is impossible, however, to completely describe climate from a biological viewpoint in this manner. Climate is the result of a complex series of atmospheric and terrestrial factors acting in equilibrium. Alteration of any one term of the balance has an effect on the others. As a result, within the broad-scale climatic features there exists a substantial variety of microclimates which are of fundamental importance. The following text incorporates some detail on this microstructure which must, however, be cursory.

CLIMATIC CONTROLS

The dominant factors which shape the Arctic climate are: the character of the solar energy input, the nature of the immediate and adjacent surfaces, weather systems and topography.

The annual and daily cycling of solar energy received on a unit surface is quite different from that experienced at lower latitudes (Fig. 1). Since the angle of incidence at high latitudes is relatively small, the energy received on a horizontal unit area in a unit time is also small; however, in summer this is compensated for by the increased length of day. Consequently the total energy available in June and July is approximately the same as at temperate latitudes. This factor and local cloudiness account for the solar radiation distribution shown in Fig. 2.

Much of the incident solar radiation is reflected back into space because of the extent and duration of snow and cloud cover. Typical reflection coefficients are given in Table 2. The reflection of solar radiation from the tundra therefore varies from about 25 per cent in early summer to about 80 per cent when snow cover arrives. Cloud cover reaches a maximum in autumn and is at its minimum in the winter months. The reflectivity is

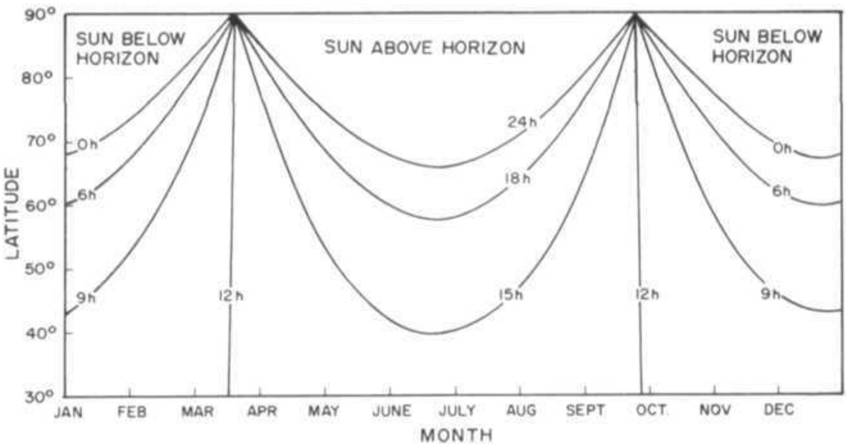

Fig. 1. Duration of daylight (hours)

TABLE 2. Reflection coefficients for typical surfaces (Kondrat'ev, 1954; Fritz, 1951)

Surface	Reflectivity in %
Exposed with continuous snow cover	80
Exposed with changing (melting) snow cover	55
Wet, after snow melt	15
Tundra in the warm season	25
Coniferous forest with snow cover	12
Deciduous forest	18
Sand surface with grassy patches	25
Complete stratocumulus cloud cover	56 to 81

dependent also on solar elevation and wave length, e.g. from a water surface it amounts to about 65% at 5 degrees and 16% at 25 degrees solar elevation.

Differences in absorption of solar radiation, energy emission, slope and aspects, heat capacities and conduction, and in local energy transfer mechanisms create meso- and micro-climates which are biologically very important. For example, small groups of conifers act as heat islands on sunny afternoons, as do areas void of snow when located within an extensive snow field. Also northeast slopes remain colder than southwest facing slopes; and near the ground large temperature gradients may occur in all directions. The disturbance of a surface may upset the energy balance and have drastic consequences, e.g. thermal erosion.

Broad-scale differences in the radiative and thermal properties of the land, sea, snow and forests result in the major climatic shears which are apparent on most maps. Relative to the continents, the oceans act as heat sinks in summer, and heat sources in winter. The temperature characteristics of the Arctic seas are transmitted to the overlying air and by wind to coastal regions. As a result of these processes and ocean currents, the tundra extends southward to James Bay and Newfoundland. Where warm ocean

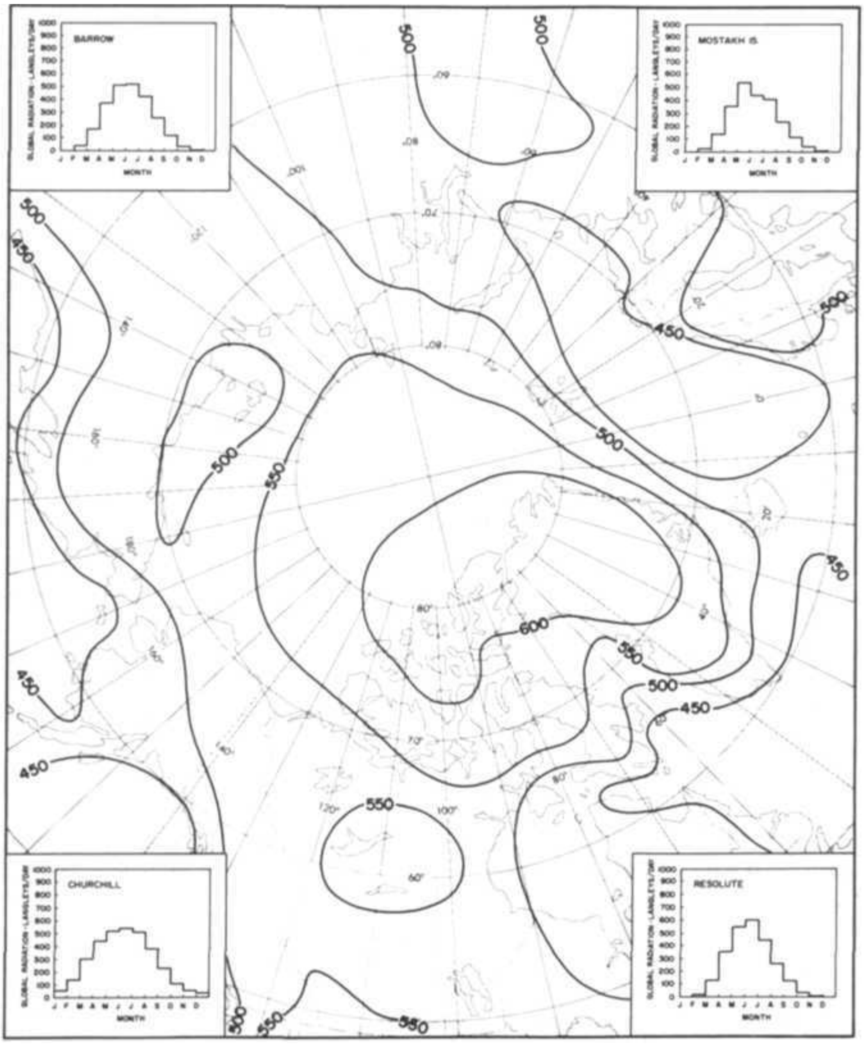

Fig. 2. Mean daily total solar radiation (Langleys) for June and the annual regime

currents penetrate northward into Arctic latitudes, such as into the Barents Sea, the tundra is displaced far to the north.

The melting of snow and ice requires considerable thermal energy. This process, combined with the high reflective and radiative properties of the snow, delays spring on the tundra. The extensive snow and ice fields profoundly affect not only the local and general climates, but also the character and movement of low and high pressure areas and frontal systems.

The favoured positions of low pressure systems and the principal storm tracks for typical winter and summer months are shown in Figs. 3 and 4. By inference, high pressure areas tend to be more persistent in those areas least frequented by cyclones.

Winter storms are most frequent over the ocean areas south of Alaska, southwest of Iceland and south of Spitzbergen. High pressure areas then dominate continental areas and the polar basin. The July pattern is significantly different. While the frequency south of Alaska and Iceland is diminished, there is an increased incidence of low pressure areas to the northeast of the continents and over the poles.

The favored storm tracks in winter extend from Newfoundland, by Greenland into the Barents and Kara Seas, and also into Baffin Bay. Secondary tracks lie from west to east along latitudes 60 and 75 degrees north over the continents. In July, the predominant track is from Newfoundland toward Spitzbergen, while there is a second preferred track northeastward into Davis Strait.

Mountain ranges profoundly influence continental-scale circulations, causing large masses of air to rise and descend. The northward displacement of the tree line near the Mackenzie River valley is manifestation of dynamic warming of air as it descends from the Western Cordillera. In certain areas the downslope winds from the mountains have a very pronounced ameliorating effect on temperature, e.g. Föhn winds along the coasts of Ellesmere Island, Baffinland, and Greenland. Humid climates occur on windward slopes, and relatively arid climates occur downwind of the ranges. Mountain climates are cold because of the decrease of air temperature with height; however, nocturnal or winter temperatures in the valleys and on the plains may be lower than on the adjacent slopes because of the drainage and ponding of cold air.

Smaller land features may also exert a major control on local climates. Lakes profoundly moderate local temperature regimes and increase early winter precipitation. Hills as well as mountains induce katabatic and anabatic winds while air is funnelled, sometimes rapidly, through passes and along valleys. Rugged terrain offers a greater resistance to air flow than smooth terrain, and as a result winds are often much stronger over the open sea than on the coast, and stronger over the open tundra than in treed or sheltered sites selected for habitation. Adjacent areas with contrasting surface cover and roughness may have sharply contrasting energy and moisture balances. These induce local air circulations which act to destroy air-density imbalances across their boundaries. Lake breezes which tend to nullify sharp thermal gradients along shore lines illustrate this effect.

THE SEASONS

In general the period of plant growth is limited to the three months, June, July, and August; winter occupies the remainder of the year. By Veselovskii's (1857) definition of summer, i.e. $T > 15°C$, that season does not occur. The date on which the mean air temperature rises above 0°C provides an index of the onset of spring, and the date on which it falls below 0°C provides an index of the onset of winter. Figs. 5 and 6 show that generally spring arrives after June 1st, and that autumn ends about September 15. For convenience this interval is referred to as summer throughout this text.

TEMPERATURE

Daily air temperatures are generally below 10°C in the cloudy summer (Fig. 7), but may rise occasionally to 20°C during brief sunny spells. The mean daily range of temperature in summer is about six degrees. The coldest months are December through April;

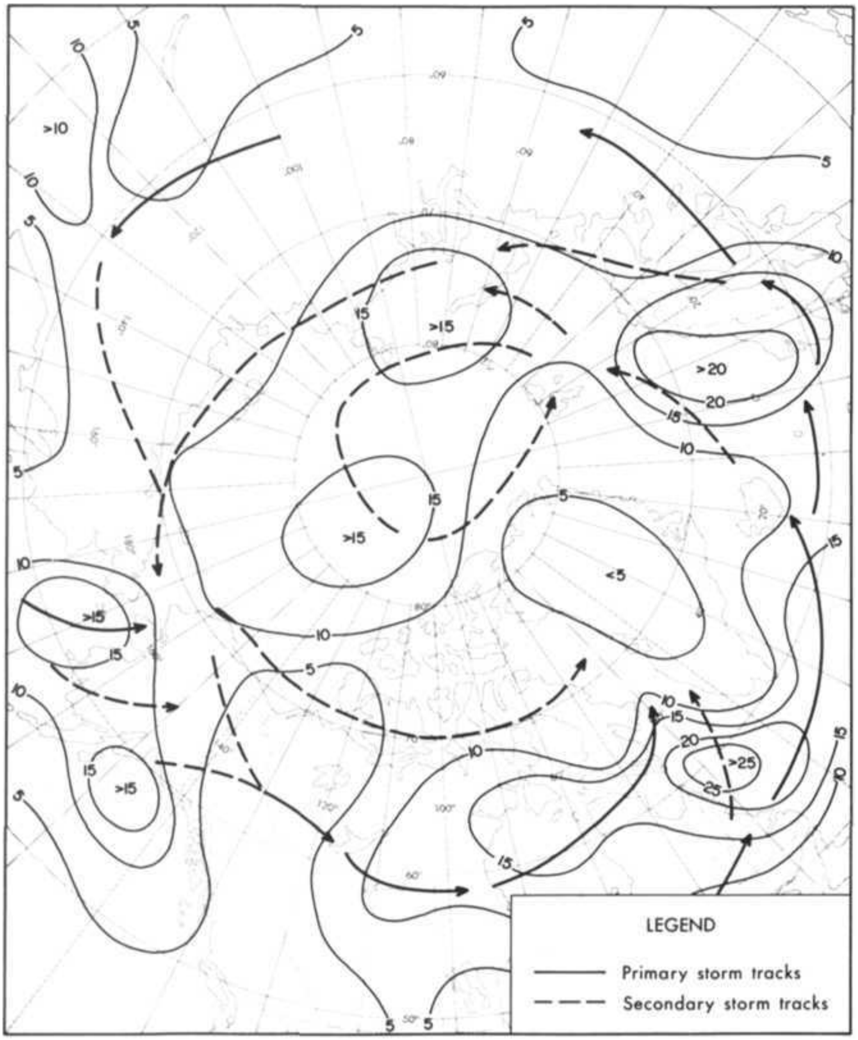

Fig. 3. Percentage frequency of cyclonic centers in a 650,000 sq.km. area and principal storm tracks in August

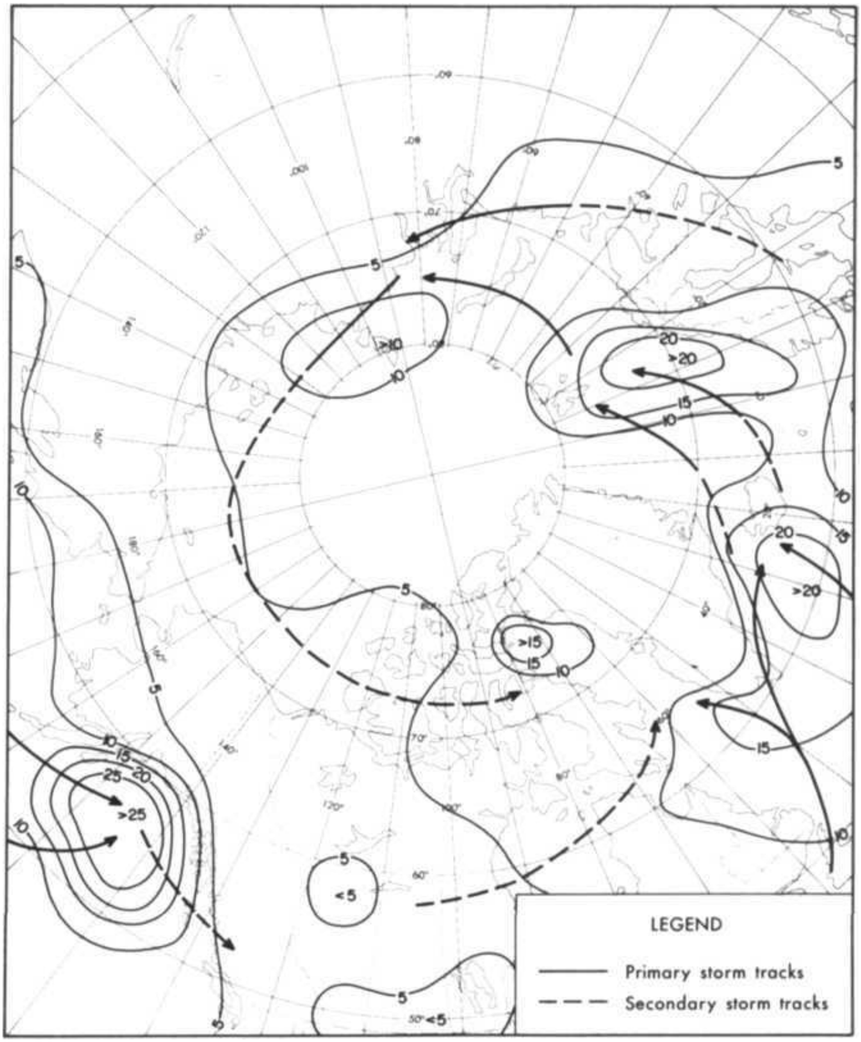

Fig. 4. Percentage frequency of cyclonic centers in a 650,000 sq.km. area and principal storm tracks in February

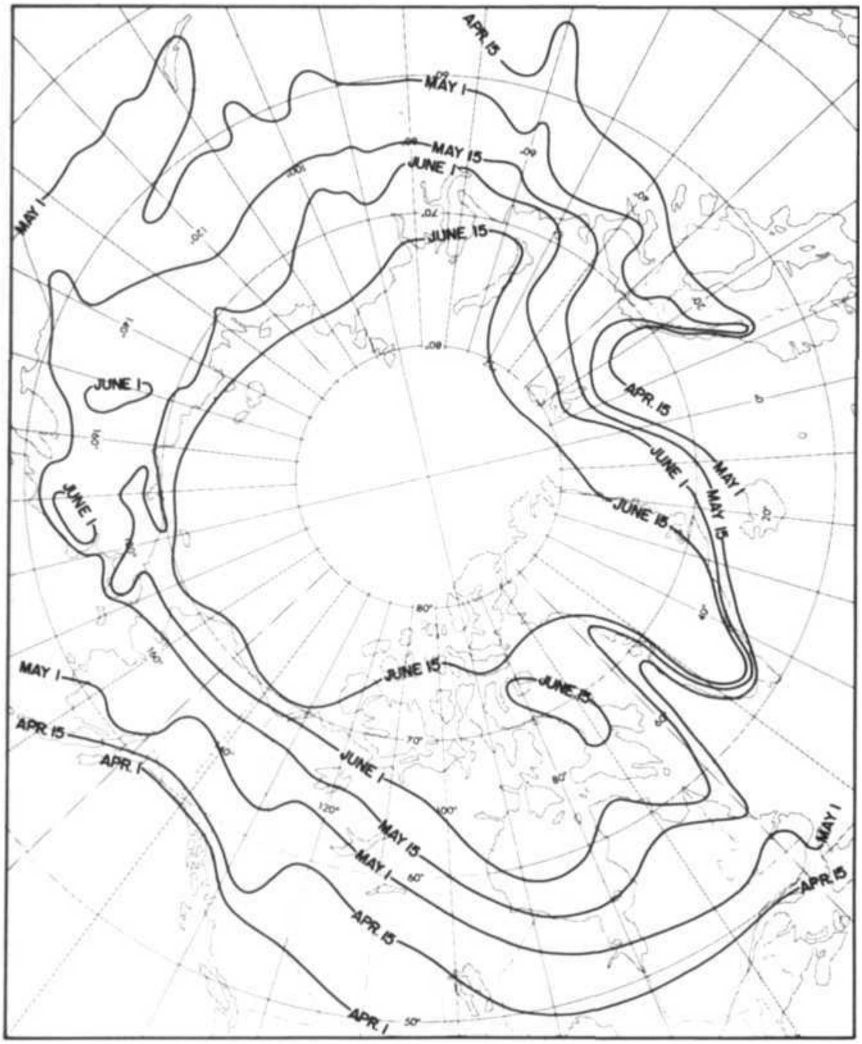

Fig. 5. Date on which the mean daily temperature rises above 0°C

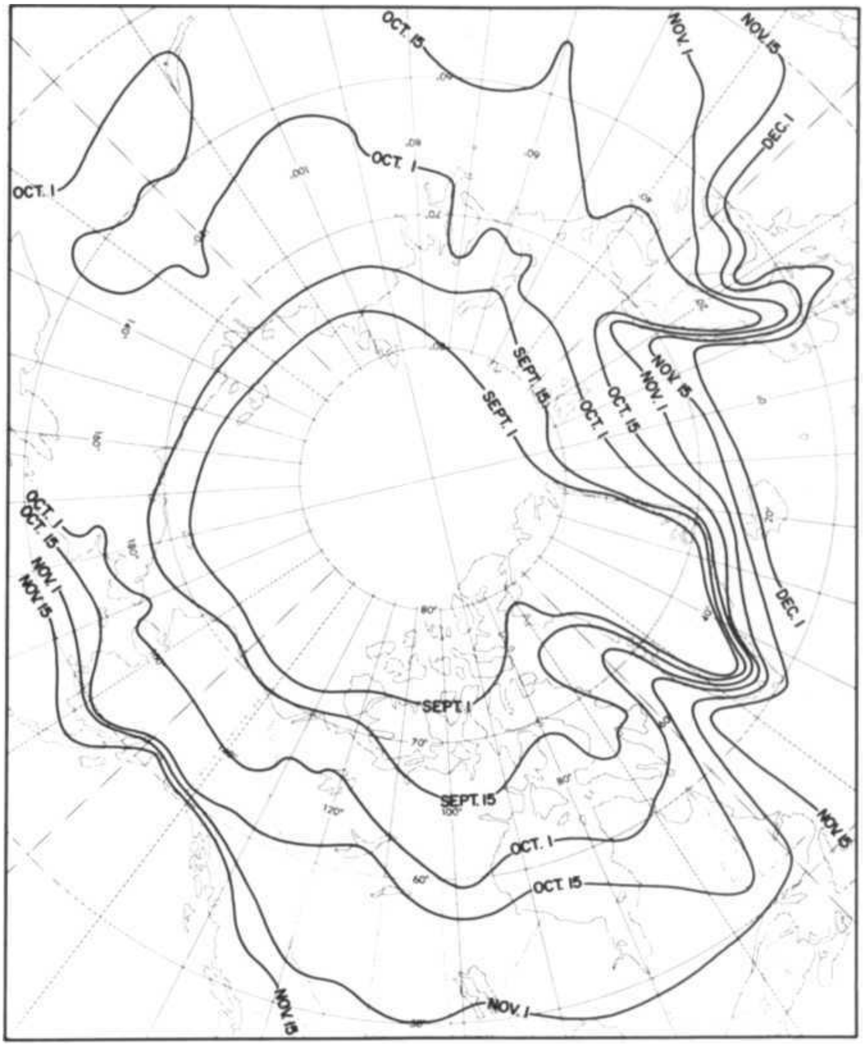

Fig. 6. Date on which the mean daily temperature falls below 0°C

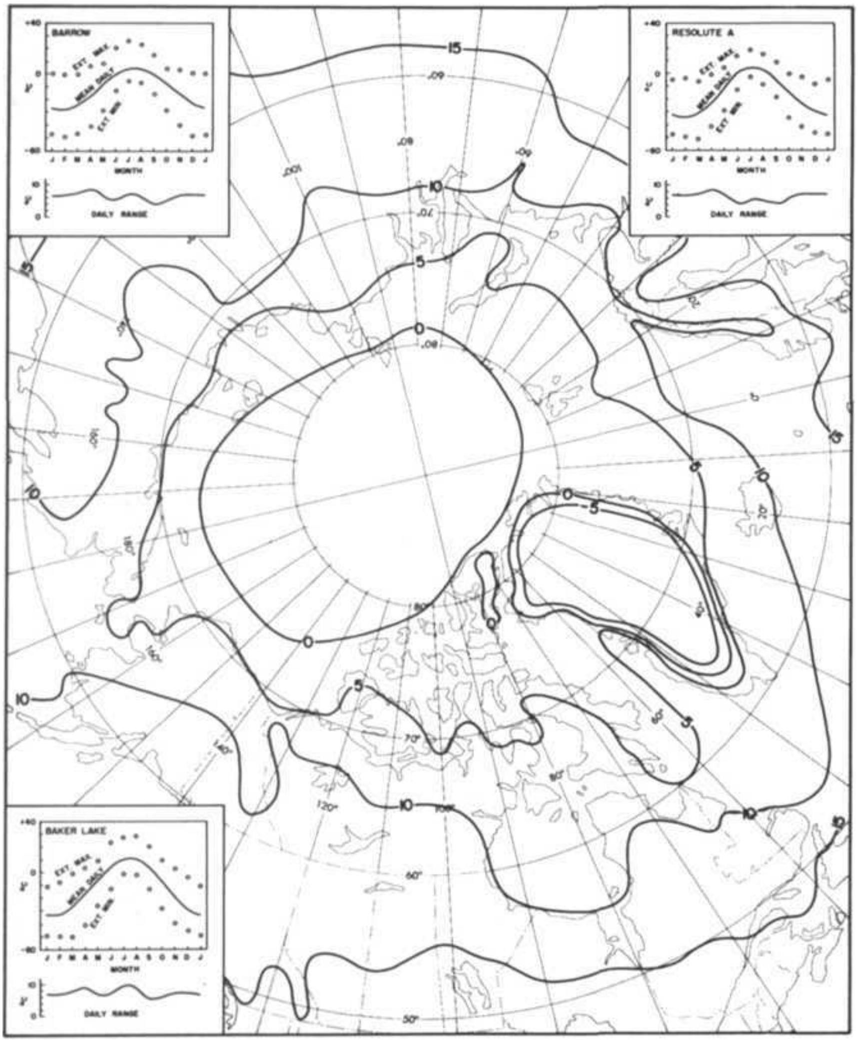

Fig. 7. August mean daily temperature °C and the annual temperature regime

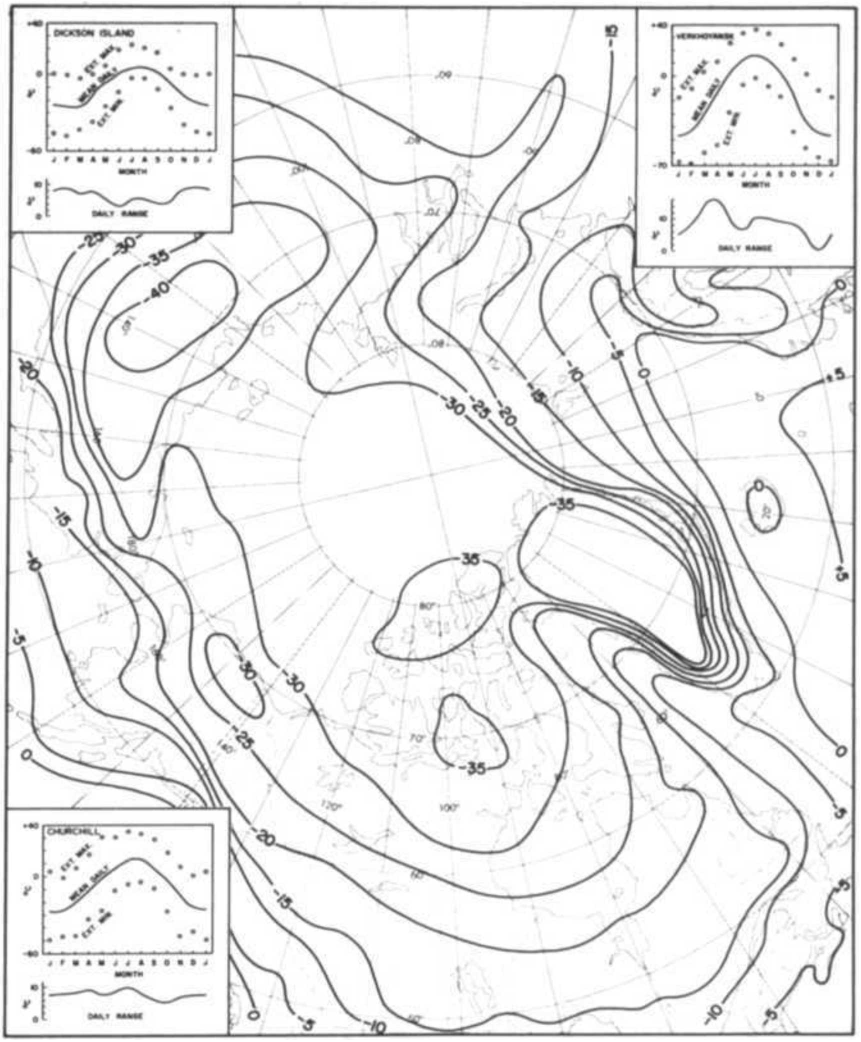

Fig. 8. February mean daily temperature °C and the annual temperature regime

Fig. 8 shows the mean daily temperature in tundra areas in February is about −30°C and the mean daily range varies from about ten degrees in continental areas to about six degrees elsewhere. Extreme low temperatures of about −50°C occur in the exposed tundra, compared to temperature extremes of —63°C at Snag, Yukon, −66°C at North Ice on the Greenland ice cap, and −68°C at Verkhoyansk and Oymyakon, U.S.S.R. Topography and vegetative cover are probably important factors in the temperature regimes at these sites. Temperatures lower than −35°C have persisted for periods of up to 20 days at several locations.

Standard meteorological measurements of air temperature are taken at 1.4 metres above the ground, within a louvred screen which is generally well exposed. This height was selected not only for convenience, but also to avoid strong vertical temperature gradients which may occur near the ground (see Fig. 9). Strong temperature inversions are persistent features of the winter regime. Screen level measurements are better estimates of the free air temperature than of temperatures of the ground surface or objects such as leaves, rocks, or branches, all of which may have significantly different temperatures depending on their radiative and thermal properties. The need for standard exposure for climatological reference purposes is further illustrated by the findings of de Percin and Falkowski (1956). They observed that lowest winter temperatures occurred in snow-covered, non-vegetated hollows; and highest winter temperatures occurred in open, windy areas, or in areas where the heat loss was reduced by trees.

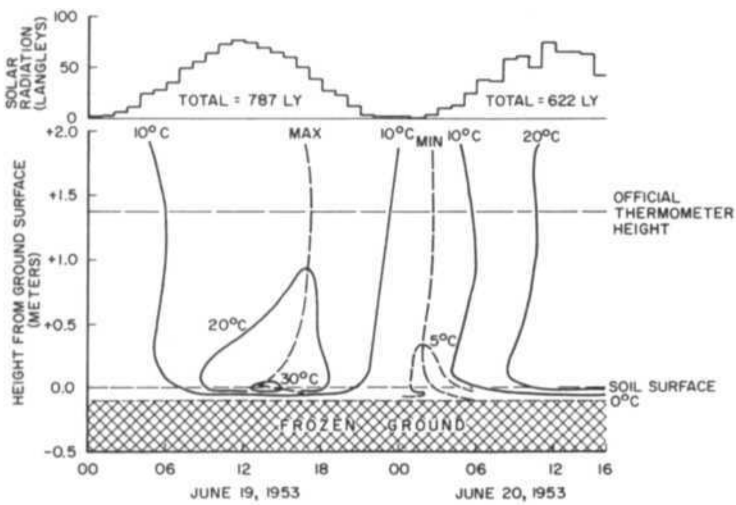

Fig. 9. Umiat, June 19-20, 1953. 69. 5°N 152°W. Sunny, light winds, grass cover (after Conover, 1960)

As shown in Fig. 9 the diurnal cycle of temperature is strongly controlled by the input of solar radiation. In summer, near the sea coast cold air advection quickly offsets the influence of solar radiation on the land, and there is little diurnal variation in temperature. There, and in general during the arctic winter, variations in air temperature are highly related to cloud cover and advection processes.

PRECIPITATION

The tundra is often termed a 'polar desert'. Annual precipitation in this area is indeed light, the Queen Elizabeth Islands and northern Greenland receiving only about 100 mm annually. However, thawing of the active layer each summer causes vast tracts of wet lands and refutes this title. Large areas are frozen swamps which melt to shallow depths during the summer period and give the impression that the Arctic is a very wet region. Travel in such areas is confined mainly to the winter months when the lands are frozen.

Fig. 10 shows that the Arctic eastern hemisphere receives substantially more precipitation than the western hemisphere. Along the Arctic Circle the annual precipitation in Canada is about 200 mm compared to 400 in Siberia and 600 in parts of the European portion of the U.S.S.R. Isohyets are not shown in oceanic areas because of the lack of suitable measurements for these areas.

Surprisingly large variations occur from year to year in rainfall amounts. Jackson (1960) writes that over Queen Elizabeth Islands 'the degree of synoptic activity controls the amount of summer precipitation although no very close relationship is to be expected because of the significance of one or two heavy falls in the small absolute totals'. Mountainous areas near open seas receive substantially more precipitation particularly on their windward flanks. Greater than 1, 000 mm are recorded in the Stanovoy and Kamchatka ranges of eastern Siberia, while over 2, 500 mm fall on the average on the Alaska Range.

By and large the annual rainfall is equal to the water equivalent of the snowfall; the proportion of snowfall increases, however, toward the pole and at high elevations, whereas rainfall is the dominant form near the Atlantic and Pacific Oceans.

Normally there is adequate precipitation for vegetative growth; deficiencies in moisture supply become critical only briefly during occasional summer droughts. Droughts have been sufficiently severe to permit serious tundra fires to occur. The low evapotranspiration rates and the presence of permafrost result in a large percentage of the precipitation running off into the tundra's poorly developed streams, stagnant ponds and lakes.

SNOW COVER

It is difficult to over-emphasize the importance of the snow cover on the tundra during eight to ten months of the year (Fig. 11). Snow is essential to the survival of many plants and animals; on the other hand, it may critically limit mobility (Morrison 1966, and Pruitt 1959) and access to food. In addition to being a source of water, snow acts as a protective blanket to many plants and animals; however, above the snow cover extremely low temperatures may occur since snow radiates as a black body. The reflection of sunlight from the snow surface and the abrasiveness of snow driven by the wind may cause physical damage to plants. Optimal snow depths for plant growth are estimated by Rikhter (1963) to be about 50 to 60 cm. Grazing animals would, of course, prefer to have no snow cover, and several authors (Kelsall 1968, and Henshaw 1968) have stated that caribou and' reindeer will not feed in snow depths greater than 50 to 80 cm or when the density exceeds 0. 50. Light penetration is negligible below 50 cm in dry snow, and below 20 cm in wet snow (Rikhter 1963).

A map of the late winter snow cover (Fig. 12) shows that on the average the depth is about 40 cm, north of 70 degrees, and from 40 to 80 cm in the continental interiors. As with precipitation, mountainous areas are the exception, depths of over 120 cm being found in Norway, and over 180 cm of snow in the mountains of southern Alaska.

Although snowfall may be fairly uniform over a region, it is quickly redistributed by the wind, and in mountainous areas by slides. Scour and sedimentation result in varied cover and density, with numerous exposed areas and drifts. The eroded snow accumulates along the upwind side of valleys and along the edges of obstacles, such as shrubs or rocks, which diminish the wind speed.

Interception of snow by the tree canopy limits the amount of snow reaching the ground in an evergreen forest. Greater accumulation therefore occurs in an open deciduous bush which reduces the wind speed and does not inhibit snow from reaching the ground. The variability of accumulation with vegetative type and land form is well illustrated in Fig. 13.

Snow falling within a forest remains light and fluffy and is easily penetrated by air, water vapor, and animals. In the open, under the influence of the wind, freshly fallen snow rapidly increases in density, and the snow cover is generally compact and capable of supporting the weight of a man. A comparison of densities is given in Fig. 14.

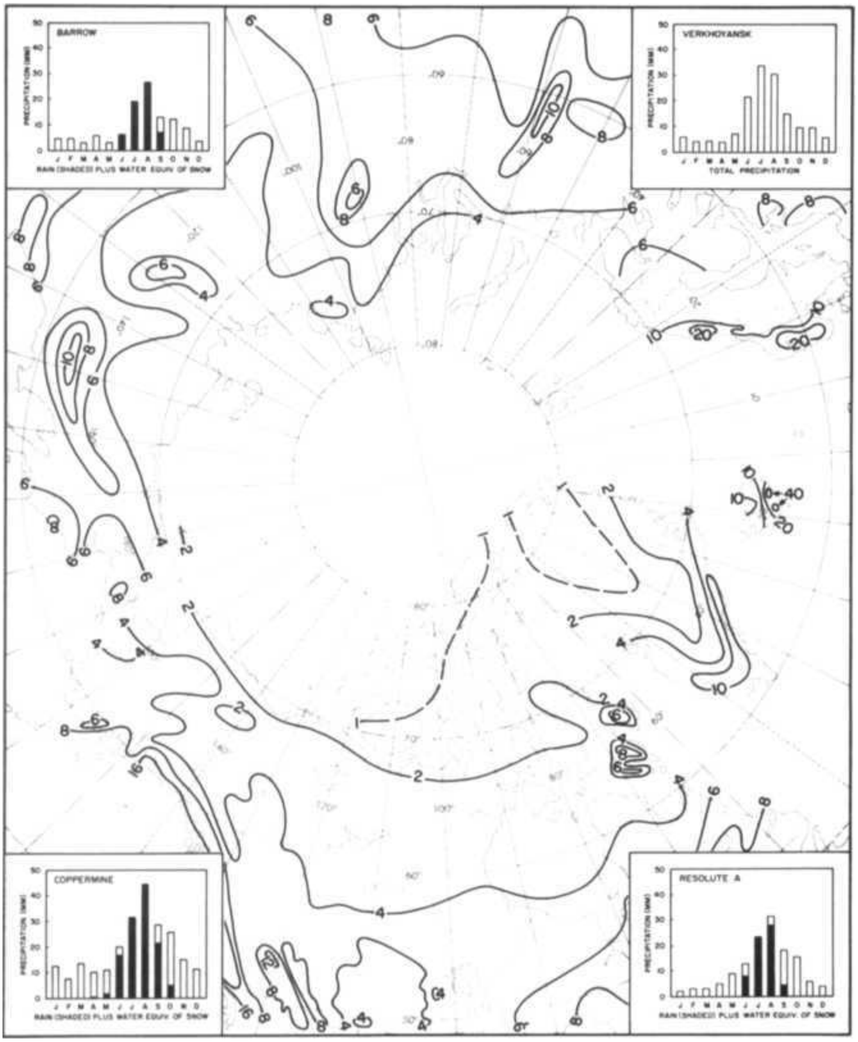

Fig. 10. Mean annual precipitation (mm x 10^2) and the annual regime

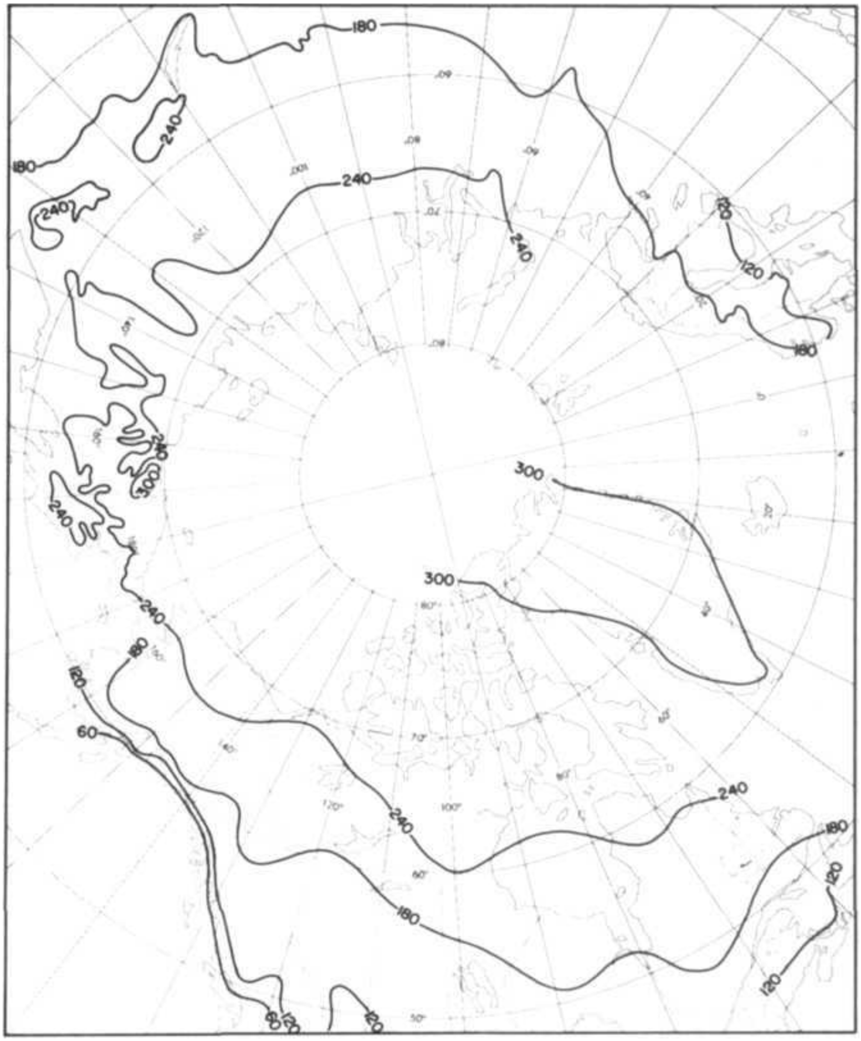

Fig. 11. Mean annual number of days with snow cover

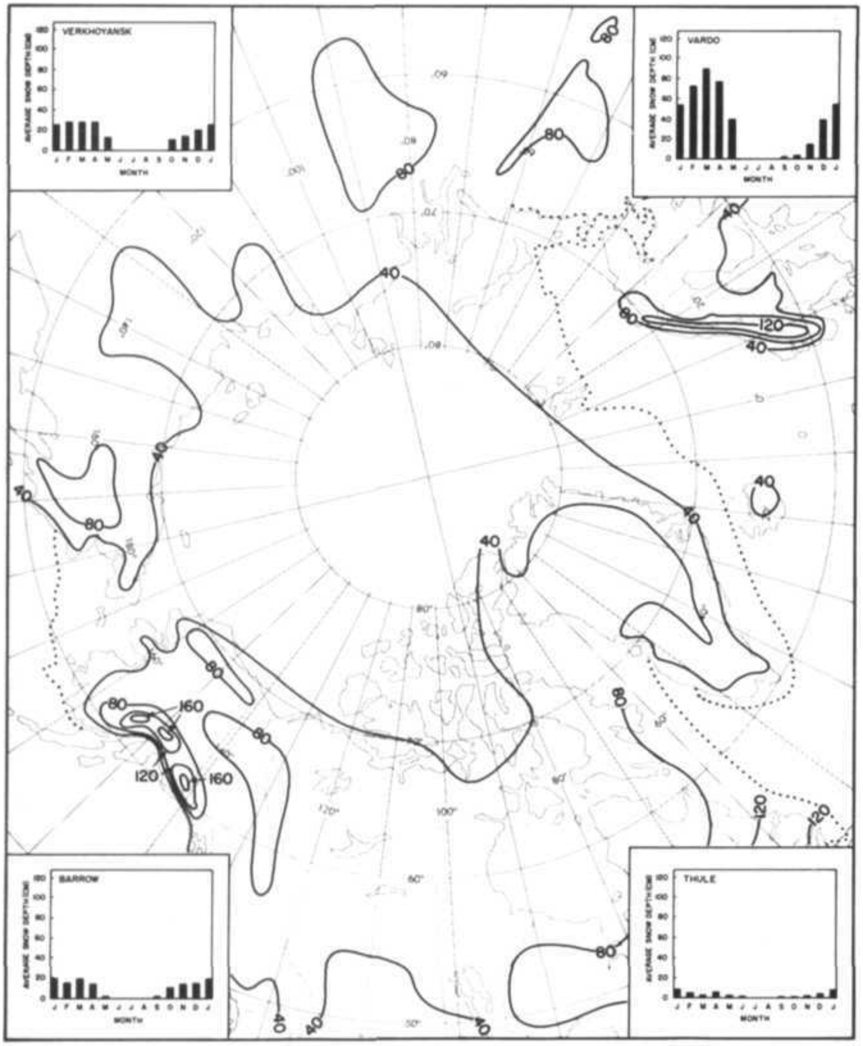

Fig. 12. Mean depth of late winter snow cover (cms) and annual regime.
N.b.—Dotted line shows average extent of sea ice in April

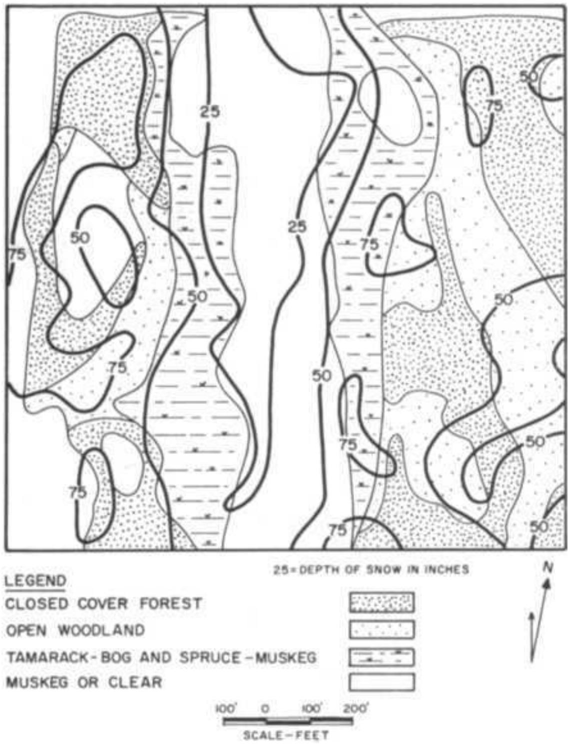

Fig. 13. Depth of snow as found within different types of vegetation

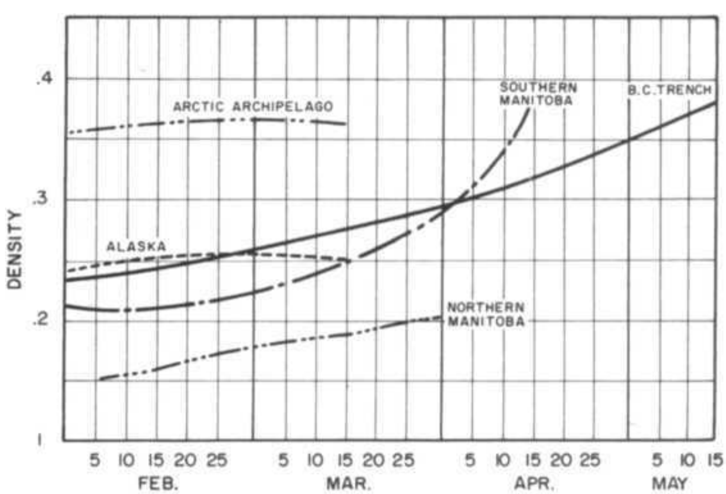

Fig. 14. Temporal variation in average snow density

WIND

Wind plays a dominant role in the tundra. It may force animals and insects to take cover; it rearranges snow, exposing food for grazing, creating barriers to travel, or causing a hard snow crust over which certain animals may walk with ease. The severe restriction on winter activities imposed by the combination of strong winds, blowing snow and low temperatures is of major importance.

It is difficult to present a meaningful hemispheric map of wind because airflow is so highly variable and easily influenced. Many settlements are in sheltered locations and wind measurements taken there are seldom representative of the general flow of air. Topography and persistent weather features produce the prevailing winds. The direction of these winds may be deduced from Figs 3 and 4 by considering topography and position relative to the favored locations of low pressure areas. The higher frequency of low pressure systems in winter in many coastal areas results in greater wind mileages occurring in that season.

Strong winds are usually the most critical. The per cent of time winds are in excess of 11 mps is shown in Fig. 15. Coastal strips have the highest frequency, and sheltered areas, such as treed valleys, the least. It should be remembered that coastal winds used in this analysis were measured in locations with some shelter. In more exposed locations winds of over 45 mps are not uncommon, e.g. Cape Hopes Advance recorded wind speeds of 56, 55, 51, 47, 43, 41 and 41 mps, over eight consecutive hours in November 1931.

Officially recorded winds are measured at 10 metres above the ground on relatively unobstructed terrain. Friction between the air and the ground results generally in a vertical shear of wind speed with height, the greatest shear occurring near the ground itself. Consequently, an animal will find relief from strong winds by lying down as well as by seeking shelter. The shelter produced by an obstacle such as a grove of trees can be felt downwind of the object at distances of up to 20 times the height of the object, and reductions of wind speed of 60 per cent can generally be realized within a distance of four times the tree height (Read 1964). The impact of trees on wind speed is clearly shown by winds measured near Churchill, Canada (Fig. 16).

TEMPERATURE AND WIND

The combination of strong winds and low temperature may result in high energy advection, the loss being greatest when the animals are wet. The cooling effect may be estimated on the basis of a formula which incorporates these two factors. Hart (Kelsall 1968) has shown a windchill of 1100 kg cal m^{-2} hr^{-1} to be critical at calving time. This corresponds to an air temperature of −7°C and wind speed of 5 mps, or 0°C and 12 mps. Table 3 shows the risk of such contingent strong winds and low temperatures at two tundra locations.

TABLE 3. Percentage frequency of simultaneous occurrences of specified temperatures and wind speeds in June (1956-1965)

Wind Speed Ranges mps	Temperature Ranges °C		
	−7 or lower	0 or lower	6 or lower
Cambridge Bay			
4-8	1.2	17.0	43.0
9-13	1.0	7.1	14.4
14 and over	0.3	0.9	1.3
Baker Lake			
4-8	0.9	10.1	36.0
9-13	0.4	5.6	14.2
14 and over	0.0	0.3	1.2

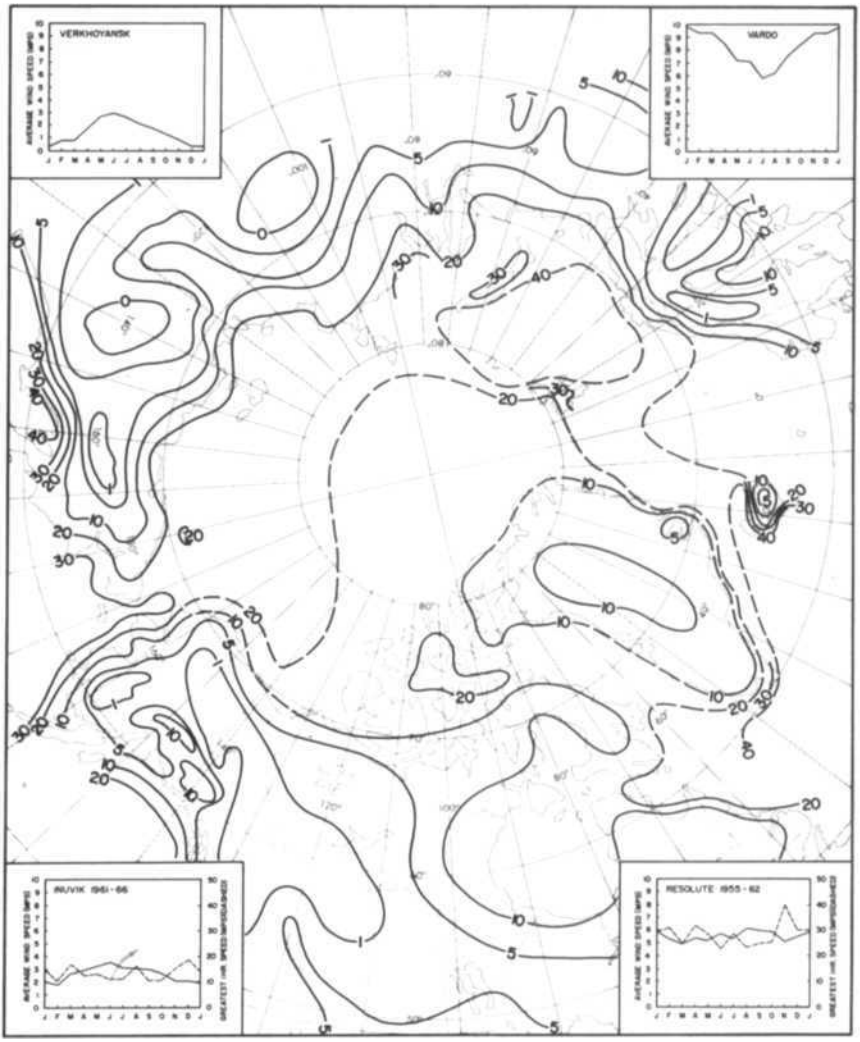

Fig. 15. Mean percentage of winds over 11 mps (24 mph), December-February, an annual wind regime

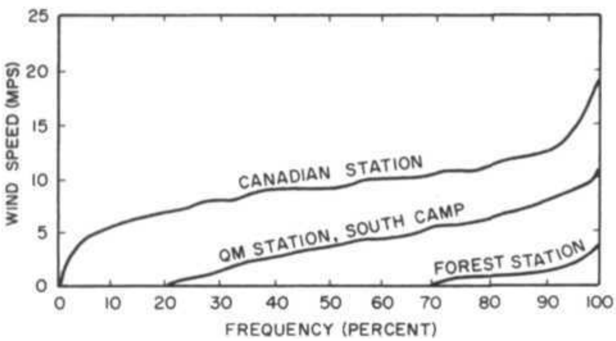

Fig. 16. A comparison of winds at Churchill, Canada showing the effect of trees (after de Percin and Falkowski, 1956)

Extreme conditions which have been experienced in the Canadian Arctic include instances of winds of 45 mps with a temperature of −30.0°C at Winter Harbour, and 27 mps with −37.0°C at York Factory. It is often assumed that lowest temperatures occur with light winds; this is not always the case, particularly in coastal areas. De Percin and Flakowski (1956) report that at Churchill 'strong winds occur as frequently with low temperatures as with high temperatures.'

CLIMATIC TRENDS

The preceding sections describe the average character of climate and certain features of its real variability. Temporal variability is equally important. Climatic change is indicated by the general retreat of forests over the past 2,000 years (Larsen 1967). Beschel (1961) has used lichenometry as well as dendrochronology and geomorphology to establish the character of glacier retreat and advance for West Greenland. His results show significantly varied climatic epochs to have occurred in the north. Davitaya *et al.* (1960) note major climatic changes, with April temperatures in western Siberia 6° to 7°C higher after 1940 than in 1880-1900. Winter temperatures at Verkhoyansk in 1930-1950 were about 4°C higher than in the latter part of the last century.

The variability of temperature and precipitation at Dawson, Canada is noted in Fig. 17. Power spectrum analysis indicates that in general the variability is random; however, a trend to lower precipitation is evident in the month of September.

SUMMARY

Human activity in winter on the tundra is limited by extreme cold, driving winds and blowing snow which challenge survival. Nevertheless, winter is the favored season for travel since the sea ice and the land are then firm underfoot. Storms in all seasons are most severe near the sea coasts where recurrent gales complicate the selection of suitable harbors and town sites, and make travel in ice fields extremely dangerous.

Both plant and animal life exist precariously, mainly by taking refuge in a particular microclimatic environment and thereby escaping the rigors of general climate. The microclimates are in a delicate state of balance, and alteration of this balance either naturally, as in climatic deviations, or unnaturally, such as through vegetative modification, may have serious consequences. For example, the alteration of the albedo can upset the energy balance at the soil surface and result in thermokarst conditions. The removal of tall vegetation will result in increased winds and shallower snow cover which may also significantly change the thermal regime near and in the ground.

The long daylength in summer tends to offset the relatively low air temperature, thereby making agriculture possible in certain areas where suitable soils exist. These areas lie generally south of the 10°C July isotherm. However, the growing period and energy

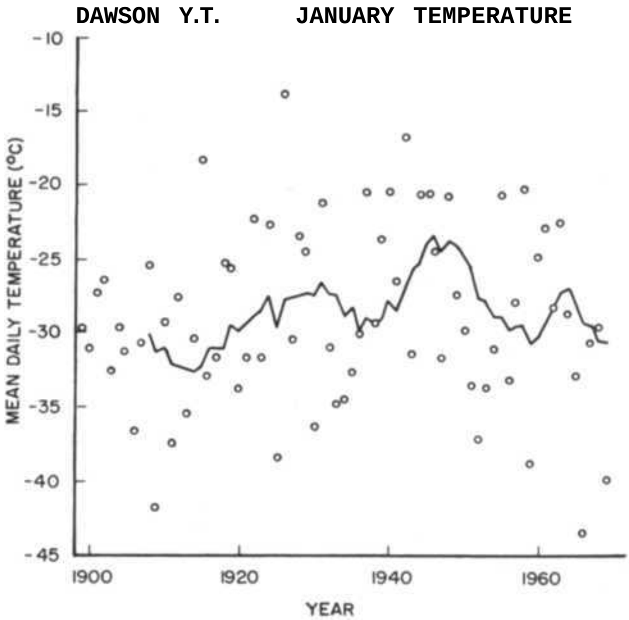

Fig. 17a. Ten-year moving mean and monthly values of January temperature

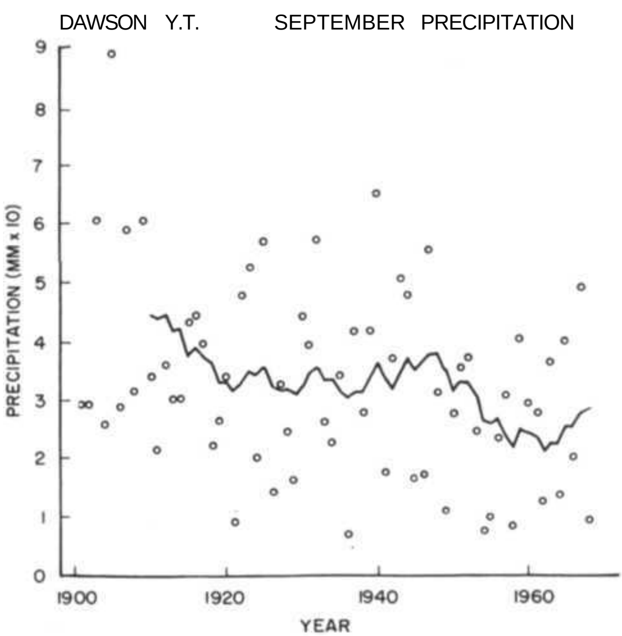

Fig. 17b. Ten-year moving mean and monthly values of September precipitation

available for growth are severely limiting and consequently, except for protected plots, agriculture is costly and uncertain.

The harsh climate poses many technical problems in construction, resource development, communications, transportation, tourism, and indeed almost every activity within the Arctic. Techniques and standards developed for temperate latitudes are frequently unsuitable for Arctic extremes. Through a more complete understanding of the varied nature of climate and its biological effects, better design and planning are possible, and activities may be prudently regulated. The Arctic paradox may then tend to disappear, and many of the problems of production and conservation will be greatly simplified.

Location of Stations Referred to in Text

Name	Country	Latitude ° '	Longitude ° '	Elevation m
Barrow	U.S.A.	71 18	156 57 W	4
Baker Lake	Canada	64 18	096 00 W	13
Cambridge Bay	Canada	69 06	105 07 W	22
Churchill	Canada	58 45	094 04 W	35
Coppermine	Canada	67 49	115 05 W	8
Dawson	Canada	64 04	139 26 W	324
Dickson Island	U.S.S.R.	73 30	080 14 E	16
Inuvik	Canada	68 18	133 29 W	61
Mostakh Island	U.S.S.R.	71 33	130 00 E	5
Oymyakon	U.S.S.R.	63 16	143 09 E	726
Resolute	Canada	74 43	094 59 W	64
Snag	Canada	62 22	140 24 W	587
Thule	Greenland	76 31	068 50 W	59
Umiat	U.S.A.	69 22	152 08 W	115
Vardo	Norway	70 22	031 06 E	15
Verkhoyansk	U.S.S.R.	67 33	133 23 E	137
Winter Harbour	Canada	74 47	110 48 W	10
York Factory	Canada	57 00	092 18 W	18

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Paper No. 4

Some Aspects of the Interrelationships of Permafrost and Tundra Biotic Communities

WILLIAM O. PRUITT, JR.[1]

'Permafrost' is a paradox, since it is neither permanent nor frost. The usual definition of permafrost is a substratum that has existed below freezing for at least two cycles of the seasons. Thus it may be peat, loam, sand, gravel or even bedrock, as long as it has been frozen for the past two years.

Permafrost can never be considered alone, either in its genesis and degradation or in its ecological effects. Permafrost forms a complex, dynamic system with climatic history, vegetational history, recent climate, present vegetation, substratum, topography, solifluction and animal activity all interacting. In any one region the permafrost regime is the result of a dynamic balance among the above factors and perhaps other, as yet unknown, factors. If any one of the factors changes the permafrost regime shifts. Thus a change in vegetation through time or a change in substratum through space will undoubtedly result in some detectable change in the permafrost regime.

In spite of the fact that permafrost affects approximately one-fifth of the land area of the Northern Hemisphere we still know surprisingly little about it. As we will see later,

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permafrost has a profound effect on vegetation, particularly tree-like vegetation. Consequently most distribution maps of permafrost are actually based to a large extent on plant distributions. This is particularly true of the maps delimiting discontinuous and continuous permafrost. Thus we must guard against circular reasoning in our interpretation of factors influencing plant distribution.

There is still no consensus as to age and length of existence of permafrost. This situation is not unexpected since the number of variants affecting permafrost affords an almost infinite number of combinations. Permafrost forms whenever there is even a small negative heat inbalance each year, so that more heat flows away from the substratum than flows into it. Such a situation will result in a thin layer being added annually to the permafrost (Brown 1966b). It is quite difficult to determine whether any given block of material was frozen by minute annual increments or by massive increments. We can only extrapolate from known influences of present climate. Numerous climatic factors affect genesis of permafrost – snow-cover, cloudiness, continentality, duration and severity of seasonal extremes, etc. Of all the climatic factors measured that of mean annual air temperature undoubtedly tells us the most about distribution of permafrost. The southern limit of permafrost coincides roughly with the −1°C mean annual air isotherm (Brown 1966a).

Next to annual mean air temperature the climatic factor of most importance to permafrost is snow-cover. Annersten (1964) has shown that the critical thickness of snow-cover for permafrost to survive is 40 cm.

> 'In the northern part of the tundra the vegetation has little influence on permafrost because it is sparse and the vegetative period lasts less than two months. It causes local variations in depth of thaw and helps to impede erosion. The destruction of the vegetation accelerates thawing only slightly.
>
> In the southern part of the tundra, the vegetation becomes more abundant, peat mantles part of the surface and attains thickness of several feet in some basins. The main influence of the vegetation is on the depth of thaw. If vegetation is removed, the depth of thaw will increase; erosion will increase and thermokarst will develop if thawing proceeds at different rates over an area or if there are local differences in the ice content of the frozen ground.
>
> In forest tundra, vegetation mass is greater than in the tundra, and the rate of accumulation of organic material is higher. Extensive peat bogs form and water basins accumulate snow leading to higher permafrost temperatures than in the tundra. If the vegetation is removed, the depth of thaw increases but this is counteracted to some extent by lower snow accumulation and a decrease in permafrost temperatures.
>
> The maximum development of vegetation occurs in the taiga. Here vegetation has its greatest influence on permafrost even in very small localized areas causing variations in its extent, depth of thaw and ground temperatures. Frequent forest fires cause variations in the occurrence and thickness of permafrost over short distances in the taiga.
>
> Mass, density, height and influence of vegetation, and rate of accumulation of organic matter are less in the steppe than in the taiga, but depth to permafrost is greater.' (Brown 1966b: 23).

Thus we see that in the zone of continuous permafrost the thermal properties of peat and other terrain factors play a relatively minor role in influencing genesis of permafrost while the general thermal properties of the ground together with climate play a more dominant role (Brown in press).

The insulating effect of vegetation and its seasonal variations are very important in permafrost formation on the southern edge of the permafrost region (Tyrtikov 1959). In general, moss and peat are more important than the shrub and tree layer, although Viereck (1965) has demonstrated a complex cycle resulting from the effects of trees and qamaniq.[1] (Pruitt 1957, 1959).

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[1] The bowl-like depression in a snow-cover in the 'shadow' of a coniferous tree.

'Vegetation has a marked insulating effect on underlying permafrost. This is true of mosses, lichens and particularly of peat. Increase in depth of thaw in permafrost areas where vegetation has been removed has been widely observed... When dry, peat has a low thermal conductivity, equivalent to that of snow (about 0. 00017 g cal/sec sq cm °C cm). When wet its thermal conductivity is greatly increased (unsaturated peat is about 0. 0007 g cal/sec sq cm °C cm; saturated peat – e.g. about 0.0011 g cal/sec sq cm °C cm); when frozen its thermal conductivity is increased many times over that of dried peat and approaches the value for ice (e.g., saturated frozen peat about 0.0056 g cal/sec sq cm °C cm). During the summer a thin surface layer of dried peat, which has a low thermal conductivity, hinders heat transfer to underlying soil. During the cold part of the year peat is saturated from the surface, and when it freezes its thermal conductivity greatly increases. Because of this, the amount of heat transferred in winter from ground to atmosphere through the frozen ice-saturated peat is greater than the amount transmitted in the opposite direction through the surface layer of dry peat and underlying wet peat in summer. A considerable portion of heat is also required during the warm period to melt the ice and to warm and evaporate the water. The net result is favourable to a permafrost condition.' (Brown 1966b).

In the discontinuous zone, terrain variations are responsible for patchy occurrence of permafrost, size of permafrost islands, depth to permafrost table and thickness of permafrost, according to Legget *et al.* (1961). Brown (in press), however, considers these factors to be: relief, vegetation, drainage, snow-cover, soil type and glacier ice. Relief may affect permafrost through orientation and degree of slope. This is particularly evident in mountainous regions but it is also effective on a much smaller scale. For example, there is a different permafrost regime on north and south facing stream banks and on the north and south sides of peat mounds (Brown in press). Indeed, Salmi (in press) has shown that palsas 'migrate away from the sun'.

In turn, permafrost affects relief through solifluction and thermokarst, which will be considered later.

Just as any change in the prime factors that resulted in a negative heat balance in the substratum was favourable to permafrost genesis, so any change that results in a positive heat balance will be favourable to permafrost degradation. Thus, a climatic change that causes more winter cloudiness and more summer sunshine may result in a more positive heat balance in the substratum, with accompanying degradation of the permafrost. Likewise, any change in vegetation will undoubtedly cause changes in the permafrost regime. Drury (1956) has postulated some exceedingly interesting natural relationships that will be discussed in more detail later.

In general, man's activities in regions with tundra and forest-tundra vegetation tend to lessen its effectiveness as insulation of the substratum. Thus man's activities in these regions act almost invariably to degrade permafrost. Over wide stretches of the Arctic, the permafrost is in such delicate balance that even apparently minor disturbances may have profound, even disastrous, consequences. For example, at Kilyivik on the Baldwin Peninsula in western Alaska (66°47' N. Lat., 162°35' W. long.) a nearly flat sedge area near the mouth of the creek was disturbed in the winter or early spring of 1959 by a large dual-wheeled vehicle. By summer the ruts were thawing, and by the summer of 1960 were deepening because of the altered thermal regime of the soil. In the Ogotoruk Valley in northwestern Alaska, which was subjected to intensive traffic in the period 1959-1961, by 'weasels' and other relatively light, track-laying vehicles especially designed for Arctic use, some of the trails have now thawed and eroded to 10 feet in depth. On the Arctic slope of Alaska trails made by winter tractor trains during the days of the U.S. Navy oil explorations in the late 'forties have thawed, eroded and caused gullies 20 or so feet wide, 10 to 15 feet in depth and many miles long. The potential effects of continuous thermal degradation of frozen substrata, as in the case of a buried, heated pipeline, have been calculated and discussed by Lachenbruch (1970).

There is almost always an unfrozen zone beneath water bodies that themselves do not freeze solid annually. Thus, formation of a new water body or increase in size of an already-existing water body, because of damming or flooding will result in degradation of existing permafrost. The resultant settling and thermokarst may be of profound ecological (and economic) importance.

Permafrost has important effects on the physical characteristics of the substratum. It is impossible at our present state of knowledge to distinguish between permafrost-caused effects and those caused by annual freeze-thaw. Many workers have noted such physical effects as immobility of the substratum, patterned ground (Washburn 1956, Drew & Tedrow 1962), heaving (Frazer 1959), palsas (Salmi, in press), pingos, oriented lakes and thaw lakes.

According to Britton (1957) frost scars result

> 'from intense and differential freezing and thawing that are affected to a considerable degree by the presence of absence of organic accumulations and a living mantle of vegetation'... 'If all conditions of materials, water supply and insulating mantle were uniform, volume increases due to ice formation would result in uniform dilation of surface. In the absence of such uniformity, differential dilation is commonplace on the tundra and one form or another of ground pattern is produced.'

In general, patterns on level ground are symmetrical but those on slopes are elongated.

Britton also noted that ice wedge polygons require permafrost. Their surface manifestation depends on microrelief, difference in distribution and permanence of standing water and in no small measure on the distribution of vegetation types. The sequence of formation is as follows. Contraction cracks open in permafrost at low temperatures, become filled with hoar and refrozen melt water. Repeated annually, increments may be 0. 5-1. 5 mm/year, and may eventually result in wedges up to 25 feet wide. The surface manifestation of the pattern depends mainly upon differential rates of thaw between ice and the matrix of frozen mineral and organic material. If the surface insulation is equally distributed the thaw will cause the ice level to be lowered and a polygonal ditch system results. In this ditch *Sphagnum* grows and accumulates and may transform the ditch to a dyke.

As is evident by now, permafrost may have profound biological effects (Benninghoff 1952, Hopkins and Sigafoos 1951, Péwé 1957, Tikhomirov 1952, Johnston and Brown 1961, Shacklette 1963, Tyrtikov 1959, among others).

Undoubtedly the most direct effect is upon plants by chilling the soil and retarding general growth. Of course, the vegetation acts, in turn, to chill the soil by shielding it from incoming solar radiant energy. Permafrost prevents deep root penetration, so that plants growing above a shallow layer are relatively unstable. On the other hand, permafrost acts as a reservoir of considerable heat and thus acts to damp wide fluctuations in soil temperature.

Because of its impermeability, permafrost has a great influence of runoff. Permafrost causes a more stable moisture regime by gradually releasing water. These two factors combine to cause permafrost areas to be characteristically wet and boggy. In spite of an excess of water, the soil is physiologically dry for plants because the low temperature of the water (and its frequent low pH due to an excess of organic solutes) retards its absorption by roots.

Because the active layer is a relatively thin film over the permanently frozen mass, minerals in the active layer may be exhausted and no replacements possible from the store immobilized below. Mineral cycling is thus restricted to the active layer. Understanding of this problem is compounded by the difficulty of distinguishing between the effects of permafrost and those of the annual freeze.

In our initial statement we noted that permafrost is not permanent. Thus its upper boundary is a sensitive indicator of ecological variations and moves upward or downward. Such pulsations result in widely varying site characteristics for plants. When the plants, particularly trees, have varying health they are subject to wind tipping, qali[2] breakage, and varying growth rates. Such variations combine to produce twisted and stair-step main stems or 'drunken forest'. Soil heaving related to annual freezing is also an important factor here. On irregular terrain, solifluction and downslope mass movements may have significant effects on the biota.

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[2] The snow that accumulates on the branches of trees.

One important biological problem about which relatively little is known is the restriction of aeration due to permafrost. Soil micro-organisms and their activity thus may be different from those in nonpermafrost regions and the intensity of their activity reduced.

One of the prime references to vegetation-permafrost interactions is Tyrtikov (1959). One can do no better than to list his conclusion.

1. 'The main influence of vegetation on the thermal exchange between the lithosphere and the atmosphere, and consequently on permafrost, is determined by its influence on the moisture regime between the soil and the atmosphere.
2. The life activity of plants resulting in the accumulation of organic matter in the soil and on the soil (forest litter, peaty horizon, peat) leads to an increase in moisture (ice content) of the surface horizons and in this manner exerts considerable influence on the heat exchange between the lithosphere and the atmosphere.
3. Organic matter in the soil and on the soil has less effect on cooling of it in winter (freezing) than on warming (thawing) in summer.
4. The vegetation exerts considerable influence on the heat exchange between the lithosphere and the atmosphere in the following ways: by transpiration which dries the soil and which reduces the temperature of the air near the surface, by reducing evaporation from the soil surface, by trapping precipitation on the surface of the plants, and by condensing moisture from the air.
5. Under vegetation canopy the intensity of solar radiation is decreased (sometimes by 100 or more times) resulting in less warming of the soil.
6. The vegetation in weakening the force of the wind contributes to the deposition of snow in a porous condition and in some regions to an accumulation of it which results in a decrease of heat radiation by the soil and subsoil in winter.
7. The influence of the vegetation on the temperature and certain other properties of the permafrost takes on many forms and tendencies and varies not only in relation to the character of the vegetation cover but also to the general climatic conditions in which it develops.
8. Any vegetative cover retards the warming (thawing) of the soil in summer. Under the vegetative cover the temperature of the soil at a depth of 15-40 cm is usually 5-15°C (mean monthly) lower and the depth of thaw is 1. 5-3 times less than in areas from which the vegetation has been removed and the organic matter in the soil and on the soil has been mineralized. This influence of the vegetation is the more significant the greater the mass, height, density and the greater the accumulation of plant matter in the soil and on its surface. Dead plant matter (litter, peat) often retards the warming (thawing) of the soil more than a living vegetation cover.
9. Any vegetative cover retards the cooling (freezing) of the soil in winter. Under a vegetative cover the temperature of the soil in winter is higher (sometimes up to 17°C for the mean monthly temperature) than in areas where the vegetation is absent and the soil does not contain organic matter.
10. Vegetation, by impeding the cooling of the soil in winter and the warming of the soil in summer, leads to a lowering (up to 3°C) or in some conditions to an increase (up to 2°C) of the temperature of the upper layers of the permafrost.
11. By decreasing the depth of thaw and retarding soil erosion, the vegetation impedes the melting of ice in the permafrost and is therefore a most important conservation agent of it.
12. The destruction of the vegetation cover causes melting of the ice in the permafrost which sometimes leads, in these areas, to the formation of vast meadows (alas), gullies, sink holes, hollows and other thermokarst forms of relief.
13. By filling in lakes and covering dry land, vegetation often contributes to the formation of permafrost in areas where it was absent.

14. In the growing over of lakes, permafrost of organic composition is formed (at least in the upper layers) which differs fundamentally from mineral types (particularly in having a high ice content).

15. The degree and heterogeneity of the influence of vegetation on the permafrost increase along a line from the north of the tundra zone to the taiga in which the maximum is reached and then it decreases in the steppe zone.

16. Permafrost weakens the development and life activity of the subsurface and above-ground organs of the plants and soil microorganisms by contributing to the lowering of the temperatures, swampiness, the impoverishment of aeration and nutritive substances of the soil (only in very dry areas do they create favourable conditions of moistening of the soil for the growth of plants). This influence is the more significant the closer to the surface of the soil the permafrost is located and may have no effect when the permafrost table is deep.

17. Where permafrost occurs near the surface it contributes to the formation of shallow root systems of plants and reduces the stability of trees against the wind.

18. To a certain degree, plants are capable of overcoming unfavourable influences of permafrost by forming additional roots and developing a positive thermotropism of the roots, i.e. the capacity to grow in the direction of the warmest part of the soil.

19. Permafrost influences the vegetation cover (by disturbing, changing or completely destroying it), by contributing to the formation of various forms of relief (spot medallions, mounds, thermokarst relief forms, landslides, nal'eds, lakes, etc.).

20. The unfavourable influence of permafrost on the development of vegetation can be completely or partially removed by thermoamelioration.

21 Thermoamelioration of the soil can raise considerably the natural output of agricultural areas in permafrost areas and extend agriculture further north in permafrost regions.

22. Vegetation is an indicator of the composition, properties of permafrost and thickness of seasonally thawed layer and can be successfully used (and is partially used) for the compilation of large-scale permafrost maps both from field observations and from aerial photographs.'

So far we have concerned ourselves with the interrelations of permafrost and plants. Permafrost also has profound, if less well-known, effects on animals. For example, the vegetational factors that dampen temperature oscillations throughout the year create conditions that are also thermally agreeable to small mammals and soil invertebrates. The reservoir of heat in a mass of permafrost is useful to animals as well as plants. But just as plant roots cannot penetrate permafrost, neither can animals. Thus fossorial animals, particularly mammals, are notably absent from permafrost areas. We must be careful of our reasoning here, however, since post-Wisconsin distributional history must be considered. By far the majority of mammalian burrowers are associated with grasslands or deciduous forests. Sources of burrowing mammals are thus separated from the tundra by the forest-tundra and the wide expanse of taiga. Florov (1952) has shown that permafrost may also influence the distribution of an insect species that has a burrowing larval stage.

On the other hand, the reservoir of moisture in permafrost that is so important to plants may act against many animals. Small mammals, in particular, are very susceptible to wetting. Saturation of the active layer, and expecially the presence of *Sphagnum,* frequently results in few or no small mammals. Saturation of the active layer requires special adaptations by large, heavy animals. The large hoofs and free-swinging gait of the caribou are undoubtedly adaptations for snow-cover but also serve as flotation mechanisms on boggy or water-soaked substrata. Moose (*Alces*) are particularly well adapted to traverse tangled, lattice-like vegetation. Such a vegetational configuration may occur as a result of trees and shrubs being twisted or killed by permafrost or solifluction. The fact that soil nutrients may be immobilized in permafrost must have a profound effect on tundra animals as well as the plants on which they feed.

Palsas are a frequent accompaniment of permafrost. They provide dry islands in a saturated sea of peat and thus enable some small mammals to survive there. For example, *Phenacomys* appears, in parts of its range, to be limited to palsas and palsa-like formations (Foster 1961). Palsas may also become important winter feeding places for caribou (*Rangifer*) for two reasons, viz. the dry surface supports better lichen growth than the boggy peat surrounding it and also the exposed, elevated surface is more likely to have a thinner snow cover than the surrounding peaty lowland.

The climate that causes permafrost to form also causes an annual ice cover of lakes, rivers and protected marine channels. Banfield (1954) has discussed the role of ice in the distribution of some northern mammals.

One can scarcely consider animals and plants as separate entities in ecology. This is particularly true in boreal regions. Biotic communities over permafrost sometimes have, to temperate-zone eyes, strange relationships. Britton (1957) has cautioned us to be aware that, for example, because of erosion during polygon cycles, different communities may be in contact. This is not necessarily an indication of their successful relationship.

Viereck (in press) described observations that showed how changes in plant cover can result in changes in soil temperature. He stressed the insulating effect of an accumulated moss or organic layer. Since saturated frozen peat has 3 times the thermal conductivity of dry peat, during warm periods in summer the upper layers dry out and decrease the heat flow downward, but in fall the organic layer becomes saturated. When frozen in winter it becomes an even better thermal conductor, but for heat flowing upward. Thus there develops a negative heat balance in the soil. Successional development of vegetation especially the development of a thick moss layer, results in colder soils and eventually permafrost. Frozen soil prevents water percolation, resulting in wetter soils and inhibition of tree growth.

Drury (1956) discussed the relations of bogs, forests and permafrost in a region of forest-tundra on the Kuskokwim River, Alaska. He described a way in which bogs may form by thawing of permafrost. First there is a break in the moss on the forest floor. Drury speculated that the break could be caused by fire,blowdown, game trail or bursting of a pingo. Qali (Pruitt 1958, 1959) also might be a factor causing destruction of the moss cover and subsequent initiation of the thaw cycle. However the break occurs, thawing starts. This results in slumping and a water-filled depression which grows in size. Hydrophilous *Sphagnum* and sedges invade the depression. As the bog pool grows it is invaded by other mat forming bog vegetation. Thus the bog grows at the expense of the forest. Drury postulated a cycle, with bogs advancing by thawing, followed by organic deposition in the wet depressions, followed by progressive drying as the peat and silt deposits thicken. Eventually a black spruce-tamarack forest is re-established, accompanied by a rise in the permafrost table.

The degraded permafrost below the ruts and gullies, on the Arctic Slope of Alaska, caused by tractor trains, supports hydrophilous vegetation. I noted, in about 1956, that populations of *Microtus oeconomus* had spread from their normal riverine location into and along the bottoms of these ruts and thence into the drier uplands. Thus this species was brought into extended contact with *Dicrostonyx groenlandicus*. Moreover, one can only speculate on the possible genetic results of having a population attenuated to one or two *Microtus* wide and perhaps thousands of *Microtus* long.

We see, then, that permafrost is one of the major components of the environment of tundra biotic communities. Its effects are toward both stability and change in the community. At our present level of knowledge it is difficult to predict the effects of human activity although, in general, such activity tends to degrade permafrost. In permafrost regions any human activity, especially one to be accompanied by modification of natural vegetation associations, should, therefore, be preceded by investigations to determine the changes to be anticipated in the permafrost regime. The ecological repercussions of such changes must be evaluated, of course, in relation to the advantages of the proposed human activity.

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Paper No. 5

Structure and Function of the Tundra Ecosystem at Barrow, Alaska

INTRODUCTION

The Tundra Biome Program of the U.S. International Biological Program is pursuing several objectives which are designed to establish a firm scientific platform from which questions concerning resource management and the quality of the tundra environment can be judged. These objectives briefly stated are:

(1) Bring basic environmental knowledge to bear on problems of degradation, maintenance, and restoration of the temperature-sensitive and cold dominated tundra/taiga ecosystems.

(2) Develop a predictive understanding on how the wet tundra ecosystem operates, particularly as exemplified in the Barrow, Alaska, area.

(3) Obtain the necessary data base from throughout the circumpolar tundras so that the behaviour of these cold-dominated ecosystems can be modeled and simulated.

The Tundra Biome Program is initiating its first year's research activities with a project designed to analyze and model the existing Barrow, Alaska environmental data. The following word model (Section 1) described the principle components of the wet tundra coastal ecosystem. The term structure refers to the physical, chemical, and biological characteristics of the plant and animal life. Function considers the physiology, ecology, and development of both plant and animal life. Particularly in case of the tundra, the structure and function of the ecosystem are intimately related to the abiotic substrata.

In addition, this report outlines how and when this NSF supported analyses and modeling effort (Section 2) will be undertaken. Finally a more detailed account of the Barrow physical setting (Section 3) is presented along with the previously prepared and updated bibliography (Section 4).

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SECTION 1–A WORD MODEL OF THE BARROW ECOSYSTEM

J. BROWN[1], F. A. PITELKA[2] and H. N. COULOMBE[3]

The intensive site of the U.S. IBP Tundra Biome Program for arctic tundra near Barrow, Alaska, encompasses a complex of habitats arrayed along a moisture-dominated gradient.

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Vegetation and soils are distributed along micro-, meso-, and macro-environments according to type and size of polygons, regional relief, and land-form type. These range from upland meadow communities (arctic brown and upland tundra soils) to wet meadow and marsh types (meadow and bog soils) to emergent aquatics (hydrosols) and open water in small ponds and lakes. Ponds, an integral aspect of all principle habitats (Figure 1), show various stages of succession resulting from both filling and erosion. Large shallow lakes occupy 30% of the area north of 71° latitude. These vegetation, soils, micro-relief and aquatic environments form a complex mosaic which influences plant productivity and animal population and diversity throughout the year.

The principle vascular producer species on the terrestrial habitats are listed in order of importance in Table I. Primary production is controlled by a combination of temperature, soil moisture, day length and nutrient supply. The more productive habitats on micro- and meso-scales are near the wetter end of the soil moisture gradient (meadows and

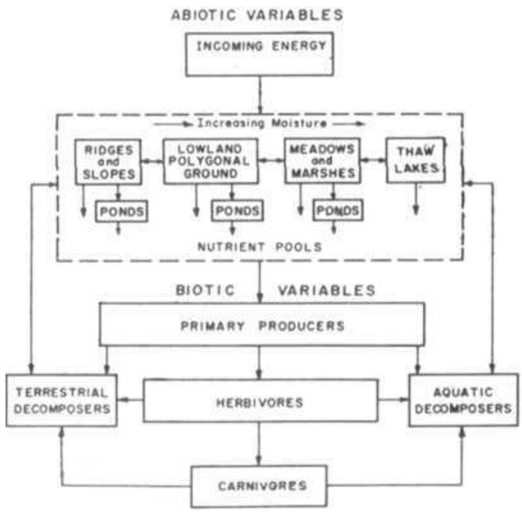

Fig. 1. Simplified diagram of the Barrow ecosystem emphasizing the predominance of ponds and the importance of a moisture gradient in terrestrial habitats.

TABLE I. Major vascular plant species in the Barrow ecosystem*

Habitat *Soils*	Ridges, polygon tops and slopes Arctic Brown and Upland Tundra	Meadows and polygon troughs Meadow Tundra and Bog Soils	Ponds Hydrosols
	Carex aquatilis	Dupontia fisheri	Arctophila fulva
	Petasites frigidus	Carex aquatilis	
	Salix pulchra	Eriophorum angustifolium	
	Arctagrostis latifolia	Eriophorum scheuchzeri	
	Poa arctica	Petasites frigidus	
	Luzula confusa	Poa arctica	
	Salix rotundifolia		
	Eriophorum scheuchzeri		

* Compiled by Dr. John Dennis, University of Calgary. Species arranged in order of decreasing occurrence.

polygon troughs). All habitats are controlled by the presence of permafrost (0°C ground temperature or colder) near the surface throughout the growing season. Especially significant to the amount of seasonal primary production are the climatic conditions of the first two or three weeks of the growing season and the previous summer's stored reserves and climate. Superimposed on this are fluctuations in nutrient cycle. On all terrestrial sites, but particularly on the wetter meso-sites, production is directly influenced by delayed effects of decay of clipped plant debris and faecal remains. It is hypothesized that the availability of nutrients to plants for growth is modulated by the lemming population through accumulation and storage of certain elements (N, K, P) in, and their ultimate release from, faecal and other dead organic matter.

Long-term rates of total decomposition in most of the habitats are approximately equal to production; there is no net accumulation of organic matter. Initial organic matter accumulation on drained lake beds is rapid. Based on radiocarbon evidence, depth of thaw measurements, and the absence of widespread organic terrain, organic accumulation and decomposition under uniform climatic conditions are assumed to reach a steady state within a relatively short period (presumably less than 100 years). A dominant acceleration effect in the decomposition process is the amount of standing dead plant matter prostrated by lemming grazing.

Prominent saprovores are dipterous larvae, collembolans, and oribatid mites. Although the rate of organic decomposition is slow, wetter habitats show higher rates of nutrient loss through decomposition compared to better-drained, drier habitats. Microbial activity appears to be several orders of magnitude below that of lower latitude wet ecosystems and, furthermore, is confined to the upper 10 centimeters or so of the soil.

There are low numbers of thermophilic bacteria in most arctic soils. Mesophilic microorganisms are greatest in numbers when the soil is frozen and drop sharply once the summer thaw occurs. Psychrophilic bacteria increase in numbers during the summer. Limited metabolic activity also occurs during the summer.

Important for the assessment of production on tundra is the distinction between above and underground components of plants. Biomass ratios below to above are of the order 5: 1 or greater. Annual production rates below to above are approximately equal.

Annual production rates for the tundra ponds and the lakes studied are very low compared to most temperate-zone water. Many of these small ponds receive seasonal influxes of organic matter (clippings, faecus, soluble organic), especially during the spring runoff. During the summer, thermal erosion of organic-rich permafrost also contributes to lakes and pond filling. Approximately 25% of the total seasonal lake production occurs beneath the ice before and after the spring thaw and after freeze-up. Production appears limited by a short growing season, low solar intensity during the growing season and nutrient deficiences, especially for phosphorus.

Plant consumption is dominated by the brown lemming (*Lemmus trimucronatus*), which utilizes standing living tissue on a year-round basis. Other vertebrate herbivores typical of tundra elsewhere are here negligible (e.g., a second microtine *Dicroslonyx;* caribou; geese) or absent (ground squirrels). The herbivory of arthropods is probably lower than in other ecosystems. The vegetation-lemming interaction is cyclic on a 'short-term' basis, the period being three to five years.

One type of carnivory is conspicuously associated with the lemming cycle, with several bird and mammal predators present in significant densities. These include jaegers, owls, and gulls (summer active), and weasels and foxes (active year-round). Other carnivory is that of predation on insects, mainly by birds but also by shrews, arachnids, and other arthropods. The most conspicuous predators are the shorebirds which concentrate on eating the larvae of Diptera.

Dominating all terrestrial and aquatic processes is the shortness of the growing season, varying between 45 and 90 days. Short growing season is partially compensated for by uninterrupted diurnal light.

ACKNOWLEDGEMENTS

The authors acknowledge the many Barrow investigators who have critically reviewed and contributed to this word model.

SECTION 2–THE SYNTHESIS AND MODELING OF THE BARROW, ALASKA, ECOSYSTEM

H. N. COULOMBE[1] and J. BROWN[2]

INTRODUCTION

In an ecosystem one is faced with a complex web of inter-related cause and effect relationships. The effect of a change in part of the system depends on the states and rates of change in many of the system's components. Such a system can only be described by specifying its components and the pathways of interactions among them. The mathematical expressions describing the interactions must be stated and the entire model operated as a set of simultaneous interactions to predict the effects of a given change or treatment. In practice, systems analysis permits such models to be constructed. Thus gaps in understanding are isolated and identification of new components and different modes of interactions are manifested as models and predictions based on them are compared with the real world (Fig. 2). The models are improved as understanding of the natural situation is improved through measurement and experimentation. In this manner, one can continuously maintain a rather complete overview of the state of that understanding.

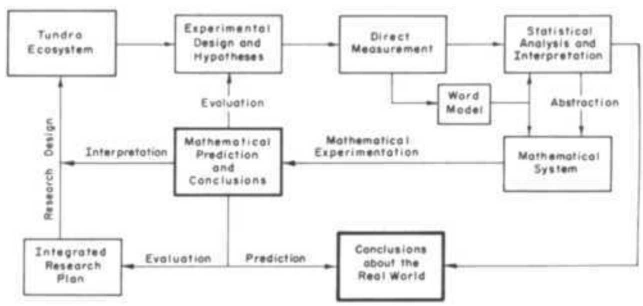

Fig. 2. Operational Relations of the Analysis of the Structure and Function of the Tundra Biome, Analysis of Ecosystems Program.

The Tundra Biome of the U.S. International Biological Program, Analysis of Ecosystems (Fig. 3 II), is in a unique position among the biomes of the U.S. Analysis of Ecosystems Program. Data accumulated on the wet tundra at Point Barrow, Alaska, are available over two decades, and include a group of intensive investigations during 1961-1967 on most aspects of energy and nutrient flow through this ecosystem. It was proposed that these data be used to construct a preliminary ecosystem model. Doing so at an early stage has several benefits: (1) gaps in understanding the tundra ecosystem components and their interactions will be identified early, so that future research projects can be quickly resolved; (2) experience will be gained in determining what types and forms of data are useful for modeling; (3) insight will be provided into consequences of human interference which will shortly increase in magnitude because of the impact of the oil industry on the cold-dominated environment of North America; and (4) a real-number basis will be available for development of models required by the Analysis of Ecosystems Program for comparing diverse ecosystems.

We proposed to bring together a portion of these data in a systems-oriented manner and accomplish the following specific objectives:

1. Review and modify the present conceptual tundra model (Moor House Model) for application to the Barrow ecosystem, including the development of the word model presented in this paper (Section 1).

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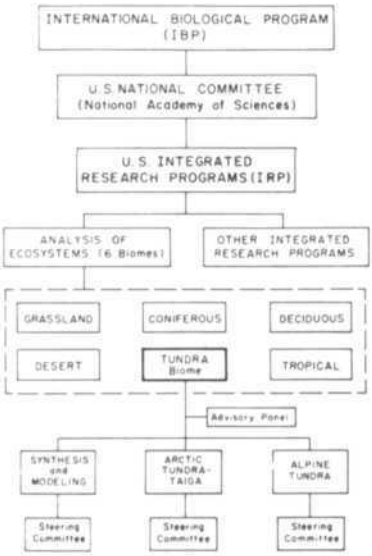

Fig. 3. Outline of Organizational Structure of the Tundra Biome-October 1969.

2. Synthesize, mathematically and statistically, the relevant portions of the Barrow data base.

3. Coordinate systems and sensitivity analyses on the synthesized data within the framework of the model.

4. Incorporate the results of the modeling into the integrated Tundra Biome research plan and other circumpolar programs.

The U.S. Tundra Biome Synthesis and Modeling project is divided into four overlapping phases: (1) Conceptual Model Development and Review; (2) Barrow Data Synthesis and Analysis; (3) Coordination of Systems and Sensitivity Analysis; and (4) Coordination with Integrated Research Program. The operational scheme of data handling and modeling is shown in Figure 4.

CONCEPTUAL MODEL DEVELOPMENT

The first stage in conceptual model development includes evolution of a verbal model as suggested by Gore and Heal (1969). The interaction of scientists concerned with various components of an ecosystem can provide a qualitative description or word model of the ecosystem's operation. An overall attempt to define the properties of the Barrow ecosystem (Fig. 5) was initially provided by Shultz (1964). This model identifies many of the interacting factors in the system and provides a basis for constructing several hypotheses concerning the year-to-year functioning of the Barrow ecosystem. However, the complexity of the physical environment at Barrow has now prompted us to identify four major habitats (Fig. 1) so that the aquatic and terrestrial components of the ecosystem could be handled in parallel through the transition from word to numerical models. The word model developed in the preceding section does not include special consideration of components or interactions common to any and all ecosystems.

The basic conceptual model for the Tundra Ecosystem was developed at the Working Session on Arctic-Subarctic Ecosystems held at Moor House Nature Reserve, Westmoreland, England, November 2-4, 1967. Processes describing the transfers between compartments are represented by numbered functions (Fig. 6), where each numbered vector represents the direction of flow, and stands for a specific interaction rate that has to be

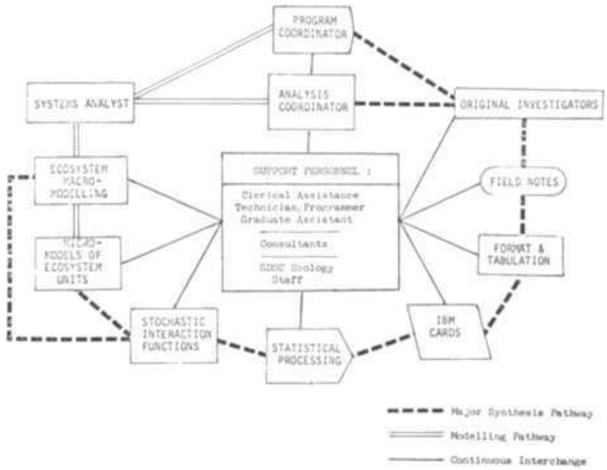

Fig. 4. Proposed scheme of data handling and responsibilities for the Barrow Modeling Project.

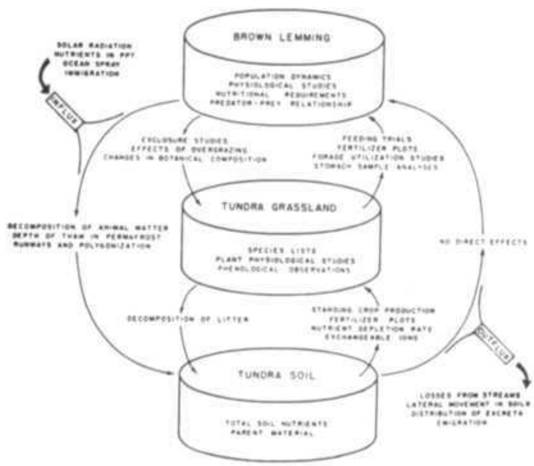

Fig. 5. Schematic diagram of the Tundra ecosystem at Pt. Barrow. (after Schultz, 1964).

empirically determined or approximated by assumptions. Each of the interaction functions may represent a complex stochastic interrelation of several variables and time functions, and many depend on values simultaneously derived in other transfer functions. The complexity of the overall model emphasizes the need for an adequately large digital computer. This model is in a continuing evolutionary process: as more attention is focused by scientists representing a wide variety of disciplines, more vectors or transfer functions are identified. The basic 'Moor House Model' (Fig. 6) encompasses thirty-one transfer functions. Discussion at the October meeting of the U.S. Tundra Biome at the University of Alaska added another nineteen transfer functions that appear to be ecologically important to consider in a total system model.

At the Ustaoset, Norway, Tundra Meeting (September 1968) it was agreed that energy and carbon flow will be modeled by at least four countries: United Kingdom, United States,

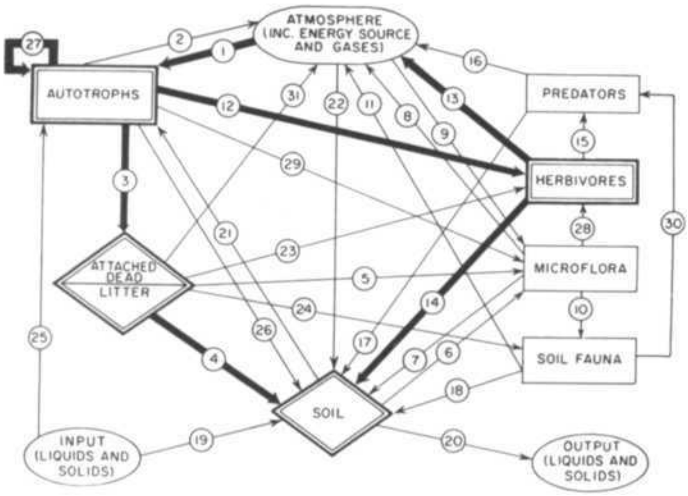

Fig. 6. Flow diagram for energy and nutrients in tundra ecosystems.

Finland, and Norway. The U.S. Tundra Biome intends to cooperate in developing a circumpolar tundra ecosystem model which should be compatible with other IBP ecosystem models. Close coordination among the U.S. Biome modeling activities, particularly the Grasslands and Desert, and the Center for the Environment and Man (previously Travelers Research Center) will help keep the development of basic models in step throughout the Analysis of Ecosystems Program. The next phase is synthesis of data to provide links necessary for translating these word and conceptual models into a numerical model so that mathematical experimentation (Fig. 2) can be carried out.

Over the past two decades the Barrow area has been the scene of intensive multidisciplinary field research. Unfortunately, the many research projects have not always been concurrent nor well integrated with one another. During early and mid 1960's, a number of key research programs were conducted. Initially several years' data from this period will be subjected to modeling and systems analysis. A workshop was held October 28-November 1, 1969, near Boulder, Colorado (Report available from Biome office) to accomplish the following objectives: (1) familiarize all participants with the model and the required form of data input; (2) determine the gross limitations of the available data and the most profitable years for which synthesis and modeling should be undertaken; (3) schedule synthesis of acceptable past research projects.

Construction and evolution of a numerical ecosystem model require data analysis in several different forms. Initially, data analysis might be more qualitative than quantitative and may consist of descriptive graphical representation and various types of sorting and computer tabulation.

The next task is to estimate the parameters of the numerical models and provide the needed distributions. Estimators are chosen in the light of the preliminary data analysis, their experiments may be designed to obtain additional data in a form useful for refined analysis.

Careful scrutiny needs to be applied to the appropriateness of different kinds of data to the statistical models to which they are subjected. Transformation of the raw data may be necessary to meet realistically the assumptions inherent in various statistical processes.

Analysis and synthesis of the Barrow data will be available to data contributors in the form of tabulations, graphic representations, fitted functions and some hypothesis-testing information. This service will aid in bringing much ecological information to the scientific community. Interaction between the contributors and the project personnel will allow recognition of the most appropriate derivations of interaction functions for use in subsequent phases of this program; decisions based on theoretical considerations within a given discipline as well as empirical bases can thus be achieved.

Application of systems analysis to study of the Barrow ecosystem will require close multidisciplinary interaction among the team of scientists working on the program at all institutions. These include physical and biological scientists, on the one hand, and systems analysts, mathematicians, statisticians and computer scientists on the other.

Two approaches to modeling the Barrow ecosystem data are envisioned: (1) macro-modeling, or consideration of the entire ecosystem; (2) micro-modeling of compartments within the ecosystem.

The resolution required for simulation of the entire ecosystem may be less than that required for acceptable biological/physical interpretation of the component processes. The complexity of this type of model requires some constraint in selection of component functions. Micro-modeling can provide additional insight for the systems simulation process in the macro-model, as the sub-systems developed provide a basis for realistic abstraction for a lower resolution system (Van Dyne 1969 a, b).

SYSTEMS ANALYSIS: AN OVERVIEW

Models symbolize the multivariate universe; systems analysis describes the interactions. Quantitative studies give real values to functional relationships between interacting components of a dynamic system. An ecosystem is one of many examples of such a system. To study a defined ecosystem, one is required to start by viewing the whole system, describing its components and relating them to the whole. Watt (1966, 1968) has described systems analysis and the systems approach. He has emphasized that if whole systems are to be studied, a strategy of research must be designed in which every step is aimed at the problem of fitting all the fragments together correctly at the end of the program. Otherwise, one may get to the end of a research program and find that the fragmental results cannot be fitted into any meaningful whole.

In order to fit complex research activities into a meaningful 'big picture' of an ecosystem which is representative of the 'real-world', experimental phases of the program must be linked to the theoretical and analytical phases embodied in the systems approach. This can be accomplished through planning and analysis projects which ultimately employ the techniques of system analysis (Van Dyne 1969a).

An ecosystem has been defined as an integrated complex of living and non-living components (Van Dyne 1969b). The functions of the system are many and include transformation, circulation and accumulation of matter and flow of energy through the medium of living organisms and their activities by means of physical processes. An ecosystem can be termed an approach or concept for studying the interaction of biological and physical processes. There has been a gradual shift in recent years from descriptive and inventory studies to the study of system functions such as energy flow, nutrient cycles and productivity. Thus different techniques, concepts and approaches are required to carry out the study of ecosystem performance or behaviour that will aid us in understanding how the ecosystem functions and how its components interact in real life.

The systems model is a combination of mathematical expressions and statistical probability distributions representing the processes and interactions in the ecosystem (e.g., rates of input and output of energy, water, minerals, organisms), the rates of transfer of these factors within the system (e.g., from soil to plant, plant to animal), and the impact of specific factors on other components (e.g., the impact of temperature on energy flow). Since the real world is probabilistic in nature even at the very finest of levels, the model should attempt to apply statistical distributions to handle the naturally occurring variations of system processes. We are attempting to describe a dynamic environment with continuously changing variables, some of which are dependent, others independent. Therefore, development of a probabilistic rather than deterministic model should be the final objective.

Systems analysis is a new tool to many biologists; it is *not a cure for poor data* (Van Dyne 1969b). It is very useful as a means of not losing information in complex problems, but it cannot improve upon the quality of the original data. On the contrary, it may indicate when data are unnecessary or when they are insufficient. Although models may appear extremely complex, they can be constructed from simple mathematical statements and statistical distributions which represent the functions, interrelationships, and values attributed to the real-world ecosystem. These statements are translated into computer language to permit computer simulation of the system. Numerical simulation is the only known technique capable of representing the complexities of the real system.

Following construction, the numerical model can be experimented with to arrive at deductions regarding the system. These deductions or results are arrived at through application of mathematical argument to test the hypotheses originally formulated and/or the findings previously available. In some instances conclusions may be drawn regarding parts of the system through physical experimentation; however, in many situations, particularly in northern lands, it is not feasible to experiment with the real environment because of cost or potential catastrophic effects, or because the entire system is too complex for the design of an all-encompassing physical experiment.

Finally, the mathematical results from the model are translated into their physical counterparts to better understand the performance of the real-world system. The analysis of model data is done by systems analysis through application of analytic and statistical techniques available to or developed by them. Results of model experimentation and interpretation can then provide input for the next iteration in the process described in Figure 2.

Results can be used by the systems analyst to validate his model. Where disagreement occurs between model results and real-world observations, the model can be modified and new mathematical experiments can be devised to test it. Concurrently additional physical experimentation might be indicated to fill knowledge gaps or to correct inaccuracies in existing data. Thus model results assist both in the construction of improved models and in the design of additional physical experiments.

After one and usually two or more iteration(s) of the sequence, the analyst is able to vary the quantitative values of the components (parameters) of his system and thus experiment with alternative system configurations. By varying each parameter value in succession while holding the others constant, he is able to determine which parameters have a significant impact on system behaviour. This technique is called sensitivity analysis. It can be used to direct research emphasis and the design of additional physical experiments to those components that have important effects on system behaviour, while diverting emphasis from less important parameters.

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SECTION 3 - ENVIRONMENTAL SETTING, BARROW, ALASKA.

J. BROWN[1]

GEOGRAPHIC SETTING

Barrow is situated at the northern extremity of the Coastal Plain Province of the Arctic Slope (Figure 7). The area reported upon is restricted to the land mass north of 71° 15' latitude. As such, it is a triangular-shaped land mass bounded by the Chukchi Sea on the west, the Arctic Ocean on the north, and Elson Lagoon and the Beaufort Sea on the east. The area is characterized by low relief, patterned ground, dominated by ice-wedge polygons, and shallow, oriented lakes and drained lake-basins. The depth of seasonal soil thaw averages 40 cm and is underlain by perennially frozen ground to several hundred meters. Elevations at the northern part of the Barrow area are less than 5 meters along wave-cut cliffs and rise to 20 meters in the southern part. Relief is rarely greater than 5 meters on the undulating inland areas. This northernmost tip of the land is the most recently emergent part of the Coastal Plain and is late Pleistocene in age.

The largest Eskimo population in the state is located within this area at the village of Barrow. Several government-operated facilities including the Naval Arctic-Research Laboratory are situated some 8-10 kilometers north of Barrow village (Figure 7). In addition to the food resources derived from migrating birds and the ocean by the natives, the only other natural resources presently being exploited at Barrow are the underground gas which is pumped from several wells south of the village and fresh water derived from several lakes and ice. As a result of earlier oil exploration and the present-day cultural activities, the immediate Barrow tundra landscape has been modified by vehicular tracks and occasional debris.

CLIMATE

The regional climate can be briefly described as consisting of long, dry, cold winters and short, moist, cool summers. Temperatures remain below freezing through most of the year. Daily maxima are higher than 0 °C on an average of 109 days. Freezing temperatures are observed every month of the year. February is generally the coldest month, having a mean of −28°C. Temperatures begin a gradual warming trend in April with a definite transition to summer during May, accompanied by an average of 5 days above freezing in that month. July is the warmest month with a monthly mean of approximately 4°C. The end of summer is reached by mid-September and by November one-half of the daily mean temperatures are −18°C or below. Mean precipitation is 116 mm. The months of March, April and May are the driest, and July and August are the wettest. The heaviest portion of the precipitation season extends into October with the highest average snowfall occurring in that month. Winter snow cover is generally melted by mid- to late-June, although late snow patches can remain well into the summer. Summer snowfalls occur occasionally. The annual mean hourly wind speed is 21. 6 km/hr and the prevailing direction is easterly. October has the highest monthly mean hourly wind speed of 24.6 km/hr and March and December the lowest with 19. 8 km/hr. Fogginess and cloudiness persist through the summer with maximum cloudiness occurring in the transition to winter during September and continuing through October and November. The presence of ice-free ocean from mid-July onward to freeze-up is a moderating factor resulting in cooler summer-time temperature and in more cloudiness and fogginess than in the adjacent inland areas. Table II presents the normals, means, and extremes from the first order weather station at Barrow (U.S.Dept. Commerce). For purposes of comparison, the monthly air temperatures and annual precipitation for Barrow and several Siberia coastal stations which have a somewhat similar climate are presented in Table III.

Black (1954) contended that precipitation at Barrow is greater than actually recorded by standard gaging methods; perhaps by a factor of 2 to 4 times. This discrepancy

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[1] USACRREL, Hanover, New Hampshire.

TABLE II Climatological normals, means, and extremes, Barrow, Alaska

Normals, Means, and Extremes

Month	Temperature: Normal: Daily maximum	Temperature: Normal: Daily minimum	Temperature: Normal: Monthly	Temperature: Extremes: Record highest	Year	Temperature: Extremes: Record lowest	Year	Normal degree days	Precipitation: Normal total	Precipitation: Maximum monthly	Year	Precipitation: Minimum monthly	Year	Precipitation: Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Snow, Sleet: Maximum monthly	Year	Snow, Sleet: Maximum in 24 hrs.	Year	Relative humidity: 2 AM	Relative humidity: 8 AM (Standard time used: ALASKAN)	Relative humidity: 2 PM	Relative humidity: 8 PM	Wind[&]: Mean hourly speed	Wind: Prevailing direction	Wind: Fastest mile: Speed	Wind: Fastest mile: Direction	Wind: Fastest mile: Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Sunrise to sunset: Partly cloudy	Sunrise to sunset: Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 70° and above	Temperatures: Max.: 32° and below	Temperatures: Min.: 32° and below	Temperatures: Min.: 0° and below	Average daily solar radiation-langleys
(a)	(b)	(b)	(b)	48		48		(b)	(b)	48		48		47		48	48		48		24	24	24	24	39	14	9	9			26	34	34	34	48	24	48	27	48	48	48	48	12
J	-9.4	-23.0	-16.2	35	1963	-53	1951	2517	0.18	1.04	1962	0.00	1939†	0.70	1937	2.4	11.9	1962	5.4	1962	64	65	64	65	11.2	ESE	49	09	1962		§	3	3	2	4	1	0	2	0	31	31	29	2
F	-12.2	-24.4	-18.3	32	1960	-56	1924	2332	0.17	0.81	1959	0.00	1936	0.36	1959	2.3	9.4	1944	3.6	1959	62	63	62	62	11.0	E	45	11	1960		5.3	12	6	10	4	1	0	1	0	28	28	27	39
M	-8.1	-21.1	-14.6	33	1967	-52	1923	2468	0.11	1.49	1963	0.00	1928	0.71	1963	2.0	15.8	1963	7.1	1963	64	64	66	65	11.2	ENE	58	27	1960		5.0	14	7	10	4	*	0	1	0	31	31	30	177
A	7.4	-7.0	.2	42	1936	-42	1924	1944	0.11	1.36	1963	0.00	1938	0.42	1963	2.2	15.4	1963	4.2	1963	72	73	73	73	11.6	NE	40	25	1961		5.9	10	7	13	4	1	0	3	0	29	30	23	390
M	23.5	13.3	18.4	45	1927	-18	1922	1445	0.12	0.81	1933	‡	1939†	0.30	1923	1.9	12.9	1933	4.5	1923	87	87	84	86	11.7	ENE	39	25	1968		8.4	4	4	23	4	*	0	8	0	26	31	4	527
J	37.5	28.7	33.1	70	1942	8	1933	957	0.36	1.15	1955	‡	1937†	0.82	1955	0.5	6.6	1933	2.9	1954	94	92	89	91	11.3	E	35	23	1961		8.0	4	6	20	4	*	*	12	*	5	25	0	545
J	44.9	33.3	39.1	78	1927	22	1936	803	0.77	2.44	1922	‡	1937	0.86	1954	0.7	9.0	1922	6.0	1922	95	91	88	91	11.6	E	35	23	1961		8.2	3	7	21	9	*	*	13	*	*	14	0	437
A	42.7	33.1	37.9	76	1968	20	1925†	840	0.90	2.81	1963	‡	1934	0.83	1960	0.6	2.9	1933	2.5	1936	95	93	89	93	12.6	E	36	23	1963†		8.9	2	3	26	10	*	*	11	*	2	15	0	262
S	33.8	27.2	30.5	62	1957	1	1957	1035	0.64	1.56	1958	0.02	1927	0.56	1959	3.0	7.9	1925	5.0	1950	92	91	89	91	13.2	E	37	07	1961		9.2	2	2	26	9	1	0	5	0	13	26	0	120
O	21.4	11.8	16.6	43	1954	-21	1963	1500	0.50	1.65	1925	0.12	1936†	1.00	1926	7.1	21.2	1925	15.0	1926	84	85	84	85	13.5	E	55	27	1963		8.7	2	4	25	11	2	0	4	0	28	31	6	41
N	5.3	-6.7	-.7	39	1937	-40	1948	1971	0.23	1.15	1965	‡	1936†	0.41	1925	3.8	19.0	1925	6.0	1925	77	76	76	75	12.7	E	54	26	1966		§	4	4	10	6	1	0	2	0	30	30	21	5
D	-5.0	-17.4	-11.2	34	1932	-55	1924	2362	0. 17	0.76	1967	0.00	1936†	0.26	1930	2.8	9.7	1925	5.0	1922	66	66	66	66	11.4	E	44	09	1960		§	§	§	§	5	1	0	2	0	31	31	29	0
YR	15.1	4.0	9.6	78	Jul. 1927	-56	Feb. 1924	20174	4.26	2.81	Aug. 1963	0.00	Jan. 1939†	1.00	Oct. 1926	29.3	21.2	Oct. 1925	15.0	Oct. 1926	79	79	78	79	11.9	E	58	27	Mar. 1960			60	53	186	74	8	*	65	*	256	323	169	212

§ Sun below horizon continuously November 19 to January 23.
Data entered in columns headed 'Clear, Partly Cloudy, and Cloudy' in both tables are for period sun above horizon.
Means and extremes in the above table are from the existing and comparable locations. Annual extremes have been exceeded at another location as follows:
Maximum monthly snowfall 26. 5 in April 1916.

(a) Length of record, years.
(b) Climatological standard normals (1931-1960).
* Less than one half.
† Also on earlier dates, months or years.
‡ Trace, an amount too small to measure.
Below-zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall in inches; wind movement in miles per hour; and relative humidity in percent. Degree day totals are the sums of the negative departures of average daily temperatures from 65°F. Sleet was included in snowfall totals beginning with July 1948. Heavy fog reduces visibility to ¼ mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3; partly cloudy days 4-7; and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter. Averages in the lower table for some months may be for more than the listed number of years.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under 'Fastest mile' the corresponding speeds are fastest observed 1-minute values.

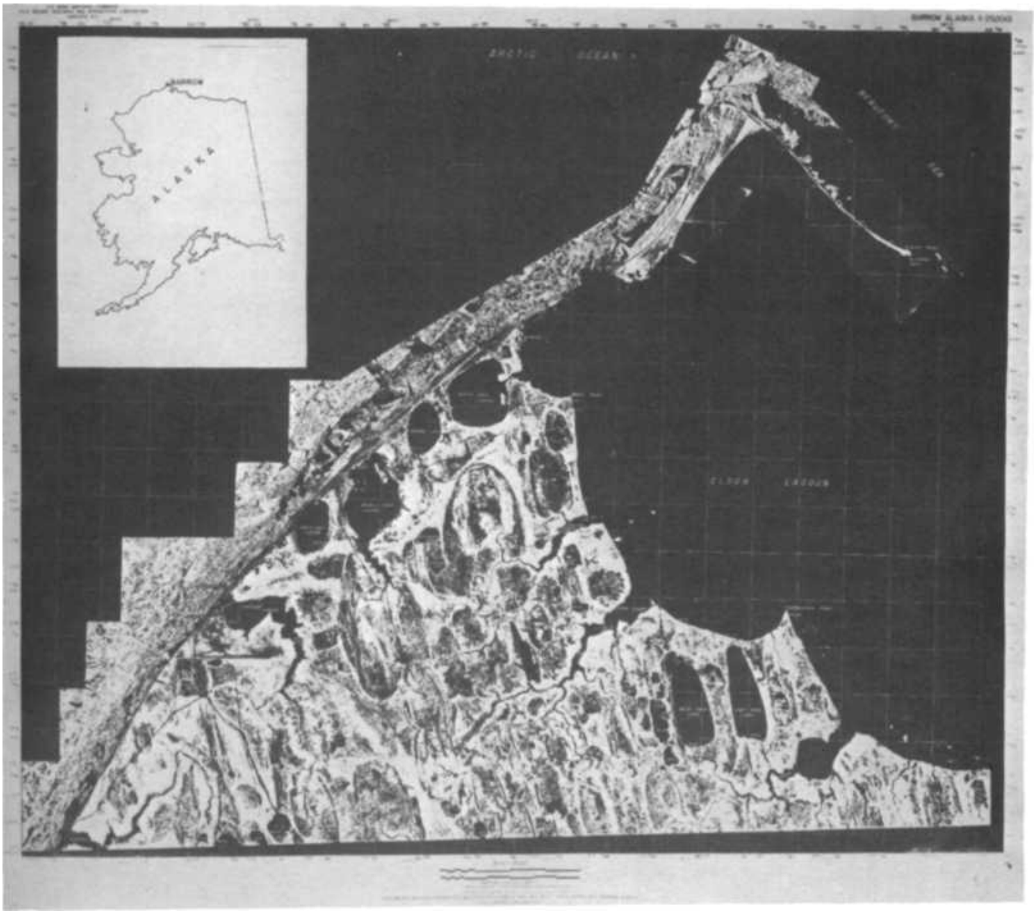

Fig. 7. Photo mosaic of Barrow, Alaska and location map.

between recorded and indirect observations such as snow depths and densities and soil moisture was thought to be a result of gaging inefficiencies caused by high winds during rain storms and snowfall. Recent data by USACRREL, in which summertime precipitation was gaged over a small watershed, agreed reasonably well with the Barrow weather station data on a seasonal basis, but demonstrated considerable variability within and between storms (Brown, Dingman, and Lewellen 1968). Mather and Thornthwaite (1956, 1958) proposed that these differences in measured precipitation were due to random variations. Benson (1962) conducted a detailed snow survey on the North Slope of Alaska to provide a more accurate approximation of snowfall. These measurements are based on snow density and drift patterns.

Both Clebsch (1957) and Mather and Thornthwaite (1956, 1958) studied evaportranspiration at Barrow, and the general conclusion has been that precipitation equals or only slightly exceeds total evapotranspiration during the summer period at Barrow (Britton 1957). The four-summer hydrologic study (1963-1966) is essentially in agreement with these conclusions (Brown, Dingman, and Lewellen 1968). It revealed that about 5% of the thaw-season precipitation runs off, but that considerable variation exists in runoff from year to year between similar storms (1 to 70%). This is a reflection of the summer precipitation record and other antecedent conditions. Therefore, since essentially all the meltwater runs off prior to the initiation of soil thaw, the precipitation period most important to the soil moisture regime occurs during the summer months.

TABLE III Climatic comparison of Barrow with several Siberian coastal stations.

Location	Lat.	Long.	Elev. (ft.)	Years of Record	Monthly Mean °F Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann. (°F)	Ppt. (in.)
Barrow	71°18'	156° 47'	31	46	-15.3	-18.7	-15.5	-0.5	18.8	33.7	39.4	38.1	30.4	16.3	0.3	-11.4	9.7	4.6
Siberian Stations																		
Bely, Ostrov	73° 20'	70° 02'	20	7	-6.5	-10.1	-10.1	1.8	18.3	30.9	39.7	41.4	35.4	24.4	10.4	- 1.3	14.5	6.6
Drovyanoy, Mys	72° 40'	70° 55'	171	7	-10.3	-11.3	-8.9	1.4	19.4	32.5	40.8	43.5	35.8	23.5	8.2	- 5.3	14.2	5.9
Diksona, Ostrov	73°30'	80° 23'	79	11	-18.4	-14.4	-13.9	-0.8	16.9	30.7	37.8	39.7	32.5	16.9	-4.5	-11.0	9.1	6.5
Preobrazheniya, Ostrov	74°38'	112° 48'	16	7	-17.7	-13.4	-16.1	-1.1	18.9	32.9	37.6	36.5	31.6	14.9	- 5.8	-14.8	8.6	4.5
Nordvik	73° 38'	110°50'	102	7	-20.9	-22.0	-22.4	-3.1	16.3	34.2	41.0	39.6	33.6	13.5	-10.1	-20.0	6.6	4.8
Pronchishchevoi, Bukhta	75°33'	113° 27'	16	7	-17.7	-17.3	-17.0	-2.0	17.2	32.7	39.2	36.7	29.1	-12.2	-8.5	-17.9	7.5	5.9
Vankarem, Mys	67° 50'	184° 04'	16	7	-11.9	-13.0	-11.6	2.8	17.2	34.9	40.3	40.3	33.8	21.9	5.7	- 6.2	12.9	4.8

VEGETATION

In general the vegetation of the Coastal Plain is meadow-like with an abundance of sedges, grasses, herbs and a few dwarf shrub species. Detailed accounts of species distribution and community structure have been written by Britton (1957, 1958), Spetzman (1959),Cantlon (1961), Wiggins (1951), Wiggins and Thomas (1962), Koranda (1954), and Brown and Johnson (1965) for the area including Barrow. Hulten (1961) observed 106 species of vascular plants in the Barrow vicinity and Wiggins and Thomas (1962) enumerates 435 species on the Alaskan Arctic Slope. The vegetation of the Coastal Plain is less complex than that of the Foothills or Brooks Range because fewer species are distributed over a lesser number of habitats (Britton 1957). Northward across the Coastal Plain to Barrow, there is a general increase in the wet grassland type of vegetation with a conspicuous increase in grasses and sedges, paralleled by poorer drainage and a reduction in woody species, particularly heaths (Britton 1957, Clebsch 1957). Cantlon (1961) distinguished a narrow Littoral zone, including Barrow, bordering the Arctic Ocean. The vegetation strongly reflects the moderating and cooling effect of the ocean.

The vegetation at Barrow occurs primarily on drained lake basins and their gently sloping divides which are the characteristic land surfaces of the area. An understanding of species population is based upon geomorphic processes and the ages of land surfaces (Britton 1957) which will be discussed later. Superimposed on these large scale features is the distribution of vegetation across microenvironments, particularly polygonal ground, frost scars and hummocks. These features, generated by cryopedological processes, create microhabitats that, within distances smaller than a meter, result in extremes of vegetation. These microstructures of vegetation were described and mapped by Wiggins (1951) for a series of four sites that represent different stages of polygonal ground development at Barrow. Others (Brown and Johnson 1965, Drew and Tedrow 1962, Tedrow and Cantlon 1958, and Britton 1957) described and graphically illustrated the edaphic control of vegetation across moisture and microgradients (Figure 8).

For the purposes of this report the distribution and structure of vegetation in the Barrow area can be briefly characterized as predominantly wet, low grassland or tundra with abrupt spatial changes in species distribution, resulting from cryopedologic and geomorphic processes peculiar to the Arctic. In addition, the moderating effect of the maritime climate at Barrow is reflected by the vegetation in size, phenology and species distribution. These differences in vegetation can serve as criteria for evaluating regional and local difference in the less easily observed pedologic and geomorphic parameters of the substrate.

SOILS

The soils of the Barrow area were described, classified and mapped by Drew (1957) whose classification corresponds to one presented by Tedrow *et al.* (1958) for Arctic Alaska that includes the genetic soils termed Arctic Brown, Tundra and Bog. Brown

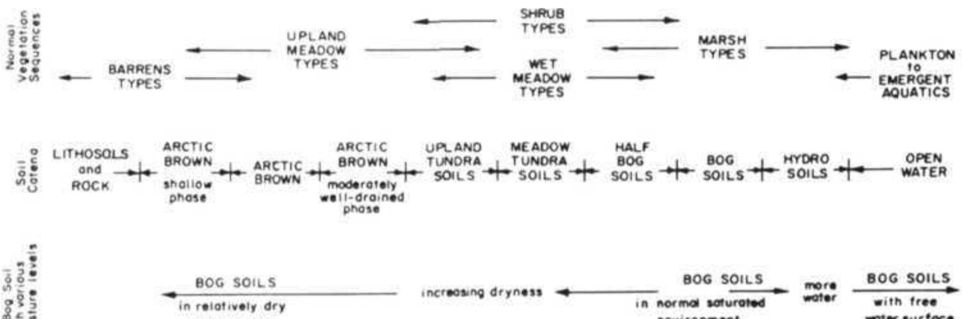

Fig. 8. Vegetation-soil relationships along a moisture gradient characteristics of the Barrow area (Tedrow and Cantlon, 1958).

(in press) demonstrated that the depth to the underlying, impervious perennially frozen ground is a function of soil moisture content. The wetter and more organic soils possess the shallower depths of thaw.

The Arctic Brown soil is formed on coarse grained material; the depth of the seasonal thaw is usually in excess of a meter and drainage is generally unimpeded. This combination results in a well-drained, brown-colored, somewhat acid soil which is considered the zonal soil of northern Alaska (Tedrow *et al.* 1958). At Barrow, this soil occupies only a limited area, specifically on top of the raised inland beach ridge where drainage conditions are optimum for its development (Drew and Tedrow 1957). Shallow, normal and imperfectly drained phases are recognized but were not mapped at a scale of 1:20, 000. Regosols are present on gravelly deposits which are excessively drained and which have undergone virtually no soil development. Beach gravels can be considered in this type soil.

The wetter mineral soils are divided into two types: Upland Tundra and Meadow Tundra. The Upland Tundra, for which dry and normal phases are recognized, are moderately to poorly drained and occur on predominantly fine-grained parent materials. The depth of thaw is generally less than 50 cm. The upper portion of the thawed soil is strongly mottled with orange-brown colors that grade into more bluish grays. A weak platy structure is observed under a thin peaty organic mat of less than 7. 5 cm and is probably a reflection of the occurrence of seasonal ice lenses. A semi-continuous buried organic layer is ubiquitous just above, and penetrating into, the perennially frozen ground. This is illustrated in Figure 9 (Douglas and Tedrow 1961). The occurrence and origin of this layer will be discussed later. The Upland Tundra soils occupy an intermediate drainage position between Arctic Brown and Meadow Tundra on the silt covered uplands. The Meadow Tundra soils, which are divided into dry, normal, and wet phases, have a peaty organic mat (7. 5 to 15 cm) over a grayish brown to bluish gray wet mineral soil. The depth of the seasonal thaw is less than in the Upland Tundra and reducing conditions are dominant. These wet tundra soils correspond qualitatively to the gley soils of the northern frost zones (Douglas 1961, Douglas and Tedrow 1961).

Bog soils occur where surface peat has accumulated to depths in excess of 15 cm and generally do not exceed 30 cm in the Barrow area. A thaw zone of saturated, gray mineral soil with some organic inclusion generally underlies the organic mat which in turn overlies the perennially frozen ground. Where the wet peat has been effectively drained by erosion or thawing of ice wedges, the peat is dry and the depth of thaw is considerably less than in wet organic soils. This dry phase is associated with high-centered polygons.

An idealized spatial relationship of these genetic soils is illustrated in Figure 10. Details of the relationship of soils, moisture regimes and vegetation are presented in Figure 8.

Drew's approach to soil mapping involved classification of the ice-wedge polygons (non-sorted types) so that local microtopography and surface drainage could be related to major soil units. The mapping legend consists of two parts: a soil classification and a polygon classification. Three types of parent materials were recognized:

1. Beach gravel along the coast;
2. Surface gravels, sand and silts of the inland beach ridge;
3. Sand, silts, clays, and peats that mantle the surfaces of drained lake basins and interfluves.

A sequence of polygon types is designated dependent upon the degree of ice-wedge information and ground deformation. An example of a polygon field containing polygons with slightly raised edges is illustrated in Figure 11 (see also Brown and Johnson (1965) for other examples of the Barrow pattern ground). In areas where more than one kind of polygon is present, combinations of types are mapped along with the dominant soil type. Planimeter measurements on this map yield the following distribution of soils and polygons: Soils: 75% Meadow Tundra; approximately 10% Bog soils; 5% Upland Tundra and only minor occurrence of Arctic Brown; and the remainder of the land surface comprising gravel beaches and recently exposed lake alluvium; Polygons: approximately 40% of the ground surface contained polygons with flat tops and about 20% contain polygons with distinct raised edges.

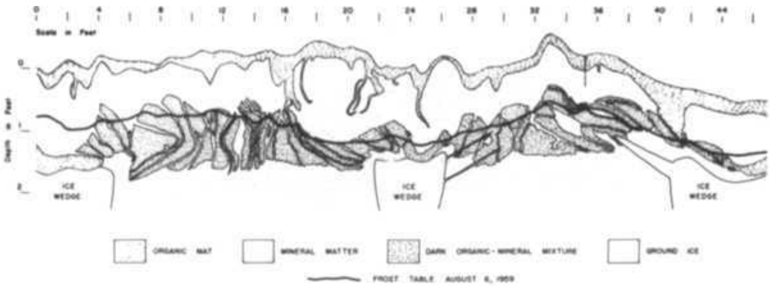

Fig. 9. Cross section of tundra soil, Barrow, Alaska (Douglas and Tedrow, 1961).

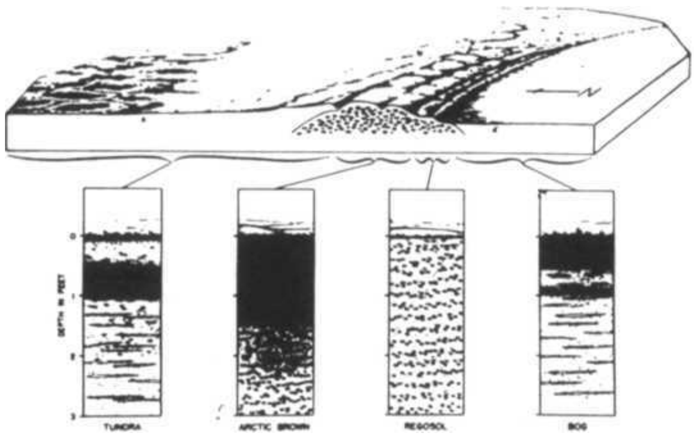

Fig. 10. Diagram of soil conditions from a tundra landscape at Barrow, Alaska (Drew *et al.*, 1958).

Douglas and Tedrow (1959) investigated rates of organic matter decomposition in different soil types. Soil temperature, moisture, and type govern the rate of decomposition. Decomposition during the summer was shown to be least in the Arctic Brown, intermediate in the Upland Tundra and dry Half Bog, and greatest in the wet phase of the Half Bog. Production of organic matter probably parallels the rate of decomposition in each soil; consequently, thick peat deposits do not form. Van Cleve (1967) found that decomposition of peat at Barrow was considerably less than for more southerly latitudes and amounted to only 1% of the total per year. The microbiology of the Barrow soils and near-surface permafrost has been investigated (Boyd 1958, Boyd and Boyd 1964). Bacteria and other microorganisms are present in the seasonally thawed soil in significant number and several viable organisms were found within the upper several meters of permafrost.

THERMAL REGIMES

Thermal regimes of ground and water masses in northern Alaska have received considerable attention for both the solution of engineering problems and natural surface phenomena. In the following sections geothermal gradients, soil temperatures, and ground temperatures below water bodies are discussed separately.

Fig. 11. Polygon field in which edges are slightly raised. Troughs are water covered. Photo taken after light snow fall in mid-summer.

Geothermal Gradients

Negative mean annual ground surface temperatures over a period of time results in the downward growth of perennially frozen ground. In northern Alaska, the maximum depth of perennially frozen ground that has been measured is 320 meters, while an extrapolation of the geothermal profile indicates a maximum depth of 405 meters located 12. 8 km south of Barrow (Brewer 1958). Figure 12 illustrates the geothermal profile at Cape Simpson Well 28, located to the southest of Barrow (Brewer 1958). The inverse temperature gradient of 23. 7 m/°C remains essentially unchanged from 76 meters through to 530 meters. Based upon rigorous analysis of these geothermal gradients, Lachenbruch and Brewer (1961) have demonstrated an increase of approximately 4°C in the mean annual ground surface temperature since about 1850, one-half of which occurred since 1930.

Figure 13 is a time-temperature curve for various depths in perennially frozen ground and the five-day average air temperature (Brewer 1958). In general, the curves are sinusoidal with pronounced assymmetry near the ground surface. The lowest measured temperature below the maximum depth of measurable seasonal change on the North Slope is −10. 6°C and is located near Barrow.

Soil Thermal Regime

Characteristics of the annual temperature wave through wet tundra soil are illustrated schematically in Figures 14 and 15 (Lachenbruch *et al.* 1962, Brewer 1958). Thawing of the soil commences when spring temperatures rise above freezing (time = t). Under normal conditions thawing proceeds to the top of the perennially frozen ground by the time autumn surface temperatures fall below freezing ($t = t_3$). From t_3 to t_5 the seasonally thawed soil freezes and the surface temperatures drop to near the annual low. Temperatures throughout the unfrozen soil drop to 0°C soon after initial freezing (t_3). As freezing progresses downward and occasionally upward, a steadily decreasing slab or sandwich of soil remains isothermal as the latent heat of fusion is being extracted. The result is the 'zero curtain' or the period during which temperatures at a given depth remain at the freezing point (t_3 to t_4). The lower part of the seasonally thawed soil freezes between t_4 and t_5. Once the soil is totally frozen the cold wave can penetrate into the perennially frozen ground. The zero curtain phenomenon is of little significance in the spring thaw period. Figure 15 presents the time-temperature curve for the 25-cm

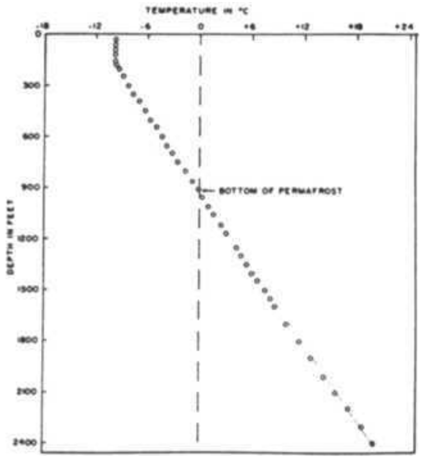

Fig. 12. Geothermal profile for Cape Simpson Well 28, Northern Alaska (Brewer, 1958).

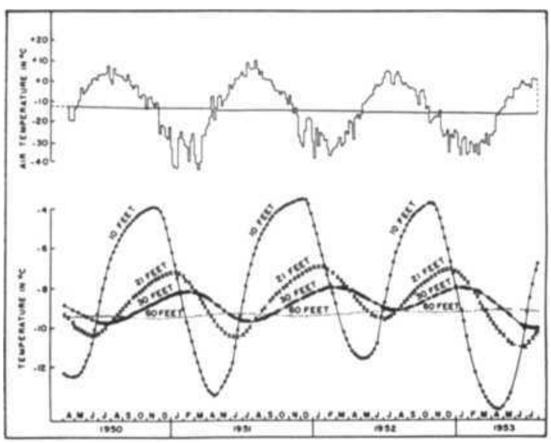

Fig. 13. Time-temperature curves for various depths in permafrost near Barrow, Alaska (Brewer, 1958).

depth in a wet tundra soil at Barrow. The average annual temperatures at the top of the perennially frozen ground at Barrow ranges between -7.0 and -9.5°C.

The rate and depth of seasonal thaw has been measured across the soil gradient illustrated in Figure 10 (Drew *et al.* 1958). The Arctic Brown soil was first to thaw, thawed to the greater depth, and froze earlier in the fall. Late season snow cover retards the initiation of thawing in Tundra and Bog soils to late June. In these soils, seasonal thaw is less than 50% that of the Arctic Brown and freeze-back was considerably slower. Tundra and Bog soils pass through a narrower diurnal and seasonal range of soil temperatures than does the Arctic Brown. The modifying effect is caused by the insulating peat layer and the high moisture content in Tundra and Bog soils. Variations in soil temperatures result from differences in texture, soil moisture, snow cover, vegetation, microrelief and exposure.

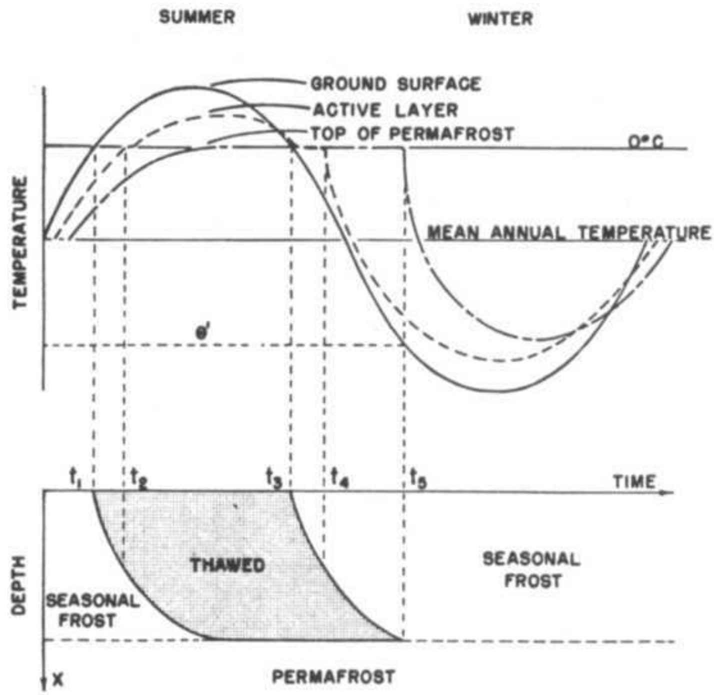

Fig. 14. Diagram illustrating the passage of the annual temperature wave through a wet tundra soil (Lachenbruch *et al.*, 1962).

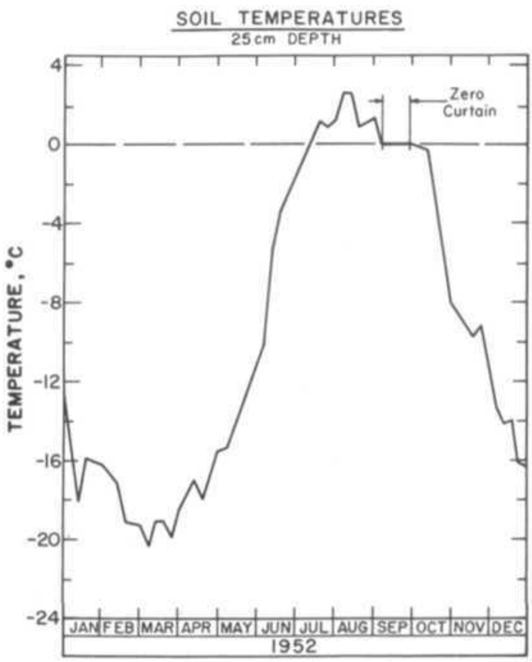

Fig. 15. Time temperature curve at a depth of 25 cm for a tundra area near Barrow, Alaska; note the prominent 'zero curtain' in the fall of each year.

Water Bodies

Masses of impounded water and flowing water influence the temperatures of the underlying ground (Brewer 1958, Lachenbruch *et al.* 1962). In general, water bodies that do not freeze to the bottom in the winter are underlain by a zone of about 60 meters of unfrozen sediment. The volume and shape of this unfrozen zone depends upon the configuration and size of the water body. In northern Alaska, lakes less than 2 meters deep usually freeze to the bottom and consequently are underlain by perennially frozen ground with temperatures up to 3°C warmer than under adjacent tundra. Shallow streams that freeze to the bottom modify the temperature of the underlying perennially frozen ground. Brewer (1958) has shown that one such stream introduced a 3°C warming to a depth of 40 meters. The effects of the proximity of the ocean upon ground temperatures at the 30-meter depth was reported by Brewer (1958). At approximately 100 meters inland, the temperature was −7.33°C; at the edge of the ocean, −4.91°C; and approximately 100 meters offshore, − 0.96°C. Lachenbruch (1957) stated that it is unlikely that perennially frozen ground would exist to depths greater than about 30 meters beneath the ocean for distances of more than roughly 500 meters offshore.

GEOMORPHOLOGY

The Barrow area is an emergent coastal plain. A sequence of weakly defined uplifted beach ridges are observed on the present tundra surface. Radiocarbon age determination from the reworked deposit of the first inland beach ridge yielded a date of 25, 000 years B. P. (Brown 1965). This may represent a transgression that took place prior to the Wisconsin maximum (Woronzofian Transgression, see Hopkins 1967, Brown 1965, Sellmann and Brown 1965). The present-day, hook-shaped gravel spit is currently building to the southeast and is believed to be at least 1,100 years old (Rex 1964, Péwé and Church 1962, Hume 1965, Brown and Sellmann 1966, and Hume and Schalk 1967). Based on a number of radiocarbon dates, Brown (1965) concluded that the majority of the soils and surficial features in the present Barrow land surface are not older than 8, 300 years and are perhaps considerably younger.

As mentioned previously, the physical aspect of the Coastal Plain and the Barrow area is dominated by polygonal ground, oriented lakes and rapidly eroding lagoonal shorelines. These active geomorphic features are intricate reflections of the perennially frozen ground and will be briefly reviewed under two broad headings: (1) polygonal ground and ice wedges; and (2) lakes and shoreline processes.

Polygonal Ground and Ice Wedges

Ice wedge polygons are inter-connecting ground patterns, generally orthogonal with diameters ranging from a few meters to more than 100 meters. The troughs form the outlines of the polygons and are underlain by ice wedges. These wedges are vertically foliated, vein-like intermeshing masses of ice that generally taper downward through the upper 10 meters of perennially frozen ground. Northern Alaska is an area of active, ice-wedge growth (Péwé1966). The thermal contraction theory is commonly accepted as the mechanism responsible for the formation of ice wedges and the resulting polygons (Lachenbruch 1962). Briefly stated, the ground contracts and cracks in winter as it cools. The cracks are partially filled with hoarfrost or spring melt-water and a vertical, vein-like mass of ice forms. The ground expands during the summer closing unfilled cracks and forcing perennially frozen ground upward to form ridges or flows in the seasonally thawed zone adjacent to the growing wedge. The contraction cracks originate at the top of the wedge and propagate upward and downward thus assuring repeated cracking in the wedge in a zone of weakness. This repeated cracking and filling of the ground with ice over many hundreds of years produces the large, V-shaped masses of ice that may eventually occupy 90% of the near-surface ground volume. Black (1963 and unpubl.) has measured the distribution and frequency of ground cracking for several types of polygonal ground in the Barrow area and found that more than 50% of the wedges crack each winter.

The geomorphic and pedologic implications of ice wedges are numerous, and only a few are briefly mentioned. Lachenbruch (1962) has indicated that the wedges or their casts serve as excellent stratigraphic markers. Ice-wedge growth is a function of climate and can be a valuable indicator of climatic variations. Their casts and truncated remains can indicate periods of thaw or thermal erosion (Brown 1965, 1967). The pushing up of ridges adjacent to wedges forms basins which impound water and can lead to thermokarst or melt-out ponds. Water flowing over ice-wedge troughs may melt the wedges and cause drainage or accentuate erosional processes. The accumulation of ice-wedge ice in the ground is responsible for increasing the volume of the ground which may result in areas of topographic highs (Hussey and Michelson 1966). Conversely, areas of low ice forms depressions. Depositional events are also detected by the locations and activity of wedges. Finally, the stirring of the soil by the pressures resulting from ice-wedge growth and seasonal expansion of the ground result in the complex soil morphology uncommon in areas lacking perennially frozen ground. Polygons are commonly thought to proceed through a cycle from initially flat surface with cracks to networks with slightly raised edges and finally to polygons with high centers and deep troughs (Black unpubl., Drew and Tedrow 1965). Subdivision of the polygons into smaller units occur with time and changing thermal regimes of the ground. This provides clues to changing climates and the relative ages of the land surfaces.

Lakes and Shoreline Processes

The presence of elliptically shaped, shallow lakes and drained lake basins having an average orientation of 10-15° west of north has led to a multiple-working hypothesis for the explanation of their occurence. A hypothesis based upon the existence of a former prevailing wind that was parallel to the long axis of the lakes has been abandoned, principally because elongation is still active today (Black and Bardsdale 1949, Black 1964). Present-day prevailing winds are approximately perpendicular to the long axis of the lakes. The second and more plausible wind theory (Livingstone, Bryan and Leahy 1954, Carson and Hussey 1962) is that orientation is in part the result of longshore currents that erode at the ends of the lakes faster than along the downwind shorelines. Carson and Hussey (1962) has refined and quantified this approach. They maintain that the sublittoral shelves which are formed along the elongated east and west shorelines inhibit erosion by wind-driven currents, wave action and thermal erosion, while these agents are active at the north and south ends of the lakes. Lewellen (1965) documented this differential rate by measurements on a sequency of aerial photography (1948-1964). He demonstrated that the north end of East Twin Lake had eroded at a rate of 1. 3 m/yr. Figure 16 illustrates the total amount of erosion along this lake shore and the adjacent lagoonal shoreline for the period of measurement.

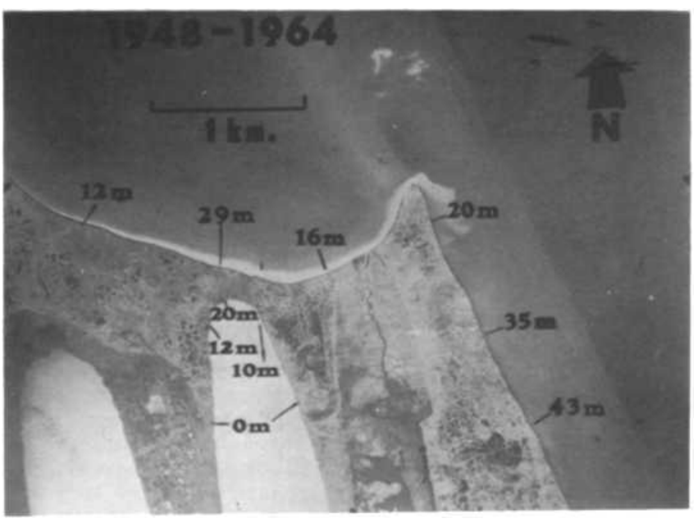

Fig. 16 Aerial photograph of Twin Lakes and Elson Lagoon shorelines indicating differential rates of erosion between 1948 and 1964.

The erosive character of the lakes as an active geomorphic agent has been described by Britton (1957, 1958) as the thaw-lake cycle. In the process of eroding the surrounding tundra, the lakes enlarge their basins. As the eroding lakes remove the interlake divides, they merge to form large lakes such as Footprint Lake in the Barrow area. Eventually a drainage divide is breached and all or part of the lake basin is drained leaving the shelves or lake bottom exposed. On this new land surface, ice wedge polygons form from either the partial thaw of the underlying truncated mesh of ice wedges or by the growth of new wedges. Small ponds remain in the old drained basins or develop in centers of raised-edge polygons. These ponds slowly erode their borders, merge with other ponds and, in turn, form new lakes.

The effect of the thaw-lake cycle on the near-surface sediment and soil parent material is considerable. Much of the near-surface sediment in the Barrow area has been reworked by the lake erosion cycle, thereby destroying the primary sedimentary structure. The presence of very old lake basins is often difficult to detect where highly developed polygonal ground has formed. For their detection, geochemical studies are useful indicators of pre-existing fresh water environments (O'Sullivan 1966, Brown 1966, in press). These combinations of geomorphic agents impose serious limitations on an interpretation of soil forming processes since second and third cycle sediments and peats may be present at any given location (Brown 1967). Britton (1957) has accurately stated that today's lake is tomorrow's land surface and that the present land surface is the site of future lakes.

In addition to erosion by lakes, the ocean and lagoonal shorelines are similarly susceptible to rapid erosion as was demonstrated by MacCarthy (1953). Erosion along the lagoon is greatly expedited by the differential thaw of the ice wedges which then permit large blocks of frozen ground to calve or slump onto the beach where they are quickly retransported into the ocean or lagoon. Rates of erosion as great as 10 meters per year have been reported from a study of some 75 kilometers of lagoonal shoreline in the Barrow area (Lewellen 1965, Lewellen and Brown 1965). Rates between 0.2 and 2m/yr are more common with differential erosion or retreat a function of cliff exposure and composition and currents and depth of offshore waters (see Figure 16 for total amount of erosion between 1948 and 1964).

SUBSURFACE GEOLOGY

The Arctic Coastal Plain is composed of the Gubik formation of Pleistocene age which uncomformably overlies rocks of Cretaceous and Tertiary age (Black 1964, O'Sullivan 1961). The Gubik sediments are shallow, near-shore marine deposits composed of admixtures of silts, fine sands and gravels. Fluvial, lacustrine and eolian decomposition and frost processes have modified the upper sediments. Black (1964) distinguished three main lithologic units: the Skull Cliff (oldest), the Meade River and the Barrow unit (youngest). The stratigraphic portion of the present research program further delineated the two near-surface units found in the Barrow areas: the Barrow unit (upper) overlies unconformably the Skull Cliff unit (lower) (Sellmann, Brown, and Schmidt 1965). The upper unit varies between 7 and 10 meters in thickness and overlies the lower unit between 2 and 7 meters below sea level. Grain size analyses from 6 holes spaced along two traverses (Sellmann and Brown 1965) 3 and 6 kilometers in length, yield the following average

	Upper Unit	Lower Unit
Less than 0.002 mm (%)	6	22
0.002 to 0.05 mm (%)	8	42
Greater than 0.05 mm (%)	86	36
Median diameter (mm)	0.11	0.04
Skewness	0.89	0.46

The upper unit was deposited in a high energy nearshore environment and the lower unit either in an alternately open and closed lagoonal environment or low energy near-shore environment. Differences in the microfossil assemblages between the units were observed. A radiocarbon date of greater than 36, 000 years was obtained from the lower units. A stratigraphic study of the Barrow village estuary indicates an accumulation of perhaps 10 meters of sediment during the past 6, 500 years within that basin (Faas 1966).

SUMMARY

The Barrow environment can be characterized as follows:

(1) Situated at the northern extremity of the Arctic Coastal Plain, it has a climate consisting of long, dry, cold winters and short, moist, cool summers. The latter is moderated by the influence of the Arctic Ocean.

(2) Vegetation is meadow-like with an abundance of sedges, grasses, herbs and a few dwarf shrub species.

(3) Soils are predominantly wet, with an average seasonal thaw of approximately 40 cm.

(4) Perennially frozen ground underlies the entire land surface to depths in excess of 300 meters.

(5) The near-surface coastal plain sediments are marine in origin and mid- to late-Pleistocene in age.

(6) The tundra landscape is characterized by active geomorphic processes such as lake erosion, polygonal ground formation and frost stirring of the soil.

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Paper No. 6

The Scientific Importance of the Circumpolar Region, and its Flora and Fauna

M.J.DUNBAR[1]

I have been asked by Dr. Fuller to speak on this formidable subject as a contribution to a synposium on Productivity and Conservation in Northern Circumpolar Lands. The word 'lands' should be emphasized, because for many years I have been paying some attention to northern seas and almost none to the land. Perhaps the invitation was pointed by intention, on the premise that, to paraphrase Professor G. E Hutchinson, copepodologists may have something useful to say to ornithologists; in fact they do, and they have done so frequently; also *vice versa*.

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I am reminded not only of Professor Hutchinson, who is a remarkable man, but also of that equally remarkable woman, Isak Dinesen (Karen Blixen),who once put into the mouth of the ghost of a Danish pirate the words 'The earth says yes to our schemes and our work, but the sea says no; and we, we love the sea ever' (Dinesen 1934). In the Arctic, perhaps depending on how we define that elusive word, the issue may be reversed, that is the land may be less kind to the schemes of mankind than is the sea, in which case, according to this thesis, we should love the land rather than the sea. And I think we do, in the Arctic.

At all events, the terrestrial environment (I now revert to the scientific jargon) of the Arctic, that part of the circumpolar north which lies north of the tree-line, is strikingly inhospitable to life for well over two-thirds of the year, and many of the larger creatures which survive actively and well in these winter conditions rely largely on the sea for their livelihood. No doubt the reason for this, in the last analysis, is that the environment offered by the Arctic seas, considered in the annual time-scale, shows less severe oscillation both in temperature and in food supply than does the Arctic land. This is not to say, however, that the oscillation of the food supply in the sea is not also impressive and to be reckoned with.

There is general agreement that the founder of modern ecology was Charles Elton, and in particular his 1927 book 'Animal Ecology'; plant ecologists may question this, but the reason I mention this here is that Elton gained much of his earliest field experience in the Arctic and this appears strongly in his earlier publications. Since then, however, the development of ecological theory moved into the temperate latitudes, and even into the tropics; and the higher latitudes, excellent as they are for general ecological studies, for some reason became the playground of specialists, 'Arctic hands', treated somewhat as curiosities by the general run of ecologists, and their publications came to be regarded as belonging to this special group alone, not part of the general literature. This was demonstrated sharply at the 1964 meeting of the AAAS, in Berkeley, California. There was a session on Arctic ecology on one day, followed by one on general ecological problems on the next. Although the first symposium dealt with the same general problems as did the second, the first was very poorly attended indeed and the second had to move into a larger auditorium to make room for the crowd. The first session was looked upon as the preserve of the 'Arctic hands', apparently, to which the general run of ecologists was perhaps not welcome, or in which they would find no interest.

I hope this situation can be remedied, because there is no doubt at all that the Arctic environments have an enormous potential contribution to the growth of modern ecology as a discipline. It would help a little, I believe, if such bodies as the Arctic Institute would deliberately organize conferences with inter-regional, or trans-regional, terms of reference, from the wet tropics to the driest Arctic, and from hot desert to cold desert. For example, Arctic ecologists are less impressed than most ecologists by such things as the rarity of sympatric speciation, the importance of the Gause Principle of Exclusion, and the more recent notion of environmental 'predictability', all of which are matters involved in general theory; they are touched upon in turn later in this paper.

EVOLUTION OF ARCTIC SYSTEMS

The ecological systems of the north are simple systems; this has been recognized for many years. The reasons for this simplicity, however, are by no means clear. The old idea that low temperature was the root cause, making it difficult for plants and animals to adapt to the high latitudes, is no longer taken seriously. In the sea and in lakes, the temperature range is not extreme throughout the year, and moreover it is now clear that metabolic adaptation to low temperature, in poikilotherms and homotherms alike, is not difficult to achieve. On land, the harshness of the winter is obviously decisive as far as living activity is concerned, and this necessitates means of avoiding the Arctic winter, either by dormancy or by migration. Growth rates, in plants and in poikilothermal animals, tend to be slow, but where there is an immediate advantage to be gained by increasing the rate of growth, as in vernal ponds and larval stages of aquatic species, the growth rates are in fact speeded up very greatly, sometimes to levels well above the normal rates in lower latitudes. It is probable that two basic factors underlie the simplicity of Arctic systems, two factors which are inter-related, namely the low biomass level and the youthfulness of the systems as such.

These two processes are related because the processes of ecological succession, being the growth of biomass and diversity from zero to climax, and of ecological evolution, being the gradual change in the nature of the climax, are basically the same (Margalef 1968, Dunbar 1968). They bear a relation to each other analagous to the relation between ontogeny and phylogeny manifested in the celebrated principle of evolutionary recapitulation. Whatever the modifications and qualifications that it has been necessary to make in the interpretation of recapitulation, the phenomenon undoubtedly exists, and the analogy with the ecological situation is probably quite precise.

Wherever the process of ecological succession, or of ecological evolution (by which I mean simply evolutionary changes in the eco-system with time) takes place, there is an increase in biomass which continues until the limits of the environmental potential have been reached: and there is an accompanying increase in diversity. This diversity, measured in terms not simply of species numbers but of their relative abundance, may oscillate somewhat in the process, depending on the nature of any environmental change that may occur, but there will be a general upward trend. (Margalef (1968) has pointed out that species respond differently to sudden opportunities for increased production, so that if the ratio of production to biomass rises swiftly there will be a reduction in diversity; the actual number of species may remain the same).

Concerning ecological evolution in the Arctic, the present controversy centres on the question of whether or not the evolutionary climax has been reached, always understood that the term 'climax' is relative and itself represents a changing, not a static, condition. I have recently marshalled some evidence to support the view that there is active evolution going on in the north and that the most important single factor is time (Dunbar 1968). On this view, which is really a development of one put forward a century ago by A. R. Wallace, the Arctic ecosystems are young and immature and have a long way to go before they reach a maturity and a saturation comparable to the tropical rain-forest. This does not mean that the Arctic climax will be anything like the rain-forest only that the Arctic climax condition has not yet been reached in the evolutionary sense, whatever that climax may turn out to be. There is no point in repeating the evidence here, but I would bring up one point that I have not brought out before, that of the probable difference in time between the onset of glacial conditions in the Arctic and the Antarctic.

Geological evidence appears to be building up for the view that the glaciation in the Antarctic began possibly about 22 million years ago. To my knowledge, no such claim has been made for the Arctic; and upon reflection there is good reason for the priority of glaciation in the Antarctic. Assuming that the climatic change of the late Tertiary, which culminated in the 'Pleistocene' glaciations, was triggered by the shifting of the poles (or the shifting of continental masses relative to the poles), then the patterns of change to be expected in the two polar regions would be very different. Before the polar shift, the two poles were in regions of open oceanic circulation, the north Pacific and the south Atlantic. Net heat loss at the poles was thus rapidly kept in control by the advection of heat to the poles by ocean currents. When the poles shifted to something close to their present positions, this transport of heat by oceanic means to the Antarctic was cut off completely, but this was not true of the Arctic, where there was still, and *is* still, heat transport from the Atlantic, and to a lesser extent from the Pacific. Moreover, the unfrozen oceanic circulation round the Antarctic continent provided precipitation immediately for the growth of the Antarctic ice-cap. A considerable lag, therefore, is to be expected between the onset of glaciation in the Antarctic continent and the onset of the same process on the northern circumpolar lands, a lag which on present evidence seems to be of the order of 18 million years.

It is a pity that we cannot compare terrestrial floras and faunas, terrestrial ecosystems, of the Antarctic with those of the Arctic. Owing to the nature of the climatic processes involved, this is impossible. But we can compare the marine ecosystems, which are also decisively affected by these changes, and it is interesting to find that both the biomass and the diversity of the Antarctic marine biota are much greater than those of the Arctic Ocean. More of course is involved here than the time factor, because several things contribute to high marine production in the Antarctic; but even in those regions where hydrodynamic factors are less important, such as the ice-covered Ross and Weddell Seas, the fact still remains that biomass and diversity are greater than in the Arctic Ocean, so that the time factor grows in possible importance. For documentation of the differences between Arctic and Antarctic in this respect, see Menzies (1963).

The youthfulness of Arctic ecosystems of the land can be seen in the lack of developed soils, especially in regions that were ice-covered during Pleistocene glacial periods, and I have suggested elsewhere that perhaps lack of soil, and the low rate of soil increment, may be more important than low temperature in accounting for the state of development of plant cover in the North. Soil, after all, is at the beginning of the process of colonization of bare rock by living organisms. 'Smooth rock gives way to weathering and the working of lichens; pockets of coarse soil form, in which pioneer plants grow and increase the humus content; spiders and insects colonize the soil; these processes continue on substrates of different chemical natures until trees grow and larger animals invade the area.... As new species of plants appear, the habitat complexity for animals increases, and new animal species open the way for new plants and new animals, and the soil capital continues to grow. The most important ingredient is time. Furthermore, the process is reversible, for uplifting or large climatic cooling can extinguish species and even whole systems, and erosion will set the growth process back to an earlier stage' (Dunbar 1968).

There is a need for experimental treatment of this question of the limiting importance of soil as opposed to that of temperature, and there are laboratories, such as the Arctic Greenhouse at the University of Alberta, well suited for such work.

The reversibility of the process of ecological evolution is worth a moment's attention here. It is well known that the ecosystems of the Arctic lands in certain areas were considerably more diverse a comparatively short time ago than they are at present (Martin and Wright 1967). Unfortunately, owing to the difficulties of paleontological technique, only the larger vertebrates have so far been studied to any great extent in this respect, but it is probably safe to treat these species as indicators of changes at other levels as well. At all events, in periglacial regions and in the ice-free refugia, animal species existed a few thousand years ago which do not exist in those regions now and which have not been replaced by ecological equivalents, so that the net result is a reduction in diversity, or at least in the number of species. The reasons for their disappearance are controversial, bit it is not easy to dismiss the agency of climatic change, and it follows that further paleontological research back to the beginnings of the glacial periods and beyond may be expected to bring to light most important evidence of the way in which the ecosystems of the land habitats have developed and changed. Such studies would be of very great interest in terms of general ecological theory.

At a recent conference at the Brookhaven Laboratories on Long Island (June 1969), Dr. L. B. Slobodkin suggested that an important element in the development of ecosystems was 'environmental predictability', thus drawing a new card from the deck which already contains such matters as environmental stability and environmental oscillation. He suggested that tropical environments were more predictable than all others and further that by reason of this predictability they attracted species to them from neighbouring regions, thus increasing the diversity and information content of the tropical systems. This argument is along the same lines as that of Margalef (1968) that the more organized and more mature system feeds on the less organized and less mature system; but I find Margalef's way of putting it more persuasive than Slobodkin's, because the 'predictability' of the environment is only one element of maturity, if indeed it is a necessary part of maturity at all. It would be hard to find, for example, an environment more predictable than the waters of the Arctic Ocean, and close examination of meteorological records might well show that Arctic environments in general, land and sea alike, are more predictable than those of the mid-latitudes. Much depends on the time-scale of this 'predictability': if it is to be measured in thousands or hundreds of thousands of years, then the Arctic land regions would not qualify, although the deep waters of the Arctic Ocean certainly would.

SPECIATION IN ARCTIC ENVIRONMENTS

I think there is a call for the investigation of the speciating processes in Arctic regions, and for their comparison with corresponding processes in lower latitudes, especially in the tropics. Here again the present orthodoxies have been built on warm temperate and tropical experience, and the polar regions have been expected to follow along as they were told. Mayr (1942) is the originator of the present orthodoxy concerning speciation, which is, broadly speaking, that the process of speciation in animals is one involving geographic isolation of populations, leading to divergences. Where obviously closely related species are found in the same region (sympatric species), it is concluded that they diverged from common ancestry allopatrically, and came together later, after the breakdown of some geographic barrier. Experience with the Arctic fauna makes one wonder about this, and may lead one to suspect that the orthodoxy is too facile an explanation. There are so many examples in the North of pairs or groups of closely related species living in the same area and even competing for the same food supply that it is difficult to avoid the conclusion that they have arisen sympatrically.

This problem is related to that of the Gause Principle of Exclusion. It is improbable that two species with similar ecological demands could coexist in the same area, then *a fortiori* the formation of two species from one ancestral form under such conditions would be unlikely. But there is already evidence that the exclusion principle, if it is accepted at all, does not apply under Arctic conditions where the summer food supply is abundant but the weather hazardous, and the same may very probably be true of the rich waters of subarctic marine areas. At all events, the existence of present sympatric species of close ecological similarity is undeniable, and I suggest that the probability of their sympatric speciation should be looked into carefully. Examples of such species are: three *Calanus* species, *finmarchicus. glacialis, hyperboreus*; two redpolls on the tundra; two closely similar species of the euphausid genus *Thysanoessa*, *raschii* and *inermis*; *the* pelagic amphipods *Pseudalibrotus glacialis* and *P. nanseni*; penguins in the Antarctic; four species of the sandpiper genus *Calidris* in Alaska and elsewhere (Holmes and Pitelka, 1968); the amphipod genus *Gammarus*. Elsewhere (Dunbar 1968 and in press) I have drawn attention to intraspecific variants in northern regions which offer similar evidence of sympatric speciation in process at present.

I have not gone deeply enough as yet into the tropical situation, but it is apparent that there is a quite different pattern of variation and species composition in the lowland wet tropics, a pattern of varieties appearing allopatrically, shifting and disappearing again, a pattern which belongs to a saturated ecosystem in equilibrium with the environment; a small-scale oscillation in a system equilibrated on the larger scale.

It is too early to offer concrete and incontrovertible evidence in favour of the process of sympatric speciation in the Arctic and Subarctic. What I am saying is that the evidence against it is weak or absent, and that there are suggestive facts in its favour. The evidence against sympatric speciation as a whole is not strong and seems to me to be largely a matter of opinion, to be interpreted either way according to inclination. The processes of speciation, after all, are probably different in detail in different stages of ecosystem development, just as the rates of evolution as such are different according to environmental opportunity.

EPHEMERAL PONDS

Certain characteristics of ephemeral ponds deserve special attention from students of Arctic ecology. Several studies have been published (Cole 1966, 1961, Wilson 1958, Gauthier 1928, Anderson and Fabris (in press)), showing that the dopepods of ephemeral ponds are larger in size, type for type, than those of permanent ponds and lakes; this is apparently true of ephemeral ponds anywhere in the world. One is at once struck by the fact that the same is true of Arctic and Antarctic copepods,and other planktonic forms, in comparison with the same species or similar species in lower latitudes, and very possibly for the same reasons. Large body size in the female greatly increases fecundity, since there is normally a non-linear relationship between body size and egg number, and this increased fecundity is taken to be an advantage in an environment with high annual oscillation in food supply, such as the Arctic. Oscillation not only of food supply but of the whole environment itself is the very nature of ephemeral ponds, and it is very probable that the evolution of large body size has occured in such situations for the same selective reasons as in the Arctic, giving greater chance of survival to the next spring period.

Another characteristic of ephemeral ponds, found by the authors already quoted, is a higher diversity of species than in permanent ponds. It seems that the sudden rich production in vernal ponds allows the existence of a greater diversity while that production lasts; and there is presumably no competition during the months of dormancy. This is the reverse of what we find in the Arctic and, in view of the environmental similarities which are shown in the two types of environment, it provides much food for thought.

MAN IN THE ARCTIC; CLIMATIC MANIPULATION

The most unpredictable element in any ecosystem is man. The dangers inherent in the presence of technological man in the North are not the subject of this paper; others in this symposium will deal with it. I should, however, spend a little time on another and (we hope) more constructive aspect of man's modern potential in the Arctic and Subarctic, namely the possibility of planned manipulation of climate and production by controlling the flow of water. I do not think that the possibility, or the advisability of damming the Bering Strait and of pumping surface water in either direction across it need to be taken very seriously, at least not for a decade or two. My own approximate arithmetic, such as it is, suggests that (1) it is not yet practically possible and (2) the benefits of doing it are in doubt. But there are other possibilities, involving operations on a smaller scale and with somewhat more predictable results. These fall into two categories: the damming of sea-straits and channels, and the control of fresh-water bodies.

Man, as Professor Vernadsky pointed out many years ago, has become a 'geomorphic force', and discussion of projects of this sort is no longer entirely fanciful; on the contrary, they have become practical possibilities.

Two straits which should be given careful thought are those of Belle Isle and Fury and Hecla. The first perhaps lies too far south for consideration at this conference, but it is worth mentioning nevertheless. Suggestions of closing the Strait of Belle Isle have been made for some years, and they have been met by the perfectly sound argument that the climate of the Gulf of St. Lawrence region is continentally determined, and from the west, so that the proposed operation would have little effect. It has been pointed out, however, by Dr. Hans Neu of the Bedford Institute of Oceanography, that a Belle Isle dam would retain a significant amount of heat in the Gulf, and since the extent of freezing of the Gulf varies greatly from year to year, such a dam might significantly reduce the severity of freezing, even in the colder years, and perhaps eliminate it almost entirely in warmer years.

Fury and Hecla Strait, between Melville Peninsula and northwestern Baffin Island, carries Arctic water from the Gulf of Boothia into Foxe Basin, at an average rate of something of the order of 0. 5 Sverdrup (0. 5 million cubic metres per second). It is the main source of the Arctic water which flows into Hudson Bay, and the closing of it would either considerably reduce the circulation in Hudson Bay or draw into Hudson Bay more water from Hudson Strait; if both occurred, the emphasis would probably be on the former effect. In any case the temperature of Hudson Bay would be raised somewhat and the time of freezing correspondingly delayed. This possibility needs quantitative study.

The planned control of the flow of large rivers has to be done with care, and with attention to local rights and interests (as witness the affair of Southern Indian Lake in Manitoba). Here again the two areas of immediate interest are Hudson Bay and the Gulf of St. Lawrence. The influx of fresh water into Hudson Bay is very large indeed, and any sizeable reduction of this influx by the diversion of water in the rivers elsewhere, which has in fact been suggested for other reasons, would raise the salinity of the surface water of the Bay, which in turn would reduce the intense vertical density stratification and stability that exist there. This should both increase productivity and delay winter freezing, with concomitant climatic and economic effects. Again, there is a need for a quantitative attack on the problem.

FINALE

In this paper I have obviously had to restrict discussion to only a very few of the extremely important scientific problems of the Arctic. There are many others, of varying degrees of apparent immediacy in terms of the interests of mankind in the North; but they are all interconnected. Small mammals are as important as oil beneath the waters, evolutionary theory as vital to mankind as aids to navigation in the narrow waters of the Arctic Archipelago. All I have had time to do is to draw attention to some of the reasons for the 'scientific importance of the circumpolar region, its flora and fauna'.

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Paper No. 7

Primary Production within Arctic Tundra Ecosystems

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INTRODUCTION

Arctic tundra ecosystems, like all others, owe their existence to the ability of plants to trap solar radiation and convert it to gross plant production. Net production then enters the detritus (decomposer) or the consumer (herbivore, carnivore) pathway. As in most terrestrial systems, the detritus pathway is the major route. This is not to deny the important role of consumers, for no ecosystem functions without them.

Tundra, desert, and saline lake ecosystems all have in common an environmental severity that results in less biological diversity, less biological production, and potentially greater

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oscillations (less homeostasis), at least at the consumer level. The classic fluctuations in both lemming populations and the carnivores that prey upon them well illustrate this point in the Arctic. It is generally accepted that a small biomass and low annual production favor ecological and taxonomic simplicity and hence system instability. Leigh (1965) has added to this that a decrease in biomass with a fixed productivity increases the turnover rate and thus decreases stability. This seems to be the case with herbivores grazing in the Point Barrow wet tundra system.

Tundra ecosystems are considered biologically fragile and are characterized by oscillation. The biological oscillations are induced by the great magnitude of the annual environmental oscillation. This results in a flourish of plant and animal growth in summer followed by a large portion of the year with little biological production. Superimposed on these dramatic seasonal oscillations are biological cycles with a 3 to 5 year pattern. The Arctic is characterized by animal populations that exhibit high fecundity, large body size, slow growth, few species, yet often large populations per species (Dunbar 1968). Plant populations are also characterized by slow growth and few species but are small in size and generally reproduce by vegetative growth rather than seed production.

The tundra is also fragile in that with removal of vegetation, the insulation cover is destroyed and thermal erosion, often resulting in thermokarst, rapidly develops. It is this triggering of a chain of events so difficult to stop and so difficult to biologically reverse that concerns many of us. In 1934, Griggs wrote of the difficulties in applying concepts of succession and climax communities, developed in temperate regions, to the Arctic. It is equally true that concepts of land use and resource management, both mineral and biological, must be approached in a far different manner in the North than in temperate regions. On this aspect we need much research.

Studies of Arctic tundra primary production have been conducted for about 20 years with the greatest amount of literature associated with the studies of lemming cycles at Point Barrow (Thompson 1955, Shanks 1960 in Bliss 1962, Pieper 1963, Schultz 1964, 1965, Dennis 1968, Tieszen and Johnson 1968). Much of the other Arctic research on primary production has been summarized by Bliss (1962, 1966) and Rodin and Bazilevich (1966). The latter publication includes information on plant and soil nutrient budgets. Current research on primary production as a part of the I.B.P. Tundra Program is underway in Finland, Norway, Disko Island in Greenland, Canada, Alaska, U.S.S.R., and in tundra-like blanquet bogs in England and Ireland. Thus within several years there will be a much larger body of knowledge on the rates of plant production, rates of animal utilization and rates of decomposition in the Arctic.

The purpose here is to review some of the literature, point out significant findings and indicate areas of needed research in the current and future Arctic programs. As used here, plant production and biomass refer to quantity of matter while productivity refers to rate (daily or annual). All figures are for net production (respirational and grazing losses not included) unless otherwise stated.

PRIMARY PRODUCTION

Annual production seems to range from a low 3 $g \cdot m^{-2}$ for a *Salix arctica* barren on Cornwallis Island (Waren Wilson 1957), 50 to 100 $g \cdot m^{-2}$ in wet tundra sites at Point Barrow (Dennis 1968), other sites in Alaska, the Yukon, and the U.S.S.R., to a high of 190 to 224 $g \cdot m^{-2}$ for *Dupontia fischeri* wet sites at Barrow (in Bliss 1962). Part of the variation results from different sampling methods, studies on different tundra communities, and yearly variation due to intensity of lemming grazing related to their 3 or 4 year population cycle.

Plant-Animal Interactions

The various studies at Barrow point to the major role of primary production in the lemming cycle, though the total picture is not yet complete. Pieper (1963) showed that peak standing crops of vegetation in 1959 and 1962 were followed by a lemming high in 1960 and 1963. With a peak in lemming population, the animals dig up much of the turf looking for roots and rhizomes. Schultz (1964) reported a 50% reduction in vigor and yield of one-half to two-thirds of the tundra and a near 90% reduction on the remainder during the 1960 lemming high. This results in a reduced plant production that year, yet a high in the nutrient content of the vegetation. The plant nutrient high is correlated with the flush of nutrients from fecal pellets and urine washed into the soil during the spring lemming build up. Pieper (1963) postulated that with reduced plant cover and plant nutrient content following the peak lemming year (nutrients carried downward with the deeper active layer that summer are trapped during freeze-up), the animals may have a limited supply of nutrients (P and N) during lactation the following spring. With a reduced plant cover the active layer thaws more deeply. This permits greater root depth and the contact of roots with a larger volume of soil and nutrient pool. During the subsequent years as plant productivity increases, litter increases, the active layer becomes shallower with a smaller thermal input, and nutrient content in the vegetation becomes higher, though the nutrient pool becomes smaller in volume with shallower summer thaw. With fall freeze-up, nutrients may move upward with the unfrozen water (Shultz 1964). The patterns of these various parameters with the lemming cycle seem well correlated. As Schultz stated in 1965, 'If it can be shown that the lemming, as evidenced by population changes, is indeed sensitive to the range of nutrients in his diet that occurs on the tundra, then we would have the final connecting wire for the tundra homeostat'.

Dennis (1968) has shown that root and rhizome production are positively correlated with increased depth of thaw and warmer soils, and that most of the live below-ground material is in the upper 25 cm. In wet sites few roots occur below 10 cm. There are also differences in species response, for *Dupontia fischeri* produces a large below-ground standing crop despite cold, wet and shallowly-thawed soils. He also noted that lemming grazing may help maintain *Dupontia* by reducing annual input of litter. Where litter increases and a shallower active layer is found, there is a shift to more *Eriophorum angustifolium*. *A* reduction in above-ground productivity with increased litter (lemming grazing excluded) was noted by Dennis (1968) in comparing the data of Thompson (1955) for his 5-year study with that of Pieper (1963) and his 4-year study. From 1950 to 1954 annual productivity averaged 73 $g \cdot m^{-2}$ in the open and 90 $g \cdot m^{-2}$ in exclosures. From 1959 to 1962 annual productivity averaged 42 $g \cdot m^{-2}$ in the open and 36 $g \cdot m^{-2}$ in exclosures, the latter area having been fenced for 8 years by 1962. The drop in productivity was 31 and 54% respectively.

Dennis (1968) presented data on below-ground: above-ground ratios for the Barrow studies (5: 1 to 14: 1) and for those of Alexsandrova (1958), ratios of 4: 1 to 13:1. Comparing these data with those of Bray (1963) for temperate region herbaceous vegetation indicates that in going from temperate to Arctic environments, the Arctic is relatively more severe for above-ground than for below-ground production. Although annual below-ground production is slower in the Arctic than in temperate regions, the roots live longer and decompose more slowly. Thus Dennis (1968) estimates 10 to 20 years for root and rhizome turnover for the Barrow tundra while Dahlman and Kucera (1965) report four years for a Missouri prairie. In addition the slow growth but longer life of tundra root and rhizome systems means that below-ground standing crop in this Arctic study is quite comparable to that of temperate region prairie where the soil environment is more favorable for production and turnover.

Dennis (1968) reported above-ground dry matter production for six plots ranged from 60 to 97 $g \cdot m^{-2}$ in 1964 and from 3 to 48 $g \cdot m^{-2}$ in 1965, a lemming high. Below-ground annual production in 1965 ranged from 1 to 58 $g \cdot m^{-2}$, showing that root and rhizome productivity was equal to shoot productivity for at least the one year. Studies on root and rhizome standing crop and productivity are very difficult to do, especially in tundra systems where there is such a large component of peat in at least the upper layers. However studies of this kind are essential if we are to better understand the relationships of above-ground and below-ground production to microtine cycles, nutrient cycling, depth of the active layer, and vegetation recovery following partial or complete removal of the turf.

The various Barrow studies show the integral role that primary production plays in the microtine cycle. Lemming grazing results in: (1) a cyclic pattern of annual net production and litter accumulation and (2) maintenance of at least one plant community type (*Dupontia fischeri*) through a reduction in litter. A crude comparison might be made between the removal of standing crop and litter by herbivores with the rapid nutrient return to the system in both wet tundra and dry short grass plains ecosystems and the removal of standing crop and litter by fire in regions of Savanna and tall grass prairie. In all these grass or grass-like systems, litter removal has an oscillating effect, usually a stimulating one, upon the producer end of the system, though the response time may vary from one to several years.

Plant Measurements

In tundra ecosystem studies, there is the need for estimating not only annual production by species, but also estimates of standing live, standing dead, and litter. Only in this way can the relative growth rates of species be made as well as estimates of transfer rates to litter and decomposition. The placement of plant samples into nylon bags or placing individual leaves on a nylon string can be used to estimate rates of decomposition. While there are data on the nutrient content of Arctic plants, the rates of nutrient uptake and release remain unknown.

With the slow growth rates of tundra plants and the frequent change in weather, it becomes difficult to correlate dry matter production with environmental parameters. The author (Bliss 1966) found that shoot growth rates (3-day periods) were significantly correlated with soil and air temperature, but that weekly estimates of dry matter production were poorly correlated with temperature due to the small number of weekly observations (8) and to the amount of temperature oscillation in 7-days. In some groups, especially woody species, the 3 to 4-day growth increment is too small to accurately measure and correlate with current environmental conditions.

Studies have been made of the rates of CO_2 utilization and release by tundra plants and these data then compared with estimates of dry matter production (Hadley and Bliss 1964, Scott and Billings 1964, Johnson and Kelley 1969). More data are needed before conclusions can be drawn, but the data indicate dry matter production can be predicted from rates of photosynthesis and respiration.

In a current study (coordinated with Dr. Jerry Brown) of primary production in relation to depth of summer thaw, litter structure and decomposition at four tundra sites in Alaska and the Yukon, estimates have been made of the 1968 annual production by sampling in late June and late August 1969 at two of the sites. At the four sites, cottongrass tussock – dwarf heath shrub communities predominate. These data show that estimates of the previous year's annual production can be made in June or August (Table 1) of the following year though these estimates are very time consuming. The data further show that at Eagle Creek less than half of the annual production is completed in late June (19), while at the Dempster Highway site 80% of current production was completed in late June (21). Although all four sites are in the Low-Arctic and contain the same vegetation type (moss cover does vary significantly), the start of the growing season must vary by several weeks and thus it is difficult to predict annual production from early season estimates. In most studies a late season estimate of annual production may be adequate unless productivity data are to be compared with short term environmental or herbivore grazing data.

Lichens form an important part of many tundra plant communities, yet their growth rates are difficult to measure and thus there are few data in the literature. Scotter (1963) reported average annual linear growth rates of 3. 4 mm for *Cladonia alpestris* and 4.1 mm for *C. rangiferina* in the Talston River region, southeast of Great Slave Lake. Pegau

TABLE 1. Net annual production ($g \cdot m^{-2}$) with standard error of the mean for two locations, 1969.

Compartment	Eagle Creek, Alaska		Dempster Highway, Yukon	
	JUNE	AUGUST	JUNE	AUGUST
1968 production	56.8 ± 7.6	59.0 ± 10.6	33. 6 ± 6.8	25.6 ± 6.2
1969 production	27.0 ± 25.2	70.0 ± 15.6	28.0 ± 10.0	34.8 ± 5.6
Standing crop (vascular)	295.0 ± 52.2	–	151.8 ±49.8	–

(1968) reported annual growth rates of 5 to 5.4 mm for the above listed species plus *C. sylvatica*. He attributed the greater growth rate on the Seward Peninsula, Alaska to the wetter summer climate. For these growth estimates it has been assumed that each lichen stalk, or podetium, branches once per year and that average annual growth equals length of podetium divided by the number of branch units per podetium. This assumption needs to be determined based upon actual studies though it is probably valid.

With lichens forming such an important part of the winter diet of caribou and reindeer, lichen growth rates, rates of recovery and animal carrying capacity must be determined more accurately for many tundras.

While growth rates of mosses are more easily determined, they are frequently ignored or their data pooled with that of the vascular plants. As with lichens, mosses often comprise a considerable percentage of the standing crop and chlorophyll of a terrestrial community. Mosses also serve the most important role of providing efficient insulative cover against excessive thaw of the permafrost.

Chlorophyll Content

From the limited data available on chlorophyll content in tundra ecosystems, some interesting patterns emerge (Tieszen and Johnson 1968, Bliss 1966). The correlation between chlorophyll *a + b* production and net annual dry matter production is high within a tundra community type (r = .88 to .99) but the correlation is much lower when comparing chlorophyll per unit dry tissue in different communities (r = .48 for Mt. Washington, r = .61 for Alaska data). Both studies have shown that communities highest in chlorophyll production are not necessarily highest in annual dry matter production because communities high in heath species possess less chlorophyll than do communities high in sedges and rushes (Table 2).

From these data it is evident that once a community type has been calibrated in terms of dry weight and chlorophyll, measurements of the latter may be used to estimate both total and annual dry matter production and thus reduce the time necessary in the tedious separation of old and new shoot growth. The role of heath species in community productivity needs much more work as does the role of mosses. Tieszen and Johnson (1968) found that mosses contributed 2 to 35% of the chlorophyll standing crop per community in northern Alaska.

TABLE 2. Chlorophyll and dry matter production in tundra communities.

Community	Current Production		
	Chlorophyll a + b ($g \cdot m^{-2}$)	Dry Matter ($g \cdot m^{-2}$)	Chlorophyll/unit dry wt.($mg. g^{-1}$)
Northern Alaska*			
Dry Sedge	0.13	34	3.78
Cotton grass	0.30	95	3.15
Willow	0.33	61	5.39
Wet Sedge	0.76	86	8.78
Mt. Washington†			
Wet Sedge	0.82	176	4.65
Heath-Rush Meadow	0.42	124	3.38
Heath-Rush Fellfield	0.62	74	8.39
Diapensia	0.18	67	2.69
Sedge-Rush-Heath	0.51	112	4.55
Heath	0.54	283	1.91
Snowbank	0.90	200	4.50

* Tieszen and Johnson 1968

† Bliss 1966

Leaf Area Index

While much of the literature on leaf area index (LAI) centers on values for crop plants, this method is now being applied to natural vegetation. Data were gathered on LAI from six alpine communities on Mt. Washington in 1967. Seven 1 dm^2 plots were clipped in each community, immediately placed in plastic bags and returned to the laboratory, where leaf area was determined by a leaf area meter using a photo-multiplier tube.

TABLE 3. Leaf area index for alpine communities on Mt. Washington with standard error of the mean.

	L.A.I.		
Community	New Leaves	Old Leaves	Total
Heath-Rush	0.87	0.07 (7%)*	0.96 ± .17
Diapensia	0.49	0.66 (57%)	1.16 ± .16
Sedge-Rush-Heath	1.36	0.07 (5%)	1.43 ± .37
Wet Sedge	1.48	–	1.48 ± .22
Heath	1.47	0.49 (25%)	1.96 ± .26
Snowbank	3.30	–	3.30 ± .74

* percent contribution of old leaves

The data in Table 3 show that LAI ranged from 0.94 in a heath-rush community to 3.30 in a snowbank community. Four of the communities had means ranging from 1.15 to 1.96 LAI. In four of the communities evergreen leaves from previous years are present. These old leaves, though not very active photosynthetically (Hadley and Bliss 1964), do contribute to the leaf area index and in the *Diapensia lapponica* and *Loiseleuria procum*-ftews-dominated cushion plant community, account for over 50% of the total leaf surface. These old leaves in Diapensia serve a very important role in maintaining a compact cushion that has a high resistance to water loss in a microenvironment where high solar radiation and wind favor high evapotranspiration rates (Courtin 1968). This cushion growth form, while characteristic of many alpine environments, is also common in windy Arctic sites, especially in the High Arctic. Studies relating plant growth form to microenvironmental conditions, especially as they relate to gross and net productivity, are vitally needed if we are to more fully understand the relative roles of LAI and chlorophyll content in dry matter production.

DISTURBANCE

Fire

Little is known of the role of fire in tundra ecosystems, yet they do occur. Fire removes most of the insulating layer of live vegetation and litter, damages or destroys the peat, and greatly changes the albedo of the surface. The result is a potential rapid increase in thermal erosion with increased runoff.

East of Inuvik, fires occurred in 1954, 1962, and 1968. The last fire burned not only tundra but also forest-tundra. Casual observations just north of Inuvik townsite show that, in the *Picea mariana* forest with an under-story of cottongrass tussock/lichen-heath, most plants other than cottongrass were killed back, yet new growth of cottongrass in 1969 was considerable. A general account of vegetation recovery following the 1954 fire is given in Cody (1964). Nine years after the fire, grasses, sedges, and forbs recovered fairly well but lichens and mosses showed little recovery. With lichens playing an important role in the diet of caribou and reindeer, it is evident that burned areas will be lost to grazing for many years.

In a current study of the effect of disturbance on summer depth of thaw (Brown *et al.* 1969) an accidental fire burned one of the tundra sites (Elliott Highway, June 25). At our late

August clipping, cottongrass tussock regrowth amounted to 37% of the total plant growth as measured June 21. Whether this regrowth represents normal late season or fire stimulated growth can only be determined by experimentation. The stimulatory effect of fire in tall grass prairie is well documented (Old 1969), but similar experimental studies of the effect of fire on growth and flowering of Arctic sedges have yet to be conducted.

Increased thaw at the Elliott site following the late June fire averaged 17 to 20% (Brown *et al.* 1969). At this site much of the expected thaw had taken place by late June. The rates of thaw and re-establishment of vegetation will be studied over the next several years to better predict the influence of tundra fire.

Turf Removal

One of the greatest concerns of ecologists is the degree to which tundra vegetation can be disturbed by seismic lines, track vehicular pipelines, and road and drill site activities, and yet re-establish a turf within 3 to 5 years prior to thermokarst development. Research of the past summer (Brown *et al.* 1969) shows that even the replacement of a mulch results in nearly as deep a thaw as does the removal of the total plant cover, 61 vs. 75 cm. respectively. The control plots averaged 32 cm. for maximum summer thaw. The changed albedo is probably the major factor even though an insulative layer was returned in the one treatment.

The removal or near-removal of life plants from track vehicle roads and potential pipelines presents many problems, for the rates of plant growth and seedling establishment are very slow, thus increasing the potential for permafrost melt and thermokarst development. Research is needed on the quickest and best methods of re-establishing a turf on these high disturbance sites before pipeline and drilling contracts are let.

CONCLUSIONS

Tundra ecosystems have been studied for over 20 years yet there is much to be done in future research. While we know the rate of annual production in several sites for quite a few years, we know little about the relationships of net annual production to leaf area index, standing crop of chlorophyll, rate of litter accumulation and decomposition, and rate of underground production and decomposition. Most tundra productivity data are presented on a dry weight basis, yet the inclusion of caloric values makes data more meaningful, though more tedious to obtain, for this permits calculation of efficiency and energy flow to decomposers and herbivores. Information is also needed on the rates of lichen and moss growth in these systems for, in some instances, the standing crops are large and they are of great importance to herbivores and the maintenance of tundra peats.

Some measurements have been made on mineral composition of tundra vegetation, especially in relation to lemming cycles, yet little is known of the rates of mineral cycling in tundra systems nor the compartmentalization of minerals within the producer end of the system.

Although tundra plant productivity is low when compared with other world biomes, daily productivity during the short growing season (*ca.* 40 to 70 days) and the rates of efficiency for carbon fixation (Bliss 1962, 1966) are comparable to many herbaceous communities of temperate regions. Yet we need more data on daily and weekly increment as well as efficiency before we will begin to understand the variation in production of diverse tundra ecosystems.

Of equal or greater urgency is the need for data on plant growth in relation to disturbance by man. This past summer research along these lines has been initiated in Alaska, the Yukon and the Northwest Territories. Some of our own studies are directed at the growth rates of cottongrass in relation to road building, bulldozing, winter and summer caterpillar tractor use, and fire. Only when such studies are undertaken will we begin to get answers so necessary for determining the degree to which the tundra insulative surface can be manipulated and yet recover before thermal and water erosion becomes serious.

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Paper No. 8

The Diversity of Tundra Vegetation

ROLAND E. BESCHEL[1]

This summary considers some of the major patterns in the vegetation of the Arctic and assesses the problem of extrapolating measurements of its biomass and productivity from sample plots to regionally valid estimates.

In contrast to the richly structured and differentiated plant cover of lower latitudes the vegetation of the tundra appears, at least from afar, as a rather uniform carpet. The several layers of vegetation within a forest provide a multitude of ecological niches on top of each other while the nearly two-dimensional tundra is obviously a more simply organized ecosystem. The flora is very small and areas of a size that bear in temperate latitudes several thousand species have in the tundra biome merely a few hundred. Endemism for parts of the Arctic is rare although a great percentage of species is endemic to the Arctic as a whole. Most tundra species have a very wide and often even circumpolar distribution. This increases the uniformity further. Many tundra plants occur also in a wide variety of habitats. Plant communities, where they have been recognized at all, appear poorly differentiated as there is a considerable overlap in their species composition. Communities have also been delimited rather more by differences in the quantity of their components than by variations in their floristic composition. The difficulty of separating communities has often been simply avoided, at least in the Canadian Arctic, by describing the plant cover of various habitats instead.

It seems therefore a relatively easy task to study tundra vegetation on a small area in detail and to arrive by extrapolation at an estimate which is applicable to most of the tundra region.

But this is only one side of the picture. An opposing view may perhaps be held with more justification.

Tundra vegetation near the limit of forests may consist of a broad transition zone to the taiga, the typical boreal forest, and this part of the tundra may be composed of open woodlands with scattered small trees, or of krummholz, or of tall shrublands, or of mosaics of these with lower vegetation. Further north the tundra may comprise shrublands of lower

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height, or dwarf-shrub heaths, or a host of combinations of herbs, graminoid plants, lichens and bryophytes. And all of these types grade towards the High Arctic into vegetation with more and more bare soils until the plant cover nearly disappears. In fact, if we exclude forests, all remaining vegetation types of the earth from deserts to grasslands, heathlands, and savannas are represented in the tundra as well. As we usually do not lump all these non-polar, non-alpine and non-tree-covered vegetation types of the remainder of the globe under one heading, one wonders why a collective term should be applied to the vegetation of arctic and alpine regions in the word 'tundra', unless we understand its use as an involuntary expression of our ignorance. However, the treeless regions of the Arctic comprise along a latitudinal macrogradient a sequence from areas where vegetation is a significant controlling agent of the environment to areas where the inorganic substrate is not at all modified by vegetation.

The flora becomes, along this latitudinal gradient, not only poorer in species, but the flora changes drastically in its composition as boreal and low arctic components are replaced northwards by truly arctic and, finally, high arctic species.

These changes may also be expressed in the alterations of major lifeform types in the flora. The relation of rooted species which control their water content to merely adnate species which can dry out, drops within the tundra from roughly 2: 3 at the timber line to about 1: 10 at the northern limit of land. Among the rooted plants annuals and tall shrubs disappear northwards rapidly and other woody plants more gradually. Plants which perennate their buds below the ground or under water decline, while plants with over-wintering buds at the soil surface compose by far the largest fraction of the vascular flora especially towards the northern limit.

In the High Arctic there is also a great decrease in the sexual reproduction of vascular plants across the boundary between arctic tundra and polar desert. The percentage of species which do not form seeds arising from pollination but propagate in various asexual ways doubles there, even when favourable years are considered.

All these changes within the tundra biome do not occur uniformly with latitude. They are strongly modified and further intensified in relation to the macrorelief of the regions. Arctic mountain ranges possess strong environmental gradients in continentality even in the very continental High Arctic. Vegetation types in mid-arctic regions range from oceanic heaths, meadows, and snowpatch communities on the windward side of the mountains to steppes and saline communities in the rain shadow.

Vegetation differences related to direction of slope seem to reach a maximum around the polar circle and may decrease again somewhat northwards. They are also more pronounced in areas with higher precipitation, possibly in connection with the duration of snow cover.

In mountain ranges of the Arctic the vegetation repeats generally the latitudinal zonation of the tundra in altitudinal belts. But small height differences in areas with low relief may be accompanied by telescoped altitudinal belts of vegetation. While thorough comparisons between arctic and alpine tundra of temperate latitudes have been made, the vegetation patterns on arctic mountains has so far received very little attention.

An arctic mountain range has greater vegetation diversity than merely rolling landscapes at the same latitude. Sheltered mountain valleys may bear well developed dwarf-shrub tundras in latitudes with otherwise prevailing polar deserts. Local wind systems may desiccate other valleys so intensely that polar steppes grow there in isolated pockets. Areas with temperature inversions, as they occur for instance close to the ice-covered Arctic Ocean, may exhibit parallel inversions in the vegetation belts.

Even greater diversity is encountered when vegetation patterns over shorter distances are considered. A host of forms of patterned ground with extraordinary variations in the stability of the substrate, wind erosion or eolian deposition, thickness of the active layer above permafrost, duration and height of the snow cover, and other factors related to the mentioned ones, e.g. grain size of the regolith and fluctuations in the water table, create a very wide range of environmental conditions in spaces of a few square meters. The vegetation reflects this diversity in pronounced gradients along environmental catenae and by plant communities or fragments of communities that are arranged in mosaics of possibly several hierarchical levels. Biomass and primary production vary often over distances of a meter by orders of magnitude, e.g. between nearly bare polygon centers and fully plant-covered polygon margins, between turf banks and steps of naked soil, or between hummock and hollow.

Perhaps even greater are the differences between vegetation on soil and vegetation on exposed bedrock or boulders. The rocky substrate is more common in the tundra than generally assumed. Nearly every area of 10 x 10 m in alpine tundra and perhaps more than half of such areas in the arctic tundra contain at least 1 m^2 of exposed rock surfaces without soil. Epipetric vegetation differs fundamentally in species composition, biology, biomass and productivity from epigeic vegetation. A square meter of rock surface with a full lichen cover which persisted during thousands of years has a biomass – in dry organic matter – several orders of magnitude below the standing crop of tundra vegetation on an equal area with soil in most of the Arctic. Diameter increments of rock lichens in the Arctic lie usually below 1 mm per year. A rough extrapolation places the annual production of a lichen covered rock surface about five orders of magnitude below the $50g/m^2$ which an average tundra may produce per year.

Vast areas of the Arctic do not have bedrock exposed and may nevertheless be covered totally by rocks. Weathering and frost action have created boulder accumulations which cover for instance hundreds of kilometers of centrol Baffin Island where a discontinuous lichen cover is by far the most common vegetation. The rock deserts in the limestone regions of the Queen Elizabeth Islands are even more barren as the surfaces of the limestone boulders weather faster than epipetric lichens can grow there.

The vegetation patterns of the tundra regions are further varied through hangovers of environmental fluctuations at earlier time. The extensive nivation during the 'Little Ice Age', roughly from the sixteenth to the nineteenth century, led to a severe alteration and even destruction of the plant cover over wide areas. Aerial photographs of central Baffin Island, for instance, indicate the extent of these recent nivations as patches with light coloured rock surfaces beside the nearly black area where the epipetric lichen cover could survive. Most of these formerly nivated depressions now possess an immature lichen cover. Estimation of the biomass of these arctic hamadas must consider the discrepancy of the potential vegetation development under present climatic conditions and the actual state of epipetric succession which reflects conditions of about a century ago.

From the foregoing it should be evident that the tundra is far from uniform. Its rich diversity in patterns and vegetation types on all scales and levels of generalizations permits and warrants a detailed subdivision in vegetation analysis and vegetation mapping. A disappointingly minute fraction of the Canadian Arctic has so far been mapped in its vegetation patterns on a large scale. The best vegetation maps for the Canadian Arctic as a whole distinguish only very few categories. The relatively most detailed map of the Canadian North can be found in the Soviet Physiographical Atlas and it is also far from adequate.

The appended diagrams and figures may serve as examples for the earlier discussed patterns of vegetation diversity as they apply to the mountainous islands of the Canadian High Arctic. They also demonstrate three levels of generalization. The prevalent communities on relatively stable substrates which can be mapped at a scale of 1: 25, 000 are shown for five areas of about 100 km^2. The five areas lie along a west to east profile across Axel Heiberg Island and adjacent Ellesmere Island at about 79°30' north. The communities are arranged in an ordination for each region which places them horizontally into a local moisture gradient and vertically into a local temperature gradient that corresponds also roughly to altitude. Such ordinations might be obtained more precisely through computer programmed multivariate analyses. These graphs are based only on judgment but ought to demonstrate more succinctly than long descriptions how the high arctic vegetation along this continentality gradient from west to east becomes more diversified, first into heath and meadow types and then into steppe types. The mesic habitats have been placed near the center of each ordination. These are occupied along the continentality gradient successively by fell-field vegetation, *Luzula* steppe, *Cassiope* heath and *Carex rupestris* steppe. Commonly observed transitions between communities are indicated by lines.

The whole range of local plant communities has been compressed into altitudinal belts (Figure 1) which have been named after typical genera. These belts rise with increasing continentality. Only the vegetation at the head of Expedition Fiord (area 4) has been mapped 1: 25, 000 for 20 x 20 km. This map gave the basis for the determination of the

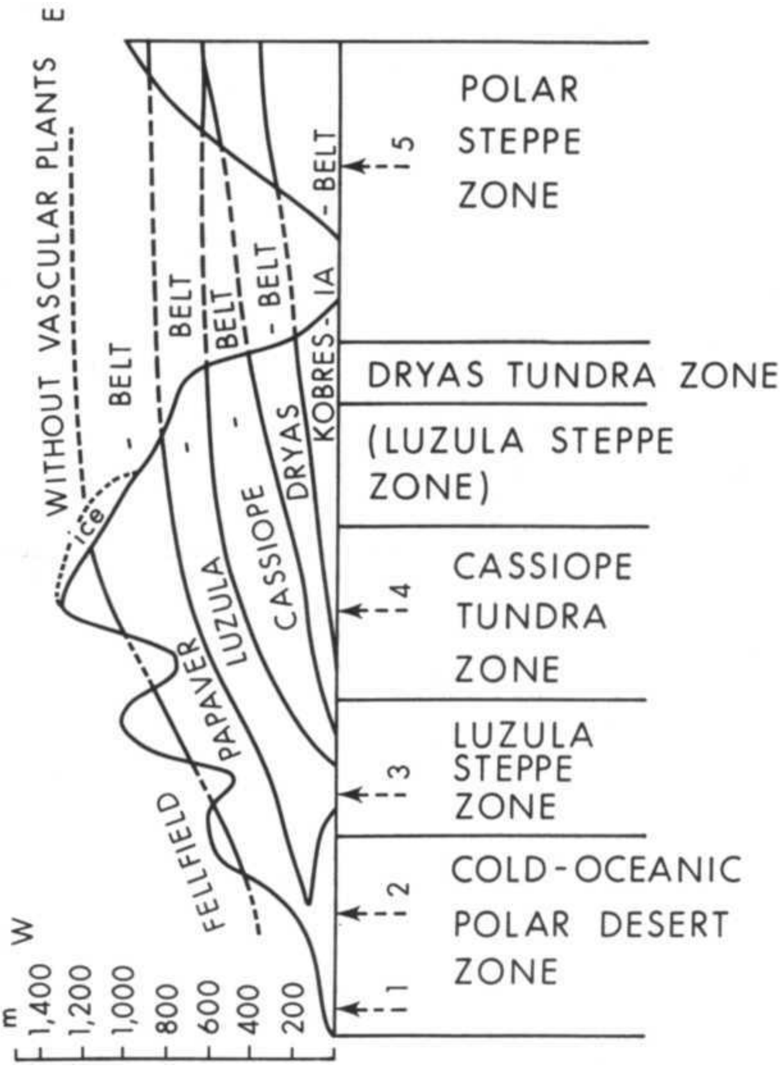

Fig. 1. Vegetation complexes along a W – E – transect across Axel Heiberg 1d. at 79° 30' N.

altitudinal belts while their heights in the other areas were determined along transects and from aerial photographs. The whole vegetation profile across Axel Heiberg Island was further segmented into vegetation zones according to the prevalent vegetation belt at lower elevation. These served in turn for an extrapolation for all the mountainous Queen Elizabeth Islands (Figure 2). This map was drawn under consideration of aerial photographs, reports in the literature, geological maps and further personal field and flight observations.

Ordinating, classifying and mapping the vegetation at various scales gives the only realistic possibility to arrive at reasonably accurate estimates for large regions after biomass and primary production have been determined in detailed studies on small sample plots. Vegetation maps are equally essential for correlations of the plant cover with patterned ground, permafrost, other geomorphological, geological, geochronological, climatological, pedological and landscape conditions over large areas. Vegetation maps must finally

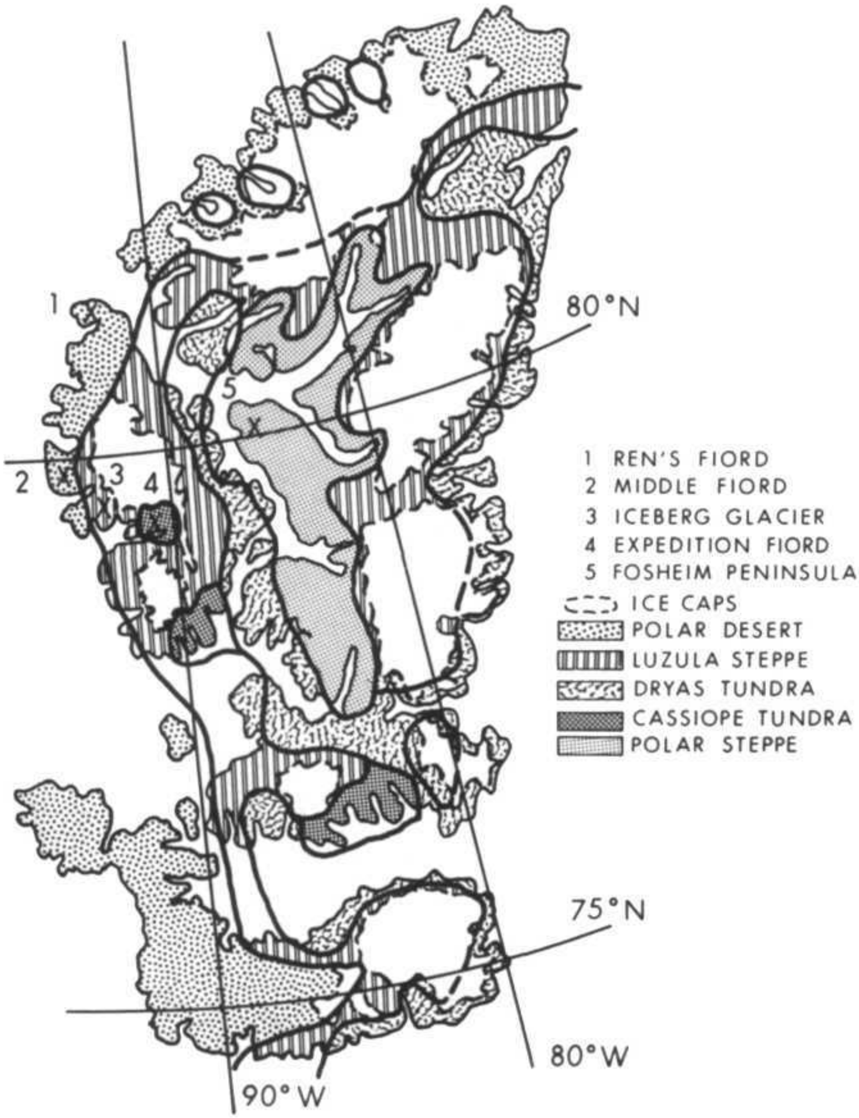

Fig. 2. Major Vegetation Zones on Ellesmere, Axel Heiberg and Devon Island.

serve together with other maps as the basis for the selection of conservation areas within the framework of general resource planning.

A more detailed factual basis for statements and a list of relevant references is given in Beschel, R. (1969)

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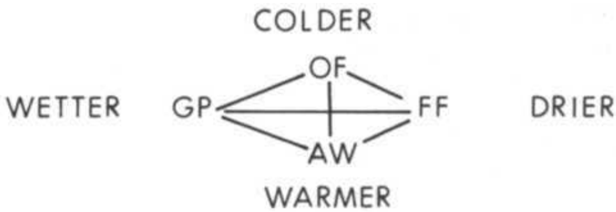
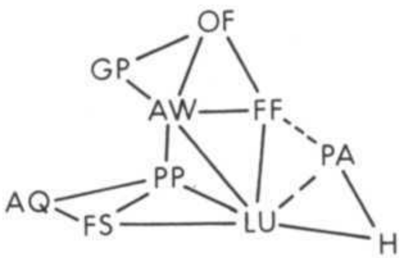
APPENDIX

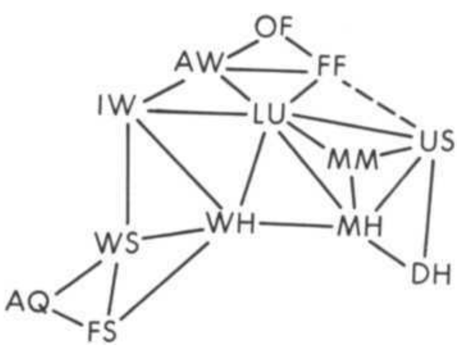
Ordination of the major plant communities on local gradients of heat and moisture in five regions along a macrogradient of increasing continentality across Axel Heiberg- and adjacent Ellesmere Island at about 79° 30' N.



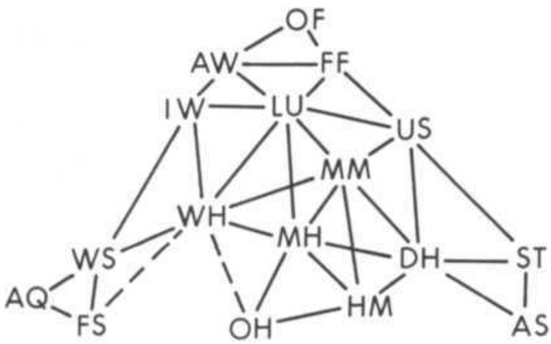
1 *REN'S FIORD* (extreme polar desert) elementary flora about 20 spp.



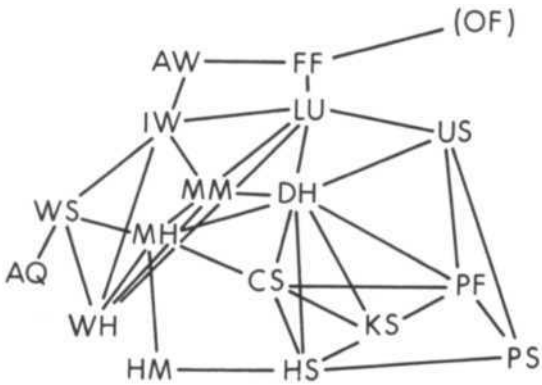
2 *MIDDLE FIORD* (polar desert) elementary flora 72 spp.



3 *ICEBERG GLACIER* (predominant Luzula steppe) elementary flora abt. 100 spp.



4 *EXPEDITION FIORD* (predominant Cassiope tundra) elementary flora 130 spp.



5 *FOSHEIM PENINSULA* (predominant polar steppe) elementary flora abt. 120 spp. (note: MH – mesic heath, but here shifted to the wet part of the moisture gradient).

KEY

AQ emergents of ponds – here mainly *Eriophorum scheuchzeri,* further east also *Pleuropogon, Alopecurus alpinus, Cardamine nymani.*

AS alkali steppe – with *Puccinellia angustata, P. andersonii, Poa hartzii, Potentilla pulchella,* which separates further east into PF, HS, PS.

AW alpine wet sward – open sods of esp. *Phippsia algida* in soaked soil with very short vegetation period.

CS sedge steppe – mainly of *Carex rupestris* and some *C. nardina* on coarser soil.

DH dry heath – of *Dryas integrifolia, Thamnolia subuliformis* and numerous fruticose lichens, here also with some spp. of ST and AS (*Festuca brachyphylla, Carex nardina, Puccinellia angustata*).

FF fell-field – scattered cushions of e.g. *Papaver cornwallisensis, Draba subcapitata.*

FS flood-plain sward – of mainly *Dupontia fisheri, Juncus biglumis.*

GP gloeoplacoid crusts – scattered tufts of e.g. *Deschampsia pumila* in an extensive crust of blue-green algae and jelly-lichens.

H heath and meadow – rudiments merge here on optimal sites into a single community of *Cassiope tetragona, Dryas integrifolia, Carex misandra, C. nardina, Epilobium latifolium.*

HM herb meadow—especially on sunny shale slopes with *Arnica alpina, Erigeron compositus, E. eriocephalus, Potentilla vahliana, Epilobium latifolium, Taraxacum spp.*

HS herb steppe—*Armeria maritima, Potentilla pulchella, P. rubricaulis, Draba arctogena, D. cinerea, Cochlearia officinalis, Braya purpurescens, Lesquerella arctica* on somewhat less stable slopes in drier sites than HM.

IW west sward of intermediate altitude—with dominating *Colpodium vahlianum, Deschampsia brevifolia, Cerastium regelii.*

KS *Kobresia* steppe—with dominant *K. myosuroides* on steeper slopes

LU *Luzula* steppe—of mainly *L. confusa* and *L. nivalis,* with numerous cushion plants of the fell-field, but without heaths.

MH mesic heath—of *Cassiope tetragona, Potentilla hyparctica, Geum rossii,* which is here limited to optimal sites.

MM mesic meadow—of *Alopecurus alpinus, Poa alpigena, Hierochloe alpina,* here also including some spp. of HM (*Taraxacum arctogenum, T. hyparcticum, Arnica alpine*) which form another community further east.

OF open fell-field—widely scattered cushions of e.g. *Saxifraga hyperborea.*

OH optimum heath—with *Vaccinium gaultherioides, Empetrum hermaphroditum, Lycopodium selago,* beside *Cassiope tetragona.*

PA bird perches—of *Poa abbreviata,* merges eastwards into US

PF fescue-bluegrass steppe—with large tufts of *Poa hartzii, Festuca brachyphylla, Deschampsia brevifolia* on the less alkaline, fine-grained soils.

PP oceanic wet sward—of here not submersed-growing *Pleuropogon sabinei,* separates further east into IW, WS, WH.

PS alkali-grass steppe—with *Puccinellia angustata, P. poacea, Agropyron boreale, Braya thorild-wulffii.*

ST lower steppe—with *Kobresia myosuroides, Carex rupestris, C. nardina, Festuca brachyphylla,* this separates further east into CS and KS.

US upper steppe—on sunny cliffs and stable boulder slopes with much *Carex nardina, Saxifraga tricuspidata, Poa abbreviata,* but without *Kobresia myosuroides.*

WH wet heath—of *Arctagrostis latifolia, Eriophorum triste, Carex misandra,* interspersed with much *Salix arctica* and even *Cassiope tetragona.*

WS wet sedge meadow—of often pure stands of *Carex stans.*

Paper No. 9

The Vegetation of the Tundra Zones in the USSR and Data about its Productivity

VERA D. ALEXANDROVA[1]

The tundra region extends within the boundaries of the Soviet Union from 30° E to 170° W and comprises (including the forest tundra) an area of 3. 21 million km^2 (Larin 1965). The plant cover differs over the extent of this huge area from north to south in relation with solar radiation and from west to east with alterations of the continentality of the climate and with orographic factors.

1. ZONAL SUBDIVISION OF THE TUNDRA REGIONS OF THE USSR

The first attempts to differentiate regions within the tundra were made in the 19th century and dealt with the European part of the tundra (Trautvetter 1851, Schrenk 1854). Pohle (1909) subdivided the tundra into an arctic and a subarctic zone. A sequence of studies appeared afterwards which dealt in varying detail either with the definition of tundra regions for the whole USSR or for individual parts of it (Gorodkov 1916, Grigoryev 1924, Berg 1930, Andreev 1932, Zinserling 1932, Sochava 1933, Sambuk and Dedov 1934, Grigoryev 1946, Leskov 1947, Andreev 1938, 1950, 1966, Gorodkov 1954, Alexandrova 1956, 1960, 1964, 1969, Norin 1961, 1965, 1966, Yurtsev 1966, 1968, and others). A comparison of the differences in the concepts of various workers regarding zonal subdivision of the plant cover in the Far North of the USSR and an attempt to give their synonymy is made in Table 1.

In spite of the differences between the various authors the same main principles were applied by a majority of them which were expressed by E. M. Lavrenko in 1940 and 1947 and were formulated more precisely by him recently (1968). The main idea is the use of vegetation differences in placoric habitats with loam soils as the decisive factor. The term placor (from the Greek plág (or pláka and ὅρος) was suggested by G. N. Vysotski (1909, 1927, 1930) to characterize upland habitats which are adequately drained under given macroclimatic conditions and on which zonal soils (*sensu* Sibirtsev 1900) and zonal plant formations develop. The placor concept is close to the corresponding one used by Nichols (1923), and related to the ideas) dealing with the development of climax formations as implied by Clements (1905, 1928, 1936, etc.), but without the demanding successional relationships with non-placoric formations. This has been repeatedly emphasized in the literature (Walter 1942: 16, 1954: 146, Whittaker 1953: 42, Lavrenko 1957: 1373, 1959: 59, Alexandrova 1964: 317).

B. A. Yurtsev (1966, 1968) separates the 'hypoarctic zone' not on the basis of the placor principle but through the sharing of 'active species' in the flora. These are species that flourish under the conditions of a given region and are more widely spread there.

A revision of the zonal separation in Arctic and Subarctic has been made on the basis of more detailed data on the structure of placoric plant communities during the last ten years for the higher latitudes of the Arctic by V. D. Alexandrova (1957, 1960, 1964, 1969) and for the southern parts of the tundra and the forest tundra by B.N. Norin (1961, 1966, 1969). This will be the basis for the following partition of these territories into zones and subzones.

The zones and subzones have been divided on the basis of a complex of traits of which the following ones contribute decisively: floristic composition, the set of dominant and characteristic life forms and the structure of placoric communities on loam soil. Each of the zones and subzones differs further in special communities on non-placoric habitats (places with excessive moisture, with longer than average snow cover, river valleys, etc.) and places with rocky and sandy ground.

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<table>
<tr><td rowspan="2">ZONES</td><td colspan="2" rowspan="2">POLAR DESERT ZONE</td><td colspan="6">T U N D R A Z O N E</td><td colspan="3" rowspan="2">FOREST TUNDRA ZONE</td><td rowspan="2">FOREST ZONE</td></tr>
<tr><td colspan="2">Arctic Tundra Subzone</td><td colspan="4">Subarctic Tundra Subzone</td></tr>
<tr><td>SUBZONES (Belts)</td><td>Subzone of the northern variant of polar desert</td><td>Subzone of the southern variant of polar desert</td><td>Subzone (belt) of the northern variant of arctic tundra</td><td>Subzone (belt) of the southern variant of arctic tundra</td><td colspan="2">Subzone (belt) of typical tundra</td><td colspan="2">Subzone (belt) of southern tundra</td><td>Subzone of northern forest tundra</td><td>Subzore of southern woodland</td><td>Subzone of Open boreal woodlands</td><td>Subzone of northern taiga</td></tr>
<tr><td>Trautvetter 1851</td><td colspan="2"></td><td colspan="2">District of alpine willows</td><td colspan="4">District of low growing birches</td><td colspan="4"></td></tr>
<tr><td>Polye 1909</td><td colspan="2"></td><td colspan="2">Arctic zone of the tundra region</td><td colspan="4">Subarctic zone of the tundra region</td><td colspan="4"></td></tr>
<tr><td>Gorodkov 1916</td><td colspan="2"></td><td colspan="2">Arctic tundra subzone</td><td colspan="4">Subzone of typical tundra</td><td colspan="2">Subzone of forest tundra</td><td colspan="2"></td></tr>
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<tr><td>Gorodkov 1935</td><td>Arctic desert & glacier subzone</td><td>Subzone of arctic desert</td><td colspan="2">Arctic tundra subzone</td><td colspan="2">Subzone of 1ichen-moss tundra</td><td colspan="2">Subzone of shrub tundra</td><td>Subzone of northern forest tundra</td><td>Subzone of southern forest tundra</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Grigoryev 1946</td><td colspan="2" rowspan="2"></td><td colspan="2">Northern (near-arctic) zone of the subarctic belt</td><td colspan="4">Southern (near-boreal) zone of the subarctic belt</td><td colspan="4" rowspan="2"></td></tr>
<tr><td colspan="2">Arctic polygon tundra</td><td>Moss-edge tundra</td><td colspan="2">Moss-1ichen tundra</td><td>Shrub tundra</td></tr>
<tr><td rowspan="2">Leskov 1947</td><td colspan="2" rowspan="2">High arctic nival region</td><td colspan="2">Arctic tundra province</td><td colspan="6">Shrubland (forest tundra) province</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">Arctic tundra belt</td><td colspan="2">Belt of moss-lichen tundra</td><td colspan="2">Belt of tundra-shrubs</td><td colspan="2">Belt of shrub-woodland (forest tundra)</td></tr>
<tr><td>Andreev 1950</td><td colspan="2"></td><td colspan="2">Arctic "semideserts" (arctic tundra)</td><td colspan="2">Moss-, lichen- & dwarf shrub tundras</td><td colspan="3">Mosaics of shrub tundras and woodlands (forest tundra)</td><td colspan="3">Northern taiga</td></tr>
<tr><td>Gorodkov 1954</td><td colspan="3">Arctic deserts</td><td>Arctic tundras</td><td colspan="2">Typical (moss- & lichen-) tundras</td><td colspan="2">Shrub- & tussock tundras</td><td colspan="2">Near-tundra woodlands (forest tundra)</td><td colspan="2">Forests of the northern taiga</td></tr>
<tr><td rowspan="2">Alexandrova 1960, 1963</td><td colspan="2">Polar Desert Zone</td><td colspan="2">Arctic Tundra Subzone</td><td colspan="8" rowspan="2"></td></tr>
<tr><td>Subzone of the northern variant of polar desert</td><td>Subzone of the southern variant of polar desert</td><td>Subzone (belt) of the northern variant of arctic tundra</td><td>Subzone (belt) of the southern variant of arctic tundra</td></tr>
<tr><td>Norin 1957, 1961</td><td colspan="2"></td><td colspan="6">Tundra zone</td><td colspan="3">Forest tundra zone</td><td>Forest zone</td></tr>
<tr><td>Sochava 1964</td><td colspan="4">High arctic formations</td><td colspan="4">Subpolar tundra formations</td><td colspan="4">Boreal (taiga) vegetation</td></tr>
<tr><td>Andreev 1966</td><td colspan="2"></td><td>Subzone of arctic semi-deserts</td><td>Subzone of arctic tundras</td><td colspan="2">Subzone of northern tundras</td><td colspan="2">Subzone of southern tundras</td><td>Subzone of woodland tundras</td><td>Subzone of open forests</td><td colspan="2">Subzone of the northern taiga</td></tr>
</table>

TABLE 1. Scheme of the zonal division of the vegetation cover of the Arctic and Subarctic within the USSR

Polar Desert Zone

In the opinion of the author only the region of present glaciation in high latitudes of the Arctic belongs to this zone. It corresponds to the 'icy zone' of L. S. Berg (1930) and to the landscape zone of arctic deserts of E. S. Korotkyevich (1958, 1967) and does not correspond to the 'arctic desert zone' in the sense of B. N. Gorodkov, who treated it more widely (Gorodkov *et al.* 1954, Sochava and Gorodkov 1956).

The polar desert zone has during the vegetation period a mean temperature close to 0°C. It is characterized on placors by the development of the special vegetation type[1] of polar desert that is well separated from the tundra type. The vegetation type of polar desert has the following specific traits:

(1) Strictly arctic (including high arcto-alpine) composition of angiosperm flora (typically: *Phippsia algida* (Soland.) R. Br., *Poa abbreviata* R. Br., *Pleuropogon sabinei* R. Br., *Papaver polare* (A. Tolm.) Perf., *Cardamine bellidifolia* L., *Draba subcapitata* Simm., *Saxifraga rivularis* L. s. lat., S. *cernua* L., and others);

(ii) peculiar structure of the vegetation cover of a thin layer of spore plants and barely protruding above it;

(iii) complete reduction of vertical stratification;

(iv) lack of a seasonal succession of phenological aspects;

(v) complete loss of the flowering plants as edificators[2]; their root system poorly developed and not closed; flowering plants remaining sterile for the greater part in phytocoenoses with lichens and mosses and not persistent, becoming overgrown by mosses and crustose lichens; regeneration from seeds occurring primarily through the deposition of seeds that ripened on single individuals in 'little hot-houses' between rocks in the vicinity;

(vi) special type of soil formation: absence of gleization, about neutral pH, high base saturation of the soil colloidal complex (Mikhailov 1960, 1961, Mikhailov and Govorukha 1961, Targulyan and Karavaeva 1964, Tedrow 1966, 1968, and others), 'patchiness' of the humus horizon, i.e. shape of pockets and tongues that appear caused by the isolated growth of the flowering plants.

This type of vegetation is developed on the placors with loam soils. The placoric communities on loam soils may be considered climatic climax communities. But they are met with in the zone of polar deserts only on small spots, as we find usually rocky habitats or structural grounds dominating there, as well as places with a very short vegetation period because of long lying snow, where the plant cover is extremely impoverished or totally lacking. In the polar desert zone occur usually small patches of high arctic mires on a mineral substratum. Fragments of tundra vegetation as well as small pockets with peat-forming mires may be encountered as extrazonal occurrences in the most favourable habitats. This is the reason why the whole flora of the polar desert region in the Arctic includes not only high arctic species but some species with a more southern area type which penetrate into the polar deserts as extrazonal elements (e.g. *Salix reptans* Rupr., *Parrya nudicaulis* (L;) Rgl., *Chrysosplenium alternifolium* L., *Lagotis minor* (Willd.) Standl. on Zevernaya Zemlya etc).

The southern limit of the polar desert zone lies within the USSR close to the +2°C July isotherm; it lies south of it in Atlantic parts and north of it in continental parts of the region.

The zone of polar deserts comprises in the Soviet sector of the Arctic a part of the northern island of Novaya Zemlya, Franz Josef Land, Severnaya Zemlya and De Long Islands. B. N. Gorodkov (1935, 1954 and others) referred also the northern part of Novaya Zemlya's southern island, the New Siberian Islands arid Wrangel Island to the zone of polar deserts, but these are better placed with the arctic tundra subzone of the tundra zone.

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[1] *Vegetation type* – in Soviet geobotany the main taxonomic unit of higher rank in vegetation classification, roughly agreeing in content with *formation* in the sense of Clements and of Western European phytocoenologists.

[2] edificator (édificateur, literally builder – the term of Braun-Blanquet et Pavillard, 1922) is used in Soviet geobotany for a species which may significantly determine in its development the environment of its plant community.

Tundra Zone

On placors of the tundra zone we find the tundra vegetation type developed which is represented by polydominant communities. Perennial *Hekistotherm* (*sensu* De Candolle 1855) plants dominate in a layer of mosses together with arcto-alpine and hypoarctic dwarf-shrubs or low growing half-prostrate shrubs (*sensu* Serebryakov 1962, 1964). Considerable areas are covered by herbaceous perennials. The plants grow on automorphic tundra soils (arctic brown soils *sensu* Tedrow 1962, 1968 and others). The vegetation has full cover, or (more often) with spots of bare ground on it. Flat as well as hummocky bogs accompany the zonal type on excessively moist sites and lichen and moss-lichen communities on sandy and rocky ground. Meadows and open woodlands enter along river valleys as extrazonal occurrences from the south. There is a characteristic combination of several genetically dissimilar flora elements in the floristic complex (Tolmachev 1957, 1962): aboriginal, eoarctic elements and migration elements. The latter are alpigen or boreal and advanced several times northwards during recent geological times with the expansions of the forest into the tundra.

Different zonal divisions of the tundra region have been proposed by many authors. Following R. Pohle (1909) we divide the tundra zone into two subzones: the subzone of the arctic tundra and the subzone of the subarctic tundra. The boundary between these subzones lies on the important botanico-geographical limit that is based on the whole complex of differences in climate, floristic composition, origin of the flora, Quaternary history, composition of plant communities, differences in life forms, etc.

The zonal plant communities of the *subarctic tundra subzone* consist within the USSR typically of associations with a well developed moss cover, usually of *Tomenthypnum nitens*, *Hylocomium splendens*, *Aulacomnium turgidem*, and *Drepanocladus. Dicranum* and *Polytrichum* species. They possess well expressed synusia of low growing, half-prostrate shrubs (*Betula nana* L., *B. exilis* Sukacz., *Salix pulchra* Cham., *S. glauca* L., *S. reptans* Rupr., and others) and contain a characteristic component of hypoarctic and boreal species derived from the forest zone. Typical of non-placoric sites are: palsa and polygon bogs on excessively moist places, shrub communities on slopes, niveal short-grass swards rich in grasses and herbs on places with long lying snow cover, and lichen and moss-lichen tundras on sands and skeletonized rocky soils. The southern limit of the subarctic tundra subzone follows the boundary of the forest tundra and lies close to the + 10°C July isotherm.

Shrubs do not form distinct synusia in the zonal associations of the *arctic tundra subzone*. Low growing, half-prostrate shrubs of the genus *Salix* occur only as admixtures in the thin herb layer and further only in southern variants of the arctic tundra. Arcto-alpine dwarf shrubs stand out as co-edificators together with the mosses. They belong to the life form of vegetatively advancing dwarf shrubs of the espalier type (*sensu* Serebryakov 1962) and grow either as plaques (*Dryas octopetala* L., *D. punctata* Juz.), or have their stems hidden in the sod (*Salix polaris* Wahlenbg.). Other willows (*S. nummularia* Anderss., S. *reticulata* L., and others) are also developed as creeping dwarf shrubs. The participation of boreal and hypoarctic species drops sharply in the arctic tundra subzone while the role of arctic and arcto-alpine herbs and monocots increases. In comparison with the subarctic tundra subzone there is more bare soil. In places where in winter the snow is blown away occur very denuded polygon tundras. But the bareness of the ground does not appear ubiquitously, i.e. in the same subzone one finds regions where tundra vegetation on placors has a full cover, e.g. in the East European northlands (Andreev, 1966), in the East Siberian Arctic, etc. Characteristic traits of the arctic tundra subzone are a lack of palsa bogs, shrub stands on slopes and in river valleys, and low meadows in snowbed communities. The limit between arctic and subarctic tundra subzone follows in the USSR roughly the +6°C July isotherm, but lies south of it in the more atlantic parts and further north in the continental regions of the Siberian Arctic.

The importance of the boundary between arctic and subarctic tundra for phytocoenology, floristics and landscape study has also been emphasized by Sochava (1956, 1964). The same boundary divides according to Grigoryev (1946) the near-arctic and the near-boreal zones of the subarctic. The essential phytogeographical and phytocoenological meaning of the southern border of the arctic tundra is explained not only through the broad climatic zonation, but more more through the special Quaternary history of the tundra region: the pulsation of the polar timber line never exceeded this limit in postglacial time

(Tikhomirov 1941) and the territory of the arctic tundra subzone was thus 'always' unforested.

Forest Tundra Zone

The region with open tundra woodlands and with the northernmost open-spaced stands of the boreal forest have been placed by B.N. Norin (1961) into a separate forest tundra zone. He based this on the development of a special vegetation type of the forest tundra (open woodland, elfin forest) which has the following characters:

(i) wide spacing of trees in the stands, but at the same time the trees having a closed root system;

(ii) truly original life forms of the tree species with krummholz mats, half- and fully depressed growth, flagging and 'skirted trees';

(iii) floristic specificity of this zone expressed by hypoarctic flora elements in the forest tundra vegetation type which find here the optimal conditions for their existence and attain their greatest richness.

The forest tundra vegetation type occurs in the forest tundra zone together with forest-, peatland-, tundra-, and meadow-communities.

Many authors have suggested, parallel with the zonal subdivision, a division of the northern territories into provinces and smaller regional entities, the districts. Thus, Gorodkov (1935) divided the tundra zone of the USSR into twelve provinces: (1) Kola Peninsula, (2) eastern European tundra, (3) western islands of the Arctic Ocean, (4) polar Ural Mountains, (5) West Siberian lowlands, (6) Central Siberian tundra, (7) Taimyr Mountains, (8) Yakutian highlands, (9) Chukotka—Anadyr Mountains, (10) islands in the East Siberian Sea, (11) highlands of the Anadyr Penzhin depression, (12) Koryak Mountains. A.I. Leskov (1947) recognized within the limit of the Far North of the USSR four regions and belts within them (cf. Table 1). The partition was carried further to 50 districts. This scheme is of great interest because of the principles on which it was based. The districts were based on geomorphological features. However, insufficient knowledge of the vegetation of these vast and at that time very inaccessible regions was responsible for many inaccurate delimitations. Alexandrova (1964, 1969) described within the arctic tundra subzone five provinces: (1) Novaya Zemlya—Vaigach, (2) Siberia, (3) Yana—Kolyma, (4) the western part of the Canadian Arctic Archipelago, (5) Spitsbergen—Greenland. Yurtzev (1966) subdivided the hypoarctic zone also into five provinces: (1) North Atlantic (with South Greenland, Iceland, Faeroe and Shetland Islands, and Northern Scandinavia as subprovinces), (2) Eastern European—West Siberian (with Lapland, Dvina—Pechora, and West Siberia as subprovinces), (3) Northern Angaridian (subprovinces: Mid Siberia, East Siberia (= Verkhoyansk—Kolyma) and Koryak—Okhotsk), (4) North Pacific (= South Beringian) (with Kuriles—Kamchatka and Commander—Aleutian Islands as subprovinces), (5) Canadian (subprovinces: Yukon, Central Canada, and Labrador).

The vertical zonation in mountains of the Far North of the USSR is analogously expressed to the latitudinal zones (oro-zones in the terminology of Ahti, 1968). It has been described in several studies (Gorodkov 1935, Grigoryev 1946, Alexandrova 1956, 1960, 1963, Gorchakovski 1966, and others).

PRODUCTIVITY DATA OF PLANT COMMUNITIES IN THE TUNDRA ZONE OF THE USSR

(a) Data on phytomass above the ground

The phytomass of tundra communities above ground level has been studied since the 1930's in connection with investigations on the productivity of reindeer pastures (Sambuk 1934, Andreev, Igoshina and Leskov 1935, Andreev 1954, Lavrenko, Andreev and Leontyev 1955, Vakhtina 1964, and others). The most comprehensive data based on collections of bulk material were obtained by V. N. Andreev for the East European northlands (Andreev 1966). A large group of botanists, about 60 people, harvested during two years under his supervision 10, 000 sample plots and gathered data on the projected cover of the various

TABLE 2. Reserves of aerial phytomass and its annual productivity in the subzones of the East European northlands (kg/ha airdry weight) after Andreev (1966:1404).

Biological Groups of Plants	ARCTIC TUNDRA				SUBARCTIC TUNDRA							
	Northern variant (arctic semi-deserts sensu Andreev)		Southern variant (arctic tundra sensu (Andreev)		"Typical tundra (northern tundra sensu Andreev)		Southern tundra (shrub tundra sensu (Andreev)		Woodland Tundra		Open Forest	
	Mass	Growth	Mass	Growth	Mass	Growth	Mass	Growth	Mass	Growth	Mass	Growth
Bryophytes	90	9	490	49	900	90	1,180	118	1,370	137	1,500	150
Fruticose lichens	–	–	10	1	90	9	270	27	420	42	300	30
Sedges	110	110	370	370	280	280	210	210	190	190	220	220
Grasses	10	10	50	50	70	70	2	2	5	5	–	–
Herbs	120	120	220	220	160	160	30	30	25	25	30	30
Arctic dwarfshrubs	160	16	100	10	70	7	–	–	–	–	–	–
Subarctic dwarfshrubs	–	–	–	–	70	7	360	36	560	56	620	62
Dwarf birch	–	–	–	–	110	44	570	228	710	284	830	232
Shrub willows	–	–	–	–	1,210	480	540	216	340	136	240	66
Trees	–	–	–	–	–	–	–	–	3,650	230	8,230	390
Total	490	270	1,240	700	2,960	1, 140	3,160	870	7,270	1,100	11,970	1,180

plant groups on more than 300, 000 quadrats. The theoretical calculations of L. G. Ramenski (1938) on the relationship of projected cover of plants with their weight were used to construct tables that give the living, aerial vegetable mass for various indices of projected cover of different biological groups of plants.

Data on the phytomass above ground and its annual productivity are given in Table 2 for the subzones in East European northlands. The mass of annual increment was determined approximately by Andreev from different kinds of observations and certain experiments. These figures have only an orienting, but, nevertheless, a very important practical value. It gives the necessary hints, even if they are only rough guidelines, for an assessment of the possible amount of reindeers on a pasture and for a determination of the pasture rotation.

The subzones of the East European northlands for which Andreev gave the amount of aerial phytomass are as follows:

(1) The subzone of 'arctic semidesert' occurs in a narrow belt near the strait of Yugorsky Shar. It has an open plant cover and more than 50% of the soil surfaces are bare. Arcto-alpine and arctic species of mosses, dwarfshrubs (esp. *Dryas* and dwarf willows) and herbs predominate as edificators. This corresponds, in the scheme of the present author for the zonal subdivision of the Arctic, to the southern variant of the arctic tundra subzone, impoverished on the shores of Yugorsky Shar by the intense ice cover of the strait.

(2) The subzone of the arctic tundra which in the present author's scheme is the southern variant of the arctic tundra, contains the shores of the Kara Sea and the Pay Khoy highlands of the Yugorsky Peninsula. It has continuous vegetation cover with the same edificators as the first.

(3) The subzone of the northern tundra (= northern belt of the subarctic tundra subzone of the author) is characterized by massively developed willow scrub of *Salix glauca, S. lanata, S. phylicifolia,* associated with herb- dwarfshrub- moss- tundra communities. Subarctic and boreal dwarfshrubs (*Ledum, Vaccinium Chamaedaphne,Andromeda*)) appeax.

(4) The subzone of the southern tundra (the southern belt of the subarctic tundra subzone) is developed as a broad belt from the Kanin Peninsula to the Ural Mountains. It is characterized by predominating dwarf birch (*Betula nana*)—moss tundra and shrub willows, complexed with palsa bogs.

The figures which Andreev obtained for the mass of the plant matter give an idea of the productivity of the vegetation cover in the East European northlands in the form of rounded numbers for each subzone *in toto.* If we add the figure that the author obtained—also through a conversion from the projected cover—for the average quantity of phytomass per area unit in the polar desert of Alexandra Island (Franz Josef Land), then we obtained the geographical sequence for the East European Arctic and Subarctic as shown in Table 3.

TABLE 3. Average amount of live, aerial phytomass in tundra and polar desert of the East European northlands (kg/ha air-dry weight).

Subzone	Mass	Source
Zone of polar desert	40	Alexandrova, 1969
Subzone of arctic tundra, northern variant	490	Andreyev, 1966
Subzone of arctic tundra, southern variant	1,240	Andreyev, 1966
Subzone of typical subarctic tundra	2,960	Andreyev, 1966
Subzone of southern subarctic tundra	3,160	Andreyev, 1966

From these data we may conclude that the quantity of aerial phytomass rises in the transition from polar desert to arctic tundra, and from the latter to subarctic tundra, every time in approximately the same order, i.e. if we take the average amount of live, aerial plant matter per unit area in the zone of the polar desert as a unit, then the relationship approximates 1:10:100.

(b) Data on the whole phytomass (aerial and underground)

The determination of the total phytomass above and below the ground is extraordinarily difficult in tundra. That is why we have so far only scattered data at our disposal. They were mostly obtained by co-workers in the Laboratory of Far North Vegetation, Geobotany Department of the Komarov Botanical Institute of the Soviet Academy of Sciences.

The phytomass of the placoric polar desert phytocoenosis was determined by V. D. Alexandrova (1969) on Alexandra Island (Franz Josef Land). The plot was selected in an area with optimal snow regimen, with loam soil deposited with an admixture of basaltic sand and gravel on an elevated (20 m.s.m.) marine terace. The surface is divided by cracks into small polygons of 15 x 20 to 10 x 40 cm.). 75% of the surface are covered with light-grey lichen crusts of *Pertusaria freyi* Erichs., *P. octomela* Erichs., *P. glomerata* Schaer. and *Ochrolechia* sp. with small black patches of a gelatinous lichen (*Collema* sp.) and scattered tiny tufts of sterile *Phippsia algida* (Soland.) R. Br. Patches of bare soil make up to 10-15% of the surface. Along the cracks extend bands of vegetation which cover also 10-15%. They are composed of mosses (*Ditrichum flexicaule* (Schleich,) Hampe, *Polytrichum alpinum* Hedw., *Distichium montanum* (Lam.) Hag., *Myurella julacea* (Vill.) Br., Sch. and Gmb., *Campylium stellatum* (Hedw.) Lange, and others) and lichens (mainly *Cetraria hiascens* (Fr.) Th. Fr. and *Stereocaulon rivulorum* H.Magn.) with some admixture of flowering plants (*Phippsia algida, Papaver polare, Saxifraga rivularis* and others). The aerial phytomass was sampled in 50 x 100 cm quadrats, the underground phytomass was found in a soil monolith of 25 x 25 x 38 cm, down to the permafrost.

The phytomass of the placoric *arctic tundra* phytocoenosis was determined by Alexandrova (1958) on Greater Lyakhov Island (New Siberian Islands) on a site in the upper part of a gentle (1°) slope in tundra with optimal snow regimen. The hillocky vegetation mat covers 60% and contains mosses (*Bartramia ithyphylla* Brid., *Ditrichum flexicaule* (Schleich.) Hampe, *Polytrichum alpinum* Hedw., *Tomenthypnum nitens* (Hedw.) Loesky, *Hyloconium splendens* (Hedw.) Br., Sch., and Gmb. var. *alaskanum* (Lesq. and James) Limpr., and others), the graminoids *Alopecurus alpinus* 'Sm. and *Luzula confusa* Lindeb., the dwarf willow *Salix polaris* Wahlenbg., many herb species (*Ranunculus sulphureus* Soland., *R. nivalis* L., *Cerastium byalinickii* Tolm., *Draba pohlei* Tolm., *Potentilla emarginata* Pursh, and others), as well as lichens (*Cetraria crispa* (Tetz.) Nyl., *Thamnolia vermicularis* (Sw.) Schaer., *Dactylina arctica* (Hook.) Nyl., and others). Over 40% of the surface occur loamy earth patches which harbour the occasional *Alopecurus alpinus, Draba micropetala* Hook., *Saxifraga platysepala* Tolm., *Thamnolia vermicularis, Psoroma hypnorum* (Hoffm) S. Gray, and others. Aerial phytomass was sampled in 50 x 100 cm quadrats separately for the earth patches and the closed mat. The phytomass in the ground was obtained from a soil monolith of 25 x 25 x 36 cm. down to the permafrost.

The phytomass of northern subarctic tundra was measured by V. F. Shamurin (1966), see Alexandrova 1969) in the Vorkuta region (Komi ASSR) on three sites with placoric conditions on loam soils:

(1) on low hummock tundra with *Polytrichum commune* Hedw., and *P. strictum* Sm. dominating on the hummocks and with *Aulacomnium palustre* (Hedw.), Schwaegr. in the depression between them; *Carex hyperborea* Drej. gives 10% cover and *Betula nana,* in a low creeping form, only 20-30 cm high another 20%;

(ii) on moderately hummocky tundra where the moss layer is also dominated by *Polytrichum* spp.; beside *Betula nana* occur low shrubs of *Salix glauca* and *S. lanata* with 10% projected cover;

(iii) on low hummock tundra with *Polytrichum commune* and *Pleurozium schreberi* (Brid.) Mitt. dominating the moss layer; lichens (*Cetraria islandica* (Fr.) Th. Fr., *Cladonia sylvatica* (L.) Hoffm.) do not exceed 5% cover; shrubs are *Betula nana*, *Salix lanata,* and *S. glauca* and in the herb- and dwarfshrub layer occur *Carex hyperborea, Vaccinium vitisidaea* L., *V.uliginosum* L. and *Empetrum hermaphroditum* (Lge.) Hagerup. Aerial plant matter was sampled in 50 x 50 cm quadrats with two replicates. The plant matter in the ground was isolated from a 25 x 25 x 100 cm monolith.

The phytomass of phytocoenoses in the *northern subarctic tundra* subzone on the West Taimyr was measured by E. A. Khodachek (1969) in the region of the right bank of the Pyasina river near the mouth of the Tareya river on: (1) placoric small-hummocky tundra with *Dryas punctata, Carex ensifolia* var. *arctisibirica* Yurts., *Hylocomium splendens* var. *alaskanum, Aulacomnium turgidum, Tomenthypnum nitens* dominating with admixture of herbs and lichens; (2) on the tundra with spot-medallions with the same dominants and rather more lichens; bare loamy spot medallions make up from 5 to 30% of the surface; this type of tundra develops in sites with thinner snow cover; (3) on the polygonal mire with *Carex stans* Srej., *C. chordorrhiza* Ehrh., *Drepanocladus intermedius* (Lindb.) Warnst., *Calliergon richardsonii* (Mitt.) Kindb. dominating on the polygons and *Carex stans* and mosses species of *Calliergon* and *Drepanocladus* in hollows between polygons; there is *Salix reptans* on the borders of polygons. Aerial plant matter was sampled in 20x20 cm quadrats with six replicates on all elements of the microrelief (spot-medallion, border, hollow) in the tundra with spot-medallions, in 50 x 50 cm quadrats with three replicates in the small-hummock tundra and the same in the polygon mire (on polygon, border and hollow). Underground plant matter was isolated from monoliths 25 x 25 cm and down to the permafrost.

Southern subarctic dwarfshrub tundra was studied by V. V. Vasilkova and V. F.Shamurin (Vikhireva-Vasilkova *et al.)* in the Koryak region. The phytomass was determined in its characteristic communities of sedge- lichen- moss- dwarfshrub tundra. It alternates in this region with shrub thickets of *Betula middendorfii* Trautv. and Mey., with patches of *Sphagnum* bogs and sedge- cottongrass- tussock tundra. The vegetation cover in the tundra with spot medallions consists of *Carex lugens* Holm., *Vaccinium uliginosum, Arctous alpina* (L.) Niedenzu, *Empetrum nigrum* s.l., *Diapensia obovata* (Fr. Schmidt) Nakai, *Loiseleuria procumbens* (L.) Desv., *Ledum decumbens* (Ait.) Small, *Claytonia acutifolia* Pall. and other representative herbs. *Aulacomnium turgidum* (Wahlenbg.) Schwaegr. and *A.palustre, Dicranum bergeri* Bland. and others stand out among the mosses. Isolated plaques of *Sphagnum lenense* H. Lindb. occur. Common lichens are *Cetraria nivalis* (L.) Ach., *C.cucullata* (Bell.). Ach., *Thamnolia vermicularis* (Sw.) Ach., *Peltigera aphthosa* (L.) Willd. and others. The hummock tundra has generally a similar plant composition but *Carex globularis* L. is especially common there. Aerial parts of the plants were cut in 50 x 50 cm quadrats in two replicates for each of the components of the micro- mosaics—for spot medallions and mats, for hummocks and hollows. The phytomass in the ground was determined in monoliths of 25 x 25 x 55 cm.

The phytomass of *southern subarctic shrub tundra* was sampled by A. T. Rakhmanina in the Komi ASSR in dwarf birch tundra where *Betula nana* forms a well developed layer of 70-80 cm height with 50-60% cover. *Salix glauca* and *S. phylicifilia* are met singly. Dwarf shrubs and herbaceous plants compose a.lower stratum with much *Carex globularis* and the dwarfshrubs *Vaccinium uliginosum, V. myrtillus, V. vitis-idaea, Empetrum hermaphroditum, Arctous alpina, Ledum palustre.* In the very luxuriant moss layer the dominants are *Polytrichum strictum, P. commune* and *Pleurozium schreberi,* while lichens *(Cladonia sylvatica, C. rangiferina, C. uncialis, Peltigera aphthosa* and some others) occur in insignificant quantities. A trench of 5 x 1 m was dug to determine the biomass. Aerial plant parts were cut in 20 x 20 cm and in 50 x 50 cm quadrats on various segments of the microrelief. Monoliths of 20 x 20 cm were taken in layers down to 1 m depth for the underground parts of the plants. The richness of the coarse stems of *Polytrichum commune* and *P. strictum* in the moss layer is mainly responsible for the surprisingly high figures which result in this tundra for the fraction of dead plant parts (113, 240 kg/ha).

All authors applied methods closely comparable to the ones used by Alexandrova (1958) for the study of aerial and underground plant mass on Greater Lyakhov Island. In particular, the. aerial fraction of the vegetation comprised those plant parts that lay in the live moss layer, or were raised above it, and the live mosses themselves. The lower, dying and decaying parts of mosses and epigeic lichens were included with the uppermost soil horizon (A).

In scanning Tables 4 and 5 one notices first that the underground phytomass exceeds in all tundra communities the one above the ground. The underground mass of live plant parts constitutes 62-83% of the total live mass. In the southern subzones of the tundra

TABLE 4. Amount of aerial and underground phytomass on several points of the Soviet Arctic and Subarctic (kg/ha airdry weight).

	Polar Desert	Arctic Tundra	Typical Tundra	Subarctic Tundra Southern Tundra		
Regions	(A)	(B)	(C)	(D)	(E)	(F)
Live plant parts	1,580	6,960	18,770	27,860	28,780	58,780
of these:						
Flowering plants	350	5,820	15,580	25,250	26,370	45,330
aerial parts	60	710	1,880	2,180	2,500	8,170
underground parts	290	5,110	13,700	23,070	23,870	37,160
Bryophytes, lichens & algae	1,230	1,140	3,190	2,610	2,410	13,450
Dead plant parts	1,610	3,790	52,220	83,090	83,910	113,240
Total live & dead plant parts	3,190	10,750	70,990	110,950	112,690	172,020
of these:						
aerial parts	1,380	2,540	8,730	10,000	9,010	21,860
underground parts	1,810	8,210	62,260	100,950	103,680	150,160

REGIONS

(A) Moss- lichen polygons in polar desert, Alexandra Island, Franz Josef Land (Alexandrova 1969).

(B) Woodrush- grass- dwarfshrub- moss tundra with hillocks and bare earth circles, Greater Lakhov Island, New Siberian Islands (Alexandrova 1958).

(C) Typical tundra in the Vorkuta region, average of three tundra communities (Shamurin 1966 in Alexandrova 1969).

(D) Southern sedge- lichen- moss- dwarfshrub tundra with spot medallions, Koryak region (Vikhiryeva-Vasilkova *et al.* 1964).

(E) Southern sedge- lichen- moss- dwarfshrub tundra with hummocks, Koryak region (Vikhiryeva-Vasilkova *et al.* 1964).

(F) Shrub tundra (yernik), East European forest tundra region (Rakhmanina 1966 in Alexandrova 1969).

the underground plant matter reaches very great amounts: more than 2 kg of airdry weight in the shrub tundra of the Komi ASSR. Together with the dead parts these figures rise correspondingly to more than 10 kg/m^2 (103. 7 t/ha) and to 15 kg/m^2 (150. 2 t/ha). The aerial mass of live and dead parts weighs correspondingly only about 1 kg/m^2 (9-10 t/ha) and about 2 kg/m^2 (21. 9 t/ha). These figures indicate that the soils of the tundra store significant reserves of fertility in the form of the great amount of organic matter.

Quite a different relationship of aerial and underground phytomass can be seen for the community of the polar desert: live plant matter below the ground contains 18. 5% while that above ground contains 81. 5% of the total. The structure of a phytocoenosis in the polar desert differs thus fundamentally from the tundra in the ratio of aerial and underground phytomass.

The data on the ratios of different plant groups, as given in Table 5, underline the differences in the structure of the phytomass among plant communities of the various subzones of Arctic and Subarctic still further. The contrast in the structure of aerial biomass

TABLE 5. Relationships of the live, aerial phytomasses of different plant groups on several points of the Soviet Arctic and Subarctic (kg/ha alrdry weight).

Biological Groups	Polar Desert		Arctic Tundra		SUBARCTIC TUNDRA Typical Tundra		Southern Tundra	
Habitat and Location	(A)		(B)		(C)		(F)	
	wt.	%	wt.	%	wt.	%	wt.	%
Flowering plants	60	4	710	38	1,880	37	8,150	38
of these:								
shrubs	–	–	–	–	1,670	33	6,300	30
dwarfshrubs	–	–	290	16	170	3	920	4
herbs & graminoids	60	4	420	22	40	1	930	4
Bryophytes	400	31	820	44	2,380	47	13,000	60
Lichens	830	65	320	18	810	16	470	2
of these:								
fruticose & foliose	520	41	260	15	810	16	470	2
crustose	290	23	60	3	–	–	–	–
gelatinous lichens & algae	20	1	–	–	–	–	–	–
Total live, aerial mass	1,290	100	1,850	100	5,070	100	21,620	100

is especially sharp between the phytocoenosis of the polar desert and the tundra phytocoenoses. While in the tundra first place in aerial phytomass is held by mosses, lichens compose the greatest fraction (66%) in the polar desert community. The part of the flowering plants is quite insignificant in the latter and all are herbaceous, as dwarfshrubs are absent. The polar desert stands out further by its very high percentage of crustose lichens which compose 24% of the whole aerial phytomass. A very characteristic feature is also the amount of algae (*Stratonostoc*) and gelatinous lichens (*Collema* sp.) whose aggregations appear in the phytomass of polar desert as conspicuous small black patches. The mass of gelatinous lichens and algae amounted to 2 g/m^2 or 1% of the whole aerial plant matter.

This relationship of the life forms approximates the arctic polar deserts to their antarctic counterparts. Their vegetation—where it has developed at all—is composed of lichens that are mainly crustose, of algae and of some mosses. Flowering plants, of which only two species (*Deschampsia antarctica* D e s v . and *Colobanthus crassifolius* (D'Urv.) Hook. fil.) occur on the antarctic mainland (on. Graham Land), grow only singly (Skottsberg 1954, Greene 1964, and others).

It is necessary to emphasize that the data given for aerial phytomass in different subzones of the European northlands (Tables 2 and 3) cannot be compared with the values for the whole aerial and underground phytomass as given in Tables 5 and 6. The former are based on a massive material while the latter stem from a few samples. More important, the former exhibit the mean content of phytomass per area unit for the whole of each subzone, while the latter give the amount of phytomass only for single points. But as they are determinations for placoric sites they give at least a first orienting idea of the reserves of live and dead vegetation in zonal phytocoenoses, i.e.phytocoenoses of the climatic climax of each subzone.

Available data for the phytomass of mountain tundra are given in Table 6.

TABLE 6. Aerial and underground plant mass in mountain tundra communities (airdry weight in kg/ha).

	Regions
(A)	Koryak region, Pipivit-Khan Mtn., 550 m.s.m. (Gavrilyuk 1964 in Vikhiryeva-Vasilkova *et al.* 1964). Dwarf shrub tundra with dominating *Arctous alpina* (L.) Niedenzu, *Rhododendron kamtschaticum* Pall., *Vaccinium uliginosum* L., *Diapensia obovata* (Fr. Schmidt), *Cetraria cucullata* (Bell.) Ach., *Alectoria ochroleuca* (Hoffm.) Mass.
(B)	Kola Peninsula, Khibin Mtns., 1, 000-1, 200 m.s.m. (Chepurko 1966). Lichen tundra with dominating *Cetraria nivalis* (L.) Ach., *C. crispa* (Retz.) Nyl., *Alectoria nigricans* (Ach.) Nyl., *A. ochroleuca* (Hoffm.) Mass.
(C)	*Ibid.*, 700-1, 000 m.s.m. Moss- lichen tundra with dominating *Rhacomitrium microcarpum* (Hedw.) Brid., *Andreaea petrophila* Ehrh., *Cladonia gracilis* (L.) Willd., *C. mitis* Sandst.
(D)	*Ibid.*, 700-1, 000 m.s.m. Tundra with spot medallions, with arcto-alpine herbs and dwarfshrubs (*Hieracium alpinum* L., *Silene acaulis* L., *Sibbaldia procumbens* L., *Saxifraga oppositifolia* L., *Dryas octopetala* L., *Salix polaris* Wahlenbg.)
(E)	*Ibid.*, 500-600 m.s.m. Birch- crowberry- dwarfshrub tundra (*Betula nana* L., *Empetrum nigrum* L.)
(F)	*Ibid.*, 500-600 m.s.m. Alpine mat of blueberry (*Vaccinium myrtillus* L.) and arcto-alpine herbs.
(G)	*Ibid.*, 500-600 m.s.m. Valley tundra of heather (*Calluna vulgaris* (L.) Hill.) and *Cetraria* spp.
(H)	Kola Peninsula, northwestern part, 170 m.s.m. (Manakov 1967). Dwarfshrub tundra with dominating *Betula nana* L., *Ledum palustre* L., *Empetrum nigrum* L., *Vaccinium vitis-idaea* L., *Festuca ovina* L., *Deschampsia flexuosa* (L.) Trin., *Cladonia rangiferina* (L.) Web., C. *alpestris* (L.) Rabh.

	Aerial Mass		Underground Mass		Total Phytomass	
Region	Live	Dead	Live	Dead	Live	Dead
(A)	1,050	540	12,450		14, 040	
(B)	240				240	
(C)	740				740	
(D)	1,700		4,760		6,460	
(E)	4,750		12, 280		17, 030	
(F)	5,350		21,650		27, 000	
(G)	4,890		7,990		12, 880	
(H)					9,610	

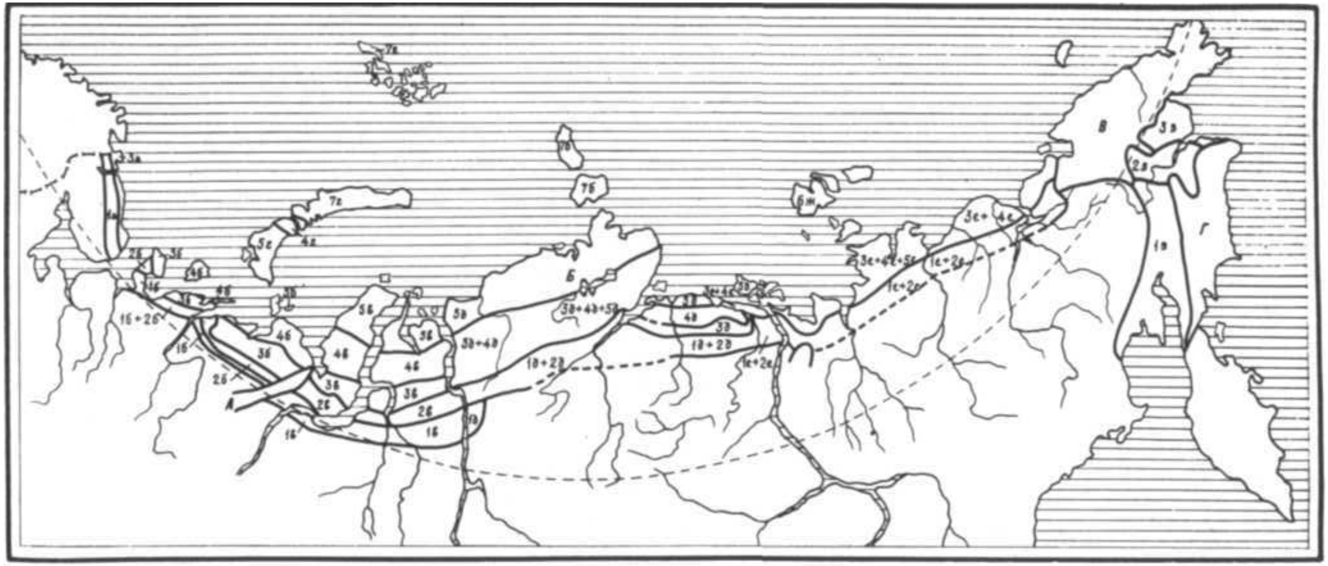

Fig. 1. Scheme of division of the vegetation of the Far North of the USSR by B. N. Borodkov (1935: 130).

1 Subzone of the southern forest-tundra.
2 Subzone of the northern forest-tundra.
3 Shrub tundra subzone.
4 Lichen-moss tundra subzone.
5 Arctic tundra subzone.
6 Arctic desert subzone.
7 Arctic desert-glacial subzone.

PROVINCES:

а Kola Peninsula
б Eastern European tundra
в West Siberian Lowlands
г Western islands of the Arctic Ocean
д Central Siberian tundra
е Plain and highlands tundra of Yakutia
ж Islands in the East Siberian Sea
з Plain and highlands tundra of the Anadyr-Penzhin depression
А Polar Ural
Б Taimyr Mountains
В Chukotka-Anadyr Mountains
Г Koryak Mountains

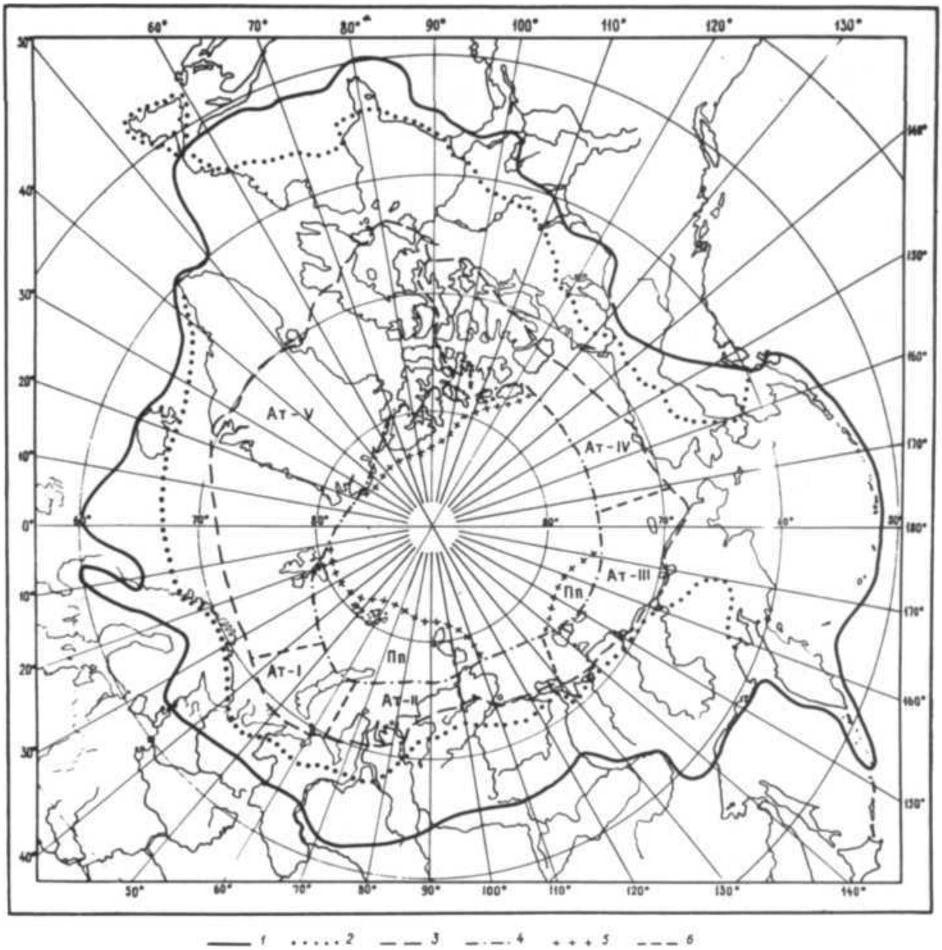

Fig. 2. Scheme of division of the Arctic and Subarctic vegetation by V. C. Alexandrova and B. A. Yurtsev (Alexandrova, 1969: 57).

1 Southern limit of the hypoarctic zone by Yurtsev (1966)
2 Northern limit of woodlands on placors
3 Southern limit of the arctic tundra subzone
4 Northern limit of the arctic tundra subzone
5 Northern limit of the polar desert zone
6 Limits of the arctic tundra subzone provinces.

PROVINCES OF THE ARCTIC TUNDRA SUBZONE:

AT-I Novaya Zemlya-Vaigach
AT-II Siberia
AT-III Yana-Kolyma
AT-IY The western part of the Canadian Arctic Archipelago
AT-Y Spitsbergen-Greenland
IIII Polar deserts.

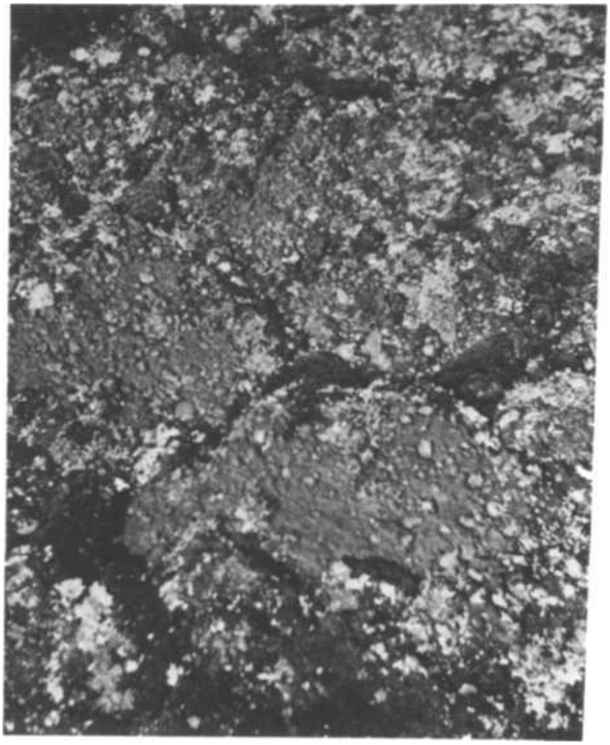

Fig. 3. Polygonal moss-lichen polar desert, Alexandra Island (Franz Josef Land). The place, where the phytomass was measured. Size of polygons 25 x 20 cm. Photo by author.

Fig. 4. Polygonal desert, Alexandra Island (Franz Josef Land) on a site with long snow cover. Patches of crustose lichens (*Ochrolechia* spp., *Pertusaria* spp.) and very small tufts of *Phippsia algida*. Photo by the author.

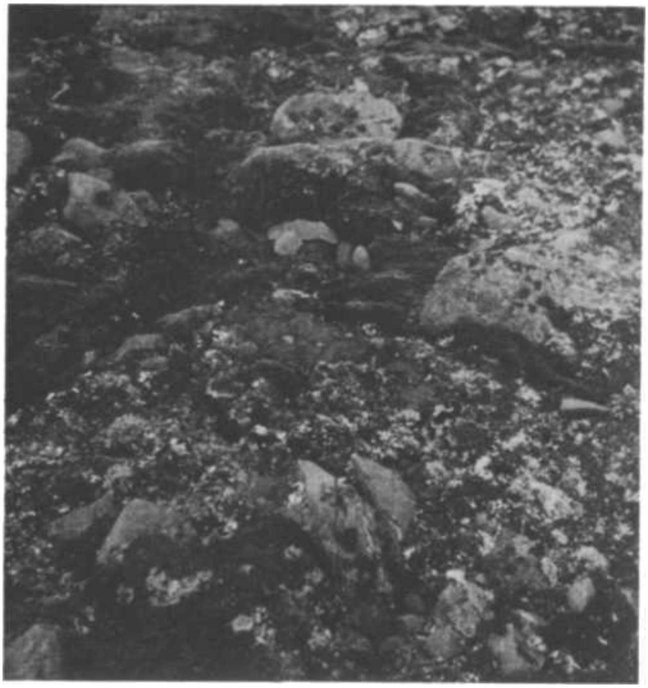

Fig. 5. Fragments of lichen-moss communities on rocky soil. Alexandra Island (Franz Josef Land). Photo by the author.

Fig. 6. Hummocky dwarfshrub (*Salix polaris*)–grass (*Alopecurus alpinus*)—*Luzula confusa*—moss arctic tundra with loamy spots on Greater Liakhov Island (New Siberian Islands) at the place where the phytomass was measured. Photo by the author.

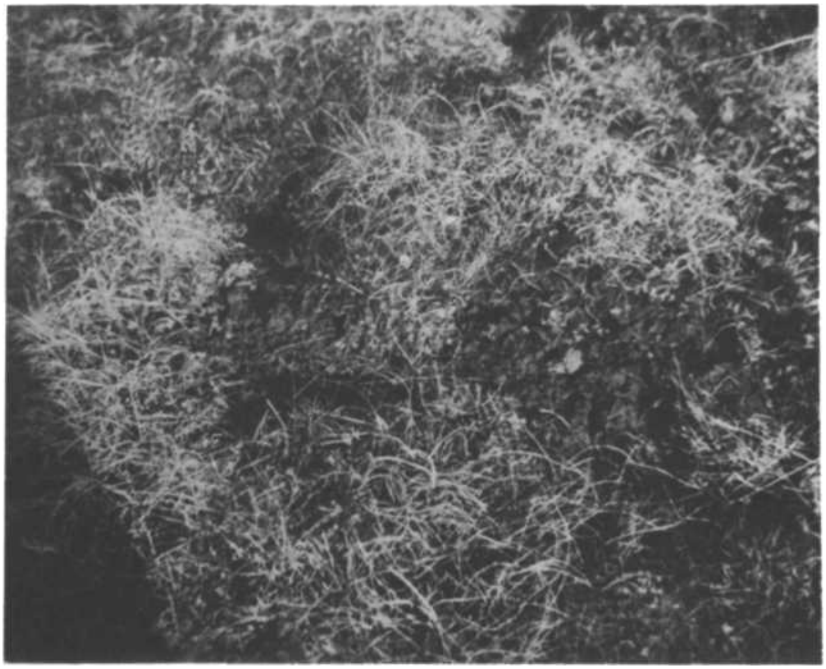

Fig. 7. As figure 6. Detail of vegetation sod at a loamy site. Photo by the author.

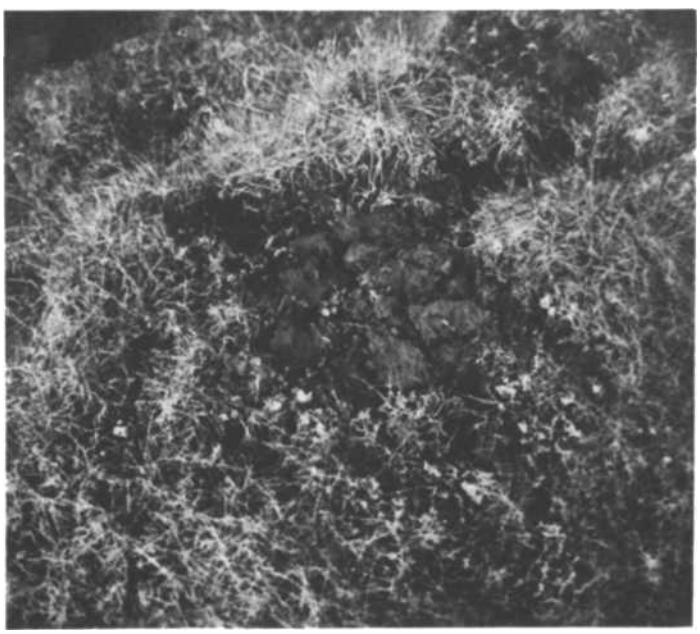

Fig. 8. As figure 6. Photo by the author.

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Paper No. 10

The Arctic Ecosystem Influenced by Fluctuations in Sun-spots and Drift-ice Movements

CHRISTIAN VIBE, Ph.D.[1]

A stable climate is a condition which enables animals to flourish in the Arctic because great fluctuations in either a negative or a positive direction have destructive effects.

For land mammals a number of years with prevailing warm and moist summers gives ample vegetation and a long growing season. The animals thrive and increase in growth, but in certain southern areas they decrease in number due to little foen activity and too much ice-cover on the pastures. Below, such a period is called 'Atlantic'.

A number of years with prevailing cold and dry summers will cause a decrease in growth and number owing to poor vegetation and a short growing season, but in certain southern areas an increase in number owing to favourable winter conditions with increasing foen activity and consequently little ice-cover on land. Below, such a period is called 'Continental'.

In periods with Atlantic climate in Greenland the Atlantic low pressure area is located more northernly than in periods with Continental climate.

In northern Greenland and parts of northern Canada the individual as well as the numerical development of land mammals is most favoured under Atlantic climatic conditions with ample vegetation, long growing seasons and mostly easily accessible food during winter (Fig. 1: 1843-78 and 1912-43. F = white Arctic Fox). Although the winters may have many days with precipitation, ice-cover is rare on land due to frequent foen winds.

In Southwest Greenland conditions are opposite. During Atlantic periods the drift-ice arrives in winter and melts around Southwest Greenland. The winters are unstable, have little foen activity and often there is rain resulting in icing up of almost all coastal regions. Consequently winter conditions for land mammals are bad in Southwest Greenland (Fig. 1: (R), 1843-78 and 1912-43); the caribou population declines.

In Continental periods conditions in northern Greenland and Arctic Canada are also opposite to those in Southwest Greenland, partly due to shorter growing season, and partly due to decreased winter drift-ice from the frozen Arctic Ocean in cold periods. The autumn ice drifts away from parts of Greenland Sea and Baffin Bay without being replaced by new ice from the north—and it stagnates during winter in Denmark Strait (East Greenland Ice) and in Davis Strait (Baffin Bay Ice). Consequently, in certain years the two first mentioned seas have little drift-ice during part of the winter, occasionally resulting in much precipitation and winter rain on the surrounding land areas, North East Greenland and the regions around Baffin Bay, respectively. Simultaneously foen activity decreases. Winter food becomes difficult to obtain, resulting in catastrophic die off in the caribou, musk-ox, fox and hare populations in these northern regions (Fig. 1: (F), 1810? -43, 1878-1912, and after 1943).

In Southwest Greenland, on the contrary, the Continental periods are favourable for the caribou (Fig. 1: (R), 1810-42, 1877-1912, and after 1943). Due to increased foen activity and consequently little ice-cover on the pastures, the animals have favourable winter conditions and increase in number.

The caribou population in West Greenland thus increases in number in the same Continental periods in which caribou, musk-ox, and white fox stagnate in Canada and North-Northeast Greenland.

The annual records of skin production enable us to follow the periods of increase and decrease in the caribou population in West Greenland since 1793. The peaks and troughs of the caribou curve very distinctly show intervals of about 66 years from peak to peak

[1] Zoological Museum, University of Copenhagen.

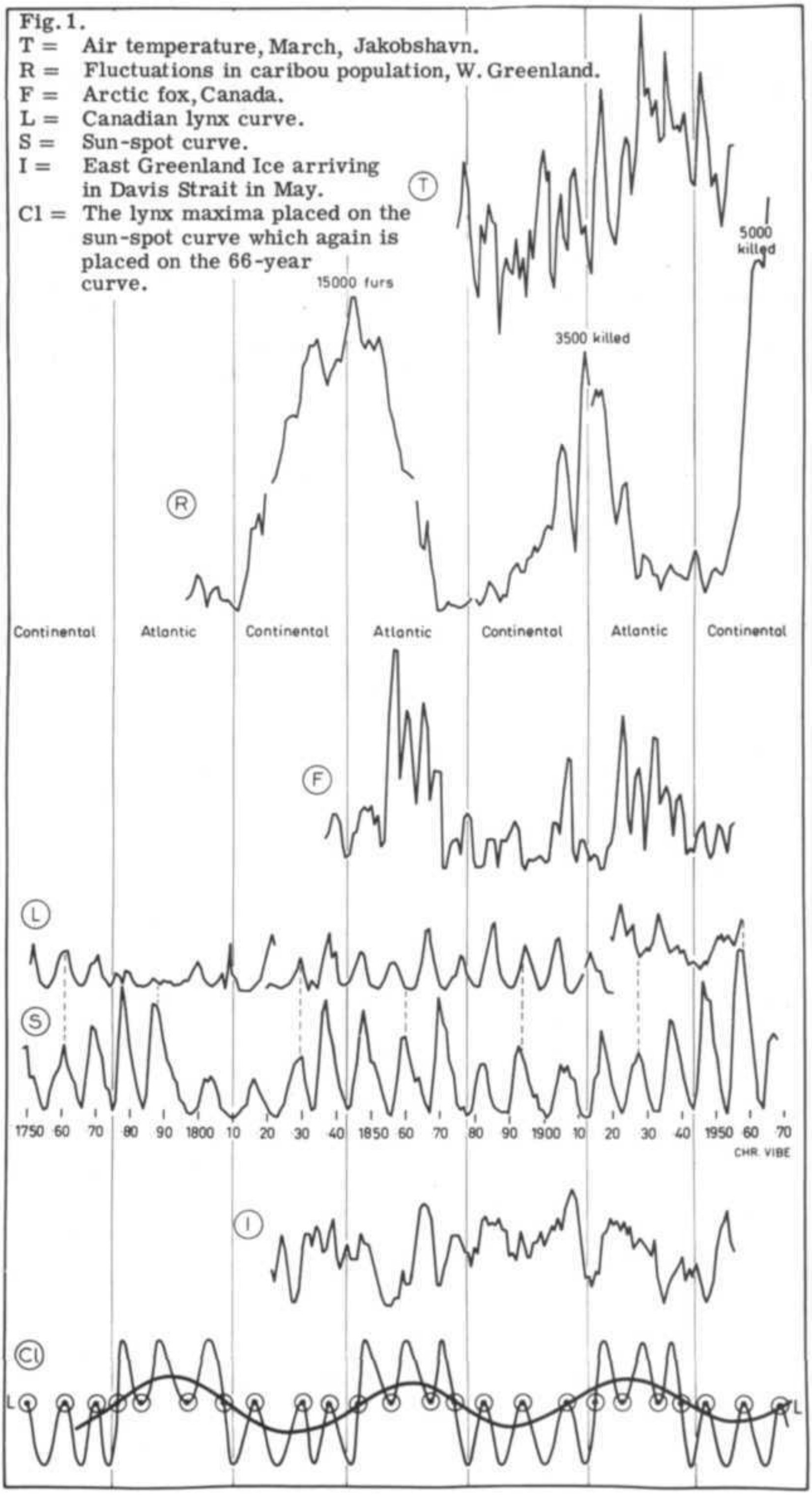

Fig. 1.
T = Air temperature, March, Jakobshavn.
R = Fluctuations in caribou population, W. Greenland.
F = Arctic fox, Canada.
L = Canadian lynx curve.
S = Sun-spot curve.
I = East Greenland Ice arriving in Davis Strait in May.
Cl = The lynx maxima placed on the sun-spot curve which again is placed on the 66-year curve.
T
15000 furs
3500 killed
5000 killed
R
Continental
Atlantic
Continental
Atlantic
Continental
Atlantic
Continental
F
L
S
1750 60 70 80 90 1800 10 20 30 40 1850 60 70 80 90 1900 10 20 30 40 1950 60 70
CHR. VIBE
I
Cl

and from trough to trough. A Continental period with increase in the caribou population in West Greenland and decrease in Northeast Canada and Northeast Greenland has, consequently, a duration of approximately 33 years. It is followed by an Atlantic period of the same duration, during which opposite conditions prevail.

Through isotope measurements of a core taken through the Greenland inland ice by the Americans at Cape Century, the Danish physicist W.Dansgaard and his collaborators found climatic oscillations indicating a 62-70 year curve, averaged for the past 800 years. This no doubt is the same as the biological curve of 66 years which is known only 2½ periods back for the caribou in West Greenland, and 3½ periods for the Canadian lynx. (The lynx curve parallels the sun spot curve in Continental periods and alternates with it in Atlantic periods, see below). It is now worthwhile to have a closer look at the drift-ice. In Atlantic periods (with a northern deplacement of the Atlantic low pressure area) it is often moving in winter, in Continental periods it does so in summer only. As each climatic period has a duration of approximately 33 years, an Atlantic period with mainly winter drift-ice returns at intervals of about 66 years, or 6 sun-spot periods.

If we consider the space of time from the sun-spot minimum in 1744 to the minimum which is supposed to occur around 1975, these 231 years include 3½ climatic periods of 66 years each, divided in 4 Continental periods of 33 years each, and 3 intervening Atlantic periods, each of the same duration.

Assuming that a period begins and ends at a sun-spot minimum we arrive at the following conclusion:

Continental Periods: (with mainly summer drift-ice, i.e. late drift-ice).	*Atlantic Periods:* (with mainly winter drift-ice, i.e. early drift-ice).
1744-1775	
	1775-1810
1810-1842	
	1842-1877
1877-1912	
	1912-1943
1943-1975?	
	ca. 1975-ca. 2008

Besides this alternation between summer and winter drift-ice in the course of 66 years, there seems to be an alternation, too, between ice-pulsation from western and eastern Polar Sea in the course of 11 years.

Figure 2 shows that the drift-ice north of Iceland arrives in two waves (W and E), which are supposed to come from different areas, i.e. W from the western and E from the eastern Polar Sea; the possibility exists also that the W wave corresponds to a late and the E to an early acceleration of the Polar Sea ice.

(The drift of 'Jeanette' and 'Fram' around 1881-84 and 1894-96 respectively demonstrate a strong ice-drift from the East in those periods. In Figure 2 it is seen that 'Jeanette' drifted during decreasing W and 'Fram' during increasing E. When from 1918-20 Amundsen did not succeed in getting into the drift-ice north of eastern Siberia, it presumably was due to decreasing E and increasing W at that time.)

Considering the occurrence of western drift-ice since 1850 in relation to the sun-spot curve, it is seen that W occurs 3 times on the declining branch, or near the bottom of the sun-spot curve, and 3 times on the increasing branch, or near the top, and so on. Consequently the incidence of western drift-ice returns to the bottom (alternatively the top) of the sun-spot curve with intervals of 66 years or 6 sun-spot periods.

In changing from bottom to top of the sun-spot curve in the course of the longer 66 year curve, the western drift-ice appears 7 times (gains one period) during each 66 year climatic period and so does the eastern drift-ice. In the 'gained' period the drift-ice comes from both western and eastern Polar Seas, i.e.: when winter drift-ice (Atlantic climate) shifts to summer drift-ice (Continental climate) and *vice versa.*

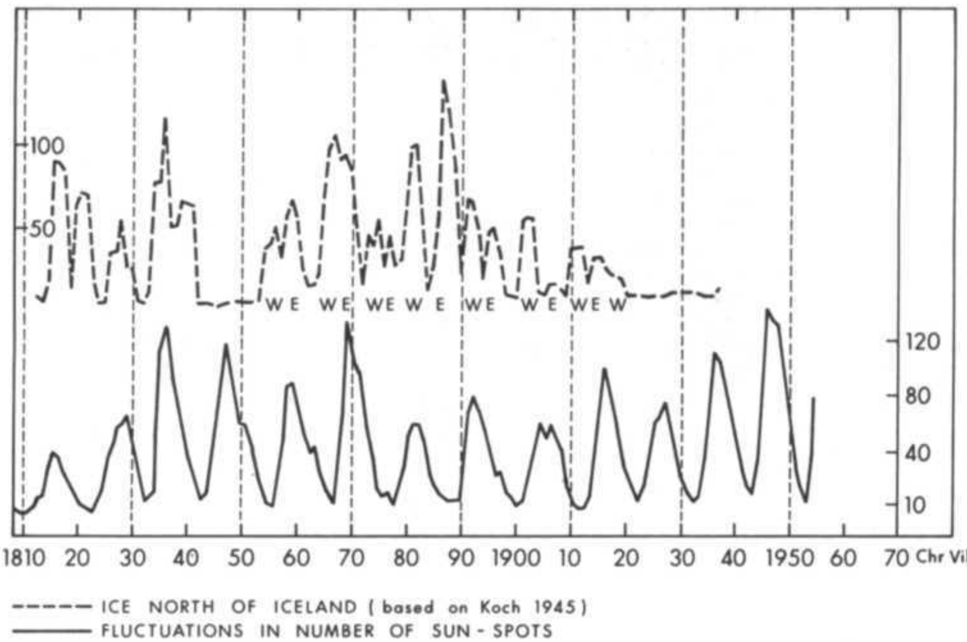

Fig. 2. Ice drift and fluctuations in the number of sun spots.

E. ice from eastern Polar Sea.

W. ice from western Polar Sea.

Thus there are 9. 4 years between the average arrival of western drift-ice as well as between the average arrival of eastern drift-ice—against the 11 year sun-spot curve.

The Canadian lynx has a similar relation to the sun-spot curve as has the western drift-ice. A comparison between the lynx curve and the sun-spot curve through 231 years shows that in Continental periods the peak of the lynx curve parallels the peak of the sun-spot curve, but in Atlantic periods it alternates with it. This is most clearly seen in the middle of each Continental (1760, 1829, 1893, 1958) and each Atlantic (1788, 1860, 1927) period, whereas the beginning and end of each such period show transitional effects.

Similar to the western drift-ice the lynx curve gains one period during each 66 year climatical period in changing from peak to trough of the sun-spot curve. Thus the average length of the lynx curve is 9.4 years against the 11-year sun-spot curve (the 66 year period may sometimes be a little shorter or longer). When we consider the space of time in which the lynx curve is most distinctly delimited, 1842-1919, we find 8 lynx peaks through 77 years equals 9. 6 years in average, (which corresponds with a longer period of 67 years).

The above-mentioned leads us to the conclusion that the course of the Canadian lynx curve is influenced by the state of the drift-ice in the western Polar Sea. And as the pulsation of western drift-ice alternates with the pulsation of eastern drift-ice, it is likely that the Canadian lynx curve alternates with a similar biological curve in Scandinavia. (Number fluctuations in Scandinavian Tetraonids seem to alternate with Canadian lynx.)

In the diagram (Fig. 3) the sun-spot curve is thought to move along the larger 66 year curve. It is then possible to draw a straight line through all lynx-maxima, 14 of which are seen, whereas there are only 12 sun-spot maxima. L indicates each lynx-maxima.

In Continental periods in West Greenland (Fig. 1: T) the March temperature will show a minimum three times in the course of a sun-spot period, whereas in Atlantic periods a

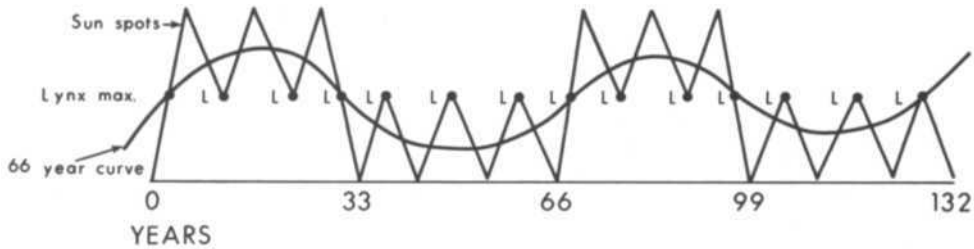

Fig. 3. The Lynx maxima placed on the sun-spot curve which is superimposed on the 66 year climatic oscillation curve (see also Fig. 1).

5-6 year curve is frequently seen in temperature and precipitation, and in the biological curves in Davis Strait (seals, blue foxes, sea birds, caribou, etc.). This may indicate that one of the aforementioned cold ice masses (negative impulses), in the Atlantic periods, does not reach Davis Strait before it melts.

The 3-4 year lemming curve is of the sun-spot curve, more exactly $^{1}/_{17}$ of the 66-year curve, in the same way as the 9-10 year lynx curve is $^{1}/_{7}$ of the 66-year curve.

The climate which affects the lemming curve is influenced by each arrival of drift-ice into the Atlantic, whether it originates from western or eastern Polar Sea, i.e. 12 negative impulses in a 66 year period to which must be added 6 negative impulses at every sun-spot minimum where the ice-drift shifts from western to eastern Polar Sea (at sun-spot minimum the drift-ice stagnates with a negative effect on temperature, at sun-spot maximum it melts with a positive effect on temperature). Another shift in the drift-ice occurs in the middle of the 66-year period when it shifts from winter- to summer-pulsation. Here two drift-ice periods melt together, which gives the lynx curve one extra period, but gives the lemming curve one less.

The lynx curve thus is influenced by 6 + 1 periods of western drift-ice through 66 years (average 9. 4—dependent on the average length of the sun-spot cycles). The lemming curve, however, is influenced by 12-1 periods of western or eastern drift-ice +6 cold periods of drift-ice stagnation =17 negative impulses through 66 years (average 3.9—dependent on the length of each sun-spot cycle). The Canadian lynx curve alternates with a similar biological curve in Scandinavia, and the Canadian lemming curve also alternates with that in Scandinavia.

The alternation of the western and eastern drift-ice in the course of the sun-spot period implies a similar alternation in the strength of the Canadian and Siberian high pressure areas, whereas the Greenland high pressure area seems to be of minor importance in this respect.

It is hoped that the theories outlined here will lead to a better understanding of biological cycles. Much work is still to be done on this important subject, especially in regard to yearly measurements of the thickness of drift-ice off East Greenland, determination of its age, place of origin, and the season when it accelerates and arrives at South Greenland and Iceland.

In a recent paper (1967) on Arctic climatic fluctuations, the author distinguishes between three drift-ice stages: stagnation, pulsation, and melting. It is, however, necessary to take into consideration the season when the drift-ice melts, as well as the geographical region where it melts. It is now evident, that the course of the drift-ice melting period in the 18th century did influence the Arctic ecosystem in a different way than that in the 20th century, owing to the upward trend in the long-acting one thousand (or 1200) year climatic curve.

It Is, therefore, preferrable to distinguish between Continental and Atlantic periods only (as shown in Figure 1). They, too, are relative, but their fluctuations seem to be rhythmic, being determined from the movements of the Atlantic low pressure area in a north-south direction, and vice versa, in the course of a 66-year period.

In the same way as too mild winters have a negative effect on land mammal populations by producing too much precipitation, they may also have a negative effect on the Arctic Sea mammals by destroying the plankton production. This happens in Atlantic periods when the drift-ice has already driven into the Atlantic in winter and melts in early spring in southern waters and during the summer in high Arctic regions. Consequently, the surface water is mixed with melt-water and not with Atlantic deep water. This has a restrictive influence on plankton production and, consequently, Arctic seals and whales have too little food in the season when their young are growing. This situation has been especially serious for the Greenland whale and the harp seal, both of which have demonstrated great fluctuations in numbers during such times.

Going back in time to the 17th century we notice that an Atlantic period began about 1645 when the drift-ice left Iceland. Simultaneously the Greenland whale left the shores of Spitsbergen and moved to the drift-ice off East Greenland probably owing to decreasing plankton production in the Spitsbergen waters.

At the beginning of the next Atlantic period about 1711, the Greenland whale seriously decreased in number in Northeast Greenland, again for the same reason mentioned above. Then the whale hunters headed for Davis Strait.

In Davis Strait the decline occurred with the beginning of the third Atlantic period about 1775. This period had a very negative effect on the populations of seals, whales, sea birds and caribou in almost all West Greenland. The main cause was probably the masses of drift-ice and melt-water simultaneously arriving in Davis Strait with the East Greenland Polar current. The Dutch abandoned whale hunting owing to scarcity of whales, and the Danes abandoned the colony Upernavik owing to scarcity of seals.

During the Continental periods succeeding each Atlantic period, ecological conditions were stabilized. This happened again in the Continental period 1810-1842. But with the beginning of the fourth Atlantic period about 1842 the Greenland whale population decreased more seriously than ever, and so did that of the harp seal everywhere in West Greenland waters where melt-water masses arrived. The eider population decreases as well—and so did the population of caribou in winters with much snow and pastures covered with ice.

The last Atlantic period experienced, began about 1912 and appeared to differ somewhat from the four preceding ones since 1600. We have now reached a higher level on the long-running climatic wave of about one thousand (or 1200) years. The melt-water mixed with Atlantic water *before* it reached Davis Strait. This resulted in the great occurrence of Atlantic cod along the coast of West Greenland in the 1930's and 1940's.

Arctic Canada and Northeast Greenland prospered much from this Atlantic period which produced abundant food for lemming, Arctic fox, Arctic hare, caribou and musk-ox.

The present Continental period began about 1943 and is expected to continue until about 1975. For Canada and Northeast Greenland it means stagnation and decrease in the land mammal populations, especially those of Northeast Greenland. The musk-ox experienced several natural catastrophes in the last decades, but strong legal protection from human persecution has saved it. In West Greenland, on the other hand, the caribou and the hare experienced a considerable increase in number for reasons explained at the beginning of this paper (p. 115). However, the West Greenland caribou population will probably not reach the high peak of last century due to the present higher level of the long-running climatical wave, and for the same reason the decrease in Canada and Northeast Greenland will probably not become severe.

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Paper No. 11

The Role of Small Mammals in Arctic Ecosystems

S. S. SCHWARZ[1]

Professor S. S. Schwarz, due to illness, has been unable to submit his contribution prior to the deadline date for the publication of these proceedings.

This contribution will be published elsewhere and noted as part of these proceedings. Information about its publication can be obtained directly from Professor Schwarz or from the Editors.

Paper No. 12

Arctic Fox in the U.S.S.R.: Biological Premises of Productivity

A. G. BANNIKOV[2]

The arctic fox inhabits the tundra and Arctic Islands of the U.S.S.R., penetrating during winter migrations also to the north onto the ice of the Arctic Ocean and to the south into the region of forest tundra and the northern part of the forest zone. The southern boundary of arctic fox denning is almost the same as the southern boundary of the tundra. The tundra in the U.S.S.R. covers 311 million hectares and within that the area of arctic fox denning is approximately 190 million hectares or 60% (Skrobov 1968).

The southern boundary of the regular migration area stretches down to the northern parts of the forest zone and sometimes goes relatively far into it. Toward the south of this area of regular wintering ground lies a wide zone of irregular 'visits'. In the European part of the U.S.S.R. these incidental occurrences have been recorded down to 56 degrees north latitude; in the Asian part down to 50 degrees north latitude. Winter dispersal of arctic fox from the breeding ground toward the north onto the ocean ice is known up to 78 degrees, 80 degrees, and 88 degrees north latitude (Chapskii 1946, Rutilevskii and Uspenskii 1957).

The phenomenon of lack of geographical variability in this species in the mainland portion of the range shown by V. I. Tsalkin (1944) is determined exclusively by the occurrence of seasonal migration among the arctic fox. Migrations do not exist among populations of arctic foxes inhabiting Bering and Mednii Islands where separate subspecies live. These migrations are also not typical for small populations of mainland arctic foxes living close to human settlements mainly because they are constantly fed by men there. Mass migrations of arctic fox usually occur every second or third year; however, local migration can occur annually.

Migrations of arctic fox start mostly in September but mass movement starts in October-November and usually ends toward March-April, that is, toward the period of heat.

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Sometimes arctic foxes have already begun their return migration in February and in other cases only in May.

In various areas, latitudinal (western or eastern) or longitudinal (southern or northern) migrations predominate. For instance, in the European north to the east of the White Sea, latitudinal migration from the northeast toward the southeast predominate; in Yamal, longitudinal movement along the shores of the Ob River inlet and Karskoye Sea predominate; and in the northern Krasnoyarski *krai* arctic foxes move up the Yenisey River. On the other hand, both to the west and to the east, there are migrations of arctic foxes along the shores of the Laptev and East Siberian Seas, etc. (Chirkova 1967, and others).

In the forest zone arctic foxes have been seen up to 1, 800 km and in some individual instances even up to 2, 000 km (Komsomolsk on the Amur River) in a straight line from the boundaries of their summer range (Belyaev 1959). The most northward point where arctic foxes have been seen lies at 88° north latitude and at a distance of approximately 800 km from the nearest land (Uspenskii 1956).

Depending on the type of habitat and the intensity of the migration the animals move in a wide front or in a narrow strip; in the latter case their tracks form beaten trails.

Lack of food is the cause and trigger of irregular, long, mass migrations of the arctic fox. However, there is no direct connection between periodic, seasonal migration and food abundance. Those arctic foxes in the best physical shape start to migrate first and among them males predominate. The last animals to migrate are those in the worst physical condition.

During deep infiltrations into the forest zone, arctic foxes move with difficulty in deep snow; they starve and quite frequently die. High mortality also occurs among arctic foxes during their long excursions onto ocean ice where they usually stay close to polar bears, feeding on the remains of their prey. Apparently only a very few of such arctic foxes return to the tundra. The great majority of animals, especially during long migrations, die from starvation and disease or are taken by hunters.

But at the same time the drive towards migration is so strong that during its peak arctic foxes travel day and night stopping for only a short time to look for food. On their way the animals also visit human settlements, but even then, bait prepared for travelling animals does not stop them for long, as experience has shown that baiting of arctic foxes can keep them only in the region of their dens up to the beginning of migration or at the very beginning of their nomadic life. Up to two-thirds of the whole population of arctic foxes leave the tundra during the years of migration. Approximately the same number of arctic foxes migrates from the mainland coast southward into the forest tundra, as northward onto the ocean ice. Thus, in winter the total territory occupied by the species increases several times but the density of the population in the tundra decreases three or more times.

During summer the arctic fox lives in open tundra and prefers rolling areas of dry open watersheds, mouths of rivers, streams, higher shores of lakes or seashore for denning. On Wrangel Island and some other places arctic foxes use shelters among the rocks and in rock crevices, etc. (Formozov 1929, Uspenskii 1958). For a den arctic fox usually choose tops of eskers or the upper part of slopes with southern exposures. This habitat is necessitated by the greater depth of the active layer of permafrost and the lower level of ground waters there (Skrobov 1960, and others). As compared with more southern variations of the tundra, arctic tundra is preferred by the arctic fox. Thus, according to V. C. Skrobov (1958) in Bolshezemelska and Malozemelska tundras, for every thousand hectares the number of dens suitable for reproduction was: in the arctic tundra 4.7; in northern (moss) tundras 2. 9; and in southern (shrub) tundras 1. 7 dens. Similar data were obtained by A.A.Romanov (1941) for the tundras of Eastern Siberia. A general pattern of increase in number of arctic fox dens per unit area from south to north has been established for all parts of the arctic fox range. On this basis a classification of productivity of arctic fox habitat has been worked out.

The size of the home ranges of the individual family of arctic fox changes depending on the area and the abundance of food. Thus, in the delta of Lena River it varies from 5 to 30 km^2, in Taimyr (during years of high number) it equals 16 to 25 km^2, in Bolshezemelska and Malozemelska tundras in more suitable places, and in the centers of concentration of arctic fox, it equals 2 km^2 (Skrobov 1958). Toward the end of summer when young arctic foxes leave their dens these family home-ranges no longer exist and the distribution of arctic foxes over the whole range is determined only by distribution of food; during this period migration starts.

The reproductive ability of arctic foxes changes sharply from year to year and depends on food supplies, climatic conditions and the age structures of the population. In one year 70-80% of the females may be pregnant and all breeding dens are occupied, but in other years the vast majority of females may be barren and only 10-15% of these breeding dens are occupied.

The number of young in one litter on the mainland tundras during an abundance of food averages 8 to 12 but occasionally goes as high as 20 and 22 (Chirkova *et al.* 1959, Rakhmanin 1959 and others). During years of a scarcity of food the average number of kits in a litter is 3-5. On islands (Kommandorskii, Kildin, and others) lower fecundity has been observed. The average number of young in one litter during favourable years was 10-13 and when food was scarce 2-3; on the average 4-6 young.

According to A. F. Chirkova *et al.* (1959) during favourable years resorption of embryos at various stages of pregnancy occurs. On the average, in every pregnant female, almost one-third of the embryos do not develop to birth; on the average, out of 10. 2 possible births, only 7.1 were born (analysis of placental scars in the uterus and number of young in the litter in the Karska tundra in 1956).

In the majority of cases the sex ratio in arctic fox is close to 1 to 1, with a small predominance of males (51 to 56%). The number of young in the population changes sharply depending on the breeding success in the previous year, the intensity of trapping and also how selective the trapping is in relation to the young individuals (Table 1).

The arctic fox has only a few natural enemies and these do not have a significant influence on the population number. Among its enemies the snowy owl, which hunts for young arctic foxes during the period of their dispersal from the dens, has greatest significance; sled dogs and herding dogs are also dangerous for arctic fox.

TABLE 1. Abundance and Relative Number of Young Arctic Foxes in Yamal at the Beginning of the Trapping Season During Various Years (According to data of V.S. Smirnov, 1967).

Index	1955	1956	1957	1958	1959	1960	1961	1962
Total Number	42,861	35,893	54,895	34,025	26,094	37,480	41,743	19,026
Percent of Young	72.5	76.4	79	20.4	67.4	79.8	68.2	1.4
Number of Young per Pair of Adults	5.28	6.46	7.51	0.51	5.32	7.88	4.28	0.03

During the period of migration in years of food scarcity epizootics of rabies occur among arctic foxes. This neuro-virus disease (virus Arctic encephalitis; Strogov 1961) has quite a wide distribution in the arctic fox population. During the last 25 years larger epizootics were observed in 1946-1947 in almost all the tundras in the U.S.S.R.: in 1953-1954 in Yukutia, in the Bolshezemelska tundra in 1947-1948, 1949-1950, 1951-1952, 1954-1955, 1955-1956 and 1958-1959 (Kantorovich 1957, 1963, Chirkova *et al.,* 1959), in Yamal in 1957-1958, 11-1962 (Meteleva and Rubanchik, 1959, Syuzyumova 1967), in the Nizhnekolymska tundra from the fall of 1958 until 1960 (Strogov 1961). Epizootics occurred only during the cold months from November until March. The study of epizootics (Kantorovich 1956, 1957, 1963, Syuzyumova 1967, and others) is based on study of the brains of more than 2, 500 arctic foxes. It showed that the virus of rabies always exists in arctic fox populations even when external symptoms and die-off do not occur (0.7 to 6% occurrence of this virus). Consequently, arctic foxes are prolonged carriers of rabies while in other animals (wolves, dogs, ermines, lemmings, voles and others) the virus was not observed during this period. During the epizootic period the virus was recovered from 10-75% of arctic foxes. The virus was recovered twice as frequently from the young animals as from the adults. Analysis of materials from the whole epizootic cycle in Yamal, from 1958 until 1963, allows us to come to the conclusion that high population density and great predominance of young animals are basic factors for the occurrence of extensive explosions of epizootics. Decrease in population density and increase in the relative number of adult individuals serve as important factors helping to terminate epizootics (Syuzyumova 1967).

Note that although Negri bodies were not found in dead animals affected by rabies, the activity of the virus in the frozen brain was shown to exist for 202 days. Not one case of this desease among human beings occurred even after they were bitten by rabid animals (Strogov 1961).

Epizootics of rabies resulted in an especially sharp decline in number within the population. For instance, in Yamal, after an epizootic in 1957-1958 more than 800 dead arctic foxes were found. In this region, during the year before the epizootic (1956-1957) 2, 976 arctic foxes were trapped and during the year of the epizootic (1957-1958) only 1, 945 were caught. During the year of the epizootic only 12 to 13% of the young survived while in other years approximately 60 to 70% survived (Syuzyumova 1967).

Under natural conditions arctic foxes and especially young animals are vulnerable to Leptospirosis (Vyshelesskii 1954). In years of epizootics of Siberian plague in reindeer dying arctic foxes were also observed. Also observed, but not studied, were dermal diseases of arctic foxes, as a result of which, the fur does not develop properly or completely, and forms bald places.

In Arctic foxes in the U.S.S.R. 58 species of parasites have been found including 11 species of Nematodes, 10 species of Cestodes, 7 of Trematodes, and 2 of Acanthocephala (Luzhkov 1963). However, the importance of parasites on the population is almost unknown.

RATE OF PRODUCTIVITY AND PRODUCTION

Before the trapping season the number of arctic foxes in the U.S.S.R. is approximately 130, 000 animals and on the average 83, 000 are trapped annually.

In basic regions of U.S.S.R. tundras (excluding tundras of Kola Peninsula) the number (with young) in the pre-season period, the density of population and the actual productivity are shown in Table 2.

As is visible from table 2 the productivity of arctic fox decreases from east to west because of the decrease in quality of the habitat.

While the average harvest in the whole territory during the last few years was 83, 000 arctic foxes, the actual productivity ranged from 43, 000 to 108, 000 during various years.

Changes in the size of the harvest are caused mainly by the changes in the number of arctic foxes during various years. In a given area the harvest of arctic fox was large once every one to four years, usually every 2 to 3 years. During the last decade there has been some equalization in fluctuation in harvesting and feeding of arctic foxes but, in general, fluctuation in the harvest of arctic foxes is correlated with the population dynamics of species in nature as was noted more than a hundred years ago (Wrangel 1841, Brandt 1956, Middendorf 1869, and others).

On Census plots in various regions of the U.S.S.R. tundra a 10-fold fluctuation in arctic fox numbers was observed. For instance, in northeastern Bolshezemelska tundra during a year of increasing numbers (1955) 39% of the dens were occupied by litters and the total number of arctic foxes within the census plot was nine times greater than in 1934 when only 5% of the dens were occupied (Dementiev 1955).

TABLE 2. Population Density, Standing Crop and Productivity of Tundras of Varying Suitability for Arctic Fox in the USSR (According to the data of V. D. Skrobov, 1969 and others).

Region	Area of Tundra (106ha.)	Habitat Suitability Class								Average No. of General Industrial Quantity Present (Possible harvest)	Average Yearly Production (Actual harvest)
		Habitat of 1st Class Suitability		Habitat of 2nd Class Suitability		Habitat of 3rd Class Suitability		Habitat of 4th Class Suitability			
		%	Population Density Per 1, 000 ha.	%	Population Density Per 1, 000 ha.	%	Population Density Per 1, 000 ha.	%	Population Density Per 1, 000 ha.	(In thousands)	
Nenetski	13.9	31.2	2.7	28	1.8	22	1.1	18.8	0.5	17	9
Yamalo-Nenetski	24.2	23-34	2.7	27-35	1.8	9-25	1.1	11	0.5	30	23
Taymyrski	88.2	13	2.0	33	1.5	26.2	1.0	30.8	0.25	35	18
Yakutia	40	16.5	1.2-2.0	33.7	1.0-1.5	36.5	0.3-0.7	14.3	0.3	29	26
Chukotski	45	–	5.0	–	2.25	–	0.75	–	0.5	11	6

The data from table 2 gives only a general picture of numerical distribution and actual productivity. For each of the areas named in table 2 the picture for a given year is far more complicated when the population dynamics of the species are taken into account.

Thus, in the Nenetski region, according to the data of L. M. Shilyaeva (1969) the number, population density and actual productivity varied from year to year as shown in the pattern on Table 3.

From Table 3 it is evident that during years of low numbers, when productivity of arctic fox decreased by a factor of 4 and more in comparison to years of high numbers, the harvest decreased only by a factor of 2, which can be explained by more intensive exploitation of the productivity during these years.

TABLE 3. Changes in Number, Population Density, and Productivity of Arctic Fox in the Nenetski Okrug from Year to Year. (According to Data of L. M. Shulyaeva, 1969).

Indexes of Number and Productivity	Number of Arctic Fox		
	Mean (1959/60, 1962/63, 1965/66)	High (1958/59, 1961/62, 1964/65)	Low (1960/61, 1963/64)
Number with young during summer (in thousands)	51	107 (up to 186)	29
Population density during summer per 1, 000 ha.	3.22	up to 12.36	2.31
Number in pretrapping season (in thousands)	16	45 (up to 61)	11
Density during trapping season per 1, 000 ha.	1.01	4.33	0.89
Harvest of the arctic fox (per 1, 000 ha.) within the denning territory.	0.52	0. 56	0.20
Within the territory of winter distribution	0.23	0.25	0.11

The number of arctic fox does not change in synchrony in different geographical regions but large increases and decreases occur simultaneously as a rule in all European tundras of the U.S.S.R. and east as far as the Lena River. The population dynamics of arctic foxes east of the Lena River have their own rhythm and only rarely correspond with the rhythm of the western populations (Chirkova 1967). On Komondorskii Islands and along both eastern and western sea coasts, where supplies of food (mainly tidal deposits) are relatively stable, the number of arctic foxes is also more constant.

Because the intensity of reproduction, migration and development of epizootics in arctic foxes depends on the number of lemmings during the preceding fall and winter, surveys of the status of this basic food (lemmings) allowed a prognosis of arctic fox 'harvests' in the U.S.S.R. to be made several months before the beginning of the trapping season (Dubrovskii and Romanov 1935, Guver 1939, Chirkova, 1955 and others). To predict the arctic fox 'crop' in certain regions information about the intensity and direction of migration is more important because in several regions lying on the migration routes high densities of animals may occur due to the influx of migrants even when the local populations are small. Inclusive of progeny the number of arctic foxes in the U.S.S.R. tundras is approximately 400, 000 animals in September of years with average 'crops'. However because of natural mortality of about two-thirds of the juveniles, the number of arctic foxes in the U.S.S.R. at the beginning of the trapping season is approximately 130, 000 animals. The average density per thousand hectares of tundras suitable for arctic fox is 0.7, the allowable harvest 0. 5 and the actual productivity approximately 0.4 arctic fox per thousand hectares.

THE HARVEST

The arctic fox is the basic object of the trapping industry in the U.S.S.R. tundra and in the fur trade of the north it supplies 90-99% of the total furs. Yamal supplies approximately 28% of all pelts of the arctic fox, Yakutia 25%, Taimyr 21%, and the far east 7%.

Approximately 5, 000 trappers are involved in the U.S.S.R. in trapping the arctic fox. On the average one trapper catches approximately 40 arctic foxes: however, some trappers, during one season, take up to 200 to 250 arctic foxes. On the average there are 40, 000 hectares of arctic fox habitat per trapper, however, the size of the exploited area varies sharply according to the region. For instance, in Yamal, there are 20, 000 hectares per trapper and in Taimyr 53, 000 hectares (Skrobov 1958).

The laws of the U.S.S.R. prohibit destruction of dens of arctic foxes. The trapping seasons are established, according to the region, from the middle of November (or the beginning of December) until the beginning (or the end) of March.

The basic method of trapping arctic foxes in the U.S.S.R. is by wooden or metal traps. The wooden traps, in the form of a narrow corridor, with bait, are placed along sea coasts, river banks and other places frequented by arctic foxes. This type of trap is especially widely used in Taimyr and Yakutia. Recently portable traps have found wide use.

Increasing interest is paid to metal traps because of their portability and greater effectiveness. According to the data of V.D. Skrobov (1968) metal traps are 5 times more effective than wooden traps. The trappers set the traps near artificial mounds placed in a circle, which helps to save time and increases the area of exploited territory.

During years of high numbers of arctic fox, collective hunts or 'tolars' are organized, in which several trappers on reindeer sleds drive around a given territory in a spiral. The arctic foxes are afraid to cross the sled tracks and gather in the center of the area where they are shot or caught with large nets.

In Yamal, Taimyr and Yakutia good results were obtained by experimental capture of live arctic foxes during a period of their migration and keeping them in cages until their fur primed.

Presently, in U.S.S.R. tundras feeding of arctic foxes, which began more than thirty years ago, is carried out on a large scale. During low density of lemmings, feeding keeps arctic foxes in one place and the animals become accustomed to traps. Feeding should begin in the summer, when the young are still in the dens, or in the early fall but it may also be done in winter in places where arctic foxes gather before the beginning of the breeding season.

In past years in U.S.S.R. tundras more than a thousand tons of low quality fish, remains of slaughtered reindeer and marine animals were fed to arctic foxes. In Taimyr alone about 600 permanent feeding stations exist. Approximately 30 arctic foxes attend one feeding station. One trapper feeds 2 to 5 tons of food annually to arctic foxes.

This artificial feeding of arctic foxes, as shown by observations in several regions, not only facilitates trapping but also increases productivity of the habitat. Where feeding is applied the percentage of surviving young increases and a large number of animals stay in one area and do not take part in the migration. As a result the decline in number is not as severe during years of unfavourable food and weather conditions.

The development and perfection of the feeding method is a very promising way of increasing the productivity of the tundra.

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Paper No. 13

Situation Report on Canadian Arctic Fox Research

A.H. MACPHERSON[1]

You may have seen my report (Macpherson 1969) on arctic fox populations. Dr. Fuller has invited me to discuss our knowledge of the subject. Perhaps the best thing I can do now is to discuss the tentative conclusions I have reached and to indicate their relevance to the trapping industry and to environmental science in the Canadian arctic tundra.

There are probably considerably fewer trappers of arctic foxes in Canada now than there were when I began my work ten years ago. Nonetheless, to those now active, the maintenance of sizeable arctic fox populations is as important as ever. In fact, in very recent years, prices have strengthened and the value of the resource is still considerable. Arctic fox trapping combined with subsistence hunting and supplemented by seasonal or part-time employment is still a common way of life at many of our arctic settlements.

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The impressive series of investigations that Professor Bannikov describes (these Proceedings), undertaken by Soviet scientists since the 1920's, were directed to a great extent towards the improvement of the industry, and in particular towards the setting of rational quotas for trapping organizations. I submit that we in Canada have no less need of scientific data to help our trappers toward improving their knowledge of the resource and its exploitation, to assist game managers in regulating its exploitation and maintenance, and to develop in the general body of resource managers a comprehension of the place of this small and valuable predator in arctic ecosystems, wherever they occur around the world.

Arctic foxes may become parents at the age of one year, and litters are large, averaging 10 or 11 in central Keewatin and Franklin districts. They thus have an enormous potential for increase, but a potential which they realize only in summers when food supplies are abundant. In most of the Canadian Arctic, the one or two species of lemmings constitute collectively the only food source which is capable of nourishing a large cohort to maturity. In regions of greater biotic diversity predators are less tied to a single resource for successful raising of young. Thus red foxes in temperate North America have been shown to turn to lower vertebrates and many other alternative foods when small rodents were scarce. On the other hand, related predators in more temperate regions appear in general to have smaller litters. The large litters of arctic foxes I think we can relate to another factor, that of winter trimming of potential breeding populations. My view is that on Canadian breeding areas there is little interaction between breeding pairs, but reproductive success hinges critically on the survival of young, which is at the mercy every year of the factors which limit lemming populations. Thus a standing population at any one time contains a very uneven distribution of age groups. Two or three years of poor breeding success thus result in very low arctic fox populations. Given sufficient data for use by agencies, management ideally would seek to preserve low populations into their next breeding seasons, and to assist in intensive exploitation of high early winter populations which inevitably become greatly trimmed before the next spring. We believe, and hope to show within the next year, that our Keewatin caribou population (for one) also exhibits great size disparity between its component cohorts, and the same may well be a feature of several other arctic bird and mammal populations as well.

Other conclusions of the work are more tentative. I have recently discussed with Soviet biologists their belief that arctic foxes show great variations from year to year in the proportion breeding. Our data do not contain evidence of such large variations in Canada, but this would be an obvious subject for further study. Another consideration is the degree to which interaction affects winter trapping success. There is evidence in the age composition of trapping harvests that pronounced shifts occur in trap-proneness not only with age but with the relative strengths of age classes. Specifically, absolutely more adult foxes are usually taken in the year after a production peak than were caught in the year of the peak in young.

Commercial arctic fox trapping is far from an ancient activity in arctic Canada. The early fur traders were after beaver and other boreal furs, and the arctic trade dates generally speaking only from about the First World War. Consequently we have short runs of data on arctic fox harvests, unlike the data for Greenland upon which Dr. Vibe has spoken (these Proceedings). General declines in catches of arctic foxes have occurred at certain inland posts. The reasons are far from clear. It seems possible that overall declines in the Keewatin catches could be explained on the basis of a growing scarcity of carrion inland through its effect on the number of foxes carried over in winter. It is well known that the once more numerous and more dispersed trappers tended to kill and leave uncached a large number of caribou, a practice which has been discouraged since the 1940's and 1950's, because of the critical state of the herds. To judge from the frequency of seal hair in arctic fox gut contents from Resolute Bay, the polar bear remains an important provider of food to arctic foxes in winter, in at least one area where this large predator and its prey are abundant. It would thus be helpful to game managers to know more about the role of large carnivores (including Man) in the winter nutrition of arctic foxes.

If lemming abundance does affect arctic fox breeding success, one might expect that hunting range might vary inversely with lemming abundance. The elucidation of the variability in this factor would also be useful in evaluating the degree of interaction among breeding pairs, the degree to which breeding foxes fill their habitat, and the impact that they have on the herbivore trophic level. Studies of breeding territory, by means of telemetry, have been begun by Mr. Wayne Speller at the University of Saskatchewan.

A further subject upon which data are lacking is the degree to which our arctic foxes disperse. Movements of the arctic fox in the USSR are extensive and regular enough to be termed migrations. There exists very little direct evidence of this phenomenon in Canada, though our trappers commonly ascribe seasonal and annual changes in arctic fox abundance to individual and group movement.

I have by no means provided a complete list of researches which I believe might be useful to trappers and game managers. One subject of considerable interest is the effect of red foxes on arctic fox abundance. The red fox has been expanding its range in northern Canada for at least the last 35 years, and in some places, such as Baffin Island, for as long as we might expect to have records. To date, no study of the extent to which it cuts into the arctic fox niche have been undertaken. Does it compete for food? Presumably, but do the trophic niches overlap at critical moments, with consequent displacement of one by the other, or at times of the year when a particular food supply is in over-abundance? Do red foxes oust arctic foxes from their traditional breeding dens to a significant extent, or not? Do dens and denning areas effectively limit the numbers of arctic foxes available to trappers, to the degree that special regulations should be made for their protection? Another question is in the acceptability of present harvesting techniques and possible more humane alternatives.

I hope that I have left you with the impression that I wish to convey, namely that the study of arctic fox populations has been begun in our country, that present conclusions are interesting and useful, though still tentative, and that we would benefit through better knowledge of many aspects of the population ecology of this widely-distributed and valuable resource. Neither the researches necessary to yield management information, nor those which might be undertaken simply to reveal more of the ecology of a species which is famous for its exaggerated population cycling, can be profitably pursued on a short-term basis. Perhaps the necessary studies could best be mounted under the aegis of a long-term integrated productivity project.

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Paper No. 14

Human Trichinosis in the Soviet Arctic and the Characteristics of the Strain of Arctic Trichinella

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The first outbreak of trichinosis in the Soviet Arctic was noted in 1956 (Ozeretskovskaya and Uspenskii 1957). On Bennet Island three of six members of an expedition who had eaten meat from a polar bear fell ill. In spite of the long incubation period (35-43 days) the course of the disease was severe. During the following 12 years seven outbreaks were recorded in the Soviet Arctic with a total of 104 persons infected. The infection was due to eating meat of the polar bear (*Thalarctos maritimus*) and brown bear (*Ursus arctos*) (Ozeretskovskaya, Romanova and Bronshtein 1969).

Clinically, trichinosis in the Arctic is characterized by a long incubation period (30. 5 ± 5. 9 to 36 ± 1.4 days), relatively less expressed muscular and abdominal syndromes in the acute phase of the invasion, and severe infection of the organs. The disease continues two to three months or even longer accompanied by psychoneurological disorders, hepatocerebral syndrome and general dystrophy. One of the 104 cases was fatal. During convalesence protracted muscular syndrome is observed. The invasion intensity fluctuates between 40 and 830 larvae per gram of muscular tissue. After five to fifteen weeks of the disease, instead of complete encapsulation of the trichinellae in the muscle, a mass dying of the larvae in the muscles and a diffuse angimyositis of an allergic character is observed (Figure 1).

Attention is drawn to the fact that all recorded outbreaks of trichinosis originated among non-resident people, members of various expeditions, geological survey teams, seasonal workers, and so on. In addition, among native inhabitants of the arctic, although there is a significant percentage of positive immunological response to trichinosis (Bessonov,

Fig. 1-A. A very severe course of trichinosis. Infection from meat of brown bear in Komi, USSR, 1959. Biopsy of calf muscle 92nd day of invasion. Diffuse myositosis, mass dying of trichinella larvae. (76x).

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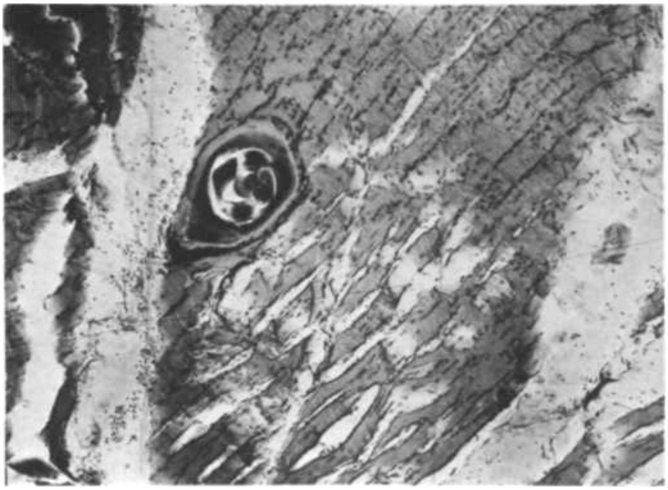

Fig. 1 -B. Trichinosis of moderate course. Infection by synanthropic strain. Biopsy more than four months after invasion. (73x).

Wolfson and Kommissarova 1969), no outbreaks of trichinosis are known. A similar situation can be observed in Alaska and Northwestern parts of Canada, Southampton Island, and Igloolik (Brown, Cronk and Sinner 1949; Brown, Green and Boag 1950; Poole 1953; Hitchcock 1950; 1951; Maynard and Pauls 1962; Rausch, Babero, Rausch and Schiller 1956; and others).

An arctic strain of trichinosis acquired in 1967 from two polar bears killed in Franz Josef Land was subjected to nine passages in white mice during two years along with another strain of trichinosis which was acquired in 1966 in a synanthropic focus of trichinosis in north Caucasus (Belorechenskii strain) and with a laboratory strain (strain of the Martsinovskii Institute). The latter was acquired from a female domestic pig in the central European part of the U.S.S.R. and was subjected to four passages in rats and eleven passages in mice during four years. The standard intensity of invasion of the latter was 12, 000-14, 000 larvae per gram of muscular tissue, the original infection being 70-80 larvae. The invasion intensity was determined by means of dissolving the diaphragm of the animals by an artificial gastric juice.

As seen in Figure 2, when compared with the laboratory one, the arctic strain possess a distinctly lower invasivity.

The second criterion was a study of the susceptibility of the arctic strain to chemotherapy by an active trichinocide preparation, thiabendasole. Table 1 shows that when applied in doses of 100 mg/kg two to four days after invasion this preparation exerted the same effect upon animals infected by any one of the three strains. However, the invasivity of larvae remaining in the muscles was, in the next passage, equal to zero in the arctic strain, 48% in Belorechenskii strain and 68% in the control (Table 2). The invasiveness of the Belorechenskii strain is not constant but there is a tendency to a sharp reduction.

Thus the arctic strain of trichinosis proved to be more susceptible to thiabendasole than the Belorechenskii and laboratory strains.

When thiabendasole was applied 7 to 13 days after invasion the effect of the treatment was 2. 5 times greater in animals infected with the arctic strain than in controls and 1. 5 times greater than in mice infected by the synanthropic strain of trichinosis. This might be a joint effect of the trichinocide effect of the preparation and process of spontaneous mass dying of the trichinella larvae in the arctic strain. An increased trichinocide effect is apparently caused by the long stay of subadult trichinella of the arctic strain in the intestine (Pereverzeva 1969).

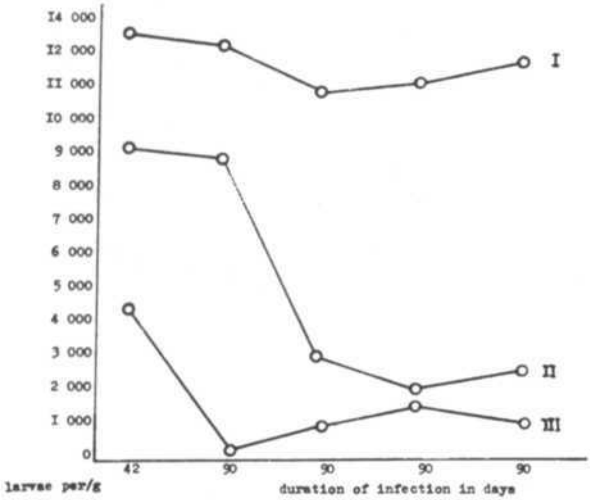

Fig. 2. Invasiveness (larvae/gram) of trichinella larvae of Martsinovskii, (I.), Belorechenskii (II), and arctic (ID) strain, passed through white mice.

TABLE 1. The decreasing (%) of Trichinella larvae density in mice invaded by arctic, Belorechenskii and Martsinovskii strains after treating by thiabendasole in dose 100 mg/kg.

	Strains		
Days of Treatment	Arctic	Belorechenskii	Martsinovskii
2-4	83.7	74.5	82.5
7-13	56.0	34.3	22.7

TABLE 2. The inhibition of invasiveness (%) of Trichinella larvae of arctic, Belorechenskii and Martsinovskii strains from mice treated by thiabendasole in dose 100 mg/kg.

	Strains		
Days of Treatment	Arctic	Belorechenskii	Martsinovskii
2-4	100	52	32
7-13	18	81	61

It is known that thiabendasole exerts especially great effect on the sub-adult trichinella in the intestine (Campbell and Cuckler 1964, 1966). The higher susceptibility of the Arctic trichinosis strain to the chemotherapeutic effect of thiabendasole substantiates the physiological difference of the strain.

The third criterion was a study of the protein composition of the trichinella larvae by method of differential discelectrophoresis on polyacrylamidegel (Davis 1964) and protein changes in animals infected by the arctic strain. For this purpose total proteins and protein fractions of blood serum were determined by the paper electrophoresis method and discelectrophoresis with amido-black stain.

For determining protein composition of live trichinella larvae, they were placed after several washings in a buffer solution with pH 6. 7. Extraction of the proteins was done by triple freezing and thawing. The sediment was separated in a refrigerator centrifuge set at 2, 000 to 3, 000 rpm at a temperature of 4°C for 15 to 20 minutes.

From discproteinograms of larval extracts of all three strains which were isolated ninety days after invasion, 76 fractions were determined (Figure 3). According to Yermolin (1967) it is possible to refer to these fractions to four major groups:

Group A—fraction of pre-albumins and albumins.

Group B—composed of four fractions-zone of $alpha_1$ globulins.

Group C—composed of three fractions in the zone of mobility of $alpha_2$ globulins.

Group D—composed of six fractions referring to the zone of $alpha_2$ globulins and gamma globulins.

Discproteinograms of the larval extracts, although having equal number of fractions, differ in the color intensity of various fractions, which is best expressed in the zones of groups B and C. In the discproteinogram of larval extract of trichinella of the laboratory strain fraction 1 of Group B and the complex fractions of Group C are especially clearly expressed. The Belorechenskii strain is characterized by clear differentiation of fraction 1 of Group B and fraction 2 of Group C. A characteristic feature of protein composition of larval extract of the arctic strain appears to be a distinct separation of the three fractions of Group C. Regardless of the less intensive coloring when compared with analogous fractions of the laboratory strain, distinct differences are obvious.

It was found when studying by similar methods the protein composition of extracts of *Fasciola hepatica* and *Fasciola gigantica* (Klimenko 1966) that the number of fractions is the same in both species. The difference consists in the intensity of color in various fractions. By analogy this may be used as a criterion for assigning strain differences in protein composition to the trichinella larvae.

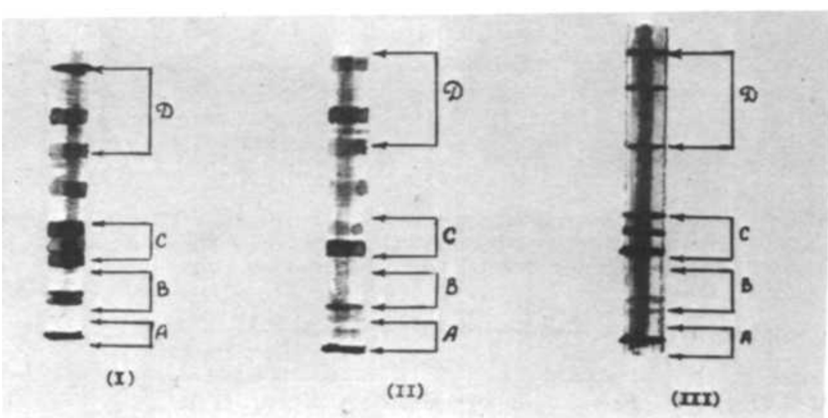

Fig. 3. Discphoregram and distribution diagram of protein spectrum of saline extract of Trichinella larvae from mice infected by Martsinovskii (I), Belorechenskii (II) and arctic (III) strain of trichinella.

The differences in the protein spectrum of trichinella larval extracts are in correlation with the different ability to cause protein shifts in the organisms of infected animals. When the total protein content of blood serum of mice infected with laboratory, Belorechenskii and arctic strains of trichinosis was compared 35, 70, and 90 days after invasion, the lowest level of proteinemia on the 35th day was found in animals invaded by the laboratory strain (Table 3, $p<0.01$). Later, the level of proteinemia in all three groups of animals is lowered, but, only in mice infected with the laboratory strain is a significant lowering of total protein content observed in comparison with healthy control animals (Table 3, $p<0.01$).

When studying protein fractions of the blood serum by paper electrophoresis, an increase of albumen fractions was observed on the 35th day after invasion in all three groups of animals (Table 3, $p<0.01$). Obviously, the latter is connected with the phenomenon that a part of the alpha globulin fraction having the greatest electrophoretic mobility (probably $alpha_1$ globulins) migrates together with albumins, which was confirmed (see below) by a study of blood serum proteins by discelectrophoresis in gel. The longer the time after invasion, the greater the lowering of albumin content, which is most clearly expressed in the group of mice infected with the laboratory strain (Table 3).

Content of alpha fractions 35 days after infection increases substantially only in the group infected by the Belorechenskii strain of trichinosis (Table 3, $p<0.01$). Content of the alpha fraction in animals infected by the arctic strain stays low during the whole observation period ($p<0.01$).

The beta globulin fraction 35 days after infection was substantially lower in all three groups of animals (Table 3-I, $p<0.02$, II, $p<0.05$, III, $p<0.02$). With increasing time after invasion a gradual increase of beta globulin content is observed, especially in the group infected by the laboratory strain of trichinosis (Table 3).

During the course of the infection a very clear shift was observed in the level of the gamma globulin fraction, but significant gamma globulinemia was observed only in the groups of mice infected with the laboratory and the Belorechenskii strains of trichinosis (Table 3, $p<0.01$ between 35 and 90 days). In animals infected by the arctic strain only a tendency to a higher level of gamma globulins was observed.

It is known that disproteinosis at early stages of trichinosis is mainly characterized by sharp changes in permeability of vascular walls for little dispersed proteins (Aikawa, Harrel and Miller 1951) and in later stages by disturbance of the protein creating function of the liver owing to its diffuse infection (Ozeretskovskaya 1960, 1967). Together with this sharp hypoproteinemia and high gamma globulinemia in animals infected by the laboratory strain must be considered the higher immunogenetic activity of this strain compared with the arctic one, which is apparently caused mainly by higher intensity of invasion.

TABLE 3. Total proteins and prote in fractions in blood serum of mice infected by Laboratory (I), Belorechenskii (II), and Arctic (III) strain of trichinosis.

Groups of Mice	Number of Days After Invasion	Total Proteins (g%)	Protein Fractions (%)			
			Albumins	Globulins		
				gamma	beta	alpha
I	35	5, 8±0, 1	52, 7±2, 4	14, 1±1, 14	20, 9±1, 61	12, 3±1, 53
	90	4, 7±0, 14	35, 3±1, 95	15, 7±2, 48	29, 6±1, 73	19, 4±1, 81
II	35	8, 2±0, 13	50, 0±3, 39	22, 7±1, 64	16, 0±0, 84	11, 3±0, 34
	90	7, 8±0, 26	44, 8±1, 34	11, 3±0, 45	25, 7±1, 12	18, 2±0, 3
III	35	8, 2±0, 3	52, 9±1, 51	14, 7±1, 73	21, 2±1, 18	11, 2±1,76
	90	7, 5±0, 38	47, 4±0, 97	11, 6±0, 51	24, 5±1, 78	16, 5±1, 29
Control		7, 9±1, 1	44, 8±2, 12	16, 4±1, 31	26, 2±1, 58	12, 6±2, 69

However, in spite of the lesser invasive ability of Belorechenskii strain larvae a significant increase of alpha globulin was observed in animals infected by this strain 35 days after invasion. It is known that the level of the latter fraction corresponds with the intensity of inflamatory-necrotic processes in organisms (Wuhrman and Wunderby 1957; Tareev, Ado, Polyantseva and Sura 1963; Tareev 1964; Alekseeva 1966). These data are in agreement with the extraordinary intensity of those processes observed during the outbreak of trichinosis caused by the North Caucasus strain and the Belorechenskii one (Ozeretskovskaya 1967; 1968; Ozeretskovskaya, Tumolskaya, Vikhert, Zalnova, Yermolin and Bronshtein 1969). The time of increase of alpha globulin levels in our experiments is in accordance with the time of maximal accumulation of 'anti-imaginal' antibodies (Oliver 1941; Oliver and Levine 1962) by trichinosis.

Thus differences of protein spectrums of animals infected by the arctic, laboratory and Belorechenskii strains were established. Those differences are obviously determined not only by the lesser ability to invade of the arctic strain of trichinosis but by a definite specificity of protein structure as well. The significant increase of the beta globulin fraction in the second and third month of invasion after infection by the laboratory strain is due to the rise of titres of specific immune precipitins (Biquet, Fran Van Ky, Moschetto and Gnamey-Koffy 1965; Bessonov and Domb 1966).

The differences in protein composition of blood serum of mice infected by the strains studied were more explicit when the method of differential disceloctrophoresis in polyacrylamide gel was employed. In the blood serum protein spectrum of healthy mice 17 fractions appeared: 2 prealbumin fractions, 4 alpha$_1$ globulin fractions, 2 beta globulin fractions, 7 alpha$_2$ globulin fractions, a lipoprotein fraction, and 1 gamma globlin fraction.

Thirty-five days after infection 17 fractions were formed in blood serum of mice of all three groups. However, in the alpha globulin zone, instead of 4 belts, 5 to 6 intensively colored fractions were found immediately beside the albumin zone. This supports our assumption that the increase in specific gravity of albumins on the paper proteinogram in this period is due to the joint migration of albumins and alpha$_1$ globulins. Those changes are especially sharply expressed on the discproteinogram of mice infected by the arctic and Belorechenskii strains of trichinosis.

On the 90th day after infection 18 fractions are differentiated in the blood serum protein spectrum of mice: 1 fraction of prealbumins, 7 fractions of albumins, 6 alpha$_1$ globulin fractions, 2 beta globulin fractions, 7 alpha$_2$ globulin fractions and 1 gamma globulin fraction (Figure 4). A peculiarity of the discproteinogram in this period is the origin of an additional fraction in the zone of the alpha$_2$ globulins which is placed near the gamma globulin zone. It is very probable that in paper electrophoresis of blood serum proteins this fraction migrates together with the gamma globulin fraction and causes a sharp increase in specific gravity of the latter.

Thus, study of discproteinograms of mice infected by synanthropic and natural arctic strains of trichinosis verifies the different biochemical specificity of the arctic strain. The data obtained show more exactly the genesis of hyperalbuminemia in the early stage of disease and high gammaglobulinemia in the later phase.

Biochemical and physiological specificity of the arctic strain of trichinosis and peculiarities of the clinical course of human trichinosis in the arctic is determined by the ecological isolation of arctic biocenoses which include *Trichinella spiralis* and its host cycle. The latter are substantially different from the host cycles in zones of moderate climate.

The basic members of this biocenosis that serve as a source of trichinosis infection of both polar bear and man, are marine mammals (Rausch, Babero, Rausch and Schiller 1956; Ozeretskovskaya and Uspenskii 1957; Lukashenko and Brzheskii 1963).

In the cycle of trichinosis infection some polar birds of prey apparently might be included (Merkushev 1960; Britov 1962) and fish and lower invertebrates—*Gammarus lacustris, Gammarus marinus* (Britov 1962). Man became part of this cycle entirely by chance and the biocenoses connected with his activities cannot play any substantial role in the cycle of trichinosis in arctic latitudes.

It may be assumed that the low invasiveness of the arctic strain of trichinosis, its ability to provoke disease only after a long incubation period and its lower rate of disporteinosis in infected animals is determined by antigen specificity which differs in the arctic strain

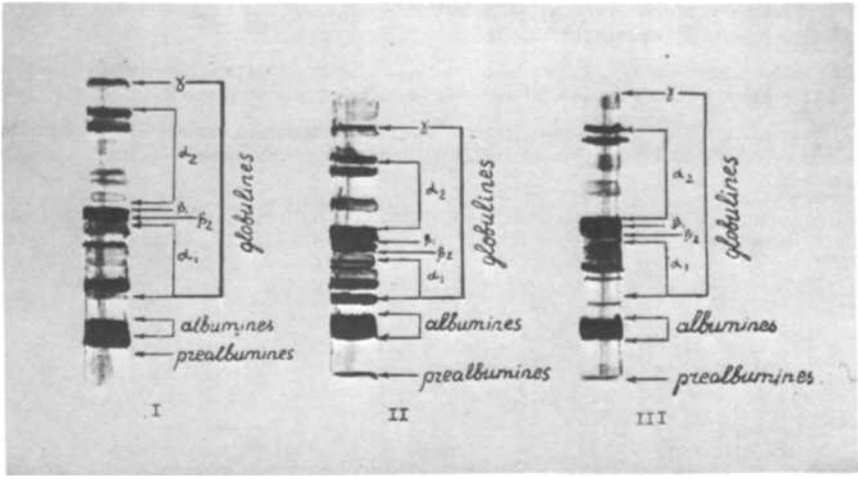

Fig. 4. Discphoregram and serum protein distribution diagram of mice infected by Martsinovskii (I), Belorechenskii (II) and arctic (III) strain of trichinosis.

of trichinosis from the specificity of the synanthropic ones and its hosts. Long incubation periods together with the long duration of the disease, long presence of intestinal trichinella and the poorly expressed globulin shifts in the blood serum of infected animals are evidence of the low immunogenetic activity of the arctic strain of trichinosis, which is a characteristic feature of trichinosis from synanthropic focuses (Ozeretskovskaya 1967; 1968).

Study of reasons for the low prevalence of overt trichinellosis among native inhabitants of the arctic in western and eastern hemispheres in spite of the great risk of infection and rather high percentage of infection by trichinosis detected by immunological investigations (see above) has great interest from this point of view. It suggests that an answer is to be found in the principle differences in immunological situations which arise in the arctic between the trichinosis pathogen and the aboriginal or emigrant host. Naturally the idea arises that trichinosis (and other arctic helminths) could, in the process of evolution, have exerted an influence on the antigenic structure of the arctic human populations just as epidemic outbreaks of small pox and cholera have shaped the antigenic character of inhabitants of lands in Europe and Asia (Efraimson 1961; Vogel and Strobel 1960; Livingstone 1961). Undoubtedly, without necessary prophylactic measures, helminthoses, and particularly trichinosis, could substantially influence the process of accommodation of man to life in arctic conditions.

CONCLUSIONS

1. A lower invasiveness of the arctic strain of trichinosis into white mice in comparison with the laboratory strain (of the Martsinovskii Institute) and with the synanthropic, North Caucasian, strain has been found. This characteristic was retained for nine passages during more than two years.

2. In an extract of trichinella larvae of the strains studied differential disceltrophoresis showed a uniform number (16) of protein fractions but differences appeared in the degree of differentiation and intensity of coloration of separate fractions. Characteristic of the arctic strain was a distinct separation of the 3 fractions of group C, the alpha$_1$ globulin zone.

3. The arctic strain of trichinosis is characterized by a lesser ability to cause hypoproteinemia in white mice in the early stage of the disease and hypergammaglobulinemia in the later phases.

4. Biological characters of the arctic strain of trichinosis are expressed in its great susceptibility to chemotherapy by thiabendasole.

5. When people who are not native inhabitants of the arctic were infected by the arctic strain of trichinosis the disease was serious in spite of a long incubation period.

6. Physiological, biochemical and clinical characterics of the arctic strain of trichinosis are caused by ecological isolation of arctic biocenoses which include *Trichinella spiralis* and its hosts.

7. In the absence of proper prophylactic measures trichinosis (and other arctic helminthoses) could be a factor hindering adaption of man to life in arctic conditions.

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Paper No. 15

Polar Bear Research in Alaska

JACK W. LENTFER[1] and JAMES W. BROOKS[2]

INTRODUCTION

The First International Scientific Meeting on the Polar Bear, held at Fairbanks, Alaska, in September 1965, brought together delegates from the United States, Canada, Denmark, Norway, and Russia, all countries which have shared in the harvest of polar bears and which retain a high and active interest in their conservation. This meeting did much to identify the types of information that would be required to develop proper conservation programs, and it inspired a Statement of Accord that included the following points, listed here in abbreviated form:

1. That the polar bear should be considered an international circumpolar resource;
2. That each nation should take steps to adequately conserve the polar bear;
3. That cubs and females accompanied by cubs require year around protection;
4. That each nation should conduct, as it sees fit, a research program to provide a basis for effective management;
5. That all nations freely exchange information. It was suggested that the International Union for the Conservation of Nature be the coordinating agency or clearing house for such information;
6. That future meetings devoted to polar bear be held.

Resulting from this meeting was an increase in bear research efforts by several nations and indications that their regulatory or management programs were receiving new and critical attention.

In January 1968, the I.U.C.N. sponsored a second polar bear conference at its Morges, Switzerland, headquarters. This meeting was aimed at bringing together those scientists actually involved with polar bears in their respective countries. It provided opportunity for a further exchange of information, for a joint analysis of research needs and priorities, and for the development of arctic-wide coordination of several research phases. Examples of cooperation agreed upon include the following.

1. Procedures for marking bears were standardized and a block of ear tag and tattoo numbers assigned each nation to avoid duplication of marks. Each country agreed to publicize tagging programs, pay for tag returns of other nations, and return tags to countries of origin. Data on recovery of marked animals would be freely exchanged.
2. Canadian and Russian scientists would continue taxonomic work based on skull morphology, and all countries would collect skulls as possible for their examination.
3. All nations would collect blood samples and provide them to Norway for analysis of serum protein differences that might indicate racial distinctions.
4. Known age tooth material, regardless of origin, would be forwarded to Alaska for sectioning and examination to further develop a technique for age determination.
5. The Federal program in Alaska would include an attempt to develop a censusing technique which could then be used by all countries.
6. Raw data relating to sex and age composition, denning areas, food habits, and diseases and parasites would be made available to all cooperating scientists for interpreting the results of studies in which each is engaged.

International cooperation in polar bear research has thus far been successful in avoiding duplication and other shortcomings that could result from lack of communication between

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investigators. A third meeting of polar bear specialists will be convened in 1970 to assess progress and further refine research programs and procedures.

Polar bear research in Alaska was initiated in 1956 with a program to obtain information from guides and hunters relating to the numbers, sex, hide size, and location of bears harvested. In addition, hunting success in relation to effort, and the number and kinds of bears sighted by aircraft hunters were recorded when possible. This program has been continued and strengthened in recent years by regulations which require that bear hides and skulls be presented to a representative of the Alaska Department of Fish and Game for inspection, sealing, and removal of a tooth within 30 days after the kill. Through the cooperation of guides and hunters, a successful specimen collection program is in progress yielding skulls, teeth, reproductive organs, blood, and muscle specimens. The collection and analysis of data and specimens from the bear harvest are supplemented by research which has involved the capture, field examination, and marking of live bears as well as limited aerial surveys and tests of radio-tracking equipment. This report presents harvest data and outlines research objectives and procedures with preliminary findings.

HARVEST CHARACTERISTICS

Numbers and sex ratios

The Alaska bear harvest during the period of 1925 through the spring of 1969 and the number of females taken in years for which this information is available are presented in Figure 1. The larger harvests in the last 15 years reflect the increased participation of trophy hunters who employ guides and aircraft. The use of aircraft makes the taking of polar bears relatively easy and permits selectivity for larger animals which are predominately males. This selectivity and the fact that females with cubs are protected cause the female element of the stocks being harvested adjacent to Alaska to feel the impact of hunting much less than might be expected by reference only to total harvest figures.

Harvest data reveal that three types of hunters exercise distinctive and rather consistent degrees of selectivity with respect to the sex of bears harvested. Non-resident (not residing in Alaska) hunters are most selective for males, resident white hunters are moderately selective, and native hunters are rarely selective except that cubs of the year and yearlings may not be taken in every instance. Actually, the difference in selectivity between non-resident and resident trophy hunters is attributable to the guides who seek larger bears for non-residents and commonly charge them a higher fee as compared to residents. Table 1 presents the harvest and sex ratio data for the three classes of hunters described above for the years 1961-1969.

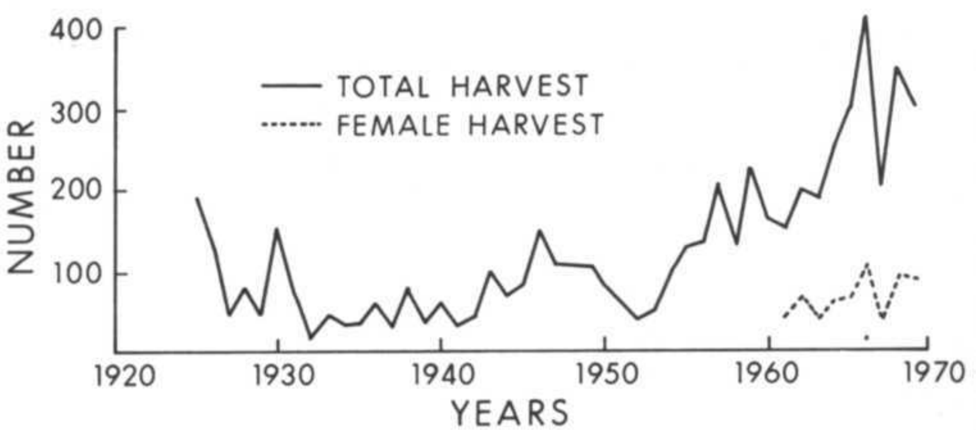

Fig. 1. Alaska Polar Bear Harvest 1925-1969.

TABLE 1. Polar Bear Harvest and Sex Ratios, 1961-1969.

Year	Non-Residents		Resident White		All Sport Hunters		Resident Native		All Hunters	
	No.	%Male	No.	%Male	No.	%Male	No.	%Male	No.	%Male
1961	70	93	59	57	129	77	23	52	152	73
1962	78	85	103	60	181	70	16	50	201	69
1963	106	88	57	68	163	81	22	68	189	79
1964	142	89	86	60	228	78	23	69	253	77
1965	159	89	116	64	275	79	21	50	296	76
1966	195	89	152	66	347	79	52	46	399	74
1967	124	97	42	69	166	90	25	50	191	80
1968	184	84	56	66	240	80	111	61	351	74
1969	227	76	44	63	290	69	27	56	298	72

TABLE 2. Average Skull Size* in Inches of Polar Bears Taken by Airplane Hunters Based In Alaska, 1966-1969.

Hunting Area	Non Resident				Resident-White				Total			
	Male Size	N†	Female Size	N†	Male Size	N†	Female Size	N†	Male Size	N†	Female Size	N†
Chukchi Sea												
1966	25.1	139	21.0	9	24.1	48	21.4	20	24.8	187	21.5	29
1967	24.9	79	21.2	6	23.1	14	22.1	4	24.6	93	21.6	10
1968	25.2	121	21.3	12	24.5	24	19.1	4	25.0	145	20.8	16
1969	24.5	119	21.3	24	24.0	10	21.3	3	24.4	129	21.3	27
Arctic Ocean												
1966	24.1	25	20.5	6	22.4	44	19.9	26	23.0	69	20.0	32
1967	23.6	22	20.0	5	22.6	14	19.9	7	23.2	36	19.9	12
1968	23.7	23	21.1	12	23.0	5	19.7	10	23.6	28	20.4	22
1969	23.4	20	21.2	20	22.5	10	20.0	7	23.1	30	20.9	27

* Skull size is greatest length without lower jaw plus greatest width.
† N = Number measured

Age Composition

As a possible indicator of changing age structure of the stocks caused by exploitation, measurements of skulls brought in by hunters have been recorded for several years. These data are presented in Table 2, with the Chukchi Sea and Arctic Ocean harvests shown separately because, as pointed out below, there is a possibility that two separate populations are involved and so require separate consideration.

While skull measurements indicate the approximate relative age of bears, cementum layers that can be demonstrated in tooth cross sections are believed to be of annual incidence and, therefore, indicate the chronological age. A sample of tooth specimens has been collected from the bear harvest each year since 1966. The resultant data are presented in Table 3, with the Chukchi Sea and Arctic Ocean specimens shown separately.

TABLE 3. Average Age Based on Tooth Cementum Layering of Polar Bears in Hunter Harvest, 1966-1968.

	Male			Female	
	Airplane				
	Non-Resident	Resident	Ground	Airplane	Ground
Arctic Ocean					
1966	10. 1 (16)*	7.2 (13)	10.6 (4)	6. 6 (8)	5. 0 (6)
1967	7.7 (17)	6.0(10)	4. 5 (2)	7.0 (8)	5. 0 (2)
1968	8. 1 (21)	6.4(7)	5. 6 (28)	5. 8 (22)	6. 2 (23)
Chukchi Sea					
1966	9. 1 (64)	7.0(13)	–	7.2 (14)	3.0(1)
1967	7. 0 (39)	7. 0 (7)	–	6.0 (12)	
1968	8. 2 (76)	5.8 (21)	–	8. 3 (8)	4.0(3)

* Numbers in parentheses are numbers in sample.

It will be seen that the age trend suggested by tooth analysis parallels the skull size trend for male bears (See Table 2). During the 1967 season, when difficult hunting conditions prevailed, the average age of bears harvested dropped slightly, as previously suggested by a decline in the skull size of the male bears taken in the harvest. We do not yet know if changes in age composition of the harvest from year to year represent true changes in the population or are caused by varying conditions for hunting or other factors. It is believed that present methods of monitoring will allow an evaluation within a few years.

IDENTITY OF POPULATIONS

It is of high priority to determine if different stocks of bears exist and, if so, their ranges. Workers in other countries are studying blood protein characteristics and making detailed skull measurements and comparisons aimed at detecting the existence of racial differences between bear stocks in various parts of the arctic basin. While we have provided material from Alaska for these studies, our own work has been limited to gross skull measurements, that is, length and width of the cleaned skulls.

It has been hypothesized that bears harvested on the Chukchi Sea to the west of Alaska belong to a different population from bears killed on the Arctic Ocean north of Alaska. The 1968 harvest provided our best sample of skull measurements and ages. These data are presented in Figure 2 so that Chukchi Sea animals can be distinguished from Arctic Ocean animals. As more data are obtained, statistical comparisons will be made between the two areas.

The major effort to determine if discrete populations of bears occur off the Alaska coast has been a movement study based on a mark and recovery program. Animals are located by helicopter in February, March, and April by tracking them on the ocean ice. They are then immobilized for marking by injecting phencyclidine hydrochloride (Sernylan, Parke, Davis and Company, Detroit, Michigan) intramuscularly with a syringe gun fired from the helicopter. Injection of a tranquilizer, propiopromazine hydrochloride (Tranvet, Diamond Laboratories, Inc., Des Moines, Iowa), appears to give a more desirable anesthesia than when only Sernylan is used. Bears are marked with a nylon tag in one ear (Rototag, Dalton Company, Henley, England) and a monel metal tag (4-1005, No. 49, National Band and Tag Company, Newport, Kentucky) in the other ear. Details on immobilizing and marking are given by Lentfer (1968, 1969).

In three years, 202 bears have been tagged off the Alaska Coast (Table 4). Three marked animals have been recaptured and 14 have been killed by hunters. A number of resightings have also been made, most during the period immediately following tagging. Recovery data, not including resightings, are summarized in Table 5.

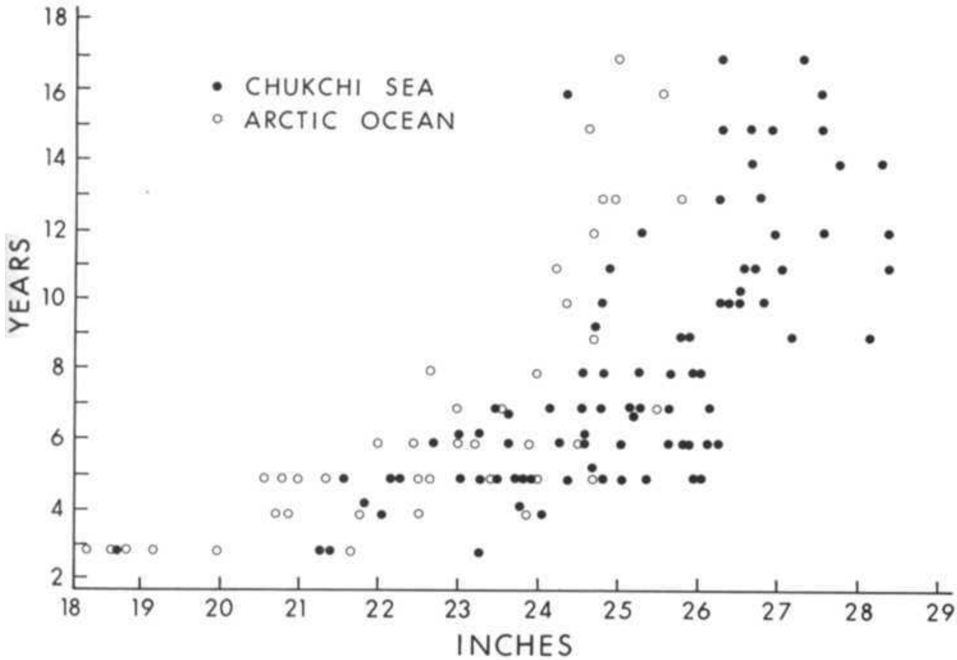

Fig. 2. Skull Size Plotted Against Age for Male Polar Bears Killed in 1968.

TABLE 4. Location and Sex and Age Composition of Polar Bear Tagged in Alaska, 1967-1969.

	Cub-of-Year*	Yearling			2-year-old		Sub-adult		Adult		
		M	F	Unk.	M	F	M	F	M	F	Total
Bering Strait											
1968		1				2			4	3	10
Lisburne											
1968		2	3	1	3	4	8	7	7	15	50
1969							1	2	4		7
Barrow											
1967		3	3		4	2	2	4	4	9	31
1968		8	1		3	7	6	11	7	37	80
1969	2		1			4	2	2	2	9	22
Barter Island											
1969		1	1								2
Total	2	15	9	1	10	19	19	26	28	73	202
Percent	1		12		14		22		50		100

* Cubs-of-year not sexed.

TABLE 5. Recovery Data on Polar Bears Tagged in Alaska.

Location Tagged	Location Recovered	Distance Between (Miles)	Time Interval	Sex	No. of Recoveries
Bering Strait	W. of Kotzebue	75	1 month	M	1
Lisburne	W. of Pt. Hope	100	1 year	M	1
Lisburne	Wainwright	175	9 months	M	1
Lisburne	Barrow	300	1 year	M	1
Barrow	N. of Vankarem-USSR (Chukotskii) Coast	500	2 years	M	1
Barrow	W. of Pt. Hope	350	1 year	M	2
Barrow	Wainwright	75	9 months	M	1
Barrow	Barrow	0	4 days	M	1
Barrow	Barrow	0	1 year	M	3
Barrow	Barrow	0	1 year	F	4
Barrow	Barter Island	325	1 year	F	1

Table 6 presents data on condition of marks on bears which have been recaptured or taken by hunters. Neither the nylon nor the metal tag appears to have a distinct advantage. Some metal tags were gone when animals were recovered, and some nylon tags were broken so that numbers could not be read.

TABLE 6. Condition of Marks on Recovered Polar Bears.

		Nylon Tag		Metal Tag			Collar		Tattoo		
Tagging to Recovery Time	No. of Recoveries*	Intact	Broken	Present Without Infection	Present Without Infection	Missing	Collar Retained	Not Collared	Legible	Illegible	Not Tattooed
4 days	1	1		1				1	1		
1 mo.	1	1		1					1		
9 mo.	2	1	1	1		1		2		1	1
1 yr.	11	5	6	7	2	2	4	7	5	4	2
2 yr.	1	1		1				1			1

* Does not include one hunter-killed bear for which data are incomplete.

An attempt has been made to have radio tracking equipment developed which would aid in determining movements. Available equipment is judged to be unsuitable because of battery life and range limitations. Attempts to develop wholly satisfactory equipment have thus far been unsuccessful.

BREEDING BIOLOGY

Reproductive organs obtained from hunter-killed bears are being studied to better understand breeding biology and productivity. There have not yet been enough female reproductive tracts examined to warrant a report. Testes and epididymides from 43 males have been examined for presence of sperm (Table 7). Sperm were not seen in specimens from a yearling and a 2-year-old animal. Sperm were seen in February, March and April specimens of all bears three years old and older. The oldest was aged at 19 years. Sperm were not seen in August specimens from mature animals.

TABLE 7. Results of Examination for Sperm in Polar Bear Testes and Epididymides.

Age Class	No. of Specimens	Date of Time Period	Sperm Observed
1	1	Jan. 3	No
2	1	Mar. 10	No
3	2	Jeb. 3-Mar. 25	Yes
4-19	34	Feb. 2-Apr. 23	Yes
Mature	5	Aug. 12-16	No

PHYSIOLOGY AND PARASITISM

Lewis and Lentfer (1967) analyzed liver samples for Vitamin A content from fourteen bears killed north of Point Barrow. Vitamin A content spanned a two-fold range (15, 000-30, 000 units per gram of liver) and showed no correlation with sex or age. Findings were in agreement with those reported by Rodahl and Moore (1943).

Approximately 70 meat samples, mostly masseter muscle, obtained in 1967, have been examined for presence of *Trichinella*. About half the samples were from bears killed west of Alaska and about half were from bears killed north of Point Barrow. Of the bears from the west, 67% were positive from *Trichinella* and of the bears killed north of Point Barrow, 72% were positive.

FUTURE RESEARCH

Most of the present programs will be continued including collection and analysis of harvest data, study of breeding biology, tagging, and an attempt to radio-track bears. New programs will include efforts to relate bear movements to ocean current and ice movements, and to develop a censusing technique, probably using infra-red photography or heat sensing equipment.

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Paper No. 16

Polar Bear Research in Canada

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The Canadian Wildlife Service started research on the polar bear (*Ursus maritimus* Phipps) in 1961. Initial emphasis was on a review of the literature (Harington 1964), locating denning areas (Harington 1966) and studying denning habits (Harington 1968).

From 1962 through 1965, polar bear milk was analysed biochemically (Baker *et al.* 1963a, 1963b), and morphometric studies begun independently were continued under Canadian Wildlife Service contracts (Manning 1964, 1969). Annual aerial surveys of coastal polar bear populations started by Manitoba in 1962 and by Ontario in 1963, have been continued to the present time.

During 1965 the plight of polar bears received increased international attention, and it became evident that data on many aspects of polar bear biology were lacking. This concern was focussed to a large extent on Canada. Polar bears are of economic importance to our Eskimo and Indian hunters; we seem to have most of the world's polar bears; and the range of the species includes a major portion of the Canadian Arctic.

The research program of the Service was consequently changed and expanded late in 1966, and has continued to develop. Our current work is designed to collect biological and management information to guide us in maintaining the bears in appropriate numbers and distribution, while still allowing for an annual kill by native hunters.

We have formed and will test the following hypotheses. In James Bay and southern Hudson Bay, polar bears are abundant and increasing in number, whereas in the High Arctic their numbers may be lower and are declining, or remaining static. Bears of one geographical area do not normally move to another. Certain groups of bears are overhunted, others should be hunted more. Differences in density may be caused by the influence of latitude on growth and reproductive rates, and food habits, as well as by hunting pressure.

We are now experimenting with census techniques (Jonkel 1968a), and studying distribution and migratory movements of polar bears by observing the movements of ear-tagged and radio-tagged bears. We are collecting skeletal, reproductive and tissue specimens from bears killed by Eskimos; conducting a food habits study; studying polar bear behaviour (Jonkel 1968b); and continuing to locate winter denning areas. Population-regulating mechanisms, reproductive rates, drugging techniques, physiological conditions, summer denning habits, pathological conditions and morphometry are also receiving special attention. This is a preliminary report on the progress of these studies.

METHODS

Trapping, handling and marking methods were described in a previous report (Jonkel 1967). The drug phencyclidine hydrochloride (*Sernylan*, Parke, David, and Company, Detroit, Michigan) is used on bears captured for the first time because it immobilizes them for a long period. Recaptured bears are usually immobilized with succinylcholine chloride (*Sucostrin*, Squibb Laboratories, Montreal). Bears drugged with Sernylan are given the tranquilizer promazine hydrochloride (*Sparine*, John Wyeth and Brother, Ltd., Windsor, Ontario) to counteract convulsions.

Bears have also been captured by helicopter on the sea ice in James Bay in March and April; and along the Ontario sea coast in September. The techniques of Manning (1967) and Lentfer (1968) were used.

Each day in September we search the coastline by helicopter along the high tide about 30 metres above the beach. When we spot a bear, we immediately herd it to high ground. We then land, prepare the necessary drugs, and remove one door from the helicopter so

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that we can fire a projectile automatic syringe. From the helicopter, hovering five to eight metres behind the bear, we fire the filled syringe into the bear's shoulder or rump muscles with a long-range syringe projector (Capchur gun, Palmer Chemical Company, Douglasville, Georgia).

Our methods of collecting specimens and conducting aerial surveys were described by Jonkel (1968a). The aerial survey methods are based on techniques developed by the Ontario Wildlife Branch.

Bears on Cape Churchill are being marked with radio transmitters embedded in plastic and metal collars in addition to other marks and tags. Techniques similar to those developed by Craighead and Craighead (1965) for grizzly bears (*U. arctos horribilis* Ord) and by Pierson and Hartwell (1965) for black bears (*U. americanus* Pallas) are used. Bears are located several times each day by means of portable receivers and directional antennae. Initially they are tracked by truck along the roads of the Churchill Research Range. Later, we locate them by mounting an antenna on the step of a light plane and flying in a grid over the areas where they are expected. A detailed report on these techniques is now being prepared.

Studies on food habits are being conducted by a University of Alberta student on contract to the Canadian Wildlife Service. He has systematically cleared polar bear scats from certain island and coastal areas each year. The scats are dried and stored until laboratory analyses can be made. Stomach samples and scats from High Arctic areas are also being collected for comparative studies.

We are co-operating with a Manitoba student at the University of Montana in studying polar bear behaviour on North Twin Island, James Bay. This is the principal research area, but we will make comparative observations in High Arctic and coastal areas. We will describe the techniques in a future report.

RESULTS

We captured 94 polar bears in the southern Hudson Bay area from October 1966 to May 1969. Seventy-nine were captured and marked for the first time; 15 were captured from one to three times. Nine of the 79 bears were killed and taken as specimens because they were either sick, wounded, given an overdose of the immobilizing drugs, or were considered dangerous to local residents. Tagged bears were observed 37 times, but extensive periods had elapsed in only 10 cases. On Cape Churchill, one sub-adult female was captured in three consecutive years, another in 1967 and 1968. An adult male was initially marked in 1968 in James Bay, and recaptured in 1969 about 20 kilometres to the south. Another adult male, captured on a James Bay island in April 1968, was observed in July of the same year about one kilometre to the south on the same island.

We are reporting elsewhere (Jonkel and Standfield 1969) on results of aerial surveys conducted with the co-operation of provincial game personnel. During a supplementary aerial survey made in November 1968 we observed 152 polar bears in a 10 by 20 by 20 kilometre triangle on Cape Churchill. From information on marked and radio-tagged bears, and from studies of bear distribution based on tracks in the boreal forest 3 to 20 kilometres from the coast, we estimated there were 200 to 250 bears on Cape Churchill. We did not survey Cape Tatnum near the Manitoba-Ontario border, or Cape Henrietta Maria, but incomplete reports from aircraft pilots indicate there were also large numbers of bears in those areas in early November.

In 1967 we radio-tagged one sub-adult female polar bear recaptured on Cape Churchill. The transmitter worked properly when mounted around her neck, but upon release of the bear, we encountered receiver problems and were unable to track her. She was observed one month later with the collar intact, but in 1968 when she was recaptured, the transmitter had been lost.

In 1968, we fitted six bears with transmitters and released them (Table 1). We lost contact with one female after five days, probably because the transmitter was damaged by her yearlings. We located her and the young daily on a small peninsula until the day the signal was lost. Bears were not moving from the area at that time, and the sudden loss of the signal indicates that the transmitter had stopped working. The pulse rates of two

TABLE 1. Polar bears fitted with radio transmitter collars in 1968 at Churchill. The transmitter of X550 was probably damaged by the yearlings on October 28. The transmitters of X553 and X554 may have suffered internal malfunctions, as they went onto rapid or continuous signals prior to the last date recorded.

Bear No.	Date released	Sex	Age	Wt.	Date of last location	Movement (kilometres)	Remarks
X550	Oct. 23	X	Adult	397 lbs. 179 kg.	Oct. 28	2	2 yearlings
X553	Oct. 25	W	Sub-adult	300 lbs. 135 kg.	Dec. 2	32	–
X554	Oct. 27	W	Adult	575 lbs. 259 kg.	Nov. 18	15	–
X505	Oct. 25	X	Adult	380 lbs. 171 kg.	Nov. 16	2	Recaptured*
X523	Oct. 28	X	Sub-adult	350 lbs. 158 kg.	Dec. 8	104	Recapturedt
X557	Oct. 29	X	Adult	480 lbs. 276 kg.	Dec. 14	144	2 cubs

* First captured in 1966, recaptured in 1967 and fitted with transmitter; receiver problems precluded tracking her.

† First captured in 1967.

other transmitters that failed increased for several days before they stopped functioning. One, at least, began transmitting a continuous signal before its failure, and the rapid drain probably exhausted the batteries.

A radio-equipped female was tracked continuously for one month, until she suddenly disappeared. We had assumed from her age and condition that she was pregnant and we had planned to follow her movement to a denning area. She made several three to four kilometre trips inland before we lost.her signal on November 16. A storm brought much colder weather at that time, and she may have moved inland to den. We searched suspected denning areas by plane, mounted with receiver and antenna, but failed to locate her. We found a major denning area about 150 kilometres to the south, in spring 1969, but only one flight had been made there in 1968, when the bear's transmitter might still have been working.

Three bears were tracked for 1½ months until they moved out onto the Hudson Bay ice. One was an adult female with 10-month-old cubs, one was a sub-adult male, and the third was a sub-adult female. The transmitter of the sub-adult male apparently failed about December 2, but the remaining two transmitters were performing well when last heard over 100 kilometres northeast of Churchill. A delay in acquiring additional funds curtailed the aerial tracking until December 20, and none of the bears could be located when the search was resumed. A final search was made on January 13 and 14, and although many polar bear tracks were observed 60 to 130 kilometres off shore, no signals were received. The batteries may have been dead by that time.

We have collected specimens from 201 bears killed by Eskimo hunters. Some specimens have been mislabelled or lost by the Eskimo assistants in the settlements, but many of the data appear valid. We are currently conducting morphometric and histological analyses of these specimens, but have little to report at this time.

We have collected 100-gram muscle samples from 73 bears for use in strontium 90 analyses, and 5-gram fat samples from 53 bears for insecticide analyses. Preliminary tests on fat samples' indicate an unexpectedly high concentration of 2.13 parts per million (p.p.m.) of dieldrin in one bear killed in a remote High Arctic area. DDT and DDT metabolite residues in concentrations up to 2. 60 p.p.m. were found in all fat samples tested. We are now selecting groups of samples for further analyses from five regions of the Canadian Arctic.

Our behavioural and food habits studies being conducted in co-operation with graduate university students are designed to give comparative information on bears from different areas. In-depth studies have already provided supporting data for our other projects. Preliminary analyses of faeces, for example, indicate that southern bears feed to a large extent on vegetation, flightless waterfowl and marine invertebrates, while High Arctic bears are more carnivorous. Preliminary studies indicate remarkable behavioural changes in the bears after the sea ice melts in July and the bears move to coastal and inland areas. The bears seem aggressive and restless when first on land, but rest more in beds, sand pits and dens as summer progresses. Another behavioural change occurs when the bears become more active and return to the ice in early November. A study of the changes in the behaviour of bears subjected to repeated contact with aircraft shows an eventual adaptation to this disturbance (Jonkel and Kolenosky 1969).

We have continued the study of denning areas begun by Harington (1966) and have located two major denning areas along the southern Hudson Bay coast. One is about 150 kilometres southwest of Cape Henrietta Maria in Ontario; the other is approximately 150 kilometres southeast of Churchill, Manitoba (Fig. 1). Both areas lie within the northern edge of the boreal forest, and may comprise the major denning areas for the southern

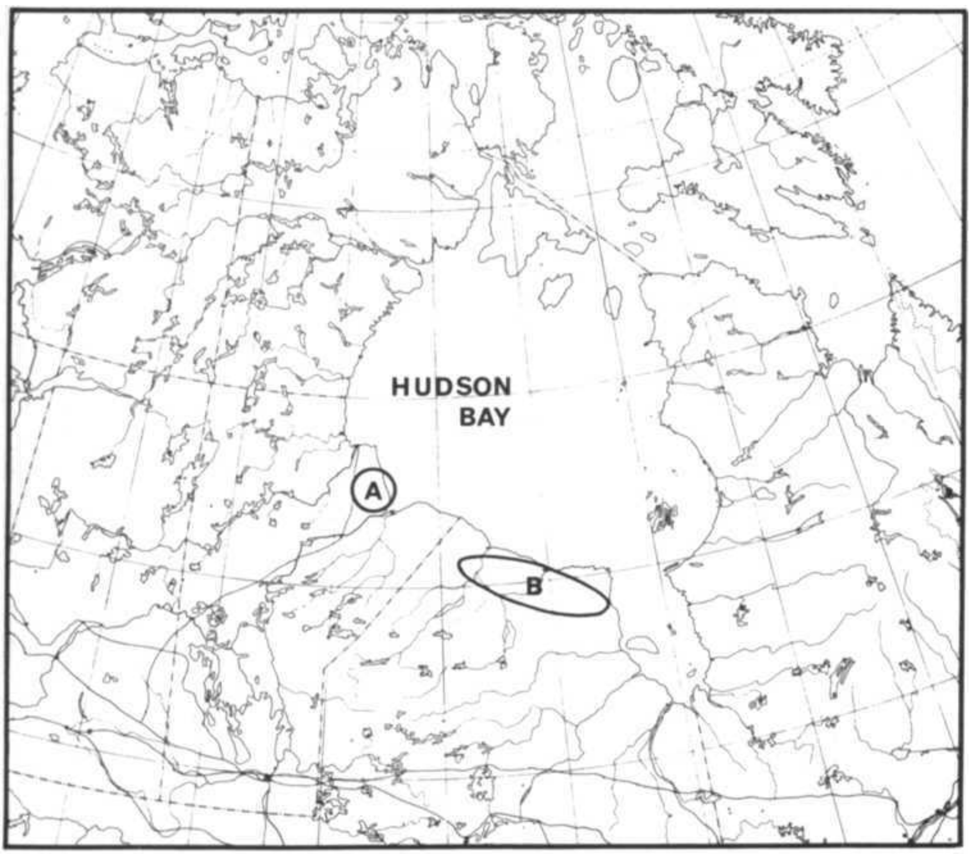

Fig. 1. Two new denning areas have been located in southern Hudson Bay. Their approximate locations are (A) near Churchill, Manitoba, and (B) near Cape Henrietta Maria, Ontario.

Hudson Bay and James Bay polar bears. Their precise location and a topographical description will be given in the coming year.

DISCUSSION

Tagging studies, aerial surveys, and our radio-tracking programs all indicate that southern Hudson Bay bears do not travel far. Approximately 100 polar bears are killed annually in northern Hudson Bay by Eskimo hunters, but no tagged bears have yet been killed in that area. Adult males and females and many sub-adults have been recaptured repeatedly by us in southern Hudson Bay.

We have not yet been able to follow individual bears for any major portion of a year, but one adult male was marked on the edge of the sea ice in mid-winter and was observed resting on a nearby lichen covered island in mid-July. This is evidence of at least one adult that has a very limited annual migration. Other recaptured bears may, of course, have travelled considerable distances between capture and recapture. More frequent or continuous records of the locations of individual bears are needed before we can confirm our present belief that bears do not usually move great distances. Long-term studies will no doubt provide data on bears which do move farther, especially in High Arctic areas where alternative foods are scarce and individual bear ranges are perhaps larger.

Based on our present data, some management changes could be justified. For example, we are considering dividing the Canadian arctic and subarctic polar bear range into smaller management units. If our research shows that these units are valid, regional management by the territories and provinces will be encouraged, and additional research and management data will be gathered for each unit. The importance of managing polar bears scientifically, particularly because they compete with man for space, was discussed by Jonkel (1969).

Preliminary studies indicate that radio-tracking of polar bears may be feasible. Several transmitters functioned properly in temperatures as low as —30°F, with the bears travelling into and out of salt water. One bear was observed in shallow water while the pulse of the transmitter was being monitored. A marked slowing of the pulse rate was the only change noted. Radio-tagging of family groups may present serious problems if the siblings or young chew the rather obvious black collar. Covering the collar with a wrapping of white waterproof tape will be attempted in 1969.

The surprising discovery of high insecticide levels in fat tissue of polar bears deserves special attention. We plan to determine these levels for polar bears from different areas of the Arctic by sampling every year. As polar bears are at the top of a food pyramid, insecticide residues may eventually reach even higher levels in this species.

Polar bears seem to be particularly attached to certain geographical areas for denning and producing young. Why these areas are particularly favoured is not yet clear, though Uspenskii and Chernyavskii (1965) and Harington (1968) have discussed and made extensive descriptions of High Arctic denning areas. Other similar areas are not used, however, and for proper management the ecological and behavioural forces concerned must be known.

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Paper no. 17

Current Investigations into Reindeer Grazing in Northern Sweden

OLOF ERIKSSON[1]

INTRODUCTION

As far as is known, the reindeer (*Ranfiger tarandus*) has been the basis of the Same or Lapp people's livelihood since the dawn of history, first as game and later as a semi-domesticated animal. In a more or less tame state it has been used by the Lapps for the last 1200 years at any rate. (The wild reindeer was exterminated in Sweden during the latter part of the last century).

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The reindeer-breeding region in Sweden covers an area of about 165, 000 km^2 (not counting the large lakes) and consists of bare mountain, sub-alpine birch woodland and coniferous forest land from about latitude 69°N. down to latitude 62°N. It is divided up into 49 administrative units called Lapp communities which all contain the different types of grazing which the reindeer need. Thus, Sweden's 240, 000 reindeer each have an area of about 1.5 km^2 to move about in. The largest community has approximately 13, 000 reindeer and the smallest 500.

About 60% of the reindeer-breeding region consists of bare mountain and sub-alpine birch woodland, which are useless for agriculture and forestry. Thus, the reindeer largely uses areas which may be regarded almost as waste lands. Thirty-five per cent of the region is pine or spruce forest and mires. Only very small parts are used for agriculture. In some cases reindeer land has been lost in the construction of water reservoirs or mining operations. The construction of roads and railways has an influence on the mobility of the herds, and there are often traffic casualties.

In the pine forests, which form the most important winter grazing grounds, there are occasional conflicts between the interests of reindeer-breeding and those of forestry. The reindeer is believed to cause damage to seedlings, when digging into the snow in order to get at the ground vegetation. The stems and twigs of small frozen pine saplings may then be accidentally snapped off. On the other hand, the reindeer breeders maintain that the large clearings produced in modern forestry operations result in drifting snow producing hard, wind-packed drifts, which make it more or less impossible for the reindeer to dig down to the ground. Ice crusts (Sw. *skare*) are also considered to form on the snow surface more often in clearings than in the forest.

Opinions are divided as to the value of controlled burning of the clearings, which is carried out periodically. The Lapps maintain that it damages the lichens for a long time afterward, while the forestry people consider that the increased growth of grass after the burning probably compensates this loss. The regulation of the levels of lakes, the expansion of tourism and the building of roads are examples of other activities which sometimes result in considerable difficulties for the reindeer breeder.

Formerly, the Lapps lived a nomadic life, following the reindeer herds on their migrations. Today this way of life has been more or less abandoned and the Lapps have obtained permanent dwellings in the villages of the reindeer-breeding region. The migrations of the reindeer from the winter grazing grounds (in the coniferous forests near the coast of the Gulf of Bothnia) to the summer grazing grounds (in the high mountains) are now followed, usually, by only a few men. The. main labour force musters only at the place where the actual work is to be done, for example, calf marking, sorting and slaughtering.

Swedish Lapps have for centuries moved with their reindeer to summer grazing grounds in Norway. This right has been guaranteed to them in treaties between Sweden and Norway—treaties which have been respected even during war-time and as late as World War II. However, Norwegian reindeer-breeding is increasing and since the turn of the century voices have been raised to demand a restriction on the Swedish grazing rights in Norway. A few years ago Norway gave notice of its desire to terminate the 1919 reindeer-grazing convention.- Negotiations about a new treaty are now in progress.

PREVIOUS INVESTIGATIONS

Most of the investigations, which have hitherto been made in the reindeer-grazing region in the northernmost part of Sweden, have been made in connection with government commissions concerning conflicts of interest between Sweden and Norway in this region. The first commission started, to a certain extent, as early as 1910 and the latest has recently presented its report. However, it is in the nature of things that such inquiries must be fairly summary, on account of the limited time that is usually available.

In the last few decades Mr. Folke Skuncke has made more protracted investigations in the reindeer-grazing region. However, he worked mainly in the more southerly parts of the reindeer's distribution area in Sweden.

CURRENT RESEARCH

In recent years the need for more detailed knowledge of the productive capacity of the most northerly reindeer-grazing grounds has become more and more acute. One reason for this is the fact that the Swedish Lapps have lost grazing grounds in Norway, a loss which must be compensated for by more intensive use of the Swedish grazing grounds, which are already heavily exploited. To this must be added the fact that the number of reindeer per family is at present too low in this region. It is considered that today a family needs about 500 reindeer to yield a reasonable standard of living: the average at present is less than 200.

In this situation we may: (a) increase the return from reindeer breeding; (b) reduce the number of reindeer breeders, by affording them other employment; or (c) increase the number of reindeer. The first two solutions lie outside the framework of this report, though not the third.

An essential preconditions for all planning of reindeer-breeding is adequate knowledge of, on the one hand, the present condition of the grazing grounds and, on the other hand, their sustained productive capacity. As this knowledge was lacking in the northern area, which is considered to be the most critical in Sweden, namely the area north and east of the Torne River (what are called the 'northern communities'), an investigation was started in July 1967. The leaders are Professor Hugo Sjors, of the Institute of Ecological Botany, University of Uppsala; and Dr.Eliel Steen, of the Department of Plant Husbandry, Agricultural College of Sweden, Uppsala. Dr. Steen has taken part in the inquiries carried out by the above-mentioned government commissions in the reindeer-grazing region.

Since the supply of winter and spring grazing is the limiting factor, as regards the number of reindeer, the main stress in the investigation was placed on studies in the winter and spring grazing grounds.

METHODS

(a) Mapping

A fairly accurate map showing, on the one hand, the distribution of the most important winter grazing grounds (lichen-rich pine forests, birch forests and treeless mountain heaths) and, on the other, their grades in regard to quality of grazing, was drawn, partly with the guidance of information obtained from reindeer-breeding Lapps.

(b) Vegetation analyses

As many vegetation analyses as possible were made over the whole investigation region. In this connection the percentage distribution of the vegetation and the heights of the plants were recorded. In order to find lightly grazed variants within corresponding climatic zones, it was necessary to make vegetation studies on the Finnish side of the frontier, where the grazing intensity had hitherto been very low.

(c) Growth and succession studies

A number of test areas from which the reindeer were excluded were constructed within the appropriate grazing areas. In these test areas experiments are being made to determine the growth rate of *Cladonia* species of the *Cladina* group as well as that of different *Stereocaulon* species. The growth in length is determined by photographing marked individual lichens at close quarters at regular intervals of time. Special attention is being devoted to the effect of the intensity of grazing on the growth rate. Attempts are being made to simulate grazing by cutting off portions of individual lichens. However, the low height of the lichen cover (often 25-30 mm) makes this work extremely difficult, as the lichen bodies are so small and fragile that they tend to break off when touched.

In a couple of areas in which the lichen cover is somewhat thicker, parts of the lichen carpet have been loosened and placed in low, perforated, plastic boxes with an area of about 600 cm^2, which makes it possible to study the annual growth in weight. The lichens are saturated with distilled water before each weighing.

Annual analyses and the photographing of marked squares measuring 50 x 50 cm^2 distributed over the test areas provide information about changes in the composition of the field and bottom layers since reindeer grazing ceased. The developments on quite bare areas are also being followed. It has been said that the large areas covered with *Stereocaulon* species in Karesuando parish, the most northerly parish in Sweden, are an indication of over-grazing, because in adjacent areas in Finland, which have little reindeer grazing, *Cl. alpestris* is predominant. By following the developments in the squares, we hope to be able to help to elucidate whether or not the predominance of *Stereocaulon* species is a sign of over-grazing.

(d) Determination of standing crop

In connection with a number of vegetation analyses, squares measuring 500 cm^2 are being cut out at random from the ground vegetation and taken to the Institute for determination of the standing crop in the field and bottom layers.

(e) Analysis of rumen samples

As far as is known, no studies of the reindeer's choice of food by the analysis of rumen samples taken under field conditions have previously been made in Sweden. During the past winter 25 rumen samples were obtained from reindeer shot by special permission in a few typical winter-grazing areas. The material has not yet been analysed.

(f) Studies of the effect of snow conditions on the winter grazing

Snow conditions affect the reindeer-breeding to a great extent. The depth of snow is not generally a great problem in these latitudes. On the other hand, the consistency of the snow may be. Crusts of ice on the snow surface formed either by the effect of the wind or by a thaw may, if the worst comes to the worst, make it impossible for the reindeer to dig down to the ground.

In normal years the ground in the investigation region freezes at the end of September. The snow which then falls remains until the middle of June. However, occasionally rain falls on the already frozen ground or else snow falls on unfrozen gound. Ice crusts may then be formed on the ground and more or less completely enclose the plants on which the reindeer graze. The consequences of this for the reindeer may be quite serious.

In recent years a series of winters with unsuitable snow conditions has affected the investigation region. The reindeer have tended to leave the winter grazing grounds and move up to the bare mountain areas, where they can always find small patches where the wind has uncovered the sparse vegetation.

Investigations are in progress as to the extent to which the large clearings created in the most important winter grazing grounds in the pine forest have an injurious effect on the reindeer-breeding. Among other things, a study is being made of possible differences in the occurrence of ice crusts within the pine forest and out in the clearings. For this purpose, a simple apparatus for measuring the strength of the ice crust has been designed. It is being used to study differences in the strength of the crust in the forest and the clearings. It will also be used to determine the maximum hardness of crusts that reindeer can normally break through.

SUMMARY

Intensive studies of the conditions for reindeer-grazing in northern Sweden have been going on since July 1967 in the region north and east of the Torne River, as part of the effort to improve reindeer husbandry in the area. A map has been drawn of the different types of grazing and also shows the value of the grazing grounds. Vegetation analyses and determinations of the 'standing crop' in the field and bottom layers are being made in the entire region. In enclosures from which the reindeer are excluded experiments are being made on the growth rates of *Cladonia* and *Stereocaulon* species in relation to the grazing intensity. The growth of the field and bottom layers in specially marked areas is

being followed from year to year. Investigations are being devoted to the effect of the snow structure on the reindeer's opportunities of finding food.

The aim is partly to determine the optimum capacity of winter grazing grounds (in a broad sense) to produce forage and partly to elucidate the effect of winter grazing on the ground vegetation. The data obtained from the different investigations should form the basis of the practical advice given to the reindeer breeders.

Paper No. 18

Reindeer Husbandry as a Land Use in Northern Canada

GEORGE W.SCOTTER[1]

Reindeer husbandry is one of the oldest known means of livelihood in the arctic and subarctic regions of Eurasia. The history of reindeer domestication has been traced back for several centuries. In Europe, the Lapps have been practising organized reindeer husbandry since the ninth century (Skuncke 1969). The domesticated reindeer (*Rangifer tarandus*) was confined to Eurasia until the late 1800's.

Between 1891 and 1902, 1, 280 reindeer were imported into Alaska from Siberia. Dr. Sheldon Jackson, first Superintendent of Education in Alaska, pioneered that introduction to supply coastal Eskimos with a dependable supplement to the depleted sea and land mammal food sources. By 1930, reindeer numbers reached 640,000 in Alaska, but by 1950 range deterioration, poor herding practices, and confused ownership had reduced them to about 25, 000 (Brady 1968). Community-owned and association herds were encouraged after an influenza epidemic resulted in heirship disputes. Such ownership resulted in less interest in the reindeer on the part of individual herdsmen. At present there are about 40,000 reindeer in Alaska. About half of these are in native ownership and the other half are government owned or in feral herds. Both state and federal government agencies are expending considerable effort to develop the industry into an economically profitable operation. Additional history of the reindeer industry in Alaska is available from other sources (Lantis 1950, Hanson 1952, DeLeonardis 1959,Nygard 1965, and Brady 1968).

The apparent success of reindeer introductions in Alaska stimulated interest in similar introductions into Canada. Five attempts have been made to develop reindeer husbandry in Canada.

LABRADOR EXPERIMENT

Impressed by the early success of the reindeer industry in Alaska, Dr. W.T.Grenfell, supported by the *Boston Transcript* and Canada Department of Agriculture, purchased 300 reindeer in Norway. The reindeer and three Lapp families arrived at Cremélière, near St. Anthony, Newfoundland, in 1908 (Grenfell 1919). The herd increased to about 1, 300 reindeer by 1912, but the Lapp herders, discouraged by the unfavourable climate and low pay, returned home. Lack of supervision caused the herd to decrease. Poaching, indifference, and ignorance among the local people also contributed to the decline. Grenfell was in France during the First World War and upon his return only 230 reindeer could be found. Although the experiment failed, Grenfell remained enthusiastic about the possibility of establishing a viable reindeer industry in Canada.

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In 1918, with assistance from the Canadian Government, about 150 of the remaining reindeer were captured and taken to Rocky Bay on the north shore of the St. Lawrence River. Subsequently the reindeer were moved to Anticosti Island and allowed to run wild. According to information provided by Consolidated Paper Corporation Limited, now Consolidated-Bathurst Limited, present owners of the island, the animals did not thrive, probably because of a lack of suitable forage (Tilton 1965). The last reindeer reported was seen in 1949 and the animals are believed to be extinct on the island (Cameron 1958).

Earlier, in 1911, the Department of the Interior purchased 50 head of reindeer from Grenfell. The animals were driven and transported by ship, rail, horse-drawn wagons and scows from St. Anthony, Newfoundland, towards their destination in the Great Slave Lake region of the District of the Mackenzie (Hedlin 1961,Inglis 1969). Throughout the journey deaths and straying caused the herd to decline. By 1916, it was reduced to a single reindeer which the herder ate; thus was the end of an experiment costing more than $60, 000.

HUDSON'S BAY REINDEER COMPANY

In May 1919, the Canadian Government appointed a Royal Commission to investigate the possibilities of reindeer and muskoxen (*Ovibos moschatus*) industries in the arctic and subarctic regions of Canada. Before the report was completed V. Stefansson, a member of the commission, resigned and applied for and was granted grazing privileges on more than 100, 000 square miles of southern Baffin Island. He then persuaded the Hudson's Bay Company to set up a subsidiary, Hudson's Bay Reindeer Company, of which he was a director and technical adviser (Stefansson 1964). S. T. Storkerson was hired to study the grazing prospects on the leasehold and reported enthusiastically on the vegetation and its suitability for reindeer.

Representatives of the Hudson's Bay Reindeer Company went to Norway to purchase reindeer, and on October 13,1921, the 'Nascopie', chartered from the parent company, sailed with 627 reindeer, of which 77 died before arrival in Amadjuak Bay on November 1. As soon as they reached land, the reindeer scattered in all directions in search of food. The six Lapp herders accompanying them from Norway were able to round up only 260 animals.

The quality and quantity of forage on that portion of Baffin Island did not bear out Storkerson's optimistic reports; evidently he had confused mosses with lichens. Reindeer lichens, an important winter forage, were very scarce, and the reindeer were forced to feed over large areas. By the summer of 1923, only 181 reindeer remained in the herd. Later that fall, the last of the Lapp herders returned to Norway. During the winter of 1924-25 most of the herd disappeared. On May 27,1927, the grazing permit of the Hudson's Bay Reindeer Company was cancelled and the enterprise officially concluded. Begun with high hopes of success, the Baffin Island experiment ended a total failure, and cost $200,000 (Stefansson 1964).

Officials of the Hudson's Bay Company attributed failure to the lack of feeding grounds; while Stefansson blamed inefficient herding and management. One of the assumptions was that good caribou country made good reindeer range. The two species do eat the same kinds of forage, but caribou are free to roam in search of food whereas reindeer, if they are to be any use to their owners, must be kept on a range sufficiently rich to allow them to be herded within a limited area. Even with good management the reindeer industry on Baffin Island would probably have failed because forage was too sparse, where the animals were set ashore, to support the herd in a limited area.

The ability of caribou to choose their own winter range areas can be particularly important in regions where there is deep or crusted snow. Caribou can move rather great distances to suitable ranges whereas reindeer need to be confined to an area within the mobility of herders.

MACKENZIE DELTA EXPERIMENT

The Royal Commission report (Rutherford, McLean, and Harkin 1922) had recommended the establishment of small experimental reindeer herds in a number of localities. Thus in April, 1926, A. E. Porsild, assisted by his brother, was appointed to make a general botanical reconnaissance of northwestern Canada with special reference to reindeer pasture and other general conditions of importance to a future reindeer industry. Porsild (1929) concluded that the arctic coast and Eskimo Lakes regions of the Mackenzie District had a carrying capacity for at least 250, 000 reindeer while the Great Bear Lake basin could support 300, 000 more.

In 1929 agreement was reached between the Canadian Government and the Lomen Reindeer Company for the delivery of 3, 000 reindeer from Alaska to the Mackenzie River delta. The delivery was completed in 1935, after a drive which took six winters and five summers (Miller 1935, Lomen 1954, Scotter 1966). The final tally was 2, 382 reindeer comprising 1,498 does, 611 bucks, and 273 steers. Only 10 per cent of the animals were from the original herd; all the others had been born on the trail. This was fewer than the 3, 000 animals Lomen had promised, but the birth of 800 fawns within a few weeks more than made up for the losses.

The reindeer venture was intended to improve the economic condition of the native people by supplementing the dwindling wildlife resources of the region. As elsewhere, the arrival of traders and the introduction of firearms into the Arctic had greatly reduced the herds of barren-ground caribou (*Rangifer tarandus groenlandicus*) and other wild mammals, which were the principal livelihood of the Eskimos. The scarcity of wild mammals forced those people to resort to trapping in order to purchase food and other necessities, and their economic condition, therefore, varied with the fluctuating supply of fur-bearing animals and the price of pelts.

The Reindeer Preserve

Location: The Reindeer Preserve, near Inuvik, Northwest Territories, is bounded by the Beaufort Sea on the north, the Mackenzie River on the west and the Anderson River on the east. The original preserve of 6, 600 square miles was established in 1933 and enlarged to 18, 000 square miles in 1952. Suggested areas for summer, winter, and spring-fall grazing are shown in Figure 1.

Vegetation: The major geographic regions of the preserve were described in detail by Mackay (1963). The northern portion of the Reindeer Preserve including Richards Island, the Pleistocene Coastlands, the northern portion of the Fluted Plains and the northern part of the Anderson River Uplands, lie within the tundra zone. The southern portion is in the boreal forest zone. The general vegetation sequence from north to south, as mapped and described by Mackay (1963, p. 164), is '... tundra; tundra with scrub willow and ground birch; scrub willow and ground birch; woodland and tundra with much scrub willow and ground birch; open woodland; and continuous woodland....'

In the poorly drained tundra area several communities and micro-communities occur in close association. They may be only a few square feet in size, but they are scattered over large areas. The frequent occurrence of tundra polygons, mounds, hummocks, ponds and lakes adds to the heterogeneity in many areas. Tussock communities are dominated by sheathed cotton-grass (*Eriophorum vaginatum*), although there is considerable variation in the composition of stands, and dwarf shrubs and sedges may be abundant or almost lacking. The depressions between tussocks and polygons are covered with *Sphagnum* spp. and other bryophytes. The polygons support a dense carpet of lichens, including *Cetraria nivalis, C. cucullata,* and *Cladonia* spp. Although several species of sedges occur on the tundra, mournful sedge (*Carex lugens*) is the most common in many communities. Dense mats of salt-marsh sedges (*Carex salina* and *C. subspathacea*) occur along seashores subject to flooding at high tide.

The better drained parts of the tundra support dryas (*Dryas integrifolia*), white heather (*Cassiope tetragona*), willows (*Salix arctica* and *S. glauca*) and grasses (*Poa* spp., *Trisetum spicatum,* and *Arctagrostis latifolia*).

Open woodlands comprise most of the area east of the Inuvik-Campbell Lake region although continuous woodlands, as mapped by Mackay, occur in the southwesterly fringe of the preserve. White spruce (*Picea glauca*) and black spruce (*Picea mariana*) are the predominant trees on most upland sites. Black spruce dominates muskeg terrain. Paper birch (*Betula resinifera*), larch (*Larix laricina*), and balsam poplar (*Populus balsamifera*) are dispersed on favourable sites. Several chens in association with sedges, grasses,

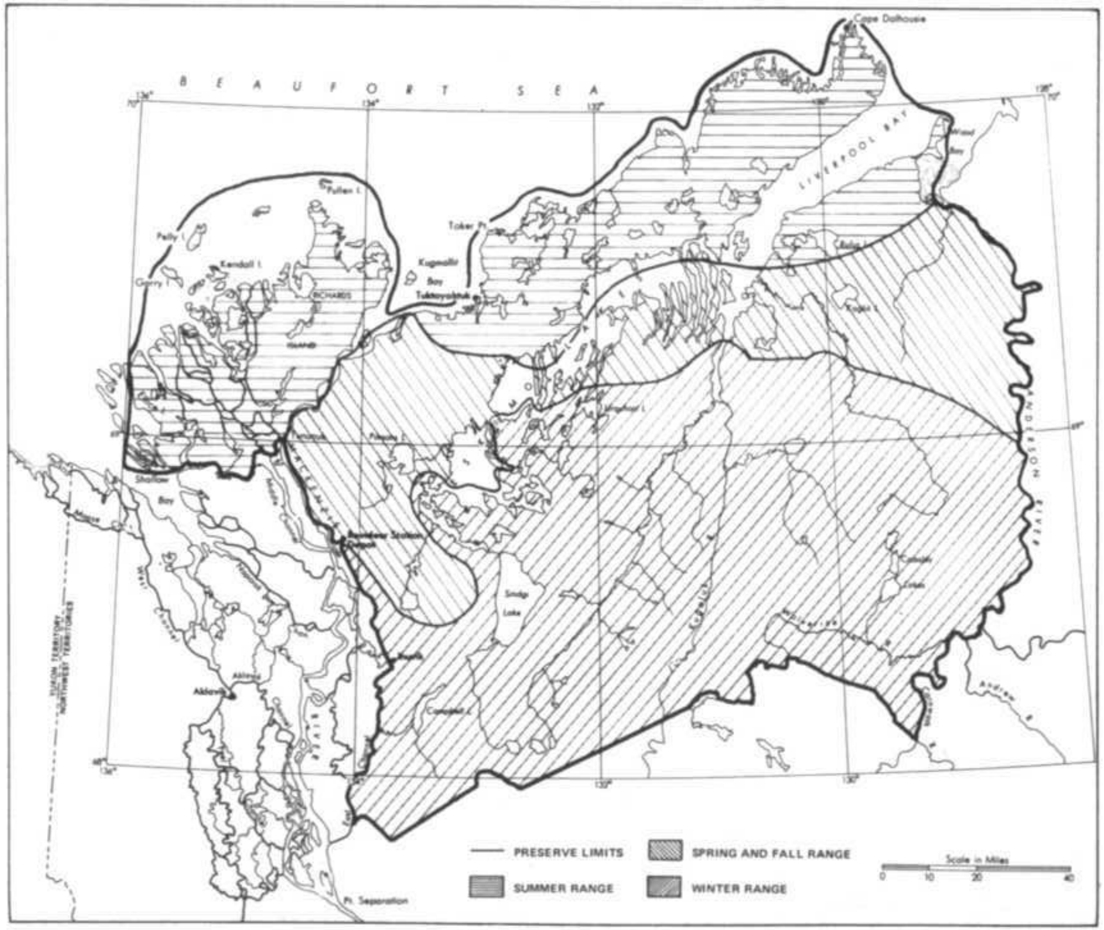

Fig. 1. Map of the Reindeer Preserve showing the suggested areas for summer, winter, and spring-fall grazing.

and various ericaceous shrubs comprise much of the cover among the trees. These lichens, especially *Cladonia alpestris, C. arbuscula, C. mitis,* and *C. rangiferina,* are a major winter forage of reindeer.

Shrub vegetation occurs between tree line and tundra with willows (*Salix spp.*), ground birch (*Betula glandulosa*), alder (*Alnus crispa*) and ericaceous shrubs characterizing this transitional zone. Several sedges, grasses, and lichens thrive in association with the shrubs. Fires have burnt part of the open woodland and shrub communities, especially between the Caribou Hills and Kugaluk River.

Climate: The coastal area of the Reindeer Preserve lies in the arctic zone and the southern portion in the subarctic (Mackay 1963). The mean annual total precipitation is low, varying from 6 inches at Tuktoyaktuk to 11 inches at Inuvik. During the summer, fog is common, especially along the coast and the July and August mean temperatures are only about 50 °F. Winters are long and cold with snowfall increasing inland from the coast.

Carrying capacity: Porsild (1929), without the benefit of maps or aerial photographs, estimated that the Arctic Coast in northerwestern Canada would support 250, 000 reindeer. The present Reindeer Preserve takes up about one-third of that area, so on the basis of Porsild's estimate it should support approximately 85, 000 reindeer (Hill 1967). Porsild (1936) estimated the original preserve would support indefinitely a total of 25,000 reindeer. Clarke (1942) estimated the carrying capacity of the original preserve of 6, 600 square miles at 50, 000 animals but S.B.Johansson, a former herd manager. lowered the estimate to 30, 000 reindeer, although the size of the preserve had since been tripled. Scotter (1968), who studied range conditions and trends in 1965 and 1966, found Johansson's estimate of 30, 000 to be acceptable, provided good range management practices were employed and the whole preserve was utilized. At the present time only about one-quarter of the preserve has been subjected to intensive use.

Past over-optimistic estimates of carrying capacity arose in part from a failure to consider the period of rotation required for lichens to recover from grazing. Skuncke (1969) concluded that from 8 to 10 times more range is required than would be indicated by theoretical calculations.

Fires have burned over many square miles of open woodland and scrub vegetation between the Caribou Hills and Kugaluk River. If the carrying capacity of the preserve is to be maintained, it is clear that control and prevention of fires on the winter range is necessary. One major fire could destroy the basis of the whole reindeer operation. Since the area is becoming more accessible to fishermen and tourists, the risk of fire is increasing.

Oil exploration on the preserve has expanded rapidly. The effects it might have on the carrying capacity of the range and the movement of reindeer is a subject of conjecture. If the best practices are employed, the effects should be minimal and temporary.

Management of the Herds

The original plan of the reindeer experiment was to set up a government-owned main herd which would form a nucleus for smaller herds as numbers permitted. The smaller herds would be turned over to suitable Eskimos and each would be assigned to particular winter and summer ranges. As the native-held herds grew in size, their holders would gradually repay the number of animals they had been given. Ultimately, these Eskimo herds would become self-supporting units. Those objectives were never reached.

Between 1938 and 1954, six native-owned herds of about 1, 000 animals each were established. Most of those herds increased in numbers for a few years and then declined, finally reverting to government ownership. The owners of the first two herds were killed in a boating accident in 1944 and their herds were amalgamated under government supervision. The last native-owned herd functioned until the managers decided to return the herd to the government in 1964.

The attempt to improve the economic conditions of the Eskimos through reindeer husbandry failed for many and complex reasons. Lantis (1954) suggested that the Eskimos' resistance to reindeer herding is based on their value system. Few Eskimos could be enthusiastic about the monotonous task of reindeer herding—changing a hunter into a herder would mean changing not only his habits but also his whole psychology. Most

Eskimos were unwilling to turn from traditional pursuits and ways of life to become mere followers of reindeer herds. In the late 1950's more rewarding employment, such as wage labour and more remunerative trapping, became available. These were seasonal and did not have to be carried on throughout the year to be profitable.

Sonnenfeld (1959) suggested that the inland Eurasian herders, who originally hunted wild reindeer, were able to make the transition to herding domesticated reindeer because they were accustomed to following animals. He speculated that reindeer ranching in Alaska might have been more successful among inland Eskimos than among those on the coast who lived in permanent settlements for a good part of the year. Perhaps the same theory could be applied to the Mackenzie Delta operation.

Other minor problems have included predation; poaching; and disease, including footrot; and an undetermined weak-bone ailment that occasionally afflicts the herds.

The Mackenzie reindeer operation suffered from attempts to apply 'Lappish' practices. Many of the methods employed in Scandinavia are years behind the animal husbandry. and range management techniques employed in livestock operations in North America. Some of the unfavourable practices included close herding, unsatisfactory herd structures with high male to female ratios, and poor breeding methods. The assumption that the pastoral practices used by the Laplanders were suitable for the Canadian reindeer operation is certainly questionable. The Fennoscandian reindeer operation itself has been plagued with problems (Scotter 1965), although the adoption of modern practices is improving the outlook for the industry.

In Canada there has been a lack of effective direction in the reindeer operation, partly because some of the people chosen as managers have lacked experience with livestock operations or wildlife management; partly because of the absence of a coherent, practical policy; partly because of a lack of biological input. The lack of funds and the great distance to the decision making body in Ottawa were major problems, also.

In 1960, the reindeer project was placed in the hands of a private contractor who, it was hoped, would put it on a self-supporting footing. However, during the entire period in private hands costs exceeded revenues by a ratio of 3 to 1.

Only casual herding with some aerial reconnaissance was used from 1963 until the termination of the contract in 1968 and during that time the reindeer population decreased from 8,400 to about 2, 800 animals. In Russia, Preobrazhenskii (1968) suggested that free and semi-free grazing should not be used, but Mäki (1966) noted that in Finland intensive reindeer husbandry is giving way to more extensive methods. In Canada casual herding with only sporadic supervision was discredited by the results obtained.

The Canadian Wildlife Service assumed responsibility for operations in April, 1968. It proposes to make scientific studies of the animals and their ranges, and to develop management techniques that will ensure a high yield of meat at reasonable cost. The eventual goal of the industry, according to the Department of Indian Affairs and Northern Development, is private ownership, preferably by native people. As in the past, the project will be heavily subsidized for the next few years. However, with added biological management and research the feasibility of continuing the operation as a viable economic industry will be tested.

Growth and Decline of the Herds

Reindeer numbers increased from 2, 382 at the time of delivery in 1935 to 9, 347 in 1942. From then until 1967 the totals fluctuated between 5, 000 and 9, 000 (Figure 2). After aerial counts in 1967, the population was estimated at approximately 2, 800 animals.

Between 1935 and 1969 an estimated 65, 000 reindeer fawns were born on the preserve. Annual fawn crops have ranged from 815, born upon arrival of the herd in 1935, to a questionable estimate of 3, 700 in 1966 (Figure 3). Some of the estimates in recent years, like the one in 1966, are questionable, since the fall herd count in 1967 was fewer than 2, 800 reindeer. The proportion of fawns in the herd has ranged from 24 to 35 per cent.

During the same period approximately 29, 000 reindeer were slaughtered, the numbers varying from none in 1935 to 1,786 in 1955 (Figure 3). Natural losses, including straying, have accounted for 30, 000 animals, ranging from 70 in 1940 to an estimated 2, 738 animals in 1945 and about 5, 600 in 1967 (Figure 3). Excluding the large loss in 1967 which may

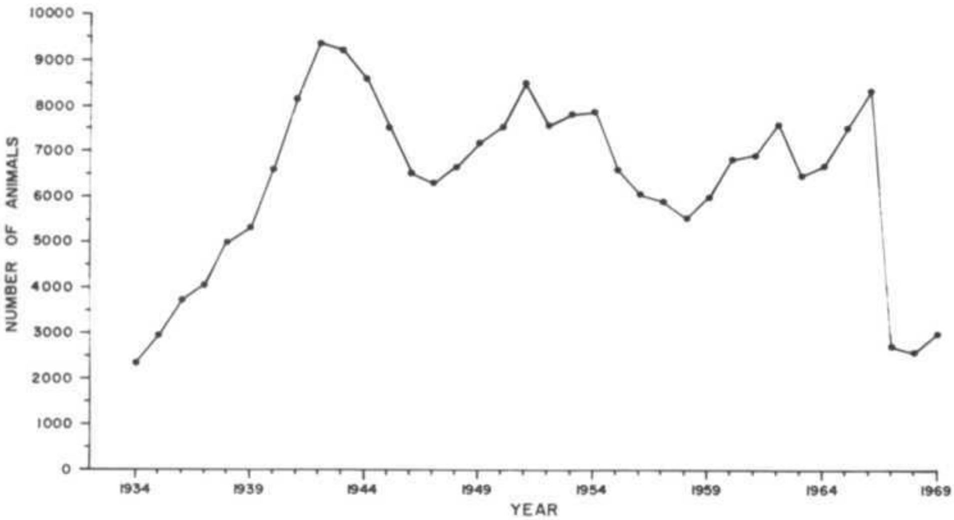

Fig. 2. Estimated total number of reindeer in all herds at the Reindeer Preserve at the end of the year, 1935 to 1968 [data taken from Krebs (1961), Hill (1967), and the files at the Reindeer Preserve].

be due to exaggerated population estimates made while the reindeer were managed under contract, losses have been as much as 36 per cent of the herd in one year. Publications by Krebs (1961) and Hill (1967) give more details on the population dynamics of the herd.

Future of the Herd

The possibility of reindeer herding as a viable industry in the Mackenzie Delta region cannot be totally dismissed. Hill (1967) estimated the potential market for reindeer meat in the area to be 150, 000 pounds in 1967, with an increase to 210, 000 to 280, 000 pounds by 1977. He calculated that a herd of 30, 000 reindeer could produce a sustained yield of over 1, 000, 000 pounds of meat per year. Certain economies in operation could be expected as the size of the reindeer operation increased. There is no doubt that the availability of fresh reindeer meat at modest cost has contributed to the economy of the Delta. In addition, the industry has provided employment for local people.

It is not as yet possible to assess the value of the reindeer project. Too much remains unknown about the yield of the herd under improved techniques, the possible impact of higher meat prices and the possibility of exports to southern markets. We need to find out whether the reindeer operation is economically feasible. It is certainly biologically possible, for reindeer have lived and reproduced there for more than three decades.

A game-ranching type of caribou operation should be considered as an alternative. This could prove to be more economical. In recent years, the Canadian reindeer industry has been little more than a game management operation. With caribou in the area on the increase, is there any advantage in game-ranching reindeer—an introduced species? Reindeer were introduced not to replace a native animal, but to supplement dwindling herds of caribou and other wildlife. The Royal Commission report advised restraint in establishing reindeer herds or granting reindeer leases in areas where there might be conflict with caribou. In addition, Rutherford, McLean, and Harkin (1922, p. 37) wrote, 'Altogether apart from the proposed introduction of domestic reindeer the vast herds of wild caribou which undoubtedly still exist in the interior mainland area... constitute a valuable national asset, the importance of which, if properly dealt with, can be enormously enhanced...'.

The fact that an exotic species is replacing a native one on the preserve has caused insufficient concern among biologists and ecologists. Hall (1963, p. 267) wrote, 'Introducing

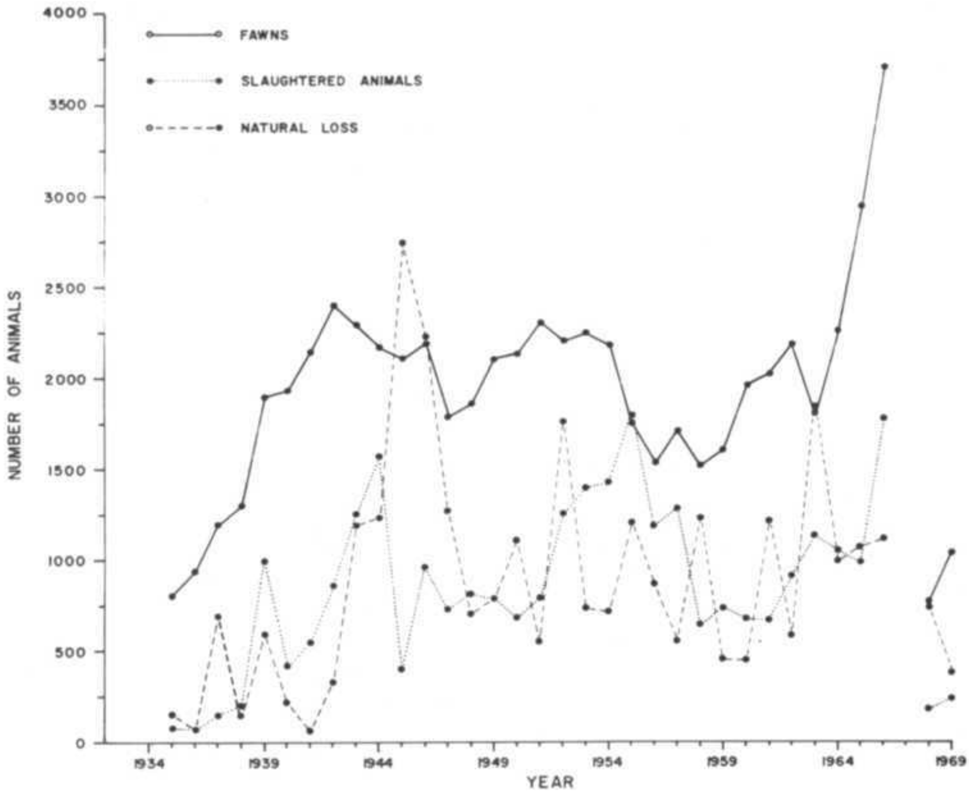

Fig. 3. Estimated number of fawns, slaughtered animals, and natural losses at the Reindeer Preserve, 1935 to 1969 [data taken from Krebs (1961), Hill (1967), and the files at the Reindeer Preserve!.

an exotic species is a destructive action resulting from the ignorance of well-meaning persons... . Introducing exotic species of vertebrates is unscientific, economically wasteful, politically short-sighted, and biologically wrong.' Perhaps the same statement should be applied to reindeer on the preserve.

Game-ranching caribou could provide natives with an activity more in line with their traditional pursuits. It could supply local areas with fresh meat at competitive prices and by-products, such as skins and hoofs, that could be used for handicrafts. In the past, caribou has been an unreliable food source in northern areas because of large fluctuations in numbers. Research and modern game management may prevent this. Kelsall (1968) stated that the caribou herd north of Great Bear Lake, which includes those animals infringing on the Reindeer Preserve, have consistently been under-utilized by humans. He suggested that harvest for export might be allowed, if properly managed. We should give priority to gaining sufficient knowledge of caribou in the northwestern District of Mackenzie and the northern Yukon to support sound management recommendations.

From the political standpoint, discontinuing the reindeer project would give rise to strong local protest but, in the long-term, game-ranching with caribou may be ecologically and economically more feasible. Unfavourable comparisons with what has been achieved in other countries may be made. It must be rememberd, however, that the Canadian government's treatment of northern natives has been different from that of other countries. In addition ecological conditions are different, so that valid comparisons are difficult to make.

NATIVE ANIMALS VERSUS REINDEER IN OTHER AREAS OF NORTHERN CANADA

In other areas of northern Canada, caribou and other native animals such as moose (*Alces alces*) and musk-oxen may offer the best potential for converting northern vegetation into commodities for consumption by man. Such animals provide meat, hides, hoofs, and other products useful to the indigenous people and other residents of the north, without the constant attention, skills and expense required to raise domesticated animals. If wildlife attractions are properly promoted, non-resident sport hunters and other tourists may well put enough cash into the economy, through the purchase of licences, hiring of guides, accommodation and meals, to more than compensate for the lack of revenue from a reindeer industry.

Information from Africa and other parts of world suggests that native ruminants are generally more efficient in the use of native forage than introduced animals. Klein (1970) believed that the wild populations of caribou and musk-oxen offer the best potential for conversion of vegetation into a usable product in northern Alaska.

CONCLUSIONS AND SUMMARY

Reindeer husbandry in Canada has had a rather inauspicious history, although introductions were conceived and begun with great expectations. The first attempt at a reindeer introduction into Canada was made in Labrador under the direction of Dr. Grenfell, but an initial increase in animal numbers was followed by failure. Two transplants from that herd, one to Anticosti Island and one to the Great Slave Lake region, were unsuccessful.

Introduction of reindeer to Baffin Island by the Hudson's Bay Reindeer Company was an almost immediate and dramatic failure. Lack of forage and inefficient herding and management were blamed.

The most successful attempt at reindeer husbandry in Canada has been the Mackenzie Delta herd established to supplement wildlife resources of the region and to improve the economic condition of the Eskimos by creating a number of viable native-owned herds.

A reindeer industry is biologically feasible, as proven by the maintenance of the reindeer herds there for 35 years. The operation, however, has been a social and economic failure for several reasons. Few Eskimos were interested in the monotony of reindeer herding—by 1964 all the native-owned units had ceased operations. In the reindeer operation there was too little consideration of modern animal husbandry and range management practices. And if that were not enough, some managers of the reindeer operation lacked experience with livestock, funds were limited, and the decision-making agency was thousands of miles away in Ottawa. More recently, the reindeer operation was managed under contract almost as a game-ranching operation but the number of animals declined markedly, presumably because of straying.

The reindeer in the Mackenzie Delta region are using a forage resource that might otherwise be used by caribou. Caribou numbers are increasing in the area, and there is less justification for maintaining a reindeer herd than when the wildlife resources were depleted. From a biological standpoint it is questionable whether an introduced species should be established to replace a native animal. The cost of operating the reindeer industry may not be worth the actual or potential benefits since caribou may provide the same products, at lower cost.

Native animals in other areas of northern Canada may offer the best potential for conversion of vegetation into useable meat products. Under free-ranging conditions, they select the highest quality forage available to them in order to meet their nutritive requirements. By comparison, reindeer are at a marked disadvantage because they must be confined to be of greatest value to their owners.

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Paper No. 19

Birds Useful to Man in Greenland

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The human population in Greenland, now numbering about 46, 000 individuals, is exclusively attached to the sea-shore where all the cities and the minor outposts are situated. The shooting of sea-birds is an ancient tradition while the true land birds, which are few in number in Greenland, as a rule are left alone. Only during the reindeer hunting, which usually takes place in September, a number of inland birds, including geese, ducks, ptarmigan and others, are shot.

The shooting of birds does not play as big an economic role as sealing, whaling and fox-hunting, but still means production of an important source of food that the Greenlanders could not be without. A special shooting culture is not developed among the Greenlanders, instead the shooting often resembles a sort of slaughter more than regular hunting. Some species of sea birds were, some years ago, threatened with extinction due to ruthless human predation which steadily increased on account of the growing population and the general distribution of guns. This sad development has been countered in recent years with various restrictions from the Greenland Government, although it must be granted that the tide has not yet turned. In 1960 a proposal to regulate shooting and protect a number of birds was sent to the Greenland Government by the Danish Nature Conservancy. This proposal, which I had the pleasure to present to the Greenland Government in the summer of 1960, after discussing details with various members of the Government, was generally well accepted and the law took effect from January 1, 1961 (cf. Gr0nlands Landsrads forhandlinger 1960, p. 21, 73 & 149; Nalunaerutit[2] 1960, ser. A, p. 84-86). Another important measure has been the prohibition of shooting at sea-bird rookeries, especially at those of the thick-billed murre or Brunnichs guillemot (*Uria lomvia*). These prohibitions have, as a rule, been issued by the local magistrates, and have been respected by the inhabitants to a variable extent. Ordinances issued by the Jakobshavn Magistrate, concerning the prohibition of shooting near several local rookeries appear to have given the best results. In Jakobshavn District red buoys were set up about 1 km from the rookeries, showing the boundary within which it was forbidden to fire shots, and in the last few years a permanent watchman has been placed near the biggest rookery of the district during the entire breeding period. Generally speaking (apart from Jakobshavn District) prohibitions are usually not taken too seriously by the inhabitants. Since the police forces are too few in number to be of much help for the preservation of wildlife and sometimes even do not know the local ordinances themselves, the result has been that the sea-birds, previously profusely flourishing, have considerably decreased in number along the West Greenland coasts.

The Greenland Government is usually ready to meet the wishes of Danish expert advice and is sympathetic to the ideas of nature conservation, but nevertheless, no general game

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[2] Nalunaerutit—The Greenland Statute Book.

acts have been proposed in Greenland, and virtually no ornithological sanctuaries have been erected. The Scientific Commission of Greenland has worked hard for a game and conservation act in recent years but for political, financial and other reasons it has not been possible to make any promulgation. However, the situation has been somewhat—but very slowly—improved owing to a number of laws, dealing with restriction in shooting time or other regulations, issued by the Greenland Government or by the local magistrates. A few of these rules have been dealt with already, and a few other recent ones will be mentioned.

Owing to increasing land reclamation in recent years in Eire, the main wintering area of the Greenland white-fronted goose (*Anser albifrons flavirostris*), the existence of this subspecies was seriously threatened and it was, therefore, agreed that it should be protected during its short stay on its breeding places in Greenland. In 1967 it was decided to prohibit egg-collecting and all shooting of adult birds as well as of goslings from June 1 to July 31 (Nalunaerutit, 1967, ser. A, p. 257). It should be mentioned here, also, that Danes or foreigners visiting or residing in Greenland, have to pay a special shooting licence, while hunting by the Greenland inhabitants is free everywhere. When a great number of Danish workmen in the southernmost part of Greenland obtained speed boats for rapid transport to vacation resorts, shooting from speed boats was prohibited in 1967 in Nanortalik District in Southwest Greenland in order not to disturb the migrating or wintering ducks, auks, cormorants etc. (Nalunaerutit 1967, ser. B, p. 40). This important regulation, it is to be hoped, will be copied in the other Southwestern Greenland districts which are occupied by large numbers of wintering sea-birds.

In Northeast Greenland, north of Scoresby Sound, which is uninhabited apart from irregular expeditions, a few mining settlements and the police sledge patrol 'Sirius', bird shooting has for many years been very restricted. The only species for which shooting in the breeding season and collection of eggs are permitted are the raven (*Corvus corax*), the fulmar (*Fulmarus glacialis*), the parasitic jaeger (*Stercorarius parasiticus*), the Glaucous gull (*Larus hyperboreus*), the Iceland gull (*Larus glaucoides*), the thick-billed murre and the dovekie (*Plautus alle*). The ptarmigan (*Lagopus mutus*), the old-squaw (*Clangula hyemalis*), the red-throated loon (*Gavia stellata*), the black guillemot (*Cepphus grylle*), and the kittiwake (*Rissa tridactyla*) and their eggs are protected from May 1 to August 1. All other birds, including all shore birds, geese, birds of prey and passerines, are fully protected.

In the following I shall deal with the bird species which are most important in the economy of the Greenlanders, particularly those of the west coast. Bird-banding has been an important technique in dealing with shooting pressure, protection, etc. of the West Greenland birds. An official bird-banding system under the directorship of the Zoological Museum of Copenhagen and the Ministry of Greenland has been carried out since 1946 and now has records of 110, 000 birds banded with about 7, 000 recoveries, by far the greater part (more than 6, 000) within the boundaries of Greenland. I have dealt with bird-banding in my book "Fuglene på Grønland" (Salomonsen 1967) and a shorter description of the unique Greenland bird-banding, the only reqular banding system operating in the Arctic region, may be found in Salomonsen (1959).

The economically most important West Greenland bird is the thick-billed murre. An analysis of the banding results has shown that about 750, 000 birds, equivalent to about 825 tons of meat, are shot annually. The flesh is eaten, the feathers are sold to the governmental trading company, skins with feathers were formerly used for clothes and blankets. Also the eggs are eaten, but egg-collecting is of importance only in Upernavik District, where about 10, 000 eggs are collected annually. The breeding cliffs are usually only accessible with great difficulty, which is the reason why egg-collecting is only of minor importance, but there is no legal restriction anywhere on egg-collecting of this species. No rational fowling takes place in Greenland, but the breeding birds are shot in great numbers near the rookeries. In small outposts situated near rookeries murres constitute the main dish during summer, and great quantities are dried and salted as nourishment during the winter. A very pernicious habit which is developed in Umanak District and also in other places is shooting of breeding birds at the rookeries by means of saloon rifles, but in most places shooting at rookeries is prohibited. In Thule District, (North Greenland) the hunters are busily occupied in summertime catching whales (narwhales, bulugas)and walrus and the slightly less than one million pairs of murre breeding in this district are, therefore, practically speaking not disturbed in their breeding season.

In Upernavik and Umanak Districts the murre is, to the contrary, heavily persecuted in summer, and in recent years a murre cannery has been erected in Upernavik, which supplies a number of southern cities with frozen murre meat in the off-season. This cannery has in recent years had a capacity of about 20, 000 murres annually. During winter both Greenlanders and Danes shoot many murres in South Greenland waters where large numbers spend the off-season. The heavy shooting of this species could probably be withstood, or could at least be managed, if the breeding places were protected from shooting. This is in many parts of Greenland - but not everywhere - accomplished through rules issued by the local magistrates, but usually with poor results. In recent years still another threat to these birds has appeared. After the breeding season both adult birds in wing moult, and hence flightless, and immatures still unable to fly undertake a long swimming voyage to the south. When the enormous flocks are passing the fishing banks off Southwest Greenland, usually late in August and early September, great numbers may accidentally be entangled in floating fishing nets and drown. In 1967 about 15, 000 succumbed in this way and were transported to the nearest coastal town where they were sold for food. This may turn out to be a dangerous situation, but at present we do not know if such events are exceptions or if some legal means should be effected to prevent them.

Shooting of thick-billed murres along the West Greenland coast concerns the following populations, as shown by means of large-scale Canadian, Greenland and European banding:

(1) The Northwest Greenland populations. A great number is shot during summer (67% of the recovered birds), a much smaller number during migration and a negligible number in winter, which usually is spent in the Newfoundland sea.

(2) The Lancaster Sound population, which mainly winters in Southwest Greenland, is shot from October to May, during migration, and on the winter range which mainly covers Egedesminde and Holsteinsborg Districts. About 160, 000 specimens of this population are shot annually.

(3) European populations, including those from Spitsbergen, the Murman Coast and Novaya Zemlya, but by far the greatest part originating from Spitsbergen, which winter off Southwest Greenland, from Sukkertoppen District to Cape Farewell, and are shot from November to February. The annual kill is about the same as for the Lancaster Sound population.

(4) Other populations. A comparatively small number of usually immature birds from the rookeries on Funk Island and on Wolstenholme Island, Hudson Strait, is shot in West Greenland, as a rule in summer. Also a few European birds, usually immature ones, are shot in summer in West Greenland.

The eider duck (*Somateria mollissima*) also constitutes a most important source of food in Greenland. The flesh is eaten, and formerly also the eggs, but according to statutory provisions issued by the Greenland Government egg-collecting is now forbidden. An exception is the Thule District where some 10, 000 eggs are still taken and cached for the winter. In this district egg-collecting has always been strictly controlled by the local magistrate, but nevertheless the number of breeding birds has diminished. Further, the down of the eider collected from the nests is sold to the trading company and used for the much demanded eider-down coverlets. Formerly when the skins were much used for bird-skin coats by the Greenlanders the eider was pursued and, consequently, it diminished alarmingly and appeared to be almost exterminated in Southwest Greenland at the beginning of this century. In 1924 and 1929 the Greenland Government then prohibited egg-collecting and the capture of mated pairs, brooding females and flightless birds. At present the Eider is shot mainly during its regular morning and evening movements between feeding places and areas where they spend the night, as well as during the spring and fall migration. A shooting analysis carried through by the Greenland Government in the years 1948-51 showed that the number of eiders shot annually in all of Greenland was about 144, 000. Fifty years previously the number was estimated as 150, 000, i.e. about the same order of magnitude. Banding has shown that about 22% of the population is shot, and this figure makes it probable that the entire population in Greenland is of a magnitude of about 50,000 pairs when immature non-breeders and other sources of error are taken into account. This is a rather inconsiderable number and, at any rate, must have been much greater previously. The amount of down purchased by the trading company corresponded in the 1820's to about 110, 000 nests annually but in about the year 1900 the figure had dwindled to about 8, 000 nests. This enormous decrease must somehow be connected with the wholesale slaughter carried out by man in the 18th century, but Vibe (1967) correlates the fluctuation of the eider and other animals in Greenland with climatic changes. This will not be discussed here, but it should be noted that the sales of rifles, shotguns, lead and shot in Greenland (Vibe, l.e., fig. 55, p. 100) cannot be correlated with the decrease in the eider stock as might be supposed a priori. Whatever the cause of the decline the situation nowadays is far from satisfactory, and the Greenland Government must deal almost every year with the eider question which is not satisfactorily settled. This is mainly due to jealousy between the population in the northern parts of Greenland which is used to shooting eiders only in the breeding period and that of South Greenland which can shoot these birds only in their winter quarters. According to the latest laws, promulgated by the Greenland Government in 1959 and 1960, shooting north of Søndre Strømfjord (Sonderstrom) is quite unrestricted, apart from the fact that in the period May 15-September 14, it is only legal to hunt 'moving flocks' not 'pairs' or breeding birds, and all shooting and other disturbances at the breeding colonies are prohibited. Collecting of down at deserted nests must not take place until after July 20. South of S0ndre Strømfjord all shooting is prohibited June 15-September 30, and only shooting at 'moving flocks' is allowed May 15-June 14. Egg-collecting is prohibited throughout (except in Thule District) and it is absolutely forbidden to visit colonies of breeding eiders. There are a number of other rules dealing with this species that it is not necessary to mention here. These laws are rather good, but in recent years it had been necessary to make a number of changes in order to satisfy special groups of the inhabitants. It is especially dangerous that Eider Duck Island in the Upernavik District now can be entered 'by hunters who want to keep lookout for seals'. No doubt the Eider Duck rules will be subject to other changes in the future.

No other sea-bird is as important for the economy of the Greenlanders as the murre and the eider. Other species that serve as a source of food are mentioned in the following paragraphs.

The red-throated loon (*Gavia stellata*) is hunted to a small degree only, as the meat is not considered particularly palatable. Banding, which only includes a small sample of birds, shows that about 7-8% of the population is shot.

The fulmar (*Fulmarus glacialis*) is usually not regarded as edible at all except in Umanak District, where the greatest breeding places in Greenland are situated and where even the eggs are collected. According to banding returns 4% are shot in Greenland, by far the greater part in Umanak District, and 0.2% are shot abroad. In the said district about half the number of birds secured are young speciments obtained in the fall (in September or early October) when they leave the breeding cliffs and are not yet fully able to fly. The other half are adult or at least fully grown birds shot or taken with hook and line from the end of April, when they arrive at the breeding places, to the end of September, when the last ones leave the area.

The great shearwater (*Puffinus gravis*) being only a summer visitor to Greenland approaches land in August and collects in huge flocks. The wing moult then takes place and the birds are able to fly only with difficulty. In this period they were in former days rather heavily persecuted from kayaks, and even yet a number are shot in August, mainly by fishermen on the fishing banks off the coast.

The cormorant (*Phalacrocorax carbo*) is extensively hunted by the Greenlanders, both in summer and at wintering places in Southwest Greenland. Banding has shown that usually 30% of the population, sometimes even 40% are shot, and that the species is steadily decreasing in number. In 1961 it was protected from March 1 to September 30, and it is now again rather rapidly increasing in number. In this case protection came right in time.

The mallard (*Anas platyrhynchos*) which is non-migratory in Greenland, is hunted only to a limited extent, probably because it is an inland bird in summer and frequents the coastal area in winter only. About 10% are shot, according to banding returns, which is a much smaller percentage than in Europe and America.

The old-squaw or long-tailed duck (*Clangula hyemalis*) which breeds rather commonly in the greater part of Greenland, both in the inland areas and along the coast, is not much persecuted by the Greenlanders. About 17% are shot in Greenland proper and to this figure should be added a few percent shot abroad.

The harlequin duck (*Histrionicus histrionicus*) is a rather common breeding bird in the southern (low-arctic) parts of Greenland. It was previously hunted only on a very modest scale and in 1963 was totally protected by the Greenland Government. All collecting of eggs was prohibited at the same time.

The king eider (*Somateria spectabilis*) breeds rather commonly in the northern (high-arctic) parts of Greenland in which areas it is virtually never shot. It winters off the ice-free coasts of Southwest Greenland, partly also off the coasts of northern Iceland and in the St. Lawrence Gulf, as banding returns have shown. Birds originating from North Greenland and the greater part of northern Canada collect in enormous numbers in July-August along the low muddy coasts and estuaries of the middle parts of Southwest Greenland and carry out their wing moult. Banding has shown that about 15% are shot in Greenland, which is distinctly less than the corresponding figure for the common eider, probably due to the fact that the king eider winters further out to sea where it is difficult to approach. To the figure mentioned should be added about 0.4% of the population shot in winter in other countries. It is prohibited to take king eider eggs in the period May 15-September 14, i.e. in the entire breeding period. During the period of wing-moult it is prohibited to shoot or catch flightless birds. Further, the bird itself is protected 'inland' i.e. on the breeding places. Finally, it is fully protected in Northeast Greenland.

The red-breasted merganser (*Mergus serrator*) is occasionally hunted by the Greenlanders; according to banding returns about 8% of the population is shot.

The white-fronted goose (*Anser albifrons*) breeds in parts of the low-arctic areas in West Greenland and winters mainly in Ireland. According to British investigations the entire Greenland population consists of 14, 000 individuals only. According to copious banding returns only 7% is shot in Greenland and about 16% in countries abroad, mainly the British Isles and Iceland. As stated above, the white-fronted goose is now protected in Greenland in the breeding period.

The pink-footed goose (*Anser fabalis brachyrhynchus*) breeds in the central parts of East Greenland and winters in Great Britain. It is protected in the greater part of its breeding area, but a few are shot by Greenlanders in Scoresby Sound District and about 9% on the winter range. The number of banded birds is too small to be of statistical value.

The snow goose (*Anser caerulescens*). This American and East Asiatic species breeds in Greenland only in Thule District where it is fully protected and appears to be increasing in number. In the summer of 1968 I observed in Thule District about 500 specimens among which were 23 pairs with goslings. There are known breeding places in Thule District other than those visited by me.

The brent goose (*Branta bernicla*) is extensively hunted by the Greenlanders, but only during migration. No banding of this species has been done in Greenland.

The barnacle goose (*Branta leucopsis*) breeds in Northeast Greenland and winters in western Scotland and northern Ireland. Investigations in its winter quarters have shown that the Greenland population consists of about 14, 000 individuals. It is fully protected in the greater parts of its breeding range in Greenland, but the inhabitants of Scoresby Sound District shoot about 0.4% of the population, while about 7% are shot in winter quarters.

The white-tailed sea-eagle (*Haliaetus albicilla*) breeds only in the southern parts of the west coast, where hardly more than 50 pairs are found. It is, unfortunately, regarded as a harmful bird in the sheep-farming districts where it is heavily persecuted, and no less than 35% are shot annually according to banding returns. In 1961, however, it was totally protected in Godthåb District and northwards, while it remained an outlaw in the southern districts. Recent attempts to give this bird full protection all over Greenland have, as yet, proved fruitless.

The peregrine falcon (*Falco peregrinus*) and the gyr falcon (*F. rusticolus*) are shot, to some extent, but the persecution is modest. Since 1961 the gyr falcon has been protected from May 15 to August 31, and egg-collecting as well as export of live or skinned birds is, forbidden everywhere. In Northeast Greenland the gyr falcon is protected throughout the year.

The ptarmigan (*Lagopus mutus*) is not persecuted very much, being mostly hunted by Danes for the sake of sport. It is protected in Southwest Greenland, northward to S0ndre

Str0mfjord from June 1 to July 31, and in Northeast Greenland from May 1 to July 31, and egg-collecting is prohibited in the same areas.

The purple sandpiper (*Calidris maritima*) is the only shore bird hunted to any extent, 14% of the population being shot. Some knots (*Calidris canutus*) and turnstones (*Arenaria interpres*) are shot during migration, but only in a modest number.

The parasitic jaeger or arctic skua (*Stercorarius parasiticus*) is hunted to some extent and 21% of the population is shot, according to banding, from June to early September.

The great black-backed gull (*Larus marinus*), the Iceland gull (*L. glaucoides*) and the glaucous gull (*L. hyperboreus*) all commonly breed in Greenland, the two first-mentioned species, however, only in the low-arctic zone. None of these species ordinarily leaves Greenland in winter. Numerous returns of banded birds show that 25% of the great black-backed gull, 23% of the Iceland gull, and 12% of the glaucous gull are shot. Most in demand are the young birds, and the percentage of birds in their first year (but nestlings not included) amounts in the three species to 73%, 84%, and 87% respectively of all specimens shot.

The kittiwake (*Rissa tridactyla*), in contrast to the gulls, leaves Greenland waters in winter. Therefore, only 5% of the population is shot, and to this figure should be added 0.1% shot abroad, the greater part in Newfoundland waters. Kittiwakes from European breeding places visit Greenland waters in summer, from June to October, in great number, the greater part being immature non-breeding birds. A considerable number of banded birds from northern Russia, Norway, the British Isles, Iceland and Denmark have been recovered in the waters along western Greenland, and it appears that they constitute about 1% of the European populations, as shown by Russian figures.

The arctic tern (*Sterna paradisaea*) is persecuted only to a slight extent, 1% of the population being shot in Greenland. Egg-collecting, which takes place everywhere and incessantly, is more important. Since 1961 egg-collecting has been forbidden after July 1 (in Upernavik District an extension may be given to July 15), but the few enforcement officers have only a limited possibility to see that this enactment is followed.

The dovekie or little auk (*Plautus alle*) is restricted to the high-arctic part of Greenland and is caught in Thule District by the Polar Eskimos with dip-nets. Thousands of specimens have been ringed as adults (or at least fully grown) on the breeding places and 7% are recaptured in later years at the breeding places, but not elsewhere. This figure is extremely small if it is borne in mind that millions of birds breed almost everywhere in the district, and in many places are never touched. Thule dovekies have never been recovered in Southwest Greenland, where a good deal of hunting of this species takes place, and they appear to winter in Newfoundland waters, from where there is, however, only one recovery. The birds shot in winter in the open water area of Southwest Greenland originate in Spitsbergen, as evidenced by a large number of banded birds, of which 0.15% are recovered in western Greenland as winter visitors. The migration in this species appears to be very similar to that in the thick-billed murre, as described above.

The black guillemot (*Cepphus grylle*) is extremely common almost everywhere in Greenland and has been banded in thousands. It is extensively hunted by Greenlanders and Danes, and 12% of the population is shot. Shooting is especially heavy in the fall (August-November) when young specimens are the desired target and 63% of the recoveries are from this period. An additional 17% are from winter, 17% from summer and only 3% from spring (March-April), when the northward migration takes place.

The common puffin (*Fratercula arctica*) leaves the breeding areas and goes to sea soon after the breeding period and, therefore, only 5% of the population is shot, according to the rather meagre banding records. Much more important, however, is the fact that the eggs are collected, with the result that the turf in which the birds have dug their breeding holes is disturbed, and this has caused the puffin to decrease steadily in recent years. It was, therefore, very important that the Greenland Government decided to protect the puffin totally in 1961 and prohibit egg-collecting for 10 years, after which period the question will be reconsidered. This act has probably been a factor in an increase in puffin numbers. They are no longer in danger of extinction, but the situation is not yet satisfactory.

The razorbill (*Alca torda*) which is common in the low-arctic parts of Greenland is hunted in the same way as the murre, but banding has been inconsiderable and very little is known about its economic importance. The Greenland population appears to winter in the Newfoundland area according to the very small number of recoveries.

The raven (*Corvus corax*) is hunted only on account of the damage it does to sheep-farming. A bounty is paid by the government and in 1966, 3, 663 specimens, almost half from the sheep-farming districts in Southwest Greenland, were presented for payment. According to banding returns 38% of the population are shot, but of the recoveries almost 80% are of immature birds. The raven is so common and wide-spread in Greenland that this unnecessary shooting probably has little effect. At any rate, there is no indication of a decrease in the population as yet.

It should finally be added that even small passerines are shot, or more commonly, stoned, by young people to some extent. Of the three commonly banded Greenland species, the Wheatear (*Oenanthe oenanthe*), the Lapland longspur or bunting (*Calcarius lapponicus*). and the snow bunting (*Plectrophenax nivalis*), the figures for recoveries in Greenland, are respectively 1%, 2%, and 2% of the populations. These small numbers do not in any way threaten these species, but this persecution appears not only unnecessary in modern times but also decidedly unethical.

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Paper No. 20

Threatened Vertebrates in Northern Circumpolar Regions

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This paper is concerned with those mammals, birds, amphibians, reptiles and fishes, that spend all or part of their life cycle in the Arctic and whose survival gives some cause for concern, either throughout their world range or within the boundaries of certain circumpolar nations.

THREATENED VERTEBRATES

The International Union for the Conservation of Nature and Natural Resources (IUCN) classifies threatened species as follows:

Endangered

Actively threatened with extinction. Continued survival unlikely without the implementation of special protective measures.

Rare

Not under immediate threat of extinction, but occurring in such small numbers and/or in such a restricted or specialized habitat that it could quickly disappear. Requires careful watching.

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[1] Survival Service Commission, IUCN, Morges, Switzerland.

Depleted

Although still occurring in numbers adequate for survival, the species has been heavily depleted and continues to decline at a rate substantially greater than can be sustained.

Indeterminate

Apparently threatened but insufficient data currently available on which to base a reliable assessment of status.

The factor common to *all* threatened species is not deterioration of status, but vulnerability to extinction in the forseeable future. Thus populations of many 'rare' species are relatively stable, and a 'depleted' species may be retained in the lists, for a period, after its populations have started to increase as a result of better management. Numerous factors, both genetic and environmental, affect the probability of a species' survival, if it is rare or subjected to pressure. Whilst the status of many species leaves little doubt as to whether or not they are threatened, decisions on borderline cases must, of necessity, be made on their individual merits.

World threatened species are those that are threatened with extinction throughout their entire range. Taxa in this category have been taken from the IUCN Red Data Book (Simon 1966, Vincent 1966, Miller 1969) or, in the case of amphibia and reptilia, from the provisional index for this volume (Honegger 1968).

Nationally threatened species for the USA and USSR have been taken from the U.S. Red Book (1968) and the Soviet List of threatened mammals and birds (Gladkov and Nasimovich 1968). Certain mammals, such as *Rangifer tarandus groenlandicus* and *Ovibos moschatus,* have been declared in danger of extinction in Canada by Order in Council.

The selection of threatened forms in other circumpolar nations has been based on the advice of scientists and conservationists in the countries concerned. This information was provided at short notice and the national lists must therefore be regarded as tentative and, very probably, incomplete.

A consideration of nationally threatened fauna raises the problem of *peripheral* species, which are those that are rare within the country under consideration, because they occur on the margin of their range. Peripheral species are not included in this paper, unless they are actively threatened with extinction.

The immediate objective of preparing an inventory of threatened species is to stimulate corrective action; the ultimate objective is to retain diversity. Threatened forms are, in effect, indicator species of mismanagement or change in the biotope. Critical situations often demand emergency treatment, but corrective action should normally seek to rectify the management of the biotope and its dependent taxa as a whole, rather than to remove the immediate threats to individual species.

NORTHERN CIRCUMPOLAR REGIONS

Rausch (1961) defined the geographical location of the arctic as 'the areas of sea and land extending from the pole southward to the northern limits of the coniferous forest (taiga)'. This boundary line suffers certain discrepancies at the extremities of the major continents and in the oceans. In these regions, it fails to delineate the polar and non-polar seas and it includes land areas that are geographically and climatically non-arctic (Baird 1964).

It has therefore been decided to adopt the northern limit of the taiga, exclusive of minor outliers (Polunin 1959 p.viii-ix) on the Eurasian and North American continents only, and the arctic waters limit proposed by Baird (1964, p. 9) as the southern boundary of the regions to be considered. This delineation excludes Iceland, the Alaska Peninsula and Aleutian Islands, but includes the whole of Greenland, Jan Mayen Island, northern Fenno-Scandinavia and Nunivak Island.

Productivity of the arctic land masses is essentitally low and their renewable resources are easily depleted. Many species of flora and terrestrial fauna are holarctic; there are few species but they are often abundant numerically. The flora is adapted to complete its life processes in the two or three months that comprise the arctic summer, after a long period of winter dormancy. Most birds migrate during the winter. The larger mammals that are present in the tundra throughout the year have fur covering with high insulation properties, which has been of considerable commercial value to man (Baird 1964, Dasmann 1967, Rausch 1961).

Productivity of the arctic seas is generally much greater than that of the land. It is particularly high at the edge of the ice in the zone in which polar and warmer waters mix. Commerical and subsistence hunting has therefore been concentrated on the ocean resources, principally the marine mammals. Heavy fishing has occurred mainly in the subarctic where fisheries are particularly good (Baird 1964).

The economy of all the indigenous arctic peoples was originally based on hunting and fishing. Until quite recently, the bulk of the peoples in the eastern Soviet and North American arctics were nomadic hunters. In other parts of Eurasia, particularly in the west, hunting was superseded by reindeer herding, beginning some few hundred years ago. Life in the arctic has been modified to varying degrees by the advance of white civilization. Most of the original Greenland eskimos have almost disappeared as a racial group, following a few centuries of intermarriage with European settlers. The Lapps are gradually being weaned from their traditional pastoralism by intermarriage and mixing with Scandinavians, Finns and Russians. Integration of the Soviet arctic peoples into the economy of the south has progressed steadily since the Revolution. Change among the North American arctic peoples, who are more scattered than those in Eurasia, has been slower and, until recently, more haphazard (Ley 1962).

Earlier contacts with whalers, sealers and trappers had a profound effect on wildlife resources through the introduction of fire-arms and the provision of a market for furs. Many native people are in the process of replacing their hunting economy with one based on wage-earning, which will reduce their immediate dependence on wildlife and their need to exploit it. On the other hand, as a result of improved medical and social services, native populations are increasing rapidly, which cannot fail to increase human pressure on a very fragile environment.

Within the past year there have been indications that the problems posed by this situation may be dwarfed by the new interest that has been aroused in the arctic as a source of minerals, which threatens to expose the environment to the full force of modern competitive technology. The present period is clearly a critical one for arctic conservation.

STATUS OF THREATENED VERTEBRATES

(a) World Threatened Forms

By definition, all world threatened taxa should be regarded as in some danger of extinction by individual nations within whose boundaries they occur.

In the following lists, data are summarized *in note form*, on distribution, major threats to survival, and current status and protection in the arctic. Taxa are listed in systematic order. Most of the information has been taken from the appropriate volume of the IUCN Red Data Book except where otherwise stated.

(*i*) *Mammals*

(1) Fin Whale *Balaenoptera physalus* Linnaeus *Depleted*

Northern and southern hemispheres; in the arctic, from Novaya Zemlya to Greenland and from Chukotskii Peninsula to Alaska (Tomilin 1957). Numbers substantially reduced by commercial whaling; stocks are well below the level required to sustain maximum yields. At present, it is economically the most important species among the large rorquals. In 1953 member nations of the International Whaling Commission (IWC) agreed to impose a minimum size limit of fin whales taken in the northern hemisphere (IWC 1954).

(2) Blue Whale *Balaenoptera musculus musculus* Linnaeus *Critically Endangered*

Northern and southern hemispheres; in the arctic, from Davis Strait to Novaya Zemlya and off Alaska and Kamchatka coasts (Tomilin, 1957). Seriously depleted by commercial whaling, mainly in the latter half of 19th century in the northern hemisphere. In 1963 world stocks estimated at 650-1, 950 whales. Totally protected by IWC members throughout its range since 1967 (IWC 1969).

(3) Humpback Whale *Megaptera novaeangliae* Borowski *Depleted*

From arctic to antarctic seas; in the arctic, in Chukchi and Bering Seas and from Baffin Bay to Novaya Zemlya (Tomilin 1957). Depleted in northern hemisphere by commerical whaling in late 19th Century. In 1965, said to be increasing in the north Atlantic; north Pacific populations estimated at 5, 000. Totally protected in north Atlantic since 1955 (Tomilin 1957) and north Pacific since 1966 (IWC 1967).

(4) Greenland Right Whale *Balaena mysticetus* Linnaeus *Seriously depleted*

Confined to arctic waters, principally regions of floating ice. Brought to the verge of extinction mainly by European whaling interests up to the end of 19th Century. Probably increasing in Bering-Chukchi-Beaufort Sea area and in eastern Canadian arctic. Estimated to be 1, 000 whales in former stock. Protected by whaling nations since 1946, but subsistence hunting by aborigines permitted.

(5) Barren-Ground Grizzly Bear *Ursus richardsoni* Swainson *Indeterminate*

(*Note:* This species probably occurs in Alaska but its exact status and distribution is dependent upon taxonomic re-classification).

In Canadian tundra from Yukon eastward between arctic coast and Great Slave Lake; east of Bathurst Inlet, rarely seen far from Thelon, Back, Dubawnt and Kazan Rivers. Probably winters below tree line in the east. Numbers reduced by overshooting, because considered to endanger human life and property, including domesticated reindeer. In 1965, numbers estimated at 500-1, 000 in Northwest Territories. Totally protected from 1949 to 1964; protection restored in 1967 (FPS 1968).

(6) Polar Bear *Thalarctos maritimus* Phipps *Depleted*

A circumpolar species; occurs on arctic island and mainland coasts and on ice floes in arctic seas. Hunted commercially since 17th Century. Range has contracted and significant depletions have occurred in some regions since 1930's through over hunting; milder climatic conditions may have affected range. World population estimates vary from 5, 000 10, 000 to well over 10, 000. Totally protected in USSR since 1960; cubs and sows with cubs protected throughout much of animals' range. Protected in reserves in James Bay (Canada), Kong Karls Island (Norway) and Wrangel Island (USSR).

(7) Atlantic Walrus *Odobenus rosmarus rosmarus* Linnaeus *Depleted*

Along coasts and on sea ice from Kara Sea and Franz Joseph Land westward to Hudson Bay and Ellesmere Island. Range and populations diminished through excessive commercial hunting since 17th Century. In 1966, world population estimated at about 25, 000. Legislation from 1949-56 in Canada, Denmark, Norway, and USSR virtually restricts hunting rights to indigenous arctic people. A striking increase in numbers seen off Norwegian coast since 1950 (Brun *et al.* 1968).

(8) Novaya Zemlya Reindeer *Rangifer tarandus pearsoni* Lydekker *Critically Endangered*

Eastern and northeastern parts of north island of Novaya Zemlya. Seriously depleted by overhunting for meat and skins. From 1930-1950 human interference and unfavourable physical and climatic conditions may have hastened decline. Numbers on the two islands estimated to be 20,000 at end of 19th Century; in 1950 only a few dozen thought to remain. Now strictly protected.

(*ii*) *Birds*

(1) Siberian White Crane *Grus leucogeranus* Pallas *Endangered*

Breeds in northeast, east and west Siberia; in the arctic between Yana and Alazeya rivers and in upper Alazeya river. Winters in northwest India and in China. Apparently decreasing as a result of human persecution and habitat destruction by agricultural development (outside the arctic). In 1965 estimated that numbers did not exceed 2, 000; majority nest in northeast Siberia. Protected over much of its range.

(2) Eskimo Curlew *Numenius borealis* J. F. Forster *Indeterminate*

Present breeding grounds unknown, formerly northern Mackenzie possibly west into north Alaska. Wintered from south Brazil to Chile. Apparently very rare, if not nearly extinct. Reduced by mass shooting particularly on U.S. eastern sea board. Protected in U.S.A. and Canada.

(3) Hudsonian Godwit *Limosa haemastica* Linnaeus *Depleted*

Breeds in North West Territories from mouth of Mackenzie River east to, perhaps, Southampton Island. Winters in southern South America. Original decline caused by excessive shooting. Now increasing in numbers, large flocks have been recorded recently from several U.S. National Wildlife Refuges. Protected over much of its range. (*Note:* Deleted from U.S. Red Book in December 1968).

(*iii*) *Amphibians and Reptiles*

Very few of the ectothermic amphibians and reptiles have adapted to the arctic regions. *Rana temporaria* and *Rana arvalis* reach the Eurasian arctic and *Rana sylvatica* reaches the North American arctic. A salamander *Hynobius keyserlingi*, a lizard *Lacerta vivipara,* and a snake *Vivipera berus* extend into the Old World Arctic (Goin and Goin 1962). None of these species is known to be threatened either on a world or a national basis (Honnegger 1968, and pers. comm.).

(*iv*) *Fishes*

Nearly all of the freshwater fishes in the arctic are anadromous and most are widely distributed around the pole (Lindsey pers. comm.). The fish fauna of these cold streams is meagre and comprises largely species which migrate to and from the sea or are capable of living in coastal brackish water. These habitats have as yet been little modified by man and none of these taxa is presently regarded as world or nationally threatened (Miller 1969 and pers. comm., Svetovidov pers. comm.).

The writer has found no evidence to suggest that any marine fish within the arctic regions is in danger of extinction. Marine species may be depleted by overfishing, but economic considerations normally curtail further exploitation before the species is seriously threatened.

This generalization would not apply to anadromous fishes. For example, the numbers and range of the Atlantic salmon (*Salmo salar* L.) have already been reduced by pollution, dam construction and overfishing in the streams in which it breeds and, in recent years, it has suffered very heavy exploitation in its feeding grounds in the Atlantic, particularly around the southern coast of Greenland. Salmon fishing in the Baltic is subject to international restriction and, unless similar controls can be introduced in the Atlantic, the future of this species over much of its range could very easily be jeopardized (Netboy 1968). In May 1969, the Northeast Atlantic Fisheries Commission recommended to member governments that fishing outside national fishery limits should be prohibited in the Convention area.

(b) Nationally Threatened Forms

The presentation and arrangement of data follow the same format as in the previous section, except that countries in which a taxon is thought to be threatened are listed after the scientific name. For most mammals, information on distribution is given for these countries only. Data on bird distribution are taken from Vaurie (1965) except where otherwise stated.

(*i*) *Mammals*

(1) Narwhal *Monodon monocerus* Linnaeus Spitsbergen

A circumpolar species occurring north of the drifting ice boundary. Rare in Spitsbergen waters, seen only occasionally and few caught (Øritsland pers. comm.). Since 1930 also rare in waters of Franz Joseph Land and Novaya Zemlya. Little exploited at present except off Greenland coast; depleted in past by extensive hunting for animal's 'horn' (Tomilin 1957). Not protected.

(2) Gray Whale *Eschrichtius glaucus* Cope U.S.A.

Two world stocks, both in Pacific Ocean, one of which summers in Chukchi Sea and winters off Baja California coast. Twice brought to the verge of extinction by commercial whaling in late 19th Century and again in 1930's. Now recovering; in 1965 California herd was estimated to number 8, 000. Since 1946 accorded total protection except for hunting by natives off Chukotskii Peninsula and Alaska, by IWC (Tomilin 1957, US Dept. of Int. 1968).

(3) European Wolf *Canis lupus lupus* Linnaeus Norway; Finland

Tundra and northern boreal forest zones of Norway (Finnmark) and northeast Finland. Radical decline in populations and range in Fenno-Scandinavia 1830-1880, principally as a result of human persecution, but also settlement and agricultural development. Lapps shoot them and destroy dens and occupants. In Finland, intensive hunting on eastern border has prevented repopulation from Kola Peninsula (Pulliainen 1965). Nearly extinct in Norway (Norderhaug pers. comm.); about 25 wolves in north Finland and perhaps another 10 in Alpine areas (Haapanen pers. comm.). Not protected. In 1970, it is hoped to increase number of National Parks in northern Norway and to protect wolves in these areas (Krogh pers. comm.).

(4) Arctic Fox *Alopex lagopus* Linnaeus Norway; Finland

Tundra regions of Fenno-Scandinavia. Population in Norway unknown but probably very low; decline caused by a variety of ecological factors. Totally protected (Norderhaug pers. comm.). From 1920-50 practically extinct in Finland but population probably increased during past 20 years (Sulkava pers. comm.). Pulliainen's studies suggest 15 pairs breed in northernmost Finland; is protected and is increasing (Haapanen pers. comm.).

(5) Wolverine *Gulo gulo* Linnaeus Norway; Finland

Tundra/taiga ecotone of Scandinavia; occurs over a wider area in Finland principally in the north and east. Decline in Fenno-Scandinavia started at end of last century, mainly as a result of human persecution. Total population probably less than 200 (Norderhaug pers. comm.). Hunting concentrated on females and cubs in spring, losses in Finland largely compensated by immigration from the east (Pulliainen 1963). Pulliainen's investigations suggest that there are 60-70 wolverines in Finland; population is probably decreasing (Haapanen pers. comm.). Not protected. Occurs in B0rgefjell National Park (Norway) and Kevo Natural Park (Finland).

(6) Ribbon Seal *Histriophoca fasciata* Zimmermann U.S.A.

Bering Straits, along coasts of Kamchatka and western Alaska (US Dept. of Int. 1968). Populations have probably never been large but in 1961, after a virtual lapse of 50 years, Soviet sealing re-started in the Bering Sea and ribbon seals comprised 87-90% of harvest. By 1964 numbers had declined to the point where it was uneconomic to hunt them in most localities in Bering Sea (American Soc.Mamm. 1968). Not protected.

(7) Barren Ground Caribou *Rangifer tarandus groenlandicus* Linnaeus Canada

(*Note:* Banfield's (1962) revision of this genus reduced the tundra caribou of North America to three subspecies, *groenlandicus, pearyi,* and *granti.* The Ungava caribou *caboti* were included in the eastern woodland form).

Tundra on Canadian mainland from Mackenzie River to Hudson Bay, on Baffin Island and some islands in Hudson Bay. Many animals winter in open boreal forest. Original population estimated at 2-3 million; reduced to 668, 000 by 1949 and to 280, 000 by 1955. Decline may have been halted, survey in 1967 suggests 357, 000 in present population (C.W.S, 1968). Depleted principally by overhunting; concomitant factors include loss of winter feeding in forest fires, wolf predation, poor calf production resulting from adverse weather in some years, parasites and diseases. Hunting generally restricted to indigenous peoples and long term non-indigenous residents; regulations exist to control wastage (Kelsall 1968, Symington 1965).

(8) Musk Ox *Ovibos moschatus* Zimmermann Canada

Principally in tundra in North West Territories from Great Bear Lake to within 100 miles of Hudson Bay, and on many arctic islands to north and east of Baffin Island. Depleted primarily by overhunting until 1917; now recovering. Wolf predation and adverse weather effect some control on natural increase. Present populations estimated to be 1, 500 on mainland and 8, 500 on arctic islands. Mainland population may have shown three fold increase since 1930. Totally protected since 1917; protected in Thelon Game Sanctuary since 1927 (Tener 1968).

(*ii*) *Birds*

(1) Barnacle goose *Branta leucopsis* Bechstein U.S.S.R.

Breeds from east Greenland and Spitsbergen to south island of Novaya Zemlya. Winters in Western Europe. In USSR hunted only casually; valued for its down (Dementiev *et al.* 1952). Numbers probably increased slightly since 1955 following protection from hunting in wintering grounds (Uspenskii 1965b). Novaya Zemlya population estimated 20, 000; still vulnerable to loss of wintering grounds (Mathews pers. comm.). Protected from hunting Archangelskaya Oblast' (Uspenskii 1969).

(2) Eurasian brent goose *Branta bernicla bernicla* Linnaeus U.S.S.R.

Breeds on coasts and wet tundra on Kolguyev Islands, Yamal Gydan, and north Taimyr Peninsulas and some outlying islands. Winters from southwest Baltic to West European coasts. Populations have decreased considerably since the turn of the century and decline has accelerated since 1935. Total wintering population estimated at 16, 500 in 1958. Main reasons for decline are disturbance in arctic breeding grounds, loss of staple food plant *Zostera*, reclamation of wintering and migration areas, and particularly heavy shooting in some European countries. Now protected in all relevant European countries except Denmark. Wintering populations reached 30,000 in 1966 (26,000 in 1968). Loss of winter (inter-tidal) habitat through development the most serious threat (Mathews and Ogilvie 1969).

(3) Atlantic brent goose *Branta bernicla hrota* Müller Spitzbergen

Breeds on arctic coasts and islands in North America from Prince Patrick Island in the west, to Greenland, Spitsbergen and Franz Joseph Land in the east. Winters on Atlantic coast of USA, U.K. and coasts of North Sea and southern Baltic. Decline in European populations attributed mainly to hunting in wintering grounds and adverse weather conditions in the arctic. Totally protected in Spitsbergen, but may have suffered some shooting and egg collecting in recent years (Salomonsen 1958). Spitsbergen/Franz Joseph Land population estimated at 2, 500-3,000 in mid-1960's; numbers continue to decline and situation is critical. Totally protected in a number of European countries, but hunting and development of spring migration areas in Denmark still a threat to Spitsbergen population (Norderhaug 1968; 1969; pers. comm.).

(4) Red-breasted goose *Branta ruficollis* Pallas U.S.S.R.

Breeds in tundra and forest tundra of west Siberia to Taimyr Peninsula. Winters in south Caspian Sea and Iran. Survival causing considerable concern. A relict species; formerly much more numerous. Depleted by goose drives (catching moulting birds) in the arctic, and shooting and other forms of disturbance in wintering grounds. Adverse weather may reduce populations in wintering areas. Kyzyl-Agach Sancturary established and close season introduced in wintering grounds but poaching and human disturbance are still problems (Uspenskii and Kishko 1967). Total population in region of 40,000 (Uspenskii pers. comm). Taimyr Peninsula population halved since 1965 mainly from increased predation by arctic foxes and dogs, late snow falls, and human development. Reserves in breeding grounds proposed. (Vinokurov pers. comm.). Protected from hunting Tyumenskaya Oblast' (Uspenskii 1969).

(5) Lesser Snow Goose *Anser caerulescens caerulescens* Linnaeus U.S.S.R.

Breeds in northeast Siberia, main nesting Wrangel Island, sporadically north coast Chukotskii Peninsula; North American arctic coast from Point Barrow east to south Baffin Land. Winters principally from southwest USA to central Mexico. Sharp reduction in numbers and range on USSR mainland; decline continued into recent decades and attributed to hunting and egg collecting in the arctic, and shooting and modification of habitat in wintering areas. Bad weather can reduce nesting and clutch size, as species breeds in concentrated colonies in few localities; population liable to substantial fluctuation. In 1960 Wrangel Island (estimated to have 400, 000 adult birds) declared a sanctuary, although local residents permitted to hunt in certain areas and take approximately 1, 000 birds/year. (Uspenskii 1967).

(6) Emperor Goose *Anser canagicus* Sewastianoff U.S.S.R.

Breeds in coastal tundra in northeast Siberia, north coast Chukotskii Peninsula to Anadyr Delta; Saint Lawrence Island and north Alaska. Winters on Alaska Peninsula through Aleutians to Kamchatka. Scarce in USSR, may be taken with other geese and therefore continues to diminish (Dementiev *et al.* 1952). No precise data on total population. Eurasian population supposed to be about a few thousand, probably decreasing (Uspenskii 1965b). Protected from hunting Magadanskaya Oblast' (Uspenskii 1969).

(7) Greenland white-tailed sea-eagle *Haliaetus albicilla groenlandicus* Brehm Greenland

Restricted to low arctic of west Greenland, where it breeds northwards to Disko Bay; resident in southwest Greenland but usually leaves northern areas in winter. Regarded as harmful in sheep farming districts, estimated 37% of birds shot. Eggs often destroyed or sold to collectors, young taken and eaten. Population estimated at 75 pairs (in 1950). Export of specimens from Greenland prohibited since 1933 (Salomonsen 1950). Total population estimated to be about 50 pairs (in 1969); protected north of Frederickshab but not in its best habitat in the south (Vibe pers. comm.).
(*Note:* Nominate race threatened in Iceland, only about 10 nesting pairs; totally protected since 1913, Gudmundsson, pers. comm.).

(8) Gyr falcon *Falco rusticolus* Linnaeus Norway; Finland; Canada

A circumpolar species nesting principally on sea coasts; resident and irregular migrant. In Norway population very small but exact status unknown (Norderhaug pers. comm.). In Finland, species common early in the century (c. 1900-1915); 200-300 eggs taken for collections in some years; after 1940, rare, not more than 5-10 pairs nesting nowadays. All remaining birds now north of taiga and are protected (Haapanen, Sulkava pers. comm.). In Canada, birds not resident in tundra throughout the year and are undoubtedly subjected to hazards in the south (Tener pers. comm.); in the north, understood to be captured and exported for falconry (Fuller pers. comm.). (*Note:* gyr falcon should be considered threatened in USSR. Kishchinski pers. comm.).

(9) Eurasian peregrine falcon *Falco peregrinus calidus* Latham Norway; Finland

Breeds in tundras of Eurasia and Arctic Ocean islands, from Lapland east to about Lena river. Winters Mediterranean to South Africa east to Russian Turkestan, Philippines and New Guinea. Declining in Norway (Norderhaug pers. comm.). Formerly occurred in Finnish tundra, but now absent. In c 1945-50, 200-300 pairs bred in Finland; by 1966-67 reduced to 5-7 pairs (Sulkava pers. comm.).

(10) North-American peregrine falcon or duck hawk *Falco peregrinus anatum* Bonaparte Canada; USA

Breeding range extends into tundra, occurs from north Alaska to north Baffin Land, south of southern USA. Winters from USA south to West Indies, Chile and Patagonia. Endangered in the USA; has been extirpated as a breeder in eastern states and is scarce and widely dispersed in other parts of its range. Cumulative effects of pesticide residues in prey suspected as a cause of decline, high content of D.D.T. and related chemicals found in eggs, fat and tissues of falcons even in remote parts of Alaskan arctic (Cade 1969); also persecution by hunters and farmers. Protected over much of United States. Numbers taken in Northwest Territories now regulated by quota, but no restriction in Yukon (US Dept. of Int. 1968; Tener 1967).

(11) Broad-billed sandpiper *Limicola falcinellus falcinellus* Pontoppidan Norway

Breeds in northern Fenno-Scandinavia and Kola Peninsula. Winters in East Mediterranean, Persian Gulf and north India to Ceylon. Population in Norway is low but exact status unknown (Norderhaug pers. comm.).

(12) Ross's gull *Rhodostethia rosea* MacGillivray U.S.S.R.

Breeds in northeast Siberia, on coasts in swampy tundra and river deltas. Wintering grounds unknown, probably pelagic in open waters of Arctic Ocean. Total numbers unknown. Little or no human utilization, population relatively stable and no special protection presently required (Flint pers. comm.). Probably numbered in scores of thousands. Winters in ice leads and could easily be affected by change in arctic biocenosis (Klshchinski, Uspenskii pers. comm.).

(13) Kittlitz's murrelet *Brachyramphus brevirostris* Vigors U.S.S.R.

Nests on southern and arctic coasts of Chukotskiy Peninsula on Wrangel and Diomede Islands and in south and west Alaska. Probably always rare, not hunted and under no immediate threat (Kishchinski pers. comm.).

(*iii*) *Amphibians and Reptiles*

None (see section a. iii).

(*iv*) *Fishes*

None (see section a. iv).

DISCUSSION

It now remains to consider the evidence on the threatened vertebrate problem and to suggest possible courses of corrective action.

Major hazards to the survival of species may be summarized under two main headings:

(a) over-exploitation of the species.

(b) modification of its environment.

A quantitative assessment of the threats to all mammals recorded in the Red Data Book in January 1969, based on Joslin's (1968) analysis, suggests that the number of species affected by one or other of these problems is approximately equal. About two thirds of the total number of threatened birds are affected by modification of the environment. Many species are, to varying degrees, affected by both factors.

A consideration of the foregoing pages leaves little doubt that over-exploitation has been by far the most significant threat to the survival of arctic vertebrates. This conclusion is confirmed by the fact that the threatened species are virtually confined to large, fairly accessible mammals and birds, which either have a value as a source of food or of skins, or present a competitor problem to man.

The second generalization is that only a relatively small proportion of these threatened forms are in serious danger of extinction. Among the world-threatened taxa, two whales, a sub-species of reindeer and two birds, all of which are now protected, have been very seriously depleted. Among the nationally-threatened taxa, significant depletion is largely confined to species that are on the periphery of their world range.

Regional variations in the trend towards species extinction are few. Migratory birds that breed in the tundra appear to be faring better on the American continent than in Eurasia. The relatively high proportion of species from Fenno-Scandinavia that are represented among the nationally threatened forms is probably due to the limited extent of tundra in this region and its utilization for pastoralism, which is more widespread than in any other part of the arctic.

(a) Over-exploitation

Three main groups of animals have been affected by over-exploitation: marine mammals, migratory birds, and terrestrial herbivores and predators. The prime mover in this situation is man, and it seems more logical to consider the facets of this problem by sub-division of the exploiters rather than the exploited.

The decline of certain migratory birds has undoubtedly been accentuated by exploitation and disturbance within their arctic breeding zones, and this subject will be re-examined later in the discussion. By far the greater part of past over-exploitation however, **has** occurred on migratory routes or wintering grounds, a detailed consideration of which would fall outside the immediate scope of this paper. The virtual absence of nationally threatened migratory birds in the North American tundra, compared with Eurasia, speaks well for the Migratory Bird Convention Act (1916) and for the co-operation between the authorities of Canada and the USA in the study and conservation of avifauna, which it has stimulated. The value of national protective legislation, as a means of conserving an international resource, is limited. Although its acceptance might be problematical and its implementation infinitely more difficult, it would clearly be desirable to introduce a similar convention for those Eurasian countries that provide the bulk of the breeding and wintering grounds for migratory birds. A start has already been made in Europe through the Paris Convention of 1950.

The plight of the marine mammals, particularly cetaceans but also some pinnipeds, may be directly attributed to their commercial over-exploitation by the maritime nations in the Northern Hemisphere. Depletion was most rapid during the latter half of the last century and the early part of the present century. The whaling saga is a particularly unhappy one. Three species have been brought to the verge of extinction in the arctic; the gray whale (whose populations are now recovering satisfactorily) has been almost exterminated not once but twice! The fin whale, although included in the Red Data Book since 1966, is still hunted intensively.

Until quite recently, international regulation of whaling amounted to little more than agreement to protect species whose populations were so depleted that it was uneconomic to hunt them. The main obstacle to effective regulation of harvests has been that some nations have invested vast sums in modern whaling fleets; consequently enlightened long-term management has been subservient to the need to recover capital outlay in the shortest possible time. Future exploitation of the ocean resources should obviously be preceded by resource surveys to determine permissible harvests before fleets are built, and nations should agree to their allotted quota before exploitation commences. It has been suggested that future whaling might follow the highly successful arrangement adopted for the management of the Pribilof fur seals, in which one nation, only, is responsible for the management of the resource and a proportion of the proceeds from the harvest is paid to the abstaining nations as compensation. In spite of administrative difficulties this suggestion would certainly merit further consideration.

Whaling tends to concentrate on relatively few species at any particular period of time, so that depletion of one species immediately imposes a greater strain on the few that remain. Yablokov and Bel'kovich (1967) have suggested that some hunting pressure might be diverted from the large whales by extending the range of present hunting of smaller whale species, such as the lesser rorqual (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), bottlenose whale (*Hyperoodon ampullatus*) and other beaked whales. Unfortunately, adoption of this proposal would not provide an alternative use for the larger whaling ships, because smaller, more manoeuvrable vessels are required, but it could divert hunting effort and add stability to the industry by its diversification.

Subsistence hunting has been a significant factor in the decline of several arctic mammals and birds. The root cause of past problems is that the arctic aborigine has accepted the advantages of modern technology without always accepting the responsibilities which go with them. Human populations in the arctic are increasing rapidly and, since the advent of modern firearms, so has their killing power. Concern for the conservation of wild life is generally lacking. Kelsall (1968) has described the heavy overkilling, large crippling losses and wastage of meat and hides, which has attended the decimation of the barren-ground caribou by Eskimos and Indians in recent years, to the point where it is no longer a reliable source of food and income. Misuse of the caribou may be an extreme example of negligent utilization, but the number of depleted arctic species of wild life affected by subsistence hunting suggests that excessive use has been fairly widespread.

Many arctic people live in isolated regions and are partially or wholly dependent upon wildlife for their livelihood. Under these circumstances, the introduction and enforcement of protective legislation present many problems. In any case, total protection is neither essential nor desirable for most species; few are in imminent danger of disappearing and, with intelligent management, their populations could be restored whilst continuing to contribute to the welfare of local people.

The solution of these problems lies in education, both in the classroom and in the field. Conventional education is essentially a long-term process; therefore early, positive action to regulate wildlife harvests through the implementation of co-operative management plans is essential, both to halt the decline of threatened species and to provide a practical demonstration of the benefits of conservation. The schemes would require biologists, to prepare the plans and to train and supervise native hunters in their implementation, and initial funds for equipment. Marketing officers would also be required to assess market outlets and to supervise the processing and disposal of produce.

Pilot projects to encourage efficient cropping of barren ground caribou have already been initiated in Canada. A determined effort has been made to eliminate wastage, large scale caribou hunts have been planned under supervision, and refrigerator plants, for meat storage, have been installed in some settlements (Symington, 1965). Kelsall (1968) estimated that the present mainland caribou ranges could support a million caribou, which at present reproduction rates would yield 150,000 animals a year, conservatively estimated to be worth $8. 25 million for meat alone. Hides, recreational activities and sport hunting could yield additional sums.

Elementary husbandry of wildlife resources should not be confined to large mammalian herbivores. Uspenskii (1967) has recommended the controlled capture of moulting snow geese and their fattening on low-grade grain prior to slaughter, as a means of increasing the yield of meat whilst avoiding population depletion. He also suggests that a proportion of the eggs could be harvested, provided collections are made early in the season and at least one egg is left in each nest, thus ensuring egg replacement by additional laying.

Conservation of threatened species must consider not only the build up of populations *in situ* but also their restoration in areas from which they have been exterminated. Re-introductions of depleted fauna have been undertaken in the arctic already and there is scope for further programmes. Uspenskii (1967) has recommended re-introduction of snow geese into the Chukotskii Peninsula, using techniques based on the experimental translocation of grey lag geese in the Lithuanian S.S.R.

If, in spite of conservation measures, a threatened species should continue to decline to the point where its existence is in jeopardy, then obviously the responsible authorities should not hesitate to take special measures to ensure its total protection, as has been done for the polar bear in the USSR (Bannikov 1968). In the case of a critically endangered animal, such as the Novaya Zemlya reindeer, of which there are no specimens in captivity, consideration might be given to the establishment of a captive breeding herd as an insurance against extinction in the wild.

The paucity of tundra species, combined with the conservatism of the indigenous people, has resulted in the over-exploitation of certain species whilst some resources are virtually untapped. Utilization of fish, particularly freshwater lake fish, would be a means of increasing available protein as well as relieving pressure on depleted species. Pilot schemes of this type have already been started in Canada (Symington 1965), and Schwarz (1967) has recommended the adoption of similar plans for arctic regions in the USSR.

Density of human populations in temperate and tropical regions has often presented an insurmountable obstacle to effective conservation of large predators. Conservation of predators in arctic regions, which are never likely to be densely populated, therefore assumes a special significance. Populations of some arctic predators have been reduced by hunting for their skins or in the belief that they represent a menace to human life. The most serious depletion, however, has resulted from predator control to reduce depredations among domesticated stock. In Scandinavia, the present predator population is too low to exert any appreciable effect on domesticated reindeer; nevertheless, the Lapps are on the point of exterminating the wolf, and probably the wolverine (Curry-Lindahl

1965). Michurin's (1967) observations in Taimyr suggest that wolves invariably preyed on wild reindeer in preference to herded, domesticated animals. The Lapps, themselves, must therefore bear much of the responsibility for predation on their livestock, because it was they who exterminated the wild reindeer in Lapland.

In countries where both the Government and the local people are intolerant of large predators, extermination of the animals is only a question of time, unless conservationists can induce a change of policy. Where politicians are more enlightened than their constituents, creation of large sanctuaries in areas that are undisturbed by pastoralism offers at least a temporary respite. Ultimately, however, the problem resolves itself into a need to wean both politician and public away from the attitude that all predators represent an obstacle to human progress and that extermination is both desirable and inevitable.

(b) Modification of the Species' Environment

Most modification of the environment can be attributed, directly or indirectly, to man. A notable exception, which assumes some significance in the arctic, is climatic change.

Climatic variation is normally used to describe slow, long-term changes that occur between glacial and interglacial periods. Superimposed on these variations, however, are shorter climatic fluctuations, which are of more immediate interest to the present discussion. Since 1885, and particularly since 1920, there has been a relatively abrupt rise in arctic temperatures, which has resulted in a retreat of arctic sea ice and low level glaciers, and a reduction in width of the cold surface layer of the Arctic Sea. There is, as yet, no definite evidence of an alteration in this trend (Hare 1955).

Vibe (1967) has made a detailed study of relatively short term climatic fluctuations in Greenland and their effects on the ecology of the fauna. Three different climatic periods are distinguished between 1810 and 1960, which have been caused by variation in the extent to which the east Greenland ice has penetrated northwards into the Davis Strait. He relates much of the fluctuation in numbers and range of Greenland wildlife during this period to climatic changes. For example, climatic fluctuation during 1860-1910 is suggested as the principal cause of decline in the populations of musk-ox and Greenland whale, and the extinction of the east Greenland caribou.

Vibe (pers. comm.) is of the opinion that climatic fluctuations have exercised a greater effect on arctic wildlife populations than is generally appreciated. In particular, he suggests that depletion of many of the marine mammals during the present century may have resulted not from over-exploitation but from the decline in production of plankton, following retreat of the sea ice.

Recent climatic changes have been greatest in the Greenland-Spitsbergen region (Hare 1955). Furthermore, in recent years changes in marine circulation between the tropics and the poles has occurred primarily in the Atlantic (Baird 1964). Whilst it would be unwise therefore to regard climatic change in the Greenland-Spitsbergen region as representative of the arctic as a whole, the effects of climatic oscillation on animal range and numbers would appear to merit more detailed investigation, particularly in those countries with a north Atlantic seaboard.

Threatened arctic vertebrates have undoubtedly been affected by man's modification of their environment but, for the most part, the changes have occurred outside the arctic. Migratory routes and wintering grounds of most arctic-breeding birds have been affected by land development and, in the northern zones of the boreal forest, caribou wintering grounds have been destroyed by fire. Kelsall (1968) estimated that 29% of the area between Great Slave and Great Bear Lakes has been burned-over during the past twenty years. Although he considered the effects on the present caribou population to have been negligible, the destruction of winter feeding will clearly impose a lower ceiling on numbers of caribou that the range will support, if they were increased by better management. Complete protection from fire is prevented by high costs, but Kelsall suggests that present protection could be made more effective by improved detection techniques and by grading and mapping the caribou's wintering grounds, so that protection could be concentrated on key areas.

In 1892, domesticated reindeer were introduced to Alaska from Siberia, as a means of stablizing native economy. Following a rapid increase in reindeer populations in the early 1930's the numbers crashed by 1940, as a result of bad herding, over-grazing and disease, and continued to decline into the 1950's (Chance 1966). The main problem here was mismanagement, but this example of species introduction in the arctic may be used to raise two subjects, namely the introduction and the domestication of wildlife, both of which can exert a profound influence on the habitat. Re-introduction of a species into a region that it is known to have occupied in recent times usually has much to commend it. The introduction of a species into a new environment, however, should not be undertaken without exhaustive research into the possible effects both on the animal and its new habitat (IUCN 1968). Largely as a result of poor management, domesticated reindeer have caused over-grazing both in Alaska and in Scandinavia (Curry-Lindahl 1965). It would be unreasonable to condemn all domestication of wild animals and their husbandry in the arctic. Nevertheless, the tundra is a very fragile environment and, under some conditions, intelligent management of wild herbivores without domestication might produce an equally satisfactory return from a wider variety of sources, and would certainly create fewer problems for the conservation of the habitat.

Radio-active fall-out has been shown to accumulate in plants that have a low mineral intake. The discovery of unusually high amounts of Strontium 90 in the antlers of caribou in the Canadian arctic, a few years ago, raised fears for the health of both humans and wildlife (Harper 1963). The amounts of Sr 90 were probably too low to present risks of adverse genetic effects or widespread disease, but the situation obviously needs to be kept under surveillance.

The widespread use of organochlorine insecticides, which are the only common pesticides that are both highly persistent and fat soluble, poses a potentially serious threat to many forms of wildlife. Effects may be felt far beyond the areas in which they are applied, because their persistence permits wide dispersal and allows time for concentration in biological systems. Most ecosystems, including the arctic, have been shown to be contaminated. Bird species appear to be less efficient than mammals in eliminating insecticide residues from their bodies. The organochlorines become concentrated in food chains and there is strong circumstantial evidence to suggest that populations of certain raptorial and fish-eating birds have declined as a result of accumulation of insecticide residues. Sub-lethal doses in adult birds may reduce viability of their young; and poisoning may result from the release of insecticides following mobilization of fats during periods of food shortage (Davis 1965, Moore 1967). All the nationally threatened avian predators listed in this paper are probably affected by the problem to some degree. Further restrictions on the use of those insecticides known to have harmful side effects are certainly required. In the long-term, development of more selective insecticides and alternative means of pest control, through biological methods or improved cultural practices, is necessary.

In the future the greatest threats to the arctic environment are likely to arise from large scale development associated with hydroelectric schemes and mineral exploitation. Exploration and drilling for oil will probably have the widest impact. Sedimentary rock formations, which are potential sites for the discovery of petroleum, occur over much of the Soviet arctic, the western third of the American mainland arctic and the northwestern region of the Canadian Archipelago. In July 1968, the discovery of an oil field, which may be one of the world's largest, at Prudhoe Bay, Alaska, was announced. The speed with which oil and gas exploration has since spread across the Mackenzie River delta and into the Canadian Archipelago has been phenomenal.

The variety and magnitude of the problems posed by oil-booms in the arctic for the conservation of species are equally staggering. Human disturbance, damage to soil and vegetation by traffic and fire hazards will be increased. Construction of road and rail routes for oil will make extraction of other resources economically feasible (Weeden 1969). Pipe lines stretching over vast distances could obstruct wildlife migration routes. Oil pollution, both on land and at sea may create special problems in the arctic. Low temperature of the sea might inhibit breakdown of oil by micro-organisms, and proximity of ice packs to the shore could reduce its dispersal (Milton 1969).

In spite of the urgency and size of these problems, Weeden (1969) considers that a progressive policy of regulation, supported by research and co-operation between the oil industry and Government resource administrators and legislators, could do much to alleviate potential disturbance. He suggests that the first requirement is to identify, through survey and assessment of land use and values, key areas in which oil exploration must be prohibited, such as the principal breeding sites of migratory birds, spawning grounds of fish, caribou calving grounds and main subsistence hunting areas. The second major requirement is to establish realistic and effective operational standards. The State of Alaska already has experience in this field, but future research should be directed to comparative studies of virgin, currently exploited and formerly exploited regions of tundra to assess damage by seismic operations and to identify the causes of damage. The industry, for its part, must accept its responsibility to reduce disturbance of the environment by adherence to scientific direction and, through the mobilization of its vast technology, to devise new safeguards against pollution and soil erosion.

There are three lessons to be learned from the impending oil-boom in Alaska. The first is that resource managers should not be deluded by the vastness of the undisturbed arctic regions. Survey and reservation of representative samples of biotopes and key wildlife areas must receive high priority in future. In the USSR, for example, Wrangel Island and 'Seven Islands', to the east of Murmansk, were still the only reserves in the true tundra until late 1968, although at least two large nature reserves are projected and a network of smaller arctic reservations is currently under consideration (Geptner 1968, Nasimovich 1968).

Secondly, effective conservation of all species and their habitats requires continued and expanded research, with the objective of replacing negative restrictions on the use of natural resources with positive management.

Finally, there is a definite need for co-ordination of research and management effort through the national exchange of data and ideas among government departments, industry and universities. Indeed, as many conservation problems are common to the arctic regions as a whole, much could be gained by increased international exchange of scientists, technicians and information between circumpolar nations.

SUMMARY AND CONCLUSIONS

The paper considers arctic vertebrates whose survival gives cause for concern. Data are presented on the current status of threatened animals; major problems confronting their survival and possible courses of corrective action are discussed.

In the arctic regions eleven vertebrates (eight mammals and three birds) are regarded as threatened throughout their world range, and there is concern for the survival of a further twenty-one (eight mammals and thirteen birds) in some circumpolar nations. National lists are tentative.

The principal cause of depletion is over-exploitation. Five world-threatened taxa have been seriously depleted. Among nationally-threatened forms, significant depletion is largely restricted to species on the periphery of their range. The remainder are not in imminent danger of extinction and their restoration could be attained by intelligent regulation of harvests; as yet, total protection is neither necessary nor desirable.

Considerably fewer migratory birds are threatened in the American tundra than in Eurasia. Eurasian countries would do well to emulate the North American example of acceptance of a comprehensive international convention for the protection of migratory birds.

In the past, enlightened management of whales and other marine mammals has been subservient to the need to recover capital outlay on shipping. In the future, exploitation should be preceded by resource surveys and international agreement to determine permissible harvests. In the interim, hunting pressure on large whales might be partially diverted to smaller species.

Within the arctic, restoration of many depleted mammals and birds is dependent upon the co-operation of indigenous peoples. The ultimate solution to conservation problems lies in progressive education. In the meantime, regulation of harvests through the application of management plans, and the diversion of some hunting to relatively untapped wildlife resources offer the best means of alleviating the situation. There is scope for re-introduction of threatened species into parts of their former range.

Climatic fluctuations have been a significant factor in the decline of some species in Greenland. The subject merits further investigation in other countries with a North Atlantic seaboard.

Modification of the arctic environment by man has had relatively little effect on the status of species, but the impending oil boom in the North American tundra could herald a rapid deterioration in this state of affairs. The identification of key areas from which oil exploration must be rigidly excluded, and the establishment of realistic operational standards for the oil industry are required urgently.

Renewed interest in the arctic as a source of minerals emphasizes three basic needs for more effective conservation:

(1) survey and reservation of representative samples of biotopes

(2) continued and expanded ecological research

(3) co-ordination of research and management effort through exchange of data and ideas among Government, industry and university both within and between the circumpolar nations.

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Paper No. 21

Conservation and Wildlife Problems in Svalbard

M.NORDERHAUG[1]

INTRODUCTION

The archipelago of Svalbard, consisting of five bigger and a number of smaller islands between 76 and 80°N (excluding Björnöya at 74° 30'N) covers a total land area of 62,000 km^2.

Compared with many other high arctic areas, Svalbard has for centuries been easily accessible, in spite of its location only 10° from the North Pole. This is mainly because the northernmost branch of the Gulf stream penetrates the waters on the west side of the archipelago. An arctic current from the northeast causes more extreme conditions in the east.

Primary production in these waters is very high during summer thus forming the basis for the existence of marine mammals, numerous seabirds and their transporting organic matter to land communities.

Ice conditions in Svalbard waters show great variation from year to year, depending mainly on temperature, precipitation and wind conditions in the eastern waters. The western coasts are normally ice free from the beginning of summer (May/June) due to the warming effect of the Gulf stream. Considerable amounts of sea ice may, however, be transported from the northeastern areas to the west coasts later in summer.

Topography varies considerably from one part of the archipelago to another, depending on different geological structures. From a biological point of view, the coastal areas are of most importance, as nearly 2/3 of the total land area are under permanent snow and ice cover. Approximately 18% of the 4, 400 km coastline of the biggest islands are also glaciated. The most important land areas, coastal plains and inland valleys less than 100m above sea level, cover only 7, 600 km^2. Most of the production in Svalbard's terrestrial ecosystems is accordingly restricted to 10-15% of the total land area. The productive period in these communities is not only related to a climatic gradient from south to north, A gradient towards more extreme conditions is also observed from west to east due to the transport of cool water and sea ice from the northeast. In the western parts, the productive period is from the end of May until the beginning of September. The average air temperature is normally above zero from June to September. Monthly averages in the warmest months, July and August, are 4. 6°C and 4. 3°C. During the winter, air temperatures may vary considerably from month to month and from year to year due to Svalbard's location close to the subarctic region. Winter temperature accordingly depends on variations in air influx partly from the south, partly from the Arctic Ocean.

A rapid rise in mean temperature occurred, beginning in the 1920's. This temperature rise reached a peak in the later 1950's and from the beginning of the 1960's a remarkable decrease in the yearly mean temperature has been observed in other parts of the Arctic

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(Vibe, 1967) and seems to be in good accordance with the suggestions by Dansgaard et. al. (1969) that a more arctic climate is now under development.

Like the arctic fauna in general, the number of animal species in Svalbard is restricted. Arctic fox (*Alopex lagopus*), Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and polar bear (*Thalarctos maritimus*) are the native terrestrial mammals, while a small herd of musk-oxen (*Ovibos moschatus*) and a now nearly extinct population of arctic hares (*Lepus arcticus groenlandicus*) have been introduced. Lemmings do not occur in Svalbard, probably due to the isolated location and extreme climate. Mammals in coastal waters are walrus, four species of seals and a few whale species. Bird life is relatively rich in the coastal regions. A total of 108 species have been observed, but only 31 breed yearly. The main groups of yearly breeders are *Anatidae* (6 species), *Charadriidae* (7 species) *Laridae* (7 species) and *Alcidae* (6 species). Only two Passeriformes, wheatear (*Oenanthe oenanthe*) and snow bunting (*Plectrophenax nivalis*) normally breed.

HUMAN ACTIVITY

Svalbard was probably discovered by Norsemen in 1194, but there is no further information about human activity in Svalbard before the rediscovery by Wlllem Barents in 1596. Then a continual exploitation of the animal resources in this area began. In the next 300 years, up to the beginning of this century, all human activity in Svalbard was in fact connected with the harvest of different arctic animals.

During the first period (1600-1800) a great whaling industry flourished. Mainly Holland, but also England, France, Spain, Germany and Denmark-Norway took part in this activity. The whale population (mainly *Balaena mysticetus*) in these waters was then very rich. Holland alone sent nearly 14, 200 ships to Svalbard between 1669 and 1778, and killed more than 57, 500 whales (Ingstad, 1948). In the second part of the whaling period a new activity expanded about 1700. Russian ships from the White Sea region then went to Svalbard mainly for walrus, but also for seals, arctic fox, polar bear, reindeer and eider down. As the Russian hunting activity decreased rapidly after 1820, the last exploitation period started when small ships from northern Norway (mainly Tromsö, Hammerfest and Vardö) went to Svalbard in increasing number. In the years after 1820, 10-15 ships took part in this activity, increasing to 60-70 in the 1880's and 1890's (when wintering expeditions also became common). The primary targets were now seals and walrus, but reindeer, polar bear, eiders (for their down) and other species were also harvested.

In 1920 the international 'Svalbard Treaty' that recognized the sovereignty of Norway over the archipelago of Svalbard was put into force. Furthermore, the equal rights of other nations to fish and hunt in the territories were stated. From a conservation point of view, the treaty also represented the first important step away from what has been called 'The Arctic Slaughter'; Norway was free to 'decree suitable measures to ensure the preservation and, if necessary, the re-constitution of the fauna and flora in Svalbard'. More than 300 years of human activity in a no-man's-land had come to an end.

After 1900 sealing activity with small vessels continued in Svalbard waters until recently, when market prices for bearded-seals (*Erignathus barbatus*) declined. The number of wintering hunters in Svalbard in this century has varied, from 30-40 in the 1920's (mainly for arctic fox) to only 4-6 (mainly for polar bear) in the last years. In general, hunting activities in Svalbard have gradually decreased up to the present time. This decrease is the result of several factors: social development and increasing incomes in other occupations, new wildlife regulations, reduced animal population, etc. Human activity in Svalbard has, however, not decreased. About 1905 a considerable coal mining industry started. At present 1, 820 men, women and children are living in two Russian mining towns and 930 people in the Norwegian mining town, all in Vestspitsbergen. Another 60-70 people occupy different winter stations. Furthermore, excellent opportunities for research in geology, glaciology, botany, zoology and other sciences contribute to an increasing scientific field activity, mainly during the summer months. Twenty-eight different expeditions with 209 participants from 11 nations visited this archipelago in 1968. The general increasing trend in arctic tourism is also observed in Svalbard. At the moment, no hotel is in operation and there is no air connection during the summer. However, Svalbard is now visited regularly by an extended coastal express route from northern Norway in the summer months. Furthermore, a number of tourist ships cruising in the northern Atlantic in the summer visit Svalbard. In the summer of 1969 probably more than 5, 000 tourists visited the area on board these ships. Hunting safaris for polar bears are yearly arranged from northern Norway (from the 1950's) and regular photo safaris were started this summer.

Outdoor recreation is also of increasing importance to permanent residents of Svalbard. Recreational hunting, skiing activities, the increasing number of motor toboggans and outboarders reflect this development. The present situation indicates that this easily accessible arctic archipelago with its unique natural features and wildlife will increase in importance for both polar research and recreation. New conservation problems will arise with these new developments, but it is encouraging to note the increasing interest in these questions in Norway.

GAME STATUS AND PRESENT PROBLEMS

The present status and problems concerning game populations in Svalbard are rather different from one species to another, a result of past and present exploitation, response to regulations put into force and new problems arising from human activities. Furthermore, the present need for a more deliberate conservation policy in Svalbard include questions of more general character.

Walrus (*Odobenus rosmarus*)

The walrus was one of the most valuable animals in Svalbard from the earliest times and of very great economic importance to the Russians in the 18th century. Its population decreased rapidly when Norwegian sealing activity started in the beginning of the 19th century. This decrease, however, was probably only the final stage in a long-term over-exploitation. In the beginning of the 1830's a yearly average of 1, 800 animals was taken but the harvest varied considerably from year to year, depending on ice conditions and the number of ships. When modern rifles were introduced and the traditional harpoon method went out the walrus era came rapidly to an end. As observed also in other parts of the Arctic, not only did walrus hunting become easier but the proportion of animals that sank increased drastically. Up to 1886-90 an average of 1, 000 animals were still taken. In 1901-05 only 136 walruses were taken annually and in 1910-14 the yearly average was 53 animals. According to Norwegian statistics, 17, 543 walruses were brought to northern Norway between 1871 and 1914. A number of walruses were also taken during the 1920's and 1930's. In spite of the decrease, a total protection of walrus in Svalbard was not put into force until 1952. A small fraction of the former population, we do not know the number of animals, survived in the least accessible northeastern parts. In the period 1960-67 there were 18 walrus observations in Svalbard and three of them indicate that reproduction still takes place in the area (Norderhaug, 1968a). The re-establishment of the Svalbard population is at present not under human control. It is, however, important to note that some hundred walruses still exist in the Franz Josef Land area close to Svalbard (S.M.Uspenskii pers. comm. 1967). We therefore hope that a slow re-establishment of the Svalbard population will now take place, partly as a result of influx from Franz Josef Land and partly as a result of local reproduction.

Polar bear (*Thalarctos maritimus*)

Polar bears have been taken in varying numbers in all periods of hunting and sealing in Svalbard. From 1875-92, 144 animals were taken per year (incomplete data), from 1893-1908,415 per year and between 1924 and 1939, 355 per year, (Iversen, 1939). Most of these bears were killed by sealers and wintering trappers. Since 1945 different categories of hunters have taken part in polar bear hunting in Svalbard waters, including sealers, weather station crews, trophy hunters, wintering trappers, miners, and participants in scientific expeditions. If we look at trends in the total harvest from 1945 up to the present a rather slight reduction in the Norwegian harvest is recognized. Between 1945 and 1967 from 137 to 536 polar bears were taken per year by Norwegians, mainly in Svalbard waters. Averages per year were: 1945-1949-375.2; 1950-1954-325.6; 1955-1959-335.8;

1960-1964—263. 8; 1965-1967-294.3. This slight reduction does not however, indicate the important changes that took place in this period in the apportionment of the Norwegian polar bear harvest in relation to hunter type. These data are shown in the following table (Norderhaug 1968b).

PROPORTION OF POLAR BEAR HARVEST TAKEN BY

PERIOD	Sealing Vessels %	Weather Station Crews %	Wintering Trappers (Svalbard) %	Exped., Miners, etc. %	Trophy Hunters %	Trappers, exped. to E.Greenl. %
1945-1949	62.7	7.9	26.5	1.3	0	1.6
1950-1954	79.4	9.2	3.5	1.4	3.7	2.8
1955-1959	60.9	9.5	12.1	6.7	8.8	2.0
1960-1964	31.8	28.2	22.0	4.8	13.2	0
1965-1967	2.4	34.1	45.1	5.8	12.6	0

Recreational hunting comprises an increasing part of the total harvest and no person is at present dependent on this animal for his living or primary income. Up to the present Norwegian polar bear hunting regulations have been relatively few. Use of the following hunting methods is prohibited: poison, traps, and guns smaller than a 6.5 mm calibre. Use of motor-toboggans and aircraft is forbidden. There are bag limits for trophy hunters (one per person) but no other regulations. The capture of living polar bears is prohibited without special permit and killing of females accompanied by cubs is not allowed in connection with trophy hunting. Polar bears are furthermore totally protected in Kong Karls Land. Under existing regulations it has not been possible to regulate the total yearly kill. The proportion of the harvest falling to each hunter type is also changing in a manner that is not well controlled. As use of setguns is legal, cubs and females accompanied by cubs do not receive protection according to the recommendations of the Fairbanks meeting in 1965. It is furthermore possible that the number of polar bears taken in Svalbard is higher than the number of cubs produced in the area, and therefore, in part, depends on an influx from other areas. New polar bear regulations will however be put into force this year. Of special importance are provisions for licensing all polar bear hunting and prohibiting the traditional, nonselective setgun method. The new regulations will form a new important tool in polar bear management. From 1970 we hope that complete regulation of all categories of hunters and of total harvest will be possible. This is especially important in the light of new results from current polar bear research, both in Svalbard and elsewhere, and the changing emphasis on the value of unique animals, increasing aesthetic and recreational values and declining importance as a source of direct profit.

Svalbard Reindeer (*Rangifer tarandus platyrhynchus*)

Reindeer have been totally protected in Svalbard since 1925. By that time many years of continued exploitation had reduced the population to a fraction of its original size. Recent studies indicate that in optimum periods this population was of the order of 6, 000 to 7, 000 animals. In 1925 only a few hundred were left, primarily as a result of an increasing number of firearms from the middle of the 19th century, increasing year round human activity (including mining activity from 1905) and use of dog teams. Data available from different statistical sources indicate a minimum harvest of 302-757 animals per year (5-year average) from the 1860's to the end of the century. From that time until 1922 a minimum of 329-560 animals per year (5-year average) was taken. In the years just before total protection was put into force (1923-25) survivors were not easy to obtain and only 55-90 were shot per year.

Protection accorded in 1925 had a marked effect in spite of some illegal hunting. In **1930** the number was probably about 1, 000 (Hoel, 1931). When the Second World War broke out the mining towns were evacuated and a number of dogs were set free in the western parts of Svalbard. Some hunting also took place during the war and in the years after thus contributing to a new reduction in the reindeer population. In this connection it is also possible that the climatic optimum in Svalbard from 1920 to 1960 had some negative importance. However, the population is now increasing steadily. Lönö (1959) estimated the number in 1958 to be 1, 200-1, 600 but this estimate was probably too low. At present, the number is estimated at 3, 700 - 4, 200, (based in part on aerial surveys in 1969) (Norderhaug, in press). In the light of the present trend we may not only foresee re-establishment of reindeer in different parts of the area, but also the time when a modest harvest will again be possible.

Eider (*Somateria mollissima borealis*)

Eggs and down of eiders represented an important product for Russian hunters. Later in the 19th century the Norwegians continued to collect on the small but very rich eider islands along the coasts. Between 1871 and 1914 from 702 to 1, 484 kg of down per year (5-year average) were imported into Norway from Svalbard. In one year (1914) 2, 451 kg were imported. With an average yield of 30 g per nest, this corresponds to a down production from 81, 700 nests. In all about 50 tons of eider down were imported to northern Norway from Svalbard in 44 years (1871-1914). This collection, a continuous over-exploitation, lasted until the war broke out in 1940. From 1945 to 1950 only 100-200 kg or less were taken each year. Since then, no permanent down collection has taken place in Svalbard although total protection was not accorded the eider until 1963. We have few exact figures of the severe reduction of the eider population in Svalbard. From one locality (Forlandsöyane) we have, however, some figures illustrating the final part of this destructive process. In 1900 the number of breeding pairs on Forlandsöyane was estimated at 10, 000 - 11, 000 pairs (Kolthoff, 1903). In 1956, 200 to 300 nests were observed there (Lövenskiold, 1964). Since 1963 a general, but slow increase has probably taken place in Svalbard and in 1968, 1, 740 pairs were counted on Förlandsöyane. At present, there are other negative factors in the picture. Heavy predation by glaucous gulls (*Larus hyperboreus*) is observed in some colonies. The number of glaucous gulls has probably increased during recent years, partly as a result of an increasing volume of refuse from mining towns and winter stations.

Restoring the eider colonies should preferably include a continual local predator control and establishment of closed breeding reserves because human disturbance on the breeding grounds may increase the predatory effect of gulls drastically.

Geese

Three species of geese breed in Svalbard, the pink-footed goose (*Anser fabalis brachyrhynchus*), brent goose (*Branta bernicla hrota*) and barnacle goose (*Branta leucopsis*). Because of difference in wintering areas and breeding habitat the problems facing each species are quite different. Pink-footed geese are the most numerous with a total population of approximately 8, 000 to 10, 000 individauls. Recoveries from 580 pink-footed geese ringed in Svalbard from 1952-57 show migration through Denmark to coastal regions in northern Germany and Holland (Holgersen, 1960). In severe winters movement farther southward is observed. There seems to be no marked decrease in this population in spite of winter hunting and the changing environment of present day Europe. This is probably a result of its widespread distribution on the breeding grounds and good adaptation to changing wintering grounds. The brents breeding in Svalbard and Franz Josef Land form, as far as we know, one small population. The main part breeds in Svalbard. Before 1900 brent were probably the most numerous Svalbard geese. Today, only a fraction is left. Formerly breeding in numbers on eider islands, its decrease is related to the intensive collection of eider down and eggs. The well known reduction of *Zostera marina* along the North Sea coasts and intensive hunting during winter as well as summer were other contributing factors. In the first part of the 1950's the total population numbered only 4, 000 individuals (Salomonsen, 1958). By 1965 the population had probably decreased further, to 2, 500 - 3, 000 birds (Norderhaug, 1968c) in spite of protective measures put into force in different parts of the breeding and wintering grounds. The species was totally protected in Svalbard in 1955 and disturbance from down collectors ceased after total protection of eiders in 1963. However, activities of tourists and expeditions are increasing. In this connection present plans for the establishment of reserves in Svalbard, including closed breeding reserves for eiders and geese on some of the islands along the coasts, should be mentioned. Ringing of 74 brent geese in Svalbard in 1954 showed that the main cause of death was hunting in Denmark, the main wintering area. In 1961 about 220 *Branta bernicla hrota* (probably all from Svalbard and Franz Josef Land) were shot in Denmark (Fog, 1967), mostly in two fjords in east Jutland. Total protection of this species in these localities, as proposed by Fog (1967), would reduce both the kill and the disturbance on the wintering grounds. In Denmark, important feeding localities used during spring migration in western Jutland are also threatened by exploitation. If these areas can be saved and local protection put into force, important progress will be made.

In severe winters the Svalbard brents move to England where, with total protection and the established reserve on Holy Island, the situation seems satisfactory. In Norway brents may be hunted between August 21 and December 23 but migration takes place along the thinly populated coastal zone. Total protection is, however, now proposed in Norway. The decreasing trend in this population is alarming and it therefore seems advisable to recommend that every possible new protective measure be put into force as soon as possible.

The third species, the barnacle goose, is in a much more favourable position. Barnacles have never been numerous in Svalbard and the population in the middle of the 1940's was probably below 1, 000 birds. Since then the population has increased and numbers, at present, over 4, 000 birds. This expansion is the result of different positive factors. In Svalbard, where the barnacle geese are totally protected, a remarkable change in breeding habits has been observed (mainly since the 1950's). Before that time most bred in the interior whereas at present probably 75% or more breed on Eider Island where brents formerly bred in numbers. Ringing of 1, 100 Svalbard barnacles in 1962-64 showed the Solway area in Scotland to be the main wintering area for this population (Boyd, 1964; Larsen and Norderhaug, 1964). Compared with the brent population, the barnacles are well protected during the winter both legally and by the presence of a National Nature Reserve on their main feeding grounds. The development of the barnacle population during the last 20 years is promising and we may hope that co-operation, especially between Denmark and Norway, will contribute to an increase also in the existing brent population.

National Parks and Reserves

In 1921, the year after the Svalbard Treaty was put into force, a proposal for establishment of some protected areas was presented to the Government by the Norwegian Conservation Society. This early interest in arctic conservation resulted in two plant reserves in Vestspitsbergen in 1932 (covering respectively 2, 240 and 175 km^2) and a polar bear reserve established in Kong Karls Land in 1939. Little further attention was given these questions until the middle of the 1960's when a 'Working Group on Wildlife Management and Conservation in Svalbard' was established in connection with the 'Inter-ministry Advisory Board for Svalbard Affairs' which is chaired by the Minister of Justice. At the same time (1967) Norsk Polarinstitutt, the Norwegian State Institute for Polar Research, started biological activities on a permanent basis. At the moment plans for national parks and nature reserves are in preparation. Field work is conducted by Norsk Polarinstitutt and general planning by the Working Group. The first stage will include proposals for one or probably two, national parks in Spitsbergen and as previously mentioned, some breeding reserves for eiders, brent geese and barnacle geese along the western coast of the archipelago. Development in this sector should also include more public information and a warden system but up to the present these questions have been given little attention.

Hunting Regulations

Finally, hunting regulations in Svalbard should also be mentioned. Regulations in effect since 1955 include hunting seasons for some bird species and total protection for a restricted number of 'rare' species. Most birds oocurring in Svalbard more or less regularly are not protected, and hunting, collection for museums and other activities are accordingly legal without permission. With increasing human activity in Svalbard, a more effective and simple system of regulation is necessary and a proposal for new regulations, according to which all terrestrial vertebrates will be given total protection, is under consideration. As a secondary step open seasons will then be established for game species.

FINAL REMARKS

In general, more information and more effective regulations seem necessary in view of the increasing number of people looking toward the arctic for research, recreation and industrial expansion. In the present situation Conservation and Wildlife Management in Svalbard will have two main objectives: (1) to restore and maintain Svalbard's wildlife and high arctic ecosystems for their uniqueness and biological productivity; and (2) to make these natural resources available for future research, recreation and harvest in a controlled manner. This is indeed a complex and difficult task but it is also a challenge, here as in all regions where research, legislation and public relations are synthesized into conservation policy for the world's last great wildernesses!

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NOTE: Statistics based on different official sources.

Paper No. 22

Problems and Forms of Fauna Conservation in the Soviet Arctic and Subarctic

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Economic exploitation of natural resources of the northern polar regions has a relatively short history. However, in spite of this fact, the fauna of the area, taking under consideration its limited specific composition, has already suffered serious losses. Sad and educational was, for instance, the fate of Steller's sea cow (*Hidrodamalis gigas*), exterminated by man (in 1768) 27 years after its discovery. Also well known is the history of extermination of the Greenland whale (*Balaena mysticetus*), etc.

At present there is an understandable fear for the future of the polar bear (*Thalassarctos maritimus*), walrus (*Odobenus rosmarus*), certain forms of wild reindeer (*Rangifer tarandus*), some species of northern seals, waterfowl (*Anseriformes*), auks (*Alciformes*), and numerous other animals of high latitudes listed partially in the 'Red Data Book' of the IUCN—the list of especially rare species of world fauna in greatest need of protection.

Human activity in the Arctic and Subarctic also disturbs the vegetation and soil covers unusually fast. Their ecosystems have an increased vulnerability, which can be explained by the specificity of natural environmental conditions of the northern polar regions as well as the specificity of the influence on them of human economic activities.

It is well known that during the summer months, under conditions of constant sunlight and lowered content of CO_2 in the atmosphere, the biological processes, not infrequently reproduction and growth of organisms, are faster and more intensive in the Arctic and Subarctic than in temperate latitudes.

However, unfavourable winter environmental conditions—prolonged polar nights; uneven and, in some places, very deep snow, covering the ground for a very long period of time; freezing, sometimes to the bottom, of reservoirs for a long period—bring to nil the benefits received by animals (and plants) during the summer in comparison with temperate zones.

As a result of this, sharp differences within the seasons of a year exist in the whole picture of the organic world of high latitudes. In the conditions of existence there, differences are very sharp also during the summer which, in effect, cause a greater uneveness in the distribution of species and individuals on the land as well as in the sea. Gradually as one moves northward, terrestrial vegetation becomes more and more depressed, biological productivity of the land decreases and life is oriented toward water bodies and, in the extreme north, towards the sea. As. a typical illustration of this phenomenon, one of the most common Arctic birds, the snow bunting (*Plectrophenax nivalis*) can serve. In a large part of its range it is an exclusively terrestrial bird. However, in northern Arctic islands, it is forced to live a 'semi-marine' life and, during certain periods, feeds on planktonic crustaceans washed by waves onto the top of the ice.

The severe improverishment in the specific composition of the fauna and flora results in extreme simplification of connections and relations in the biocenoses of high latitudes,

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in sharp changes in the picture of animal life, and in sharp changes in animal numbers within species and populations during different years. The abundance of lemmings in the tundra (in a large part of northern Eurasia *Lemmus obensis)* depending mainly on co-action of abiotic environmental factors, directly or indirectly determines the whole profile of fauna in the tundra, and not only the number of mouse-eaters but also other species of mammals and birds, and among the latter, waterfowl, gallinaceous birds, shore birds, etc.

Besides the 3-4 year lemming cycles of changing abundance in the forest-tundra and in the southern part of the tundra, there occur longer, 8-12 year cycles in the number of varying hares (*Lepus timidus*), willow-grouse (*Lagopus lagopus*) etc. In general, the unusually high amplitude of changes of number within species or populations (in any case among terrestrial vertebrates) represents one of the most typical characteristics of the Arctic fauna. For instance, the amplitude of changes in the number of varying hare in Northern Yakutia can reach 240, 000% (Naumov and Popov 1954; in the northern part of the forest zone in the European part of the USSR this index is at least 20 times smaller). In the Arctic seas the abundance of numerous vertebrates is determined mainly by the arrival and abundance of the Arctic cod (*Boreogadus saida*).

It should be mentioned that even more prolonged cycles in climatic changes, which have an important influence on animal life, are also typical of the Arctic and Subarctic. Until a short time ago, a period of significant warming up was observed. This process, developing during the past half century, was, according to the Russian climatologist V. Yu. Vize (1940), 'the greatest fluctuation of the climate marked in meteorological chronicles' and it was expecially prominent in 1920-1930. It resulted directly in a northward expansion of the ranges of numerous species of animals and plants. As was first shown in the USSR by L. N. Tyulina (1936, 1937), the northern boundary of the red fox range was significiantly expanded into the tundra during that period. In the Soviet tundra not less than 30 species of boreal birds, according to their origin, started to nest regularly, shifts in the dates of returns to the Arctic of numerous migratory species occurred etc. (Uspenskii 1969). At the same time, directly or indirectly connected with it, there was a 'shrinkage' in the range and a reduction in numbers of several representatives of the Arctic fauna. For instance, glazed frost forming in the tundra resulted in a 'shrinkage' of range and decline in number of hoofed mammals, among them the reindeer (resulting in barrenness of animals and their death from starvation). Apparently the glazed frost also appeared to be one of the most important factors limiting the range and number of the willow-grouse in Northern Europe.

Also a direct 'squeezing-out' of representatives of the aboriginal fauna by infiltrating species occurred. Thus, in the Northern European part of the USSR and in many regions of Siberia during the last decades an invasion of the tundra by the red fox (*Vulpes vulpes*) occurred. According to the information gathered, from the beginning of the present century its range expanded northward in various parts of the USSR for 200 and more kilometers. The red fox, as a closely related species ecologically, represents a serious competitor for the arctic fox where food is concerned. It also preys upon the arctic fox and, what is even more significant, occupies arctic fox den sites, the number of which is limited in the tundra.

Thus, a stage of some kind of 'unstable equilibrium' is a typical characteristic of the organic world of the ecosystems of the Subarctic and especially of the Arctic, which must be taken into consideration in the exploitation of the natural resources in that part of our globe.

The influence of man on the nature of the Arctic and Subarctic is increasing extremely rapidly, mainly due to the development of industry and transport. Arctic and Subarctic regions of the USSR have become important or even basic sources of minerals within a few decades. Exploitation of the accumulated, large hydroelectrical resources began etc., etc. The impact of economic development of the extreme northern regions of the USSR (in its administrative boundaries including some areas of Siberia belonging to the taiga zone) can be judged on the basis of the growth of the population. In 1926 there were 732. 7 thousand people, while in 1968 there were approximately 5 million people; the relative size of the urban population for that period increased from 8% to 66% there (Tyurdenen and Andreev 1968).

Professional hunting and exploitation of the marine resources, together with the reindeer industry and commercial fishing, are the traditional branches of the economy of the native population of the Soviet Arctic and Subarctic. They survived and are developing intensively, forming the basis of the economy of northern collective farms and state farms. However, developing even more intensively in those regions and taking the form of hunting tourism is sport hunting. This is due to the fast growth of the urban population.

In evaluating the degree of human influence on nature, particularly on the fauna of the Arctic and Subarctic, we must remember that the great majority of species are nomadic or strictly migratory forms. These animals consequently are experiencing constantly increasing sport and professional hunting pressure, but fall outside the regions where their reserves can be maintained by breeding, such as the densely populated temperate regions further to the south. Increasing less sharply is an indirect, mostly unfavourable human influence in the regions of the migration and wintering grounds of Arctic animals. This is shown, for example, by a limitation of suitable conditions for wintering, due to land reclamation, pollution of waters by oil products, etc.

However, at the same time, in the forms of economic development of the Arctic and Subarctic regions, there are some special features which to some extent make it easier to deal with the problems of the fauna and of nature conservation in general. In contrast to southern regions where man has developed or is developing large, continuous areas, in the northern polar regions, particularly in the Soviet Arctic and Subarctic, the influence of man on nature occurs mainly in localized centres, frequently quite far apart. The same tendency is to be seen in the development of one of the branches of the economy—the northern reindeer industry—in the tundras of the USSR. During recent decades an increase in herds of domesticated reindeer (in collective and state farms), the introduction of rational, rotating methods of grazing reindeer and a shift among the native population towards a settled type of life, have led to releasing parts of pastures that were unproductive or unsuitable for one reason or another.

Consequently, in spite of the rapid growth of industry and population, natural reserves serving as places for the enrichment of natural resources, including game animals, were set aside or formed from the beginning. The situation in primeval regions of the Soviet tundra where wild reindeer live can serve as a clear example of this. In very large areas, particularly in northeastern Siberia in 1920, this species was already considered extinct. Later, however, wild reindeer started to appear again on abandoned pastures on the Chukotskii peninsula, as well as in several other regions (of course, quite a significant role was played there by general conservation measures).

The conservation of natural resources, ecosystems and individual representatives of the fauna and flora of the Soviet Far North was the subject of a series of special government legal acts. Among them the most important in the solving of problems of preservation of the arctic animals were: the bill of the Council of National Commissars, brought into effect in 1921, 'for the protection of fish and animal habitat in the Arctic Ocean and in the White Sea'; and the resolution of the Council of Ministers of the Russian Soviet Federative Socialist Republic, effective since 1956, 'on measures of animal conservation in the Arctic'.

The bill of 1921, as indicated by its title, was directed towards safeguarding the national interest in the fishery and professional hunting industries of the north and so towards conservation of resources of the economically important fauna. The resolution of 1956, containing provisions for the complete closure of polar bear hunting in the USSR, professional hunting of walruses and wild reindeer (hunting for walruses and reindeer in limited numbers is permitted for the native people on the basis of special licences), other measures of their preservation and strong limitations in the exploitation of the breeding grounds of sea birds and eider colonies, plays an important role in the preservation and restitution of numerous species of Arctic fauna, especially of the polar bear and reindeer. I will discuss the polar bear problem in detail later. The number of wild reindeer for instance, in the largest herd in the USSR, the Taimyr herd (inhabiting Taimyr peninsula and the mountainous regions of Middle Siberia surrounding it) increased from approximately 100, 000 animals in 1950 to 300, 000 in 1966, thanks to these measures.

The 'Seven Islands' reserve ensures protection of part of arctic nature within the system of state nature reserves of the USSR, in which scientific establishments may conduct complex long-term investigations on lands withdrawn from industrial utilization. (Officially the reserve is a subdivision of the Kandalaksha national reserve with its administrative centre in the town of Kandalaksha in Murmansk oblast'). These islands, lying off the northern shore of eastern Murmansk were declared protected as nesting grounds of gyrfalcons (*Falco rusticolus*) and guarded by a special warden in the XVII century, by the order of the Czar Aleksey Mikhailovich. The Seven Islands reserve in its present form was established in 1938, with the main purpose of preserving the breeding grounds of sea birds (nesting colonies of the Atlantic murre or guillemot *Uria aalge*, kittiwake *Rissa tridactyla*, pufin *Fratercula arctica*, etc. and nesting sites of the eider *Somateria mollissima).*

On Wrangel Island a permanent game reserve was established in 1960, the purposes of which are conservation, survey and marking of polar bears, snow geese *Anser caerulescens* (in a nesting colony unique because of the number—more than 200, 000 nesting pairs), walruses on their hauling-out places, inhabitants of bird 'bazaars' and other species of the local fauna. In 1968 it was granted the status of a 'republic' reserve, and in the future it will apparently be reorganized as a 'national' reserve. A series of reserves of local importance also exist in the north of Archangelskaya oblast', Magadanskaya oblast', etc. Finally, preparations are now being made in the USSR for the organization of a planned system of nature conservation establishments—parks and reserves. In particular the establishment of national reserves is planned on the Taimyr peninsula, in northern Yakutia and the Chukotskii peninsula.

Local hunting regulations in effect in the northern regions of the USSR include measures for the rational utilization and conservation of the arctic fauna. As a rule, destructive methods of hunting animals, such as hunting with the assistance of motorized vehicles, use of poisons, etc. are prohibited in these territories. Destruction of bird nests and arctic fox dens, capturing moulting birds, and taking wild bird eggs (except in special cases and with individual permits in the nesting colonies of sea birds) are prohibited there. These regulations prohibit hunting at any time of the year for certain especially valuable and rare animals, including, in the Archangelskaya oblast', swans *Cygnus* spp. eiders, barnacle geese *Branta leucopsis* and in addition all waterfowl wintering on ice-free reservoirs. In the Tyumenskaya oblast' and Krasnoyarskii krai hunting is also prohibited for red-breasted geese *Branta ruficollis* and all birds of prey except hawks (*Accipiter* spp.). In Magadanskaya oblast' hunting is prohibited for snow sheep or big-horn *Ovis* (*ammon*) *nivicola,* swans, emperor goose *Anser canagicus,* eiders, brent goose *Branta bernicla* and snow goose; in relation to this latter species some exceptions are made for the native population of Wrangel Island.

Local departments of Wildlife Management organize on their own territories partial (seasonal or for the preservation of individual species) or full reserves; and, in general, they determine the standards of hunting, dates of the beginning and end of the season, norms and methods of taking animals (however, dates and limits of hunting cannot be more liberal than regulations established for the whole country permit).

The general control of the realization of faunal conservation measures, expecially in the Arctic and Subarctic, as well as preparation of these regulations in the USSR, lies in the hands of the Department of Nature Conservation, Reserves and Game within the Ministry of Agriculture (the Scientific-Technical Council of the Department) and, acting under its supervision, the Central Laboratory for Nature Conservation, which have in their structure special subdivisions devoted specifically to the conservation of natural resources in the Arctic.

Among the species of the Arctic fauna, special attention is paid in the USSR to polar bears, both as to their study and also to their protection. The species has been the subject of numerous studies by Russian and Soviet zoologists and naturalists. Several important works about it can be found in general geographical publications and faunistic notes from past centuries (Pallas 1776, Wrangel 1841, Middendorf 1868-1875, Simashko 1851, Anuchin 1876, and others). From 1900 to 1930 Russian literature on the polar bear was enriched by works on its distribution and ecology in various regions of the Soviet Arctic (Geptner 1936, Tsalkin 1936, Kolyushev 1936, Rutilevskii 1939), on the systematics of this species (Birulya 1932) and combined publications on the fauna of the USSR and Soviet Arctic (Ognev 1926, 1931, Adderberg 1935 and others).

Among later works can be mentioned publications by Chapskii (1946) and by Rutilevskii and Uspenskii (1957), summarizing zoological studies conducted in the central regions of the Arctic Ocean. Also should be mentioned publications on the analysis of present distribution and numerous publications concerned with the number of polar bears in the

Soviet Arctic (Huzin 1960, Parovshchikov 1 9 6 4 , 1965, 1967, Uspenskii 1961, Uspenskii and Chernyavskii 1965) and various aspects of its ecology (Kostian 1954, Afonskaya and Krumina 1958, Uspenskii 1961, and others). During the same time comprehensive works on the fauna of the USSR and its North were published (Novikov 1956, Stroganov 1962, Geptner, *et al.* 1967).

This special interest in the polar bear taken by scientists in the USSR and other countries has been a feature of the last 10-15 years, stimulated by the initiative of the IUCN, including discussions on the state of knowledge and conservation of the species held during IUCN's Fourth (1954) and Fifth (1956) General Assemblies, and also the First International Conference (1965) and the First International Workshop (1968) on the polar bear.

From the middle of the 1950's a program of study of the systematics of the polar bear, its numbers and ecology in various regions of the Soviet Arctic has been undertaken jointly by the Central Bureau for Wildlife Management and Reserves of the R.S.F.S.R. and the University of Moscow. Since 1965 co-ordination of these activities has been done by the Department of Nature Conservation, Nature Reserves and Game of the USSR Ministry of Agriculture. Since then its Central Laboratory started to work on a special topic 'The Polar Bear in the Soviet Arctic and Its Conservation', co-operating in the realization of this study with other scientific establishments (the University of Moscow, Zoological Institute and Institute of Evolutional Morphology and Animal Ecology of the Soviet Academy of Science, Arctic and Antarctic Institute, Institute of Parasitology and Parasitic Diseases of the Soviet Academy of Medical Science) and administrative establishments (Central Bureau of Wildlife Management and Reserves of the R.S.F.S.R. and Central Bureau of the Hydrometeorological Service).

The basic interest of Soviet zoologists during recent years has concentrated on aspects of the numerical strength of the species, its population dynamics and population structure. Thus, data have been gathered from surveys of the wintering grounds of the females in the main breeding areas of the polar bears (Wrangel Island and Franz Josef Land), aerial counts of polar bears in large areas of the Arctic and other sources of information on the present distribution and number of animals in various parts of the Soviet Arctic, including analyses of replies to questionnaires circulated to employees of polar stations, hunters, and other observers.

I would like to mention that analysis of the data thus gathered allowed us to estimate the present world stock of polar bear at 10, 000 animals. Observations and hunting statistics concerned with the Soviet Arctic show that a decrease in numbers had already started in the XIX century. The process continued especially sharply in the Soviet Arctic as well as, apparently, in other Arctic regions, in the 1930's, when the annual harvest exceeded 1, 000 animals in the USSR and possibly 2, 000 in the whole Arctic. The decline continued until the mid 1950's, when numbers reached a minimum of approximately 5, 000 individauls. It is very probable that the decline was then halted by the cessation of polar bear hunting in the USSR (1956), i.e. by the reduction in the average annual harvest to the extent of the 400 to 500 individuals that had usually been taken from the population. Towards the end of the 1950's and the beginning of the 1960's a growth in the polar bear population occurred. However, at the present time this has ceased (due to an increase in the harvest beyond the borders of the Soviet Union) and the number of animals is keeping at a relatively even level.

Important for preservation of the species is the question of its population structure which remains essentially open. Analysis of craniological collections of polar bears in the museums of the USSR, conducted by F. B. Chernyavskii (1969), showed that this species is characterized by a high degree of stable geographical uniformity as well as an absolute uniformity of the skull form. At the some time he noticed a tendency towards an increase in the size of the skulls of polar bears from north-east Asia. This observation together with data obtained recently by T. Larsen (1968) and some others, suggests the possible presence of two main systems of ice circulation in the Arctic, which also carry the polar bears adrift. Thus, we cannot exclude the possibility of two geographical races of polar bears, one inhabiting the near Atlantic and the other the near Pacific regions of the Arctic Ocean (in these parts of the Arctic basin, separated by the underwater Lomonosov Ridge, significant hydrological and zoogeographical differences are generally observed). However, their geographical isolation is quite likely far from complete.

In solving the problem of the population structure ofthis species, the method of marking polar bears opens up a great opportunity. In the USSR the first attempts to realize such projects were made in 1967 in Franz Josef Land. In 1969 this work was continued on Wrangel Island where completely trustworthy results were obtained (sows were immobilized and marked in their dens there shortly before the animals started to leave their winter hideouts).

The current study of polar bears in the USSR includes also an investigation of morphological and biochemical features of the species, its parasitology (particularly trichinellosis), palaeontology, etc. The results of this study are to be published in a special series 'The Polar Bear and its Conservation in the Soviet Arctic'.

The study of polar bears conducted in the Soviet Arctic has, as one of its basic aims, the preservation of the species. In the same spirit, practical measures are undertaken in the USSR. Since 1938, hunting animals from boats without absolute necessity was prohibited in the polar stations. From the end of the 1940's hunting for polar bears was prohibited in several regions. And finally in 1956, the previously mentioned bill passed by the Ministers' Council of the R.S.F.S.R. closed hunting for polar bears everywhere. According to this bill, the only allowable form of economic utilization of this species in the USSR is the live capture of young cubs for zoos (but only when a special licence has been obtained). Since 1968, the use of firearms to scare off the sows while capturing their cubs has been prohibited. Illegal killing of the polar bear is penalized in the USSR by a fine of 200 roubles. In the preservation of these animals, the establishment of the reserve on Wrangel Island plays a particularly important role (200 pregnant females regularly winter there).

Nevertheless, the more than 10-year-long experiment with the protection of this species in the USSR has not yet given the results hoped for and the danger of complete extinction of the polar bear still exists. What the experiment has undoubtedly proved is that regulation of hunting by one individual country by itself cannot ensure the preservation of the species. In general, a similar conclusion can be drawn from the analysis of the distribution and dispersion of the animals because the hunting of these animals is done not only within territorial but also on international waters (i.e. under such circumstances it needs international regulations).

A clear need exists therefore to institute an international convention which would rationally regulate the exploitation of the polar bear stocks by the parties involved and completely remove the danger of the extinction. A comprehensive study of the polar bears conducted in the majority of the countries who share the Arctic may give in the nearest future, we shall hope, hopeful premises for an opportunity to determine the basic total allowable harvest quota and also the share to each Arctic country. In this latter case the actual character of the animal's distribution within its entire range should be taken into consideration as well as the needs of the local native people, but not the commercial interests of one country or another. This follows from the already existing declaration of the polar bear as 'an international polar resource' (transaction of the First International Conference on the Polar Bear) and from the generally accepted norms of international law.

The specificity of the arctic ecosystems, their simplicity and instability, their extreme vulnerability to economic activities, the peculiarities of the geographical distribution of its mobile components naturally emphasize the necessity of a much wider profile of the international-legal protection of the entire natural complex of the Arctic, and especially those species the conservation of which exceeds the limits of ability of individual countries.

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Paper No. 23

Whither Wildlife Resource Management in the Northwest Territories?

A.W.F.BANFIELD[1]

I am very concerned about the future prospects for wise management of the renewable natural resources in the Northwest Territories of Canada, particularly wildlife resources. Unfortunately, nothing I have heard at this conference allays my previous anxiety. We have learned that renewable resource management will be subjected to a systems analysis approach. Conservationists must be prepared to substantiate their claims of benefits to be derived from the natural environment by cost-benefit data.

Now, the systems analysis approach does not frighten an ecologist. Ecologists were among the first to develop such an approach. Charles Elton drew flow charts and box sub systems in his *Animal Ecology* in 1927. Today ecologists study the energy flow and the efficiency of organisms in utilizing this energy in the ecosystems. What worries me today in the administration of the renewable resources of Canada's northland is probably in the area of cybernetics. Why is there such a low efficiency in the utilization of scientific information on hand in the management of these resources? There already are many quantitative studies in the hands of the authorities that could serve as a basis for the application of wise management policies and regulations. But there seems to be little effort made of information retrieval! Recent government policy decisions indicate little long-term planning. The benefits of wise wildlife resource management, either for the resident native and European population or to humanity in general, are ignored. Instead, policy decisions seem to be made on a day to day *ad hoc* basis with short term local goals in mind.

[1] Brock University, St. Catharines, Ontario. Canada.

I refer in particular to recent regulations passed under the Game Ordinance by the Northwest Territories Council. Over the past few years regulations have been adopted concerning the hunting of barren-ground grizzly bears, musk-ox, and caribou which were contrary to the recommendations of research reports prepared by the Canadian Wildlife Service. The same holds for the institution of wolf bounties. In these cases the Council either ignored the advice of its research advisers or refused to solicit the Wildlife Service's advice.

In the Spring of 1969 the regulations respecting the hunting of caribou, were changed to permit any resident of the Northwest Territories (a person who has lived in the Territories for 6 months) to shoot five caribou at any season (even in the calving season). Furthermore, the regulations permit the sale of legally taken caribou under a generous quota system. Under these regulations the most affluent resident can hunt caribou far afield at any season by aircraft and ski-doo: and the sale of caribou meat (mostly hindquarters) to northern towns-people is encouraged. Entrepreneurs may pay native hunters for their caribou rights to traffic in the meat. These regulations seem beyond the possibility of adequate supervision.

For many years the Northwest Territories administration cooperated with the provincial game authorities and offered leadership in the subject of caribou conservation for native utilization. It now appears likely that the Prairie Provinces will be forced to liberalize their caribou regulations to match those of the territories. It is doubtful if the current caribou populations could survive such a concerted onslaught.

I feel something like Saint Paul on the road to Damascus when he was struck by a 'fireball', when I recall how I aided in the persecution of certain missions in the 1940's and 1950's for trafficking in caribou meat. Perhaps the Pope had the same thoughts when he recently authorized fishless Fridays.

This Council action has been hailed in some quarters as an example of democracy in action. The will of a few active local proponents of open caribou hunting has been adopted. I don't believe it is an example of responsible democracy when a renewable natural resource is to be exploited for the short-term benefits of a privileged few, ignoring the long term benefits to native populations, and Canadians in general, which would accrue from wise management.

Much has been said about the patronizing attitude of the Department of Indian Affairs and Northern Development in Ottawa towards the Territorial government. Let me point out the other side of the coin in this case. Consider the Department's role as father to the Northwest Territories Council's role as Junior. Junior is demanding the keys to the family car but father, doubting Junior's sense of responsibility, has given him a bicycle instead. The bicycle represents the control of the renewable natural resources. (Some of us may feel that it was really the family heritage that was given and not a cheap substitute, but it is a fair comment on the Department's evaluation of renewable resource management.) Junior, like a wilful child, proceeds to wreck the bicycle and continues to scream for the family car (full provincial autonomy). Since, as a Canadian I, too, am interested in the family belongings, I hope Dad doesn't give Junior the keys until he proves he is responsible.

President Carrothers' address didn't reassure me either. He said nothing to dispel the feeling that the government's future approach to renewable natural resource management will continue to be immediate short-term exploitation. He spoke of the establishment of an economic council and an economic board for the Northwest Territories. Today in North Africa and the Middle East one can see the ruins of ancient cities lying abandoned on desolate, stony plains. It is now recognized that these cities were abandoned because they exhausted their natural resources. I can well imagine that the governments of these city states; had economic councils and economic boards that somehow overlooked the excessive exploitation of the natural resources of the land. I can even imagine a cost-benefit study that recommended the introduction of the goat to utilize more efficiently the declining vegetative resources and to replace the declining native wildlife. Today ecologists recognize that excessive goat populations have constituted a degrading force in Middle East ecosystems for more than a thousand years.

My plea, then, to northern legislators and administrators is to utilize the information that is already available in research reports. They will provide a first approximation to ecosystem management at this critical time. Second, let us turn our backs on the short-term exploitive policy in resource management which has proved to be so disastrous for over two thousand years. Surely the promotion of self government in the territories does not necessitate returning each time to 'square one' in resource management, ignoring the available accumulated knowledge.

Paper No. 24

The Impact of Oil Development in Alaska (A Photo Essay)

DAVID R. KLEIN[1]

The discovery of oil on 18 July 1968 near Prudhoe Bay on Alaska's arctic coastal plain (The North Slope) and the subsequent flurry of oil and gas exploration and development has already had a pronounced impact on the tundra environment over a large area radiating from the discovery well. Since exploration and development of the North Slope oil reserves can be considered to be in an embryonic stage, the future impact of this oil boom will be of an almost incomprehensible magnitude.

In addition to the direct effects of oil development on the North Slope, there will be subsidiary effects in other parts of Alaska resulting from the transportation of men and materials from staging areas further south, the increased human populations in areas previously totally unpopulated, or with extremely low densities, and the transportation of the oil and gas to world markets and to Alaskan refineries. In this latter category of oil transportation, the proposed construction of an 800 mile pipeline 48 inches in diameter from near Prudhoe Bay on the arctic coast to Valdez, an ice-free port on the Gulf of Alaska, poses problems of ecological disturbance that require immediate attention if they are to be dealt with realistically during the planning, construction and operation of the pipeline. During the winter of 1968-69 a winter haul road was hastily constructed from the end of an all-year road near Fairbanks to the North Slope. The road was not competitive with air freighting and has now been abandoned, leaving a permanent scar for over 350 miles across northern Alaska.

The following series of photographs, mostly taken during July and August, 1969, show characteristics of the terrain of the North Slope, activities associated with oil development, and environmental problems resulting from man's activities in the North.

I THE NORTH SLOPE

Photographs I-1 to I-23

II THE TRANS ALASKA PIPELINE, THE WINTER HAUL ROAD AND ASSOCIATED PROBLEMS

Photographs II-1 to II-10

[1] Alaska Cooperative Wildlife Research Unit, College, Alaska.

Photo I-1 The Arctic Ocean coast at Pt. Storkersen. The tundra is being eroded by wave action. Note the exposed ice lenses, characteristic of permafrost in the wet coastal plain.

Photo I-2 Natural frost polygons on the coastal tundra which are characteristic of areas underlain by ice lenses.

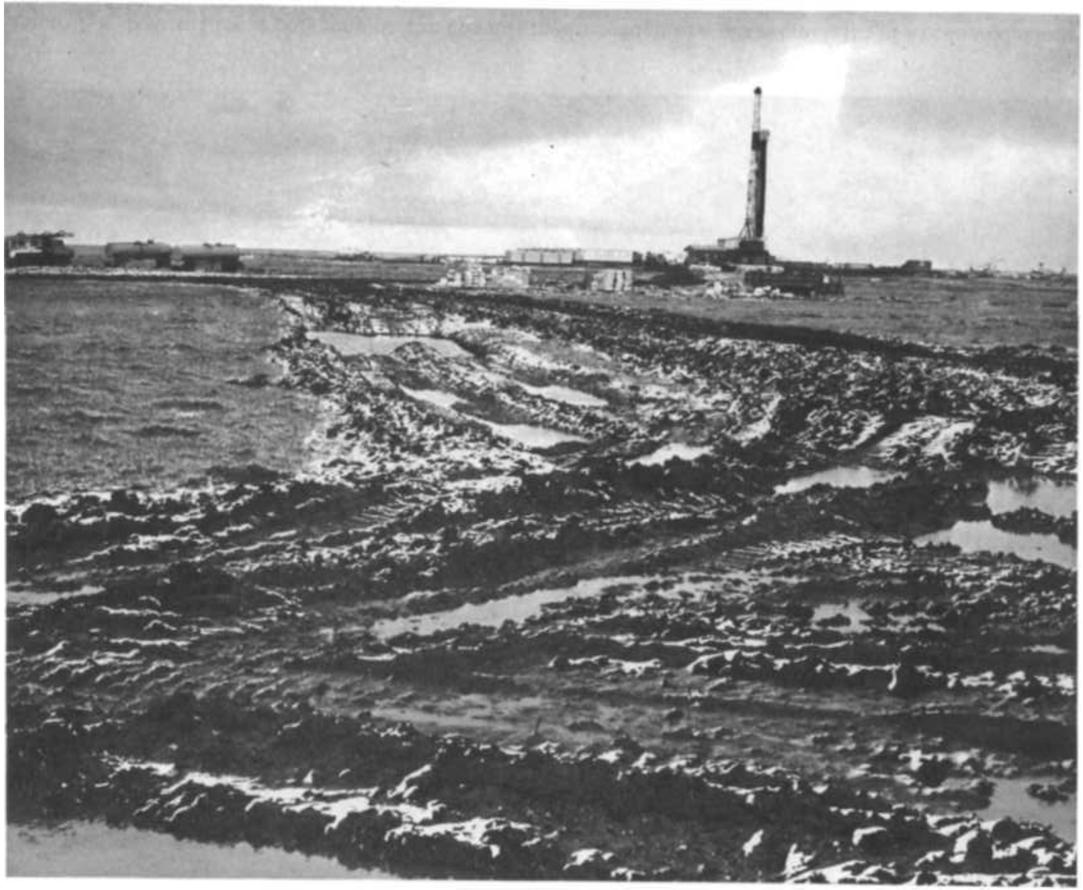

Photo I-3 The use of an insufficient layer of gravel in road construction has resulted in thawing of the permafrost and severe degradation of the tundra at this well site at Pt. Storkersen.

Photo I-4 Gravel for this camp, rig pad and air strip was trucked 25 miles in winter over the frozen tundra from the Sagavanirktok River. The collapsible rubberized fuel tanks shown above and to the left of the airplane are a practical means of fuel storage which eliminate the need for use of 50 gallon steel drums, and the problem of their disposal when empty. The rubber fuel tanks, however, are subjected to rupture from snow pressure in winter or by snow removal equipment and they should be adequately diked to contain the fuel in the event of a leak.

Photo I-5 An oil rig on the Kuparuk River. Here good foundation is available on an old gravel bar although the adjacent air strip is partially awash due to unseasonably high water. Use of such sites causes minimal permanent disturbance to the land although siltation and possible pollution of the adjacent river could present a threat to fish populations.

Photo I-6 A well drilling site on the coastal tundra near Prudhoe Bay. The surface of the tundra is only inches above the water table. A gravel road bed 4-5 feet thick appears to be adequate to provide support for heavy equipment and it has not caused thawing of the underlying permafrost. Sewage from the camp is contained in the small diked lagoon in the foreground. The effectiveness of this method of handling sewage and its influence on the ecology of the surrounding water systems is not yet known.

Photo I-7 An abandoned well site on the coastal plain near Prudhoe Bay. Insufficient gravel was used here and the resulting damage to the tundra is fairly extensive. Also indiscriminate use of tracked vehicles has left numerous scars on the tundra radiating from the site.

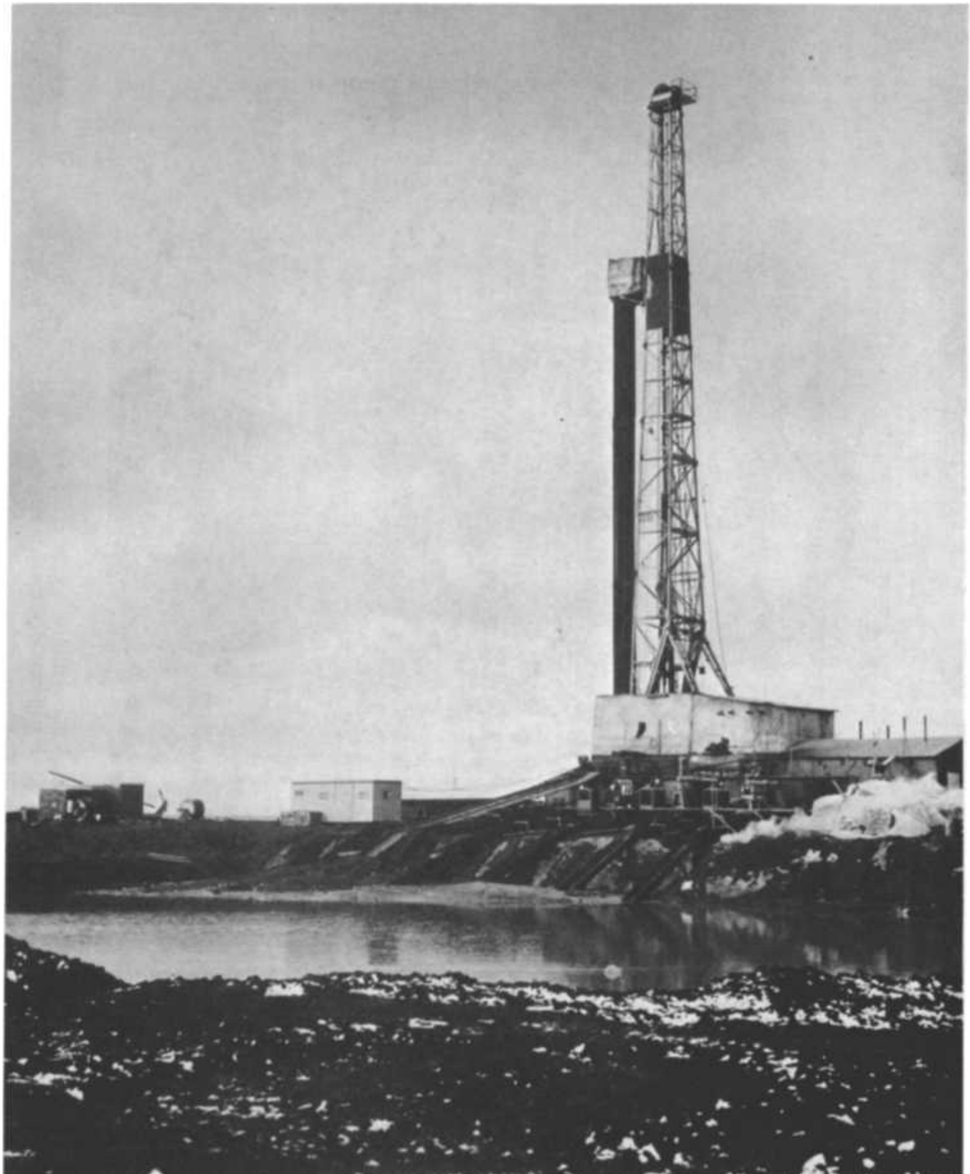

Photo I-8 A well being drilled at Pt. Storkersen showing the sump constructed to contain drill 'mud' and possible test quantities of crude oil.

Photo I-9 The use of tracked or wheeled vehicles on the tundra during spring and summer destroys the vegetative cover and induces thawing of the permafrost. Soil erosion and permanent scars result.

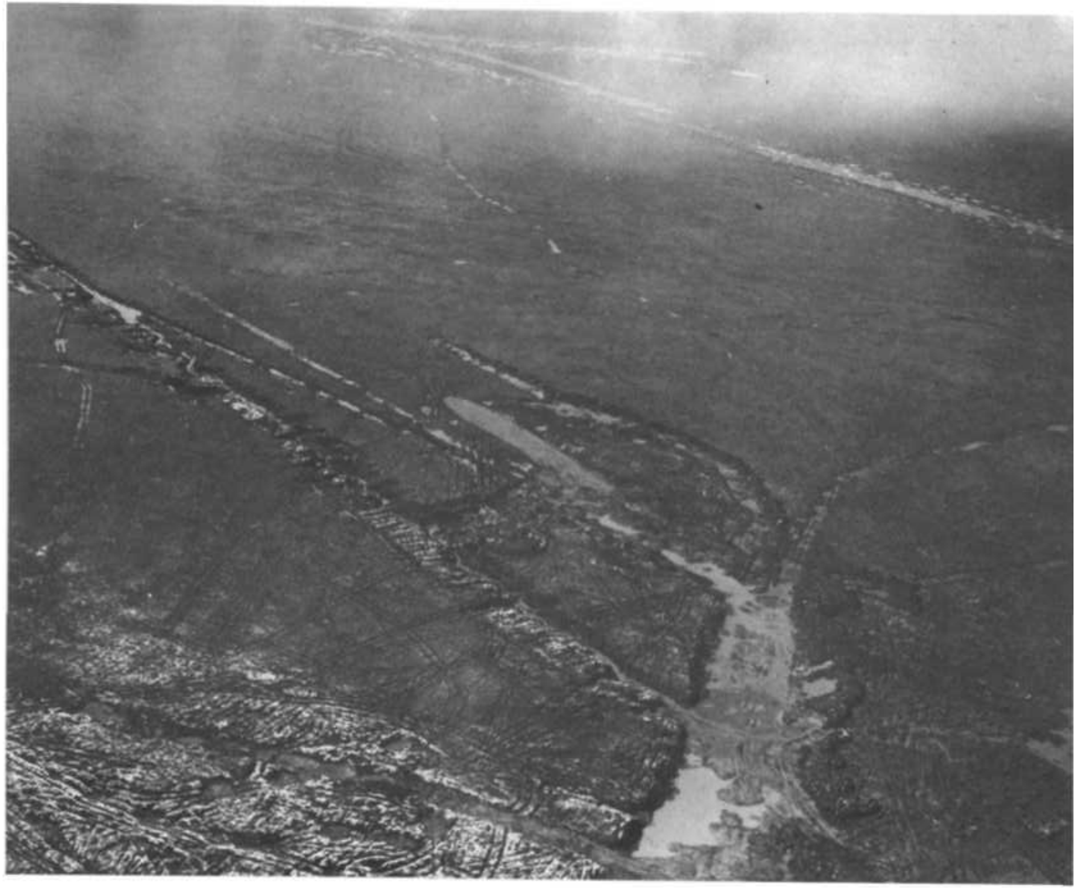

Photo I-10 Severe scarring of the tundra has occurred here adjacent to a drilling operation. Soil erosion is occurring in the ditches created by bulldozers and silt-laden waters are flowing into adjacent clear streams.

Photo I-11 Here a thaw lake has been modified with a bulldozer to provide an extended runway on the lake ice for landing large aircraft. This landing area was used to supply a well being drilled west of the Sagavanirktok River.

Photo I-12 A small topping plant (refinery) for local fuel needs under construction at Prudhoe Bay. Note the improper road construction in the left background; no gravel has been used and the adjacent tundra has been scraped to the center to form a raised road bed. Thawing of the permafrost in the adjacent ditches is occurring and inducing slumping and calving of the adjacent road and tundra.

Photo I-13 A large pingo on the coastal plain north of Prudhoe Bay. Pingos are prominent land marks on an otherwise flat terrain and serve as reference points for tracked vehicle travel. They also provide an elevated platform for survey work in conjunction with seismic operations. This concentration of human activity may seriously affect the arctic fox which shows a high preference for pingos for den sites.

Photo I-14 A mobile seismic operations camp at Pt. Storkersen. Inadequate waste disposal is frequently a characteristic of these field camps of contractors subsidiary to the larger oil companies.

Photo I-15 Abandoned oil drums and scarred tundra mark this North Slope lake which was used as an aircraft landing area during the past winter for supplying oil exploration activities.

Photo I-16 A clear tundra stream adjacent to the airstrip at Sagwon is being needlessly degraded through the accumulation of litter.

Photo I-17 Solid waste left from a seismic operation mars the beauty of the adjacent tundra stream. Such waste, often shallowly buried, is subject to excavation and scattering by arctic foxes and grizzly bears. The only satisfactory solution appears to be complete removal of solid waste at such sites.

Photo I-18 Tugs and barges lying off Prudhoe Bay with freight for North Slope oil development. The oil drums on the beach in the foreground are a few of thousands littering the Arctic Ocean beaches from past and present military, government and oil industry operations.

Photo I-19 Solid waste accumulating at Sagwon, a distribution center for oil activity near the northern foothills of the Brooks Range. Such sites, operated independent of the oil companies, frequently have no programs to solve waste disposal problems.

Photo I-20 A giant flying crane in operation on the North Slope freighting heavy equipment and materials. These craft can move entire oil rigs and camps, eliminating the necessity of using tracked vehicles during the summer when the tundra surface is subject to damage.

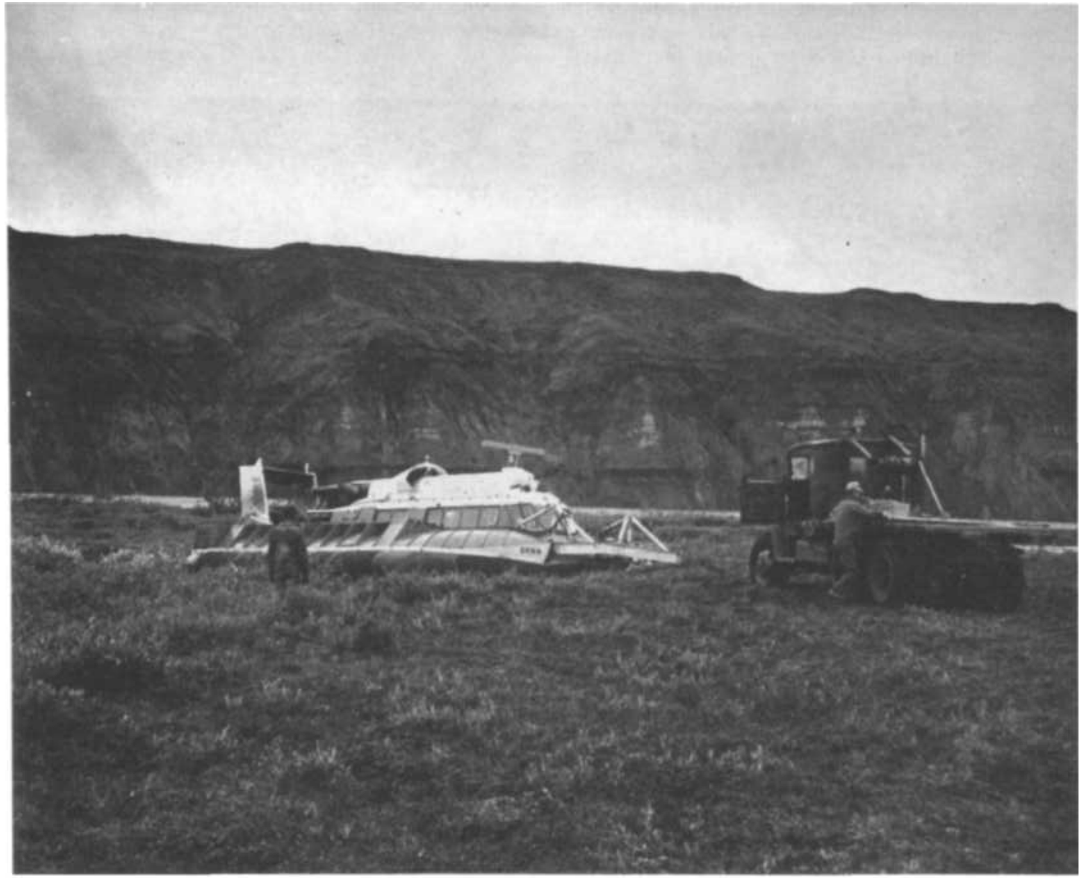

Photo I-21 A hovercraft, modified for seismic exploration, which was damaged on the Sagavanirktok River. These craft travel over the tundra on a cushion of air and cause no apparent disturbance to the vegetation or tundra.

Photo I-22 The north side of the Brooks Range near Peters Lake in the Arctic Wildlife Range which is closed to seismic exploration and drilling for oil. This is a popular area for mountaineering.

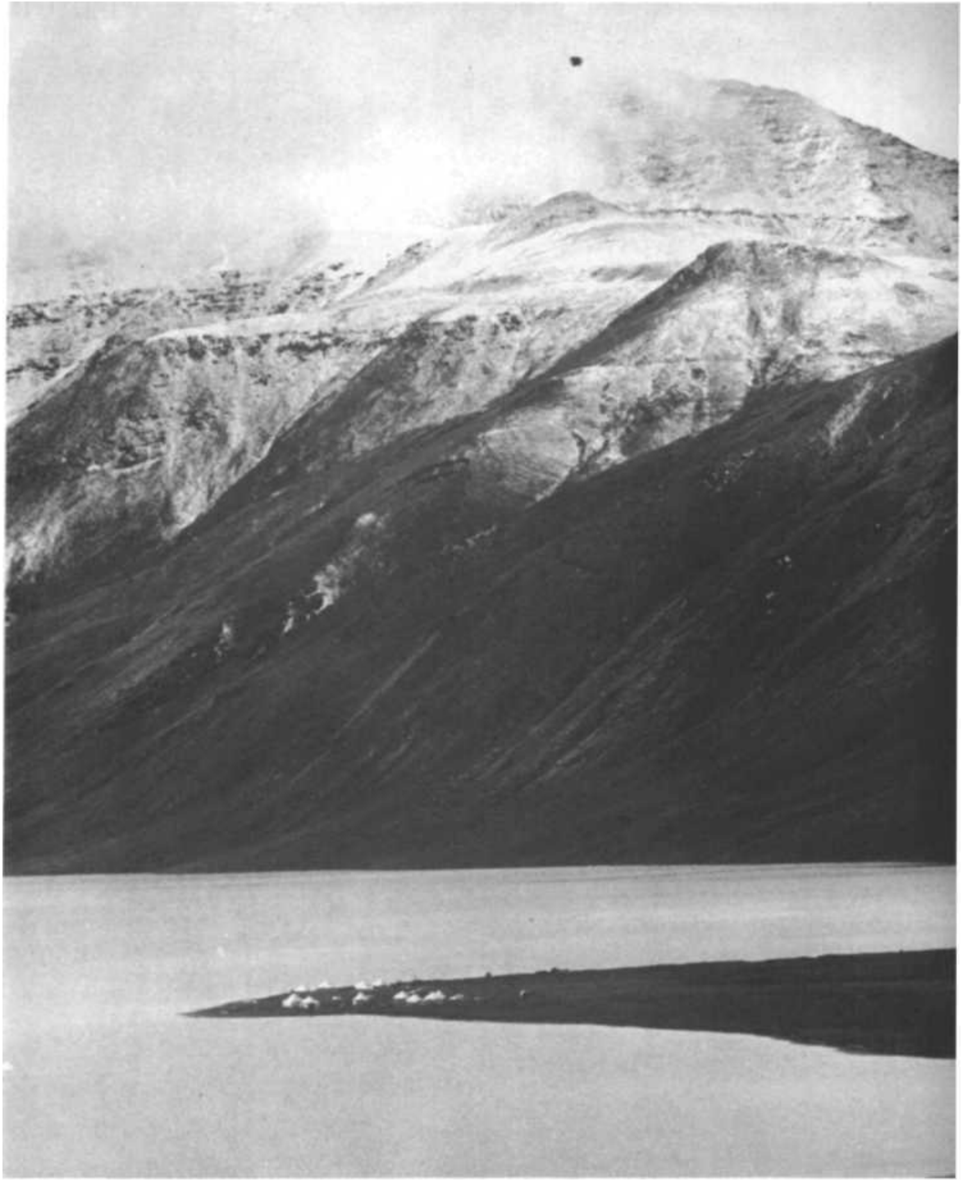

Photo I-23 A tent camp of oil company geologists doing surficial exploration with the aid of helicopters, Peters Lake, Arctic Wildlife Range. Such large concentrations of men and equipment create serious problems of waste disposal. J.E.Hobbie (Aquatic ecology in the Arctic National Wildlife Range. Proc. Alaskan Sci. Conf. 1961 p. 31-36) pointed out the possible threats to disruption of the nutrient cycles in Peters and Schrader Lakes with the concentration of people on their shores. After detailed limnological studies of the lake water systems he estimated that human wastes from concentrations of 20 men or more on the lakes could markedly alter their ecology. Strict regulations must be maintained and rigidly enforced to govern the disposal of human waste and the removal of solid waste from camp sites such as the one shown in the photo.

Photo II-1 The route of the proposed Trans Alaska Pipeline at Grayling Lake, in the southern foothills of the Brooks Range. This narrow valley does not appear to offer sufficient space for the passage of both a pipeline and road without endangering the lake through siltation. The lake is noted for its abundance of grayling and it has considerable recreational value now and this value will increase on the future.

Photo II-2 The Chena River valley adjacent to the proposed Trans Alaska Pipeline route. This area, lying 10 miles east of Fairbanks, is prime moose, waterfowl, beaver and muskrat habitat. It is readily accessible by river and receives heavy recreational use for hunting, sport fishing, trapping, boating and camping. These recreational values are threatened by the construction of the pipeline.

Photo II-3 The southern coast of Alaska in Prince William Sound near the terminus of the proposed Trans Alaska Pipeline.

Photo II-4 Ice fog, obscuring the city of Fairbanks in January 1969. Two oil refineries, planned for the Fairbanks area, will use oil from the Trans Alaska Pipeline and threaten to contribute to the already serious air pollution problem of the area.

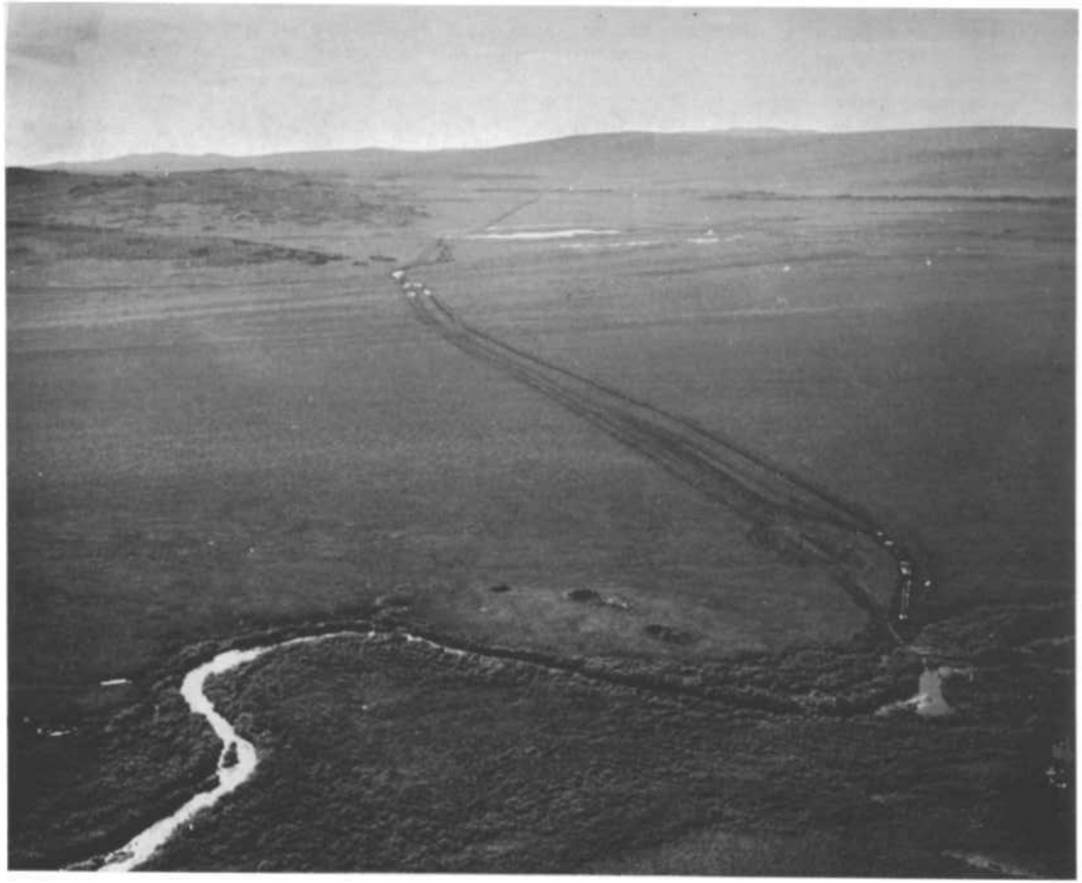

Photo II-5 A section of the winter haul road where it crosses Kanuti Basin in the Dall Mountains. Unnecessary disturbance of the tundra has resulted here from failure to restrict the traffic to one track.

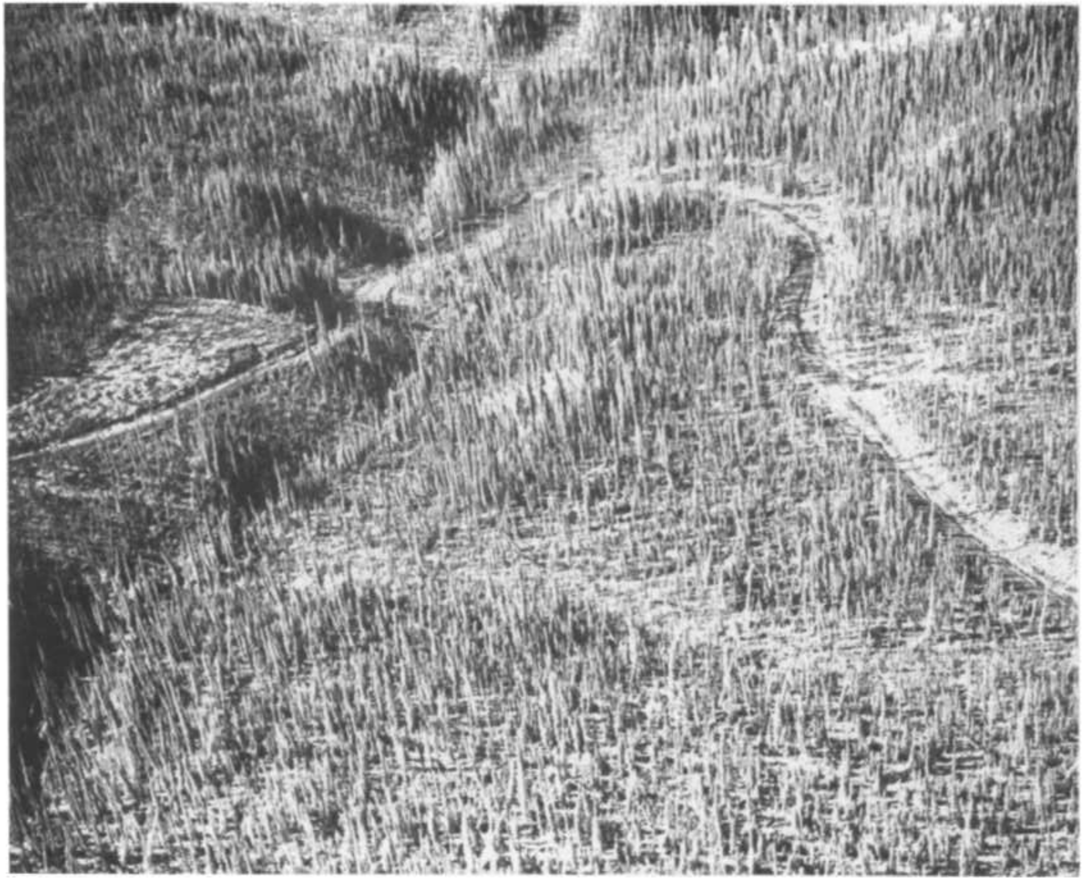

Photo II-6 A portion of the winter haul road in the hills south of the Yukon River near Stevens Village. Note the gullying and flowing of the light-colored aeolian soils on the section of road on the right of the photo.

Photo II-7 A section of the winter haul road just north of the Yukon River. Here the road skirts along the shores of lakes of high value for nesting waterfowl. Routing of the road away from the lake shores would have minimized the threat of siltation of the lake waters and would have maintained the aesthetic appearance of the lakes. Trumpeter swans nest in this lake system.

Photo II-8 The winter haul road which was constructed from Fairbanks to Alaska's 'North Slope' in 1969. This section is near the Arctic Circle south of Bettles. The rutted appearance and associated thawing of the underlying permafrost is the result of the continued use of the highway by trucks after the spring thaw had commenced. The road will now require extensive repair before it can be put into winter use again and continued degradation of the permafrost can be expected in the future. This problem could have been avoided by timely closing of the road to traffic before the spring thaw began.

Photo II-9 Trucks stranded at Sagwon on the North Slope by the spring breakup of the southern portion of the winter haul road.

Photo II-10 Legislation alone will not prevent degradation of the northern environment as shown in this picture taken along a highway on the Kenai Peninsula. Provision for adequate enforcement of laws is also essential as well as, and perhaps more importantly, the development of a land-use ethic among the general public.

Paper No. 25

Arctic Terrain and Oil Field Development

G. REMPEL

There is currently a tremendous enthusiasm for the oil potential of the North. This is borne out by the fact that almost all the sedimentary basins of the Canadian north, shown in Figure 1, are currently under lease. A westward extension of this region includes Prudhoe Bay in northern Alaska where a major oil discovery was made in 1968. Exploration commitments have been made, work will proceed and, hopefully, development will follow. It remains to ensure that this work is conducted under a regulatory climate based on informed opinion which will recognize both resource and conservation needs.

Land portions of the sedimentary basins in Canada north of Latitude 60°, shown in Figure 1, comprise about 470, 000 square miles. It has been estimated that the development of the oil reserves in this region will require the direct use of 1, 350 square miles or not quite 0. 3 percent of the total. This includes seismic lines, well sites, roads, pipelines, camp sites, storage dumps and airfields. About $^1/_3$ of the land requirement is for seismic work and wildcat wells which is a temporary use, after which a considerable portion will revert to the original state. The effect of this work on arctic terrain will depend to a large measure on the amount of ice in the permafrost soils. Fine-grained frozen soils are particularly susceptible to disturbance by natural and artificial forces. The Norman Wells oil field, which lies near the southern limit of continuous permafrost, is a good starting point in a discussion of effects of oil field developments on arctic terrain.

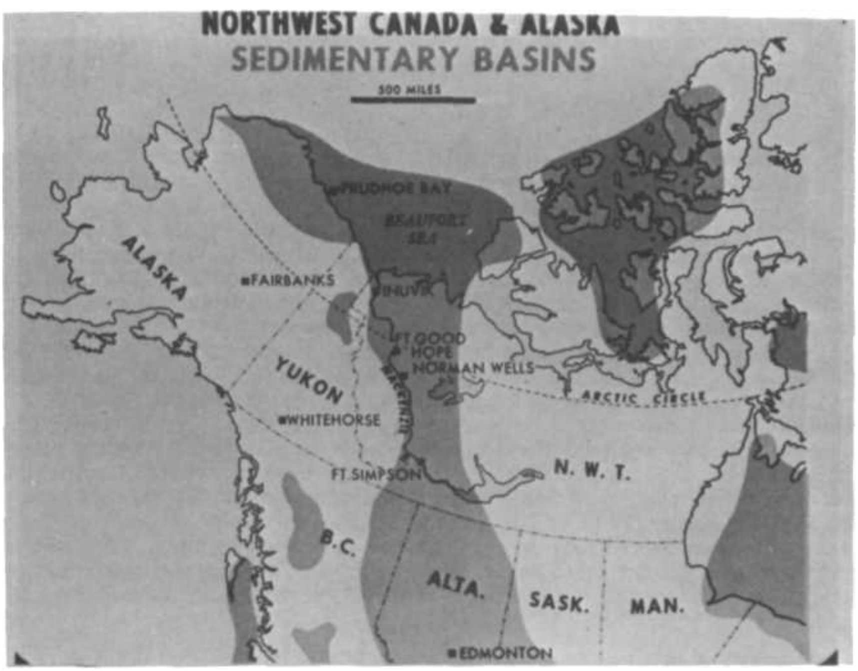

Fig. 1. Sedimentary Basins.

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(1) Imperial Oil Limited, Calgary, Alberta, Canada.

Despite the 50 years of activity in the Norman Wells area, including the major wartime 'crash' development programs of 1943-45, there is now little evidence of terrain degradation in the field. Flowline rights-of-way, well sites and seismic lines have grown back with secondary cover and a return to stable conditions is quite evident. The area is still within the forested region of the north. Tundra terrain, on the other hand, may be more sensitive to man's intrusion. This type of terrain is prevalent along the northern coast in that area generally outlined in Figure 2.

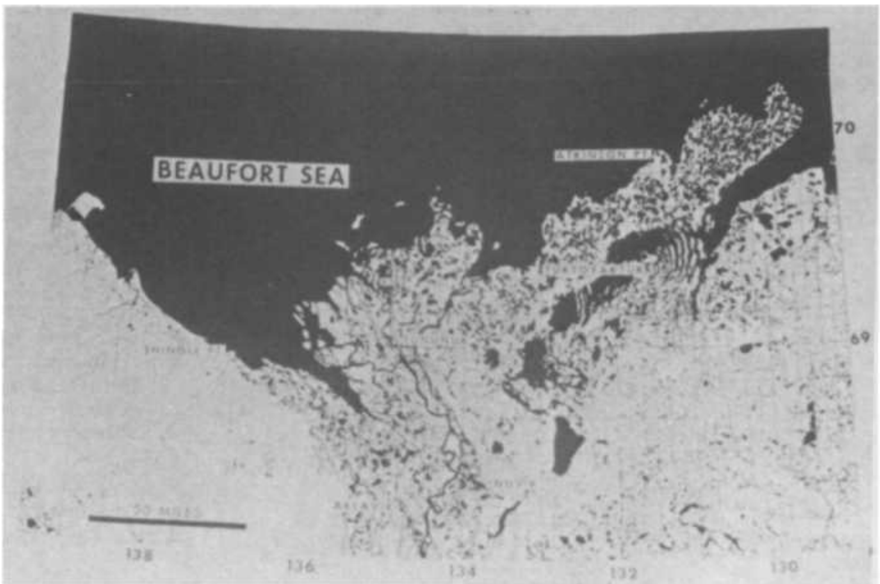

Fig. 2. Western Arctic Mainland.

In most places, however, it is not so sensitive that only one or two passes of a tracked vehicle, even in summer, will necessarily mar the landscape for many decades—unless one puts a blade on the front of the unit and strips away the insulating cover of vegetation; or alternatively makes many passes over the same trail. Figure 3 is an example of the small amount of terrain alteration which has resulted from a seismic operation conducted with tracked vehicles over tundra terrain in the summer of 1963. The underlying soils are in a 'sensitive' area of generally fine-grained sediments with a high ice content. Another view of a seismic line over tundra in which the surface was unbroken is shown in Figure 4. During an inspection flight last summer at a few thousand feet over the area, many of the old lines were no longer visible from the air. These examples are from areas of low relief. Negotiating steep slopes with track vehicles fitted with aggressive grouser bars can be somewhat more damaging to the terrain. New concepts in track design which show good drawbar characteristics with reduced ground disturbance are currently under test. Dr. Radforth, a noted expert in muskeg classification, has conducted experiments with this new track and has reported surprisingly good test results. Field operating trials, will, of course, be necessary to evaluate the operational usefulness of the new design. Air cushion vehicles have been used with some success on flat tundra terrain. Surface disturbances are slight. Hilly terrain and tree cover preclude the use of this type of craft over a considerable portion of the Canadian arctic mainland.

Winter operations of course cause the least ground disturbance. This is the period when heavy loads required for drilling operations are moved. Figure 5, from the Tuktoyaktuk area, shows a winter line which is now hard to spot from the air. In some low areas, as shown in Figure 6, the evidence of the previous winter's work may persist. A small amount of subsidence may occur, but generally the recovery of vegetation has been found to be rapid.

Fig. 3. Summer Seismic Line—Track Vehicles Only.

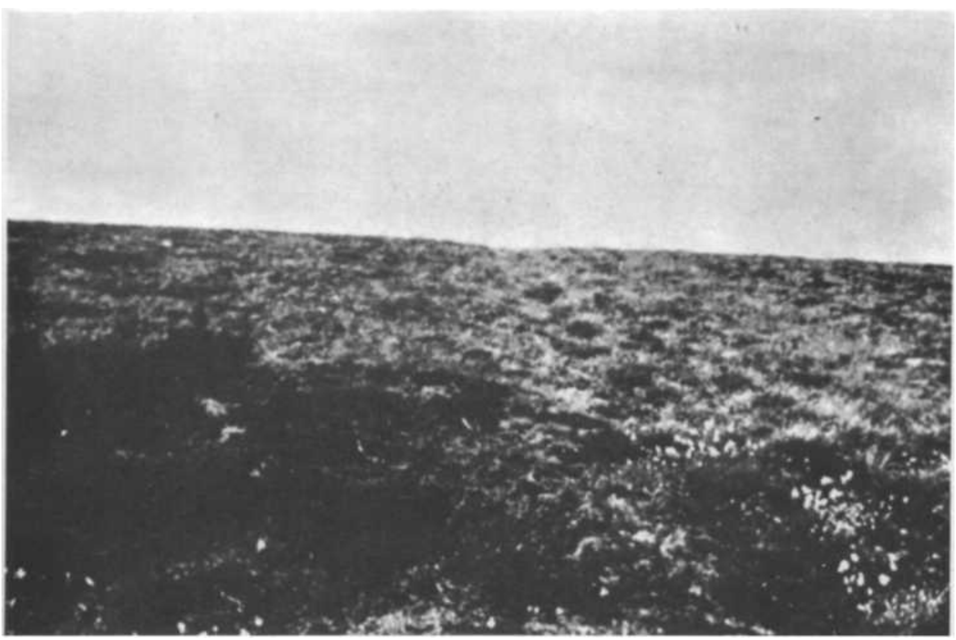

Fig. 4. Summer Seismic Line-Track Vehicles Only.

Fig. 5. Winter Seismic Line-Bulldozed.

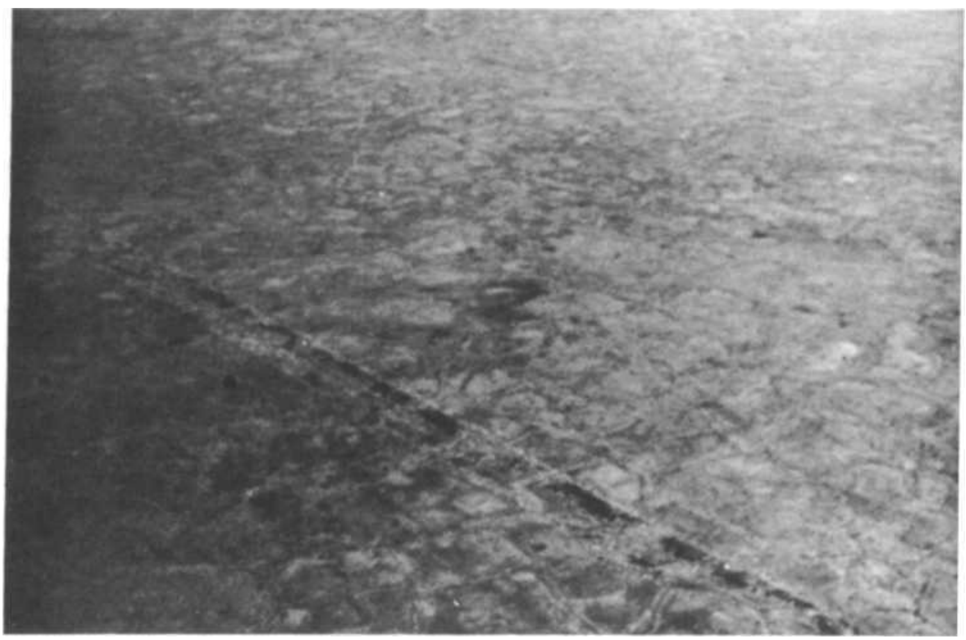

Fig. 6. Winter Seismic Line in Low Area—Bulldozed.

An example of seismic work in which the tundra vegetation was stripped from the underlying permafrost by bulldozers during the summer is shown in Figure 7. This work was done in 1965, with the picture taken the following summer. Operations of this type ceased in 1965. The 1965 bulldozed line was inspected in 1968 and again this summer. It was apparent that most of the subsidence had taken place the first year of exposure. By 1968, as shown in Figure 8, some natural regeneration of vegetation was evident. There was little evidence of erosion even on the hillsides. Consequently, siltation of streams should be slight. Figure 9 illustrates the condition of a portion of the same line as observed this past summer. It is apparent that thermal subsidence and erosion are not necessarily coincidental, and the term 'thermal erosion' should not be used indiscriminantly, as it has been in the past. Permafrost experts and geographers use the term 'thermokarst' to describe subsidence caused by thawing. Thermokarst, being associated with permafrost, is an arctic phenomenon, whereas erosion may be initiated in any climatic zone with the removal of sufficient cover on slopes.

Fig. 7. 1965 Bulldozed Summer Line—Condition in 1966.

The contrast between ordinary seismic vehicle traffic in summer and a bulldozed trail is illustrated in Figure 10. Note the slight alteration of terrain by seismic vehicles which have travelled alongside the bulldozed line. Figure 11 shows a heavily loaded track vehicle of the type used in seismic operations traversing the tundra in summer. It can be seen that the surface vegetation cover is essentially unbroken. To the left of the newly made trail is a three-year-old bulldozed line of a previous summer operation.

Thermokarst is of special significance in the construction and operation of large diameter pipelines in arctic terrain. As a result of the observation of bulldozed lines and construction projects in the arctic and discussions with numerous arctic experts, Imperial Oil decided to initiate a modest experimental project on stabilization and restoration of disturbed ground in arctic tundra. One tests plot on a summer bulldozed line near Tuktoyaktuk is shown in Figure 12. The upper plot shows fall seeding of crested wheat grass, a portion of which is covered with sawdust. In the foreground is a 3-week-old (July seeding) Reed canary grass. There appears to be a good catch. Stakes are used to measure frost recession. There is another test site at Inuvik, and similar tests are apparently being conducted in Alaska.

Fig. 8. 1965 Bulldozed Summer Line—Condition in 1968.

Fig. 9. 1965 Bulldozed Summer Line—Condition in 1969.

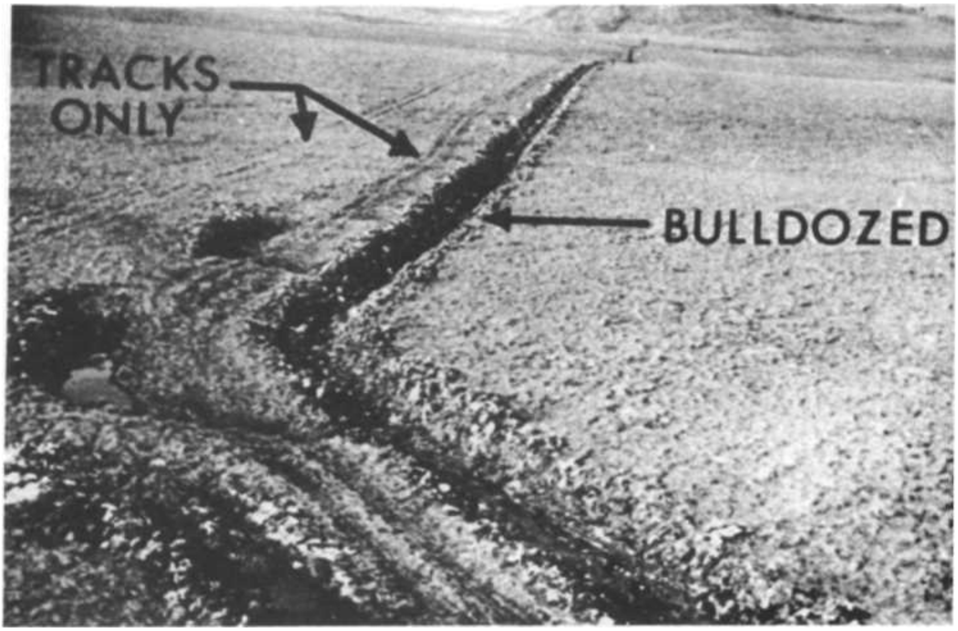

Fig. 10. Bulldozed Line vs. Tracks only.

Fig. 11. Seismic Track Vehicle on Tundra.

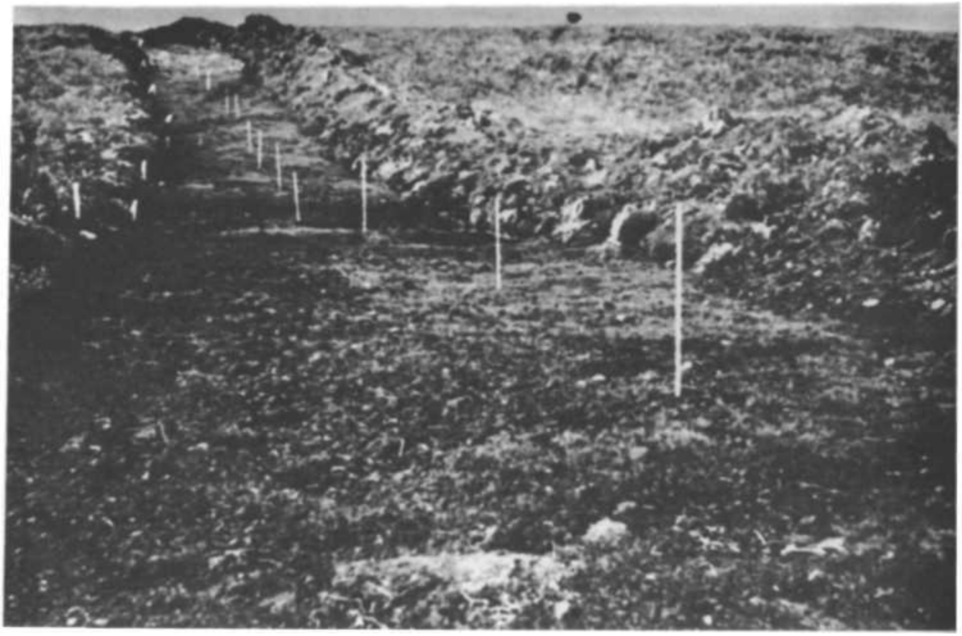

Fig. 12. Test Plot-Seeded.

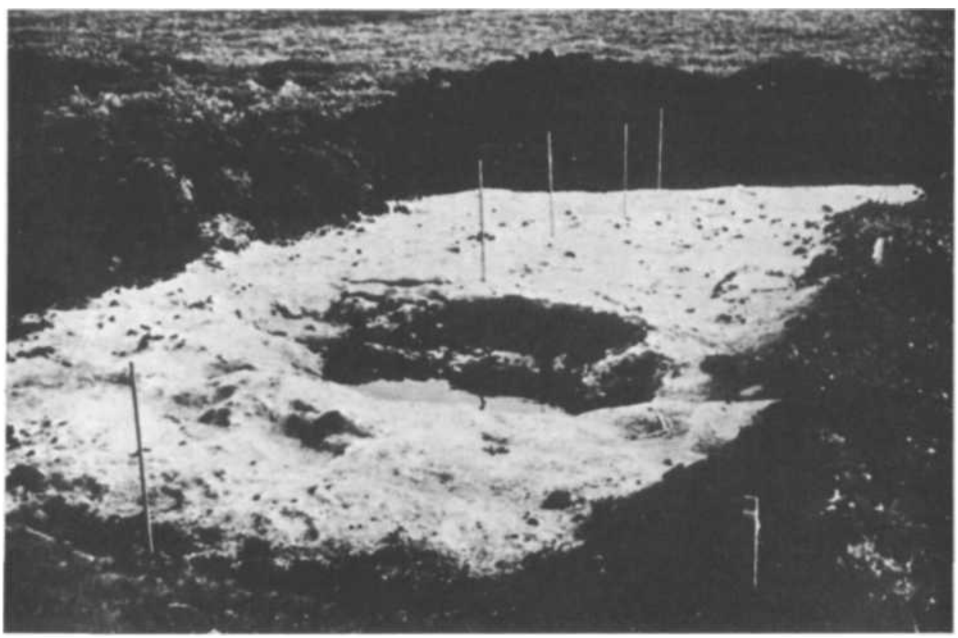

Fig. 13. Preservation of Permafrost—Sawdust over Peat Mound.

Figure 13 shows an experiment in permafrost preservation using a 2-inch layer of sawdust over a peat mound. The amount of thawing induced by a break in the cover is shown. New growth in the foreground from Reed canary seed was subsequently covered because birds took a heavy toll of seeds. Our last report indicated the grass had been harvested by rodents.

These experiments and observations, along with other studies under way on ground temperatures, terrain classification and general environmental conditions, should make it possible to better predict the long-term effects of particular types of operations.

This paper has reviewed the impact of oil field operations on arctic terrain. It has been an attempt to place in perspective the amount of damage which has occurred and how it has occurred in the Canadian north. It is in some measure contrary to those currently popular reports and displays which only dramatize the degradation of landscape. The effect on terrain depends on many factors, among which are the type of equipment used, season of work, method of operating, nature of terrain and, perhaps most important of all, the dedication and knowledge of those directing and performing the work. Terrain surrounding producing fields, oil gathering terminals and living compounds will be preserved Economic reasons will dictate this because stability of structures and trafficability will depend on preservation of permafrost. Precautions will be needed to avoid oil seeps from wells and pipelines. Established engineering methods can be used for structures and roads. Various theoretical and model studies on how to preserve permafrost around a well producing hot oil are underway. An influx of people with recreational needs will put some strain on the environment. The risk of fire in both forest and tundra zones caused by careless campers or poor work practices will increase. The experience at Inuvik last year brings this problem into sharp focus.

The oil industry is aware that its impact on terrain is only one facet of the total ecological balance in the arctic. It will require the cooperative effort of many disciplines and many interests to minimize environmental changes. Many of those disciplines and interests are represented at this conference, which provides an excellent opportunity to exchange views and discuss problems of mutual concern.

Paper No. 26

Man in Nature: A Strategy for Alaskan Living

ROBERT B.WEEDEN[1]

People move to Alaska for many reasons and, because of the distance and cost of moving, the reasons rarely are trivial. Major population increases have come in boom times; one might infer that the lure of economic benefits has been paramount. But recessions have followed the booms and those with purely economic motives often have gone back 'Outside' where, if they were going to starve, they could do it in a comfortable climate. Even in our exciting times in Alaska a man spends $1. 32 for what he could buy in Seattle for $1. 00; he earns only $1. 21 for a dollar's worth of labor by national standards. Clearly the Alaskan is not as well off as the average American.

Or is he? Is there something in the air, the romance of Alaska that creates the captivating incentive that money fails to provide? Do people stay because they expect to take part in a legend? I think they do. In Alaska people perceive and respond to a uniqueness comprising the freshness of history, the indefinable lure of 'frontier' and, above all, the

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wilderness. Despite the comings and goings of boomers, I think the heart of Alaskans is in Alaska.

If ever it was important for a people to gauge accurately their own feelings about themselves and their environment, it is true in Alaska today. History and Nature have proffered an array of choices that our civilization has never seen before. The only decision we cannot make is to stay aloof from change. If we Alaskans do not make our own choices, others will happily do it for us.

The most obvious element in the situation is the economic upheaval since the September 10, 1969 oil lease sale in Anchorage. On that day Alaskans, who had earned a total personal income of a little over a billion dollars in 1969, received slightly over $900, 000, 000 in lease payments and bonuses on State lands near Prudhoe Bay. The expectation of significant continued income from future lease sales and from oil and gas production suggests that the rather desperate search for revenue characterizing the decade after statehood is over.

An equally important ingredient is that the inherent character and productivity of the land are largely undiminished. Over vast areas of the State there is hardly any evidence of human use. Air and water are as pure as anywhere in this polluted world. Renewable resources are (with a few exceptions) harvested below or barely at annual production levels. Surface transportation nets cover only one-fourth of the State, sparsely. In short, the present array of choices is not greatly diminished by past mistakes or heavy capital investments.

Third, a major group of Alaskans, the approximately 60, 000 Indians, Eskimos, and Aleuts of the State, may suddenly gain economic and land-owner stature such as they have never had before. These people face individual and group choices that are in many ways more difficult and unsettling than those confronting other Alaskans.

Fourth, the richness of the present opportunity is largely due to the recognition by Alaskans that their new wealth brings new responsibilities of decision. To some the responsibility is mainly fiscal: to invest for greater dollar return in time. Others see the social good that could come from expenditures for education, sanitation, public works or various welfare programs. As just one example of this widespread awareness, there will be a series of public discussions this autumn, sponsored by the Brookings Institute and led by the Alaska State Legislative Council, in which Alaskans will consider policies for the uses of public revenues.

In this context it seems both appropriate and urgent that there be full and vigorous public debate of various strategies for Alaskan living. Among the several alternatives, I am urging one that involves exceptional recognition of Nature as an integral part of the human environment. If this style of life touches the hearts and minds of Alaskans we will necessarily have to adopt bold policies relative to population growth and industrialization. These, in turn, will require that specific tactics of resource and environmental use immediately be brought to bear on current political and economic decisions.

The general idea is simple. I see Alaska as a place where people elect to withhold the full force of their technical and procreative powers so as to reap the rich harvest of tangible and intellectual resources the wild North can promise. I do not propose turning Alaska into a permanent nature preserve, administered by some monstrous conservationistic bureaucracy. Neither do I propose that Alaska welcome industrialization unreservedly, mimicking the unenviable environments technology has spawned all over the world The middle road is not, in this case, a politically viable compromise, because walking it will be much harder than taking either of the other paths. Rather, I chose it because I believe in diversity of opportunity—economic, materialistic, creative, recreative—as a prime element in the good life. Not everyone wants to be a bird-watcher. Not everyone should be ensnared in the television syndrome.

POLICIES FOR LEADERS

If this idea is to work, Alaskans and their governments must adopt three basic policies: limited population, selective industrialization and environmental consciousness. All are indispensable. All are fraught with emotional polarities, and their acceptance and institutionalization will be extremely difficult.

There is no need to belabor the now-obvious perils of excessive population. In policy terms, whereas much of the world cannot long survive without a *reduction* in population, and whereas America itself must take steps to *limit* further population growth, Alaska is one of the few self-supporting units of government that can justify conceiving of and working toward an *optimal* population (which may be at a level somewhat higher than our present quarter-million people). The concept of optimal population admittedly is poorly defined. To me it means the general population level at which people enjoy the widest freedom of cultural and economic pursuits. There is an obvious interaction of dollars, culture and population; a few rich people could finance a performance of an opera, but it takes more middle-income people to do the same thing. 'Optimal population levels' may be dynamic rather than static, rising and lowering as cultural and environmental shifts take place.

The life style I advocate will be impossible unless we develop and practice a policy of population regulation. We will need to limit the number of births among Alaskans through legalized abortion, birth-control measures, incentives for small families or other methods and combinations that are acceptable and effective. We will have to restrict immigration, possibly approaching this tricky problem from a strategy of reducing the incentive for people to immigrate, rather than by barring entry to those who knock on the door.

The spacing or geographic distribution of people is an equally important subject. In Alaska, big settlements have been growing bigger and small places have been getting smaller for several decades, with a net annual increase in total state population. Roughly one-third of all Alaskans now live in Anchorage and its satellite communities. Another one-third live in the towns of Fairbanks, Palmer, Kenai-Soldotna, Ketchikan, Juneau, and Sitka. The trend toward urbanization is essentially conservative of landscape, and it should be encouraged in Alaska. Towns and cities should be made more attractive in both opportunity and appearance. Conversely, out-dated programs such as the Homestead Act (by which the Federal Government gives large acreages to private persons, ostensibly for agriculture but now for other uses including land speculation) should be abandoned. These programs result in the scattering of people along road systems, leading to high costs for services and degradation of the countryside.

(The entire mix of federal, state, and local government programs for hinterland development are in dire need of overhaul, reappraisal, coordination and redirection. Again, Alaskan conditions favor concerted long-term land planning because large blocks of land are under jurisdiction of a few public agencies responsible for management in the public interest. There is an unbreakable two-way relation between public lands management, access and transportation, settlement patterns and population policy.)

The second policy, that of selective industrialization, is closely tied to the first. If we reject outright the conventional myth that population growth is a necessary handmaiden to progress, we do not have to look for industries that 'provide jobs'—and end up attracting 102 job-seekers for every 100 jobs they offer. We can foster industries that are capital-intensive rather than labor-intensive, and select those least likely to degrade the natural environment through noxious effluents or outputs. We can also reject extravagant power generation projects justified with self-fulfilling projections of demand from processing industries and population growth; neither the manufacturing plants nor the increased population are desirable. Traditional tax enticements to new industries could be scrapped unless they carry out the environmental or social policies of the State.

Out of a total civilian work force of about 100, 000 people in 1968, approximately 91, 000 had jobs. Over one-third of all working people were employed in trades and services, about 6 to 8 per cent each in transportation, manufacturing (including logging) and contract construction, and smaller proportions in mining, financial and other occupations. The main sources of 'new money' in the Alaskan economy have been federal government expenditures, commercial fish, oil and gas, forest products, minerals and tourism, in order of decreasing dollar value[1]. In 1969 the great increase in oil and gas revenues (mostly lease payments and bonuses, not production) have changed the relative ranking of these sources of money, and the new picture may hold for a number of years.

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[1] Data from Vol. VI, Nos. 1 and 3, Alaska Review of Business and Economic Conditions, Institute of Social, Economic and Government Research, University of Alaska, College, Alaska.

The important point for this discussion is that revenue from the Cook Inlet and Arctic oilfields has given Alaska a tremendous bank balance after many years when federal expenditures were the critical factor in survival of the economy. Assuming that gas and oil revenues from those fields will be high for several decades, and assuming a continued net inflow of federal dollars, there is no need for economic policy that strains the productive capacities of renewable resources, and no need for aggressive expansionism in mining, tourism, manufacturing and other industries. There is a greater need to turn our attention to the serious social inequities in our local economy, a prime example being poverty and joblessness among Alaskan natives—a condition that is worsening rather than improving as our total dollar flow rises.

The third policy, for which I suggest the label 'environmental consciousness,' depends on Alaskans adopting Aldo Leopold's 'land ethic' Incorporated into government it would become 'ecomanagement,' a term Jaro Mayda[1] coined to express the broad new tasks of conservation, encompassing all individual aspects of environment, the whole concept 'environment' (since this is more than the sum of its parts) and the interplay of man and environment. Operationally this policy would seek always to maximize the full spectrum of human benefits from the use of space and other natural resources, not merely to maximize revenue. It would defend man against himself in the common environmental problems of air, water and noise pollution. It would be the basis for defense of those delightfully 'useless' animals, plants, and empty miles that may be the ultimate salvation of man, and which unquestionably are an important foundation for scientific knowledge, artistic creativity and personal re-creation and pleasure.

PETROLEUM IN THE NEW ALASKA.

As I said earlier, adopting these policies would mean completely different approaches to environmental management. Alaskan oil developments provide an excellent and timely example; I will describe the current situation briefly and suggest two steps to take immediately to cope with the oil giant.

If the first guesses of petroleum geologists are correct, close to one-half of Alaska and its offshore waters may be underlain by oil-or gas-bearing strata. This includes most of the State outside of the Alaska Range, Brooks Range and mountainous Interior areas. Some private seismic work or drilling has occurred in practically all of the oil regions of the State, but two, Cook Inlet and the central Arctic, have had the lion's share of attention. The first production wells were spudded on the Kenai Peninsula in 1958; the Swanson River field was developed there and, together with about 16 wells offshore in adjacent Cook Inlet, this field produces all of Alaska's present output of about 200, 000 barrels per day. A small refinery exists near Kenai, but most Alaskan oil is shipped as 'crude' out of shore facilities on the east and west sides of Cook Inlet.

Exploration and production activity in the Inlet and on the Kenai Peninsula gave Alaskans a fairly clear idea of the sorts of problems oilfield development brings. The network of thousands of miles of intertwining tractor trails across marshes, forests and alpine areas jolted people into sharp awareness that even looking for oil causes problems. Strictly enforced regulations helped: anyone who compared the seeded roadsides and healing 'cat' trails on the Kenai National Moose Range with the debris and scarring on state lands just outside the Range could see this readily. Air and water pollution came, as inevitably they will. A cloud of smoke is sometimes visible for miles when wasted natural gas is flared from the Inlet's wells. Hundreds of oil spills from tankers, wells, and pipes have been recorded by government agencies. A few big ones have killed ducks or befouled the nets of fishermen (Cook Inlet has an important commerical and recreational salmon fishery). Life in Anchorage has changed, too, with the advent of oilmen and boomers. No longer a small town serving nearby military bases and tourists, Anchorage has swept into an era of burgeoning population, acute land allocation problems, and school and public service expansion suggesting that, like Alice, someone ate from the wrong side of the mushroom.

But Anchorage had its growing pains and Kenai its land scarring before oil. Petroleum development simply intensified and added new facets to the problem. It is in the Arctic,

[1] Mayda J., 1967. Environment and Resources: from Conservation to Ecomanagement. School of Law, University of Puerto Rico. 254 pp.

with its virginal and vulnerable landscape, that the impact of oil is most obvious. The gnawing scars from seemingly harmless trails of construction vehicles, the puzzles of permafrost engineering, the unsuitability of ordinary sanitation techniques, the fantastic longevity and visibility of debris, the oil spills, the huge demand for gravel for camps and airstrips, the question of whether caribou will be frightened and displaced by surface feeder pipes and the general bustle of oilfield operations—these are now commonplace topics of conservation in the North. Technological man has burst upon the Arctic, a stranger. He can ride roughshod for a time over the tundra to his shining golden visions, but always nagged by the feeling he could do much better. Science cannot yet be of much help. Government is an uncertain watchdog, alternately barking and licking its chops.

Bigger questions for Alaska lie beyond Prudhoe Bay and Cook Inlet. Can petroleum be shipped out of Alaska by pipeline, tanker or any other means without chronic and catastrophic oil spills? Will the Arctic oilfield, now confined to the central Arctic north of the Brooks Range, expand west into the huge Naval Petroleum Reserve No. 4 and east to the lovely Arctic National Wildlife Range? Will the semi-secret explorations in Bristol Bay and on the Alaska Peninsula turn that fabulous big-game, waterfowl, and salmon paradise into another Prudhoe? Can offshore drilling in the savage Gulf of Alaska or the Beaufort Sea be done without a series of Santa Barbara's? Will the next big strike be on the delta of the Yukon River, where Secretary of the Interior Walter Hickel is said to have more than a passing financial interest at stake?

In view of these and other managerial complexities that neither industry, state nor federal governments have been able to solve, I propose a complete shutdown for at least three years of all further oil and gas exploration in Alaska and adjacent waters, outside of present lease areas in Cook Inlet and the central Arctic. In my judgement the immediate and permanent benefits from this action would far outweigh any temporary reduction in revenues to geophysical contractors or to the State of Alaska. First, this action would let the oil and gas industry turn its full attention to getting known petroleum reserves into production and to market safely, and with minimum losses to the environment. Second, the moratorium would give governments time to establish a full range of regulations for oilfield conservation and for the protection of the landscape and wildlife. Even more critical is the need for resource agencies to obtain the staff and funds to explain and enforce these regulations, and to establish training programs jointly with industry. Third, universities and others could begin basic full-scale studies of tundra and taiga disturbances, so that better evaluations of the regulations would be possible. Fourth, and very importantly, oil companies and the government could steadily improve techniques of slant drilling, seismic systems, helicopter, hovercraft and overland vehicle usage, and sanitation, so that future exploration could be done in safety and with minor and tolerable damage to the land. Fifth, the State of Alaska could study its new role as rich man, learning how to make the most social mileage out of its financial windfall. Finally, the moratorium would allow resource agencies and private groups to develop sound proposals for lands to be reserved permanently from oil and gas exploration and exploitation, based on their importance to science or exceptional wildlife, scenic or recreational values.

Eventually more of the potential oil lands would be explored. This should come on the initiative of the government, not industry. It should be done when the national and global situation clearly calls for development of new reserves, and it should be done on lands selected by the government. And, as oil and gas are public resources under public land, the public, through government, should dictate the conditions and techniques of exploration. I suggest that a separate industry-government corporation be established to explore each parcel as it is opened up, with companies and individual entrepreneurs bidding for a share in the venture. The corporation would then conduct all exploration work with the best technology available, sharing geophysical data within the corporation. This would eliminate the haste and secrecy that have caused such wasteful and destructive duplication of seismic lines, shot holes, camps, roads, airstrips, test wells and gravel pits in the Arctic. Petroleum discoveries would be developed by the private members ofthe exploration group, under a unitization plan, dividing proceeds in the ratio of original bids for exploration. I am convinced that if we act sensibly, using the knowledge we have or can soon develop, the Arctic, Cook Inlet and perhaps other oilfields can be developed into showpieces of public and private cooperation. Alaska would necessarily have to sacrifice some of her wildness, some of her cleanness of landscape, and some of her outdoor playgrounds and classrooms, doing this not blindly but in full knowledge that a good bargain has been struck by men for men.

The future Alaska I rather wistfully envision would have more people than now—perhaps 500, 000 or so—but they would be in the same population centers as now. There would be awesome stretches of semi-wilderness where people lived who prized solitude or who enjoyed making their way from the seasonal fruits of the countryside. There would be relatively smaller stretches of true wilderness, balanced by local areas where facilities were developed for the enjoyment of Nature by larger numbers of visitors. There would be a comfortable network of roads where needed, planned, mile by mile, to display and preserve the countryside and to host appropriate commerical, residential and recreational uses. Public revenues would come from the usual range of personal and corporate taxes and from the State's share of Alaskan resources extracted for private profit: oil, gas, fish, minerals, timber, water. Alaskans would be teachers, scientists, civil servants, tradesmen, miners, fishermen, loggers, financiers, artists—a reasonable sample of the whole range of occupations open to modern societies.

Anyone who knows Alaska will remark that what I have in mind is simply to perpetuate the present. Today's Alaska, however, is a result of a complex and dynamic history. The economic, psychological and global events that made Alaska what it is are already pushing it towards something else. That 'something else', I fear, is a repetition of the dollar-rich, culture-poor, trash-and poison-ridden landscape so characteristic of industrial America. Changing this destiny requires a revolution in the attitudes of every man (and especially of these who lead) towards his own sources of happiness, his own life style and his own environment.

In a very real sense what I am proposing is not only a milieu for Alaskans but an opportunity for the world. The world needs an embodiment of the frontier mythology, the sense of horizons unexplored, the mystery of uninhabited miles. It needs a place where wolves stalk the strand lines in the dark, because a land that can produce a wolf is a healthy, robust and perfect land. The world desperately needs a place to stand under a bright auroral curtain on a winter's evening, in awe of the cosmic cold and silence, But more than these things the world needs to know that there is a place where men live amidst a balanced interplay of the goods of technology and the fruits of Nature. Unless we can prove that a modern society can thrive in harmony with the land, the bits of wildness we salvage in Alaska will be nothing more than curious artifacts in the sad museum of mankind.

Paper No. 27

Research on Human Pressures on Scottish Mountain Tundra, Soils, and Animals

ADAM WATSON, NEIL BAYFIELD and STANLEY M. MOYES[1]

INTRODUCTION

Since late 1967 the Nature Conservancy has supported research by full-time workers on urgent conservation problems that have quickly followed from new skiing developments on Scottish mountain tundra. Our preliminary findings are summarized in this paper. The paper is based on a talk given during the informal evening presentation at Edmonton. It is published here because the results of the work may be useful to those who, in 1969, began research on tundra damage and rehabilitation in arctic Canada and Alaska. It

[1] The Nature Conservancy, Blackhall, Banchory, Kincardineshire, Scotland.

describes the conservation problems, states what research our small team has done and gives a few practical results. It also gives some of our impressions on matters even where we have no quantitative data, because this may be useful in providing ideas for work elsewhere. The paper is therefore a progress report on only two years' detailed work, and full definitive results will be published later.

The main problem is that the construction of new ski lifts and roads in the early 1960's, and consequent heavy human traffic in summer and winter, have been followed by soil erosion, damage to vegetation and a threat to wild animals on two areas of arctic-alpine ground on mountains in the Cairngorms region of Scotland. The number of people using ski lifts or tows at Cairngorm increased ten-fold during the three winters from 1962 to 1965. On any Saturday or Sunday, it is now common for up to 70 buses and hundreds of cars to jam the car park at Cairngorm or at Cairnwell, and for thousands of people to be out on the slopes at each place. In summer the chair lifts take hundreds of people a day on to the high mountain tundra and indeed these lifts are not economic unless they operate in summer as well as in winter. These places have become top tourist attractions in a region that is taking a massive increase of general tourism. This increase is such that flagging local economies and resident human populations have boomed, and construction of hotels and other facilities has increased at a faster rate than in other tourist areas in Britain.

Unfortunately, some of the best areas in Scotland for snow and skiing are also of great conservation value. Their scientific interest is considerable, as they contain the largest block of mountain tundra in Britain and a corresponding assembly of arctic-alpine vegetation and arctic animals such as rock ptarmigan, snow bunting and various arctic insects. The Cairngorms mountain massif also contains one of the largest wilderness areas left in Britain and so is of great value to those who appreciate wilderness. Some of the area affected by new or proposed developments lies within or near the Cairngorms National Nature Reserve which is the largest of the Nature Conservancy's reserves in Britain. The whole region, including much ground outside the Reserve, was one of several Scottish areas chosen as potential National Parks in the late 1940's, though legislation on this was never implemented.

THE GENERAL PROBLEM

The problem, described in more detail by Watson (1967), is that construction operations and human traffic have caused damage to soils and vegetation in the sensitive arctic-alpine zone. At sea level or in valleys up to 300 m, soil laid by construction work rapidly becomes colonized and completely covered by natural vegetation, often within one growing season provided the slopes are not too steep such as along roadside banks. However, in the arctic-alpine zone much of the ground, even in the natural state, is already only thinly covered with vegetation due to the severe climate and poor soils. Any new pressure is followed by a rapid removal of plant cover and a very slow subsequent recovery.

There is an immediate practical and economic threat of erosion or wash-outs of skiing areas, ski lifts, paths, roads, bridges, etc. Poorly constructed roads and lifts have already required expensive maintenance and repairs. There is also the possibility of massive washing away of roads, bridges, ski lifts, etc. A great flood occurred in this area in 1956 (Baird and Lewis, 1957), before the ski grounds were made, and the new ski road and bridges were washed away in a big flood in 1960. Dr. Fraser Darling, on a visit to Cairngorm with us in June 1967 just after the thaw, when the mountain appeared at its rawest and most badly eroded for the year, looked up at the hill and forecast that it could possibly be 'another Aberfan' if steps were not taken to counteract the increasing damage.

These changes have also made a serious eyesore in a place which many tourists see. Many tourists come to the Highlands to see their famed wild scenery, and there is a danger that they will stop coming to places which become seriously disfigured. We must therefore be careful in tourist developments that we do not kill the goose that lays the golden egg. An important question for the future is that new skiing developments—which are likely to happen now, this year or next year and not at some possible time far ahead—should be planned well in advance and properly carried out, to minimize damage and respect amenity.

There is also a potential threat to animals which are of great interest to tourist naturalists, either (a) directly due to human disturbance or (b) indirectly due to habitat damage.

RESEARCH ORGANIZATION

I have done a part-time study of bird populations near ski lifts since 1962, and in 1966 began exploratory work (Watson 1967) on the other problems. The first full-time workers were employed by the Nature Conservancy in late 1967; Neil Bayfield began detailed research on vegetation, soils and people, assisted by Stanley Moyes. Alex Mather of the Geography Department at the University of Aberdeen, surveyed the geomorphological problems in 1967-68 (Mather 1968) and Dr. R.C. Welch of the Nature Conservancy's Monks Wood Experimental Station began research on insect populations in 1968.

We decided at the beginning to concentrate on quantitative work on small local areas, if possible experimental, and to leave sociological problems, such as why people come and what they want, entirely to geographers and others who have since begun to study these aspects.

COMPARISON WITH ARCTIC TUNDRA

In the Scottish mountains, there are some remarkable similarities to arctic tundra, as well as important differences. Below the mountains, there are remnants of the pine-birch-juniper forest which stretched over much of the lowland and upland in north Scotland at the time of the Roman invasion. It is the local equivalent of the boreal forest. The 'tundra' zone on the mountains comes almost to the sea down to 180 m in very exposed parts of northwest Scotland, but only to about 750 m in the Cairngorms area. The heaths and grasslands of this zone appear similar to mountain tundra vegetation in the arctic, for instance in north Norway, Baffin Island arid Alaska. Many plant species and communities are the same (McVean and Ratcliffe 1962), though the Scottish flora is less varied probably because it is insular. Snow is important in determining the types of plant community. The general appearance of the terrain is also remarkably similar to that of rolling arctic mountains that are largely or wholly unglaciated, such as the hills at Eagle Creek in Alaska or the lower parts of Cumberland Peninsula in Baffin Island. The highest ground is very similar to the stony 'fell fields' of the high arctic.

The skiing grounds lie from 600-1200 m and the highest hills go up to 1300 m. The present tree line of relict natural pine *Pinus sylvestris* and birch *Betula pubescens* forest below Cairngorm is at 500 m, and a zone of dwarf moorland heath (up to 30 cm high) dominated by heather *Calluna vulgaris* stretches above this to meet the more varied arctic-alpine zone at about 750 m. The *Calluna* zone is burned, on a rotation, and this probably explains why there is generally no scrub zone in Scotland between the moor and the mountain tundra-one of the main differences from subarctic areas like north Norway or Alaska.

The arctic-alpine zone contains various plant species as local dominants, such as *Empetrum hermaphroditum*, *Vaccinium myrtillus, Rhacomitrium lanuginosum,* and there are numerous grasses and sedges, particularly *Nardus stricta, Carex bigelowii, Eriophorum angustifolium,* and *Juncus trifidus. Salix herbacea* and *Vaccinium uliginosum* are common in areas of long snow lie. Mosses and lichens are common, and there is a wide variety of other arctic plants. However, even at 500 m some of the most exposed ground consists of gravel with little or no vegetation. Bare ground is widespread above 700 m, with either gravel or scree, and covers most of the terrain above 1000 m and almost all of it above 1100-1200 m.

Winter temperatures are much higher in the Scottish mountains than in arctic or subarctic areas. Thaws sometimes occur even in mid-winter months on the highest summits, and there are frequent alterations of freezing and thawing at intermediate altitudes. Nevertheless, winters are sometimes long and severe and snowfalls are heavy. The precipitation on the high arctic-alpine ground is 150-225 cm a year, and much of this falls as snow.

The windiness of the area is a striking difference from some calm areas in the arctic, such as Central Alaska and the Yukon. Heavy snowfalls almost never occur without gales, which blow the exposed ridges clear and fill the hollows deeply. This provides the skiing, which is dependable in certain hollows from January until early May.

Summer temperatures are low, at 1300 m similar to the raw cold summers at sea level in the polar archipelago of Canada (Baird 1957). Above 1000 m,even snow-free vegetation seldom grows before early May and often not till late May or early June. Killing frosts usually begin to brown the grasses and leaves of *Vaccinium myrtillus* in early August.

There is no permafrost, but solifluction is widespread, with stone stripes, raised hummock tundra, occasional stone polygons and frost heaving of vegetation. There are no glaciers but the area is near to glaciation, with several semi-permanent snow beds. The ground freezes commonly to a depth of 20 cm and this, combined with the frequent crossing of the freezing threshold, makes big problems that begin to compare in severity to those associated with permafrost. For example, during thaws the top few centimetres of the soil are often above freezing point, lying loose over a rigid frozen mass below Construction operations, passage of tractors, and even passage of people on skis or on foot in these conditions can strip off the top layer of soil and vegetation almost like peeling a skin layer off an onion.

As in much of the arctic, the red grouse *Lagopus lagopus scoticus* or willow ptarmigan is a common resident between the trees and the arctic-alpine zone, where it meets the rock ptarmigan *Lagopus mutus*. Snow buntings *Plectrophenax nivalis* nest occasionally on the high stony plateaux and a snowy owl *Nyctea scandiaca* has often been seen in summer there. The dotterel *Eudromias morinellus,* which is a characteristic bird of Eurasian arctic tundra, nests on the mossy-grassy plateaux and rolling summits. The dunlin or red-backed sandpiper *Calidris alpina* and golden plover *Pluvialis apricaria* breed on all but the highest plateaux, as well as on the peat bogs lower down. Wheatears *Oenanthe oenanthe* and meadow pipits *Anthus pratensis* are common breeders in the arctic-alpine zone.

The varying or mountain hare *Lepus timidus* occurs throughout both zones and digs snow burrows like the closely related *Lepus arcticus* in high-arctic Canada. Red deer *Cervus elaphus* live throughout the area, and reindeer *Rangifer tarandus* were re-introduced there from Lapland in the early 1950's, having beoome extinct in Scotland many centuries ago. The new reindeer herd has increased slowly to a total of about 70, now all Scottish-born animals.

ANIMAL POPULATIONS

The main approach here was to compare populations on disturbed areas at the skiing grounds and on other nearby areas where few or no people go. At the beginning, the little evidence available (based on anecdotal impressions from a great many people, including scientists as well as local resident gamekeepers and naturalists) suggested that populations would suffer decreases, so the appropriate null hypothesis put forward was that populations on disturbed areas would show (a) poorer reproductive performance and/or (b) lower population densities of the adult breeding stock.

Populations of the two ptarmigan species were studied at two ski grounds, one at Cairnwell over base-rich schists and limestones and the other at Cairngorm over base-poor granite, with, in each case, appropriate undisturbed 'controls' over similar rocks nearby. Such control areas are essential. Without them, a short-term decrease on a disturbed area over a few years of research might be wrongly attributed to disturbance, yet a decrease might be occurring on undisturbed areas also. Work began at Cairnwell in 1962 and at Cairngorm in 1966. On all areas, the reproductive performance (number of young reared per adult) and the density of the breeding stock of both species have fluctuated from one year to another. However, the critical point is that both species reared as many young and maintained as high breeding stocks when on a disturbed area as on the appropriate nearby undisturbed area. On the base-rich areas, both species consistently reared more young (1. 4-2 young reared per old bird) and also maintained higher breeding stocks (one pair per 1.2-3.0 ha, or one pair per 3-8 acres) than on the base-poor areas at Cairngorm (only 0-0.4 young reared per old bird and breeding stocks dropping to five times as low as the lowest at Cairnwell) and this difference was maintained throughout the period of increasing human use of both areas. It is associated with better nutritive value of the food plants on the base-rich ground (Moss 1968).

Studies of behaviour show that even the most disturbed ground is occupied by territorial rock ptarmigan and red grouse (willow ptarmigan). The birds have become tame and used to people, and pay little or no attention to people passing overhead on the chair lifts or skiing downhill near them. We found two nests within 10 m of a ski pylon, one of them within 3 m of it. Although there is more bare ground on the disturbed areas than on the undisturbed, and thus less vegetation, this difference has not yet gone to a point where the ptarmigan populations have been affected (but see end of section on vegetation damage due to burial). Likewise the populations of meadow pipits have not been affected on disturbed areas.

Dotterel populations are very sparse, and even before the ski developments no dotterel actually used the skiing grounds, which are not suitable habitat-the dotterel breeds on flat or gently rolling high plateaux on the tops of the hills, not on the steep slopes. Because of this, we had to take a different approach, studying a population *near* the skiing ground at Cairngorm but not actually on it. However, this dotterel area is crossed by many walkers in summer, moving out from the nearby chair lift. We compared this with a population on another hill 10 km away where few or no people go. Both areas lie over the same base-poor granite. A third population was studied over a base-rich rock.

The breeding stocks and reproductive performance of all populations of dotterel have gone up and down from one year to another. But in any one year since 1966, the disturbed and undisturbed populations have shown no appreciable difference. Statements such as Parslow's (1967) that dotterel have decreased in the Cairngorms due to increased human use of these hills, must therefore be seriously questioned, particularly as they were not backed up by any quantitative data. It can also be questioned by Nethersole-Thompson's (1970) conclusion from a detailed study of dotterel, that reproductive success and breeding stocks fluctuated from year to year, even in decades before large numbers of people came to these hills. Nethersole-Thompson's work was mainly done on the granite hills of the Cairngorms. On the undisturbed third area, over a base-rich schist, we have found that breeding stocks were apparently no higher than on disturbed or undisturbed areas over the granite. However, they consistently reproduced better, rearing 0. 7-1. 3 young per old bird in different years, compared with only 0. 2-0. 4 over the granite. Nethersole-Thompson (1970) never found it better than 0. 4 on the granite, over a longer period of years. These results show similar differences in reproductive success to those shown by the two species of ptarmigan on base-rich and base-poor areas. It is interesting that an insectivorous bird should show the same trends, suggesting either a difference in the abundance or availability of the invertebrates, or a difference in their nutritive value. These differences in dotterel population dynamics may well be important in relation to human impact, as the 'good' dotterel areas may be threatened by future skiing developments.

The adult populations and number of young of hares on the disturbed area at Cairnwell were as high as on the nearby undisturbed area. Populations on the base-poor Cairngorm were too low to make any valid comparison.

The introduced reindeer herd has increased very slowly. Their owner-manager, Mr. Mikel Utsi (personal communication) considers that loose untrained dogs owned by summer tourists are a menace by direct disturbance of the reindeer and that they cause losses due to desertion of new-born calves in mid-summer. However, the reindeer also increased very slowly from 1954 to 1961 before the new road was made and the ski grounds developed. Also, in this case there is not a control, as there is no comparable population on an undisturbed area. The verdict with the reindeer is therefore uncertain.

With the red deer, there is evidence that the most disturbed areas have been used less during daylight than they were before the new developments, whereas there has been no change on undisturbed areas. It is often claimed that extra human disturbance makes deer-shooting more difficult. On the face of it this may seem reasonable, but there are flaws in the logic of the argument and hence it should not be accepted until it is properly tested by research. At present, the matter in Scotland rests entirely on subjective opinion.

By extrapolating to arctic America, we might expect disturbed areas to maintain their populations of game species such as the two ptarmigan species and the hare, but perhaps to suffer a decrease in use by the deer. In Scotland, there has been no increase in trigger-happy shooting by summer or winter visitors near the ski grounds and this may be an important difference from arctic America, where oil developments bring in many workers who are keen on shooting or hunting.

The research on insect populations by Dr. R. C. Welch began in 1968. The work involves sampling with pitfall traps at a remote, relatively undisturbed site at about 1, 200 m on the Ben MacDhui plateau 5 km south of Cairngorm, and at another heavily-disturbed site at about the same altitude beside the path from the top chairlift station to the summit of Cairngorm. Stanley Moyes has done the sampling about every two weeks from the main thaw (usually late June) until October. It is very much an exploratory piece of work, as so little background information is available. In fact it is the first time that insects have been sampled throughout a whole spring-autumn season at the same sites on the arctic-alpine zone in Scotland. Previous visitors have collected only sporadically, but we do now have the possibility of finding within-season changes in the abundance of different species, as well as of looking for evidence of differences due to disturbance of vegetation and soils as a result of human impact.

SOIL EROSION AND VEGETATION DAMAGE

Soil Erosion

The main method here is to map the skiing grounds once a year. The area of damaged ground and the extent of damage is thus plotted and graded, and year-to-year changes followed. The main sediment flows originate in bare areas such as poorly-drained roads, channels bulldozed to catch drifted snow, and ground laid bare by constructing the ski lifts and by the trampling of people. Extensive sediment flow is largely restricted to above 900 m, a zone with steep slopes, high rainfall and a poor natural cover of vegetation. Sediment flow has been much more serious at Cairngorm than at Cairnwell. This is associated with a different substrate over the Cairngorm granite, where much of the surface soil consists of small pieces of granite gravel or sand up to 4-6 mm in size. On the more fertile rocks at Cairnwell, the soil is deeper and more fertile and consists of very little gravel or sand. It is less loose, and less subject to frost heaving and movement due to rain and severe wind.

Quantitative work on compaction and infiltration began in 1969. Dirt roads appear to be deeply compacted, and this probably reduces infiltration. Preliminary evidence suggests that on other bulldozed areas, such as trenches dug to hold snow along the ski tows, infiltration is greater than on nearby undamaged ground. On the other hand, these machine-damaged areas have a friable surface that is readily washed away.

In the heather moorland from 600-800 m on Cairngorm and Cairnwell, much damage has occurred over deposits of peat. In wet weather, or during superficial thaws when the peat underneath is frozen, the passage of caterpillar tractors does serious damage, stripping off vegetation and altering drainage so that small morasses begin to form. A vicious circle of events then occurs, as the tractors successively get stuck and so have to take new routes, thus leading to more damage.

Vegetation of any kind enormously reduces sediment wash-off. Experiments in the greenhouse, pouring water on to typical Cairngorm sandy soil, showed that 100-600 times as much soil was washed away where there was no vegetation as where there was grass, moss or even simply the roots of vegetation.

Vegetation damage due to burial

Considerable areas of slope on the skiing grounds at Cairngorm at first glance appear to be completely bare because the vegetation has been stripped off or killed on the surface, but in fact much of the ground is bare because vegetation lying underneath has been buried under sediment flow washed down by erosion at higher altitudes.

Field experiments were done to test the ability of various species to tolerate burial by between 0 and 10 cm of Cairngorm soil. Lichen and mosses were all buried by 2. 5 and

5 cm of soil respectively, and showed no visible cover after two months. Taller alpine plants including *Vaccinium uliginosum* and *myrtillus, Empetrum hermaphroditum, Festuca ovina, Carex bigelowii* and *Juncus trifidus* were largely buried by 5 cm of soil and showed little or no cover after two months. *Carex bigelowii* was the only species at high altitudes to make visible growth through the sediment. It also suffered the smallest reduction in total cover and at the deeper depths of burial was the most abundant species to survive above the sediment.

These experiments gave an explanation for the observation that the vegetation communities on the areas most affected by sediment deposition had shifted towards much less heath, moss and lichen, and more sedges. Although no effect has yet been observed on the populations of rock ptarmigan, red grouse (willow ptarmigan) and hares, these populations are bound to be reduced in future if these changes in the plant communities ever become general all over the ski grounds—all three game species feed mainly on heaths and seldom on sedges.

Vegetation damage due to trampling

Extensive damage of vegetation, and increased erosion, have occurred at Cairngorm on heavily-trampled areas around all buildings, on a rapidly-widening path between the top chairlift and the summit of Cairngorm, around the summit and on the slopes below it.

Small plots were subjected to known levels of trampling in the field, on different plant communities in summer and winter, and damage was assessed two weeks after each experiment. The most resistant species tested was *Trichophorum cespitosum. Trichophorum* was a very good indicator, as it responded in a uniform fashion over a wide range of trampling intensities. Other good indicators are (i) changes in the cover and growth form of *Calluna* and (ii) the proportion of bare ground in some cases. *Sphagnum rubellum* is an example of a poor indicator, as it shows damage saturation too quickly and shows little further change with increasing human pressure.

Effect of snow on trampling

Experiments show that even a slight snow cover of 1 cm appreciably reduces the presence transmitted to the ground surface by trampling. Dry snow is more protective than wet, and high-density snow more protective than low-density snow. From these results, it is possible to surmise that most winter damage to vegetation should be to hummocks of bare ground which is exposed above the general snow level because of drifting by wind, or because of local thawing. These points are confirmed by survey work in the field.

Rehabilitation by soil stabilizers and sods

Experiments in the greenhouse, involving water poured on Cairngorm soil, showed that erosion netting of 2. 5 cm mesh reduced sediment wash-off by more than 50% and successively more up to 75% reduction with 3 mm mesh. However, the best method by far was to spray bitumen which almost completely stopped wash-off.

In addition, sods were planted on bare slopes to test their efficiency at renewing vegetation cover. We used 13 cm x 61 cm sods of lowland soil and lowland vegetation, on bare ground in the arctic-alpine zone. This was successful even at 1200 m,and the vegetation expanded marginally outwards on to nearby bare ground; the best species for expansion was *Rumex acetosella* which occurs naturally at high altitudes. Expansion by fertilized sods was better, but even so was not good enough to make this method appear very suitable for large-scale reclamation unless the sods were planted fairly close toether.

Rehabilitation by reseeding

Before we began this research project, a few plots of bare gound were reseeded by Robert Clyde, manager of the Cairngorm ski lift, advised by Mr. G. Copeman of the North of Scotland College of Agriculture. Commercial seeds were used and certain species have proved better than others. The seeds mixture used by Mr. Clyde for Cairngorm Sports Development Limited in the last four years has been timothy S. 50, timothy Canadian *Phleum pratense,* creeping red fescue *Festuca rubra,* New Zealand crested dogstail *Cynosurus cristatus* and smooth stalked meadow grass *Poa pratensis* in proportions 10: 10: 20: 8: 8. The ground is treated with 3 tons per acre (about 1500 kg/ha) of lime, ½ ton per acre of basic slag and 4 cwt per acre of compound fertilizer, and the whole mixture is sprayed with bitumen at a rate of 6½ sq. yd. per imperial gallon (costing £100 for 88 gallons). This is now done as a routine measure by Mr. Clyde on all areas that become seriously damaged in the course of construction operations.

The performance of the various reseeds was assessed by quadrat analysis. Fescue and timothy both did relatively well at all altitudes, being present in 70-100% of the quadrats thrown on each reseeded area. Smooth stalked meadow grass was more variable, being present in 25-100% of quadrats thrown. This species appeared to be particularly vigorous on the highest reseeds. Crested dogstail was found in 55-85% of quadrats on reseeded areas below 750 m,but was absent above this altitude. Reseeds have produced the most complete vegetation cover (64-83% vegetation) at the lower altitudes but have given satisfactory if thin cover (48% vegetation) even at 1100 m. They have been successful on peat as well as on mineral soil. Growth of the reseeded grasses generally slowed down after the first year, but continued again with further application of fertilizer.

Mosses formed a major part of the vegetation (from 19-39%) even in swards only a year old. On untreated bare ground alongside the reseeds (i.e. a control area), there has been no colonization by other vascular species but on the older reseeded areas below 900 m we have recorded a little colonization by *Cerastiutn* sp., *Poa annua,Agrostis* sp. and *Calluna vulgaris.*

We have tried several other reseed mixtures, in comparison with the one used by Cairngorm Sports Development. The data confirm the success of red fescue and timothy and suggest that, particularly at the lower altitudes (below 800 m), *Agrostis tenuis* might be a good substitute for dogstail, which does not do well on Cairngorm. *Lolium perenne* was found to give a relatively good cover but looked rather unhealthy in the second season, and probably needs too high a level of fertility to do well on Cairngorm for long periods.

Some observations in 1966 and 1967, on indigenous arctic-alpine species that were pioneering on bare ground, suggested other species that might be useful for rehabilitation work. Sorrel *Rumex acetosella* had colonized well on mineral soil and peat. Cloudberry *Rubus chamaemorus* recovered well on peat that had been churned by tractors, possibly due to propagation from torn underground rhizomes. *Alchemilla alpine, Poa annua,* and *Deschampsia flexuosa* had colonized well on mineral soil, and *Polytrichum* species on peat at lower altitudes. We used only grass mixtures for reseeding, because it was easy to get large amounts of seed quickly and because we had to take some action urgently. However, some of these other species might well be worth trying on Cairngorm in future, as well as on damaged areas in the Arctic. This might be cheaper in the long run, as the introduced commercial grasses often need to be re-fertilized again after a year or two.

We have done some experiments to test the vegetation 'take' under various kinds of stabilizer, using the same seeds mixture, lime and fertilizer as before. Bitumen-water emulsion, straw and netting, straw and latex, straw and bitumen-oil emulsion, and a control, were used. There was little difference in the results but the vegetation cover with the two bitumen treatments was slightly better than the others. On eroded ground such as at Cairngorm, the stabilizer must fulfil two functions—soil stabilization (which was achieved by all the above methods), and reduction of water loss from the very porous soil (i.e. preventing the seeding from drying out in the critical early stage of germination and establishment). Bitumen does seem best suited on both scores. Latex does not bind the rather large-particled granite soils of Cairngorm, and so is probably best suited to small-particled soils, such as the deep loesses in Alaska or for reclamation of sand dunes. Wood pulp was not tested but has the disadvantage that it does not prevent water loss. All the above materials eventually break down and become part of the soil within a few years.

Dung from hares, sheep and the two ptarmigan species has been sampled on reseeded sites at different altitudes in comparison with nearby indigenous vegetation. At two sites at 900 m and 1100 m, there was if anything more dung on the indigenous vegetation, probably reflecting the generally poorer 'take' of grasses on the high-altitude reseeds.

By contrast, at two sites lower down on sandy and peaty soil at 650 m, nearly all the dung was found on the reseeds and very little on the indigenous vegetation.

In conclusion, there may be objections from purists about the idea of artifical rehabilitation with fertilizers and commercial grass seeds in an area of conservation value. However, we regard this method as a necessary 'holding operation' which already shows that indigenous bryophytes are thriving on the treated plots but not on untreated ground. What kind of plant community will eventually occur is conjecture, but we expect the commercial species to decrease eventually and be replaced by indigenous species, unless repeated doses of fertilizer are made to keep the agricultural species healthy. At any rate, this method dramatically halts soil erosion immediately. We have therefore no hesitation in recommending it. Damage occurred so quickly and extensively that there was no time to carry out a long-term research programme, building up experiments and trials with indigenous species over a number of years.

Natural colonization of vegetation on bare ground

On areas of ground laid bare of vegetation by human impact, the rate of recovery by colonization of indigenous vegetation has been rapid at 400-500 m but virtually nil at 900 m and above, within the few years of our research project. At a given altitude, colonization is slower on exposed ridges and on dry areas, and faster in damp hollows.

Colonization has been slower on the poor granite at Cairngorm than at the same altitude on the fertile base-rich soils at Cairnwell. At Cairnwell, bared mineral soil has become almost completely covered by *Alchemilla alpina*, mosses, *Rumex* spp., *Cerastium* sp., and grass species within two years in some places at 600 m. Other details are given in the reseeding section.

Research on paths and people

In 1969, research was begun to study the reasons why people deviate from paths; and hence why paths enlarge and why vegetation and soils near these paths become increasingly damaged.

We examined paths to find if various physical features were associated with the width of the path. Paths are generally widest if the surface is wet and rough, on a steep slope and with smooth ground on either side. Path width is also associated with soil type e.g. wider on peat than on gravel, and wider on clay than on sand.

Counts of people were begun in 1968-69 on the ski grounds, in relation to detailed maps and assessments of damage on specific plant communities. This was extended in 1969 to include direct counts on the routes taken by people off the immediate ski grounds, in relation to paths and other features. This is important because of the increasing human traffic to the high plateau south of the Cairngorm ski grounds, an outstanding area for scientific value. Results have not been fully analysed, but preliminary findings suggest that only about two thirds of the people going between the chair lift and the summit of Cairngorm actually walk on the path. Fewer people use the path on their way downhill than when going uphill. Furthermore, people on average take more steps when going steeply down and each downward step displaces more material downhill than does an uphill step.

REMEDIES AND FUTURE DANGERS

The main remedies suggested by Watson (1967) were to stop large-scale use of tractors and bulldozers, to channel people on to prepared paths that could withstand heavy traffic and to sell only return tickets on the chairlift in summer. A possible future danger mentioned then has already happened on a big scale. This is the bulldozing of deep channels to hold drifted snow in exposed places on the ski runs and under the ski tows where the snow readily blows away, and the smoothing by bulldozers of wider ski slopes so that obstacles such as boulders and long heather can be removed right down to bare soil and replaced by smooth slopes of grass. All these new developments have been followed by erosion, even though this has been partly halted by subsequent reseeding. One good point is that there will be less need in future for using bulldozers to push snow on to the runs, which was something that frequently damaged the vegetation and rutted the ground in winter before the channels were dug. Since 1967, one of the main dangers on badly damaged areas is clearly severe sediment flow after rain or snow-thaw, and consequent burial of vegetation. An important need on such areas is to lead water away as quickly as possible by prepared drains into natural water-courses where it is fairly harmless, rather than allow it to lead to gullying, sheet erosion and vegetation burial on a wide front elsewhere.

Since 1967, damage by tractors and bulldozers has been so serious at Cairngorm that special roads have had to be built to channel much of this traffic. Also, the smooth re-seeded areas became a natural line of easy descent for walkers, and Cairngorm Sports Development Ltd. in 1968 put up notices about erosion which have helped to keep people off these areas. They have also tried to channel walkers by putting up notices and fences directing people on to certain routes, and this has been partly successful. Damage around the immediate surroundings of some buildings has been eased, and the look of the place greatly improved, by laying out better stairways and granite blocks on flat places. The chairlift staff at Cairngorm have spent much effort on litter-collection, and they have even hopefully planted trees on the lower slopes.

Tarmac or concrete was suggested by Watson (1967) as a possible way of channelling people on the main paths and preventing sediment flow off gravel roads to nearby vegetation. However, this might look out of place on a mountain, could be dangerous on steep slopes liable to be icy in winter, and might not last long in an area of severe frost action. Mr. R. Clyde of Cairngorm Sports Development Ltd. improved the drainage of some gravel roads in 1969 and reinforced some road surfaces with many graphite blocks. So far this seems to be successful in reducing sediment flow as well as improving the appearance of the roads and their surfaces for car and foot traffic. Perhaps granite boulders forming steps would be best for paths. There is an urgent need in upland Scotland for research on the best type of material for roads and above all for paths in heavy use, now that tourism is rapidly increasing and the Scottish Tourist Board and Highlands and Islands Development Board are making vigorous attempts to attract more tourists to this part of Scotland. Brand-new paths, well sited, well drained and of the correct gradient and surface to avoid over-widening, are also needed.

If these things were to have been properly done so that no environmental degradation occurred and the costs had been absorbed by the ski-lift operators who have already sometimes been in financial difficulties, skiing would probably never have been developed. Hence, if it is agreed that it is in the interests of the community that skiing is to increase and at the same time that environmental degradation is not to occur, then public money may well have to be spent on some of the rehabilitation. This has already happened at Cairngorm, with a grant from the Highlands and Islands Development Board for drainage and other rehabilitation. Helicopters are more expensive for transporting materials than the more damaging caterpillar tractors, but might be cheaper in the long run if the total cost, private plus public, is added up. The economics need study, but the difference in terms of environment would be enormously to the good, even if the total long-term cost were to be greater.

There is a need for planners to take much tighter control over current and future developments in the skiing areas that have already been used. Furthermore, other Scottish mountains of outstanding conservation interest and wilderness value are now being actively considered for new skiing developments. There is a danger that, as Watson (1967) wrote, 'one of the last areas in Scotland still more than a few miles from a road may be spoiled as a wilderness area for the increasing minority who enjoy this, and the unique high-arctic nature of the scene on the plateaux may also be spoiled. The reason for keeping a few of these areas for the enjoyment of these minorities is similar to that for preserving our art galleries which also provide enjoyment for a minority.'

SUMMARY

1. During the last few years the building of new roads and ski lifts, and a consequent increase of human traffic in summer and winter, have damaged vegetation and soils on mountain tundra in Scotland. This has made an eye-sore in a tourist area of high environmental quality, and has led to erosion which is a serious potential threat to the roads

and ski lifts themselves. There is also a threat to populations of animals, due to direct disturbance or indirectly to habitat change.

2. This paper compares conditions in the Scottish mountains and in arctic North America, and describes a research programme by a small team studying human impact near the Scottish ski lifts.

3. Research on animal populations shows that there has been no effect so far on rock ptarmigan or red grouse (willow ptarmigan) populations, or on dotterel and other species; however there has been less daylight use of the developed areas by deer.

4. The research has involved field survey and experimental studies of erosion, compaction, vegetation damage, and the use of paths, as well as assessments of the success of various methods of rehabilitation on different kinds of substrate.

5. There are various lessons from these events, which should be attended to in case of similar future developments elsewhere.

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Paper No. 28

The Influence of Man on Vegetation at Churchill

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The Churchill area was inhabited by Eskimos and Indians long before the strait and bay were discovered by Henry Hudson in 1610. Since that time, the fascination of exploration coupled with the development of trade has drawn an ever increasing number of travellers to this northern area. Many expeditions were organized in search of a north-west passage and trading posts became established at the mouths of the major rivers. In 1770, the present Fort Prince of Wales was completed on the west bank of the Churchill River.

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The main Churchill settlement developed on the other side of the river and remained a small, isolated community until 1931, when the rail link with the south and the Grain Elevator were completed bringing with them an increasing population and trade. The present harbour is open to shipping from June until September, handling exports of grain, flour, lumber, and cattle, while imports include automobiles, china and glassware (Scoggan 1959). In more recent years, a military base and rocket range have been developed and the population which numbers 6, 000 (Woodcock 1969) enjoys daily air connection with the south. Clearly, Churchill has changed from an isolated northern settlement to a major rail terminal and a northern centre of significant proportions.

Yet close examination reveals that there are many conflicts in what was once an harmonious man-environment relationship. To resolve this unbalanced situation, the natural ecosystem of the Churchill area and its subsequent alteration must be analyzed from the ecological and social point of view if corrective remedial action is to be taken.

Churchill has a unique location on the shores of Hudson Bay, where there are recent alluvial and marine deposits, and is adjacent to two physiographic regions, the Hudson Bay Lowlands and the Precambrian Shield. The latter is characterized by two main types of surface, one controlled by bedrock, the other by a thick mantle of glacial material (Ritchie 1962). There are extensive plains of glacial clays and outwash sands, moraines, raised beaches, and all forms of glacially molded drift. The surface ranges from rugged rock outcrops to gravel ridges and undulating till plains. These have been available for colonization for the past 6, 000 to 7, 000 years and because of the wide range of physiography and drainage patterns, a rich variety of communities and diversified flora have resulted.

The vegetation on the Precambrian Shield is divided into tundra, forest-tundra, open coniferous forest and closed coniferous forest, while bogs and fens characterize the Hudson Bay Lowlands. Ritchie (1957) states that the chief factor governing the nature of the vegetation is probably topography or drainage pattern, while climate, disturbance and history are important as secondary local factors.

Plant growth is slow with reproduction frequently by vegetative means rather than by seed. Flowering is often erratic and certainly not an annual occurrence in many species. Plant collections have been made in the Churchill area since the middle of the eighteenth century. Scoggan (1959) lists 354 species of vascular plants in geographical ranges which he delimits as low-subarctic, high-subarctic, low-arctic and high-arctic. Ritchie (1962) gives a list of 580 species and varieties for the area north of 56° latitude. Of this number, 41% in Manitoba are confined to the Hudson Bay Lowlands, and 23% to the Shield, the remainder occurring in both physiographic regions. The Lowlands have a relatively rich flora, the majority of species being arctic or subarctic with circumpolar species predominating.

Beckett (1959) lists 75 adventive plants mostly of the weedy type that have invaded the Churchill townsite and harbour mainly since 1927 when construction for the rail terminal started. Some are spreading while others are unable to survive the short growing season. She comments that in sites disturbed 25-30 years ago and left untouched, native species are again beginning to take over. Similarly at Fort Prince of Wales, there no longer appears any trace of plants introduced during European occupation in the eighteenth and nineteenth centuries. Native species have recolonized the disturbed sites but the rocky ruins left by man remain. The relative isolation of the Fort may well have contributed to this recovery.

With this brief sketch of the landscape and its associated plant life, some of the changes that have taken place can be considered. Northern ecosystems naturally evolve slowly and at Churchill they have been increasingly modified by other factors for the past 300 years. In several areas it is clear that the present tundra vegetation is secondary, the result of fire (Ritchie 1962), which has eliminated extensive areas of forest. Fire has devastating consequences in the north. It destroys the insulating layer of standing vegetation with the loss of plant cover which may not be renewable for generations. It consumes organic matter in the upper part of the soil, damages peat and initiates erosion, in many instances in an irreversible train of reactions. It may be several generations before even the effects of mild fire are erased. As northern areas become more accessible to exploration, hunters, fishermen, tourists and others, fire risks will undoubtedly increase. Steps should be taken to acquaint all who travel through these areas with the devastating effects of fire.

Trees have been cut for building material in an indiscriminate fashion as witnessed by the open spaces around campsites and the townsite of Churchill. Nowhere is there a co-ordinated land use approach to the development and utilization of the Churchill area. Gravel permits are easily acquired and pits are opened wherever it is most convenient. There is no attempt to confine workings to exploit specific areas. The ugly scar and debris that will be left to mark innumerable sites for untold decades cause little concern. Unless specified areas are designated for gravel use every available esker will bear the imprint of man.

In a similar vein, there is no policy regarding the return of worked surfaces to a reasonable state and no programs for revegetation and reafforestation exist—apparently because of the seeming endlessness of the tundra. Extensive army manoeuvers, rocket ranges and training programs have also left an indelible trail of debris and destruction. In the immediate townsite area, some of the old dirt trails have been paved and new roads created, reaching further and further into the wilderness. But modern vehicles make roads a luxury rather than a necessity. Track vehicles of all types roam at will over the tundra, each etching a trail across the low plant growth. One journey over the sub-arctic vegetation can destroy the product of decades of interaction between plants and their environment. Studies will determine how many years it takes for slowly growing lichens, mosses and vascular plants to recover. A series of sampling sites on dated trails across the tundra are being established for this purpose (productivity studies, etc.). Churchill has the advantage that a wide range of landforms and vegetation types exist in reasonably close proximity to each other. It would be helpful to have marked and otherwise delimited trails so that vehicles could be confined to routes where the minimum of damage would ensue. In addition, controls could be exerted and information released regarding the fragile nature of the tundra and the effects of mechanical vehicles on it.

An ever-increasing quantity of garbage concomitant with modern society is very evident at Churchill. The shoreline, rock pools, heaths and forests are marred by garbage, rusting piles of metal, discarded refrigerators, old cars and all other manner of refuse. This is indiscriminately dumped in a 25-mile radius from the town to compete with, and destroy, the colorful vegetation. As is so familiar in many towns further south, there is no local conscience regarding garbage disposal and here there is no official policy, with the result that the problem increases daily, despoiling more and more of the landscape. Sanitation and sewage problems are. distressingly obvious and their solution a real challenge.

Churchill is a growing community. Anyone wishing to build or develop within the area of local government jurisdiction must obtain a permit from the local district Area Administrator of the Department of Municipal Affairs. Nowadays, buildings must be within the area presently surveyed and serviced with sewers, water, hydro, roads and telephones.

However, there is a legacy of the past which shows the absence of long-term planning and people have been living for many years on the bay shore, tidal flats and elsewhere in appalling conditions. There is a rapid turnover in population, somewhat reminiscent of the nomadic way of life of indigenous people, which stifles the efforts of the few permanent residents who wish to have pride in their surroundings. Too many go north to seek their fortune and have no vestige of interest in the community or country in which they find themselves.

When concern and understanding are displayed by the authorities and suitable local involvement, interest and educational programs are stimulated, an approach will be made to the solution of the problems of northern development and living. Churchill could take the lead if someone cared enough to accept the challenge. At present, the townsite suffers from an admixture of Federal and Provincial authority and insufficient concern for the area from either group. Recent interest may prove more vital than past abortive promises and murmurings. There is no desire to condemn any person or agency, but only to plead for an awareness of the existing problems, including the people and the unique vegetation-environment complex that may rapidly vanish if it is not protected. Our understanding of northern landscapes is superficial and research is required before whole segments are irretrievably lost. The north needs protection and preservation because it is the world's last great wilderness and has a sensitive ecology. Although it is vast, carelessness and ignorance can despoil large areas. We must minimize needless damage and consider the multiple effects of man, including pesticides on food chains, buildings on permafrost and the impact of exploration.

The post-glacial history of the Churchill area, its location on the shores of Hudson Bay, and the diversity of landforms and variety of vegetation types make it of considerable interest to natural scientists, geographers, historians and tourists. However, few understand the importance of preserving this landscape and vegetation. It is our responsibility as ecologists to persuade the governments to plan an orderly development of the region. This should include maintenance of the diversity of habitats, wise use of the forest, and the setting aside of natural areas for recreation, enjoyment and scientific study. We must have a strategy for the development of a practical program. We now need an informed basis for value judgements. As the Science Council said in 1968: 'Science has much to offer in the quest to make sure that the full economic potential of Canada's north is realized and that the cultural life of the population of this area is enriched.'

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Paper No. 29

Churchill-A Pattern for the Future?

H. **A.** Hochbaum[1]

Arriving at Churchill by the long wilderness route from the south, one is surprised to learn that its history of trade goes back to 1689 when 28 casks of white whale oil were shipped to the London Market (Kenney 1932:22). The tourist, lured to Churchill by promise of an easy view of the subarctic, is astounded to find himself in the midst of the largest dump, the ugliest gravel pit and the most hopeless slum in Canada. Visitors coming by sea may find this sad place their only view of Canada. Young Eskimos, brought to Churchill for their education, meet all this as their first experience with modern civilization. Churchill, for all its long history, remains a frontier community where the common pattern is for each citizen to take what is needed where and when it is most easily available, to discard what is no longer required, each to his most convenience.

The first impression of Churchill Townsite is of discarded trash, papers, cans, broken bottles, plastic containers of every description scattered to all views from wherever one

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stands. One cannot escape by going past the edge of town or to the Hudson Bay shoreline. The waste is omni-present, its volume beyond the dwellings enlarged by cars and ice boxes, washing machines and broken machinery. Not even by aircraft, up and away from all of this, can one by sure of escaping the frightful scene. Private camps on Crown Land, often are helter-skelter wastes of Seven-up and Coke cans, broken glass of broad vintage, renewed each year and emphasized by mixed plastics and papers clinging to the hoary willows. One thousand years from now, a student examining its trash might easily arrive at the exact date when the Dymond Lake goose hunting camp or the several isolated oil exploration camps had their beginning.

Taverner and Sutton (1934:7), studying the birds of Churchill thirty-five years ago found that 'one has only to walk a few steps from the center of activity to find one's self in a primitive wilderness'. Now at the edge of Churchill one suddenly becomes aware that rubbish of papers, cans, bottles and old cars is 'small potatoes' compared with massive discard of heavy metals—boilers, pipes, chains, sheets and tubes—thrown away by public agencies, expensive materials no longer useable, cast wherever convenient, just off the main lanes of travel. Because the Hudson Bay shore is seldom used by residents, though one of the most beautiful coastlines in Canada, much of this heavy waste now violates the edge of the sea. The old dump for Churchill Townsite verged upon the breaking surf. Another shoreline heap of waste, mostly metal, is located along a beautiful stretch of the Barrier Rocks just north of Fort Churchill, a community which casts its raw sewage on the beach. The Townsite dump was closed this year but will remain an ugly wound forever. Theoretically no dumping now takes place anywhere in the region except on the one large active public disposal grounds east of Fort Churchill. But a small gravel parkway invites the casual dumper to throw new trash on old at the Fort Churchill Barrier Rocks, while the sight of roadside refuse almost everywhere induces a 'who cares' attitude, with steady discard, here, there and everywhere.

Gravel is the natural resource most widely available around Churchill and most abundantly used. It is there for the taking and apparently is taken whenever and wherever needed. There are a few designated sites such as the massive gravel pit of the National Harbors Board violating the Hudson Bay just east of Churchill Townsite. But small casual diggings found wherever there is gravel suggest no control over its use, no end to the steady corruption of the natural scene resulting from these diggings.

Viewing such mightly scars at the edge of wilderness one can only guess at the beauty of the scene so recently and abundantly spoiled. Insight into the continuing tragedy is clearly grained by examining the new road leading to Cape Merry. Here, until 1967, one could step from the Townsite dump, over a rise and quickly beyond the view of the domineering grain elevator, entering upon a wild tundra scene that must have changed little since the white man first set eyes here. The only handiwork of man in sight was Fort Prince of Wales, across the Churchill River, To honor Canada's Centennial year, a road was built from the Townsite to within a hundred yards or so of the Cape. Instead of hauling gravel from nearby pits already active, road metal was scraped from either side as needed, the volume of these mutilations exceeding the disruption caused by the road itself. Where an ancient beachline could not hold a car, this rubble was pushed to either side, compounding the damage, the whole of this Centennial celebration spoiling Cape Merry forever. In harmony with local color, the trail leads to a parking lot of littered trash and broken bottles.

The Churchill Development Plan (Jones 1968) points out that the 'government has been the single resource and the single industry comprising the economic base of the community'. Churchill, in effect, is a company town, with no pattern of self administration. And the Government of Manitoba is the owner of all of the land being spoiled by dumping and gravel mining. When I talked with individual citizens of Churchill Townsite I found wide concern over the casual dropping of trash and the reckless harvesting of gravel and other natural resources. A lack of civic pride and leadership was considered by most to be the foundation of this carelessness. What then can the small man do, they exclaimed, when government agencies themselves have done even more to spoil the landscape? Officials in charge of major government departments deplored the situation, often held the military responsible for the largest desecrations, and considered that the Manitoba Government should exert its authority in restoring and protecting the public landscape. One suggestion was made that the Barrier Beach and the wild country adjacent to Churchill should be made into a National or Provincial Park. Another popular idea was that each public agency, including the departed military, should be pressed to clean up the mess it has created. But there is yet no plan or pattern to restore or protect this historic and once beautiful place. In the meantime, the frontier spirit of irresponsibility continues, extending out and beyond the community by way of new roads and improved transportation. Anyone can go anywhere to take what he wants without asking, leaving behind what he does not need without question, always with the understanding that the North country is so large that small aggressions hardly count, always with the irresponsibility of people who are there for but a short time, and everlastingly with the careless abandon of those, large and small, who are aware they need not account for their actions.

Dr. W. A. Fuller, opening the Tundra Conference, insisted that we must not meet here to condemn. Thus, let us view Churchill's tragedy as a lesson for the future. Churchill has been harmed and the well-being of the North is elsewhere threatened by a failure of the custodians of public land, provincial or federal, to establish and enforce good laws governing wilderness behaviour and resource use. Free men remain free only under law. In the absence of restraints, one or two generations of plunder easily wreck pristine country, rebbing future generations of the freedom to use and enjoy both its beauty and its resources.

We have been considering the dangers of oil pollution and other massive industrial aggressions on the land. And yet there is little enforcement of controls on even the smallest transgressions. Research has shown that tracked vehicles indelibly mar the environment, and yet any person can go nearly anywhere in a vehicle of any design. York Factory, the historic source of our western trade and culture, has been raped during the past six years, torn asunder, its structure badly marred, its priceless hand-carved or hand-wrought appointments vandalized, or else transported to private homes in Toronto, Chicago, Oklahoma City and other places far and wide. The citizens of Eskimo Point live on top of their own waste. Perhaps, a ton or more of wild geese rotted last fall in hunting camps along the Hudson Bay coast, spoiled by the September heat. The boosters for tourism, spellbound by the seemingly endless supply of northern wildlife, ignore the simple laws of Moses to entice hunters and their dollars into the wilderness.

Is this the pattern of the future? Indeed it is, if the landlord does not soon accept the responsibilities of stewardship. The main function of government in resource management is protective. Unless good protection is soon enforced, Churchill's pattern is indeed the pattern of the future.

Are there hopeful signs? The Manitoba Government recently has shown more than a token interest in the plight of Churchill. The R.C.M.P. in the Churchill area are now briskly and efficiently enforcing the laws protecting migratory birds. Citizens of southern Canada, aware of the plunder, are beginning to call for better care of their lands in the north. Perhaps a new trend is developing in recreational use of wildlife resources, for at Bathurst Inlet, in the western Arctic, a private camp has been established in a pristine setting to cater only to those who wish to harvest wildlife with field glass and camera. Interest and concern for the north is being awakened. Let us hope that the legal foundations for protection may soon be established and broadly enforced.

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Paper No. 30

Some Comments on Human Resources in the North

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Look down on a map of the northern hemisphere centred on the North Pole. You will find a vast inland sea, whose limits bear tracing. Starting at the International Date Line at the Bering Strait and moving west is a solid shore line, for nearly half the circumference marked 'Union of Soviet Socialist Republics'. Moving on, the Scandinavian shore quickly gives way to a wide sea passage that offers an obvious escape route into the Atlantic between Norway and the vast island of Greenland. Immediately west of Greenland is a roughly triangular agglomeration of islands, its vertex pointing northward. The western side of the triangle, constituting about one fifth of the circumference of the boreal sea, offers a broken shore. It continues more smoothly past Alaska and is interrupted by the Bering Strait. It continues where we started to trace the coast, at the easternmost extremity of the Soviet Union. Measured from the northernmost tip of Canada the diameter of this northern sea as it passes through the north pole to the coast of the U.S.S.R. is approximately the distance from Toronto, Ontario to Regina, Saskatchewan. Except at the shore line this northern sea is permanently clogged with polar ice which until the recent 'Manhattan' test was generally regarded as unnavigable. Even at the coast the pack ice retreats only for brief seasons.

The agglomeration of islands is the extremity of Northern Canada. Viewed from the North Pole, Canada is an irregular triangle starting at the Arctic archipelago, continuing south to the forty-ninth parallel and beyond to the north shore of Lake Erie and the Saint Lawrence River. It is divided by a line of dominant significance. This line runs roughly from the north-east tip of the Yukon, which is not so very far from the north-east tip of Alaska, south-east to the south-western shore of Hudson Bay, and curves north through the wide peninsula of New Quebec and into Labrador. This is the tree line. North lies tundra. Here there is no growing season, for there is nothing of significance to grow and precipitation decreases from south to north. Elevations rarely rise above a thousand feet, although in the northernmost parts are mountains containing thousands of square miles of ice caps and glaciers. Most of the land north of the tree line lies within the Canadian Shield. It is known to contain natural resources of a non-recurring extractive type—gold, lead, zinc, iron, nickel, oil, copper, uranium.

Returning for a moment to our overview of Canada from the North Pole, its population is seen to be concentrated along a southern waterway over which Newfoundland stands eastern guard and which penetrates into the heart of the continent through the St. Lawrence Seaway to the head of the Great Lakes. There is a random scattering of people across the prairies, and a modest concentration of people in the extreme south-west corner, the evergreen playground of south-west British Columbia. For the rest of Canada, so the population map indicates, numbers are of no apparent significance.

This, in gross description, was Canada in 1867. It is Canada today. Who will wager it will not be Canada a hundred years from now?

Turn the map around so that north is up and south is down. That's the Canada we are familiar with. The tree line is still there. The topography is still the same. The resources have not changed. And the population is still huddled along the southern base of the triangle, trying to catch warmth from a neighbour's hearth.

Now let your vision zoom into the part of Canada that lies north of 60 degrees north latitude and east of the Yukon Territory—east of the Mackenzie Mountains. Here lies one-third of the land mass of Canada. The tree line cuts it diagonally in two. What of the population that looked so insignificant on the map of Canada? Thirty thousand human beings—roughly one for every fifty square miles—live in sixty settlements and in some two hundred seasonal camps. Over a third of the people are Eskimos, having lived north of the tree line and on the edge of subsistence and disaster for five thousand years. About

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a fourth are Indians, northern cousins in the Athabaskan group, occupying for even longer the boreal forest region of the Mackenzie watershed and the tributaries of that vast river system. About two-fifths of the people are Europeans. Apart from seasonal sojourners who began leaving their seed in the indigenous population two centuries ago, the white man's time span in the north can be counted in decades. About half the whites today are dependent on the payroll of the federal government. Many others are adventurers—prospectors, trappers, labourers in the mines, agents of enterprise. The balance constitute a hard core of northern oriented whites.

How do these northern Canadians live? The cost of living in the north is about one third higher than in the south. Most whites live reasonably well. But the income of the Indians and the Eskimos is one sixth of the Canadian average. Calculate your income at the national average, and remember that there are more poor people in Canada than there are wealthy; divide that by six; then increase prices by one third; now live on your income. It is not difficult to imagine what this means in terms of food, clothing, shelter, health and education of the indigenous peoples of the north. Their birth rate is nearly two and a half times the national average. The infant mortality rate is more than four times. Their life expectancy is decades shorter than the national average.

How does one govern a country like that? What is its political future? What, above all, is the responsibility of the Canadian nation for the economic and social development of the Northwest Territories?

No one knows the limits of the natural resources that lie north of sixty degrees north latitude. We do know that recurring natural resources such as forest and agricultural products, meat and fur bearing animals, and fish, are limited, and many are non-competitive even now. Non-recurring natural resources are there in abundance, but that term has yet to be translated definitively into commodities, tons and dollars. We do know something about the human resources.

In the spring of 1965 the Minister of Northern Affairs announced in the House of Commons that the Government of Canada would appoint a Commission to advise the Minister respecting the political development of the Northwest Territories, having regard, among other things, to its social and economic development. That Commission consisted of Jean Beetz, a long-time colleague of the present Prime Minister, then Professor of Constitutional Law at the University of Montreal and now Dean of Law at that University; John Parker, mining engineer and Mayor of Yellowknife and now Deputy Commissioner of the Northwest Territories; and myself. After fifteen months of study, travel, and public hearings, we reported to the Minister at the end of August 1966.

To provide a frame work in which to handle the vast problems which pervade the north, we stated six postulates which we believed reflected the values by which various programs of development might be judged. If they sound obvious to you, I would ask those of you who know the north whether in your experience they have had any real application to the northern peoples. They are as follows: (1) every citizen of Canada has a claim to participate in the institutions of responsible government under the Canadian constitution; it is a goal of political development of the Northwest Territories that the optimum number of Canadian citizens resident in the Territories should, at an optimum speed, participate in government as fully as Canadian citizens resident in the provinces; (2) the competence of political institutions should be commensurate with the dimensions of the social and economic problems in the political unit; (3) the structure and technique of government should not be foreign to the Canadian political tradition; (4) every resident of the Northwest Territories for whom freedom of movement within and without the Territories is not a realistic fact has a claim to economic opportunity that will provide a standard of living that does not deviate substantially from the Canadian norm; (5) so long as the Northwest Territories remains a political unit or units separate from the provinces, the federal government has a major, although not necessarily an exclusive, responsibility for its economic development; (6) the Eskimos and Indians, as indigenous minorities, should be free to maintain their cultural and ethnic identities, subject to fundamental human rights. We sought to state this last premise in the form of choice, in the form of freedom to choose, recognizing that the desire to take advantage of economic opportunity may involve the individual in paying the price of giving up an appreciable measure of his cultural and ethnic identity.

Our first recommendation related to the issue whether the Northwest Territories should be divided into two. The intention of the advocates of division was that the western part, containing the bulk of the white population, would advance more quickly from its present colonial state to a form of self-government, hopefully provincial status.

We recommended against division because we did not consider it timely. Basically we considered that division now would run the grave risk of turning the eastern residue of the north into a permanent federal preserve with little likelihood of effective participation in government by the native peoples, mainly Eskimos. It would also create a white majority in the west with a large, dissatisfied native minority, largely Indians and Metis. In short, we considered that division at this time would run counter to one of our own postulates. In balance we concluded that what was required now was not provincehood but the means to growth to provincehood; that the best move for the peoples of the Northwest Territories at the present time would be to retain the Territories as a political unit, to locate the government of the Territories within the Territories, to decentralize its operations as far as practicable, to transfer administrative functions from the central to the territorial government in order that the latter might be accountable on site for the administration of the public business, and to concentrate on economic development and opportunity for the residents of the north.

A second preliminary issue on which we made a recommendation was on the location of the capital. The government acted in September, 1967, on our recommendation that the capital be re-located from Ottawa to Yellowknife.

The first group of recommendations following the issue of division and the location of the capital involve developing a structure of government in the north to the point at which conversion to provincial status is a reasonable and comparatively simple step. This would be accomplished by increasing the size of the Council, increasing the scope of operations of the territorial government, and giving it machinery of government and administration adequate to the task, yet retaining controls in the central government that reflect its financial responsibilities in the north. It also involves a program of continuing education in the field of public affairs. We recommended the establishment of seven major ministries of the territorial government and the creation of an executive council made up of the heads of the ministries. The major departments would be economic development and finance, local government, education, welfare and social services, public works, justice, and lands and resources. Of these we visualised the most important to be the first, the Department of Economic Development and Finance. In association with the creation of this department we recommended the establishment of an economic development board to operate in the public sector of the economy and an economic development corporation to operate in the private sector. These recommendations also involve the allocation of considerable public funds.

One of the first tasks of the economic development board would be to embark on regional economic planning. We do not claim to know what resources or what enterprises or industries should be developed or where or in what manner. These matters we would leave to the informed judgment of the economic development board and the economic development corporation. In any event, the formation of policies of this kind should follow a thorough appraisal of human and natural resources—the people, their land and waters. Regional economic planning we would tie in with the development of local government.

Government has come to the residents of the north in the reverse order to which it has come historically to most peoples. The entire north has been enfranchised now for four federal elections. The residents outside Mackenzie District received the territorial franchise only in 1966. And there is no form of local government, as we understand the term, in most settlements in the north and therefore no local franchise. We envisaged that local governments would send representatives to regional groups for the purpose not of government but economic planning at the grass roots or lichen level under the general aegis and ultimate responsibility of the economic development board. To encourage the development of local government we recommended the creation of a cadre of local government officers, part of the staff of a territorial institute of public affairs that would carry out a territory-wide program of education in the field of public affairs. To local government we would also tie in a more general program of adult education. The reasoning behind this is that the potential development of the north requires the same kind of continuous attention and special skills as does its economic development, and comparable machinery should therefore be provided to give reasonable expectation that all northern residents can and will grow to political maturity. In association with all this we recommended that administrative functions be transferred to the territorial civil service on a specific schedule as soon as possible, a move which we considered essential to the scheme of responsible government.

Most vital of all, we recommended the coordination of educational and economic opportunity. I don't know whether the indigenes of the north will ultimately find their destiny in the north or in the south. It is said that the potential economic base in the north is insufficient to support a population much larger than the present—that before the insurgence of the white man the natives were in rough balance with their environment and that even the white man's technology will not appreciably increase the support which the land and waters can give the people. If this is true, then with a rising native population there must be migration south. But mobility is a factor of education, as is the development of economic potential within the north. It is imperative, therefore, that there be a coordination of education and economic opportunity, wherever that opportunity is to be found. As we stated at one point in our report, it is all very well that people should be free to work out their own destiny; but freedom without opportunity will produce a destiny that is predetermined by those who, having the means, withhold the opportunity.

What has the government done in response to our recommendations? Ottawa continues to give the impression, perhaps unfair, that it views the north largely in economic terms, particularly on the issue of subsurface rights. Political judgment can have a high economic component. With the discovery of oil at Prudhoe Bay and the natural speculation as to potential riches in the Arctic Islands, there may be even more reluctance to encourage political development that might increase pressure to transfer political control to the government of the Territories. The government has taken a 45% interest in the Ottawa-oriented Pan-Arctic consortium, but has not created a northern-oriented development board or a development corporation. It has not therefore been feasible for the government of the Territories to proceed with our recommendations for a fully tripartite regional scheme of economic, political and educational development. Yet the federal government recently announced a regional plan for pollution control, training local inhabitants to put the scheme into effect with on-scene regional commanders. I don't find it very encouraging that the government should be ready to embark on a program of training Indians and Eskimos to look out for the white man's oil slicks but is not ready to support and foster a major program of economic, political and educational development at the regional level. Rivalry seems to be emerging between Yellowknife and Ottawa on the whole question of economic development. Ottawa appears to be building a major staff to take an overview of the matter, while Yellowknife's Department of Industry and Development grows as a competing force.

When our report was filed in August 1966, the then Minister stated that the government expected to publish a White Paper by Christmas. Three years have passed without the release of such a statement of policy. Last week (October 10, 1969) the Northwest Territories Council recessed its session at Baker Lake to reconvene in Yellowknife in mid-November. The Council has stated in public telegrams to the Minister and the Prime Minister that at this meeting they hope to receive from the Minister a public statement of policy that will allow the implementation of our economic and constitutional recommendations, particularly an increase in the number of elected representatives and a commensurate reduction in the number of appointees; the extension of the term on Council to four years from three; the creation of an executive committee of the Council; and the creation of an economic development board and an economic development corporation.

Some parts of the report have been implemented by the federal and Territorial governments. The capital was established at Yellowknife and was moved from Ottawa to Yellowknife in a mass migration in September 1967. In April 1969, responsibility was transferred to Yellowknife for educational and welfare services and development of local government in the Mackenzie region. Next month welfare services in the eastern arctic will come under Yellowknife and will be coordinated from Frobisher Bay. Educational services in the eastern arctic, involving over 600 teaching personnel and over 10, 000 students, will be transferred to the Northwest Territories government on 1st April, 1970. The Northern Administration Branch of the Department in Ottawa has been dissolved in anticipation of these moves. I interpret this to mean that the advocates of division have lost their cause unless some major unforeseeable event occurs to change men's minds. The Territories' government has established a departmental structure: treasurer; public works; local government; territorial secretary; industry and development; and education and social development. The expectation is that Ottawa may soon lower the voting age to 19.

Yet Ottawa will not agree that the Commissioner be paid by a charge on the Northwest Territories consolidated revenue fund. It insists that the Commissioner is accountable to the Minister in Ottawa, as distinct from the residents in the Territories, and must be paid by Ottawa, not from the consolidated revenue fund of the Territories. I find the symbolism of that view discouraging.

What, then, of the future? I attempted at the outset to intimate that certain dominant physical characteristics of the Northwest Territories which have prevailed literally for ages will continue to dictate what man does or will want to do in the north in the next century. I then attempted to suggest that the most important challenge facing Canada in the north today is the social, economic and political development of the citizens of Canada who reside and make their living in the north. My views on the challenge facing the Canadian north can merely be an adventuristic extension of my opinion of what should happen in the north today.

If the north is to be developed in a dynamic way it must progress equally on three fronts—the economic, the social and the political. The federal government holds the purse strings to economic development and the legislative strings to political development. But the nuts and bolts of social development are in the hands of the people of the north. Once they are given effective tools of political adequacy and economic opportunity, the real burden will be on them—particularly the large minority of educated whites—to build all-inclusive social machinery that will carry the north forward to political, economic and social equality within the Canadian nation.

Paper No. 31

Land Problems and People Problems—The Eskimo as Conservationist

JIM LOTZ[1]

So much nonsense has been written about the Canadian Eskimo that it takes a great deal of temerity or ignorance to launch yet another idea aimed at aiding these traditional peoples of the tundra regions. In the past fifteen years of accelerated cultural contact, the Eskimo has been romanticized, patronized, commercialized and finally bureaucratized. In Alaska, Eskimos are alleged to ask 'Who is your anthropologist?'; in Canada, the question might be phrased as 'Who are your civil servants?'. It always comes as a shock to non-Canadians to learn that Canada's Eskimos number only about 15, 000.

The Eskimo in Canada has given rise to a veritable research industry. Their language has been dissected, their graveyards excavated, their kinship systems unravelled, their adaptability studied, their problems probed. But the field seems to have been almost worked out now for a number of reasons. With a small population, only a certain number of studies can be made. The simple, descriptive studies have been done; skilled specialists are now needed for an understanding of complex problems. Research cannot continue indefinitely. A standing joke described a nuclear Navaho family as comprising one father, one mother, three children, and two anthropologists. To which family grouping

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could be added, in the Canadian North, one social worker, one economic development specialist and two 'counsellors'—one from the Federal Government and one from the Territorial Government.

The other reason for the exhaustion of research possibilities among Canadian Eskimos is that there has been little pay-off for the people on whom the research has been done. Anthropologists and others have done a great deal to alert government officials to the real dimensions of the 'Eskimo problem'. Those social scientists who have been accepted by the Eskimos have assisted these people to understand the limits of the possible. The work done by the Northern Science Research Group of the Department of Indian Affairs and Northern Development in their Mackenzie Delta Research Project has been quite outstanding. But too much Eskimo research has resulted in an accumulation of research reports, theses and papers. The Eskimo has been a 'good thing' for many academics, a captive audience that could be exploited for publication. The careful, realistic, ethically planned research projects stand out like solitary peaks in the flat plains of mediocre writing and research. At one end of the spectrum, 'pure research', untainted by any considerations of applicability, has brought promotion and increased status to academics. The Stefansson syndrome ('He spent a year with the Eskimos, you know') is appearing on many campuses. At the other end of the spectrum there have been quick studies to find a solution to the 'Eskimo problem', which has resulted in simple nose counting being rationalized as research.

What has never seemingly been questioned by the Eskimo research industry—or the government—has been the utility of the studies for helping the Eskimo identify meaningful opportunities for solving his own problems his own way. Little of the Negro Research Industry helped Black Americans to determine possible ways of identifying and solving their problems in terms that has relevance to them. In the North, few people have cared or dared to question the basic assumptions underlying Canada's northern development policy.

Between those ethnologists and anthropologists and others who seek to 'keep' the Eskimo in his unspoiled primitive state and government officials who want to drag him into the industrial world, the Eskimo as a person seems to have been lost. I remember asking an ethnologist how the new government housing programs would affect the Eskimo he was studying. He blinked and said, 'I don't know anything about that'. And the recent frantic attempts to impress the industrial job ethic on the Eskimos have become apparent in the public utterances of government officials before such bodies as the House of Commons Standing Committee on Indian Affairs and Northern Development.

Here I would like to pay tribute to the officials of that Department. Every scientist knows the problems of carrying out research in a free spirit of enquiry on sensitive national problems. During my time in the Department I was allowed great latitude in following my interests wherever they led. Since that time, the Canadian Research Centre for Anthropology has received Departmental grants to aid its northern research program. The support that this Conference has received from that Department also indicates that the government is aware and concerned about the human and ecological problems of the Canadian North. The role of the scientist in modern society, however, must be to question every aspect of reality. In social science, it is important that the enquirer also attempts to put forward alternative possibilities at every level from the theoretical to the practical, and also be aware that he is attempting to understand what is going on, and not to condemn any person or agency.

THE DEVELOPMENTAL THRUST

Looking back over the fifteen years since 1954, when the Canadian Government officially disovered the North, it is possible to get some understanding of what the problems of the Yukon and the Northwest Territories really are.

From the beginning, the regions north of 60°N were seen as mineral rich areas just waiting to be 'opened up'. The myth of the rich north, based on singular developments such as the Klondike Gold Rush and the wartime demand for uranium from Great Bear Lake, still persists. There was an initial enthusiasm about the richness of the north and a continuing series of disillusionments as the best laid schemes of men crashed down on the harsh reality of the land. At the same time that high hopes were being raised about the fabulously wealthy north by certain politicians and others charged with 'developing' the area, others in government departments—cartographers, geologists, geophysicists, oceanographers—were accumulating a great deal of data and solid knowledge on the exact dimensions of the Territories. There was the familiar slippage between cautious scientific estimates and enthusiastic boosterism. When the new American nation burst its boundaries and went west in the nineteenth century, the land seemed to offer an endless bounty. It took a hundred years for skilled and sensitive men to realize that the land was being looted and that a delicate ecology was being disturbed. By the time the conservation movement got into its stride, much damage had been done and it has taken most of this century to repair the ravages of the nineteenth century and to introduce modern concepts of land management. There is still a lot of mess and waste around, and needless harm is still being done to the land, but there is plenty of vociferous opposition to any planned despoliation of special areas like the Redwoods of California.

Canada's northern development policy to date has been equated with the exploitation of mineral resources. These are located in very specific areas. Any mining or oil development in that Arctic will involve a total approach to resource development. It will not be enough to open a mine, rip out the minerals and then leave the land and the people wounded.

For every northern 'developer' of the exploitive type, there seems to be, in Canada, a northern 'conserver'. If the eyes of the developer see numerous mines springing up in the tundra and oil spouting forth at the tap of a rock, the conservationists worry about the birds and the vegetation. No Eskimo group has had so much attention and money lavished on them as have the Whooping Cranes.

White 'outsiders' have a curiously ambivalent attitude towards the North. What they seem to ignore is that they are strangers in a land in which the Eskimo has lived for a long time. They also seem intent on clashing with each other on every occasion, oblivious of the fact that both mineral exploitation and conservation can be parts of the same holistic approach to development, and that these aspects can be complementary and not competitive. It seems very obvious that the Canadian Mining Industry—as distinct from fly-by-night operators—is showing concern for the ecology of the areas in which the companies operate. International Nickel Company run advertisments in the press and on the radio about reafforestation of mining areas. The Canadian North needs large capital inputs for any form of development. It is less the large mining companies that we should worry about than the small operators trying to clean up and clear out. A northern development approach that plays up the idea of the rich north and encourages any small operator or greedy individual to take what he wants (and provides subsidies and propaganda for these activities) is obviously going to result in serious insult to the environment. But the crude, opportunistic, exploitive approach to northern development seems to be petering out.

The North provides instant feedback and the warning signs about the unanticipated consequence of an exploitive northern development policy are now flashing vividly. It seems obvious that the Canadian North—despite all the political exhortations—is not the American West. It cannot stand an incessant assault upon its ecology. Enough evidence will be presented at this conference to show that ecological damage has been done by the unthinking and acquistive thrust for development. It is my intention to comment on the human damage being done, and to suggest possible ways to resolve some of the problems of the land and the people.

'The Eskimo Problem'

The resource development pattern in the Canadian North, with its boosterism, its boomer talk, its careless use of the land, has a quaint nineteenth century air about it. The cultural lag appears in the program of human development also. In public statements, the nineteenth century paternalistic attitude appears. A linear, reductionist approach has been suggested for solving the Eskimo problem. The general logic seems to go this way. The Canadian North is a mineral rich area. There is very little else on which to build an economic base for development. Therefore the government must aid those who wish to mine the North. The mines will need labour. The Eskimos live in the North. They will provide a source of labour for the mines. They must be educated and trained to work in northern mines. This will be done by southern Canadians who do not speak Eskimo and whose education seldom includes any grounding in anthropology. This logic falls apart on closer examination. There have been only one or two mines in the tundra. Rankin Inlet had a short life and closed when the rich ore pocket was exhausted. Where are the other mines? There are prospects for new mines in northern Quebec. Attempts are being made to develop copper bodies in the Coppermine area, with no notable success to date. There is a 'mountain of pure iron ore' in northern Baffin Island, in an area with a very short shipping season. Each time this mine receives mention, the tonnage goes up and the shipping season seems to increase. At the present time, there appears to be an oversupply of iron ore in the world. Even if every mineral prospect in the tundra became a mine, it is doubtful whether this would create employment for all Eskimos requiring jobs. These mines would require a high level of science and technology, membership in a union and a high standard of education. The North is a capital-intensive area and many of the ideas of using Eskimos as miners seem to be based on the belief that there will be plenty of pick and shovel and other unskilled work to be done around such operations. More than this, the Eskimos have not had 300 years experience of the machine and of machine modes of thought. The Eskimo is a logical person, but there is no indication that machine-based logic is the only valid form of human mental activity. There is a persistent belief that the Eskimo is 'naturally' mechanically inclined. It is hard to determine how this belief arose, but I remember once reading in *Hints to Travellers,* that handy Royal Geographical Society guide to the Englishman abroad, about an Arctic explorer who got his watch mended by an Eskimo. From such slender beginnings do stereotypes often grow.

While not denying that mining offers possible options for Eskimo employment, it does seem as if the government, in pushing for jobs for Eskimos, has run into a blind alley. In 1968-69, the Department of Indian Affairs and Northern Development stated that its policy for northern employment was to ensure that, by 1978, 75% of all government jobs in the North would be held by northerners. Again, we have paper promises. The Department of Indian Affairs and Northern Development has no control over personnel policies of other government departments. Nor may it have much say in the Territorial Government hiring policy. The logic of suggesting that a job in the government is the ultimate goal to which all northerners should aspire may escape some people who have had close contact with life in the northern bureaucracy. Even a brief glance at the qualifications needed for positions in the rapidly expanding Northwest Territories Government will raise doubts about the validity of the Department's suggestion. All seem to require university graduation, specialized skills and wide experience—qualifications that few northerners and no northern native peoples possess.

While the White Man in the North sees himself as leading the Eskimos across the gulf between the cultures, both sides of the gulf seem to be drifting rapidly apart. The traditional Eskimo culture is being lost and the North is moving rapidly into post-industrial society where knowledge and information are the important resource bases, and flexibility, adaptability and sensitivity to feedback are needed for people to make sense of a dynamic world. In such a world people do not have 'jobs'—an industrial term. They have a number of roles that can vary with the operational setting. People do not learn one skill that carries them through life, but learn how to learn, so that they can take advantage of available opportunities. So much western education—up to the Ph.D. level-is merely trade training, based on an accumulation of skills and a piece of paper that enables a person to command a price in the labor market. The very terms used indicate the problem—men are seen as commodities to be bought and sold. They are seen as ends to the fulfilment of the needs of a machine-oriented, consumer society. There is ample evidence to indicate that this pattern of industrial society is beginning to disintegrate, like ice in the spring sun.

The Eskimo problem highlights the dilemma of the transition from one form of society to another. Why should the Eskimo work in mining or for the Government? Is dependence on welfare a shameful thing for the Eskimo? There is evidence that the Eskimo sees the white newcomers who shower benefits on them merely as another resource in the ecology —a cow to be milked, a presence to be courted or avoided. Culture provides a pair of spectacles through which people see their distinct worlds. In the North, the white outsider's view has either been obtained through pink lenses or through those of darkest black. Increasingly, the white presence in the Arctic is being resented by the native peoples there. The white man is being seen as an irrational and erratic source of benefits—someone who promises things, and does not deliver, someone who lives in a separate world with many benefits denied the local people. When the expected benefits promised by the white man do not arrive, there is always an 'explanation'. Usually, it is 'budgetary cuts' or 'financial limitations'. The northern peoples respond by sullen silence, by self help attempts (such as the co-operatives) or by other strategies. At Rae, in 1968, a prophet arose, and the cargo cult approach—obtaining the benefits of the white man's world, without having to put up with presence of the white man—may appeal to northern native peoples.

The fact that the Eskimo seems to be perched on a plateau between two worlds, is being ignored. Life is much safer and surer than ever before for these people. But the future is murky. The Eskimo experience with the white man has not been reassuring in the main, and an avoidance pattern is developing that could bring bitterness to the North. 'Two nations', a dual economy, a caste system, a wide gap between affluent whites and poor Eskimos demonstrate the dilemmas of western style development where benefits accrue to only one privileged group. While the white policy-makers look for jobs for Eskimos in mining, government and the service industries, the Eskimos are glancing west and east. In Greenland they see a more enlightened policy of social development for a people identified as 'Greenlanders' and not as 'Eskimos' and 'Whites'. In Alaska they see strong native organizations using the political process to claim traditional land rights. The Alaska Federation of Natives and other nativistic groups have laid claim to large areas of Alaska on the basis of aboriginal rights, and they have held up development of all kinds in many areas.

The acceptance of the validity of traditional cultures is a fairly recent phenomenon. Science, among other things, is an attempt to understand an existing reality. Under the influence of such thinkers as Claude Levi-Strauss, anthropologists are beginning to re-examine traditional cultures. 'Re-search' implies looking at old realities anew. Traditional cultures were specific ways of adapting to an environment—'natural' and 'human'. They were neither barbarous perversions of man's nature nor idealized expressions of unspoiled and untroubled savage states. The Rousseau-ish strain of romanticism is still rampant in Canada.

When traditional peoples like the Alaskan natives learn from their knowledge of the old ways how to handle whites who see development only as an immediate exploitation of the most accessible and easily saleable parts of the natural environment, it is about time that those involved in northern Canada give pause. The United States experience can serve Canada as a Distant Early Warning Line—if we can sort the signals from the noise.

Northern development in Canada has reached what appears to be the 'take off point, as far as can be determined, with the new mines at Pine Point, Cassiar, New Imperial, and elsewhere bringing forth wealth. The development thrust has squeezed in two directions. The land is being insulted and the people of the North, especially the traditional peoples whose home the Arctic is, are being damaged or shut out of possibilities for a meaningful life. They flit around the fringes of the white man's world like shadows, 'looked after' and kept alive by a welfare state bureaucracy.

It would be presumptuous for another white man to offer advice to the Eskimos. We have had numerous conferences in Canada where people whose interest in the North was pecuniary or short term have pontificated on what 'The North' and the native peoples needed. A people who have survived in the land may have no need of such advice. A land that is so large and vast will not be changed by clich6s and platitudes poured out in southern latitudes. The earth will abide, the people endure.

For the white man's world is changing, even as he offers his way to the Eskimo as the ultimate life style for all. The white man's concept of central place and total control is slowly slipping, in the North as elsewhere. It is more visible in the North, and so perhaps preventive measures of a therapeutic approach can be more readily accepted there. Here paternalism—no matter how well intentioned—must be replaced by participatory democracy where people are involved and consulted about matters that concern them. This must be coupled with a scientific understanding of the operational limitations that will replace the wild guessing that has passed for forecasting in the past.

TYING THE ENDS TOGETHER

Elsewhere, I have stressed the necessity of thinking of the Eskimo-White relationship in terms of a symbiosis and not as a parasitic arrangement that it only too frequently becomes. Our understanding of physics and biology permit modern men to conceptualize about new models for human action. The nineteenth century modes of thought, based on inadequate knowledge about the natural world, can be now discarded. In the Canadian North, the modern world has arrived in a series of explosions compressed into the past fifteen years. The North needs a high level of science and technology—and this implies that we must begin with the concepts of science that are becoming available from recent research in the physical and the biological sciences. As in everything else in the North, there has to be a great leap in the conceptual frameworks that guide our actions and influence our programs there.

In Labrador-Ungava, south of the tree line, lichen forms much of the ground cover. Lichen is a symbiosis between an alga and a fungus. It takes hundreds of years to achieve a thickness of a few inches, in a climate that lacks heat and light, on a soil that contains few nutrients. The lichen lives between the air and the rock, clinging tenaciously to an inhospitable earth surface. Yet this vegetation can be stripped off a surface swiftly by a bulldozer blade clearing a site for a mine.

Obviously northern mining companies have to watch out for the land. The North is vast, but small errors and carelessness can lead to widespread ecological damage that can harm large areas. Evidence of damage is already appearing. The tundra has the advantage that, in its immensity, it is yet a fairly simple habitat where the consequences of actions affecting the ecology can be seen and understood in a short space of time and without too much difficulty. We do not have to wait long in the timeless land to see how Man affects the land. The Arctic provides almost instant feedback, but skill and sensitivity are needed to understand what is happening now and to prevent further damage.

I do not intend to discuss how ecological damage can be identified and repaired. I am more concerned, in this paper, with who will do the repairing.

And here arises the possibility of uniting, in a mutually meaningful manner, a damaged land and an insulted people. It is to be hoped that, in their search for possibilities for Eskimo employment, the Department of Indian Affairs and Northern Development does not neglect the idea of creating careers in occupations that are healing and integrative, and not merely exploitive or of a service nature. Instead of painting the Eskimos into an industrial corner, the government can outline areas where careers could be developed that are meaningful to young Eskimos. It is among the young Eskimos that the need is most acute for meaningful employment. This is not so much as Eskimo problem as a problem of all young people. It is more serious among the Eskimos because their external environment is less rich than that of most southern youths.

In the United States, the rapid increase in technology has led to what seems to be an ethical and political impasse. Literally millions of the poor are without jobs, employment, or the prospects of employment. This same situation is rapidly developing in Canada. Here the young Eskimo is a favoured person. He has a culture he can still reach, touch and understand; even though it has been devalued by change agents, it remains alive in the anthropological and historical records and in the memories of the old people. Accelerating urbanization and industrialization hit semi-skilled and unskilled workers hard—the machine has no culture and can become obsolete in a matter of a few years.

How can young Eskimos bridge the gap and move out of their present state of limbo into a meaningful future for themselves and other members of their culture? The usual way of handling the older section of the Eskimo community is to mouth platitudes like; 'We shall have to lose an entire generation', 'They can live on welfare', 'There is nothing you can do with the ones who never went to school.' In discussing the ways in which Eskimos might act as conservationists, it is necessary to stress that this suggestion is not put forward as a 'final solution' to the Eskimo problem. Nor is the romantic viewpoint espoused that all Eskimos were natural conservationists in their approach to the land and its resources in the past. The way in which some Eskimo groups slaughtered the caribou with rifles should indicate that there is nothing 'natural' about their behaviour in this respect. The Eskimo perhaps viewed the land as the farmer does—as a source of sustenance. And there are good farmers who understand and work with the land, and bad farmers who abuse the soil and ruin it. Unlike urban dwellers in southern Canada, the Eskimos cannot escape the land and the natural environment. In traditional times, the Eskimo had to know the land—not from a sense of aesthetics, but for the sake of survival. And knowing the land meant learning its regularities and its vagaries in detail.

How can this assist the Eskimo in bridging the yawning gap between traditional society and the post-industrial world?

Any employment in the future must have a number of characteristics. It must carry status. It must be science based and open ended in the sense that it must involve the learning process as an integral part of daily operations. It must be restorative and recreative in the sense of determining new ways of developing and expanding a person's potential. The opportunities should be integrative and self-actualizing, helping the person to understand the complex realities of his own being and of the external environment.

If there is a need to heal and care for the tundra, there is also a need to heal and care for the tundra people—not in a veterinary hygienic way, but in a genuinely scientific and humanistic manner. Any conservation efforts could and should involve Eskimos—young people working with the conservationists, learning with them through doing those monotonous jobs that are part of the process of scientific training. Older Eskimos could provide logistical support, and the old people, now sitting on the sidelines of life, could be involved by telling what the land was like. In this way, old and young could contribute to the healing process, one providing the muscle and the other the mind.

Eskimos could be involved in interpreting the landscape for visitors. At one time the concept that one of the North's main functions would be to serve as an outdoor learning laboratory and classroom for a total sensory immersion would have given rise to a certain degree of hilarity. For a number of years, Europeans, and especially the English, have looked upon the Arctic as a place in which to disport themselves, living with the Eskimos and sledging all over the landscape. Now it is possible for schoolboy and affluent Americans to visit the Arctic. The former trip costs $1, 700 out of Toronto, the latter $3, 900. Of course, one can always get a free guided tour of the Arctic if you join the ranks of Arctic boosters, or have sufficient influence to join those private and government sponsored tours during which people are taken around to see the booming North, or travel with the intent of solving all northern problems in a series of one day visits and overnight stops.

A POSSIBILITY

Regrettably, in Canada, there has been little debate on northern development. The Government seems to believe in the idea of the Holy Grail and, firm in their illusions, they have until recently displayed little willingness to discuss other options for development or to exchange folklore for scientific knowledge. All this is changing. What is happening in the North cannot be kept from the eyes of all Canadians.

This paper has attempted to outline a *possible* way of linking the land and the people of the tundra together. Careers in conservation would make Eskimos mobile—if they wished to stay in the North, they could do so. If they wished to travel and to live 'outside', they could do this also. Their skills and their knowledge would be portable, just as they were in the old days. For this was the way it was in the old days. A man could carry little on his back in the tundra, but much in his mind. A concerned scientific effort needs to be made in the North if the vicious circle of despoliation of the land and despair in the people is not to turn into a downward spiral as it has done in places like Appalachia. The most depressing thing about Canada's North at this time is the human waste, lives being lived out in tatters and without form, shape or promise.

It is usual to talk about financial limitations as the restraining factor on any new idea. Quite obviously, the government must be informed and involved in any new endeavours for employing Eskimos in conservation. But I do not believe that Government can handle this problem. As with western style development programs elsewhere in the world, the first rush of adventurous speculation and action has been replaced by bureaucratic inertia and in-fighting between different departments and agencies. There is a need for a third party in the North, some group or agency that stands between Eskimos and the government and serves as a channel of communication, a nursery of new ideas, an 'entr'aide', an enabling mechanism to unclog the channels and untie the red tape, while animating everyone in an understanding of the limits of the real world.

For anyone who has watched, bemused as millions have been poured into projects with little pay-off in the North, it is enchanting to see the defensive attitude taken by government over ideas out of line with their stream of thought. Money could be found for a pilot project—perhaps from one of those numerous other government agencies that have sprung up to solve Canada's people problems. The human and ecological cost of not doing something to repair the damage in the North should be obvious to the most unskilled eye. In 1968, budgets in the Yukon Territory were cut for fire protection, although there seemed to be ample funds to 'help' developers of the booster type. In June, 1969, half a million acres of Yukon forest were on fire. One fire burned down the new mining town of Faro. It is not mere chance that the Yukon's newest mining venture is named for a game of chance.

If funds are to be invested in northern development in the future, they can best be spent not on roads or on dubious economic ventures rationalized as attempts to 'develop' the country that result in benefits to a favoured few, but on training young Eskimos in the skills of conservation. Each year, the Department of Indian Affairs and Northern Development faithfully budgets $10, 000, 000 for roads in the Territories. The Department obviously sees this program as one that 'opens up' the North. A small part of one year's road budget, spent on training young people in the techniques of conservation, would have higher pay-off in every way. The land would suffer less, and young Eskimos would have access to a wider range of opportunities and possibilities than in the mining industry and the government. Their knowledge and their skills would be welcome anywhere in the world, for the North is not the only place suffering from ecological damage under the impact of exploitive development.

In conservation and like pursuits, working with scientists, young and old Eskimos could come together with other Canadians in the relationship of equals that science involves. A selective search of the past, and a scrutiny of the present could lead to a more meaningful movement into the future. All involved would learn from each other and enrich each other's understanding of the limits of the possible in that strange land at the world's end—the Canadian Arctic.

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Paper No. 32

Maintaining the Tourist Potential of the Yukon

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In my view catering to what we choose to call 'tourists' but could more aptly be termed 'recreationists' has implications that go far beyond the simple selling of services on a cash register basis. We must not only know what the tourist is looking for and attempt to offer him just that; we must do so in a manner that is consistent with good environmental practices. Of course we must not lose sight of the fact that 'tourism' is important

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from an economical standpoint but we must be thoroughly aware that its maintenance is in jeopardy if we allow it to proliferate too greatly, too fast or in the wrong manner. Tourism, especially in the Yukon's fragile natural environment which in itself is by far the major attraction, could be extremely damaging in an ecological sense, as damaging perhaps as the destruction that will follow in the wake of heedless mineral and forest exploitation.

For its continued growth and maintenance the industry we loosely term 'tourism' is closely associated with, and dependent upon, the other uses and development to which Yukon lands and waters are increasingly being subjected and, since in many cases 'tourism' and other resource developments are mutually exclusive, it follows that our subject is a complex one and hard to do proper justice to within the confines of a paper such as this. At best an illustration of the background against which the industry should be seen and a summing up of its main problems can be indulged in, both of which may help to create a better insight and interest in this most important aspect of the land use and management scene in the Yukon.

BASIC REQUIREMENTS

The basic requirements for attracting tourists to any region, including the Yukon, are:

(1) We have to have something to offer; experiences in a natural environment that afford the complete change of pace and scene that is the epitome of an effective vacation.

(2) We have to have roads and waterways whereby the vacationers have access to the various areas where this change of pace and scene can be found; where there are accommodations and facilities for them and their pursuits; and where there are congenial hosts who are knowledgeable about the country in which they live and are in tune with the vacation psyche of their guests.

(3) Society at large in the region has to make a thorough and concerted effort in order to create an optimum tourist environment. The general atmosphere has to be one that fosters this situation as nearly to an ideal one as possible. To achieve this all levels (from Government down to the man in the street) have to be conscious of this. Switzerland is a case in point; there are few places in Switzerland where the visitor is not made to feel as if the country is just there for him to enjoy.

(4) We have to make an equally thorough and concerted effort to put the region on the map, far and wide, in an effective manner, in a very competitive market.

How does the Yukon measure up in respect of the above? Few Canadians, let alone other nationalities, know the Yukon or even know much about it. Some may have sketchy notions derived from highly coloured tales about the greed and bar-room activities of the Gold Rush—notions perpetuated by crass promotional efforts on this theme and by sensation minded news media—and lately some may have heard rumors of oil, mineral and forest exploitation in the area which causes even Cabinet Ministers to breathlessly speak of 'the Yukon's limitless resources'. But the fact that the Yukon is an immense area with a wide variety of, as yet, almost untouched natural splendour has been discovered by only a few, and then mostly by our neighbours from the United States who have learned the tremendous value of unspoiled surroundings the hard way. There still is such a thing as the 'spell of the Yukon'. Visitors are impressed by the realization that nature still holds sway over the vastness of this beautiful land; that one can walk 'beyond the horizon' and remain in solitude; that lakes, streams, mountains and valleys have that pristine quality that allows visiting humans however citified to rediscover their affinity with nature. But the tremendous importance of the Yukon as an area for recreation and rehabilitation for society's victims of over-industrialization tends to be over-shadowed completely by the preoccupation with the immediate gain type of extractive resource exploitation that is displayed in the North by individuals and Government alike.

The pressure of unbridled technology, coupled with witless dollar pursuit and thoughts only of the 'here and now', threatens to swamp permanently all other values that the Yukon and the North in general offer in far greater abundance than mere extractive exploitation of resources. That this is a far cry from the climate that is needed to bring about a healthy and desirable tourist industry goes without saying.

There is still time in the Yukon, although not for very much longer, not only to maintain the still existing quality environment but also to create conditions where, through proper management, the tourist industry can be developed into a prime economic force surviving long after the mines will be depleted. In the Yukon experiences that should be the birthright of everyone, those of being able to drink pure water from virtually any lake or stream, of breathing clean air, of enjoying clean uncluttered landscapes, are still possible; but to preserve this type of rapidly vanishing quality environment we have to engage in far ranging planning with much more initiative and imagination than has been the case to date.

PRESENT STRUCTURE

To fully understand the pitfalls and frustrations on the path to even a semblance of orderly and enlightened planning and management of the Yukon natural environment, it is necessary to look briefly into the present socio-political structure of the Yukon Territory. Control over the Yukon's natural resources, land and water, rests with the Federal Government in Ottawa; more specifically with the Department of Indian Affairs and Northern Development. The representative of this Department is a Government appointed Commissioner residing in the Yukon's capital, Whitehorse. While an elected seven-member Territorial Council has some say in matters of a local and routine nature it has none over the Yukon's natural environment. Commissioner and Council together are called the Government of the Yukon Territory. One elected Member of Parliament represents the Territory in the House of Commons.

Decisions affecting lands, forests and waters are almost exclusively made by the distinct Ottawa Government with two exceptions, namely 'tourism' and 'game'. Responsibility in these two areas has been delegated to the Government of the Yukon Territory. However, since decisions affecting the environment on which tourism and the habitat upon which wildlife depends are made in Ottawa, local control of these matters is more theoretical than real. The overall policy of the Federal and Territorial Departments concerned for the main part is geared to non-renewable resource exploitation and to date has displayed little visible understanding of ecological concepts or apparent desire to nurture and maintain the Yukon Territory carefully as an integrated whole.

Little pressure towards ecologically responsible planning is being exerted on the Government by the scant 15, 000 population which lives in the Yukon's 207, 000 square miles. Neither a population dependent as it is for its livelihood on the fortunes of extractive resource industries and/or—not to forget–promotion thereof, nor a Government preoccupied with this type of development, can be expected to display a great measure of conservation ethics. The bull-dozer is king and to many inhabitants of the area and certainly to the great majority of visiting wise men from the East and other assorted promotional groups, the Territory's main attractions are the excavations made for mining development rather than the more subtle values of natural splendour. Even the Yukon's rivers and lakes are primarily seen as potential hydro-power development sites or as a saleable commodity by a brand new crop of businessmen who propose to sell the water to the South in order to dilute the gross pollution there.

This then is the climate that exists and its creators will have to be confronted with the need for a vastly more enlightened and sophisticated approach to the preservation of the quality environment we are still fortunate to possess, in order to make a healthy and ecologically inoffensive tourist industry possible, let alone maintain it. The need for such overall planning has been stressed quite vigorously by D. W. Carr and Associates in the major report 'The Yukon Economy: Its Potential for Growth and Continuity', which was prepared in 1968 for the Department of Indian Affairs and Northern Development and the Government of the Yukon Territory.

TOURIST POTENTIAL

Assets of the Yukon

(1) In the works of the Carr Report: '... unspoiled beauty, a delight to the tourist ... high fresh spaciousness and an almost unbelievable refuge from the frustrations and mass hysteria of Southern cities ...'

(2) More specifically, rivers, lakes and streams for boating and fishing; forests, broad valleys and hills for hiking and trail rides; abundant wildlife for both the animal lover and the hunter; mountain ranges to delight the mountaineer; endless opportunities for photography and nature study and, above all, clean waters, clean air, unspoiled surroundings and, to date, a lack of the crass commercialism displayed in the almost over-run semi-wilderness areas in the populated South.

(3) An interesting history; the very recent one of the era of river travel and the Gold Rush and, to my mind, the much more fascinating history of the indigenous people of the Territory, their life in the wilderness and their early contacts with the first white explorers.

In contrast to these impressive assets of the Territory in relation to tourism and recreation the list of what the Yukon lacks is much longer.

The Yukon Lacks

(1) A sufficiently financed and imaginatively executed program publicizing its assets and whereabouts to the degree necessary to attract a sufficient number of visitors and tourist facility operators.

(2) A classification of lands and areas along the lines of what is being done in the U.S.A., spelling out to what use certain lands and areas can be put, in order to safeguard the present and future interests of the Yukon and its people in maintaining its environmental quality realistically.

(3) A concerted plan of wildlife management using modern concepts and methods, applying wherever possible lessons learned elsewhere in this respect.

(4) A comprehensive set of regulations dealing with safeguarding the quality of water and air, and the aesthetic aspects of environment and scenery, on a day to day basis, and effective machinery for the enforcement of such regulations.

(5) Quality control of tourist establishment and implementation of standards that must be adhered to by operators in various categories of facilities in order to quality for a business licence and be allowed to operate.

(6) Sufficiently financed and staffed forest fire prevention and suppression facilities, and adequate forestry research and planning.

(7) A program for paving the existing road network which has to be used simultaneously by heavy ore trucks and tourist vehicles.

These are impressive obstacles placed in the way of tourist operations based on the natural splendour of the Yukon. I can assure you from bitter experience in our own small enterprise, which is based on the non-wasting asset of nature and its manifestations, that these obstacles are very real indeed and, at this moment at least, mostly insurmountable. Since they form the key to the overall development of a viable Yukon industry which, to the greatest degree possible under Yukon climatological conditions could also develop the hinterland, I wish to expand each point separately.

(1) Tourist Promotion and Advertising

The territorial Department of Travel and Information in Whitehorse, a function of the Territorial Government, is responsible for the overall publicity of the Yukon's tourist attractions and for liaison with those facilities in the Yukon which are considered to be in the realm of tourism.

The size of its budget is determined by Territorial Council and appears to be wholly inadequate. There appears to be less than $6, 000 available per year for national and international magazine and newspaper advertising (an amount probably less than what is spent by a small supermarket using comparatively cheap local media); it is completely insufficient in terms of putting a territory such as the Yukon on the map internationally.

The Department responds to written requests for information by sending kits containing folders, brochures and maps accompanied, where necessary, by a personal letter. This is quite effective in the case of the specific enquirer but fails to create a steady dissemination of information extolling the many-splendoured virtues of the Territory to the recreationist, and hence reaches comparatively few people.

Moreover, what magazine publicity can be afforded on this budget appears to be slanted towards persuading travellers on their way to Alaska to leave a few dollars in the Yukon on their way *through* rather than actively and consciously attracting visitors to the Yukon for the sake of what the Yukon itself has to offer in so great a measure.

Great confusion still reigns in the minds of Canadians and other nationalities alike as to what is variously called 'the North', 'The Northwest Territories', 'the Yukon Territory', 'the Arctic', etc. This conjures up visions of Eskimos, igloos, whales, and a haze of blizzards, ice-fog and snow. That there is a large region of great natural beauty with a habitable climate north of the 60th parallel is virtually unknown to our fellow man south of 60°. The Yukon Territory suffers geographical displacement at the hands of even Ottawa Departments which cheerfully address letters to 'Yukon, Northwest Territories' or worse, 'Yukon, U.S.A.' and we have the envelopes to prove it'.

Perhaps one explanation for the present half-hearted attempt at creating a healthy climate for a viable tourist industry in the Yukon can be found in the already mentioned fact of the apparent single-minded pursuit of extractive development displayed by the Government and the resulting saturation of the Territory with like-minded people. People imbued with the resource type of philosophy traditionally are interested only in using the country for extracting what is of direct dollar value, and are not interested in husbanding and nurturing the country for what they call parasitic or inferior industries such as tourism or for other long range considerations, however valuable to future generations. As such they are unlikely to look upon the tourist industry as an end in itself although they are not above attempting to cash in on tourism as a sideline.

The latter would explain the stress placed upon the importance of early mining history, the bar-room atmosphere and other gaudy aspects of the Gold Rush, pure sightseeing and 'gimmick type' tourist traps; all of which can be established in already accessible areas; and all of which are to an almost negligible degree dependent on the quality of the natural environment. In contrast the development of hinterland, wilderness–type facilities depends almost entirely on preservation of the quality of the surroundings.

'Development' of the hinterland in this manner would require environmental management of a type that mining and timber interests traditionally oppose as being a major hindrance to their extractive development. As such one can quite easily find support for expenditure promoting or establishing tourist come-ons based on various situations, the maintenance and promotion of which would not be considered offensive by industry.

Industry has no objection to promoting the 'glamour' of various devastations such as tailing piles, mined out creeks, abandoned Gold Rush towns etc., but has little use for intrusion by a tourist industry into the hinterland which they like to consider to be their exclusive domain. In particular, the Yukon, through its present utter lack of resource management regulations, creates a veritable haven for resource promoters fleeing the provinces due to the mounting pressure of increasing environmental controls there.

(2) *Land-Use Classification*

At present there is no land classification system in the Yukon Territory. With the exception of municipally and privately owned lands and waters, all Yukon lands and waters are controlled by the Federal Government in Ottawa. The mining laws prescribe that mining has precedence over all other forms of land use. There is no policy to actively promote the use of land in the Territory for purposes other than mining, logging or oil exploration. The words 'multiple use' are used on occasion by Government agencies but, since no legal definition or description of what it means exists, the term is used to cover a multitude of sins. Under present conditions in the Yukon the term could probably be described most aptly as meaning building a log cabin while simultaneously using the logs for firewood.

The prospective tourist facility operator will find the road to acquiring land for his business and to selecting an area where his subsequent investment would be reasonably safeguarded, to be one wrought with pitfalls.

It is nearly impossible to find out under what conditions, and at what prices and acreages, land is available. There is a lack of understanding on the part of the land issuing agencies as to the requirements of land and type of land that can be used by the tourist industry with regard to the various types of operations that are possible in the Yukon.

When asking the former Minister of Indian Affairs and Northern Development for a clear explanation of land use policy, availability and prices of land in the Territory, the written reply was that such information was available to officials of Indian Affairs and Northern Development but not to the public 'since it would only tend to confuse them'.

Nature-based tourist facilities are equally frustrated by the lack of a land classification which clearly spells out to what use various areas may or may not be put. The wilderness aspects of our natural environment, and not only in the Yukon, are assuming tremendous importance in the lives of millions of people who are confined to the decaying atmosphere of large cities. Yet in the Yukon where this aspect can be capitalized upon in an enduring manner on so great a scale, no attempt has been made to designate such things as wilderness areas, watersheds, national forests, wild rivers, parks or other areas of ecological or other importance, where there would be at least an indication that perhaps other contingencies than mere extractive resource use are considered. A half-hearted attempt is being made to arrive at establishment of a national park in the Territory but at the time of writing the Government appears to be prepared to succumb to such a degree to the wishes of the exploiters' lobbies that this 'park' would be open to mining and logging interests; a far cry from the original park concept.

A nature-based tourist facility operator is at the mercy of all development other than his own, and at this time cannot even hope to receive help on the part of the Department charged with resource management; although in all fairness it must be said that some of the officials involved, on an individual basis, certainly are aware of the problems and are quite sympathetic, but due to the overall policy in effect are unable to assist.

(*3*) *Wildlife*

As explained before, a token responsibility for wildlife management exists in the Yukon through the so-called Game Branch where the 'Director of Game', with two assistants, a secretary and a wholly inadequate budget, caters mostly to the interests of the big game guides and outfitters, and administers Territorial game laws. Jurisdiction over wildlife habitat is non-existent, however, as this is in the hands of the Federal Government. The Canadian Wildlife Service, which is a branch of the Department of Indian Affairs and Northern Development, boasts a total of one representative in the whole of the Yukon Territory-a biologist engaged in a study of the Grizzly Bear. There is no game management zoning in the Yukon, nor has an attempt at a game count ever been made, although there is a wolf bounty, a wolf poisoning program and even an open season on cow moose.

(*4*) *Pollution and Environmental Quality Control*

Practically no legislation is in effect with respect to pollution control in air and water; and there is no such legislation whatsoever with respect to aesthetic values of the environment. Insofar as water pollution is concerned, which is an extremely important issue in the Yukon considering the increase in mine mills, the possibility of a smelter and the spectre of even pulp mills, the only water pollution legislation can be found in the Canada Fisheries Act and the Territorial Mining Safety Ordinance. The former Act is administered by one Fisheries Officer, the latter by one Mining Inspector. Both men are required to cover all of the Yukon's 207, 000 square miles and both regulations are considered to be totally inadequate by legal experts.

The Government itself appears to be one of the greatest sinners in continuing to allow, for instance, dumping of raw sewage in Yukon waters and allowing shoreline garbage dumps. The Yukon river below Whitehorse is a sordid case in point which yearly prompts a number of visitors to complain in writing to the Commissioner and the local papers.

Increased operation of industrial plants spells increased need for first class waste disposal methods. Conventional tailings ponds where the mine waste effluent is allowed to sediment out and the (supposedly) harmless liquid is decanted and returned to the stream will, on the admission of the Department of Fisheries research people, not work effectively in this climate unless constructed extremely well, extremely large and supervised constantly. The reason is that in the Yukon winter climate, tailings ponds are ineffective for the greater portion of the year since they freeze down to ground level. They therefore should be of a capacity that will hold more than one year's flow of waste and should be engineered with the same care as is bestowed upon the painstaking construction of the mine establishment itself, something unheard of up-to-date. When one considers that Anvil Mine alone, being situated on a main tributary of the Yukon River system, will have a daily discharge of over 4, 000 tons of mine waste to which vast quantities of water are added, then it seems obvious that unless a concerted effort is being made to find a method of rendering the effluent harmless in a manner effective under Yukon conditions, we are simply going to repeat in the Yukon the gross mistakes that always *have been* made everywhere and still, almost consistently, are *being* made.

Unpolluted water being one of the main attractions to tourists, the importance of water quality control cannot be overemphasized and stressing this aspect in a paper such as this is wholly relevant.

Some studies in this regard are being done by the Department of Energy, Mines and Resources, but it remains to be seen whether the effect will come in time to prevent irreparable damage. Establishment of a smelter or pulp mill under Yukon conditions would entail even more precautions in order to safeguard land and waters affected.

The aesthetic aspects of the environment are mostly forgotten in the Territory, Around communities and highways, visitors are often treated to a proliferation of garbage dumps, car dumps, dilapidated buildings, unsightly bull-dozer cuts and slashes, gravel pits, piles and windrows of dead trees etc. In the hinterland, exploration companies and crews leave their debris behind when they are finished with their work, and many a lake and stream in pristine surroundings has junk on its shores and gas drums on its surface. The fragile northern tundra faces despoliation by the activities of oil exploration crews.

No legislation to preserve aesthetic appeal of the landscape is in existence and here again this bodes ill for tourist industry in the more populated areas and in the hinterland, since any type of detrimental and uncontrolled damage next to a tourist enterprise can kill it as effectively as if the source of visitors had dried up.

(5) *Quality Control of Tourist Establishments*

Quality control of tourist facilities and implementation of operating standards appears to be quite necessary in order to prevent development of the type of sordid establishments that are so objectionable in other parts of the continent and can give the whole industry a black eye.

At present the Department of National Health and Welfare administers a set of regulations dealing with the sanitary aspects of tourist operations and can close them down if these regulations are not complied with. There are no regulations in existence, however, which prescribe standards for minimum physical facilities or aesthetic aspects of the various types of operations.

To acquire a business licence it is only necessary to fill out a form, state the business one considers oneself to be in and pay the prescribed fee. There does not appear to be any connection between the standards required for that business and one's right to have a business licence.

(6) *Forestry*

The incidence of forest fires in the Yukon is a deterrent to establishment of tourist facilities in the hinterland and possibly even in areas along the highways. The Yukon's semi-arid climate creates summer conditions which are a source of anxiety every year. A burnt environment is just as damaging to a nature-based facility as having the facility itself burn down.

The Carr Report quotes a figure of a yearly burn rate of . 6% and suggests that this rate without too great a financial sacrifice could be reduced to 0.1%. However when, periodically, conditions combine to produce a virtually explosive situation in Yukon forests, the lower figure is probably unrealistic over a number of years. It is extremely important, however, that no avenue remains unexplored if it is thought to lead to a decrease in the number and acreage of forest fires. This paper is being written not even halfway through the 1969 fire season and already this year's forest fires are reported to have set an all time record in the history of the Yukon Territory, greater than the 1958 high when 96 fires burned 1. 5 million acres.

According to the Yukon Forest Service 70% of forest fires in the Yukon are man made. With the greatly increased activities by mining, logging and exploration companies in the hinterland and a greater recreational use of the environment it would appear that the present forest fire protection and facilities are inadequate. A realistic system of not only suppression but, more important, prevention of fires, should be developed while the present arbitrary designation of 'protected' and 'unprotected' zones should be placed on a more meaningful basis than simply proximity to highways and rivers, as seems to be the case.

Insofar as logging operations in themselves are concerned, issuing of permits for such operations should always be carefully considered in the overall context of recreational use of the environment and other considerations such as watershed management, wildlife habitat, etc. Similar considerations should play an important role in the issuing of permits for power line construction and road construction, in particular tote roads. Unfortunately in none of the cases mentioned does it appear that these considerations are held to be of importance at this time.

(7) *Roads*

Perhaps the most important single item to the tourist industry is accessibility of the tourist areas. At present the road situation is becoming increasingly deplorable and will become more so as industrial activity in the Yukon increases.

The surface of the main artery to the Yukon, the Alaska Highway, by now can be found in its ditches, making the crown of the road and the ditches equally uncomfortable to drive on. Territorial roads also with but a few exceptions are becoming much harder to maintain due to the fact that no gravel road surface has been developed yet that will, with any degree of success, withstand the constant pounding of trucks weighing close to 100, 000 lbs. each. Dust conditions and rough road surfaces during periods of dry weather, which is most of the time, are extremely detrimental to tourism.

The only two roads giving access to the interior Yukon from the Alaska Highway are the Campbell Highway and the Klondike Highway. When the Anvil Mine near Ross River goes into production this Fall these roads will be subject to 100, 000 lb. ore truck traffic of a conservatively estimated frequency of one truck every 14 minutes or an overall vehicle frequency of one every 3 minutes day and night, year round. Since this will virtually render the road impassable for private and tourist traffic, unless a means can be found whereby the surface is dust-proofed and hard enough to remain reasonably smooth, interior Yukon will effectively be inaccessible to tourist traffic commencing this Fall.

The only answer would appear to be construction of a railroad into the interior or paving of the existing road system: neither of which seems to be close at hand.

SUMMARY

From experience gained during a 17 year residence in the Yukon, of which the last five were devoted to establishing a wilderness retreat for paying guests, I think that the foregoing appraisal is both true and realistic.

In some circles however, it will be denounced as being defeatist, dismal, unkind, or all of these. This is predictable and in line with two Yukon traditions; the first one being to wait for calamities to happen and to take action when it is too late, the other one of viewing the Yukon on a short-term basis only with what could be termed a 'rapist' attitude.

It is, by virtue of its unquestioned stewardship over the one third of the Canadian landmass (population 50, 000) which lies 'north of 60', the clear responsibility of the Federal Government, and the Federal Government alone, to initiate a break with these traditions. A demonstration of this type of leadership will soon change the economic climate in a manner to spur development of an industrial and settlement pattern that will be conducive to long term growth and maintenance of the Territory.

There are hopeful signs that there may be a new awareness in this respect in Ottawa; there certainly is no lack of precedents to learn from.

But, unless this awareness is implemented in enlightened and effective action, fast, the Yukon Tourist Industry will die in the cradle and many other values this beautiful country holds out to us in abundance and perpetuity will vanish with it.

Paper No. 33

The Potential For, and Impact Of Tourism in the Northwest Territories

M.P.McCONNELL[1]

INTRODUCTION

Tourism is now generally recognized as an industry, and in fact one of the major industries of the world. According to one report, out of a total world trade of approximately $200 billion in 1967, international tourism accounted for $15 billion. It is a rapidly growing industry. In Canada, for example, expenditures by foreign visitors increased from $222 million in 1946 to $337 million in 1956, and then to $840 million in 1966. It is also a complex industry which incorporates or uses within its systems many facilities and services which are only partially designed to serve the tourism industry. Compared to many other industries, mining for example, tourism is a difficult industry to define or describe.

There has even been difficulty in obtaining agreement throughout the world, at the working level within the industry, on the definition of a 'tourist'. At its 1950 General Assembly the International Union of Official Travel Organizations (I.U.O.T.O.) adopted a definition which includes, in the broad category of tourists, persons travelling for reasons of pleasure, health, business and meetings; but not for purposes such as employment or change of residence. It is important to recognize that this definition is not in universal use, and therefore statistics from one country or area cannot necessarily be compared to those of another country or area.

In the Northwest Territories to date, we have been concerned only with 'pleasure' or 'vacation' travel. We are concerned with pleasure travel within the N.W.T. by Territorial residents, but have been unable to obtain measurements of this phase of the tourism industry. The N.W.T. statistics in this paper on past development and future prospects therefore relate only to vacation travel by visitors, and the term 'tourist' is used in a more restricted sense than may be normal at meetings with international representation.

There is one other general comment which may help to establish a perspective for this paper. The present size of the industry, and even its potential, may appear relatively insignificant when compared to other parts of Canada, or to other countries. The Territories embrace more than one-third of Canada (1, 300, 000 square miles), but the significance of tourism should be measured in relation to people (population 32, 000), not in relation to acres of land or to the size of the tourism industry in other areas.

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STATUS OF THE INDUSTRY IN THE N. W T.

There are no records on pleasure travel available for the Northwest Territories prior to 1959. It can be assumed that there were no major fluctuations in travel volume and that there was gradual expansion to the 1959 level. In that year the number of pleasure travellers to the N.W.T. was estimated at 600 and their expenditure at $350, 000. There were only six hotels and motels, three tourist camps and two outfitters.

There has been a steady expansion of the industry during the 1960's. By 1968 the volume of pleasure travellers had increased to 9, 000 and their estimated expenditure to more than $ 3 million. In that year there were 14 hotels and motels, 29 tourist camps, and 18 licensed outfitters. These totals may not be impressive when compared with other parts of Canada, but they do represent a spectacular growth rate. Tourism is now a significant force in the economic life of the Territories and ranks third, behind mining and oil, among its industries.

This growth rate has been achieved by interaction of a number of forces: social and economic factors such as higher disposable income and increased leisure time; improvements in the transportation system; investment in new accommodation and services by the private sector; activity by some communities in the promotion and reception of visitors; organization of the Northwest Territories Tourist Association as a spokesman for industry; and the strong support for the tourism industry provided in part by the Government of Canada and, in particular, by the Government of the Northwest Territories.

The character of the tourism industry in the Territories during this period might be described as typically 'frontier North American'. The development pattern has not been unlike that of northern parts of some of the provinces, with sport fishing and sport hunting providing much of the initial impetus. The new accommodation is largely in the form of fly-in fishing camps and lodges for sportsmen. A shift in emphasis is, however, already apparent. It appears that during 1969 visitor volume over the limited highway system will, for the first time, surpass the number of air-tourists. The main travel motivation of our auto-tourists is 'sightseeing and general interest in the North', not fishing or hunting. There is also an apparent increase, among present and potential air-tourists, in what might be described as 'Arctic experience', i.e. seeing the land and the people.

The origin of visitors is almost totally North American at the present time. In 1968 only 5 out of 3, 500 guests at lodges and outfitters were from Europe, and 89% of the total were residents of the United States. The origin of auto-tourists is quite different: 54% Canadian, 42% from the United States and 3% from other countries. As might be expected, there is also a dramatic difference between the expenditure by air-tourists and auto-tourists. The average per capita expenditure by guests of lodges and outfitters in 1968 was $620 while the reported expenditure per capita by auto-tourists was $35. There is more similarity between the various categories of tourists when viewed from the standpoint of occupation. The following table lists the five main groups as a percentage of the total number of persons travelling for pleasure by the three main travel systems:

	Highway Travel	Scheduled Airline	Lodges & Outfitters
Professional	18.9%	33.8%	35.0%
Owner/Manager	13.4	18.5	31.0
Skilled Worker	18.0	5.4	7.0
Retired	9.6	4.3	15.0
Sales	3.9	7.6	7.0
All Other Categories (students, farmers, unskilled workers, etc.)	36.2	30.4	5.0
	100%	100%	100%

We do not have as much detailed information on the educational level, but visitor studies have indicated that, regardless of the travel system used, individuals who are at least high school graduates account for more than 50% of all visitors. Among air-tourists there is a higher educational average, with university graduates alone accounting for more than 40% of the total pleasure travellers.

From our study to date of pleasure travel to the N.W.T. it is possible to draw a partial but useful profile of our average tourist. He or she has an above average education and has probably had at least some training at the university level; is probably a U.S. citizen, and is likely to be in the professional ranks or an owner/ manager in a business enterprise. Beyond this point, we cannot continue the profile because of apparent differences in primary motivation between auto-tourists and those travelling by air. Incomplete as it may be, this profile provides a guide for future planning of visitor promotion and development of facilities, attractions and travel systems.

MARKET POTENTIAL

In the past it has been a relatively simple task to define a market area. In North America auto-tourists have been the basis of the tourism industry. The prime market area for any location was described by placing a compass on a map and drawing a circle with a 500 mile radius. While a small percentage of visitors come from a longer distance, this somewhat arbitrary definition of the market area appeared applicable in most cases. It would be totally inapplicable to the Northwest Territories because a circle with a 500 mile radius drawn with its centre at the highway crossing of the N.W.T.'s southern boundary, would reach only part way to Edmonton, Alberta. A 500 mile circle based on Cambridge Bay would not even reach to the Territorial capital of Yellowknife.

There are several influences at work in our society which affect the definition of a market area for auto-tourists. In relation to the Territories, the main influences are: the increase in disposable income, longer vacation periods, earlier retirement and improved transportation systems. These influences combine to transform the entire North American continent into a market area for auto-touring to the Territories. The deciding factor is no longer distance. Instead we must look at characteristics of the population, such as income level and retirement, plus motivation. This may explain why California, despite distance, ranks third among the provinces and states as a point of origin for N.W.T.'s auto-tourists.

No estimate of the potential number of N.W.T. auto-tourists from Canada and the United States has been made to date. A reliable estimate could only be based on continent-wide study which included motivation as well as available time and money. It is doubtful that the results would justify the cost at this stage of development. For our purposes we can adopt an arbitrary approach and say that approximately 1% of the population have the time, money and motivation, or can be motivated, to join the ranks of auto-tourists in the Territories. This represents a potential in excess of 2 million people; more than enough to submerge our limited highway system, even if they were spread over the next 20 years.

The real potential, however, lies in the field of air travel. Only a very small portion of the N.W.T. is served by road. To bring the tourism industry to the greater part of the Territories' 1, 300, 000 square miles, we have to look to the air-tourist. This expands our market area to literally embrace the world. The critical decision facing a potential air-tourist is: to fly or not to fly. When he decides to fly, distance is not a major factor.

We can draw some conclusions about the potential market for air travel to the Territories from the estimate that 25 million Americans and 18 million Europeans now have the leisure time and money to fly across the Atlantic. For many of these travellers, a flight across some part of the Northwest Territories is the shortest and least expensive route. Assuming motivation and provision of adequate facilities, it is technically possible to tap this tremendous flow of trans-Atlantic travel and to bring hundreds of thousands of air-tourists to the Northwest Territories.

So far, in considering potential, we have assumed that motivation exists or can be created. This also assumes that the Territories have something to offer which will provide the basis for motivation. A detailed listing of the Territories' attractions should not be required in this presentation. It may help establish our perspective, however, to read two recent statements. The first is from a study into American attitudes towards leisure travel in Canada:

> 'The sophisticated traveller is willing to venture out into new physical and emotional territory. The openness of the Canadian North-West would appeal to him, and an introduction to Eskimo culture would capture his imagination. For the first time in history, a large group of people are now able and willing to do what only the organized private safaris for the very rich could do in the past.'

The second quote is from the pen of German travel writer and author, Dr. Hans-Otto Meissner, who spent several weeks travelling throughout the Territories and who commented on its appeal to Europeans:

> 'It is not for the big crowds wishing amusement and entertainment and an ordinary good time—but for all those who love unspoiled nature and the thrill to travel through limitless wilderness. The Northwest Territories and all the rest of northern Canada has the unique opportunity to offer for holiday makers from the densely-populated countries the blissful sensation to be away from it all. —Nowhere else on the globe are the open spaces so wide, the people so few and the lakes so many.'

To summarize the discussion on potential very briefly, we can say that the Northwest Territories has vacation attractions to offer; that it is not an area for mass tourism, in the sense of beaches and resorts in the highly populated areas of North America, because of cost and motivational factors; but that, contrary to popular conception, the potential for development of pleasure travel to the Territories is so great that marketing its attractions presents no major problem. The main problem lies with the Territories' ability to accommodate and service large numbers of people without losing their particular appeal and without damaging their physical resources and social structure.

IMPACT

The impact of tourism is usually considered only in economic terms. We can offer very little detailed information at this point because the first detailed study of economic impact is now in the planning stage. The leakage and multiplier factors for the tourism industry are unknown. We collected some data in 1968 which gives at least an indication of economic impact:

1. Lodges and outfitters employed more than 400 employees during the peak tourist season and total value of earnings amounted to approximately $450, 000.

2. Payments to resident air charter operators by guests of lodges and outfitters amounted to $220, 000.

3. Direct revenue to the Territorial Government through its limited taxing and licensing authority amounted to approximately $32, 000.

No measurements have been made of the benefits to the Territories through the supply of goods and services either directly to tourists, or indirectly through operators of services and facilities. We suspect that the net economic benefit to the Territories will be proportionately less than in other parts of Canada, but not necessarily less than other Territorial industries. It appears that a major part of the economic benefit from development of the tourism industry in the Territories is divided among other parts of Canada which provide the bulk of goods and services.

SOCIAL IMPACT

Tourism has been described as not just an industry with invisible smokestacks, but one of the greatest forces in the world today for social change. There are probably very few who will disagree with the statement. Communication between people of two areas, two cultures or two countries is much more effective and meaningful when it takes place face-to-face on the home ground of one of the parties.

In the Territories we recognize that tourism is effecting social change, both among the visitors and residents. The greater impact is probably felt by the residents, particularly the indigenous people, whose contacts with well educated, widely travelled people from the 'outside' are suddenly being multiplied tenfold. We do not completely understand the interaction and social change which is taking place. We believe that the social impact of visitors from other countries and other cultures is generally beneficial. The degree of benefit will depend on a number of factors, including the understanding of tourism by residents; the degree and form of contact; the attitude of visitors; and the visitor volume.

The latter factor, volume, is a potential hazard in the Territories. The social structure in a small indigenous community in the Arctic or Subarctic is fragile, in part because it lacks numerical strength. A sudden and continuing flow of large numbers of tourists could submerge or drastically alter the character of the community. It could also lead to effective isolation of visitors from residents, thus eliminating social benefits for residents and removing one of the main travel motivating factors for the visitors.

IMPACT ON THE LAND AND ITS RESOURCES

The impact of large-scale industrial development on the natural environment of the Arctic has received a great deal of attention in recent months. The tourism industry also affects the natural environment and the effects are bound to grow as the volume of tourists grows. It is literally impossible to introduce any development by man that does not affect the natural environment. The effects may be good or bad, depending on the individual viewpoint.

Tourism can have a heavy localized impact on the environment. For example, we have already experienced damage to the fragile soil cover in two or three campgrounds along the Mackenzie Highway System. Our new campgrounds are designed as a series of loops, so that sections can be closed off and allowed to rest and regenerate for a period of years.

The growth rate of fish is relatively slow due to cold temperatures, short ice-free season and limited food supply. Our lakes and rivers could be fished down fairly quickly by heavy angling pressure, and we do not have the alternative prospect of family resort development which is the pattern followed in many southern areas. With the help of the Department of Fisheries and the Fisheries Research Board of Canada, we have established a zoning system to control the size and number of sport fishing camps in remote areas. Many of the camp operators have responded by encouraging their clients to use barbless hooks so that fish can be safely released, and by encouraging their guests to take home less than the legal limit. We expect that eventually the 'fishing for fun' approach will be adopted on at least some lakes and rivers in the Territories, and all fish, or perhaps all but one, will be released to provide sport for other anglers.

Hunting of big game animals by non-residents was opened several years ago in the Mackenzie Mountains. It is carried out under strict controls by a limited number of outfitters, and there is no indication of adverse effects on the big game population. There has been at least one benefit from opening of this area for hunting; the acquisition of data on the big game population that otherwise could only have been gathered over a period of years at a substantial cost to the public. In this particular case, considering the economic benefits and the knowledge acquired, the impact must be considered as beneficial.

At various times proposals have been made to open sport hunting seasons on other big game animals in other parts of the Territories. There are two approaches to this problem: from the philosophical standpoint and from the viewpoint of resource management. In any debate on the subject it is essential that we first establish the approach on which our argument is based. The philosophical approach has impact on men's minds. Some hold that it is wrong to hunt and kill animals for sport; others are proponents of the hunting tradition; and a large number of people do not have strong views on either side. The resource management approach is based on optimizing the benefit through harvesting a sustained yield from the resource.

The most likely conflict in any given situation is between those who are philosophically opposed to sport hunting and those who advocate sport hunting because of its economic **benefits.** Assuming that the wildlife population can support a controlled harvest, we may then have to choose between, on the one hand, supporting a philosophy which is opposed to sport hunting and, on the other, enabling a group of economically depressed people to augment their income by revenue from guiding and outfitting. In neither case is there likely to be an adverse affect on the natural environment unless the balance of nature is so disturbed that overpopulation results in damage to the habitat.

The establishment of various types of protected areas such as parks, nature preserves, wilderness rivers, etc. is a very specialized subject and cannot be dealt with adequately as a part of this paper. They fulfill a special function by preserving the natural environment in selected areas from the impact of development. As long as adequate provision is made for access, they are major assets to the tourism industry. At this time we can offer more questions than answers concerning establishment of these special areas in the Territories. Apart from National Parks which are part of a national system, we wonder about the type, purpose, size, number, etc. of protected areas which should be established in the Territories. We are not prepared to adopt without question a system which may be suited to the environment of southern Canada. The Territories are different and in most respects, require a different approach. We hope to have answers to some of our own questions on protected areas as a result of a study which is now underway.

DEVELOPMENT PATTERN

It is probably not desirable to 'master plan' development of the tourism industry in the Territories, because it would probably lead to inflexibility and inhibit innovation and initiative by groups and individuals. There are certain general guidelines which can be drawn from the foregoing review of potential and impact. We look forward to more precise guidelines being developed through an 'Overview Survey of Tourism and Outdoor Recreation' which is now underway.

1. In expansion of the tourism industry, the economic and social interests of the residents of the Northwest Territories must receive first priority. This may seem so obvious that it does not need to be stated, but it is easy to lose sight of this priority under the pressure of outside investors and other interests.

2. A balance is required between development and preservation of the natural environment. Northerners are flexing their collective muscles and want to join in the mainstream of life in the 20th Century. They are not prepared to accept a role as quaint inhabitants of a gigantic northern preserve. Some of the natural environment will be changed as a result of the development which must take place, but the changes should be only those which are necessary and which will not destroy the attractions which are the basis of the tourism industry.

3. While there is massive potential for development of the tourism industry, the fragile nature of the social structure in the smaller communities, and of the natural environment, dictates the need for a somewhat cautious and controlled development process.

4. For the continued expansion and prosperity of the tourism industry, there is a need to maintain and enhance the 'character' of the northern travel experience. This may require a broad range of efforts including education of residents in the traditional cultures as well as in service functions; architecture in keeping with the environment; and even a degree of selectivity in visitor promotion through emphasis on 'explore' and 'adventure' themes.

5. Extension of the main tourist season to at least six months duration is required in order to improve the economics of investment in the tourism plant; to spread the increased volume of visitors more equitably throughout the year so as to cushion the impact on the populace; and to extend the employment season for residents.

Paper No. 34

Present National Parks and Future Needs in Canada

JOHN A. CARRUTHERS[1]

My objectives in presenting this paper are to give you some insight into the National Parks System, to relate the National Parks System to northern conservation, to outline the need for scientific support for new parks and to talk about the evolving conservation conscience in Canada.

There are present nineteen national parks in Canada, scattered mainly across the South. They range in size from St. Lawrence Islands (about 1 square mile) to Wood Buffalo (17, 300 square miles). The purposes of national parks in general include the conservation of resources and the protection of undisturbed conditions for research and for the enjoyment of all Canadians and visitors to Canada, in perpetuity. In many respects this is quite difficult to achieve and often requires some form of compromise between use and preservation.

We are striving to set aside additional areas to create a system of national parks which will be representative of the Canadian landscape. However, this is not easy. It is of interest to note that about 97% of the lands presently in the Canadian National Parks System were formerly federal lands which were dedicated in the past for national park uses on the basis of scenery, geography, wildlife preservation and easy availability. Times have changed. Land is much more difficult to acquire, expensive and much negotiation and co-operation is necessary with the provinces and territories.

Many of the vegetation zones or outstanding areas of the Canadian landscape are represented in the present Parks. These include the Boreal, Sub-alpine and Montane to mention a few. Some regions are well represented and others only in a token fashion. The most obvious gaps include the Prairie Grasslands, the Pacific Coast Forest and the Arctic Tundra of Canada's huge northland.

There has been much work and considerable progress in recent years towards filling these and other gaps in the System. You may have heard of our efforts in the Gaspé area of Quebec, Gros Morne in Newfoundland, Kouchibouquac in New Brunswick, and for a grassland park in Saskatchewan near Val Marie, a Pacific Coast Park in British Columbia, and a park on the tree line near Great Slave Lake in the Northwest Territories. This latter proposed park will include Arctic Tundra and Canadian Shield landscape. It will encompass about 2, 800 square miles and covers the ecotone between the Boreal Forest and the Barrens of the Northwest Territories. This will be a first step in the right direction with respect to conservation of Canada's Arctic Tundra through National Park designation. However, we do not plan to stop here.

In the North, together with the Great Slave Lake park proposal, we have identified two other potential parks—in the Kluane and the Nahanni areas. The possible establishment of these sites as National Parks could conceivably be supplemented by a chain of parks across the far north, along the shoreline of the Arctic Ocean and including some of the features of the Arctic and Queen Elizabeth Islands.

We plan to assess systematically the whole of Canada with a view to adding to the National Parks System typical representatives of significant physical and ecological areas of the tundra and other regions. Our first consideration is to locate quality areas, rather than just large areas *per se*. The need is great for assistance from those expert in the identification of significant sub-regions of the tundra affected by ecological, climatic and geological considerations. We think of the arid desert-like topography of much of Southampton Island, the lush tundra vegetation in the Bathurst Inlet area, the coast tundra plain and pingo areas near Tuktoyaktuk in the Northwest Territories, the glacier and fiord country of northeast Baffin Island, major wildlife areas such as the Thelon for caribou and musk ox, Victoria Island for char spawning lakes, and many more. I do not wish to

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imply here that the areas we are thinking of are for the sake of individual natural curiosities or particular species alone. My examples are but elements or components of the northern ecosystems which we wish to have represented in our Parks System. I agree completely with Dr. W. A. Fuller (1968) when he said, during the Canadian National Parks Conference in Calgary last year, 'Parks should not be chosen to preserve only natural curiosities, but they should be planned to include examples of every landscape zone in the country, each with its geological, biological, historical and scenic resources intact.'

The assessment of the Canadian landscape for National Park potential is a large task and it can only be accomplished by using every existing relevant fact and the experience of every organization working in the field. The establishment of contacts and good communication is the key to accelerating our program. Besides myself, another contact man in our organization is Mr. Don B. Coombs, ARDA Co-ordinator, Recreation Sector, Canadian Land Inventory, 161 Laurier Avenue, West, Ottawa (our I.B.P. contact man). Mr. Coombs and I will be looking for information on the location and quality of significant ecological communities in the Arctic and elsewhere.

It is here, in the Canadian North, that we can use the knowledge, experience and support of scientists such as yourselves to provide us with the ammunition needed, not only to defend our choice of areas, but to help us select these areas in the first place. Each area will require an examination of the case for preserving the ecology and the case for exploiting the resources. This will help to minimize resource use conflicts and thus hasten progress in expanding the Parks System. When decisions regarding use of an area have to be made, knowledge of the natural resource potentials and the expressions of support for the various uses will be important factors in deciding the outcome, be it in favour of a National Park or some other resource use.

We know that many of these northern areas are coming under increasing pressures. If we are to get northern regions represented in our System we must act now. Huge commercial forces, as exemplified by the recent multi-million dollar developments for oil in Alaska and the successful pursuit of the Northwest Passage, underline the urgency and point to potential conflicts and possible hazards to the environment. However, research into the natural resources of the Tundra Region has only barely begun. Our mutual efforts must be accelerated if we are to ensure that there is a firm base for sound land use planning and resource management which includes identification and dedication of new national park lands.

Some of you may be wondering what controls are exercised over land use in a National Park and what happens to a piece of land once it is brought into the System. Briefly, following a thorough examination of a park area and many other aspects, a provisional master plan is prepared for that park. This includes a land use plan based on a five class system now being applied to the existing and new national parks. The present national parks contain developments that we have to live with and the zoning has had to take this into account. In new parks the basis from the start is an overall land use plan (under the five class system) based on the purposes of the parks and the parks' resources. The development of visitor services and other intensive use facilities is limited to Class V, Intensive Use Areas. Highway construction, serviced campgrounds and outdoor activity areas are located in Class IV, the General Outdoor Recreation Areas. The concept of the 'wilderness threshold' best describes areas in Class III, Natural Environment Areas. This Class also acts as a 'land bank' and provides a backdrop for many park facilities. The distinguishing feature of Class II, Wilderness Recreation Areas, is the controlled utilization of the landscape by man in close contact with nature. Only trails penetrate these areas. The Special Areas, Class I, contain special features of high cultural or natural value requiring protection or preservation. Access is controlled in keeping with the objectives of the area. I wish to stress, however, that not all of these classes need be represented in a park master plan. In the northern areas it is conceivable that only Classes I, II and III may apply. This would give the maximum protection of the natural landscape yet provide for appropriate visitor use and scientific research.

We, in the National Parks Service, do not feel that our form of protection is the only form which can be used to meet environmental protection objectives. To varying degrees, the Provincial reserves and parks systems, along with Territorial game and bird sanctuaries and preserves, also result directly or indirectly in preservation of some or all of the components of the ecosystems contained in them. An example of a Provincial area which comes to mind is the newly established 7, 000 square mile Polar Bear Provincial Park in Ontario. It encompasses part of the Arctic Tundra of the Hudson Bay—James Bay region. Some of the most southern polar bear habitat is preserved within it. Classed as a Primitive Park, the area is assured of a good deal of protection. Examples of large Territorial areas are the Migratory Bird Sanctuaries such as Queen Maud Gulf (24, 240 square miles) for the protection of Ross and Lesser Snow Geese and the Dewey Soper Sanctuary (3, 300 square miles) on Baffin Island for Blue and Lesser Snow Geese. You may be aware that such sanctuaries were established under the Migratory Birds Convention Act, the regulations for which provide some measure of control over disturbance of the natural environment where possible molestation of habitat is a consideration.

People have a variety of reasons for wishing to preserve areas of Canada's North. Some seek to protect the wildlife of the Arctic Barrens for the sake of the wildlife species themselves or for the sake of the humans who ultimately depend on them for survival. Others seek to save areas of our vast north in a natural wilderness state, for they feel that some of this wild, rugged, last frontier must be retained for them to visit, or to just know that it exists. Some wish northern ecosystems preserved to protect floral species for research and protection of the biotic base for possible future world food production. These are just some of the reasons for promoting northern conservation and an ethical approach to land use, but they are all valid reasons. We in National Parks wish to expand our System in Canada's North for such reasons as these and feel that we have a significant role to play in the conservation of the tundra.

A growing interest in northern conservation was brought home to us when we held public meetings this year in Yellowknife in connection with the establishment of a National Park on Great Slave Lake. We received indications of strong support from across the entire Nation. Letters of support were even received from the U.S.A. and from Japan. I am pleased to be able to say that it is thus apparent that a conservation conscience is developing here in Canada. We realize that only as such a conscience builds will we be able to pursue our dreams of giving additional northern areas National Park status. In the National Parks Service we are working to stimulate this public awareness and concern through our interpretive programs and through our public hearing programs. The former are already well on their way and the latter are developing in connection with out National Park provisional master plans. We anticipate that this public participation trend will expand to include more public hearings relating to our plans for new National Parks.

In concluding, I can say that the future looks promising for tundra conservation from a National Parks' point of view. We have done much in recent years towards the establishment of new parks and in directing our efforts towards developing a National Parks System which is more truly representative of the Canadian landscape. However, public and scientific support must continue to grow, to enable us to spend more time and money in the selection and establishment of new northern parks.

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Paper No. 35

A Conservation Regime for the North—What Have the Lawyers to Offer?

A. R. THOMPSON[1]

As I begin to write this paper, I sit sun-drenched on the sands of Kitsilano Beach, the Vancouver city-centre colour-etched across the bay. Mountains landscape this urban skyline. In the foreground sailboats decorate the bay, and its waters are slashed by the wash of power-boats. Children play in the sand. For a brief moment, in this setting of harmony between man and his environment, I have a silent remembrance for those men and women, whoever they were, who conceived and nurtured this concordance of city and sea—this 20 miles of beaches and parklands encircling the heartland of the city.

This fragment of feeling forms a central theme for conservationists, and it is possibly the only theme they hold in common—an experience of escape from urbanization, of peace after turmoil, and of nostalgia for a gentler way of life imagined to have prevailed when man was more attuned to his environment.

For in other respects the conservationists exhibit basic ideological conflicts and their language reveals semantic chasms. One could not attend to the 20th Alaska Science Conference in Fairbanks without sensing underlying conflicts of ideas and goals. In fact no sensing was required, for the conflict erupted at times into explicit confrontation, with proponents of oil development denounced for their predatory policies and scientists called 'stupid' for their suggestions as to conservation practices for the trans-Alaska oil pipeline.

Lawyers whose job is to formulate laws and regulations must be sensitive to these ideological and semantic 'hang-ups', for the law-making process is essentially one of seeking a consensus of those many viewpoints that are brought to bear on the formulation of policy under a parliamentary form of government. An examination of the extremes of conservation sentiment should reveal these 'hang-ups'. At one extreme, as I see it, is the development ethic, with the norm being as rapid exploitation of resources as possible for the social benefit of mankind, with conservation playing a cautionary role; at the other extreme is the preservation ethic, presuming in favour of the natural order of things and viewing any development with skepticism.

In the North American context, development of resources is usually an enterprise of private capital. The development ethic becomes more explicit and may be stated as follows:

> Any enterprise that an individual or corporation initiates and prosecutes for profit is presumed to be in the best interests of society. Society may impose restrictions on the conduct of the enterprise and may even prohibit it, but the onus is on those who advocate restrictions to justify them and the restrictions won't be justifiable if they would render the enterprise unprofitable unless serious matters of public health and welfare are at stake.

With this basic ideology, the businessman views conservation restrictions as desirable so long as the enterprise remains viable after the cost of the restrictions is absorbed. For example, conservation conditions for an oil pipeline will be accepted by the businessman—and even advocated by him—so long as they do not prevent the project or make it impractical, and so long as the cost (and delay can be a major cost factor) does not place in jeopardy a proper return on invested capital together with compensation for the risks involved in the enterprise. Naturally the businessman leans against such restrictions, for any additional cost factor in an enterprise is undesirable, not because the businessman is seeking unconscionable profits, but because cost factors usually entail uncertainties (e.g. increases in pollution control charges; unexpected cost side-effects of a program to enable caribou to migrate across surface pipelines), and it is an elementary business axiom to minimize risks.

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This same businessman may be president of the local fish and game association, a member of the Alpine Club, and a conscientious advocate of 'conservation'. If he is a vice-president of Humble Oil and Refining Co., he may pronounce that the oil industry 'will continue to make every effort to protect the life and beauty of the environment.'[1]

Many scientists—biologists, zoologists, ecologists—exhibit symptoms of the other extreme. The scientist's life work may be to research and describe an Arctic biotic system. I picture him in his remote research station in the Brooks Range or on the Mackenzie River coming to terms with his wilderness and viewing man as the intruder. It's not surprising that he should place a high value on the natural order of things and demand that the unique Arctic environment be preserved. At least he will plead passionately that no development should take place until the short and long-range environmental effects can be predicted, and unless the development benefits and the environmental detriments have been weighed and a healthy balance shown in favour of the former.

In short, the ideological spectrum of conservationists shifts from an ethic of development to an ethic of preservation, and the semantics of conservation range equally as far. Hence, it can be explained why 'conservation' of the north slope in Alaska means a moratorium on oil development to one conservationist[2] and tidy housekeeping of the development to another.

In the past the development ethic has obviously carried the day. But the ecologists are mounting a crescendo of warnings about environmental hazards and evidence is mounting that mankind must take these warnings seriously. What, in these circumstances, can be expected of policy scientists such as economists and lawyers?

The economists have done the most homework and their discipline is beginning to produce the theoretical framework for the assessment of the costs of environmental deterioration. It should be remembered that his usual task is to provide conceptual tools for decision-making in business and government and therefore his view of conservation is essentially development-oriented. He may define 'conservation' as 'maximizing social benefits over time by proper distribution of resource use over time'.[3] This definition takes development for granted, but would ration use to achieve maximization of present and future benefits to mankind. The concern for future benefits hasn't been taken too seriously, however, for, as one economist has said, 'the concept of conservation as a policy of shifting the use of non-renewable resources toward the future (one of conservation's valid meanings) appears to have no part in current discussion'. But the economist's measure of social benefits is becoming a broader one than the businessman's litmus paper of profit and loss statements. The economist is now trying to introduce broad environmental considerations such as health and recreation values into his cost-benefit studies. I quote two economists, Tussing and Erickson:

> Great progress has been made in the last few years in developing a conceptual framework in which to measure the economic value of recreation, scenery, open space, clean air and the like; and there have been heroic attempts to assign actual dollar values to certain of these goods within limited assumptions. It is unlikely, however, that such methodologies, let alone the 'shadow prices' they develop, will achieve general concensus in the immediate future. Except for the most narrowly commercial aspects of these goods ('tourism', the cost of water treatment, etc.), formal cost-benefit analysis is unlikely to play a central part in the decision-making process for resolving these conflicts.[5]

Despite this pessimism, Dr. Tussing told the U.S. Department of the Interior Hearing on the Trans-Alaska Pipeline System last August that he thought 'a tentative but workable set of criteria for assessing the cost of environmental damage could be drawn up by a competent team of natural scientists, engineers, appraisers and economists within perhaps two months on the basis of available information'.

Like the economist's the lawyer's conservation ideology is likely to be grounded in the development ethic, for the clients from whom he receives his instructions are more likely to be business enterprises than governments, and even the government client is likely to be development-minded. Therefore, it should be expected that the laws and regulations governing natural resources will be development laws with conservation provisions appearing more as afterthought and more as health and safety measures for people than

[1] See page 307 for this and subsequent references.

as comprehensive schemes for protection of the environment. So far as I am aware, the lawyers have been slower than the economists to appreciate the broader range of environmental concerns, and they have yet to turn their minds to conceptual studies of systems governing the exploitation of resources. The lawyers cannot excuse their failure in this respect by saying that their discipline has no contribution to make. It is their job to study legislative incentives to rational development or rash exploitation of resources, systems of sanctions and penalties available to control conservation malpractices, and administrative and judicial techniques conducive to good resource management. This conservation methodology is as important a research area for lawyers as is cost-benefit methodology for economists, for too often it is the missing link in the process of transforming scientific research and engineering skills into practical applications in the field.

Now, I will describe the conservation laws and regulations that apply in the tundra regions of Alaska and northern Canada, and I will invite you to conclude whether I have been fair in labelling them as mainly afterthoughts with little consideration given to overall environmental factors.

Lawyers look for two sources of authority and responsibility when they study land use. The first is the owner of the land. The second is the state. In regions like Alaska and northern Canada, the state is also the landowner, but division of responsibility may nevertheless occur if the country is a federation and if ownership and authority to regulate land use do not coincide in one government but are divided between the federal government and a state government. Such is the case in Alaska where the State of Alaska has political authority to regulate land use but land ownership, with minor but important exceptions, is vested in the federal government.[6]

While regulatory capability in the tundra region of Alaska will remain bifurcated between state and federal governments[7], authority and responsibility in northern Canada is reposed solely with the federal government at Ottawa, which is both landowner and legislator in the Yukon and Northwest Territories. However, divided responsibility does not necessarily end with coincidence of ownership and political control in one government, for governments as large as the federal governments in Ottawa and Washington spawn their own divided bureaucracies, with inter-agency rivalries often standing in the way of unified policies and actions.

Oil development poses the present threat to the tundra in Alaska and northern Canada and therefore laws regulating this development will first be considered.

As landowner, the United States has enacted laws and regulations governing exploration and leasing on the federal public lands, including those in Alaska. Since these lands cover more than 90% of the land surface of Alaska at the present time, these United States laws and regulations are of prime importance. Subpart 3107 of Title 43 of the Code of Federal Regulations authorizes exploration for oil and gas. It provides for the posting of a $5, 000 bond for each project conditioned on 'full and faithful compliance with all of the terms and conditions of the regulations in this subpart... ',but none of these regulations can be identified as conservation-slanted except an elliptical reference to 'additional measures' taken to 'rehabilitate the land'. The $5, 000 bond can be escalated into a $ 25, 000 bond for the entire state of a $ 50, 000 bond for the whole of the United States.

The Mineral Leasing Act, 1920 authorizes oil and gas leasing of the federal public lands. Part 211 of Title 30 of the Code of Federal Regulations prescribes the oil and gas operating procedures. Regulation ss. 221. 32 provides the only procedure identifiable as a conservation measure in the sense of environmental protection. It stipulates that:

> ss. 221. 32 *Pollution and surface damage.*
> The lessee shall not pollute streams or damage the surface or pollute the underground water of the leased or other land. If useless liquid products of wells cannot be treated or destroyed of if a volume of such products is too great for disposal by usual methods without damage, the supervisor must be consulted and the useless liquids disposed of by some method approved by him.

So much for the federal regulations governing exploration and leasing. The State of Alaska has a regulatory power, too, and operators on the federal lands, as well as operators on state lands, must comply with state conservation laws and regulations. The Alaska oil and gas conservation statute[8] is typical of such statutes in North America. The preoccupation is with conservation of the petroleum resources. Therefore 'waste' is prohibited[9], and waste is defined in terms of inefficient petroleum reservoir engineering, inefficient above-ground storage of oil and unnecessary flaring of gas or escape of oil. Conservation measures in a broader sense of protection of the environment are included only incidentally. Thus, the state oil and gas conservation regulations provide that:

> 2062. Fire hazard.
>
> Any rubbish or debris that might constitute a fire hazard shall be removed to a distance of at least 100 feet from the well, all tanks and separators. All waste oil shall be burned or disposed of in a manner to avert creating a fire hazard.
>
> 2108. Location clean-up.
>
> The operator shall clean up the location and level the pits within one year of the plugging, unless an extension of time is granted by the Committee. All loose debris shall be buried or burned and the location left in a clean and generally level condition. These requirements shall be limited to onshore operations.
>
> 2155. Earthen reservoirs.
>
> Oil or oil field waste shall not be stored or retained in earthen pits or open receptacles except on permission of the Committee.
>
> 2161. Disposal of brine and other wastes.
>
> Salt water shall be disposed of, with the permission of the Committe, in any manner which will not contaminate fresh water sources or endanger other natural resources.

So much for state regulations. It is apparent that only obvious hazards to the environment such as spillage of oil or salt water or the escape of fire were in the minds of the legislators when these federal and state laws and regulations were enacted. That better prospects are in sight is evidenced by a proposed set of exploration regulations under study by the State of Alaska. The proposal is included as Appendix A to this paper.

There are two cases in Alaska where the regulatory scheme governing oil operations has been designed especially for protection of the environment. In each case, the scheme applies to wildlife reserves. In the first case, the discovery of oil in the Kenai Peninsula of southern Alaska threatened the forests with the ravages of uncontrolled running of seismic lines. Therefore, the federal Bureau of Sport Fisheries and Wildlife promulgated a set of *Geophysical Operation Procedures* to protect the federal lands included in the the Kenai National Moose Range. The following sample provisions will indicate the particularity of these procedures:

> Geophysical operations using tracked or large-wheeled vehicles may be conducted from December 1 through March 31 provided snow and ice cover are sufficient to protect wildlife resources.
>
> Scarring of ground and removal of other vegetative cover is prohibited.
>
> Moss and grass removal is not permitted in open muskeg.
>
> Streams may be crossed only at approved sites.

The procedures are set forth in full in Appendix B to this paper.

The second case covers oil and gas *leasing* in Alaska wildlife refuges. The approach is to make the lease granted under the *Mineral Leasing Act, 1920* subject to a set of special stipulations designed to protect the environment. A quick reading of Appendix C, where these stipulations are set out in full, will reveal them to provide a comprehensive regulatory scheme dealing with erosion, pollution, fire precautions, mobile equipment, drilling operations and surface restoration. The stipulations are given the sanction of being made conditions of the lease so that failure to comply will be grounds for cancellation of the lease. Additional bonding may also be required to pay for damages to wildlife habitat or to wildlife improvements.

In both cases the noticeable features are that the lands in question had prior designations as wildlife sanctuaries and there existed a specific agency of government charged with their care and staffed to provide supervision.

So far as northern Canada is concerned, the simple fact is that there are no laws or regulations in either The Yukon Territory or the Northwest Territories dealing in a general way with protection of the environment. The Canada Oil and Gas Drilling Production Regulations[11] provide, like the Alaska oil conservation laws, for such obvious measures as restoration of the surface after abandonment of a well[12], disposal of salt water[13] and safe storage of drilling fluids and wastes.[14] *The Yukon Mining Safety Ordinance*[15] provides in s. 18 that:

> 18. The owner of a mine shall dispose of arsenic sludge or any other by-products of his mine that are dangerous to people, domestic animals, wild animals, fish or property in such a manner that they will not cause injury to any person, animal, fish or property.

The only other authority to which a conservation officer could appeal in the Yukon Territory to correct an abuse of the environment by a mine operator would be a term in the mining agreement made between Canada and the operator such as a provision that the operator will

> '(b) construct and operate a crushing and screening plant and a concentrator to produce lead and zinc concentrates, and *dispose of its mill tailings in a good and minerlike fashion,* satisfactory to the Minister' (italics supplied)[16]

During the last session of Parliament, a new *Oil and Gas Production and Conservation Act* was introduced and given third reading in the Senate[17]. The Act will apply to all oil and gas operations in the Yukon Territory and the Northwest Territories. Again, it is a typical oil and gas conservation statute in the development ethic, its purposes being to encourage efficient producing practices without unnecessary waste. The only reference to environmental protection is s. 12 (q) which authorizes the making of regulations.

> (q) prescribing the measures necessary to prevent pollution of air, land or water as a result of the exploration and drilling for or the production, storage, transportation, distribution, measurement, processing or handling of any oil or gas or any substance obtained from or associated with oil or gas

When it was called to the attention of the Department of Indian Affairs and Northern Development, which is responsible for the Bill, that s. 12 (q) failed to deal with surface damages other than pollution, and contained no provision for surface restoration, the department's response was that these measures would be better dealt with in a comprehensive land use code which would apply to logging and mining as well as to oil and gas operations.

Such a code has been promised for the Territories and should not be delayed. Already *ad hoc* arrangements have been necessary to guard against damage in the ecologically-sensitive region of the Old Crow Flats in the Yukon Territory where an extensive oil exploration-program is underway.[18] It is characteristic of the traditionally-accepted priorities that the legislators should have turned their attention first to the oil leasing regulations[19], then to oil and gas conservation-laws and only as a last priority to laws protecting the environment, and these laws have yet to appear.

So far attention has been focussed on the laws and regulations governing operating procedures of permittees and lessees who are carrying out geophysical or drilling and producing operations, because such operations are obviously the source of damage to the environment. But it seems to me that the formulation of a comprehensive and effective regime for protection of the environment must start with evaluation of basic permit and leasing laws. In both Alaska and northern Canada mining and oil and gas operations begin from some form of land disposition by the state. The state's system of disposition, because it initiates the whole process, can either be the stimulus to rash and uncontrolled exploitation of a resource or the incentive to careful planning and husbandry within a total resource concept. It is easy to demonstrate that the oil leasing laws in Alaska have stimulated an uncontrollable rush of exploration activity. The reason is that the state's desire to maximize revenues forced it to offer for sale as much prospective acreage as possible at the time when oil industry interest was at a peak, and such offering forced the industry to rush forward with as much exploration work as possible for the purpose of evaluating acreage and making informed bids at the state's sale. Other factors contributed to this stampede. The high value placed on competitiveness in the economy in the United States is reflected in leasing laws that limit leases to small 2560-acre parcels of land and restrict total lease holdings so that there will be a multitude of entrepreneurs coming forward with exploration programs.

Canada's oil leasing laws are also boom-oriented, though there are features such as larger holdings and longer duration of permits and leases that might make a Prudhoe Bay-type discovery in the Mackenzie delta or the Arctic Islands a little less of an exploration scramble. No matter how much oil companies need to keep adding to their oil reserves, and however much underdeveloped regions like Alaska and northern Canada need resource revenues, there must be folly in systems that precipitate headlong assaults over thousands of miles of tundra in the search for scattered petroleum reservoirs. When one also considers that there is no present need for the oil, that already Prudhoe Bay is causing uneasiness in oil markets and that the effects of rushing into production may well be exacerbated hostility between New England consumers and Texan producers, increased alienation of the western provinces of Canada from the East, further humiliation of the oil export-dependent countries of the Middle East, Africa and South America, as well as environmental degradation of vast portions of the Arctic, it is difficult to imagine any long term interest that would not be better served by a slower more considered pace of development.

My last remarks relate to enforcement of conservation regimes. Lawyers look for internal and external sanctions for curbing human conduct. Internal sanctions are the moral authority of the law or regulation itself and built-in incentives that win compliance with the law or regulation as a matter of self-interest. External sanctions are provided by enforcers and penalties. Obviously, internal sanctions are preferable. But laws that increase the burden of exploring and producing under Arctic winter conditions in the name of conservation won't be seen by all to have high moral purpose, and economic incentives to good conservation practices cannot always be devised. Therefore, external enforcement is needed as well and, despite the objections of businessmen, it is necessary to spell out offences, stipulate penalties and deploy enforcement officers. However, the emphasis should be on internal sanctions.

Companies do respond to the authority of the law in a moral way. In fact, companies often pursue policies that result in performance standards higher than those required by law. In my view the two key factors to establishing the moral authority of a conservation regime are public demand for good conservation practices and strong government action. Conservationists can be counted on to continue to sound the clarion for environmental restraints. It is the government role that concerns me most. How can the operations manager of an oil company justify extra operating costs to management in the name of conservation measures if the record of the government, as measured by inadequate staffing and budget, exhibits indifferences to conservation goals?

The government role is also the key to good conservation laws and to effective policing of those laws. It is no coincidence that adequate conservation laws are to be found in Alaska only in the wildlife reserves where strong federal and state agencies have an established responsibility to provide good environmental care. In the Province of Alberta, strong agencies of government have been developed to deal with the oil industry, and they have combined their experience to provide a comprehensive regime for protection of the province's forested lands.[20] This cooperation also permits specialized response to extraordinary environmental hazards that arise from time to time. For example, the regulations set out as Appendix D were passed to deal with the danger to wild fowl created by the commencement of oil operations in the duck breeding grounds of Zama Lake in northern Alberta. The provision that 'if it appears that oil will pollute the lake water before the flow of oil can be stopped, depending on the circumstances the Board may require that the well shall be set on fire immediately' exhibits a confidence on the part of the administering agency, the Oil and Gas Conservation Board, that its field engineers and conservation officers can assess a situation expertly, communicate an opinion rapidly and carry out instructions on the spot.

If I seem to have labored this need for strong government agencies, it is because I believe that good conservation laws and regulations are, by themselves, not enough, and because I am apprehensive that the Department of Indian Affairs and Northern Development will not be able to back-up its proposed new Land-Use Regulations by an adequate level of administration and enforcement. Forestry and wildlife officers, tundra specialists and oil conservation engineers must be hired now and given generous budgets to undertake crash experimental programs, for, as matters now stand, a major oil discovery on the Yukon plateau or in the Mackenzie delta will not mark time so that conservation technology and government can catch up. The oil industry has shown on the north slope and by the Manhattan project how it can mobilize resources in crash programs to meet new technological demands. If the public interest in the north's resources is to be husbanded half as well as are the private interests, there should be emergency action by the government as well. The new Land-Use Regulations and the new pollution control regulations are to be commended, but they will be mere window-dressing without staffing and budget to back them up!

May I conclude this paper by advocating:

1. Conservationists should insist upon and make good use of the opportunity to contribute to the new Land-Use Regulations to be proposed by the Department of Indian Affairs and Northern Development. Because these new procedures will have legal form merely as regulations, they will *not* be scrutinized in Parliament as a bill before Parliament would be. Maybe some form of public hearing should be demanded such as is presently being conducted by the U.S. Department of the Interior respecting the stipulations which will govern the construction of the Trans-Alaska Pipeline System.

2. Conservationists should also participate in the review which the Department of Indian Affairs and Northern Development has said it has underway respecting the Canada Oil and Gas Land Regulations governing oil and gas leasing in the Yukon and Northwest Territories. This review will no doubt look into incentives and efficiencies which can spur development, and oil industry voices will be heard, as they should be. But this review should also inquire into how the brakes can be applied if a major oil discovery precipitates an exploration stampede. Perhaps simulation techniques could be used to study the effects of such a discovery. The subject is a complex one, but nevertheless, in my opinion, the revision of these regulations should be brought out of the halls of the lobbyists and into the public forum once the proposed amendments are prepared by the Department.

3. Conservationists should urge the Government of Canada to back its proposed new regulations by *now* providing the administrative structure and the staffing that will be necessary for an effective regime. It is hard to fault the governments in Alaska for being overtaken by Prudhoe Bay owing to the unprecedented nature of the discovery in North America. But no such plea of 'hindsight' will be available to excuse inaction on the part of the Canadian Government. Nor can lack of money be an excuse. Any commercial corporation which owned assets of the present dollar value of the land and mineral rights in northern Canada could not possibly justify to shareholders a failure to provide funds for proper care and management. Practical methods of raising the required funds, if they cannot be made available from general revenues, might be taxation of mineral permit and lease holders or creation of a northern lands commission which would raise money by issuing debentures secured on the land and mineral resources.

In conclusion, the lawyers have no magic to offer. Good laws and regulations must be backed by good administration, just as they must be based on sound technology and science. If I do not seem to be adequately impressed by the Department's proposed new conservation regulations, it is because so much more than just good laws is needed. The oil industry's record of careful land use in western Canada is an outstanding one. But that has not been accomplished without the industry being a major focus of government policy and action, without a populace of farmers and ranchers ready to cry outrage at every false move, and without a proven technology in the use of agticultural and ranching land and a developing technology respecting the forested lands. In the tundra regions of the north there are few local voices and there is little technology. The development now taking place, and which at any moment can assume 'rush' proportions, has irreversible consequences. Is the Government of Canada ready to give top priority to northern conservation along with northern development ?

REFERENCES

(1) J. H. Galloway, as reported in the Fairbanks Daily New-Miner August 28, 1969.

(2) Dr. Robert Weeden.

(3) Lovejoy and Homan, *Economic Aspects of Oil Conservation Regulation,* p. 9, John Hopkins, 1967.

(4) *Ibid,* p. 16.

(5) Tussing & Erickson, *Mining and Public Policy in Alaska,* p. 15, Institute of Social, Economic Government Research, University of Alaska, 1969.

(6) The exceptions in the tundra region are the lands around Prudhoe Bay which were selected by the State pursuant to its entitlement under the Statehood Act of 1956. By virtue of this entitlement there is the likelihood that the State will ultimately select all of the sedimentary portions of the tundra lands for their petroleum potentials, save for the Naval Petroleum Reserve No. 4 and the Arctic Wildlife Range which have been permanently withdrawn for federal agency purposes.

(7) I have written at greater length about this subject in *Petroleum Land Policies-Alaska and Northern Canada,* Boreal Institute, University of Alberta, Occasional Paper #5, 1969.

(8) Title 31. Oil & Gas, Chapter 05, Conservation.

(9) Sec. 31.05.020.

(10) Sec. 31. 05. 170 (11).

(11) SOR/61-253, Lewis & Thompson, *Canadian Oil & Gas,* Fed. (4B), Div. D.

(12) Section 16.

(13) Section 32.

(14) Sections 31, 33.

(15) *Ordinances of The Yukon Territory,* Cap. 75.

(16) For example, see clause 3 (1) (b) of the Anvil Agreement of August 21, 1967.

(17) Bill S-29, 3rd reading on Mar. 20, 1969, see Senate Debates p. 1238

(18) These arrangements require the operator to give 30 days notice prior to commencing work so that the Canadian Wildlife Service can give their guidance to avoid unnecessary damage to the wildlife habitat.

(19) The leasing regulations for the Yukon Territory and the Northwest Territories are the *Canada Oil and Gas Land Regulations* of 1961, SOR/61-253, Lewis & Thompson, *Canadian Oil and Gas,* Fed. (4B),Div.D.

(20) These agencies are the Department of Lands and Forests, The Department of Mines and Minerals, and the Oil and Gas Conservation Board. The laws and regulations are the Geophysical Regulations, Alta. Reg. 425/59; the Oil and Gas Conservation Regulations, Alta. Reg. 183/69; The Right of Entry Arbitration Act, R.S.A. 1955, c. 290 and regulations thereunder, Alta. Reg. 418/62; License of Occupation Regulations, Alta. Reg. 201/58; Public Lands Pipe Line Regulations, Alta. Reg. 246/58; Pipe Line Fire Precaution Regulations, Alta. Reg. 225/62.

APPENDIX A

NOTICE TO THE MINERAL INDUSTRY

The Division of Lands is in the process of developing regulations governing exploration activities on state lands. It is the policy of the state to encourage the development of its natural resources under the multiple use concept consistent with the public interest. We believe it is necessary to regulate exploration activities to assure that a maximum of lands can be left open to mineral development under the multiple use concept. The basic purpose of the regulations will be to minimize adverse effects of exploration activities to other uses and thus minimize the need to limit exploration activities. Enclosed is a draft of regulations which we believe will accomplish this purpose. Your review and ideas before we submit the proposals for formal hearing and adoption procedures will be appreciated. We would be glad to meet with groups or individuals to explain and discuss our proposal.

TITLE II NATURAL RESOURCES January 17, 1969

Division I Lands

Chapter—Exploration

1. General Provisions and Definitions.

1.11 Purpose.

The purpose of these regulations is to establish procedures for conducting exploration activities on State of Alaska lands which will encourage exploration for leasable, salable and locatable minerals and at the same time minimize adverse effects such activities may have on the lands and their resources.

1.12 Applicability.

These regulations apply to all mineral exploration activities on Alaska State lands including operations on lands under prospecting sites, mining claims and mining leasehold locations under Parts 604, 605 and 606, of the Mining Rights Regulations, Title 11, Chapter 6. They do not apply to operations under state administered oil and gas leases, coal leases, coal prospecting permits, mining leases or offshore prospecting permits by the holder of the permit or lease or his authorized agent.

1.13 Lands Open to Exploration Activities

All state lands except those specifically closed to exploration activities are open for exploration. Exploration permits may be issued for closed lands at the discretion of the Director where not prevented by law and for units of the State Park System in accord with the State Park Regulations, Chapter 7, Division 1 of Title 11.

1.14 Authority.

The authority for these regulations is contained in AS 38.05.020(b) (1), AS 38.05.285 and As 38.05.350.

1.2 Definitions.

The following terms shall have the meaning indicated unless the context clearly requires a different meaning.

1.201 'Exploration' means any activity relating to the search for mineral deposits. It includes but is not limited to geophysical operations, construction of roads and trails, excavations and cross-country transit by motorized vehicle over state lands for purposes of finding or gathering information on mineral deposits.

1.202 'State lands' means lands owned or administered by the State of Alaska including lands which have been disposed of with the minerals reserved to the state under AS 38.05.125 and lands on which the state has obtained the mineral interest of the United States of America.

1.203 'Authorized officer' means any person designated by the Director to perform the duties required herein.

1.3 General Stipulations and Restrictions.

All exploration activities authorized by these regulations are subject to the following:

(1) Activities employing wheeled or tracked vehicles will be conducted in such a manner as to minimize surface damage.

(2) Trail widths will be kept to the minimum necessary or authorized by the director and may not exceed 20 feet. Surface may be cleared of timber, stumps and snags. Due care must be used to avoid scarring or removal of ground vegetative cover.

(3) Drainage systems shall not be blocked. Cuts or fills causing siltation or accumualtion of debris in streams shall be avoided and if they occur must be repaired to the satisfaction of the Director.

(4) All operations must be conducted so as not to change the character or cause pollution of streams, lakes, ponds, water-holes, seeps and marshes or damage to fish and wildlife resources.

(5) Surface damage which may induce soil movement and/or water pollution must be corrected to the satisfaction of the Director.

(6) Vegetation must not be disturbed within 300 feet of any waters designated in an exploration permit except at stream crossings.

(7) No explosives may be used within one-fourth mile of designated fishery waters.

(8) Trails and campsites must be kept clean. All garbage and foreign debris must be eliminated by removal, burning or burial.

(9) Existing roads and trails shall be used whenever possible.

(10) All survey monuments, witness corners, reference monuments and bearing trees must be protected against destruction, obliteration or damage. The operator must re-establish any damaged or obliterated markers in accordance with accepted survey practice of the Division of Lands.

(11) The operator shall make every reasonable effort to prevent, control or supress any fire in the operating area. Reports of uncontrolled fires must be immediately reported to the fire protecting agency.

(12) Fill all holes, pits and excavations except as necessary to verify discovery on prospecting sites, mining claims and leasehold locations.

(13) No entry may be made on land, the surface of which has been granted or leased by the State of Alaska or on land for which the state has received the reserved interest of the United States until good faith attempts have been made to agree on settlement for damages which may be caused by such entry. If agreement cannot be reached, operations may be commenced on the land only with the specific approval of the Director and after making adequate provision for full payment of any damages which the owner may suffer.

(14) No test hole on lands under mineral lease permit or claim to others will be allowed in excess of 1000 feet.

1.4 Exploration Permits

A permit is required for all explorations activities on state lands which requires any of the following:

(1) Clearing of surface area, including trails.

(2) Excavation or sluicing of surface material.

(3) Test drilling.

(4) Use of tracked or wheeled vehicles except along established trails or roads except such vehicles as may be designated as exceptions by the Director.

(5) Use of explosives.

(6) Cause the discharge of any material including soil into waters.

1.401 Application for Permit.

The application for permit must contain following information in sufficient detail to allow evaluation of the planned operations effect on the land.

(1) A detailed map showing the location of all activities for which a permit is required including trails, roads, clearing excavations, routes of vehicle travel, test holes, shot points, campsites and water sources desired.

(2) A description of the proposed operation including approximate depth of all test holes and excavations contemplated, type of equipment that will be used, kind and amount of drilling, mud or other chemical, plan for disposal of garbage and other refuse from the operation.

(3) Any other information that the Director may require. Applications must be submitted in triplicate and must be accompanied by a $20. 00 filing fee.

1.402 Term.

Permits will be granted for any term requested but not to exceed one year. The permit may be extended for any number of consecutive periods, each period not to exceed one year, upon showing of need. Any modifications in the original plan must be indicated. The Director may modify existing stipulations or require additional stipulation in the approval of the extension. Applications for extension must be accompanied by a $20. 00 filing fee.

1.403 Effective Date.

The effective date of the permit shall be the first day of the month following the date on which the permit was signed on behalf of Alaska; provided, however, upon request by the applicant, the permit may be dated the first day of the month in which the permit was signed on behalf of Alaska.

1. 404 Terms and Conditions.

Each permit issued is subject to the provisions of Section 1. 3 and any provision the Director determines is necessary to assure compliance with these regulations including:

(1) A bond in an amount determined to be reasonable and sufficient to protect the state's interests.

(2) A provision for cancellation of the permit upon violation of any terms of the permit.

1.5 Waiver of Conditions.

The Director may waive or alter the requirements of these regulations when he believes it is in the interest of the state and it is shown to his satisfaction that the requirement will cause unreasonable hardship on the permittee or will prevent adequate exploration.

1.6 Suspension and Cancellation.

Operations under these regulations may be suspended on order of the Director or his authorized officer for a reasonable time to determine if the conditions of the regulations or the permit is being complied with or upon violation of any of the provisions of the regulations or the permit. Any violation may result in termination of the permit or loss of the right to continue exploration.

1. 7 Inspection of Operation.

All operations under these regulations are subject to inspection by the Director or his authorized officer.

1.8 Penalty.

Any exploration on state lands done in violation of these regulations shall be considered waste, trespass or injury to state lands under AS 38. 05. 360.

APPENDIX B

GEOPHYSICAL OPERATION PROCEDURES

Kenai National Moose Range

This office is authorized under 43 CFR, Part 3120, Subpart 3120, Sec. 3120, 3-3 (January 1, 1966) to issue Special Use Permits for geophysical operations in the portion of the Kenai National Moose Range open to oil and gas leasing and subject to the following Special Conditions which are a part of the geophysical permit.

SPECIAL CONDITIONS

(1) As used herein:

(a) The term 'Wildlife Resource' and 'Wildlife Resources' includes all fish, animals and birds, and all vegetable matter including trees, plants, shrubs, grass, muskeg and marsh within, on, under or over the permit area; and all lands, waters and all beds of waters within the permit area and all appurtenances to lands and waters and beds of waters within the permit area, whether natural or constructed;

(b) The term 'authorized officer' means the Refuge Manager of the Bureau of Sport Fisheries and Wildlife and his superior officers in the Bureau of Sport Fisheries and WildUfe, U.S. Fish and Wildlife Service, including the Secretary of the Interior;

(c) The term 'permittee' means the person or concern who is the lessee or optionee of a Federal oil and gas lease within the permit area and who executes this permit. The term 'permittee' also includes a person or concern conducting geophysical operations under authority from the permittee and who has been given written permission from the contracting officer to operate for and in behalf of the permittee herein.

(d) The term 'permit area' means the area designated on the map attached hereto;

(e) The term 'geophysical operations' means exploration for petroleum and related hydrocarbons only by means of seismograph, gravity meter and magnetometer. It does not mean exploration by core hole or slim hole or by any other operations.

(2) The permittee hereby agrees that he shall:

(a) Comply with all the rules and regulations of the authorized officer and of the Secretary of the Interior;

(b) Prior to the beginning of operations under this permit, properly appoint and maintain at all times during the term of this permit a local agent employed by the permittee, upon whom may validly be served written orders or notices respecting all matters contained in this permit, and inform the authorized officer in writing of the name and address of such local agent;

(c) Conduct all authorized activities in a manner satisfactory to the authorized officer.

(d) Conduct all authorized activities with due regard for good wildlife resources management and avoid damage to all wildlife resources including damage to improvements, timber, crops, wildlife range and waters, wildlife cover, and the permittee will fill all sump holes, ditches and all other excavations and holes made by him and cover, remove or burn, to the satisfaction of the authorized officer, all debris, and restore the surface of the permit area to its former condition. The authorized officer shall have the right at all times to enter and inspect the premises, the installations and the operational activities of the permittee within the permit area;

(e) Take such steps as will be necessary to prevent damage to wildlife resources;

(f) Do all in his power to prevent and suppress forest, brush, or grass fires and fires to wildlife resources and to see to it that his employees, contractors, subcontractors and all employees of contractors and subcontractors do likewise;

(g) Maintain adequate equipment to prevent damage to wildlife resources;

(h) Conduct all operations in such manner that pollutants of any nature, including the intrusion of subsurface waters, are not introduced to the refuge lands;

(i) Fill and cover all holes, pits and excavations made by the permittee to the satisfaction of the authorized officer;

(j) Remove all structures and equipment and debris of any nature whatsoever prior to the termination of this permit;

(k) Comply with and see to it that his agents, employees, contractors and subcontractors and employees thereof comply with all Federal, State or Territorial laws relating to hunting, fishing and trapping;

(l) Prevent the erosion of the land, pollution of the water resources and damage to the watershed and do all things necessary to prevent or reduce to the fullest extent the scarring of the land;

(m) Agree to comply with any new requirements imposed by the Secretary of the Interior or the authorized officer on the conduct of operations under the terms of this permit in order to give complete protection to wildlife resources;

(n) Compliance with any new requirements, amendments or modifications of this permit by the authorized officer will be immediate.

(3) The permittee hereby agrees that he shall not:

(a) Construct roads or trails without first obtaining written approval of the authorized officer or construct any facility which might interfere with wildlife resources or drainage;

(b) Modify or change the character of streams, lakes, ponds, water holes, seeps, muskegs and marshes, except by advance approval in writing by the authorized officer, nor shall he in any way pollute streams, lakes, ponds, water holes, seeps, marshes or wildlife resources within the permit area;

(c) Conduct operations under this permit that might tend to damage any wildlife resource or interfere with wildlife concentrations;

(d) Use explosives in fish spawning or rearing areas, nesting areas, lambing grounds, or areas of wildlife concentrations or during periods of intense wildlife activity or at any time or in any manner that might damage any wildlife resources or use explosives or helicopters, airplanes or automotive vehicles in areas that might be periodically closed by the Refuge Manager;

(e) Use any water or water source within the permit area without advance approval in writing from the authorized officer;

(f) Use mobile equipment under such conditions and in such manner as will in the opinion of the authorized officer damage wildlife resources, cause scarring and erosion, or interfere with wildlife resources;

(g) Burn rubbish, trash or other inflammable materials or substances or use explosives in a manner or at a time when such burning or explosions would constitute a fire hazard. All burning throughout the fire season will be done in conformance with the Bureau of Land Management, U.S. Department of the Interior regulations and procedures;

(h) Cut timber or brush without first obtaining the written permission of the authorized officer.

(4) The permittee herein recognizes the right of the authorized officer to close certain areas within the permit area to geophysical activity from time to time because of wildlife nesting activities, concentrations of wildlife for feeding purposes, and for other reasons connected with hunting within the permit area and with the conservation of wildlife resources. The permittee herein further recognizes that the migratory nature of wildlife renders it impossible to delineate these closed areas in advance. Therefore, the permittee hereby agrees that he will not conduct geophysical activities within areas which may from time to time in the future be closed by the authorized officer, provided that notice of such closure is posted in a position open to public inspection in the authorized officer's office for the Kenai National Moose Range, and that the office of the permittee's authorized officer is notified thereof in advance.

(5) The permitee herein recognizes that the physical manner by which geophysical operations are conducted under this permit may be changed from time to time by the authorized officer. Therefore, the permitee hereby agrees that he will conduct all his geophysical operations in strict conformance with the regulations of the authorized officer. The regulations of the authorized officer are and will be posted at all times in a place open to public inspection in the authorized officer's office for the Kenai Moose Range.

(6) The bond which has been executed by the permittee and his surety to cover the permittee's performance of all the terms of this permit will not relieve the permittee from liability for damages over and above the total amount of the bond unless the surety shall make payment therefore, and the bond will not relieve the permittee from damages over and above the amount of the bond and will not relieve the permittee from the forfeiture and other penalty or damages provisions of this permit.

(7) The permittee agrees and recognizes that this permit does not alter, change, amend, relieve or eliminate the necessity for the permittee to fully comply with all other Federal, Territorial or State statutes and regulations applicable to the conduct of geophysical operations. The permittee herein further agrees that he will comply with Federal statutes or regulations pertaining to the obtaining of the consent of the mineral owner, mineral lease offeror, mineral lease holder or mineral lease optionee to the conduct of geophysical operation on lease or mineral acreage within the permit area.

(8) The permittee herein, recognizes that this permit will be immediately cancelled for violation of any of the terms of this permit. Cancellation will be effective upon notice thereof given to the office of the permittee's authorized officer.

Signature__________________________
(Permittee)

Date____________________ __________________________
(Title)

RULES AND REGULATIONS OF THE REFUGE MANAGER

1. Prior to submitting a formal geophysical proposal the permittee will meet with the Refuge Manager to discuss the proposal and details of the Special Conditions. Maps showing requested seismic lines will be presented at the discussion.

2. Following the meeting the permittee may submit five (5) copies of a formal geophysical proposal with 1: 63, 360 scale maps showing in detail the geophysical work planned. The formal proposal will include at least the following information:
   a. Items involving approval of locations will be shown on 1: 63, 360 maps.
   b. The exact routes of travel desired. It is the responsibility of the permittee to choose routes traversable with his equipment.

c. The total miles of line in the program.
d. The number of shot points.
e. The depth of shot holes.
f. The size and kind of charge.
g. The distance between shot points.
h. A diagram showing shot point patterns.
i. A diagram showing the number and pattern of geophones.
j. The number, kind and size of drills used.
k. Kind and amount of drilling mud and other chemicals required for the total program
l. When hydraulic vibrators or other non-explosive methods are to be used, the weight and other descriptions of the equipment must be included.
m. Water sources desired.
n. Kind of vehicles or aircraft, and number of each to be used.
o. Campsite locations desired.
p. Number and size of trailers and other equipment to be at the camp.
q. Sewage disposal plans for the camp.

3. Geophysical operations using airborne equipment may be conducted from December 1 through April 30.

4. Geophysical operations using tracked or large-wheeled vehicles may be conducted from December 1 through March 31 provided snow and ice cover are sufficient to protect wildlife resources.

5. Maximum trail width is fifteen (15) feet. Surface of ground may be cleared of timber, stumps and snags.
Scarring of ground and removal of other vegetative cover is prohibited. No topsoil will be removed in clearing right-of-way. No cuts and/or fills are authorized.

6. Trails will follow a meander course with a minimum of straightline cuts. Any necessary straight-line cut will be less than one-half (½) mile in length and will avoid hilltop crossings.

7. Drainage systems may not be blocked.

8. Moss and grass removal is not permitted in open muskeg.

9. Streams may be crossed only at approved sites.
Portable bridges or logs will be used on stream crossings where ice strength is questionable or stream banks may be disturbed.

10. Shot holes must be at least ¼ mile from any water body that may have fishery value.

11. Timber or brush will not be distrubed within 300 feet of any lake or stream, or within ¼ mile of any special designated waters, except for approved stream crossings.

12. A blind approach must be used at the intersection of a trail and the Moose Range boundary or any road or large stream.

13. In certain areas vehicle travel will be restricted to existing seismic trails.

14. Operations will cease during thawing weather to prevent damage to the ground.

15. Camps will be at locations approved by the Refuge Manager.

16. Shot holes will be promptly plugged using expanding parachute plugs.

17. Trails and campsites must be kept clean. All garbage and debris must be removed from the Moose Range.

18. A progress report must be submitted to the Refuge Manager twice weekly.

19. A bond in the amount of $10, 000 will be posted in favor of the Fish and Wildlife Service.

20. At the completion of the geophysical program all trails must be thickly strewn with trees for a distance of ½ mile from their intersection with the Moose Range boundary or any road or large stream.

FAILURE BY THE BUREAU TO ENFORCE ANY OF THE CONDITIONS OR REQUIREMENTS OF THE PERMIT DOES NOT CONSTITUTE A WAIVER BY THE BUREAU OF SUCH CONDITIONS OR REQUIREMENTS.

____________________________ ____________________________

Permittee Refuge Manager

Date____________________

APPENDIX C

STIPULATIONS IN LEASES ON WILDLIFE LANDS
ss. 3120. 3-3, TITLE 43, CFR

NOTE

Stipulations.

For inclusion in oil and gas leases entered into pursuant to this section relating to oil and gas leases in wildlife refuge, game range, and coordination lands.

Instructions.

(1) The following stipulations will be made a part of Interior Department lease forms. These stipulations will be made applicable as terms and conditions of performance by lessees under all oil and gas leases entered into under authority vested in the Secretary of the Interior over game range, coordination or Alaska Wildlife lands pursuant to the order of the Secretary of the Interior published in 23 F.R. 227, January 11, 1958.

(2) Should compliance with one or more of these terms and conditions be considered unduly burdensome and unnecessary to the protection of wildlife resources, the lessee may request waiver thereof by letter addressed to the Secretary of the Interior setting forth in full the reasons why a waiver is considered necessary. The authority to grant such waivers shall be discretionary and may be exercised only by the Secretary or the Under Secretary of the Interior.

(3) The authorized officer shall (a) approve no plan of operation that contains provisions inconsistent with the stipulations hereinafter set forth, (b) waive no term or condition in a lease or (c) exercise no discretion vested in him unless he is satisfied the exercise of that discretion will not damage any wildlife resource.

(4) Drilling and production operations under the lease shall be under the direction of the Geological Survey.

Terms and conditions.

(1) as used herein:

(a) The term 'lessee' includes the lessee, heirs and assigns of the lessee and persons operating on behalf of the lessee;

(b) The term 'wildlife resources' includes fish and wildlife resources and concentrations, fish and wildlife management operations and range improvements and facilities;

(c) The term 'authorized officer' means the State Director of the Bureau of Land Management in the State in which the land is located, and, in Alaska, the Refuge Manager of the Bureau of Sport Fisheries and Wildlife;

(2) The lessee shall:

(a) Comply with all the rules and regulations of the Secretary of the Interior:

(b) Prior to the beginning of operations, appoint and maintain at all times during the term of the lease a local agent upon whom may be served written orders or notices respecting matters contained in these stipulations and inform the authorized officer in writing of the name and address of such agent. If a substitute agent is appointed, the lessee shall immediately inform the said representative;

(c) Conduct all authorized activities in a manner satisfactory to the authorized officer with due regard for good land management and avoid damage to improvements, timber, crops and wildlife cover, and fill all sump holes, ditches, and other excavations or cover all debris and, so far as reasonably possible, restore the surface of the leased lands to their former condition and, when required, bury all pipelines below plow depth. The authorized officer shall have the right to enter all the premises at any time to inspect both the installation and operational activities of the lessee;

(d) Take such steps as may be necessary to prevent damage to wildlife;

(e) Do all in his power to prevent and suppress forest, brush, or grass fires and require his employees, contractors, subcontractors and employees of contractors or subcontractors to do likewise;

(f) Install adequate blow-out prevention equipment;

(g) Construct ring dikes and sump pits to confine drilling mud and other pollutants and make safe disposition of salt water by use of injection wells or such other method as may be approved in the plan of operation;

(h) Cover flare pits in areas of wildlife concentration;

(i) Remove derricks, dikes, equipment and structures not required in producing operations within 60 days after the completion of drilling;

(j) Comply with and see to it that his agents and employees comply with all Federal, State or territorial laws relating to hunting, fishing and trapping;

(k) Commit the lease to any unit plan required in the interest of conservation of oil or gas resources or for the protection of wildlife;

(l) Prior to the conduct of geological, geophysical or core drilling operations, or construction of any facilities, or prior to operations to drill or produce, submit in triplicate for approval in writing by the authorized officer a plan of operation that will include detailed statements indicating the manner in which the lessee will comply with these stipulations together with a statement that the lessee agrees that compliance with these stipulations and with the approved plan of operations are conditions of performance under this lease and that failure to comply with these provisions (unless they are waived by the Secretary or the Under Secretary of the Interior) will be grounds for cancellation of the lease by the United States. Notwithstanding other provisions in these stipulations, the lessee shall include in any plan of operation specific provisions relating to: the time, place, depth and strength of seismographic shots, maps showing the location of his leases included in the plan, actual and proposed access roads, bunkhouses, proposed well locations, storage and utility facilities, water storage, pipelines and pumping stations, the type of safety equipment that will be employed; the methods to be used to assure the disposition of drilling mud, pollutants, and other debris; the location of facilities in relation to flood levels; and such other specific matters as the authorized officer may require. The plan of operation shall be kept current in all respects and all revisions and amendments submitted to the authorized officer for written approval;

(m) Do all things reasonably necessary to prevent or reduce to the fullest extent scarring and erosion of the land, pollution of the water resources and any damage to the watershed. Where construction, operation or maintenance of any of the facilities on or connected with this lease causes damage to the watershed or pollution of the water resource, the lessee agrees to repair such damage, including reseeding, and to take such corrective measures to prevent further pollution or damage to the watershed as are deemed necessary by the authorized officer;

(n) File the bond required by section 2a (4) of the lease before conducting any operations on the leasehold, and file any additional bond required by the authorized officer to pay for damages to wildlife habitat, including trees and shrubs, or wildlife improvements:

(o) Agree to respect and comply with any new requirements imposed by the Secretary of the Interior, or the authorized officer, on the operating program as operating experience proves necessary in order to give complete protection to wildlife populations and wildlife habitat on the areas leased.

(3) The lessee shall not:

(a) Construct roads, pipelines, utility lines and attendant facilities that are either unnecessary or which might interfere with wildlife habitat or resources or with drainage:

(b) Modify or change the character of streams, lakes, ponds, water holes, seeps and marshes, except by advance approval in writing by the authorized officer, nor shall he in any way pollute such streams, lakes, ponds, water holes, seeps or marshes;

(c) Conduct operations at such times as will interfere with wildlife concentrations;

(d) Conduct geological or geophysical explorations that might damage any wildlife resource and such operations shall be conducted only in accordance with advance approval in writing by the authorized officer as to the time, manner of travel and disturbances of surfaces and the facilities required for the protection of wildlife.

(e) Use explosives in fish spawning or rearing areas, nesting areas, lambing grounds or other areas of wildlife concentration during periods of intense activity or at any other time or in any manner that might damage any wildlife resources; the pattern size, and depth of seismographic shots shall be submitted to the authorized officer for advance approval in writing and, immediately following the detonation of any seismographic charge, the hole shall be filled or plugged and any surface damage repaired to the satisfaction of the authorized officer;

(f) Without advance approval in writing, use any water or water source controlled or developed by the United States;

(g) Use mobile equipment under such conditions as to permanently damage surface resources, cause scarring and erosion, or interfere with wildlife concentration;

(h) Conduct geological, or geophysical or core drilling operations, or construct roads, bunkhouses or any facilities, or drill or produce under a lease until the submittal and approval in writing of a plan of operation pursuant to section (2) (m) supra or deviate therefrom until any revisions or amendments of said plan have been approved in writing by the authorized officer.

(i) Burn rubbish, trash, or other inflammable materials or use explosives in a manner or at a time that would constitute a fire hazard.

APPENDIX D

INTERIM DIRECTIVE NO. ID 69-3 ZAMA LAKE-A-Z AREA

THE PROVINCE OF ALBERTA OIL AND GAS CONSERVATION BOARD

To all Operators:

The Zama Lake A-Z Area as shown on the attached map, is North America's largest and most important duck breeding ground and geese staging area. With the discovery of high pressure oil and gas reservoirs in this area, the Department of Lands and Forests became very concerned about the damage of air and particularly water pollution.

In order to accommodate the search for oil and gas in this area and to ensure the breeding ground and staging area would not be endangered, the Board in conjunction with the Department of Lands and Forests have drawn up the following special requirements for the drilling and subsequent production of wells in the area.

SPECIAL DRILLING REQUIREMENTS

1. Intermediate casing must be run to at least 3000 feet and cemented to at least 300 feet above the shoe or at least 300 feet above the top of the Slave Point Formation whichever is the shallower. This casing must be run before the well is drilled to more than 50 feet below the base of the Sulphur Point Formation.

2. Upon completion of the well the surface casing shall be provided with a vent containing a 2-inch valve. This valve shall remain closed except for periodic checks for pressure in the surface casing.

3. If a blowout occurs the Oil and Gas Conservation Board shall be notified immediately and if it appears that oil will pollute the lake water before the flow of oil can be stopped, depending on the circumstances the Board may require that the well shall be set on fire immediately.

4. All drilling fluids, shale, oil, salt water or other well effluents must be contained in steel tanks and trucked to dumping grounds approved by an officer of the Department of Lands and Forests. Lubricating oil from motors, pumps or drives must be gathered and not drained on to the ground.

5. All refuse shall be contained or burned. Oily or chemical refuse shall be stored in steel containers until disposed to the dumping grounds.

6. Suitable pits shall be constructed at the dumping grounds designated by the Department of Lands and Forests to contain all drilling fluids. Upon completion of drilling operations the pit shall be filled and the dumping ground restored to the satisfaction of an officer of the Department of Lands and Forests.

7. The wellsite area shall be solidly diked at least 30 inches in height to prevent accidental escape of fluids due to unforeseen circumstances.

8. If at any time conditions at a wellsite or dumping ground are considered a pollution hazard, an officer of the Department will have authority to suspend operations until such time as the situation is corrected, but if corrective measures involve the shutting down of any drilling or producing operations at the well, the matter shall be reported to an Oil and Gas Conservation Board representative who shall take the appropriate action with a view to the prevention of both pollution and hazard to the well.

9. At the completion of drilling or servicing operations, the surface on which the equipment was located shall be scraped to a sufficient depth (normally 4-8 inches) to ensure no contaminants are left on the site. All scrapings are to be hauled to the dumping grounds for disposal.

10. All wellsites and dumping grounds must be cleaned up to the satisfaction of an officer of the Department prior to March 31st in any year, unless extended by the Director of Lands having regards to weather conditions and terrain.

11. When drilling on ice the total area to be used for the drilling operation shall be covered with earth, gravel or sand preferred, to a depth of at least 4 inches to absorb any drilling fluids, chemicals or oil spilled during the drilling operation. A packed snow dike will be permitted.

12. No drilling operations shall be carried out between April 1st and July 1st of each year or such other period as may be prescribed by the Department of Lands and Forests.

SPECIAL PRODUCTION REQUIREMENTS

<u>Battery Area</u>

The surface elevation of the pad upon which a battery is to be built shall be at least 2 feet above high water level.

Storage Tanks

The storage tanks shall be surrounded by a suitable dike and the tanks shall be equipped with an automatic high liquid level shut off.

Tank Dikes

1. The dike capacity shall be equal to total oil storage capacity enclosed.

2. The dike walls shall be compacted when built.

3. There shall be no drain line through the dike.

4. The area within the dike shall be graded to one corner where a sump shall be constructed so that any oil spills can be readily pumped out.

Flare Pits

1. The flare pit shall have a minimum capacity sufficient to contain 24 hours production from all wells connected to the battery plus 600 barrels.

2. Unless suitable clay material is available for pit construction, the pit shall be lined with a suitable impermeable liner.

3. The excavation of the pit shall be kept to a minimum in order to avoid penetrating the water hole.

4. Any liquids in the flare pit shall be suitably disposed outside the A-Z area at least once per month.

Flare Stacks

Until gas conservation is required, the stock tank vapours and gas from the treaters and separators shall be gathered and burned through a vertical flare stack. The vertical stack shall be:

1. A minimum of 40' in height.

2. Equipped with
   (a) an automatic ignition device
   (b) a wind guard
   (c) a mist extractor, and
   (d) a liquid knockout.

3. Gas lines to the flare stack shall be equipped with a flash arrestor.

4. The flare stack shall be located outside the flare pit but within a diked area adjacent to the pit.

Treaters and Separators

1. Treaters and separators shall be equipped with automatic high level shut offs and shall be housed and heated.

2. Outlets from pressure relief valves and burst plates shall discharge to a pit with a 24 hour capacity.

General

1. The entire battery site including flare pits, pipe line pumps and truck loading facilities shall be enclosed within a 3 foot dike and 4 foot ditch along the inside of the dike.

2. All automatic controls shall be checked manually once per month.

3. All pumping wells must be equipped with pressure shutoffs set so that pumping will be stopped before there is danger of stuffing box failure.

4. The battery is to be checked at least once per day by the battery operator.

5. The battery must be serviced by an all-weather road.

6. There shall not be more than one battery per quadrant of a township.

7. Any accident resulting in the escape of oil or produced water must be reported to the local Forestry office immediately and immediate action taken to contain and collect the escaped liquids.

8. Flowlines shall be buried a minimum of 30 inches with markers placed along the flow-line right-of-way.

9. Location and method of construction of causeways shall be submitted to the Department of Lands and Forests for approval 7 days prior to construction.

10. No production operations shall be carried out during the period April 1st to July 1st of each year or such other period as may be prescribed by the Department of Lands and Forests.

ISSUED at the City of Calgary, Alberta, this 3rd Day of July, 1969.

OIL AND GAS CONSERVATION BOARD

A. F. Manyluk, Deputy Chairman

Paper No. 36

Conservation in Canada's North

J. K. NAYSMITH[1]

There probably has never been a period in our history when public interest in the subject of natural resources development has been more intense or directed than it is at the present time. With the advent in the North of intensive oil exploration, mining developments, experiments in transportation, and proposals for diverting waters, the Canadian's concept of his country has acquired a new dimension. Gratifying as this development may be from an economic growth standpoint, it brings to those responsible for administration and management of these resources, a growing awareness for what may be termed environmental disbenefits often inherent in such development. Today I would like to address the question of environmental quality in relation to resource development and to refer specifically to some measures we feel are necessary to minimize disturbance to the natural environment.

I think it is important here to draw a distinction between the concept of conservation and the question of maintaining the quality of the environment. I suggest the former denotes *'managed-use'* whereas inherent in the latter is the principle of *preservation.* Conservation in terms of nonrenewable resources implies reduction of waste in the extraction and conversion processes and when applied to renewable resources usually means manipulation of the resource-base in such a way as to increase productivity.

Although conservation of natural resources is a quantifiable concept, those natural resource problems dealing with environmental quality are usually more complex since they involve diseconomies which do not flow through the market place. Originally, the central issue of natural resources development was one of supply but, over a relatively long period, scientific and technological developments have tended to alleviate this concern. However, in comparatively recent years, disturbance of the environment resulting from resource use has received increased attention.

Initially, instances of pollution, erosion, and disfigured landscapes were of a local nature and resulted in correspondingly local reaction. Today, major developments over significantly larger areas have given rise to regional and national concern.

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An example of this phenomenon is Canada's Arctic and sub-Arctic area, generally defined by the political boundaries of the Yukon and Northwest Territories which, in turn, comprise forty per cent of Canada's land mass. Prior to 1964, relatively small progress was made in resource development north of the 60th parallel and based largely on the production of gold. The average number of mining claims recorded each year was less than 6, 000, representing an area of less than 50 square miles, and land held under oil and gas permits averaged approximately 86, 000 square miles per year. Since 1964, resource exploration has undergone remarkable expansion, and cutting of merchantable timber has been added as a third resource industry. A few figures will illustrate the extent of this growth. During the year 1968, the number of mineral claims recorded jumped to 52, 000, covering an area of almost 4, 000 square miles. This represents a 50-fold increase over the pre-1964 period. During the same year, land under lease for oil and gas exploration had skyrocketed to 500, 000 square miles, a 6-fold increase over 1964. Last winter, 8, 000 miles of seismic lines were cut and this may well increase to over 15, 000 miles during the coming winter.

Sound regulations are a prime requisite in such a situation if environmental quality is to be considered seriously. Equally important, however, is effective administration and enforcement of the regulations. The Canadian Department of Indian Affairs and Northern Development, through the Northern Economic Development Branch, has complete and direct responsibility for administration and management of all natural resources in the Yukon and Northwest Territories, with the sole exception of game. This organizational structure within one department, responsible to a single minister, effectively eliminates most of the confusion which can arise when several agencies with divided jurisdiction are involved in natural resource programs in the same region.

The Northern Economic Development Branch consists of three divisions, the Economic Staff Group, the Oil and Mineral Division, and the Water, Forests and Land Division. This Branch is responsible for programs and regulations, which, we hope, provide initially a favourable climate for resource exploration and development in the far North and ultimately for the conservation and orderly utilization of these same resources in the future. The Canadian Wildlife Service and the National and Historic Parks Branch, also agencies of the Department, enjoy international reputations in matters relating to conservation and advise and contribute to northern environmental management.

Associated with resource exploration activities, and particularly with widespread geophysical operations, is the danger of long-term and often needless damage to the ecological balance of a region. Many of us have seen, for example, where seismic exploration on permafrost areas has disturbed the active layer and resulted in thermal erosion. Geophysical exploration for minerals covers less total area than seismic exploration, but often the effects are more concentrated.

LAND-USE REGULATIONS

To deal with operations of this type, and others which disturb the land surface in a similar way, the Department proposes to implement 'Land-Use Regulations'. These regulations are designed to provide basic operating guidelines for those involved in the use of any public lands in the Yukon and Northwest Territories. The purpose of the regulations will be to provide the Department of Indian Affairs and Northern Development with a measure of control over the types and methods of northern exploration, development and, where necessary, reclamation operations, in order to reduce or minimize needless permanent damage to the land surface. At this point, a working draft of the regulations has been developed and the next step is to discuss this draft edition with representatives of conservation organizations and with industrial associations.

Canada's North covers approximately 1. 5 million square miles and, obviously, regulations pertinent to one area will be of no consequence in another. For this reason, we propose dividing the north into regulatory zones based on sensitivity to disturbance. For example, . the type of restriction applied to operations on Ellesmere Island, the west coast of Hudson Bay, and the Liard River watershed of the Yukon Territory will differ radically, to deal with variations in soil, vegetation and climate.

Thus, in addition to general regulations which will apply to every permittee, there will be a set of stipulations which will vary, depending on the zone in which the operation is to be conducted. The stipulations will be specific about the types of equipment which can be used, the methods and timing of operations. Within the various zones, there will be special areas such as wildlife sanctuaries and national parks where no operations may be conducted.

Companies will apply for a land-use permit, submit monthly and annual reports of their activities affecting the environment, and pay land-use fees at a standard rate per acre. This rate will vary from zone to zone in accordance with a fixed schedule. In addition, it is planned to include in the regulations, special provisions for land-use operations in relation to survey lines and monuments, highways and roads.

This very general outline does not, of course, describe the final package. Rather, these are the general principles we propose, which will undergo close scrutiny and refinement during our forthcoming discussions with conservationists and industry.

EXPERIMENTAL RESERACH BASIN PROGRAM

A second program, complementary to the Land-Use Regulations, is the experimental research basin program. In order to clearly identify and assess the environmental effects of current land-use practices and, where necessary, to devise and test alternative methods or control measures, the Department of Indian Affairs and Northern Development intends to establish a number of experimental research basins in the Yukon and Northwest Territories.

For this purpose, we define our experimental basin as a small sub-basin which is representative of a larger region and in which natural conditions are deliberately modified. By proper instrumentation and study techniques, the effects of the modifications on the natural environment are noted and assessed by reference to quantitative and qualitative changes produced on the water regime and other control factors within the basin. Although the central focus of the program is on land-use practices, the experimental basins will also provide valuable representative information on far northern hydrology. Ultimately the program will include many disciplines and involve specialists in pedology, ground water and river morphology, forest ecology, water chemistry, limnology, and river and lake ice. It is a prpgram of applied research, in which the land surface will be deliberately and carefully altered and the results scientifically measured over an extended period of time.

It is planned to locate one experimental basin in each of the four following regions: Lower Mackenzie River; Lower Liard River; Upper Liard River; and Dubawnt-Kazan Rivers watershed, southwest of Baker Lake.

These regions have been selected because of their current or anticipated level of resource exploration and development activity. The exact site of the experimental basin within a region depends upon the types of surface modification to be undertaken, which, in turn, is determined by practical land-use problems experienced by activities in the regions.

The entire program is expected to run over a prolonged period of perhaps ten years. For this reason, it was thought that water research committees of a number of Canadian Universities would be most appropriate institutions to undertake the experimental research basin program on behalf of the Department of Indian Affairs and Northern Development. In addition, it has been found that such insititutions have a good deal of available talent with competence in this very specialized field. The universities of Laval, Alberta, Saskatchewan and British Columbia were approached and are currently participating in the program.

Another area of concern in the north involves water pollution and includes both surface water in rivers, lakes and streams, and ocean pollution that could result from major oil spills or maritime disasters. Dealing first of all with prevention of pollution to surface water resources, the Department of Indian Affairs and Northern Development is currently drafting Northern Water Rights and Pollution Control Legislation for introduction into the forthcoming session of Parliament. The legislation is intended to accomplish on a regional basis what the proposed Canada Water Act does nationally.

NORTHERN WATER RIGHTS AND POLLUTION CONTROL LEGISLATION

The legislation has a fourfold purpose:

1. to provide for equitable distribution or sharing of surface water resources among those with legitimate and often conflicting claims to the use of a given water resource;
2. to ensure that disposition of water rights is done in a manner that is consistent with immediate and long-term regional and national interest;
3. to ensure that all water development works are designed and constructed to acceptable engineering standards; and
4. probably most important of all, to establish and maintain the principle that rights to use of water for beneficial purposes are dependent on users accepting the responsibility for maintaining the quality of the water, or restoring its quality after use, to acceptable standards before discharging the water back to the natural environment.

Administratively, the legislation means that anyone wishing to use water must acquire a water right licence to do so, a common requirement used in most water management programs in North America. The unique feature of our proposed legislation is that each water right licence will contain water pollution control conditions applicable to the water development works and to undertakings such as mines and sewage systems which are pertinent to the development. Should the licencee fail to meet these water quality standards, the Department has authority to suspend or cancel the water rights licence which means, of course, to suspend or cancel the ability of the licencee to operate his works or undertaking that is causing the pollution.

OFFSHORE POLLUTION

Finally, the Northern Economic Development Branch is working with other federal and provincial agencies and departments on the subject of offshore pollution.

The Canadian Government has a long standing Interdepartmental Committee on water which has established a Working Group for Contingency Planning with the specific responsibility of determining measures and making plans to prevent and combat disaster pollution in Canadian waters. The Department of Indian Affairs and Northern Development is represented on this group by an official from the Northern Economic Development Branch and from the Canadian Wildlife Service.

The activities of the working group embrace prevention and combatting of disaster pollution and determining liability and the compensation arrangements after the fact.

The working group is now engaged in drawing up a National Contingency Plan as a first priority. This plan will detail the organization framework for tackling a pollution diaster after it happens. It is expected that Canada will be appropriately divided into regions for purposes of combatting disaster pollution, each with an appointed On-Scene Commander. He will have the authority to mobilize and utilize all government resources to clean up the disaster area. Possibly, stockpiles of vital material, such as emulsifiers, will be held at strategic points, such as Resolute Bay, to be ready at hand should a disaster occur. A significant part of this program will be organizing and training staff and operations personnel needed to carry out the local plan.

With regard to preventive measures, there is already federal legislation that can be brought to bear. The Canada Shipping Act now gives the Minister of Transport authority for regulating and preventing pollution of Canadian waters by oil, chemicals, garbage, sewage, or any other matter. Also, when the Minister has reasonable cause to believe that the cargo or fuel of a vessel in distress in Canadian waters is polluting water or coastal property, he may have the vessel, its cargo or its fuel destroyed or removed.

Others Acts and Regulations relating to the oil and gas industry are applicable. The Oil and Gas Production and Conservation Act empowers the Federal Government to make Regulations respecting transportation of oil and gas obtained from the Yukon and Northwest Territories, in particular with regard to pipelines. This provision will be very significant should there ever by an inter-island pipeline in the Canadian Archipelago.

In addition, the Canada Oil and Gas Drilling and Production Regulations apply to all operations on Canada lands under the control and management of the Minister. Thus, the Regulations apply to Canada lands in the Yukon and Northwest Territories and Arctic Islands, as well as to the seabed of the continental shelf on the Arctic, Pacific and Atlantic margin of Canada, including Hudson Bay.

These Regulations provide measures to ensure safe and proper drilling, operating and abandonment of wells and, on-shore, for restoration of the surface when operations are complete. Under Section 31, the operator is required to dispose properly of waste and to prevent pollution, and should the operator at any time fail to take preventive and remedial measures, as directed by the Minister, the Minister is authorized to seize and take possession of the well and all equipment necessary, and to take over management and control of the well for such time as may be required to carry out remedial measures.

WILDLIFE

In the Yukon Territory and the Northwest Territories, the territorial administrations are responsible for their wildlife resources. The Canadian Wildlife Service, however, provides the research necessary for intelligent management of those resources. On one particular occasion, the Northern Economic Development Branch was able to implement a recommendation of the Canadian Wildlife Service which resulted in what we believe is a major innovation in forest fire protection.

In 1966, the Northern Economic Development Branch, at the request of the Canadian Wildlife Service, undertook a program of protecting from wild-fire that portion of the barren ground caribou range lying southeast of Great Slave Lake. This area, covering approximately 30, 000 square miles contains virtually no merchantable timber but is the winter feeding ground of the 160, 000 caribou known as the Beverly herd. The Caribou-Range Protection Unit of the Mackenzie Forest Service was established and consists of reconnaissance aircraft, water bombers and ground forces. Over the past four years it has fought and extinguished over 60 wild-fires in the caribou range.

It soon became apparent that suppression control could not be exercised with equal effectiveness over the entire area and the Wildlife Service was asked to divide the total range into priority areas based upon the observed location of the caribou herd over the past 10-year period. This was done and now a system of measuring the optimal degree of suppression based on the least-loss theory of fire control is being developed by the Canadian Wildlife Service and the Northern Economic Development Branch.

I believe that this program of protecting a forest area for reasons other than timber values is unique, at least in Canada. Because of its success, a similar program was implemented in 1969 in the reindeer range east of the Mackenzie Dalta.

SUMMARY

I have attempted to outline the Canadian government's, and in particular the Department of Northern Development's programs, of conservation in the North. In general, the problem of protecting the national environment has been considered from the aspects of

1. land surface damage and the complementary program of experimental research basins;
2. inland water pollution; and
3. offshore water pollution.

We are fortunate in that this frontier area is still virtually unscathed. However, we must act quickly and decisively if the legislation which we are proposing is to be of a preventive rather than a remedial nature.

Resolutions of the Conference on Productivity and Conservation in Northern Circumpolar Lands: 15-17 October 1969, Edmonton, Alberta.

GENERAL RESOLUTION

1. Recognizing that modification of the environment resulting from technological development may have deleterious effects on renewable natural resources which are frequently in a state of precarious balance in circumpolar regions;
2. Recognizing that destruction of environmental quality in one area of the circumpolar regions may have destructive effects on adjacent areas;
3. Recognizing the rights of indigenous peoples, the esthetic and recreational potentials, and the need for orderly, social and economic developments of these regions;
4. Recognizing that economic and social developments can be implemented at a speed which outpaces our present ability to obtain the necessary information on which to base rational management; and
5. Recognizing the special problems associated with the maintenance of habitats, communities and viable populations of northern wildlife, certain important species of which are threatened with extinction through over-exploitation and/or modification of the environment; and

NOTING that in spite of the various internationally organized studies now underway such as IBP and IHD, and that IUCN and IBP have internationally approved programs MAR and TELMA relating to northern lands and endangered habitats; and that man's knowledge of environmental conditions and environmental management, particularly for circumpolar regions, is in urgent need of improvement; and

NOTING further that UNESCO is planning to organize a major world wide program on these matters under the title 'Man and the Biosphere' to begin in 1972; this conference resolves:

1. That those countries whose boundaries encompass circumpolar regions undertake such action through education, inventory and monitoring, based on comprehensive research programs, and by laws and their administration, as may be required to protect the natural resources endangered by man's activities in northern lands;
2. That in view of the proximity and interrelated resource management needs of circumpolar countries, management plans and associated researoh programs demand strong efforts of international coordination;
3. That resource management and research programs to fulfil both social and economic goals should take account of and include efforts designed to further the demands, rights and aspirations of all sections of the society they serve, in particular those of native and northern residents;
4. That agencies responsible for resource management recognize the urgent need for establishment of goals and long range plans prior to the implementation of resource development programs;
5. (a) That the circumpolar countries undertake an adequate inventory of resources, including details of the geophysical characteristics of land, water and air as well as their use capabilities;
(b) That these countries establish research areas for productivity and conservation studies as may be required for the thorough understanding of ecological systems indigenous to their territories and develop within these areas the research facilities and human resources required to achieve such understanding;
(c) That these countries plan and execute such research as may be required to identify, and if necessary remedy or guard against, the harmful effects of social, industrial and other developments within the circumpolar region;
(d) That these countries undertake the research necessary to determine what changes

in environmental factors threaten species and habitats, and apply measures appropriate for the restoration and maintenance of their populations.

RESOLUTION RESPECTING ROLE OF CANADIAN GOVERNMENT IN CIRCUMPOLAR REGIONS OF CANADA

The Conference welcomes the statement of the Minister for Indian Affairs and Northern Development outlining the government's program for protection of the northern environment in Canada and COMMENDS this program for its comprehensive approach to the problems arising from human activity and development in the sensitive circumpolar regions.

In welcoming and endorsing this program, deep concern is expressed that it should be implemented on a scale and with a speed and determination that will adequately cope with the thrust of development now penetrating the north. There are four major concerns:

1. The importance of the proposed land-use regulations and their technical complexity require that they receive the broadest scrutiny of those who have knowledge and experience to offer. Therefore, the Department for Indian Affairs and Northern Development should take advantage of this knowledge and experience by broadly circulating the proposed land-use regulations and by inviting written submissions and public hearings.
2. The mining and oil leasing regulations, because they authorize and regulate resource development, are as important as land-use regulations in their impact on the northern environment. Since it has been announced that the Canada Oil and Gas Land Regulations are under review by the Department for Indian Affairs and Nprthern Development, they, too, should be the subject of broadly-based submissions and hearings.
3. Current budget curtailments give grave concern that there will be inadequate staff and financial resources in the Department to administer and enforce the new land-use regulations. It is therefore urged that the people of Canada and the government recognize that there is now need for high priority to be given to the Department's role in protecting the northern environment.
4. It is also urged that the announced program of research into northern ecology be broadened and strengthened so as to bring to bear all available scientific and technical resources in as short a time as possible.

RESOLUTION ON THREATENED SPECIES

RECOGNIZING that the extinction of species by man's activities represents the ultimate form of environmental degradation;

NOTING that in the circumpolar regions, eleven vertebrates are currently regarded as threatened throughout their world range and that there is concern for the survival of a further twenty-one vertebrates in some circumpolar nations;

NOTING FURTHER that particular concern has been expressed for the *Polar Bear*, the *Atlantic Walrus* and various species of *waterfowl*, in the U.S.S.R.; the *Wolf* and the *Brown Bear* in FENNO-SCANDINAVIA; the *Greenland White-tailed Sea-Eagle* and the *Thick-billed Murre* in GREENLAND; and the *Atlantic Brent Goose* as a result of persecution in its DANISH wintering grounds;

THIS CONFERENCE URGES all countries responsible for lands in the circumpolar region to initiate research and management programs and take all necessary legal action to ensure the survival of adequate populations of these threatened species.

RESOLUTION ON INDIGENOUS PEOPLE

NOTING that the Eskimo delegation has expressed deep concern about the damage which their lands have experienced and are continuing to experience and about the social upheavals which have accompanied various incursions by non-Eskimo groups when developing northern lands;

The conference SHARES the concern of the Eskimo delegation that the northern lands and culture be conserved and ASKS that full consideration be given to their request that the rights of indigenous people in the north be clarified and established;

and FURTHER RESOLVES that the paper[1] submitted by the Eskimo delegation to the Conference be brought to the attention of the Minister for Indian Affairs and Northern Development.

RESOLUTION OF THANKS

The Conference RECORDS its very great appreciation to the following organizations which contributed funds, facilities and assistance which helped to make this Conference both possible and highly successful:

IBP (PT) Central Office
Canadian Committee of IBP
IUCN
Canadian Department of Indian Affairs and Northern Development
Atlantic Richfield Company
Province of Alberta (through the Premier: Mr. H. E. Strom)
City of Edmonton (through the Mayor: Dr. Ivor Dent)
University of Alberta

Organizing Committee of the Conference (Directed by Dr.W. A. Fuller):
and all the 'Behind the Scenes' helpers whose cheerfulness, friendliness and willingness to help will be remembered by all the participants.

APPENDIX TO THE RESOLUTIONS OF THE CONFERENCE ON PRODUCTIVITY AND CONSERVATION IN NORTHERN CIRCUMPOLAR LANDS.

Brief presented by Mr. Charlie Gruben, delegate of Tuktoyaktuk, N.W.T., concerning rights of indigenous peoples in the Canadian Arctic.

We are very glad to have been invited to attend this interesting meeting, and we appreciate it very much, because the matters discussed here are all of a great concern to us, perhaps may I say, of vital importance to us, Eskimos, as after all we have lived, are living now and will live in the North country, our homeland. We are the inhabitants; everybody else live only a very short time, coming and going in the arctic. Therefore, we believe that we should not only be observers, but participants and have a say in the deliberations, because we are involved in all problems; and we do not want to be only onlookers, because all changes, all developments, in every field, economics, industries, politics, shall influence our life, our way of living, our economy, in one word our future in one way or another and we want to be integrated, to be included, in future development of the arctic region and to be well informed first of plan of actions, secondly to be asked perhaps on matters concerning us of our opinion and views. Too often in the past decisions and actions have been settled without consultation and we were faced with a matter of fact situation, unaware and unprepared. We believe that such policies and procedures could and should be remedied by more communications and information from all parties concerned and involved.

As civilization penetrates deeper and deeper into the Arctic land and even water, there are many thoughts and questions, many issues to be clarified and explained because they are important, crucial and pressing now.

Land

Several times in the past in the North, in a settlement such as Tuktoyaktuk for instance, people or houses have been 'shuffled' here and there to make room for schools, for exam-

[1] See Appendix to the Resolutions

ple for Dewline, for R.C.M.P. barracks (dwellings); allowances and compensations were given to persons which made us believe that, after all, we have a certain right on our land. We would like to know what is legally our 'Rights' on the lot we are living on, on the land we have hunted, so far we considered this as our property, building upon it our dwellings, improving one way or another this 'spot' where we are living on. What about aboriginal rights? What about compensation? How can our Prime Minister say aboriginal rights will not be recognized when today our neighbors and relatives next door in Alaska are negotiating such a settlement with their government ?

Trapping Area

With all the developments and consequences, research and exploration of various kind on land, on ice and in the sea, many problems and questions arise:

(1) In our area, Tuktoyaktuk, since 1955, when Dewline was built, trapping became poorer and poorer; it is practically impossible now to live off trapping only. That is the impact of all ways of transportation in our area, plane, helicopter, cat-trains on the tundra, seismic blasting on land and sea. Is not this a sufficient factor to disturb animal life in land and sea? Trails are visible from aircraft, all around our trapping ground. One year we had to send a protest as creeks were dammed and no fish caught in the harbour of Tuktoyaktuk. This summer no whale were caught in our water. Is it due to blasting (seismic operation) ? We believe that this operation has something to do with it. It is the first time in the history of Tuktoyaktuk that we do not harvest whales (only one was killed by the hunters this summer).

Therefore we strongly urge the persons in charge to show concern for our interests and welfare and take into consideration our plea and our situation.

What can be done to remedy this situation? Our land trapping area is spoiled. What are *our rights ?* What about oil or mineral findings in this area? Will our people share in the benefits?

We cannot call on treaty; as far as we know there were none enacted between Eskimo and government. Only this and I quote from Bob Cockney's biography:

> 'In 1929, when we were at Aklavik, an important man arrived, his name O. J. Fennie. There was a meeting, gathered there were many Eskimos. He wanted to make treaty with them; when asked how much will people receive for 12 months, he (Fennie) answered $ 5. 00. Then he (Bob) answered, you keep your money; $ 5. 00 will be of no help for us in this Country where every item is very expensive. What we want is this: when we shall be in need, give us some food; people, widowed, blind, sick, give them ration; Fennie answered that these words were good, there will be no treaty and he will follow what has been said.'

So now where do we stand? Even the pieces of land where our houses are, are not even ours. Out trapping grounds gradually spoiled, do not afford anymore for our needs of livelihood.

There is no other option left than work for our living, employment in order to adapt ourselves to this new way of living.

(1) More *communications* between companies and *employees* are needed and, along with this, *more education* to prepare us for such a step.

(2) More training, if possible, in our own environment, for instance, marine training, here in Tuktoyaktuk, ships are here all year (cf. what is done in Newfoundland). Oil Companies could also train some people, and so on for other companies and business in the North.

(3) Industries should be set up in the North. Fur shops operating in our area are a success. Other industries employing men should be taken into consideration, fish canneries for instance.

You gentlemen are interested and concerned with conservation in the Tundra. We, who, have lived there since long before your people even knew of it, we are also concerned with the conservation and development of our people, our culture, our way of life, and we will need the support of every citizen who cares about the North and its people.

Tundra Conference Summary

FRANK FRASER DARLING[1]

I suppose I ought to thank you Bill for those very kind words. However, in a way, you are just piling up the agony. He said I would have some scribbled notes and indeed I have. I don't know where they start or finish and they are nearly as large as the volume of papers I have collected since I came. Nevertheless, I also feel that there is a hint of anti-climax after that burst of resolution euphoria which we've just had and therefore I am going to speak on a purely personal plane about my impresssions of this conference rather than make a summary of it.

I think the first thing that struck me in the talking at this conference was the importance of permafrost. When you are young and start thinking about Arctic affairs you tend to look upon permafrost as perhaps an enemy and the longer you go on you realize that permafrost is the great friend of the Arctic. Without the permafrost, we would be in a very bad way indeed and when you've been around a bit in the Arctic you see the unhappy things that happen when permafrost is injured. At the very best, as at Fairbanks, you start a dairy farm and finish up with a first-class golf course because so many lenses of ice have melted that you have got this beautiful golf course laid out with bunkers and everything else. Then, you see the more terrible effects of permafrost where the tracked vehicles have gone and, as a result, we have gullies and, as yet, we don't know the end of this.

Nevertheless, conservation-minded people and engineers are as one; one of their first principles is the conservation of the permafrost. The engineer does not want to injure it because if he does he lays himself open to trouble, but I suppose we could well say that the contractor who runs around making the tracks is not an engineer, he is a transport contractor moving things from point A to point B. I think this conference has emphasized the engineer and the biologist (or the conservationist, if you like; I don't like that word very much) as co-operators with this desire or aim in common; the do not wish to destroy.

Now there were later papers speaking of the vegetation and the behaviour, almost, of the permafrost and we can see how subtle a thing it is. There has been a great deal of research on permafrost and I am a great admirer of Max Brewer of the Arctic Research Laboratory. I am surprised he isn't here. I would like there to be a book on permafrost that is comprehensible to people in several disciplines concerned with the Arctic. I am sure there are those present who could assist in writing such a book.

Now, on the vegetation of the Arctic region: we learned very well in that first day of the conference, the subtle quality of the behaviour of plants. We speak of behaviour of animals and we even call it ethology (I still prefer to call it animal behaviour myself) but I was struck, listening to those papers that morning, by the quality of the behaviour of plants in this Arctic environment. It was very beautiful. And the animal behaviour and the plant behaviour was, as I listened, a very beautiful whole, and emphasizes what I feel myself, the unity

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[1] Shefford Woodlands House, Newbury, Berkshire, England. Vice President, IUCN, Morges, Switzerland and Vice President, The Conservation Foundation, Washington, D.C.

of ecology. You cannot differentiate and speak of plant ecology and animal ecology. There is only one ecology. I thought that in the first morning this was remarkably emphasized in the papers we heard.

Another point which I hadn't sufficiently realized before is that the Arctic environment is not just simple in the ecologists' sense of the word, but it is unsaturated. This should be recognized, I think, much more than it is: that the Pleistocene was one set of upheavals from which this environment has not yet recovered and this is part of how subject the Arctic environment is to catastrophe. It is not just, you see, a matter of the simplicity of the ecosystems, it is the lack of having got back to the complexity which the Arctic ecosystem, as a whole, is capable of reaching. That also came to me out of this meeting. When I heard that the soil temperature at Barrow had risen 4°C (I didn't quite catch if it was this century or in another century) I wondered then and there whether this had anything to do with the rising CO_2 content of the atmosphere which I think is a phenomenon of very great possible importance for the Arctic as a whole, and indeed for the whole planet.

This Pleistocene series of catastrophes, from which the Arctic is still recovering, has been almost immediately followed by the technological era. One wonders how the Arctic is going to recover from the technological impact. If I may say so, I did not feel that we had enough indication in the conference of policy in the face of the impact we are suffering and of which we are obviously going to suffer very much more. We have had discreet research described in plenty, but I think not enough said on the impact of development as a whole on the Arctic, and this does mean the whole Arctic region. It is inevitable, Ladies and Gentlemen, that we must have listened more to Canadian and Alaskan experiences in this conference; we can't help that. Our friends, the Russians, have been here but, if I may say so, I have not learned nearly as much about Russian Arctic as I had hoped to, but we will hope for a greater freedom if eventually we can get over this question of tongues.

We've had some talk about the Mining laws and the boom environment, and of course the oil strike is in the same category—it creates the boom environment. I think you will agree that the legal situation, with the laws and the administration under which we work, do tend to create this boom environment, if we strike it rich. Environmentally this is a bad job. We want more time. If there could be postponement this would be very helpful to us. We are caught unaware. I think the oil industry and all the rest of us have been caught unaware by this very big strike in Alaska. I would agree with what Bob Weeden was saying this morning—that one must obviously go ahead with the strike that has been made, but if we could have more ecological survey (he said moratorium) and some postponement of a further proliferation all over the place the whole environment would benefit, because we do not really need that oil just now. One can understand the necessity of making this strike available economically and immediately because so much oil is set in areas of the world that are politically unstable.

I think you will agree that the paper on Wednesday afternoon by Mr. J. Naysmith, who is a civil servant, was a very fine and very constructive insight into what I would call the best type of Civil Service mind at work. He was tackling the jobs of administration in a scientific manner and his statement 'conservation is reduction of waste' are words which many of us interested in the biological side of things might remember. I think it was a very good statement. He did emphasize to us that there was co-ordination between bodies but not anything like enough, at least that is how I understood him. He asked for the quantification of values by conservation; now this is a very real need and I, as a so-called ecologist, feel this as very truly a rebuke. We are all as bad as one another in ecology. We shuffle in our chair and say 'we need much more research before we can make a decision on that'. The administrator is faced with the necessity of making a quick decision. If the technologists, the physical scientists, are able to come forward and say, 'yes, here is a decision', the administrator is almost compelled to take it. Now, the ecologist, I feel, must come off this extreme; of course the ecologist is seeing things on a broad front—he is also trying to see round corners. This is his work, but he has got a great deal of information of one sort and another and he has got quite a lot upon which he can give an answer which does not need to be faultless. We are all making decisions which may be either very wrong, wrong, or almost right. Very few of us make decisions which are absolutely right and the ecologist, I feel, on the whole, is a very truthful person. My impression is this—he must be prepared to come out of his shell, not taking refuge in saying we want much more research before we can answer this question, but coming out and saying things and getting on with the jobs that are before him. And I think he can be prepared to take the brunt when occasionally he is wrong. So Mr. Naysmith, I felt, did not rebuke us, although I felt the rebuke; he put it to us that ecology or conservation must come up with some quantitative values. I know of course you may say, 'How can you put quantitative values on intangibles?', but it is remarkable what you can do if you take enough trouble. We can approach very near to economics. We are always using the dollar sign and, of course, that is a symbol which our economists tend to mistake for reality. We in ecology are always trying to seek reality. These intangibles in conservation are the reality all the same, but they don't carry this symbol of the dollar sign. However, I think if we tried we could reach much more quantitative values than we do and, furthermore, in ecological forecasting we can attempt to follow the technique of the Hudson School which is not dealing with biological affairs but often dealing with social affairs as well as the physical sciences. I think they call them 'scenarios' and they follow imagined consequences through to the far end and do come up with statements which certainly merit everybody examining closely. They are attempting to see consequences, which is exactly what the ecologist is trying to do. I think we should try to follow something similar.

Now on the 'wholeness' of the Arctic region (I think we are all aware of this); I was impressed by Dr. Vibe's talk in which he showed us how sensitive, how terribly sensitive, certain animals and certain biomes in the Arctic are, in the face of comparatively slight climatic changes. These catastrophes to musk-ox in East Greenland and to caribou elsewhere are a result of snow and glazed frosts referable to a great deal of open water in the polar sea at intervals of about 66 years. You can see that the whole polar region is one in which we cannot have truly what you would call 'national enclaves'. We must think in terms of the whole polar region and we see how closely linked one part is with another with quite slight changes. This conference would have had here, I am sure, had he been alive now, Don Foote. He was, I don't know what you would call him, an ecologist or an anthropologist, but he was something of both. He was a man who saw things very big. He died within this year, I believe. This is a very great loss to Arctic thinking. He was interested in what you might call geographical engineering and at the time of his death, had about thirty-two big projects that had been considered for this geographical engineering in the Arctic. I think it was his intention to work out some sort of a scenario of what would happen if any of these large pieces of engineering had been carried through. I didn't know this until recently but if there were these large measures of geographical engineering in mind, we ought to be thinking more about them. None of the five nations concerned with the Arctic can think too much in terms of their own country.

Reindeer and caribou are creatures that have been in my mind for a good many years, certainly over forty. I was associated with Sir Wilfred Grenfell and the possibility of reintroducing reindeer into Labrador. We had hoped, back in 1929, to establish a research ranch at Northwest River on the Hamilton Inlet in Labrador. I learned a great deal from that effort. He was a great lobbier. He saw all the Johnnies on the Empire Marketing Board, whom we were trying to touch for the money, individually; everyone agreed with him saying it was a splendid idea and he sent me a telegram saying it was in the bag, so carry on. Well, I didn't carry on; perhaps this is native Scots caution, I don't know, but I didn't. The Empire Marketing Board turned it down so we never got any farther with the reindeer. The point is, and the lesson to me was, that a group of men individually will say anthing, collectively they are all frightened of each other. They couldn't face up to our scheme. They thought it was some sort of **a** Father Christmas idea and they would not go for it. That was forty years ago. Reindeer were a long way from people's minds forty years ago but now it is very different. There was the session here in which we learned that reindeer culture is scarcely holding its own and I think we must realize that the reason is that people will no longer face the prime need of reindeer culture, which is one of movement. The whole world is changing this way—nobody is prepared to move constantly. It is a great pity, it would suit me splendidly, but then I am not a very techological type of fellow. However, if you have to have things like radio and a bit of chromium plate round the place, it costs money. Reindeer culture has never dealt with things that cost money. You make things from the natural resources you have around you and from the reindeer themselves. The reindeer-caribou culture is essentially self-sufficient, and today, it seems, nobody is prepared to live that life.

I learned everything I could about the Alaskan reindeer situation until the crash in the 1940's and we see there that one reason for the crash was that nobody was prepared to follow reindeer and the kind of nomadic culture which was demanded. If you go up 20, 000 feet over western Alaska today, you can see the scars there where the reindeer were in those days. They overgrazed and they crashed. I can see really very little hope for reindeer culture in the future. I think there is much more chance, as Dr.Scotter pointed out, for a possible caribou cropping or ranching scheme. It would not be a ranching scheme in the way of having fenced ranches because by fencing these creatures one loses out. Rather it would be one in which one family or tribe presumably worked a certain area.

One more word about reindeer culture and movement. There is something rather like it in Scandinavia and Scotland in the shieling life. In the spring the young folk take the cattle to the high grazings and they stayed there with them until the autumn. This meant that the low ground, the arable ground where the crops for the winter were grown, were completely free from grazing stock. There was a certain amount of grass on the low ground for the winter (foggage we called it) when the cattle came down. Now the shieling has pretty well gone and it is a pity. I think in Scandinavia it is losing out badly, is that right? Is the high ground life really going? It is decreasing very rapidly says our friend from Norway. This is a bad thing because with my very limited experience, the shieling life wasn't half bad. One had the beauty of the weather in the high places. It was the young folk who were up there and they had a very pleasant time indeed. There were not the old folks saying 'yes' or 'no' to them because the old folk were down on the low ground looking after the crops. (I believe I am talking too much,Bill? He says nothing so I must be.)

I think now I should come to this morning. Last night I was a little disappointed that we had not got on to some of the things which were very near to my own heart. This morning somehow or other, despite the injunctions from yourself, sir, you let the lid off and we had a marvellous morning, I think you will admit. I don't know whether it was constructive or not, but I think it was. But I was sad. I felt the suffering of some of the people who amused us this morning. Al Hochbaum for example; he was always a wit. I have known this for a long time and this morning his biting irony (almost invective) was very deeply felt. It was, if I may say so, a splendid performance on his part, of impressing upon us how we were ill-treating the environment. He was talking of Churchill and roundabout but, my goodness, we can apply it to the whole circumpolar region. Dr.Salomonsen got up and said 'You think things are bad but you should see what is happening with us'. It is just the same with where I have lived for so long. Not in the Arctic, perhaps, but when I lived on an island off the north of Scotland I used to look north and realize there was nothing but sea and ice straight over the North Pole to the Bering Strait before you struck land. I was on your fringe and I know that even in the north of Scotland the litter and the dirt are getting bad. This is a fault of our age, altogether, and we are not giving enough attention to getting rid of our indestructible wastes. We are the only species, aren't we, that can produce indestructible wastes? At least I think we are. Even corrugated iron will rot sometime, but asbestos will not. This morning, then, was a time when a great deal of emotion was felt throughout the company. We are all moved by emotion; we all work that way really, however hard we may try not to as scientists. We are all moved by emotion, and if we're not, God knows what we *are* moved by. I think there is a difference between emotion, which is a noble thing in itself, and sentimentality, which is very bad however you look at it. I think, Sir, when you gave us your injunction not to be emotional, possibly you meant don't let us be sentimental. Would you agree? You don't mind us being emotional as we were this morning? I think it was a very good show indeed.

Now in all our deliberations we did just mention the population problem but quite rightly we never got down to it because had we done so we should have wasted this tundra conference and had a hyper-emotional discussion on the population problem. Nevertheless, we must not forget that the population problem is the biggest thing we have to face and pollution is a function of population, although it need not be. I really do not see that pollution has to be a function of high population. We could get on with the job of managing pollution anytime if we were ready to cope with it. But within a country, commercial enterprise is against commercial enterprise; one cannot afford to pull back on pollution because the other fellow would be able to produce cheaper. Even if we got legislation within a country to stop pollution it would set us back *vis-à-vis* some other country. It is now export or die, so pollution goes on. As I say, it is not necessarily a function of population increase, but the population problem is at the root of almost everything we have been talking about in the last three days. I do not know really what the population policy is but we have got to find out before long.

I will finish on a slightly more formal note. Perhaps some of what I have to say here has been said in the resolutions but I believe the Arctic circumpolar zone represents the largest continuous tract of wilderness and wildlife habitat now remaining in the northern hemisphere. Moreover, it supports species and communities of very high scientific interest. Have we so far taken this seriously? I think not! Scientific reserves are, as we heard again this afternoon, an absolute necessity. We need places where research can go on unimpeded and where the creatures and the plants that live within that reserve can be expected to persist. I think the riches which the great oil strike give should make it possible, as a mere gesture of humanity towards the earth, to set up invaluable reserves, and the feeling has been apparent throughout this conference—that we should set aside large reserves. There is no doubt whatever that the face of Alaska where I have had the good fortune to be able to travel a great deal one way or another, is still its greatest asset, and this oil strike need not unduly deface Alaska. We must give up something, we know that, but considering the power of Alaska to awe one and the wilderness quality of a great deal of Alaska (and that applies right around the polar region) we should be prepared to give up large areas of it for research value, for wilderness value, and the very fact that it is there.

You know you do not need to be able to be in the wilderness necessarily, to enjoy it. I have heard so often about places, 'Well, what is the good of having that, if the public can't get into it?' This is one way of thinking, but it is false. It doesn't matter whether we can get into it—it sometimes matters that we can't. After all, to get into it may take great strength; all well and good—that is what it is for. Those of us who cannot get into these places can still read, we can still imagine, and so we can still enjoy the wilderness. I think we should have this feeling about large areas in the Holarctic region.

We have had some comment on national parks and I have been sorry to hear that there has been some objection from the indigenous people toward the establishment of national parks in their country. I am sorry because I feel that national parks are one of answers to their problem. The native people should look upon the establishment of a large national park as one of the safeguards of their country. William Catlin, who made those wonderful paintings of Indians in western America back in the early 19th century, long before national parks were thought of in any serious way, actually said, 'Could we not make the west into a great park where man, the denizens of the wild, and the scenery should be one vast park?' Now I feel this must come more and more into our thinking about national parks. There is no need to exclude people. That has been done in various places, and much of the recent philosophy in establishing national parks is to find places where there are no people. I think this is wrong. I see no reason why any national park in the Arctic should not remain inviolably the country of the indigenous people who use it in pursuit of their life ways. The Eskimos did not damage the permafrost and most of the Indians who lived in these Arctic and sub-Arctic areas have not greatly damaged the environment either. I see no reason why they should not be left to live their lives within that area. And on that line I would also follow up by saying that these people, Eskimos and Indians, know their country; they can live in it, move in it, better than we can, and could they not come much more into our lives by being the custodians of the Arctic? If we need law enforcement officers, why should not the Eskimos and Indians themselves be these officers? They could, to a very large extent. These are the people who can get about and who live there. It is their country. This is a way of our impressing on them and on ourselves that it is their country. May I say how deeply moved I was by the speech this morn-morning by Mr. Charlie Gruben of Tuktoyaktuk. I am sure that what he said about the enjoyment of his country could be harmonized with this greater appreciation of wilderness and national park quality of much of the Arctic region.

And in coming to an end of this summary which perhaps is not a summary at all, but merely my own thoughts, I feel, and I am sure you will agree, that this conference does not end tonight. It must be a continuing thing and I would like some effort towards finding—I don't know whether consortium is too official a sort of word—some way in which research endeavour and a sense of dealing with the management of the Arctic as a whole, should be possible between the five nations. You realize that Antarctica, which nobody has sovereign rights in, is being quite well managed by the powers that have an interest there. They do not own it or anything like that. There is no need to go and raise the flag anywhere in the Antarctic but there is excellent scientific co-ordination and co-operation. I would ask, and put it to you, that in the Arctic with only five nations concerned, we ought to be able to go yery much further in this co-operation than we have done up to now. In the early spring of this year the International Union for Conservation of Nature organized a tremendously successful research conference in Switzerland on international polar bear research. I was supposed to be Chairman of that group (I suppose this must have been because I saw no land north from where I lived until the land south through the Bering Strait: there is no other good reason) but I was ill and unable to take the chair at that meeting. There is no doubt now that co-ordinated co-operative research is on the move. I feel we could do much more in many other fields in the management of this extremely beautiful, but still largely pristine, area of the world.

I would close by just mentioning something I thought was very fine. Bob Weeden's last paragraph this morning spoke of 'the world needs an embodiment of the frontier mythology, the sense of horizons unexplored, the mystery of uninhabited miles. It needs a place where wolves stalk the strand lines in dark because a land that can produce a wolf is a healthy, robust and perfect land'. This I think is a beautiful thought; there is hope yet for the country that can produce a wolf. As a species, humanity has not done a very good job by the wolf, but the days of being frightened of it are over and I think the fact that the Arctic can still produce wolves should give us hope for the future.

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