IUCN Species Survival Commission

Biology and Conservation of Freshwater Cetaceans in Asia

Edited by Randall R. Reeves, Brian D. Smith and Toshio Kasuya

Occasional Paper of the IUCN Species Survival Commission No. 23

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The Department of the Environment Transport and the Regions (DETR), UK supports a Red List Officer post at the SSC Centre in Cambridge, UK, where the SSC Trade Programme staff are also located. Together with two other Government-funded agencies, Scottish Natural Heritage and the Royal Botanic Gardens, Kew, the DETR is also financing a specialist plants officer. Further support for the centre is being offered by two NGO members of IUCN: the World Wide Fund for Nature – UK, and Conservation International, US.

The Center for Marine Conservation (CMC), with its headquarters in the US, provides valuable in-kind and funding support to the marine work of SSC. It is the major funder of the Marine Turtle Specialist Group, employs the MTSG Programme Officer, and administers funds on behalf of the Shark and Cetacean Specialist Groups. A CMC staff member acts as SSC staff liaison for the marine specialist groups and the marine focal point for SSC, and also supports the development of SSC's work in the marine realm. CMC serves as the marine focal point for the IUCN/SSC Red List Programme. It is dedicated to protecting ocean environments and conserving the global abundance and diversity of marine life through science-based advocacy, research and public education.

Whale and Dolphin Conservation Society (WDCS) is an international charity dedicated to the protection of cetaceans and their environment. It provides support for cetacean conservation and protection activities around the world. WDCS has a special interest in river cetaceans and collaborated with the SSC Cetacean Specialist Group in establishing the Asian River Dolphin Committee in 1992-3. Since then, WDCS has sponsored numerous field projects, workshops, and meetings, several of which are highlighted in this volume. For further information please refer to the WDCS website www.wdcs.org

Ocean Park Conservation Foundation (OPCF) based at Ocean Park, Hong Kong, was founded in 1993 with the main purpose of contributing to the conservation of cetaceans and the preservation of cetacean habitat in Asia. Freshwater and coastal small cetaceans are the focus of OPCF's activities. The Foundation has supported studies of river dolphins in Pakistan, India, Nepal, Bangladesh, and China, and of finless porpoises in the Yangtze River.

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Contents

Executive Summary

River dolphins and porpoises are among the world's most threatened mammal species. They inhabit some of the largest river systems of southern Asia, and their environmental requirements link them to food and water-security issues in the world's most densely populated human environments. River cetaceans historically ranged upstream from the estuarine zone to rocky barriers and shallow reaches in headwater streams. Populations of river cetaceans have declined dramatically in recent years and much of their range has been lost.

River cetaceans are threatened in many ways. Over-harvesting of fish and crustaceans reduces the availability of their prey. Deforestation and intensive floodplain farming increase the sediment load of river channels and degrade cetacean habitat. Industrial effluents, human sewage, mining waste, and agricultural runoff contaminate water. Dolphins and porpoises die from accidental entanglement in gill nets, and mortality rates increase as the use of these nets spreads. Possibly the most significant threat to river cetaceans is the construction of large water development structures, most notably dams, barrages, and levees.

The environmental consequences of water development projects are significant and far reaching. These structures fragment populations and reduce the environmental complexity that makes rivers suitable for aquatic species. Water development proceeds, however, with little understanding or concern about the effects on cetaceans, or on the assemblage of other life that shares their habitat.

This volume brings together current information on the status of Asian freshwater cetacean populations, the factors that have caused their recent declines, and what can be done to improve their chances for survival. All of the species or populations in question are classified as Endangered or Critically Endangered in the *1996 IUCN Red List of Threatened Animals*.

The baiji (*Lipotes vexillifer*), an endemic dolphin species in the Yangtze River of China, is the world's most critically endangered cetacean with a population estimated at only a few tens of individuals. The recent decline in baiji abundance has been attributed to excessive bycatch in fisheries, reduced abundance of prey due to overfishing, and severe degradation of the Yangtze environment. A last-ditch effort to capture the remaining individuals for translocation to a "semi-natural reserve" has been unsuccessful, and there is little hope for the survival of this species.

A second cetacean species shares the Yangtze River system with the baiji. The finless porpoise (*Neophocaena phocaenoides*) population in the Yangtze is the world's only freshwater-adapted population of porpoises. Yangtze finless porpoises are considered a subspecies, and they appear to be morphologically, behaviorally, and genetically different from the marine finless porpoises that occur in Chinese coastal waters and elsewhere in eastern and southern Asia. Although population estimates are crude, there are thought to be at least hundreds, and perhaps a few thousand, finless porpoises remaining in the Yangtze system, including Dongting and Poyang lakes. The species is legally protected (as is the baiji), but factors similar to those that have caused the demise of the baiji are operating on the finless porpoise – incidental killing, loss of high-quality habitat, reduced food supplies, and pollution. A small group of porpoises inhabits the "semi-natural reserve" that was originally designed for baiji, but *ex situ* conservation efforts are not particularly promising. While the finless porpoise seems to have been better able than the baiji to tolerate the deteriorating conditions in the Yangtze River over the last several decades, its future is highly uncertain.

Dolphins inhabit several large rivers of southern Asia. Two closely related species are covered in this volume: the Ganges susu (*Platanista gangetica*) and the Indus bhulan (*Platanista minor*). These are obligate river dolphins that occurred historically from the deltaic zones upriver to the mountain foothills where rapids blocked their dispersal. Another unrelated dolphin species, the Irrawaddy dolphin (*Orcaella brevirostris*), occurs far up the Ayeyarwady (Irrawaddy, hence the name) and Mekong rivers of Southeast Asia but it, like the finless porpoise, also inhabits marine coastal waters. None of the papers or reports in this volume deals in-depth with the freshwater populations of Irrawaddy dolphins, but in the future, they should be included in the category "Asian freshwater cetaceans." These populations are subject to many of the same threats and are in urgent need of assessment and protection.

The Ganges susu occurs in the inland waters of Bangladesh, India, and Nepal. Its traditional strongholds have been the Ganges, Brahmaputra, Meghna, and Karnaphuli river systems. Susus still occur in these rivers and, at least seasonally, in many of their tributaries. There are at least a few hundred susus in both the Ganges and Brahmaputra systems, and their total abundance may be in the low thousands. However, with the extensive development of irrigation, flood control, and hydroelectric projects in Asian rivers, the susu's metapopulation has become increasingly fragmented. Groups of dolphins upstream of dams and barrages have either disappeared or declined with little prospect of recovery. Susus are caught incidentally in fisheries and are also hunted deliberately in portions of their range in both India and Bangladesh. There is a strong localized demand for their oil to be used as a fish attractant and as medicine or liniment. Despite valiant efforts by conservationists in all three of the range states, the susu is almost certainly losing ground in the face of overwhelming human demands on freshwater resources, including the water itself.

The same is true of the Indus bhulan, whose historic range included the entire navigable length of the Indus mainstem as well as several of its large tributaries. As dams and barrages have subdivided the Indus, the bhulan population's range has progressively shrunk. Today, significant numbers of dolphins occur in only three discrete river segments, with a total population of only hundreds. The species' fate rests entirely in the hands of Pakistan, a nation burdened with a chronic shortage of freshwater resources to sustain its growing human population. Although the bhulan is officially protected, it must compete with humans for Indus water. The problems of bycatch and pollution affect the bulan as they do the susu.

This volume includes three meeting reports and 14 papers. Two of the meetings were held in Bangladesh in 1997 – a meeting of the Asian River Dolphin Committee and a workshop on the effects of water development on river cetaceans. The third was held in Hong Kong in 1997 to develop a conservation plan for the Yangtze population of finless porpoises.

In addition to the aforementioned workshop report, there are three papers on water development issues. The first is a register compiled by a team of scientists, listing and mapping water development projects (dams, barrages, embankments, ship locks, etc.) in Asia that have affected river cetaceans. The second paper reviews water development projects in China and how they are thought to have affected baiji and finless porpoise populations. The third focuses on Farakka Barrage in eastern India and provides a detailed examination of how the barrage and its associated structures have affected the susu.

One paper contains data on the behavior of baiji. The authors ruefully note that their observations in the wild may be the last ever reported for this probably doomed species.

Two research papers on the Ganges susu are included. In one of them, a team of scientists present a synthesis of available data on the species' occurrence in the Ganges and its tributaries. This is the first time anyone has attempted a comprehensive review of the susu's status in the entire Ganges system. The second paper is a summary of what is known about occurrence of the susu, or "shushuk" as it is called locally, in the Karnaphuli River and several smaller rivers of southeast Bangladesh.

Three papers, in addition to the workshop report, are devoted to the Yangtze finless porpoise population. The first of these provides a summary of work conducted at the Wuhan Institute of Hydrobiology and includes information on the animals brought into the baiji "semi-natural reserve." The second is a preliminary analysis of genetic differences between the finless porpoises in the Yangtze River and those in marine coastal waters of China. The third paper contains the results of surveys conducted in the lower Yangtze by a team of researchers from Nanjing Normal University.

In the final section of the volume, five papers address methods for studying freshwater cetaceans. These include reviews of survey methods and of genetic and demographic issues related to conservation of small, fragmented cetacean populations. One of the papers is a field report on the use of specially designed "vests" for attaching telemetry devices to finless porpoises. Finally, two papers are included on river dolphins in South America. In one study, botos (*Inia geoffrensis*) were captured alive, sampled, instrumented with radio tags, and released. In the other, standard surveys of botos and tucuxis (*Sotalia fluviatilis*) in the upper Amazon were used to investigate habitat preferences of the two species. The purpose of this section is to provide Asian scientists with fresh ideas about how they might pursue their own research and conservation efforts with river cetaceans.

The Cetacean Specialist Group of the IUCN Species Survival Commission has regarded freshwater and coastal small cetaceans as its highest priority for more than a decade. Unfortunately, although much has been learned in recent years about where these animals occur and how many there are, very little progress has been made in improving their chances for survival. Bycatch is a major threat wherever certain kinds of fishing, particularly gillnet fishing, are practiced. There is no reason to believe that any cetacean population in an Asian freshwater system is sufficiently robust, or well enough studied, to be subject to sustained-yield exploitation, whether deliberate or accidental. River damming has the direct effect of dividing dolphin populations for large parts of the year, if not permanently. In addition, flow regulation, diversion, and channelization are known to alter geomorphic processes and to degrade downstream habitat for both dolphins and their prey. The threats to human health posed by the contamination of inland fresh waters with artificial chemicals, sewage, and agricultural runoff should be sufficiently alarming to prompt remedial action, so that it would be unnecessary to invoke concern about the effects on cetaceans. Yet in spite of what is known, these threats continue largely unchecked in Asian rivers.

The baiji is deemed a "national treasure" in China, in some respects rivalling the giant panda (*Ailuropoda melanoleuca*) as an animal worthy of extreme efforts to ensure its survival. The baiji's imminent extinction is a national tragedy and an international disgrace. The story of the baiji's decline, tied as it is to the rampant degradation of a once-productive river system, needs to be told and re-told. Its message – that our freshwater resources are exhaustible and that a river's capacity for serving human needs is finite – can be applied in other contexts, including some in Asia where other small cetaceans are in trouble and headed in the same direction as the baiji.

Preface

Early in his tenure as chairman of the SSC Cetacean Specialist Group (CSG), Bill Perrin decided that a major focus of the group would be the conservation of river dolphins. A landmark event in this regard was a workshop on the biology and conservation of the platanistoid dolphins, held in Wuhan, China, in 1986. In its first action plan, the CSG identified 24 priority projects for conserving freshwater dolphins. These projects were updated and consolidated in the CSG action plan for 1994-1998, which included 23 such projects. Besides projects aimed at particular species, areas, or issues, two were broader in scope, generally intended to address problems related to river dolphin conservation. One of these projects was to establish an Asian river dolphin research committee. The other was to promote increased consideration of river faunas in internationally funded development. The following collection of papers is, in many respects, a "progress report" on those two projects, and on other more narrowly focused CSG action-plan projects related to freshwater cetaceans in Asia.

In 1992, Steve Leatherwood (CSG chairman from 1991 until his death in 1997), Reeves, and R.S. Lal Mohan organized a meeting of Asian scientists in Delhi. This event launched the Asian River Dolphin Committee (ARDC), which met formally for the first time in Hong Kong in 1994 and again in Bangladesh in 1997. The ARDC was intended mainly to provide a forum and framework for scientists studying the three freshwater platanistoids endemic to Asia: the Yangtze River dolphin, or baiji (*Lipotes vexillifer*); the Ganges River dolphin, or susu (*Platanista gangetica*); and the Indus River dolphin, or bhulan (*P. minor*). The committee also construed its mandate to include the Yangtze River population of the finless porpoise (*Neophocaena phocaenoides*). The contents of this Occasional Paper are largely derived from the work of the ARDC and its individual members. Two papers on South American river dolphins have been included because they provide examples of research methods that might also be applied in studies of Asian freshwater cetaceans.

It would be wonderful if we could say here that scientists, conservation activists, and resource managers had been successful in their efforts to reverse the alarming trends revealed at the Wuhan workshop. Unfortunately, however, most of what we have to offer is more bad news. The baiji population is apparently much smaller than was thought to be the case in 1986, now numbering in the tens rather than hundreds. All evidence points to a similar decline in the Yangtze's endemic freshwater population of finless porpoises, although it may still number in the low thousands. Meanwhile, the degradation of the Yangtze River's natural attributes continues unabated. The fragmented population of Indus dolphins may be relatively stable at a few hundred individuals, but its habitat remains under enormous pressure as Pakistan struggles to achieve economic growth and political stability. Scientists from India, Bangladesh, and Nepal have conducted an impressive array of research initiatives, providing a much clearer picture of the Ganges dolphin's status than was available in 1986. Its range, like that of the Indus species, has shrunk as a result of dam construction and water abstraction, and it faces ongoing threats of pollution, accidental killing in fisheries, and, in some areas, direct exploitation. The vastness and complexity of its distribution make estimating the Ganges dolphin's total abundance highly speculative, but we suspect that it is in the order of a few thousand individuals.

There is a lot more to accomplish before the situation of Asia's freshwater cetaceans improves. Two recent developments should help raise their profile and keep them high on government agendas. The Indian River Dolphin Committee was formed in 1997 by WWF-India to strengthen ongoing efforts to conserve river dolphins in India. At its 1998 annual meeting, the standing Sub-committee on Small Cetaceans of the International Whaling Commission's Scientific Committee decided to make freshwater cetaceans a priority topic for its meeting this year. The CSG will continue to encourage governments, non-governmental and inter-governmental organizations, and the scientific community to invest resources in studying and conserving freshwater cetaceans.

We are pleased to acknowledge the organizations and individuals who provided support for the work presented in this volume. We are grateful to the contributors who wrote the papers and helped us compile the reports. We particularly thank the Whale and Dolphin Conservation Society and the Ocean Park Conservation Foundation for providing financial support, without which the ARDC meeting, the two workshops (on water development and Yangtze finless porpoises), and several of the projects that resulted in papers included in the volume would not have been possible. We acknowledge the importance of the Species Survival Commission for facilitating our work and supporting this publication, and the help of Anna Knee with final editing and production. We are indebted to those individual scientists who took the time to review the papers; their critical comments have been invaluable.

In particular, we are grateful to Amie Bräutigam of the Center for Marine Conservation for her conscientious, thorough and always constructive efforts to move this volume past the dream stage and into production. Finally, we acknowledge the enormous contributions of the late Steve Leatherwood, who championed and helped guide river cetacean conservation efforts until only a few weeks before his death.

This volume is dedicated to our wives – Randi Olsen, Cindy Shaw, and Kazuko Kasuya – for many years of patience and support.

Randall R. Reeves
Brian D. Smith
Toshio Kasuya
February 2000

Chapter 1

Introduction

Report of the Second Meeting of the Asian River Dolphin Committee, 22–24 February 1997, Rajendrapur, Bangladesh

Edited by Brian D. Smith and Randall R. Reeves

Introduction

The second meeting of the Asian River Dolphin Committee (ARDC) was called to order on 22 February 1997 at the Centre for Development Management, Rajendrapur, Bangladesh. A.K.M. Aminul Haque, the local host, welcomed participants, and Zhou Kaiya, chairman of the ARDC, expressed appreciation to the meeting's co-sponsors: the Ocean Park Conservation Foundation (OPCF), the Whale and Dolphin Conservation Society (WDCS), and the IUCN/SSC Cetacean Specialist Group (CSG). Randall Reeves, chairman of the CSG, reviewed the history of past meetings, workshops, and seminars, and spoke about the enormous contributions of the late Stephen Leatherwood in organizing and championing the ARDC. A moment of silence was observed in Steve's honor. Brian Smith discussed the organization of the meeting - the first day devoted to presentations; the second devoted to working group sessions on conservation threats, conservation initiatives, biodiversity perspective, and research and monitoring; and the third devoted to discussions of recommendations and ARDC business.

Randall Reeves, Brian Smith, and Alison Smith (representing WDCS) acted as rapporteurs. The proposed agenda, list of ARDC members and invited participants (Appendix 1), and documents brought to the meeting by participants (Appendix 2) were distributed.

Objectives

The ARDC was formally constituted at the first meeting in Hong Kong, 5-7 December 1994. The Committee is a group of scientists and conservationists who represent their respective countries in a personal capacity on a volunteer basis.

Membership includes representatives of the range states for Asian platanistoid dolphins and the Yangtze River population of finless porpoises (*Neophocaena phocaenoides*). The objective of the ARDC is to provide a forum for:

1. information exchange;
2. development of standard scientific methods;
3. coordinating research programs and conservation actions, with particular emphasis on situations in which river basins cross international borders, making bilateral or multi-lateral management of aquatic wildlife and habitat essential; and
4. generating appropriate advice to management bodies concerning the needs and priorities for research and conservation action (Reeves and Leatherwood 1995).

Current membership

There are 17 range-state representatives, with three scientific members from India, three from China, two from Bangladesh, two from Nepal, and two from Pakistan. Additional members are to be invited by consensus of the current membership. Officers of the CSG are considered ex-officio members. Scientific experts and representatives of funding agencies are encouraged to participate in Committee activities, as appropriate.

Contents of this Report

Recommendations of the meeting represent a consensus of ARDC members. They are organized according to those that apply to individual countries and those that apply to all range states. The recommendations are not presented in order of priority; the Committee believes that high priority should be given to all of them. The section Review and Discussion of Conservation Issues (including its referenced appendices), is based on presentations, discussions, and working-group sessions of the meeting.

Recommendations for conserving Asian river dolphins

China

1. The Committee **recognizes** that, despite the dedicated efforts of individuals at the Department of River Dolphin Research of the Institute of Hydrobiology, Chinese Academy of Sciences, the Biology Department

of Nanjing Normal University, and other Chinese institutions, the status of baiji continues to deteriorate and that extinction is a real possibility in the near future. We reaffirm the recommendations made for baiji at the Hong Kong meeting (Reeves and Leatherwood 1995) and express disappointment that so little progress has been made towards implementing them.

2. We **commend** the recent attention given to the Yangtze finless porpoise by Chinese authorities but note the evident lack of a comprehensive action plan for its conservation (as called for in the Hong Kong meeting report; Reeves and Leatherwood 1995). We recommend that a workshop be convened, involving Chinese and international scientists, to evaluate the state of knowledge about this population and to formulate a long-term plan for its conservation.
3. The Committee **recommends** that the Yangtze finless porpoise be designated a Class One species under the Chinese National Wildlife Legislation, giving it full protection from deliberate capture.
4. The Committee **acknowledges** the large-scale plan to survey baiji and finless porpoises in the Yangtze River. We **recommend** that the surveys be conducted with methods that can be replicated and evaluated using standard statistical procedures.
5. The Committee **expresses concern** about the increase in the use of electricity and explosives for fishing in the Yangtze River. We **recommend** that a public awareness campaign be initiated to educate fishermen about the destructive effects of these types of fishing and that the Ministry of Agriculture take action to enforce laws prohibiting such methods.

India

1. The Committee **recommends** that regional wildlife, fishery, and water resource managers from the state governments of Bihar, Uttar Pradesh, Rajasthan, Assam, West Bengal, and Madhya Pradesh meet to develop a nationwide river dolphin conservation plan and that individual states organize dolphin conservation groups with assistance from the ARDC.
2. The Committee **considers** the killing of river dolphins, whether accidental or intentional, to be one of the primary reasons for population declines. We **recommend** that the Government of India, in consultation with state governments, encourage and support alternative employment for gillnet fishermen, enforce laws that prohibit deliberate killing of dolphins, regulate the use of non-selective fishing gear, and establish gillnet-free zones in river segments frequented by dolphins.
3. The use of dolphin oil to attract fish provides a market incentive for deliberate killing and reduces the incentive for fishermen to avoid incidentally capturing dolphins. We **commend** Indian scientists for their efforts to investigate and distribute alternative products and **recommend** that further experiments be conducted on vegetable, fish, and other oils. Appropriate substitutes should be made widely available at low cost to fishermen who currently use dolphin oil to attract fish. Considering that dolphin carcasses are expensive, it might be possible for local entrepreneurs to distribute substitutes as a profitable venture.
4. The Committee **recommends** that the Ministry of Environment and Forests collaborate with state wildlife management agencies to strengthen efforts to assess populations and habitats of river dolphins in India. Emphasis should be given to fragmented populations.
5. The Committee **emphasizes** the importance of protected areas for conserving river dolphins and **commends** the states of Bihar and Uttar Pradesh for establishing the Vikramshila Gangetic Dolphin Sanctuary and Sarnath Turtle Sanctuary, respectively. We **urge** that management plans for these areas be strengthened and that new protected areas be established in additional areas of dolphin habitat.
6. The Committee **recommends** that the Government of India initiate consultations with the Government of Nepal to create a transboundary protected area for river dolphins and other aquatic fauna in the segment of the Karnali or Ghaghara River between Katerniya Ghat, India, and Gola Ghat, Nepal. Management plans for the area should integrate the conservation of aquatic fauna with the economic and nutritional needs of local people.

Nepal

1. The Committee **reemphasizes** the urgency of the situation of river dolphins in Nepal. We **restate** the recommendation from the Hong Kong meeting that the segment of river between Gola Ghat, Nepal, and Katerniya Ghat, India, be designated as a protected area for the conservation of aquatic biodiversity (Reeves and Leatherwood 1995). This portion of the Karnali contains the only potentially viable population of dolphins in Nepal. We also **recommend** that the protected area be managed to include the development needs of local people. Establishment of the protected area will require coordination between the Ministry of Forests, Ministry of Population and Environment, and Ministry of Local Development in Nepal, and appropriate agencies of the Government of India.
2. The Committee **expresses alarm** about reports that plans for a high dam on the Karnali River have been renewed with support from private investors. We

unequivocally state that, if built, the dam will seriously reduce biodiversity and almost certainly lead to the extinction of dolphins in Nepal.

3. The Committee **expresses disappointment** that no action has been taken to prohibit commercial gillnet fishing in the Karnali River, as recommended in the Hong Kong meeting report (Reeves and Leatherwood 1995). We thus **restate** the recommendation that immediate action be taken in this regard, preferably as part of a fishery management program that encourages traditional fishing practices by local people and prohibits the sale of fishing rights to outside contractors.
4. The Committee **recommends** that a long-term biomonitoring program, which includes dolphins as a major component, be implemented in the Karnali River. Such a program could be accomplished with the financial support and assistance of research-oriented nature tourism.

Pakistan

1. The Committee **acknowledges** the progress that has been made in monitoring populations of dolphins in the provinces of Sindh and Punjab. We **recommend** that these activities continue but that survey methods be refined and standardized, and that a protocol for habitat assessment be integrated with the dolphin survey work.
2. The Committee **commends** the Pakistan Water and Power Development Authority for establishing a Wetlands Committee to protect aquatic habitat and fauna in the Indus river basin. We **recommend** that the Wetlands Committee formulate policy and guidelines regarding the conservation of river dolphins, with the cooperation of Wildlife, Forest, and Fisheries departments, and appropriate national and international NGOs.
3. The Committee **expresses concern** about the development of the Qadir Pur and Kandkhot gas fields along the center of the Sindh Dolphin Reserve, between the Sukkur and Guddu barrages. We **recommend** that a rigorous assessment of potential impacts be conducted and independently reviewed. The assessment should include provisions for long-term monitoring and appropriate threat mitigation.
4. The Committee **recommends** that a program be initiated to rescue dolphins that enter irrigation canals or pass downstream of the Sukkur Barrage. These animals are lost to the overall population and are at increased risk, whether from human activities or the lack of sufficient water. A dolphin rescue program will need to include substantial public awareness and research components.
5. The Committee **recommends** that a comprehensive investigation be conducted on the ecology of the Indus River between Chashma and Sukkur barrages. Special emphasis should be given to water quality, fisheries, and dolphin capture in fishing gear.

Bangladesh

1. The Committee **acknowledges** that its previously expressed concern about the Bangladesh Flood Action Plan (FAP) has been partially addressed by the work of Smith *et al.* (1998). It also recognizes that the current FAP emphasizes a more integrated approach than did previous versions, with more attention now being paid to environmental impacts and management. We **express concern**, however, about the impacts of specific projects implemented as part of the FAP, and others implemented outside the FAP, by the Government of Bangladesh. These projects include: (1) the Bank Protection and River Training Pilot Projects (FAP 21/22), (2) the Brahmaputra River Bank Protection Works, (3) the Dhaleswari Closure Dam (part of the Jamuna Bridge Project), (4) the Jamalpur Priority Project (FAP 3.1), (5) the Jamuna Bridge Embankments, and (6) the Kalni-Kushiyara River Improvement Project (FAP 6).

   We **recommend** that river dolphins be routinely considered in independently reviewed environmental impact assessments of these projects. Mitigation should involve designs to reduce or avoid impacts in the first place, and the option of abandoning projects with excessive environmental impacts should be considered.
2. The Committee **expresses continuing concern** about the status of dolphins in Kaptai Lake and in the Karnaphuli, Feni, Sangu, and Matamuhuri rivers. We **recommend** that these areas be investigated more systematically than has been done to date.
3. The Committee **commends** the Forest Department of the Government of Bangladesh for their dolphin survey efforts. We **recommend** that this work be strengthened by standardizing survey techniques, conducting training seminars, and including components related to habitat assessment.
4. The Committee **recommends** that protected areas be established for river dolphins and other aquatic fauna in deep pool areas (*duars*) of the Surma and Kalni/Kushiyara rivers. This recommendation can be accomplished as a component of fishery management initiatives for protecting the overwintering habitat of commercially valuable fishes (*boromaach*), including major carp, catfish, and other large migratory species. When effectively implemented, such sanctuaries have been successful in protecting fish broodstock (Bangladesh Water Development Board 1994). The involvement of local fishermen in surveillance and enforcement is essential.

5. The Committee **recommends** that prohibitions against the use, sale, transport, and manufacture of destructive fishing gear, such as *current jals* and *kona ber jals* (small mesh monofilament nets used to catch small fish), *jam jals* (rectangular bottom nets used to catch broodstock of commercially valuable fish species in *duars*), and *vim jals* (extremely fine-mesh fixed nets used mainly to catch prawns) be implemented and strictly enforced. Enforcement will require shutting down marketing centers and eliminating smuggling.

Recommendations applying to all range states

1. Relevant and important literature on dolphin biology, population assessment methods, river ecosystems etc., is generally unavailable to researchers in Asia. We **recommend** that a bibliography of source materials be compiled and that a library be established so that Asian researchers have access to this literature.
2. The Committee **emphasizes** the need for transboundary perspectives for conserving river dolphin populations. A transboundary approach requires cooperation among national and international agencies. One mechanism for establishing links among such agencies within Asia would be the environmental component of the South Asian Association for Regional Cooperation (SAARC).
3. The Committee **recognizes** that conservation initiatives not supported by local people are likely to fail, even if some short-term success is achieved. We **recommend** that public awareness programs be strengthened in areas where they exist and implemented in riverine communities where they do not. Emphasis should be placed on communities located adjacent to existing and proposed protected areas. Such programs must be interactive and respect local values, perceptions, and traditions.
4. The environmental consequences of water development projects are significant and far-reaching. Engineering structures often fragment cetacean populations and reduce the environmental complexity that makes rivers suitable for aquatic species. Water development proceeds with little understanding or concern about the effects on cetaceans and other aquatic organisms. We **recommend** that international and national financial institutions, public and private, be required to address the question of impacts of proposed development on river cetaceans and other aquatic fauna. In every case, water development planning should include an independently reviewed environmental impact assessment, and project financing should include funds to mitigate the harmful effects identified in such an assessment.
5. Preserving river cetaceans requires the availability of sufficient prey. Local people depend on fish and crustaceans as important sources of food and income. In many areas, non-local contractors purchase exclusive fishing rights from regional governments. These professional fishermen often use non-selective fishing methods (e.g. monofilament plastic gillnets and electricity) that deplete fish resources and result in the accidental removals of river cetaceans. We **recommend** that traditional fishing methods (e.g. single hook and lines, throw-nets, seine nets) be encouraged and that riverine fisheries be managed on a sustainable basis for the benefit of local communities.
6. Research and conservation initiatives aimed at river cetaceans can be most effectively implemented by agencies, organizations, and people from the range states. However there is often a shortage of adequately trained people. We **recommend** that education and training be recognized as high priorities and that regional programs in aquatic wildlife and fishery management be developed, with scholarships provided to qualified students.
7. The Committee **recognizes** the difficulty of implementing effective conservation programs when there is so much uncertainty about the status, distribution, life history, ecology, behavior, and habitat of river cetaceans throughout most of their range. The need for standardized survey techniques has been noted by the IUCN/SSC Cetacean Specialist Group (Project #49 of the 1994-1998 Action Plan for the Conservation of Cetaceans; Reeves and Leatherwood 1994), and the ARDC endorses the call for workshops and seminars to address this need. Specifically, we **recommend** that regional meetings be held within Asia to develop appropriate methods and instruct local researchers.

Review of the species

Baiji

The baiji (*Lipotes vexillifer*) inhabits the Yangtze River of China and is undoubtedly the most endangered of the river dolphin species. The baiji is classified by IUCN as Critically Endangered (IUCN 1996), meaning that the species is facing a very high risk of extinction in the wild in the near future. Because of the small population size, and pervasive and increasing environmental problems in the Yangtze River, efforts to conserve the baiji have been reduced to attempting to translocate all remaining animals from the main river into a single "semi-natural reserve" - a blocked-off side channel. The ability of the reserve to provide greater protection for baiji has not yet been proven.

Yangtze finless porpoise

Finless porpoises in the Yangtze River are sympatric with the baiji and considered geographically separate and morphologically distinct from nearby marine populations of the same species in the Yellow and East China seas. The Yangtze finless porpoise is subjected to the same threats as the baiji, and its population is believed to be declining. IUCN classifies the population as Endangered (IUCN 1996).

Bhulan

The bhulan (*Platanista minor*) lives in the Indus River of Pakistan and, following the baiji, is the second most endangered river dolphin. The bhulan survives as a metapopulation of a few hundred individuals, divided into five or fewer subpopulations, of which only three are likely to be viable. Large portions of bhulan habitat were lost as the Indus River was transformed by extensive water development from a dynamic alluvial system into an artificially controlled and subdivided waterway.

Susu

The susu (*Platanista gangetica*) is closely related to the bhulan and inhabits the Ganges/ Brahmaputra/Megna and Karnaphuli river systems. Although the metapopulation of this species probably totals at least several thousand individuals, isolated subpopulations, especially in Nepal and in the Karnaphuli system of Bangladesh, have become extinct or been critically reduced by the barrier effects of dams and barrages. The trend for this species is towards a shrinking range, as dolphins are eliminated from smaller tributaries, and a declining population, as animals are killed in fishing gear and directed hunts, and as they compete unsuccessfully with humans for shrinking water and prey resources. Both the susu and bhulan are classified as Endangered by IUCN (IUCN 1996).

Irrawaddy dolphin

Freshwater populations of the Irrawaddy dolphin (*Orcaella brevirostris*) inhabit the Ayeyarwady (formerly known as Irrawaddy) River of Myanmar, the Mahakam River of Indonesia, and the Mekong River of Vietnam, Cambodia, and Laos. Little is known about these populations, but there is an urgent need to find out more as their habitat is being increasingly degraded by human activities. The following report does not explicitly address Irrawaddy dolphins, but many of the research and conservation issues discussed below can be applied equally to them.

Review and discussion of conservation issues

It is important to recognize that many of the threats discussed below are symptoms of human over-population.

Conservation threats

Accidental removals

Accidental capture in fishing gear is among the most critical threats facing river cetaceans. The absence of systematic effort to investigate the problem, however, makes it difficult to quantify its magnitude or to establish priorities for regulating fishing activities. Information on cetacean bycatch is particularly difficult to obtain because riverine fisheries tend to be decentralized and seasonal. In some cases, there is a strong disincentive for fishermen to report by-catch because they can be prosecuted for causing the death of a dolphin (Sinha and Mohan cited examples from India). In other cases, fishermen wish to keep the carcass for oil, to be sold or used in their own households.

In the Ganges river system, according to Sinha, small-mesh monofilament plastic nets cause the greatest damage because of their extensive use and because dolphins cannot break free of them once entangled. Dolphins also become entangled in large-mesh nets but, apparently, often manage to escape. Sinha reported that the incidence of entanglement changes seasonally for different age classes. Juvenile dolphins are caught mainly in nets set in shallow waters during the onset of the monsoon, while adults are generally caught during the dry season in the main channel.

In the Yangtze River, mortality caused by rolling hooks (long lines with many hooks laid on the bottom), explosives, and electricity is a problem for both baiji and finless porpoises. Fishing with electricity is particularly damaging because of its non-selective effects and the rapid increase in the number of fishermen using this method. Unfortunately, electricity fishing is especially widespread in the center of the baiji's present-day distribution - the middle reaches of the Yangtze River between Dongting and Poyang lakes. All three of these fishing methods are illegal, but regulations are generally not enforced. Destructive fishing methods affect not only river cetacean populations, but also the long-term sustainability of valuable fisheries.

Liu and Wang proposed two possible explanations for the greater present abundance of finless porpoises in the Yangtze River, in comparison to that of baiji. One is that finless porpoises are less vulnerable to entanglement in gillnets. Porpoises are said to be found mainly in shallow water, and gillnets are said to be set mainly in deep water. Porpoises are also said to be less vulnerable to entanglement in rolling hooks because they forage on smaller fish in the water column, while rolling hooks are set on the bottom to catch larger fish, the preferred prey of baiji. Another possibility is that although the bycatch of Yangtze finless porpoises has been high, less attention has been paid to them than to baiji, at least until recently. If this were true, it would mean that the population of finless porpoises in the Yangtze was more abundant initially, or perhaps that porpoises are substantially more productive than baiji.

Another source of accidental removals is escape into irrigation canals. When river cetaceans move through the regulators of irrigation canals they are unable to return to the main channel and have almost no chance of surviving. In Pakistan, Chaudhry reports that dolphins are occasionally found trapped in shallow pools downstream of the Sukkur Barrage during the dry season. Even if these animals can survive in these pools, which is doubtful, they are effectively lost to the overall population of the species.

Deliberate removals

River cetaceans are protected by national, provincial, or state legislation from deliberate killing throughout most of their range. Moreover, traditional practices involving deliberate capture have generally declined except in a few areas. Mohan reported that in the 100km segment of the Brahmaputra River between Jorhat and Dibrugarh, the Misim people kill an estimated 10-15 dolphins each year, apparently for food, and that commercial fishermen occasionally capture dolphins and bury them in the river bank to attract fish. Sinha reported that in the Ganges River near Patna, India, fishermen sometimes kill dolphins to prevent them taking fish from their nets and damaging the nets during entanglement. A small group of fishermen, from a Hindu minority caste in the Sylhet District of Bangladesh, are said to hunt dolphins in the Kalni-Kushiyara River during winter months with long iron-tipped bamboo harpoons (Smith *et al.* 1998).

During the late 1960s and early 1970s several expeditions removed susus and bhulans from the Brahmaputra and Indus rivers, respectively, for research and captive display purposes (Klinowska 1991). During the 1970s and 1980s, a total of 22 Irrawaddy dolphins were removed from the Mahakam River, Indonesia, and Semayang Lake, an appended water body of the same river, for captive display (Tas'an and Leatherwood 1984, Wirawan 1989). The effect of these removals on the dolphin populations in these areas is unknown.

Use of dolphin products

Dolphin oil is sometimes used by people in Bangladesh, India, and Pakistan as a liniment, claimed to be effective for treating rheumatism, burns, and nervous disorders, and as a tonic for treating impotence and asthma. Pregnant women sometimes drink the oil in the belief that it will ensure a healthy baby. Some minority groups in India and Bangladesh eat the meat of river dolphins, but Hindus generally do not. Muslims are discouraged from eating dolphin flesh for religious reasons.

Dolphin meat, entrails, and oil are used by fishermen in the Ganges and Brahmaputra rivers of India and Bangladesh to attract the Schilbeid fish (*Clupisoma garua*) (Motwani and Srivastava 1961, Smith *et al.* 1988). In the Brahmaputra River of Bangladesh, fishermen trail bound pieces of dolphin body parts alongside small boats while sprinkling the water with a mixture of oil and minced dolphin flesh. Small unbaited hooks are used to catch the fish as they come to the surface within the oil slick (Smith *et al.* 1988). Sinha and Mohan have documented similar fishing methods in the Ganges and Brahmaputra rivers of India. Judging by the number of dolphin carcasses needed to supply fisheries that use dolphin oil as an attractant, the number of susus killed, accidentally or deliberately, almost certainly exceeds the sustainable yield.

Interrupted movements

Numerous barriers have been constructed in Asian rivers. These have affected the migration and dispersal patterns of river cetaceans and other aquatic fauna. The bhulan has the most severely fragmented species population, with only three potentially viable subpopulations remaining: those between the Chashma-Taunsa, Taunsa-Guddu, and Guddu-Sukkur barrages (Khan and Niazi 1989, Reeves *et al.* 1991).

Susus in Nepal have been dramatically affected by the construction of barrages. Surveys in 1993 found very few or no dolphins in Nepal's four largest rivers, the Mahakali, Karnali, Narayani, and Sapta Kosi (Smith *et al.* 1994), all known to have once supported dolphins (Shrestha 1989), and all blocked by barrages close to the Nepal/India border. Only the Karnali River contains enough animals for a potentially viable population (Smith *et al.* 1994). The Farakka Barrage interrupts dolphin movement approximately at the center of the Ganges/ Brahmaputra/ Megna complex. There are few barrages in the Brahmaputra system thus far, but the upper and lower Teesta barrages in India and Bangladesh, respectively, probably block dolphin movements. A small subpopulation may be isolated between these two structures. The Kaptai Dam has subdivided the dolphin population in the Karnaphuli system. Scattered reports of sightings in recent years indicate that at least a few dolphins remain in the Kaptai Reservoir. Whether these animals constitute a reproducing subpopulation or, alternatively, are old individuals that have survived since the dam was built remains uncertain. This is the only known example of a reservoir-entrapped cetacean population that might provide insight about adaptation to conditions in an artificial lake.

Baiji apparently were extirpated from the Xinan River after construction of the Xinanjiang Dam in 1956. According to Zhou, a baiji specimen was taken from the river above the dam site one year before construction of the dam. The Gezhouba Dam is the only dam currently in place in the mainstem of the Yangtze. Although two specimens of baiji were reported to have been collected approximately 50km upstream of the dam site (Zhou *et al.* 1977), according to Liu, Wang, and Zhou, neither baiji nor finless porpoises remained upstream of the dam when it was built in the 1970s. The Three Gorges Dam will affect cetacean habitat in the Yangtze River (Chen and Hua 1987), but its location places it upstream of the Gezhouba Dam and the current range of both baiji and finless porpoises, so it will not fragment the population of either.

Barrages may not be absolute barriers to upstream migrations, but there is good evidence from the extirpation or severe reduction of upstream populations of dolphins in Pakistan and Nepal (Khan and Niazi 1989, Smith *et al.* 1994) that barrages at least impede upstream movement to a considerable degree. A small upstream population would quickly go extinct if the number of downstream migrants was greater than the number of upstream migrants. This could occur as the result of partial, as well as complete, obstruction of movement.

Habitat degradation

Large water development projects, including embankments, high dams, and barrages, have had profound effects on the ecology of Asian rivers, and they are certainly the main causes of habitat degradation within some large river environments.

Dam construction and operation cause major changes in the flow regime, sediment load, and water quality of rivers. Dams eliminate many of the dynamic attributes of downstream waters and block the flow-through of sediment essential to the formation of islands and bars. Downstream flows are normally not allowed to overspill riverbanks onto adjacent floodplains. As a result, fish production decreases dramatically. Natural fluctuations in flow, temperature, and detritus loading, which provide optimal conditions for a large number of aquatic organisms, are suppressed by dams, and the number of ecological niches available for supporting diverse communities of riverine biota is reduced.

Barrages are gated dams built across rivers to regulate water discharge. During the monsoon season, the gates are generally left open and then progressively lowered as the flood recedes to divert water into canals for irrigation and sometimes navigation purposes. Reduced water supplies downstream of barrages have meant that dry-season habitat is diminished or eliminated. In the Ganges River below Farakka Barrage, the main river channel often becomes shallow enough to cross on foot, with only scattered pools containing sufficient water to sustain dolphins. Also below Farakka, saline encroachment has presumably reduced the amount of habitat available to river dolphins. Judging by their distribution, it is assumed that *Platanista* dolphins cannot live in marine waters, for either physiological or ecological reasons.

Embankments restrict the flow of water, sediment, and biota to a more uniform channel. When flows begin to recede at the end of the monsoon season, sediments are deposited in the riverbed instead of on the floodplain. Habitat in deep pools can be eliminated or reduced in size because of increased sedimentation and decreased hydraulic complexity. Embankments artificially raise the riverbank, preventing overspill onto the adjacent floodplain, thereby restricting access to critical habitat for the reproduction and growth of floodplain-dependent fish.

In the Yangtze River, more than 1,800 floodgates have been built in tributaries that connect lakes to the main river. These structures have blocked spawning migrations of fish, thereby decreasing the availability of prey for the baiji and Yangtze finless porpoise (Zhou 1989).

Other smaller-scale, but nevertheless destructive, causes of habitat degradation include: (a) sand and gravel mining in tributaries and along the mainstem bank, which alters the hydraulics and substrate composition of fish spawning habitat; and (b) removing woody debris from the river channel, generally for fuelwood consumption, which eliminates essential rearing habitat for juvenile fish and reduces microhabitat complexity.

Vessel traffic

Very little is known about the effects of vessel traffic on river dolphins and porpoises. Ferry crossings, commercial ports, and primary fishing grounds in Asian rivers are generally located downstream of convergent channels or sharp meanders, which are also the preferred habitat of river dolphins. River dolphins are often observed swimming in areas with high vessel traffic, that includes small boats, motorized ferries, and in some locations large container ships and oil tankers, with no visible damaging effects. Mortality from propeller collisions, however, has been reported for baiji and finless porpoises, particularly in the lower reaches of the Yangtze River, where waterways contain high levels of large commercial vessel traffic (Zhou 1992). A single susu was also reported by fishermen to have been killed by the propeller of a cargo boat in the Brahmaputra river near the India/Bangladesh border (Mohan 1996). Dolphins may be more vulnerable to collisions during calving and nursing periods.

Pollution

The water quality of Asian rivers is badly degraded, and burgeoning human populations guarantee that the problem will worsen (Lean *et al.* 1990, Dudgeon 1992). Although governments have taken some measures to control pollution, levels of fecal coliform from human sewage, trace metals from industrial and mining activity, and dangerous compounds, including PCB's, butyltins from boat paints, and dioxins from "green revolution" pesticides remain high and are increasing in many areas.

Although dolphins are frequently observed swimming in highly polluted waters, such as the Hoogly River, near Calcutta, and the Burhiganga River, near Dhaka, pollution may have harmful long-term consequences, especially persistent chemicals and trace metals. Dolphins may be particularly vulnerable to this type of pollution because they feed at the top of the food chain. Chemical and trace metal pollutants bioaccumulate over the life span of the cetaceans, except during pregnancy and lactation, when females 'dump' much of their pollutant loads to their calves, who thereby get a 'headstart' on their own accumulation. A study of susus in the Ganges River showed that residue levels of DDT and PCB were high and that the dolphins were unable to metabolize organochlorines (Kannan *et al.* 1993, 1994). Kannan *et al.* (1994) concluded that river dolphins in India may be at greater risk from environmental contamination than marine cetaceans because pollution discharge sites in the Ganges River are often located in preferred habitat.

Conservation initiatives

Transborder issues

The complete range of migration and dispersal of animal populations must be considered if conservation initiatives are to be effective. Transborder approaches are often essential because cetaceans do not recognize national borders, and conservation threats in one country can lead to the extirpation of dolphins in another. Areas where a transborder approach is appropriate include:

1. the Karnali or Ghaghara River, between the Chisapani Gorge in Nepal and the Girajipur Barrage in India;
2. the Teesta River, between the Upper Teesta Barrage in India and the Lower Teesta Barrage in Bangladesh;
3. the Surma and Kalni/Kushiyara rivers, between the site of the proposed Tipaimukh High Dam in India and the confluence of these two rivers with the Upper Megna River in Bangladesh; and
4. the Ganges River between the Farakka Barrage in India and the confluence of the Ganges and Brahmaputra rivers in Bangladesh.

Protected areas

Several Committee members stressed the importance of incorporating the subsistence activities of local communities into management plans for protected areas. The IUCN (1994) defines protected areas that include community needs as "Managed Resource Protected Areas." An example of an area that meets this definition, at least in principle, is the Tamshiyacu-Tahuayo Communal Reserve in Peru, where local communities manage fisheries for sustainable use (e.g. the use of nets and lances is prohibited during low water) and commercial fisheries are banned (IUCN 1994). This type of protected area may be more readily supported by local people and therefore more viable in the long term - if adequate protection for river cetaceans and their prey base can be assured.

Protected areas should ideally encompass the entire range of seasonal movements and life history stages of the animal populations that they are intended to protect. If this proves impossible, areas where the animals are thought to be particularly vulnerable (e.g. calving or nursery areas) should be targeted as priorities for protection. The extent and configuration of protected areas should be determined according to information on stock structure, movement patterns, suitability of available habitat, and potential for reducing threats. A preliminary list of areas that warrant consideration for the establishment of new protected areas would include:

1. the Indus River between Sukkur and Taunsa barrages in Pakistan;
2. the Karnali or Ghaghara River, on both sides of the Nepal/India border;
3. the Kulsi and Subansari tributaries of the Brahmaputra River in India;
4. the Surma and Kalni/Kushiyara rivers in Bangladesh; and
5. the Yangtze River, in segments encompassing the mouths of Poyang and Dongting lakes in China.

Suggested guidelines for managing protected areas are to:

1. Encourage local people to participate in planning and management.
2. Ensure that any exploitation of aquatic and riparian resources is sustainable and benefits local people.
3. Prohibit and enforce regulations restricting the use of non-selective fishing methods, including gillnets, rolling hooks, explosives, poisons, and electricity.
4. Implement environmental education programs, highlighting aquatic species and explaining the rationale for having the protected area.
5. Ensure enforcement of laws and regulations protecting the cetaceans (and other fauna) for which the protected area was created.
6. Monitor water quality and enforce legal standards.
7. Control the use of motorized vessels, even for enforcement and monitoring activities, as they can be hazardous for cetaceans and other aquatic fauna.

Tourism

Well-managed tourism can contribute to conservation while providing employment and revenue to local communities. However, even well-intentioned tourism may cause harm in some cases. At a minimum, local people should be trained and hired as guides, boatmen, and support staff. Environmentally appropriate standards for tourism programs that include aquatic fauna should be developed and adopted. Tourism must be managed to ensure that it does not contribute to environmental degradation or cultural disintegration. A portion of all profits should be invested in local conservation and social development. Programs that use participating tourists to accomplish research and conservation goals should be encouraged.

Public awareness and community involvement

Local support for cetacean conservation efforts is vital. Local people should be encouraged to become involved in planning and awareness programs that focus on the cultural, economic, and ecological value of aquatic fauna. Whenever possible, cetacean conservation programs should be linked to projects that also benefit local fisheries. Popular media, including video, posters, comic books, and radio should be used to publicize the conservation needs and value of river cetaceans, especially targeting communities within and near protected areas.

Research

Close coordination should be maintained among agencies and scientists involved in research and conservation activities. One mechanism for facilitating coordination would be to conduct collaborative research on focal populations, where standardized methods could be developed and taught to collaborating scientists. These studies could then be linked to broader-scale programs.

Local scientists should be involved in all phases of research activities. Hiring local people as boatmen and observers helps to establish two-way communication between researchers and river communities. Interviews with fishermen and other riverine people can be a good source of information about the behavior and habitat of dolphins. Exchanges during interviews can also help researchers understand cultural attitudes towards these animals.

Procedures for conducting population assessment, habitat assessment, life history and carcass analyses, and stock discrimination studies were discussed (see Appendices 3-6, respectively, for details).

Biodiversity perspective

River cetaceans live within a diverse community of aquatic organisms, including aquatic insects, fish, crustaceans, molluscs, amphibians, and reptiles. Many species are economically important to local communities and have conservation importance because of their endangered status. For instance, threatened crocodilians, including gharials (*Gavialis gangeticus*), muggers (*Crocodylus palustris*), and saltwater crocodiles (*Crocodylus porous*), share aquatic habitat with river dolphins in the Ganges/Brahmaputra/Megna river system. Historically, gharials and muggers shared habitat with the bhulan in the Indus River, and Chinese alligators (*Alligator sinensis*) shared habitat with the baiji and finless porpoises in the Yangtze River, but these species have now been extirpated from those areas. Smooth (*Lutra perspicillata*), Asian small-clawed (*Aonyx cinerea*), and Eurasian (*Lutra lutra*) otters also occur in rivers inhabited by cetaceans, but information on the status of these otters is lacking for most of their range. The overlap in habitat requirements and similarity of conservation threats mean that an ecosystem approach for conserving aquatic fauna in Asian rivers is desirable.

Inter-sessional responsibilities of ARDC members

It is the responsibility of ARDC members to promote recommendations of the meeting and to assist appropriate government agencies, local and international non-governmental organisations, and river basin communities with implementation. It was also agreed that the Committee should produce and distribute a newsletter, preferably twice a year but at least annually, to keep members informed about activities and developments.

Membership, election of Chairman, and venue of the next meeting

At the end of the meeting, Ravindra Kumar Sinha was elected chairman for the next two years. It was agreed that the next meeting should be held in Nepal during late 1998 or early 1999, and that Sapkota, Shrestha, and Jung (non-member participant) would assist the chairman in organizing the event. The possibility was discussed of opening up membership of the Committee to scientists and conservationists from Asian states with freshwater populations of Irrawaddy dolphins (e.g. Myanmar, Laos, Cambodia, Vietnam, and Indonesia). It was agreed that new members would be welcome if funding for their participation could be obtained. The Committee also agreed that government liaison officers from existing member states should be invited to attend the next meeting if they could fund their own participation.

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Appendix 2. List of documents distributed at the meeting

Ahmed, B. A report on the water development schemes and the status and conservation of the shushuk *P. gangetica* in the south-eastern regions of Bangladesh.

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Appendix 3. Population assessment

Credible estimates of abundance do not exist for river cetaceans for most of their range. Although direct counts in segments of some rivers are available, it is often difficult to judge their accuracy. Techniques for surveying river dolphins have not been well developed or standardized, as they have for marine cetaceans. Thus, there is an ongoing need for regional workshops or seminars on survey methods, as specifically recommended in the IUCN/SSC Cetacean Specialist Group Action Plan for the Conservation of Cetaceans (Project #49; Reeves and Leatherwood 1994).

For the foreseeable future, dolphin survey activities will be low-budget programs conducted by researchers with limited experience using the analytical methods generally applied in marine cetacean surveys. Simplicity and economy are, therefore, major considerations (see Smith and Reeves, this volume).

Survey reports should include detailed descriptions of methods, search effort, and environmental conditions, as well as sightings, so that the data can be evaluated and future surveys designed to follow comparable procedures. Assumptions made during data analysis need to be clearly stated. At a minimum, information recorded during a sighting survey should include:

1. the beginning and endpoints of the segment(s) of river surveyed;
2. the total amount of time spent searching for cetaceans;
3. the number of observers and survey vessels;
4. the total number of cetacean groups observed;
5. the number of cetaceans estimated for each group (preferably as best, high, and low estimates; see Smith *et al.* 1994); and
6. locations of all cetacean sightings, referenced to named localities or Global Positioning System coordinates.

Direct counting can be an inexpensive and appropriate method for estimating the absolute abundance of cetaceans in narrow channels. It is imperative, however, that a rigorous protocol be followed and that sufficient time be spent searching for the animals in preferred habitat to account for long submergences. Preferred habitat of dolphins in Asian rivers is generally located in deep pools downstream of channel convergences and sharp meanders, and upstream and downstream of mid-channel islands (see Chen and Hua 1989 and Hua *et al.* 1989 for baiji; Pilleri and Zbinden 1974 and Bhatti and Pilleri 1982 for bhulans; Kasuya and Haque 1972, Smith 1993 and Smith *et al.* 1998 for susus; and Lloze 1973 and Smith *et al.* 1997 for Irrawaddy dolphins); no published information is available on the habitat of the Yangtze finless porpoise.

Estimating absolute abundance (i.e. the total number of animals within the segment of river being studied) with sampling methods requires a measure of precision (i.e. associated error due to sampling bias) and entails applying population assessment methods that are generally more expensive and complex than survey efforts that have been conducted to date. Sampling techniques should be investigated before attempting to use them for estimating absolute abundance in wide channels; see Vidal *et al.* (1997) for a discussion of sampling techniques used to investigate the abundance of Amazon river dolphins (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the upper Amazon River. Problems that will need to be addressed are: (1) the clumped distribution of dolphins within discrete sections of river channel, (2) the difficulty of following random or standardized transect lines within complex river morphology, and (3) biases in counts and group group size estimates caused by the fact that submerged animals can be missed.

The relative abundance of river cetaceans (i.e. an index used for detecting population trends over time) can often be estimated with less effort and expense than estimating absolute abundance, especially in wide channels. Resource managers need to be made aware that detecting population trends from a series of relative abundance or absolute abundance estimates requires multiple surveys conducted during the same season and similar water stages over a several-year period. The statistical power to detect population trends must be considered because the consequences of failing to detect a trend due to small sample sizes could lead to an unwarranted management recommendation that no conservation action is needed (Forney *et al.* 1991, Taylor and Gerrodette 1993)

Appendix 4. Habitat assessment

Broad-scale information on habitat should be collected routinely during cetacean surveys. Positions from GPS coordinates can be plotted on a recent map of the river system. Morphological characteristics of cetacean habitat should be recorded according to a simple classification scheme, such as found in Kellerhals and Church (1989). Biological characteristics, including the presence or absence of riparian vegetation and other aquatic fauna, and human activities, including the type and intensity of fisheries and vessel traffic, should be recorded. These data can be used to analyze preferences of cetaceans for various types of habitat and to identify anthropogenic factors that could explain changes in the distribution and abundance of animals over time.

Core areas, where cetaceans are regularly or seasonally found at high densities, should be identified for more intensive research and management. Habitat studies in core areas could include more detailed investigations on:

1. species composition and catch-per-unit-effort indices of local fisheries;
2. environmental requirements of cetacean prey;
3. morphologic and hydrologic conditions during different phases of the annual flood cycle;
4. composition and status of aquatic fauna (e.g. turtles, otters, and crocodilians) coexisting with river cetaceans; and
5. changes in the way cetaceans use habitat according to season, water level, and nature and amount of human activity.

These data can help managers acquire an ecosystem perspective.

Appendix 5. Life history and carcass analyses

Information on the life history of river cetaceans is useful for understanding the general biology of species, discriminating populations, evaluating the viability of fragmented populations, and assessing the feasibility of translocation. Investigations are limited, however, by the paucity of specimens and by difficulties of photo-identification, tagging, and obtaining biopsies.

Kasuya and Yamada conducted dissections of two *Platanista gangetica* specimens before and during the meeting. These helped demonstrate the scientific importance of making full use of any fresh specimens that become available. For example, Yamada noted that the shape, position, and fiber direction of major shoulder muscles differed from published descriptions.

A detailed description of methods for conducting life history studies and sampling river dolphin carcasses is beyond the scope of this report (see Geraci and Lounsbury (1993) and Jefferson *et al.* (1994)). The steps that should be taken while processing the carcass of a small cetacean include:

1. Determine the species and sex.
2. Take photographs from dorsal, ventral, and lateral perspectives.
3. Record the condition of the carcass.
4. Take standard external measurements.
5. Examine mammary glands and attempt to express milk.
6. Measure blubber thickness to investigate nutritional condition.
7. Investigate the cause of death by looking for net or hook marks, contusions, lacerations, and internal hemorrhaging.
8. Examine, collect, and preserve stomach contents for investigating prey composition.
9. Collect teeth for age estimation from growth layers.
10. Preserve and examine reproductive organs to evaluate development stage and reproductive history.
11. Collect and preserve tissue samples for genetic and toxicology studies.
12. Collect and identify parasites to help identify populations and evaluate the sublethal consequences of pollution.
13. Record and collect fetus, if present.

Very limited information on the life history of river dolphins can be obtained during sighting surveys. The presence of neonates should be recorded to document calving season(s) and to establish approximately where calving occurs. Adults and juveniles can sometimes be distinguished. A record of the location and number of juvenile, adult, and "unknown" dolphins may be useful for identifying age-class differences in seasonal movements and habitat use. The sex and specific age classes of animals cannot be routinely determined in the field. Field data accompanied by complete age and sex classifications should be regarded with suspicion.

Appendix 6. Stock discrimination

Conservation strategies for all species, including freshwater cetaceans, should aim to preserve the full range of genetic variation. Thus, strategies need to be directed towards populations that are, by definition, presumed to be uniquely adapted to their range.

Whenever possible information from both genetics and morphology should be used to distinguish population units. Information from bioacoustics, organochlorine levels, and parasite species can also be used. Skin or liver samples should be collected and stored in a 20% DMSO and saturated sodium chloride solution. A sterilized knife or disposable razor blades should be used to avoid cross-contamination of samples. A small amount of tissue can be obtained from animals caught accidentally in fishing nets by scraping skin from their dorsal fin or flukes. Sometimes a piece of sloughed skin can be found in the net.

Vials containing tissue samples should be labeled both inside and outside with the date, location, sex of the animal, and name of the collector. Samples should be stored at a central repository within each country, preferably an institution with a CITES export permit. Although the actual analysis of genetic materials may have to be conducted abroad, local scientists should be involved in research activities to the maximum extent possible.

A list of museum specimens of river cetaceans housed within and outside of Asia should be compiled. Standard measurements of available skeletal materials should be taken, ideally by a single researcher in order to reduce variability.

Chapter 2

Water Development Issues

Report of the Workshop on the Effects of Water Development on River Cetaceans, 26–28 February 1997, Rajendrapur, Bangladesh

Edited by B.D. Smith and R.R. Reeves

Introduction

River dolphins and porpoises are among the world's most threatened mammal species. They inhabit some of the largest river systems of southern Asia, and their environmental requirements link them to food and water-security issues in the world's most densely populated human environments. River cetaceans historically ranged upstream from the estuarine zone to rocky barriers and shallow reaches in headwater streams. Populations of river cetaceans have declined dramatically in recent years and much of their range has been lost (see Mohan 1989, Perrin and Brownell 1989, Reeves *et al.* 1991, Reeves *et al.* 1993, Leatherwood 1994, Leatherwood and Reeves 1994, Smith *et al.* 1994, Zhou *et al.* 1994, Smith 1996).

River cetaceans are threatened in many ways. Over-harvesting of fish and crustaceans reduces the availability of their prey. Deforestation and intensive floodplain farming increase the sediment load of river channels and degrade cetacean habitat. Industrial effluents, human sewage, mining waste, and agricultural runoff contaminate water quality. Dolphins and porpoises die from accidental entanglement in gill nets, and mortality rates increase as the use of these nets spreads. Possibly the most significant threat to river cetaceans is the construction of large water development structures, most notably dams, barrages, and levees.

The environmental consequences of water development projects are significant and far reaching. These structures fragment populations and reduce the environmental complexity that makes rivers suitable for aquatic species to live. Water development proceeds, however, with little understanding or concern about the effects on cetaceans, or on the assemblage of other life that shares their habitat.

The aim of the Workshop on the Effects of Water Development on River Cetaceans, held 26–28 February 1997 in Rajendrapur, Bangladesh, was to convene a group of experts in relevant fields who would share information and develop problem-solving approaches. Participants included cetacean biologists, a river ecologist, a fluvial geomorphologist, hydrological engineers, and officials from irrigation and power authorities. A workshop of this type had been recommended in the IUCN/SSC Cetacean Specialist Group Action Plan for the Conservation of Cetaceans (Reeves and Leatherwood 1994) and in the Report of the First Meeting of the Asian River Dolphin Committee (Reeves and Leatherwood 1995). The workshop was formally endorsed by the Society for Marine Mammalogy, the U.S. Marine Mammal Commission, and the Scientific Committee of the International Whaling Commission.

The agenda of the meeting focused on:

1. developing guidelines for use by water authorities to ensure that the needs of river cetaceans are taken into account in planning and decision-making;
2. defining essential habitat characteristics for river cetaceans;
3. identifying the impacts of water development projects on river cetaceans;
4. considering the ecological requirements of other riverine fauna occurring within the range of river cetaceans;
5. evaluating technical options to eliminate or reduce the effects of water development on river cetaceans; and
6. completing a register of water development projects affecting Asian river cetaceans.

A working hypothesis was that any water development that causes large-scale alterations in natural flow will have pervasive and persistent effects on river cetaceans and other native biota. We emphasized the functional significance of hydrological dynamics and morphological structure for explaining the ability of Asian rivers to support cetaceans and a wide array of other species. We also considered the barrier effects of structures, including dams, barrages, and embankments, built in or along river channels.

Species and distribution

Obligate river dolphins live only in fresh water; their physiological and ecological requirements apparently make it impossible for them to live in marine waters (Leatherwood and Reeves 1994). In Asia, all three species of obligate river dolphins are classified by IUCN as Endangered or Critically Endangered (IUCN 1996). Listed in order of the most threatened to the least, these are the baiji (*Lipotes vexillifer*), in the Yangtze River of China; the bhulan (*Platanista minor*), in the Indus river of Pakistan; and the susu (*Platanista gangetica*), in the Ganges/Brahmaputra/Megna and Karnaphuli river systems of Nepal, India, and Bangladesh.

Other small cetaceans normally associated with marine environments, but that often or sometimes range far upstream in large Asian rivers, include: the finless porpoise (*Neophocaena phocaenoides*), in the Yangtze River of China, and the Irrawaddy dolphin (*Orcaella brevirostris*), in the Ayeyarwady (formerly Irrawaddy) River of Myanmar (formerly Burma), Mahakam River of Indonesia, and Mekong River of Laos, Cambodia, and Vietnam. Finless porpoises in the Yangtze River are considered a discrete geographical population and, as such, are classified by IUCN as Endangered (IUCN 1996). Freshwater populations of Irrawaddy dolphins have been little studied but are thought to be in decline.

Characteristics of Asian rivers

Physical

The seasonal flood cycle and erodible alluvial soils of Asian rivers determine their physical structure over time and area. Sediments are deposited at the inside bend of meanders, forming alternate point bars, and eroded at the outside bend of meanders, causing the main channel to migrate across the floodplain. River flows converge in pools, causing scouring, and diverge in riffles, causing deposition; these effects are greatly magnified at high flows (Brookes 1996). The relatively flat geography crossed by large Asian rivers means that tectonic forces or engineering projects that constrain discharge can dramatically affect the direction and hydraulic character of channel flow.

During high flows, the main channel overflows the riverbanks and the floodplain becomes an integral part of the surface flow system. The large amounts of sediments deposited on floodplains provide a record of formative factors, including climate change and human activity (Lewin 1996). A great proportion of river sediments may also be derived from the erosion of floodplain materials during flood recession so that the physical and chemical characteristics of these materials largely determine the water and sediment characteristics of the main channel (Lewin 1996).

Rivers are intimately linked to groundwater aquifers (Ward and Stanford 1989). A slight drop in the height of the water table can decrease the availability of water retained in low-lying areas of the floodplain during the dry season (Welcomme 1979), and groundwater returns are a significant component of river discharge (Lewin 1996).

The physical, and therefore biological, character of large rivers is shaped by a dynamic interaction of longitudinal (downstream), lateral (on and off the floodplain), and vertical (river-groundwater) processes. Although the specific features of river channels change over time, the average form remains the same in the absence of human intervention (Brookes 1996). Changes that exceed the boundaries of this dynamic equilibrium often have severe ecological consequences.

Ecological

With their hydrological dynamism and morphological complexity, Asian rivers provide heterogeneous habitat that supports high biotic diversity. Hydraulic refuge, the seasonal availability of the floodplain, and the lateral exchange of materials between the floodplain and main channel are among the features of these river systems that make them suitable for cetaceans.

Eddy counter-current pools are located downstream of meanders and channel convergences and divergences, and upstream and downstream of mid-channel islands. The attractive force of eddy currents traps primary nutrients and woody debris and gives protection to riverine organisms at all trophic levels (i.e. single cell organisms to megafauna, such as cetaceans and crocodilians) from the strong hydraulic force of the main flow. Counter-currents retain nutrients (e.g. phosphorous and reduced organic carbon) in a circumscribed area, thereby creating a patchy distribution of biotic productivity and diversity (Smith 1993, Smith *et al.* 1996). Woody debris, trapped by counter-currents and deposited on adjacent point bars, provides substrate for algal primary producers and bacteria and fungal consumers, and an array of cover and hydraulic gradients, which support multi-species fish and invertebrate communities (Sedell *et al.* 1984).

Counter-current pools are the primary habitat of river dolphins. River dolphins often take advantage of the ecotone created by the transition between scour pools and running waters, visible as eddy turbulence. They prey on species migrating along the mainstem, while monitoring foraging opportunities from within the hydraulic refuge of counter-currents (Smith 1993). Counter-current areas are biological "hotspots" within large Asian rivers, and they are crucial for preserving native biodiversity.

Even though their distribution may be centered in eddy counter-current areas, dolphins and other large predators in Asian rivers are ultimately dependent on production that originates on laterally-linked floodplains. Massive amounts of nutrients and organic matter are cycled back into the main channel during the flood season, resulting in biological productivity greater than if the floodplain were permanently inundated or permanently dry (Junk *et al.* 1989). Many fish and crustacean species migrate during high flows to seasonally available floodplain habitat. Fish production is directly related to the area of available floodplain, while the mainstem of the river-floodplain system is used as a migration corridor providing access to resources and refugia (Junk *et al.* 1989).

How water development projects affect river dolphins and porpoises

High dams

Dam construction and operation cause major changes in the flow regime, sediment load, and water quality of running waters. Dams degrade the dynamic attributes of downstream waters and eliminate the flow of sediments essential to the formation of stream channel islands and bars (Ward 1975, Sioli 1986, Ligon *et al.* 1995). Downstream discharge is prevented from reaching the critical magnitude necessary for water to overspill riverbanks onto adjacent floodplains, thereby resulting in dramatic decreases in biological production (Junk *et al.* 1989). Dams suppress natural fluctuations in flow, temperature, and detritus loading, which encompass optimum conditions for a large number of aquatic organisms, and the number of ecological niches available for supporting diverse biotic communities is reduced.

Barrages

Barrages are gated dams built across rivers to regulate water discharge. In the Asian subcontinent barrages are used primarily to divert water into canals for irrigation and sometimes to facilitate navigation (as in the case of Farakka barrage in the Ganges River of India). During monsoon season flows, the gates are generally left open. They are then progressively lowered as the flood recedes. Although downstream movement of cetaceans through barrages can occur while the gates are open, high-velocity currents within the openings probably prevent, or at least impede to a considerable degree, upstream movement. The persistence of isolated upstream subpopulations would be profoundly affected if more animals emigrated downstream past a barrage than immigrated into the subpopulation (Reeves *et al.* 1991). Even if such attrition were not occurring in upstream subpopulations, the effects of fragmenting a species population can increase its vulnerability to environmental, demographic, genetic, and aetiological threats (Gilpin 1987). It may be instructive to consider that dolphins no longer occur in sufficient numbers to constitute viable populations upstream of barrages in the Mahakali, Sapta Kosi, and Narayani rivers of Nepal (Smith *et al.* 1994).

Barrages also block migratory routes of anadromous and catadromous fish species. A dramatic illustration of the impact of barrages on migratory fish is that after completion of the Farakka Barrage, landings of hilsa (*Hilsa ilisha*), a commercially important anadromous fish, declined upstream of the barrage by more than 99% (Jhingran 1982). The ecology of rivers below barrages is also altered such that during the dry season, downstream flows are often reduced to only what seeps beneath the structure.

Closure dams

Closure dams cut off the flow of a distributary that is causing unwanted erosion or flooding. These dams eliminate downstream habitat in the former distributary channel and generally cause counter-current pools, located in the old channel divergence, to fill with sediments.

Levees or embankments

Levees constructed along the shoreline of a river contain the flow of water, sediments, and biota in a more confined and uniform channel. By artificially raising riverbanks, these structures prevent overspill onto the adjacent floodplain. When high flows begin to recede at the end of the monsoon season, sediments are deposited in the riverbed instead of on the floodplain. This decreases hydraulic complexity and often eliminates or reduces the size of counter-current pools. Embankments restrict access to floodplain habitat, with devastating effects on the reproduction and rearing of floodplain-dependent fishes and crustaceans (Ward and Stanford 1989).

Withdrawal of water

Dry-season withdrawal of surface water, whether by diversion, pumping, or evaporation from man-made reservoirs, reduces the amount of habitat available for cetaceans and other aquatic organisms. Overwintering fish broodstocks become increasingly vulnerable to overfishing and natural mortality as water supply is reduced. The withdrawal of subsurface water through tubewells can also lower the water table and reduce year-round aquatic habitat in low-lying areas of the floodplain (Welcomme 1979). This process has potentially drastic long-term implications for maintaining sufficient dry-season flows in the main channel.

Dredging and loop cutting

Some reaches of rivers are dredged to benefit navigation and reduce flooding. Smaller rivers are straightened by eliminating meanders and loops. Loops are cut by gouging a shallow canal across the base of the loop and allowing the monsoon flood to excavate the bypass channel. This practice results in the deposition of large amounts of sediment and the elimination of counter-current pools downstream of the cut.

Overview of water development projects in Asian countries with river cetaceans

(See also Smith *et al.*, this volume – Register of water development projects; figure references in this report refer to the maps in that paper.)

Bangladesh

Water development projects in Bangladesh are largely focused on flood protection and irrigation. A notable exception is Kaptai Dam in the Karnaphuli River located in the far south of the country, built primarily for hydropower. Following floods in 1987 and 1988, the World Bank was asked by the Government of Bangladesh to coordinate an action plan for flood control. The original Flood Action Plan (FAP) advocated the containment of major rivers in Bangladesh by constructing an extensive series of embankments along both banks. The plan generated great controversy, due to its extensive environmental and social implications, and was subsequently re-evaluated. Although still controversial, the current FAP recognizes that many of the earlier technical solutions for flood control could have significant problems. The scope of the current FAP has been scaled down, but several large embankment and dredging projects are still being implemented (see Smith *et al.* 1998).

At least 16 water development projects in Bangladesh affect rivers that historically supported or currently support dolphins. These include one high dam, six closure dams, two barrages, five levee or embankment projects, and two dredging projects (Figure 1). All of the dam and barrage projects have already been constructed. The levee and dredging projects are underway. The completed projects mentioned above do not include extensive embankment and dredging projects implemented before the FAP.

China

The Yangtze River system has been highly modified by the construction of flood control and irrigation projects in tributary lakes and streams. Numerous lakes along the river have been cut off from the river mainstem, precluding the natural movements of fish and other organisms that depended on the lakes for reproduction and foraging habitat. Upstream habitat in the main river has been eliminated by the Gezhouba Dam, and dolphins and porpoises are prevented by smaller dams from entering most or all Yangtze tributaries. The baiji apparently was extirpated from the Xinan River after construction of a high dam in 1956.

At least six water development projects in China affect rivers that historically supported or currently support cetaceans. These include four high dams, one dredging project, and one ship lock (Figure 2). All of these projects have already been constructed, except for the Three Gorges Dam, which is underway. These projects do not include numerous smaller projects, which, in combination, have greatly affected ecological conditions in the Yangtze River.

India

High dams and barrages have greatly altered flows and fragmented the dolphin population in the Ganges river system of India. Several Indian barrages affect river dolphins in Nepal and Bangladesh. The most notable of these is the Farakka Barrage, which divides the overall population of Ganges susus at approximately the geographical center of their range. The Kanpur Barrage will further fragment susus in the Ganges mainstem. The Girija, Gandak, and Kosi barrages have isolated dolphin populations in their farthest upstream range in Nepal. The Upper Sarda Barrage has eliminated the dry season water supply to the Sarda River in Nepal. The Indrapuri Barrage in the Son River of India has isolated an upstream population and no dolphins occur downstream during the dry season because of a lack of water. If constructed, the Tipaimukh High Dam will affect cetaceans in downstream waters of the Surma and Kalni-Kushiyara distributaries in Bangladesh.

At least 42 water development projects in India affect rivers that historically supported or currently support dolphins. These include 20 high dams and 21 barrages (Figure 3, except the Tipaimukh High Dam, which is on Figure 1). All of these projects have already been constructed, except the Kanpur Barrage and Tipaimukh Dam, which are underway and planned, respectively.

Nepal

Barrages have been built in Nepal's four largest rivers, all of which are tributaries of the Ganges. The Karnali River contains the last remaining population of susus that might have enough animals to be viable. These dolphins are threatened by the proposed construction of the Chisapani high dam.

At least eight water development projects in Nepal affect rivers that historically supported or currently support dolphins. These include two high dams, four barrages, and one embankment or levee project (Figure 3). All of these projects have been constructed, except the three high dams – Chisapani, Pancheshwar, and Arun III, which are in advanced stages of planning.

Pakistan

The Indus River Basin has been highly modified by an extensive network of dams and barrages, and the bhulan population is severely fragmented. Although Reeves *et al.* (1991) suggested that five or six subpopulations might exist, it is generally assumed that only three of these are potentially viable.

At least 25 water development projects in Pakistan affect rivers that historically supported or currently support dolphins. These include eight high dams and 17 barrages (Figure 4). All of these projects have already been constructed, except the Kalabagh high dam and the Ghazi-Gariala Barrage, which are underway.

Guidelines for considering the needs of river cetaceans during the planning and management of water development projects

1. Ecosystem Integrity. Maintaining the natural attributes of a river is critical for conserving river dolphins, porpoises, and other native species. In evaluating options for water development, four basic principles of riverine ecology must be kept in mind:

a) There is no "surplus" water; any large-scale withdrawal will have ecological consequences.
b) The floodplain is an integral part of the river.
c) An alluvial river must be allowed to migrate.
d) Rivers need to maintain their natural temporal and spatial variability.

2. Required Habitat Conditions. River cetaceans need suitable alluvial habitat to survive and reproduce. River flows must be sufficient year-round to allow free movement between deep pools. Fresh water of adequate depth, current speed, and temperature is essential.

3. Dam Siting and Management. Dams drastically affect downstream habitat. If built, dams should be located in tributaries, or as a last resort, in the mainstem upstream of major tributaries. This placement is necessary to ensure adequate sediment supplies and spawning habitat downstream. Large daily fluctuations in flow should be avoided. Equilibrium between sediment erosion and deposition is necessary to maintain essential habitat features. This can often be accomplished by managing flow releases according to environmental criteria.

4. Barrier Effects. The siting and operation of dams or barrages must recognize risks associated with barrier effects (which apply to other riverine fauna as well as cetaceans, including crocodilians, turtles, and many migratory fishes). In some river systems, individual cetaceans are known to move over distances of at least tens of kilometers. How far and under what conditions these animals migrate are uncertain. Dams completely and permanently divide populations. Barrages interrupt free movement, at least during much of the year, and probably restrict gene flow. Such effects increase a population's vulnerability to extinction.

5. Fish Migrations. The availability of sufficient prey is essential for maintaining healthy populations of dolphins and porpoises. Water development projects often block migratory pathways within the river channel and onto the floodplain, causing declines in the stocks of fish and crustaceans. Fishways should accommodate the specific needs of species in their new, modified environment. Fishways should be designed so that their operation can be modified in the light of experimentation and monitoring. Where fish and crustacean stocks have been depleted, floodplains should be managed to ensure natural spawning and rearing habitat.

6. Migration Corridors. No technical solution is available to mitigate the barrier effects of dams or barrages on riverine cetaceans, although the construction of migration corridors has been discussed. At present, far too little is known about the behavior of river dolphins and porpoises to design such corridors. Appropriate research on behavior is needed before a cetacean "swimway" can be designed and tested.

7. Interventionist Approaches. Before interventionist approaches to mitigating the effects of water development on river cetaceans – for example, translocation – can be seriously considered, much more needs to be learned about the animals' movements, behavior, and habitat requirements. Obtaining such information will require extensive field studies and wider application of new techniques (e.g. telemetry, genetic analyses, and habitat assessment with aerial photographs and geographic information systems).

8. Captive Propagation. Maintaining a self-sustaining captive population of river cetaceans or porpoises would be an extremely expensive and controversial proposition – if it could be done at all. At present, there is no basis for adopting captive propagation as mitigation for water development. Wild animals should be conserved as integral parts of natural ecosystems.

9. Assessing Environmental Impacts. Aquatic biodiversity, including dolphins and porpoises, must be considered when assessing the impacts of planned water developments. Adequate information on the pre-development ecological conditions of the river is essential. Cumulative and synergistic impacts of multiple developments should be considered. Methods for assessing potential impacts should be standardized. Results can then be used for comparison between projects and for post-development monitoring. An independent panel of qualified experts should evaluate environmental impact assessments. If the impacts of a water development project are judged to be severe and cannot be reduced to acceptable levels, then the option of not constructing the project should be considered.

10. Research and Monitoring. Post-development empirical studies are needed to monitor the operational aspects of water development projects, as well as the effects on upstream and downstream populations of cetaceans and their habitat. Based on what is known about the life history of riverine cetaceans, it is likely that it would take tens of years to know for certain that an affected population had stabilized or was decreasing. Detecting trends in the abundance of small populations is difficult and requires intensive survey effort. Aerial photo reconnaissance and remote sensing imagery are required for regional habitat inventories. Given the wide range of river channels inhabited by river dolphins, a sliding scale of resolution is necessary: 1:6,000 for small channels and 1:12,000 for large channels. Photo reconnaissance should be repeated every 5 years, or following a significant flood.

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Register of Water Development Projects Affecting River Cetaceans in Asia

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(For addresses please refer to the end of the chapter).

Introduction

Water development projects have dramatically affected the ecology of river systems throughout southern Asia. River cetaceans are among the organisms that are particularly vulnerable to the effects of interrupted movements and habitat degradation caused by these projects (see Chen and Hua 1989, Reeves *et al.* 1991, Reeves and Leatherwood 1994, Smith *et al*. 1998, Ahmed, this volume, Liu *et al.* this volume, Sinha, this volume, Smith and Reeves, this volume, Reeves and Smith 1999). An important step in addressing the threats posed by water development is to identify projects affecting the waterways inhabited by freshwater dolphins and porpoises. The following register represents an attempt to accomplish this task, but we admit that our information is incomplete. Also, new projects undoubtedly will be proposed and undertaken in the future. Important information about water development projects is often classified or buried in consultant reports. Governments, international financial institutions, and private companies should make this information available. Transparency is essential to any meaningful assessment of the environmental impacts of water development and the potential for mitigation.

All river cetaceans in Asia are classified by IUCN as Endangered or Critically Endangered (IUCN 1996). In China, water development threatens the baiji (*Lipotes vexillifer*), the world's most endangered cetacean, as well as an endemic freshwater population of finless porpoises (*Neophocaena phocaenoides*). Water development threatens the bhulan (*Platanista minor*) in Pakistan and the susu (*Platanista gangetica*) in Nepal, India, and Bangladesh. It also affects the Irrawaddy dolphin (*Orcaella brevirostris*), a generally marine species that occurs far upstream in the Mahakam river system of Indonesia, the Ayeyarwady (formerly Irrawaddy) river system of Myanmar (formerly Burma), and the Mekong river system of Vietnam, Cambodia, and Laos (classified by IUCN as Data Deficient; IUCN 1996). The present register does not address this dolphin species or the rivers that it inhabits.

Sources of information for the register are from indicated documents and personal observations of the editors. For convenience, the register is organized by country. It is important to recognize, however, that projects located in one country often have significant and far-reaching effects on the riverine environments in other countries. The impacts of projects must be addressed from a river basin perspective.

Glossary of hydrological and engineering terms used in the register *

Barrage: a low gated dam used to divert water for irrigation, flood control, and/or navigation purposes. Normally the gates remain closed during the low-water season and are opened during the high-water season with differing levels of regulation in between.

Catchment area (also known as a watershed): a part of the earth's surface that is occupied by a drainage system and consists of a surface stream with all its tributaries and impounded bodies of water.

Closure dam (also known as a dike): a dam without an outlet that creates a reservoir, prevents the inflow of a distributary (generally to reduce bank erosion), or blocks salt water incursion from an estuary to protect upstream freshwater supplies.

Dredging: the scooping, or suction of underwater material from a waterway, usually undertaken to maintain a navigation channel but also to construct bridge pilings and to facilitate water flow and thereby prevent flooding.

Embankment (also known as a levee, revetment, floodwall, or bund): a structure paralleling a channel that confines river flow within a specified area and prevents it from overflowing onto the adjacent floodplain during all or part of the seasonal flow regime. Embankments may or may not be accompanied by groynes (see below).

Gross storage capacity (also known as reservoir volume): the volume of a reservoir when filled to normal pool or water level.

Groyne: a structure oriented crosswise to a channel for deflecting water flow to prevent erosion of an embankment.

Hard point (also known as a guide bund): an embankment built on the outside edge of a meander or along the banks of a distributary or tributary junction to direct flow away from areas of channel erosion.

High dam: an artificial barrier with a height of 15m or more that is constructed across a watercourse to impound water and regulate flow for generating hydroelectricity and flood prevention.

Reservoir: a man-made water body for storage, regulation, and controlled release.

* Some of the definitions were adapted from the Glossary of Hydrologic Terms compiled by the US National Oceanic and Atmospheric Administration, available at: http://www.srh.noaa.gov/wgrfc/glossary/s.html

Abbreviations used in the register

AF	average flow
CA	catchment area
CMS	cubic meters per second
DFD	design flood discharge
EFV	elevated fill volume
GH	gate height at outlet
GSC	gross storage capacity
HH	hydraulic head
HMF	historical maximum flow
IPC	installed power capacity
LB	length of barrage
LD	length at top of dam
MDC	maximum discharge of canal
MHAF	maximum height above foundation
NB	number of bays (outlets)
NSL	normal storage level
SA	submergence area
WB	width of bays
?	information uncertain or unavailable

Register of Water Development Projects Affecting River Cetaceans in Asia

BANGLADESH

At least 16 water development projects in Bangladesh affect rivers that historically supported or currently support dolphins. These include one high dam, six closure dams, two barrages, five embankment projects, and two dredging projects (Figure 1). The Padma (Ganges River in India) has also been greatly affected by the Farakka Barrage, and the Kalni/Kushiyara and Surma rivers will be affected if plans proceed to construct a high dam on the Barak River (see India section).

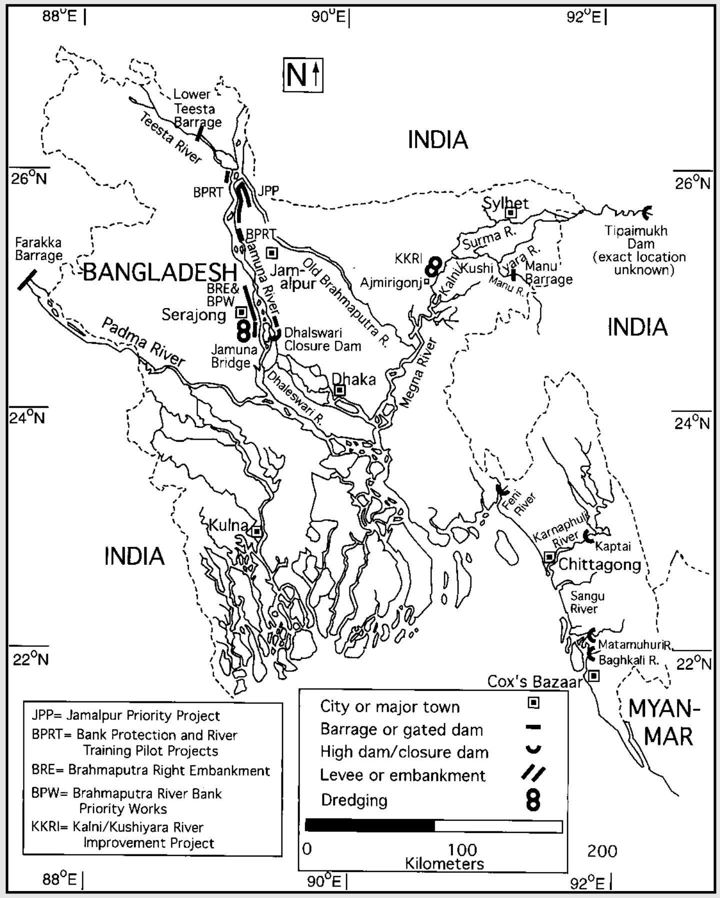

Figure 1. Map of the Padma (Ganges)/ Jamuna (Brahmaputra)/Megna and Karnaphuli/Sangu river systems in Bangladesh showing barrage, high dam, embankment, and dredging projects (planned, underway, and already constructed).

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
High Dams						
Kaptai Dam	Karnaphuli River at Kaptai, Chittagong	Hydropower, flood control, and navigation	Earth dam CA=11,000km^2 DFD=15,194cms LD=671m MHAF=46m SA=1,165km^2	Completed in 1961	With the exception of a single dead dolphin found floating and a report of two sightings in 1992, we have no information on the occurrence of dolphins in the reservoir. Recent surveys conducted from approx. 5km below the dam to the river mouth recorded 28-37 dolphins.	2,10,11,12
Closure Dams						
Bagkhali Dam (exact name unknown)	Bagkhali River at Jhilonja near Cox's Bazaar	To prevent saltwater intrusion so that upstream water can be abstracted for irrigation.	Water-filled rubber tube 100-120m long and approx. 4m high.	Construction completed around 1994	Surveys of the 10.4km segment of river below the dam in January 1999 found no dolphins. Local people reported occasionally observing dolphins downstream of the dam throughout the year and upstream of the dam during the monsoon season. A lower jaw of a susu was recovered from a fisherman who reportedly caught it just below the dam in January 1998.	11

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Dewanganj Dam (exact name unknown, not shown on map)	Dewanganj, a branch of the Old Brahmaputra River	?	?	Year of completion unknown. Dam apparently failed.	?	9
Dhaleswari Dam (part of the Jamuna Bridge Project)	Dhaleswari River at the divergence of the Jamuna River near Sirajgonj	Protection of bridge foundation from erosive floods.	Elimination of flow from the upstream inlet. Flows will be reduced by 21% in the downstream section and by as much as 51% in the Pungli, Louhajang, and Elongjani distributaries	Construction completed around 1996	No information is available on the occurrence of dolphins in the Dhaleswari River or Pungli, Louhajang, and Elongjani distributaries. Dolphins have been observed farther downstream in the Turag and Burhiganga rivers.	9,12
Feni Dam	Mouth of Feni River near Feni	Flood control, irrigation, and to stabilize water levels in the Feni, Muhuri, Kalidas, and Pahari rivers.	LD=3.4km NSL=3.8m GSC=27.1 million m^3 Associated regulator: NB=40 DFD=2,718cms	Completed in 1986	No information is available on the historical or current occurrence of dolphins in the Feni River/Reservoir or the Muhuri, Kalidas, and Pahari tributaries.	3, Dam signpost
Fulchari Dam (exact name unknown, not shown on map)	Fulchari distributary of the Jamuna River	?	?	Year of completion unknown. Dam apparently failed.	?	9
Matamuhuri Dams (3)	Matamuhuri River in all three channels entering the delta	To prevent saltwater intrusion so that upstream water can be abstracted for irrigation	The dams are approximately 50m long and 3m high.	These dams are reported to have been rebuilt yearly since the early 1970s.	Conflicting reports from local people of dolphins occurring above and below the dams. Surveys upstream of the dams in January 1999 found no dolphins.	11
Barrages						
Manu Barrage	Manu River near Manu	Irrigation by diversion of water to the Kawadigi Hoar (appended lake)	No water released during the dry season ?	Completed in 1983	Dolphins apparently absent from the Manu River above and below the barrage during the dry season. We have no information on the occurrence of dolphins during the monsoon.	5,12
Teesta Barrage (lower)	Teesta River near Rangpur	Irrigation and flood control	?	Completed in 1990	No information on the historical or current occurrence of dolphins above or below the barrage.	12
Embankments						
Bank Protection and River Training Pilot Projects (FAP 21/22)	Right bank of Jamuna River near Kamarjani and left bank of Jamuna River near Bahadurabad	Prototype works to investigate whether river training is feasible or desirable.	Three embankments on right bank. Eight slope revetments on right and left banks.	Embankments recently constructed. Slope revetments currently in construction.	Dolphins observed in the area during surveys in April 1996. Project will reduce hydraulic complexity and eliminate spawning habitat for floodplain-dependent fish.	6,12
Brahmaputra Right Embankment (BRE)	Jamuna River near Serajgonj, Rajshahi	Protection of Serajgonj and adjacent floodplain.	Embankment length 220km. Over half the length of the embankment has been eroded.	Completion date unknown.	Dolphins observed in the area during surveys in October 1995 and in April 1996. The embankment has reduced hydraulic complexity and eliminated spawning habitat for floodplain-dependent fish.	4,12

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Brahmaputra River Bank Priority Works (BPW)	Jamuna River near Serajgonj, Rajshahi	Protection of Serajgonj from migration of Jamuna River	Two hard points linking the existing realigned BRE with low earth embankments.	Advanced stages of planning	Dolphins observed in the area during surveys in October 1995 and in April 1996. Additional impacts beyond the effects of the existing BRE are unknown.	4,12
Jamuna Bridge Project Embankments	Jamuna River slightly upstream of Serajgonj, Rajshahi	Protection of bridge foundation from erosive flooding.	Paired embankments upstream and a hard point/guide bund on the right bank downstream. Embankment on left bank will be linked to BPW.	Completed in 1998	Dolphins observed in the area during surveys in October 1995 and in April 1996. Project will reduce hydraulic complexity and eliminate spawning habitat for floodplain-dependent fish.	9,12
Jamalpur Priority Project (FAP 3.1)	Divergence of Jamuna and Old Brahmaputra rivers near Jamalpur	Flood control and drainage	82km embankment along left bank of the Jamuna river and a 43km embankment along the right bank of the Old Brahmaputra River.	Detailed engineering study in progress.	Dolphins observed in the area during surveys in April 1996. Project will reduce hydraulic complexity and eliminate spawning habitat for floodplain-dependent fish.	7,12
Dredging						
Jamuna Bridge Project Dedging	Jamuna River upstream of Serajgonj, Rajshahi	Facilitate construction of bridge	**?**	Dredging believed to have been completed after bridge commissioned in 1998	Dolphins observed in the area during surveys in October 1995 and in April 1996. Potential problem with increased turbidity during dredging operations and increased sedimentation downstream.	9,12
Kalni-Kushiyara River Improvement Project	Kushiyara River between Asmiriganj and Katkhal, Chittagong	Facilitate passage of water in the Kushiyara River during the monsoon season.	Dredging at three sites extending for 0.25-1.0 km each. If successful, 10 additional sites will be dredged in the 50km stretch of river between Markuli and Mudha.	Advanced stages of planning	Dolphins observed in the area during surveys in October 1995. Potential problem with increased turbidity during dredging. Project could potentially benefit dolphins by increasing counter-current habitat.	1,12,13

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CHINA

At least six water development projects in China have affected rivers that historically supported or currently support dolphins and porpoises. These include four high dams, one dredging project, and one ship lock (Figure 2). The list does not include numerous smaller projects, especially embankments and dams on tributaries of the Yangtze, which have greatly affected ecological conditions in river channels and adjoining lake systems.

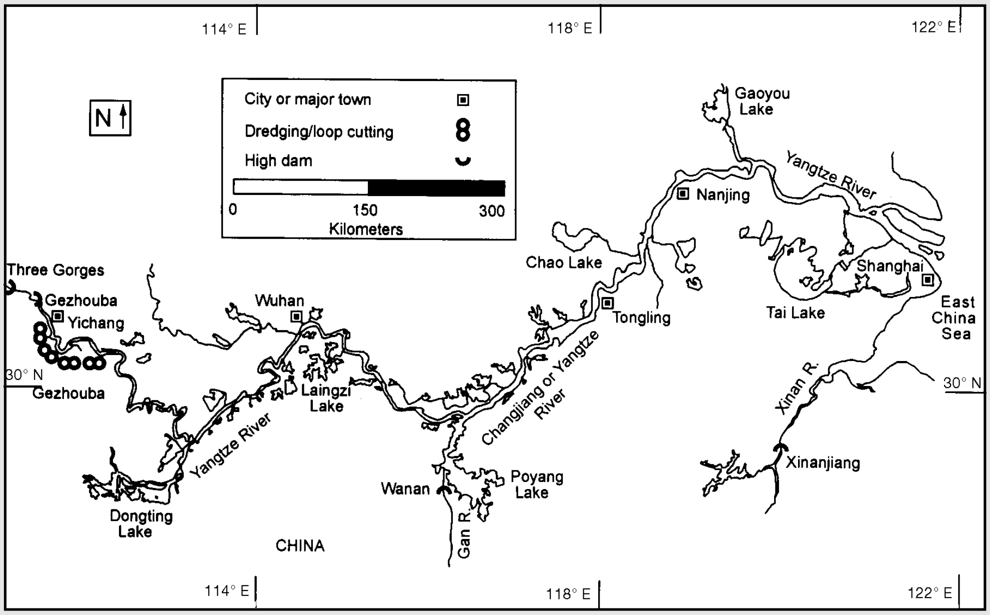

Figure 2. Map of the Yangtze and Xinan river systems in China showing high dam and dredging projects (underway and already constructed).

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
High Dams						
Gezhouba Dam	Yangtze River at Yichang, Hubei Province	Hydropower, flood control and navigation	AF=14,000cms CA=1 million km^2 DFD=0.114 million cms GSC 1.58 billion m^3 HMF=110,000cms IC=271.5MW LD=2,606m MHAF=54m NSL=66m	Construction started in 1970. Dam closed in 1981. Project completed in 1989.	Elimination of habitat upstream of the dam. Elimination of counter-current habitat in the 410km river section between Zicheng to Chenglingji.	1,4,5,6, 7,9,10
Three Gorges Dam	Yangtze River at Sandouping, 40km upstream of Yichang, Hubei Provence	Hydropower, flood control, and navigation	CA=64,000km^2 (reservoir only) GSC=39.3 billion m^3 IC= 1,820MW LD (main dam)=1,983m LD (flood discharge dam)=483m MHAF=180m NSL=175m Two lines of ship locks in five levels.	Construction started in 1994. Dam closed in 1997. Project scheduled to be completed in 2009.	The Gezhouba Dam has already eliminated access to upstream habitat. Dam expected to result in further habitat degradation downstream.	2,4,5,6, 7,10
Wanan Dam	Ganjiang (tributary entering Poyang Lake), Jiangxi Province	Hydropower, flood control, and irrigation	AF=947cms CA=29.9 billion m^3 GSC=2.2 billion m^3 IC=50MW MHAF=58m NSL=100m	Construction started in 1981. Dam closed in 1984. Project completed in 1990.	Previous records of baiji and finless porpoises in the river and Poyang Lake. Baiji is believed to have been extirpated from both water bodies and finless porpoises no longer occur upstream of the dam.	1,5,12

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Xinanjiang Dam	Xinanjiang tributary of Qiantangjiang, Zhejiang Province	Hydropower, flood control, and irrigation	AF=357cms CA=11.3 billion m^3 GSC=22 billion m^3 IC=66MW MHAF=105	Construction started in 1957. Project completed in 1960.	Baiji occurred historically in the Qiantangjiang but was apparently extirpated after dam construction. The status of finless porpoises in the river is unknown.	1,5,6,9,10
Dredging						
Gezhouba Dam Curve Cutting	Changjiang below Yichang, Hubei Province	Navigation and flood control	**?**	Year of completion unknown.	Elimination of counter-current habitat in the 410km river section between Zicheng and Chenglingji.	3,5
Ship Locks						
Madian Ship Lock	Guganhe River, Jiangsu Province	Flood control, irrigation, and navigation	DFD=180cms Lock length=42.9m Lock width=7m Water diverted =80cms	Completed in 1958	A baiji was found dead at the bottom of a gate, apparently drawn in by the opening of the lock in 1979.	8,11

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INDIA

At least 42 water development projects in India have affected rivers that historically supported or currently support dolphins. These include 19 high dams and 23 barrages (Figure 3, except for Tipaimukh High Dam, which is on Figure 1). We have virtually no information about water development projects in the Brahmaputra River of India, or in the tributaries of the Kalni-Kushiyara and Surma rivers of Bangladesh located in the Tripura, Cachar, and Meghalaya states of eastern India. The register also does not include numerous small dams and barrages, and extensive embankments, estimated to be 3,465km in length in 1998 (7), constructed in the Ganges mainstem and in the Gandak, Buri Gandak, Bagmati, Kamala, Yamuna, and Son rivers, as well in their minor tributaries.

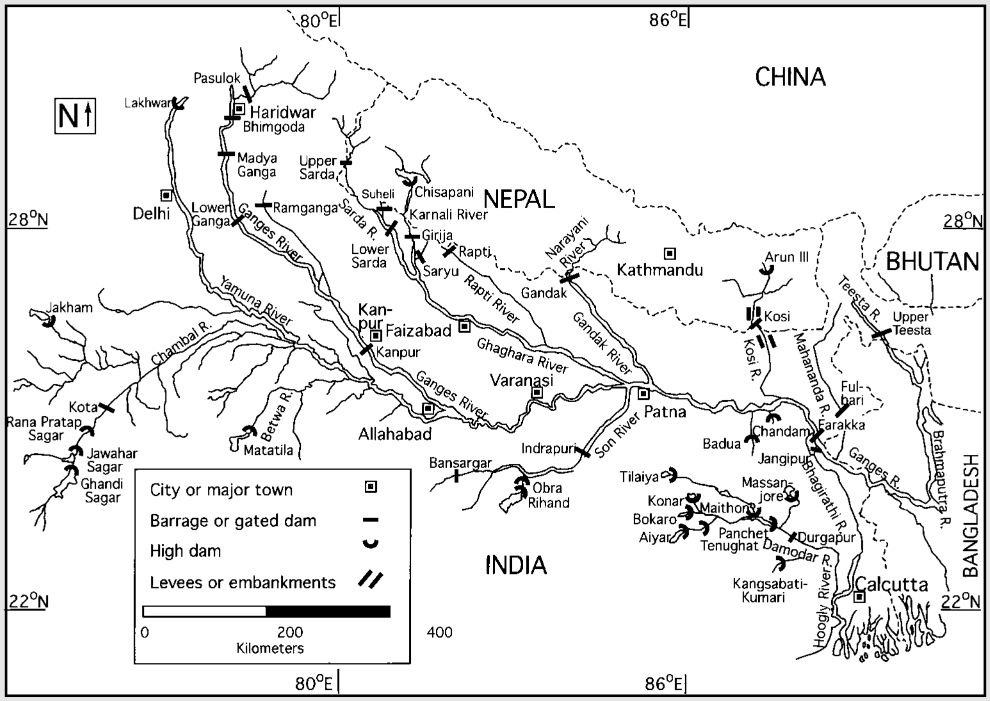

Figure 3. Map of the Ganges river system in India and Nepal showing barrage, high dam, and embankment projects (planned, underway, and already constructed).

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
High Dams						
Badua Dam	Badua River near Bhagalpur, Bihar	Irrigation	Earth dam CA=480km^2 DFD=2,832cms GSC=128.3 million m^3 LD=130m MHAF=58m	Completed in 1965	Historical or current occurrence of dolphins upstream and downstream of the dam is unknown but doubtful. Industrial development, altered flow regime, and elimination of sediment supply have degraded downstream habitat.	1,3,10
Chandan Dam	Chandan River near Bhagalpur, Bihar	Irrigation	Earth dam CA=549km^2 DFD=3,115cms GSC=157.2 million m^3 LD=183m MHAF=45m	Completed in 1972	Historical or current occurrence of dolphins upstream and downstream of the dam is unknown but doubtful. Industrial development, altered flow regime, and elimination of sediment supply have degraded downstream habitat.	1,3,10
Gandhi Sagar Dam	Chambal River near Chaurasigar, Madhya Pradesh	Irrigation and hydropower	Masonry dam CA=23,140km^2 DFD=21,240cms GSC=7.746 billion m^3 HH=44m IPC=11MW LD=254m MHAF=64m	Completed in 1960	Historical or current occurrence of dolphins upstream of the dam is unknown but doubtful. Local water officials report that there are currently no dolphins downstream of the dam but local people report their historical occurrence.	1,3,10

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Ichari Dam (not shown on map)	Ton River (tributary of Yamuna), Dehra Dun District, Uttar Pradesh	Hydropower	Concrete gravity CA=4,913km² DFD=13,500cms GSC=8 million m³ HH=125m IPC=240MW LD=65m MHAF=60m	Completed in 1975	We have been unable to find the exact location of this dam. Historical and current occurrence of dolphins upstream and downstream of the dam is unknown.	1,3,10
Jakham Dam	Jakham River near Halda Khers, Chittorgarh, Rajisthan	Irrigation	Straight gravity masonry CA=1,010km² DFD=7,970cms GSC=142 million m³ LD=90m MHF=81m	Construction began in 1969. Current status is unknown.	Historical occurrence of dolphins upstream and downstream of the dam is unknown but probable. Current occurrence unlikely because of altered conditions in the reservoir and because downstream habitat has been degraded by industrial development, altered flow regime, and elimination of sediment supply.	1,3,10
Jawahar Sagar Dam	Chambal River, 31km south of Kota, Rajisthan	Hydropower	Concrete gravity dam CA=27,195km² DFD=21,225cms GSC=444 million m³ HH=37m IPC=33MW LD=393m MHAF=36m	Completed in 1973	Historical occurrence of dolphins upstream and downstream of the dam is unknown but probable. Current occurrence unlikely because of altered conditions in the reservoir and because downstream habitat has been degraded by industrial development, altered flow regime, and elimination of sediment supply.	1,3,10
Kangsabati-Kumari Dam	Kangsabati and Kumari rivers at Mukutmanipur, West Bengal	Irrigation and flood control	Gravity earth dam w/concrete saddle spillway CA=3,626km² GSC=1.036 billion m³ LD=10,400m MHAF=41m	Completed in 1965	Historical occurrence upstream or downstream of the dam is unknown. Current occurrence unlikely because of altered conditions in the reservoir, and absence of water and intensive industrial development downstream.	1,3,9
Konar Dam	Konar River near Harzibagh, Bihar	Irrigation, industrial water supply, and flood control	Earth fill gravity w/concrete spillway CA=997km² DFD=6,792cms GSC=350.3 million m³ LD=110m MHAF=58m	Completed in 1955	Historical occurrence of dolphins upstream and downstream of the dam is unknown but doubtful. Industrial development, altered flow regime, and elimination of sediment supply have degraded downstream habitat.	1,3,10
Lakhwar Dam (not shown on map)	Yamuna River near Dakpathar, Uttar Pradesh	Hydropower and irrigation	Cored concrete gravity dam CA=2,080km² DFD=8,000cms GSC=580 million m³ HH=171m IPC=600MW LD=103m MHAF=192m	Construction began in 1979. Current status is unknown	We have been unable to find the exact location of this dam. Historical and current occurrence of dolphins upstream and downstream of the dam is unknown.	1,3,10
Maithon Dam	Barakar River near Dhanbad, Bihar	Irrigation, hydropower, flood control, and industrial and urban water supply	Earth fill gravity w/concrete spillway CA=6,294km² DFD=14,160cms GSC=1.369 billion m³ HH=39m IPC=60MW LD=186 MHAF=56m	Completed in 1956	Historical occurrence of dolphins upstream and downstream of the dam is unknown. Current occurrence unlikely because of altered conditions in the reservoir and because the downstream habitat has been degraded by industrial development and an interrupted flow regime.	1,3,10
Massanjore Dam	Mayurakshi River at Massanjore, Bihar/West Bengal Border	Hydropower, irrigation and flood control	Boulder masonry CA=1,859km² GSC=616.7 million m³ LD=640m MHAF=47m	Completed in 1955	Historical occurrence of dolphins upstream and downstream of the dam is unknown. Current occurrence unlikely because of altered conditions in the reservoir and absence of water downstream.	1,3,10

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Matatila Dam	Betwa River, Uttar Pradesh	Irrigation and hydropower	Masonry spillway with earthen flanks CA=20,718km^2 DFD=23,360cms GSC=1.132 billion m^3 HH=30m IPC=30MW LD=6,329m MHAF=46m	Completed in 1958	Historical occurrence of dolphins upstream and downstream of the dam is unknown but they may occur downstream.	1,3,10
Obra Dam	Rihand River near Obra village, Uttar Pradesh	Hydropower and cooling water supply to Obra Thermal Power Station	Earth and rockfill with spillway on right bank CA=547km^2 DFD=13,880cms GSC=211 million m^3 LD=1,956m MHAF=30m	Completed in 1970	Historical and current occurrence of dolphins unknown but dolphins may occur downstream of the dam. They have been reported to occur in the Sone River farther downstream.	1,3,10
Panchet Dam	Damodar River near Dhanbad, Bihar	Irrigation, hydropower, flood control and public water supply	Earth fill gravity w/concrete spillway CA=10,966km^2 DFD=17,842cms GSC=1.497 billion m^3 HH=31m IPC=40MW LD=233m MHAF=49m	Completed in 1958	Historical occurrence of dolphins upstream and downstream of the dam is unknown. Current occurrence unlikely because of altered conditions in the reservoir and downstream habitat has been degraded by industrial development and an interrupted flow regime.	1,3,10
Rana Pratap Sagar Dam	Chambal River, 51 km south of Kota, Rajisthan	Irrigation and hydropower	Masonry dam CA=24,864km^2 DFD=18,408cms GSC=2.9 billion m^3 HH=58m IPC=43MW LD=1,143m MHAF=58m	Completed in 1970	Historical occurrence of dolphins is unknown but probable. Local water officials report that there are currently no dolphins upstream or downstream of the dam but local people report their historical occurrence.	1,3,10
Rihand Dam	Rihand River at Pipri, Mirzapur, Uttar Pradesh	Hydropower	Straight concrete dam CA=13,333km^2 DFD=17,275cms GSC=10.6 billion m^3 HH=44–76m IPC=300MW LD=190m MHAF=91m	Completed in 1962	Historical and current occurrence of dolphins upstream and downstream of the dam is unknown. Current occurrence upstream unlikely because of altered conditions in the reservoir. Dolphins have been reported to occur farther downstream in the Sone River.	1,3,10
Tenughat Dam	Damodar River near Giridih, Bihar	Irrigation	Rolled earth filled dam w/masonry spillway CA=4,481km^2 DFD=15,989cms GSC=1.024 billion m^3 LD=348m MHAF=63m	Completed in 1981	Historical occurrence of dolphins upstream or downstream of the dam is unknown. Current occurrence unlikely because of altered conditions in the reservoir and lack of water and intensive industrial development downstream.	1,3,10
Tilaiya Dam	Barakar River near Hazaribagh, Bihar	Irrigation, hydropower and flood control	Gravity CA=984km^2 DFD=3,853cms GSC=556.3 million m^3 LD=156m MHAF=45m	Completed in 1953	Historical occurrence of dolphins upstream or downstream of the dam is unknown but unlikely.	1,3,10
Tipaimukh Dam (see Bangladesh map)	Surma River, Cachar	?	?	?	Dolphins known to occur downstream in the Kalni-Kushiyara and Surma distributaries in Bangladesh. We have no other information about this dam.	14
Barrages						
Banbasa or Upper Sarda Barrage	Sarda (India) or Mahakali (Nepal) River near the Nepal/India border, Tanakpur, Uttar Pradesh	Irrigation and possible future hydropower development	CA=14,817km^2 DFD=16,990cms LB=598m NB=30 (weir), 4 (under-sluice) WB=15m	Completed in 1928	Dry season supply of water has been eliminated to the Mahakali River in Nepal and upper Sarda River in India. Historical report of dolphin occurrence below the barrage but this population is now believed to have been extirpated.	2,8,10,13

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Bansargar Barrage	Sone River near Sidhi, Madhya Pradesh	Irrigation and diversion for hydropower	NB=16 WB=18m	Construction started in 1980. Year of completion unknown.	Recent surveys found 10 dolphins upstream of the dam. The status of dolphins between the Bansargar and Indrapuri barrages is unknown.	11,12
Bhimgoda Barrage	Ganga River near Haridwar, Uttar Pradesh	Irrigation	CA=23,375km^2 DFD=19,300cms LB=580m NB=22 WB=18m	Completed in 1986	A single dolphin was reported in Nagal (approx. 50km upstream of the Bhimgoda Barrage) in September 1994. We have no other information but suspect that any remaining upstream population is likely to be extremely small.	2,8
Durgapur Barrage	Damodar River at Durgapur, West Bengal	Irrigation	?	Completed in 1955	?	Indicated on map of India
Farakka Barrage	Ganges mainstem at Farakka, West Bengal	Diversion of water to the Bhagirathi and Hooghly rivers to improve navigation to the Calcutta Port.	CA=962,788km^2 DFD=75,600cms LB=2244m NB=84 (spillway), 24 (under-sluice), and 1 (fishlock) WB=18.3m, except fish lock=8.2m	Completed in 1975	Fragmentation of Ganges population at approximate geographical center of their range, saline encroachment in delta habitat of Bangladesh, interrupted migrations of prey, and downstream water supply and aquatic habitat reduced or eliminated during the dry season.	4,6,9,14
Fulbari Barrage	Mahananda River in West Bengal	?	?	Year of completion unknown	A carcass of a pregnant female dolphin was recovered from the Mariadhar tributary of the Panar River, which empties into the Mahananda above the barrage. An adult female was also killed in the Lohandra River, a tributary of the Bhalwa River, which empties into the Panar.	12
Gandak or Tribeni Barrage	Gandak (India) or Narayani (Nepal) River at Balmikinagar, Bihar	Irrigation and hydropower	CA=38,850km^2 DFD=24,070cms GH=4.9m LB=739m MDC (east)=443cms MDC (west)=553cms NB=36 WB=18m	Completed in 1968	A single dolphin was observed upstream of the barrage in 1993. Recent surveys have found no dolphins above or immediately below the barrage.	2,8,12,13
Girija Barrage	Ghaghara River near Kailashpuri, Uttar Pradesh	Irrigation and flood control	CA=45,550km^2 DFD=22,200cms LB=716m NB=35 WB=18m	Completed in 1976	21–30 dolphins observed upstream of the barrage in 1993. Insufficient water to support dolphins during the dry season immediately downstream of the barrage.	2,10,12,13
Gomti Barrage (not shown on map)	Gomti River near Lucknow, Uttar Pradesh	Flood control and water supply	CA=3,408km^2 DFD=4,246cms LB=202m NB=11 WB=18m	Completed in 1979	Dolphins sighted at the confluence of the Gomti and Ganges rivers but no surveys have been conducted further upstream. Local people report historical occurrence of dolphins as far upstream as Lucknow. Pollution from industry and reduced flow has degraded downstream habitat.	Barrage signpost, 12
Indrapuri Barrage	Sone River near Sasaram, Bihar	Irrigation and flood control	CA=68,915km^2 DFD=40,493cms LB=1,606m (1,407m) NB=60 WB=18m	Completed in 1965	Local wildlife officials report that a few dolphins still occur upstream of the barrage. Recent surveys found 10 dolphins upstream of the Bansagar Barrage, which is located 150–200km upstream of the Indrapuri Barrage. No dolphins were observed immediately downstream of the barrage during informal surveys in March 1994 and September 1995.	2,10,12

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Jangipur Barrage	Bhagirathi River near Jangipur, West Bengal	To prevent backflow from the Bhagirathi River to the Ganges	LB=218m NB=15 WB=18m	Completed in 1975	Recent surveys found 104–132 dolphins downstream of the barrage until Tribenighat, where the river's name changes to the Hoogly.	11,12
Kanpur Barrage	Ganges River at Kanpur, Uttar Pradesh	Irrigation and flood control	CA=87,650km^2 LB=593m NB=29 WB=18m	Under construction. Planned to be completed in 2004.	Dolphins have been recorded upstream and downstream of the barrage. The structure will interrupt upstream movements in the monsoon season and upstream and downstream movements in the dry season.	11,12
Kosi Barrage	Kosi River at Nepal/India border near Bhimnagar, Nepal and Birpur, Bihar, India	Irrigation and flood control	CA=61,788km^2 DFD=26,897cms GH=6.4m LB=1,149m MDC (east)=425cms NB=56 WB=18.3m	Completed in 1965	Three dolphins were observed upstream of the barrage in 1993. Insufficient water to support dolphins during the dry season immediately downstream of the barrage.	2,10,12,13
Kota Barrage	Chambal River at Kota, Rajasthan	Irrigation	DFD=21,237cms LB=552m	Completed in 1960	Historical occurrence of dolphins upstream of the barrage is unknown. Current occurrence immediately downstream is unlikely because habitat has been degraded by industrial development and an interrupted flow regime.	Barrage signpost, 11
Lower Ganga or Narora Barrage	Ganges River at Narora, near Moradabad, Uttar Pradesh	Irrigation and water supply to nuclear power plant	CA=32,880km^2 DFD=14,165cms LB=922m NB=54 WB=12m	Completed in 1966	Recent surveys recorded 35 dolphins between the Lower Ganga and Middle Ganga barrages. Dolphins also reported to occur downstream.	2,12
Middle Ganga, Madhya, or Bijnor Barrage	Ganges River at Bijnor, Uttar Pradesh	Irrigation	CA=29,250km^2 DFD=15,000cms LB=579m NB=28 WB=18m	Completed in 1984.	One or two dolphins were reported to occur upstream of the barrage in January 1993. Dolphins are currently believed to be extirpated from the Ganges upstream of this barrage.	2,8,12
Pasulok or Virbhadra Barrage	Ganges River near Rishkesh, Uttar Pradesh	Diversion for hydropower	CA=21,400km^2 DFD=14,400cms LB=312m NB=15 WB=18m	Completed in 1980	Historical occurrence of dolphins upstream of the barrage is unknown but unlikely above Haridwar.	2
Ramganga Barrage	Ramganga River at Kalagarh (Bijnor), Uttar Pradesh	Irrigation	CA=3,134km^2 DFD=7,365cms LB=408m NB=20 WB=18	Completed in 1975	Historical and current occurrence of dolphins upstream of the dam is unknown. Dolphins occur downstream in the Ganges mainstem at Bijnor.	1,3,8,10
Rapti Barrage	Rapti River approx. 4km downstream of Nepal/India border, Uttar Pradesh	Irrigation	**?**	**?**	No dolphins were found in recent surveys of the Rapti River in Nepal during the monsoon season but local people reported their occasional occurrence during the monsoon. Probable occurrence of dolphins downstream of the barrage but no surveys have been conducted.	11,12
Sarda Nagar or Lower Sarda Barrage	Sarda River (tributary of Ganges) in Lakhimpur Kheri, Uttar Pradesh	Irrigation	CA=17,818km^2 DFD=11,400cms LB=408m NB=20 WB=18m	Completed in 1974	Historical reports of dolphin occurrence upstream and downstream of the barrage. Upstream population now believed to be extirpated. It is possible that some dolphins may immigrate from the link canal connecting the Sarda River to the Ghaghara or Karnali River.	2,12,13

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Saryu Barrage	Saryu River approx. 20km upstream of confluence with Ghaghara River, Uttar Pradesh	Irrigation	CA=4,506km^2 DFD=4,600cms LB=243m NB=12 WB=18m	Completed in 1982	No dolphins currently occur upstream in Nepal where the river is known as the Babai. Historical occurrence of dolphins upstream of the barrage is unknown. Dolphins probably occur downstream near the confluence with the Ghaghara River but no surveys have been conducted.	Barrage signpost
Suheli Barrage	Suheli River approx. 45km upstream of Sarda Nagar near Palya, Uttar Pradesh	Irrigation	CA=1,295km^2 DFD=2000cms NB=11 WB=12m	Completed in 1984	Historical and current occurrence of dolphins upstream of the barrage is unknown. Approximately 10 dolphins recorded downstream of the barrage in the monsoon season.	11,12
Teesta Barrage (upper)	Teesta River (tributary of Brahmaputra) just upstream of the India/ Bangladesh border	Irrigation and flood control	**?**	**?**	We have no information on the historical or current occurrence of dolphins in this river.	5

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NEPAL

We identified eight water development projects in Nepal affecting rivers that historically supported or currently support dolphins. These include three high dams, four barrages (Kosi, Girija, Banbasa, and Tribeni – included in India section above), and one embankment project (Figure 3).

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
High Dams						
Arun III	Arun River (tributary of the Sapta Kosi River) near Khanbari	Hydropower	CA=5,240km^2 IPC=400MW MHAF=65m	Geotechnical studies have been completed. The project was recently denied financing from the World Bank.	Dolphins do not occur upstream of the dam site. During surveys in 1993, three dolphins were observed downstream in the Sapta Kosi River until the Kosi Barrage at the Nepal/India border.	3,5
Karnali/ Chisapani	Karnali River near Chisapani	Hydropower, irrigation, and flood control	Gravel fill with central core CA=43,000km^2 EFV=42 million m^3 IPC=10,800MW MHAF=260m	Geotechnical studies have been completed. A license for a pre-construction survey to the Enron corporation (USA) is pending.	Dolphins do not currently occur upstream of the dam site. During surveys in 1993, 21–30 dolphins were observed downstream of Chisapani to the Girija Barrage in India. We expect that, if the dam is built, it will cause drastic changes to the downstream environment leading to extinction of Nepal's last potentially viable dolphin population.	2,3,4,5
Pancheshwar (not shown on map)	Mahakali River near northern border with India	Hydropower, irrigation, and flood control	MHAF=315m (if built it would be the world's highest dam) IPC=6,480MW	Planned. Nepal and India signed the Mahakali Integrated Development Treaty approving its construction	Dolphins historically occurred downstream in Nepal and India but have been extirpated due to lack of water released by the Banbasa or Upper Sarda Barrage (see India section). Additional effects from regulated water and reduced sediment to the Sarda and Ganges mainstem are unknown.	1,3
Embankments						
Kosi Embankment	Sapta Kosi River near Hanumanagar, Nepal	Flood control and irrigation	Embankment and groyne field on the east bank of the Sapta Kosi River from the Kosi barrage upstream to the gorge at the Siwalik hills. Irrigation canal diverts water at upstream end.	Year of completion unknown.	During 1993, three dolphins were observed in the river. See Kosi Barrage in India section.	3

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PAKISTAN

We identified 25 water development projects in Pakistan affecting rivers that historically supported or currently support dolphins. These include eight high dams and 17 barrages (Figure 4). These do not include the numerous embankments that have been built, often associated with the barrages documented below.

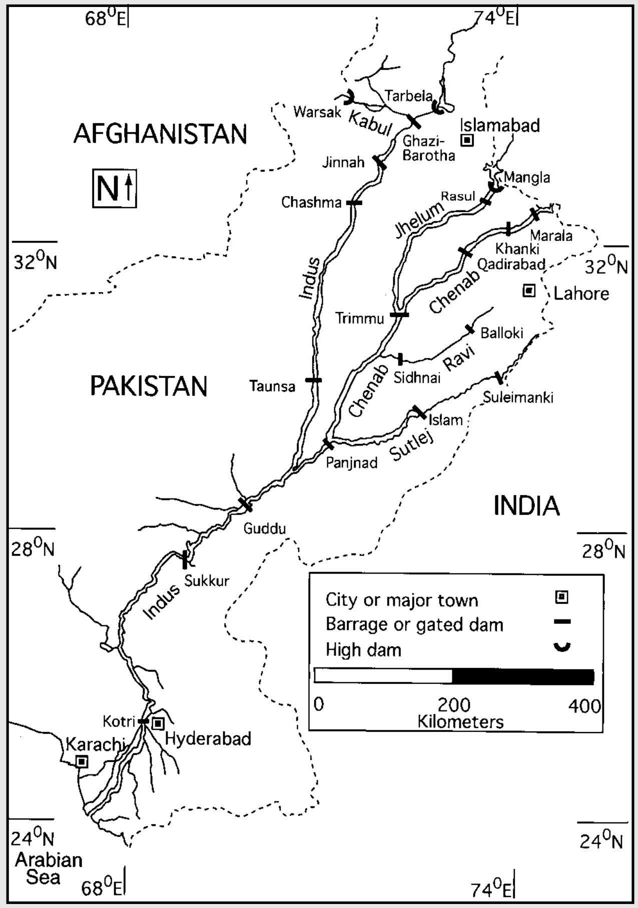

Figure 4. Map of the Indus river system in Pakistan showing barrage and high dam projects (planned, underway, and already constructed).

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
High Dams						
Jari Dam (not shown on map)	Jhelum River near Pakistan/ India border	Hydropower and irrigation	Earthfill LD=4,421m MHAF=83m	Completed in 1967	This dam is associated with the Mangla dam but the exact location or hydrologic relation is unknown.	3
Kalabagh Dam (not shown on map)	Indus River above the Jinnha Barrage	Hydropower, irrigation and flood control	Earthfill IPC=3,600MW LD=636m MHAF=80m	Advanced stages of planning	Previous record of upstream population but these animals are now extirpated.	1,2
Mangla Dam	Jhelum River near Pakistan/ India border	Hydropower and irrigation	Earthfill DFD=25,200cms LD=3,140m MHAF=116m	Completed in 1967	Upstream and downstream population doubtful. This dam has two associated dams: Jari and Sukian.	3,6,11
Sukian Dam (not shown on map)	Jhelum River near Pakistan/ India border	Hydropower and irrigation	Earthfill LD=5,152m MHAF=44m	Completed in 1967	This dam is associated with the Mangla dam but the exact location or hydrologic relation is unknown.	3
Tarbela Dam	Indus River at Tarbela, NW Frontier	Hydropower	Earth-rockfill LD=2,952m MHAF=160m	Completed in 1976	Upstream and downstream population doubtful.	6,11,12,14
Warsak Dam	Kabul River at Pakistan/ Afghanistan border, NW Frontier	Hydropower	Concrete LD=228m MHAF=76m	Completed in 1960	No possible upstream dolphin population. Population immediately downstream is doubtful.	13,14

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Basha Dam (not shown on map)	Indus River 320km upstream of Tarbela Dam	Hydropower, irrigation and flood control	Earth-rockfill MHAF=211m IPC=3360MW	Preliminary stages of planning	No upstream or downstream dolphin population. Dam will regulate water flow in lower reaches of Indus river.	14
Khanpur Dam (not shown on map)	Northern tributary of Kabul river	Irrigation and drinking water	Earth-rockfill LD=507m MHAF=55m	Completed in 1984	No possible upstream dolphin population. Population immediately downstream is doubtful	14
Barrages						
Ghazi-Gariala (Barotha)	Indus River 7km below Tarbela Dam	Barrage to divert water for hydropower generation in 52km canal.	GSC=1,700m^3 MHAF=339m IPC=1450MW	Under construction	Previous record of upstream population but these animals are now extirpated.	2,7,14
Balloki Barrage	Ravi River, Punjab	Irrigation and flood control	LB=427m MDC=198cms (Lower Bari Doab); 524cms (Balloki-Sidhnai Link)	Completed in 1913/65	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Chashma Barrage	Indus River near Kundian, Punjab	Irrigation and flood control	DFD=31,152cms LB=951m MDC=614cms (Chasma/Jhelum Link); 14cms (Paharpur)	Completed in 1971	Previous record of upstream population but these animals are believed to have been extirpated.	2,3,6,9, 10,11,12
Guddu Barrage	Indus River, at Sind/ Punjab border	Irrigation and flood control	DFD=31,152cms LB=1,189m MDC=240cms (Ghotki); 439cms (Begari)	Completed in 1962	143 dolphins were counted between Guddu and Taunsa barrage in December 1996. This barrage separates the two largest extant populations of bhulan. See Sukkur Barrage for details of downstream population.	5,10,11,12
Islam Barrage	Sutlej River near Karmpur and Hasipur, Punjab	Irrigation and flood control	DFD=7,731cms LB=281m MDC=153cms (Bahawal); 16cms (Qaim); 138cms (Mailsi)	Completed in 1927/65	Previous record of upstream population but these animals are now believed to be extirpated.	6,11,12
Jinnha Barrage	Indus River near Kalabagh	Irrigation	DFD=26,600cms LB=1,152m NB=42 (main), 7 (undersluice) WB=18m	1946	Previous record of upstream population but these animals are now extirpated.	2,4,6,11,12
Khanki Barrage	Chenab River near Wazirabad and Gujrat, Punjab	Irrigation and flood control	DFD=21,240cms LB=1219m MDC=326cms (Lower Chenab)	Completed in 1891	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Kotri Barrage	Indus River at Kotri (near Hyderabad), Sind	Irrigation and flood control	DFD=24,780cms LB=805m MDC=368cms (Pinyari); 406cms (Fullel); 116cms (Akramwal); 257cms (Kalsi Bhagar)	Completed in 1954	Occasional dolphins escape downstream of Sukkur Barrage but these animals have virtually no chance of surviving because of lack of water. No dolphins occur downstream.	6,11,12
Marala Barrage	Chenab River near Sialkot	Irrigation and flood control	LB=1,219m MDC=467cms (Upper Chenab); 623cms (Marala/Ravi Link)	Completed in 1912/68	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Panjnad Barrage	Chenab River near Uch, Punjab	Irrigation and flood control	DFD=19,824cms LB=859m MDC=271cms (Panjnad); 30cms (Abbasia)	Completed in 1932	Previous record of upstream population but very few to no animals are believed to remain.	6,8,11, 12,13

Project	River and location	Purpose	Technical and Hydrological Specifications	Status	Summary of dolphin occurrence and potential or realized impacts	Sources
Qadirabad Barrage	Chenab River near Chiniot, Punjab	Irrigation and flood control	DFD=25,488cms LB=914m MDC=527cms (Qadirabad-Balloki Link)	Completed in 1967	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Rasul Barrage	Jhelum River at Rasul, near Thelum, Punjab	Irrigation and flood control	DFD=24,780cms LB=914m MDC=54cms (Rasul-Qadirabad Link); 187cms (Lower Jhelum)	Completed in 1901/1967	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Sidhnai Barrage	Ravi River at Sidhai (near Multan), Punjab	Irrigation and flood control	DFD=4,729cms LB=183m MDC=286cms (Sidhnai-Mailsi Link); 113cms (Sidhnai Feeder)	Completed in 1965	No dolphins currently occur upstream or downstream of the barrage. Their historical occurrence is unknown.	6,11,12
Sukkur (Lloyd) Barrage	Indus River at Sukkur, Sind	Irrigation and flood control	DFD=42,480cms LB=987m MDC=386cms (E. Nara); 59cms (K.F. East); 308cms (Rohri); 55cms (K.F. West); 146cms (Northwest); 302cms (Rice); 89cms (Dadu)	Completed in 1932	Upstream dolphin population largest in the Indus river system. 339–458 animals counted in April/May 1996.	6,10,11,12
Suleimanki Barrage	Sutlej River at Suleimanki near the India/ Pakistan border	Irrigation and flood control	DFD=9204cms LB=443m MDC=139cms (Sadigia); 95cms (Fordurah); 171cms (Pakpattan)	Completed in 1926	Previous record of upstream population but these animals are believed to have been extirpated.	6,11,12,13
Taunsa Barrage	Indus River at Taunsa (near Kot Addu), Punjab	Irrigation and flood control	DFD=21,240cms LB=1,176m MDC=235cms (Muzaffargarh); 396cms (TP Link); 249cms (DG Khan); 367cms (Desert)	Completed 1959	39 dolphins counted upstream of the barrage in December 1998.	6,9,10,11, 12
Trimmu Barrage	Chenab River at confluence of Jhelum near Jhang Sadar, Punjab	Irrigation and flood control	DFD=18,266cms LB=677m MDC=148cms (Haveli)	Completed 1939	A dolphin was seen upstream in the Jhelum River in 1976 but no recent sightings have been reported.	6,11,12

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Effects of Water Development on River Cetaceans in China

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Abstract

Water development projects, including dams, embankments, and ship locks, have had extensive deleterious effects on two species of river cetacean in China: the baiji (*Lipotes vexillifer*) and the Yangtze population of finless porpoises (*Neophocaena phocaenoides asiaeorientalis*). The Gezhouba and Three Gorges dams are located in the mainstem of the Yangtze. The latter, once completed, is expected to further degrade counter-current habitat in the upper and middle reaches of the river. Numerous smaller dams in tributaries of the Yangtze and its appended lakes have dramatically reduced the availability of migratory fish. Baiji once occurred in the Xinan River but apparently were extirpated after the construction of a high dam.

Introduction

Two cetacean species, the baiji (*Lipotes vexillifer*) and the finless porpoise (*Neophocaena phocaenoides*), inhabit the Yangtze river system of China. Although the baiji once occurred in the Xinan River, it is now apparently endemic to the Yangtze River. The baiji is classified by IUCN as Critically Endangered (IUCN 1996) and is thought to be very close to extinction (see Smith and Reeves, this volume). Finless porpoises in the Yangtze River are regarded as an isolated population (Gao and Zhou 1993, 1995, Reeves *et al.* 1997), and this population is classified by IUCN as Endangered (IUCN 1996). Water development projects, including the construction of dams, embankments, and ship locks, are among the most serious threats to freshwater cetaceans in China.

The Yangtze River is the third largest in the world. It is 6,279km long and has a total drainage area of 1,800,000km^2. There are 121 appended lakes and hundreds of tributaries, 437 with drainage areas greater than 1,000km^2. Appended lakes include Dongting and Poyang, the largest freshwater bodies in China (Changjiang Hydraulic Committee 1994). The Yangtze River, together with its tributaries and appended lakes, supports a great diversity of fish species belonging to 17 orders, 52 families, and 178 genera (Changjiang Hydraulic Committee 1994). Among these fishes are the Critically Endangered Yangtze sturgeon (*Acipenser dabyanus*) and Chinese paddlefish (*Psephurus gladius*) (IUCN 1996).

The Yangtze River is critical to the economic development of China. The river provides hydroelectricity, functions as a transportation corridor, and is an important source of water for agricultural and industrial development. The annual electricity-generating capacity of the river has been estimated to be as high as 2.35 trillion kWh, which would supply 39% of the projected needs of the country (Changjiang Hydraulic Committee 1994). Water development in the Yangtze threatens the ecological integrity of riverine habitat that supports cetaceans and their prey.

Water development and its effects on cetaceans

Yangtze mainstem

The Gezhouba Dam was the first dam built in the Yangtze mainstem and is located about 2km downstream of the exit of Three Gorges at Yichang, Hubei Province (see Smith *et al.,* this volume). Construction of the dam began in December 1970; the main river was closed in January 1981; and the project was completed in 1989. Two baiji specimens were taken in the 1940s upstream of Yichang, in Huanglingmiao and Liantuo (Zhou *et al.* 1977). Baiji no longer occur, however, in waters upstream of Jingzhou (also called Shashi), located 150km downstream of Yichang. Finless porpoises still occur as far upstream as Yichang, which raises interesting questions about the ability of this species to adapt to altered conditions downstream of the dam (Wang Ding *et al.,* this volume).

The Three Gorges Dam is being constructed in the Xiling Gorge at Sandouping, Hubei Province, 38km upstream from the Gezhouba Dam (see Smith *et al.* this volume). Construction began in 1994, and the temporary closure dam was finished on 8 November 1997. The first generators are scheduled to be finished in 2003 and the project to be completed in 2009. Chen and Hua (1987), Chen and Hua (1989) and Chen *et al.* (1993) studied the projected impacts of the Three Gorges Dam. They suggested that its construction would eliminate habitat for the baiji above Ouchikou, thereby causing the species' range to decline by about 200km. We expect that the dam will have similar effects on the Yangtze finless porpoise, since the two species have similar environmental requirements. The reason behind the predicted decline in habitat is that the clear water released below the dam will erode river sediments and eliminate counter-currents that are the preferred habitat of baiji (see Hua *et al.* 1989). Existing counter-currents in the 158km segment of river downstream from Ouchikou to Chenglingji are expected to shrink in size, thereby causing a decline of cetacean abundance. The study also suggested that stratification of the reservoir would cause temperature changes in the dam discharge, which could affect mating cues and the survival of newborn calves. An indirect impact of the dam might be to increase the frequency of collisions between ships and cetaceans because of improved navigation. There are no plans for constructing additional dams in the mainstem of the Yangtze below Gezhouba, but several more are planned for upstream.

Tributaries and appended lakes

Many smaller dams and regulators have been built for irrigation and flood control on tributaries of the Yangtze and its appended lakes. These dams have blocked access to habitat critical for the reproduction of migratory fishes. No fish ladder or other passage facilities were incorporated in the construction of these dams. These dams, combined with intensive fishing and increasing pollution, have caused a dramatic decline in fish resources. For instance, the catch of Chinese anchovy (*Colia ectenes*) declined by more than 99% between the 1970s and 1980s (Zhou and Li 1989). This migratory fish has been recorded in the diet of finless porpoises (Zhou Kaiya, unpublished) and is probably also eaten by baiji.

The only lakes still connected with the Yangtze mainstem are Dongting and Poyang. These lakes have become increasingly shallow because of siltation caused by deforestation and agricultural development. It was predicted that Dongting Lake could disappear altogether in 15 years (Cai *et al.* 1987). Chen and Hua (1989), however, predicted that the depth of the lake would increase after the construction of the Three Gorges Dam. This is because once the dam is in operation, water levels in the Yangtze mainstem will become much lower during the flood season, thereby causing the lake to flush sediments entrained in the faster current at the lake mouth.

Although baiji once occurred in Dongting and Poyang lakes, they have not been seen there in recent years. Finless porpoises still occur in both lakes, but they may also disappear in the near future. Yangtze finless porpoises have been observed in the Gan River, a tributary emptying into Poyang Lake, as far upstream as Ganzhou where the Zangshui and Gongshui rivers meet. These animals were apparently extirpated from waters upstream of the Wanan Dam after it was built in 1981 (Zhou *et al.* 1993).

Twenty-two dams are planned for tributaries flowing into Poyang Lake, including the Fu, Xin, Yuan, and Li rivers. Forty dams are planned for tributaries emptying into Dongting Lake, including the Xiang, Yuan, and Li rivers.

The Madian Ship Lock is located in the Guganhe River, which is a tributary of the Yangtze, about 10km from the mainstem (see Smith *et al.* this volume). In February 1979, a baiji was found dead at the bottom of one of the lock gates.

Xinan River

Baiji once occurred in the Qiantang River, but they have not been seen since construction of a high dam in 1957 on the Xinan River, a tributary of the Qiantang (see Smith *et al.* this volume). An adult specimen was taken from the Qiantang River and is kept at the Zhejiang Natural History Museum. No resident population of finless porpoises has been found in the Qiantang River, but animals from the coastal population occasionally move up into the river. Two specimens were taken from the river in 1974 and 1987. They were both identified as coming from the coastal population (Gao and Zhou 1995).

Conclusion

Construction of hydroelectric, irrigation, navigation, and flood control projects in the Yangtze river basin benefits the economic development of China. These developments also threaten the survival of river cetaceans. The challenge is to balance economic development with conserving wildlife.

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Status of the Ganges River Dolphin (*Platanista gangetica*) in the Vicinity of Farakka Barrage, India

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Abstract

The Farakka Barrage has interrupted the movements of Ganges river dolphins (*Platanista gangetica*) and migratory fishes in the Ganges River near the middle of their range. Luxuriant growth of macrophytes and excessive siltation in the reservoir behind the barrage have resulted in the formation of a large mid-channel island. Intensive fishing with non-selective gear has probably caused a decline in the number of dolphins near the barrage and in the adjacent feeder canal, which carries water from the Ganges to the Bhagirathi River. During surveys conducted in the post-monsoon, winter, summer, and monsoon seasons of 1991 through to 1996, a maximum of 10 dolphins were observed in a 3.5km segment of river upstream and a maximum of five in a 3.5km segment downstream of the barrage. The difference in ecological conditions on both sides of the barrage was evidenced by a marked difference in the catch composition of local fisheries. Air-breathing fishes and other species most often associated with a lentic environment were frequently caught upstream of the barrage, while only lotic species were caught downstream of the barrage. During surveys of the feeder canal in 1995 and 1996, 14–21 dolphins were observed. The feeder canal

should be managed as a protected area for dolphins. Research is needed on nutrient enrichment, siltation rates, and methods to control macrophyte growth near the barrage. Fishing should be prohibited downstream of the barrage during the monsoon and post-monsoon seasons to protect the breeding and early-growth stages of dolphin prey. Discharge of pollutants into the feeder canal should be prohibited.

Introduction

The Ganges river dolphin, or susu (*Platanista gangetica*), is widely distributed in the Ganges, Brahmaputra, Meghna, and Karnaphuli river systems of Nepal, India, and Bangladesh, with a total population of perhaps a few thousand individuals (Mohan 1989, Reeves and Brownell 1989, Reeves *et al.* 1993), or possibly less (Mohan *et al.* 1997). These river dolphins prefer particular channel reaches with counter-currents and deep pools (Smith 1993). The construction of dams and barrages interrupts dolphin movements and reduces the physiographic and hydrologic complexity that makes rivers suitable for dolphins (Reeves and Leatherwood 1994b). Barrages are low gated dams built to divert water, primarily for irrigation and flood control, but also, in the case of Farakka, for navigation purposes. Barrages have subdivided the metapopulation of susus in many areas throughout the Ganges system (see Smith *et al.*, this volume). Some subpopulations have become extinct and others are threatened with extirpation, especially in Nepal (Smith *et al.* 1994).

Figure 1. Map of lower Ganges River system showing positions of the Farakka Barrage, Feeder Canal, and Jangipur Barrage.

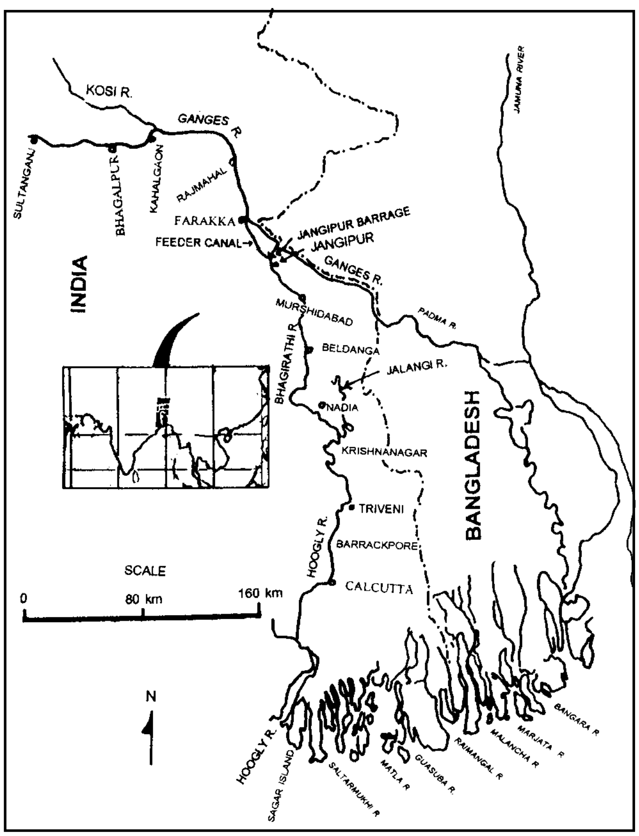


Table 1. Technical specifications of the Farakka Barrage Complex.

Structure	Specifications	
Farakka Barrage	Length	2.2km
	No. of bays	119
	Span of each bay	18m
	Design discharge	75,600cms
	Min. pond level	21.9m
Head-regulator	Min. pond level	21.9m
	Design discharge	1,120cms
	No. of bays	11
	Span of each bay	12m
Feeder Canal	Length	38.3km
	Design discharge	1,120cms
	Bed width	150.9m
	Surface width	182.9m
	Full supply depth	6.1m
Jangipur Barrage	Length	212.8m
	No. of bays	15
	Span of each bay	12m

Source: Anon. (1975).

The Farakka Barrage (Figure 1, Table 1) became operational in 1975. It is located in the Ganges mainstem close to the border with Bangladesh. The barrage is a barrier to the movement of dolphins at the approximate center of their geographic range. The barrage also obstructs the movements of other aquatic species, including an endangered crocodilian, the gharial (*Gavialis gangeticus*), and commercially and nutritionally valuable fishes, such as the hilsa (*Hilsa ilisha*).

Reeves and Leatherwood (1994a) emphasized the need for understanding the physical and biotic conditions that make riverine habitat suitable for dolphins. The purpose of the present paper is to: (1) present information on the physical and biological characteristics of the Ganges River near the Farakka Barrage, (2) evaluate the impacts of this structure on river dolphins and their habitat, and (3) establish priorities for research and conservation near the barrage. Baseline information on the status of river dolphins before and immediately after construction of the Farakka Barrage is lacking. The present paper should therefore be considered as a starting point for future investigations.

Study area

The Ganges River divides into the Padma and Bhagirathi rivers at Jangipur, about 40km downstream of Farakka.

The Bhagirathi River is a small distributary, which flows for about 320km before becoming the Hoogly River near the tidal zone at Tribenighat. The Padma River flows for approximately 90km along the India/Bangladesh border before entering Bangladesh where it joins the Jamuna or Brahmaputra River. The Farakka Barrage, and its associated canal and regulator system (Figure 2), was constructed to supply silt-free water to the Hoogly throughout the year, thereby increasing its navigable depth. A feeder canal, whose head-regulator is located just upstream of the barrage, carries the supplemental flow to the Bhagirathi. The Jangipur Barrage was constructed to prevent backflow from the Bhagirathi into the Ganges (Anon. 1975). According to barrage authorities, during the early monsoon, rains fall more heavily in the Brahmaputra catchment basin and cause the river flow in the Padma to become reversed. Some of this flow enters the Bhagirathi River through the Jangipur Barrage.

A large reservoir is contained behind the Farakka Barrage when the gates are closed during the low-water season. Above the barrage, water velocity is reduced as far upstream as Rajmahal (approximately 40km). A few kilometers downstream of Rajmahal, the Ganges divides into two channels, with more water flowing through the left one. During the dry season, there is no flow through the right channel until it receives water from the Ghumani River, a small tributary located three kilometers upstream of the barrage. Between these two channels is a large island of about 100 km^2, partially cultivated and covered by wild grasses. The island is not submerged during the monsoon season. The left bank of the reservoir is a floodplain used for seasonal cultivation, and the right bank is raised with rock embankments. Water height in the reservoir varies by 11–12m from the highest to the lowest water stage.

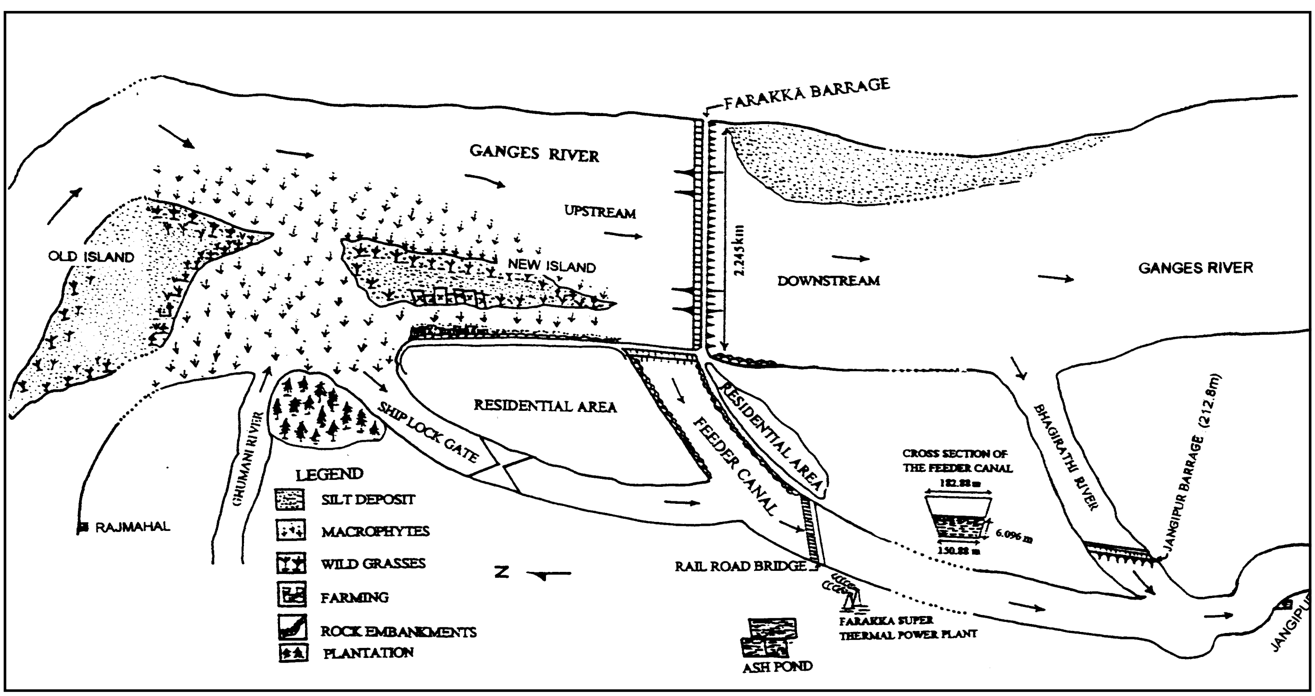
The Farakka Super Thermal Power Plant is located on the right bank of the Feeder Canal, approximately 4km downstream of the head-regulator. A township of approximately 0.1 million people has developed near Farakka, adding to pollution and the need for water abstraction.

Methods

During the post-monsoon (October–November), winter (January–March), summer (April–June), and monsoon (July–September) seasons of 1991–94, 12 surveys were conducted of the Ganges mainstem, 3.5km on both sides of the barrage, and of the 3km of the Feeder Canal immediately downstream from the head-regulator. Four surveys were also conducted in April and August 1995 and in March and September 1996 of the entire feeder canal to the convergence with the Bhagirathi River (38.3km). Two teams searched from country boats powered by sail and paddle. Each team consisted of two or three researchers and two local fishermen. Following the recommendations of a panel of experts (Perrin and Brownell 1989) and using a similar method as Smith *et al.* (1994), a direct count was used to estimate dolphin abundance.

Surveys of the entire feeder canal were conducted using an inflatable paddleboat with four observers searching forward from the bow and occasionally backward from the

Figure 2. Detailed sketch map of the Farraka Barrage Complex.



stern. One boat was sufficient for observing dolphins throughout the channel because the maximum width was only 182m.

During most surveys, fish were sampled from the catch of fishermen at landing sites located upstream and downstream of the barrage. Fish were identified using Talwar and Jhingran (1991). Casual observations were made of channel morphology, fishing methods, and the presence of macrophytes and filamentous algae.

Results

Distribution and abundance of dolphins

Dolphins were seen in the feeder canal, within 3km of the head-regulator, in the post-monsoon season of 1991 and the winter season of 1992 (Table 2). Very few or no dolphins were seen in the 3.5km segments upstream and downstream of the barrage during the winter and summer seasons. More dolphins were observed on both sides of the barrage during the monsoon season when the gates were open and water levels were almost equal or the flow direction was reversed. Our survey team could not approach within 500m downstream of the barrage during the monsoon-season surveys due to strong currents. The four or five dolphins observed during the two monsoon surveys, therefore, represent a conservative estimate of the total number present in this 3.5km segment. During the post-monsoon season, the number of dolphins in the segment downstream of the barrage was generally less, probably due to recession of the current caused by closure of the barrage gates.

Table 2. Dolphins counted during surveys in the post-monsoon, winter, summer, and monsoon seasons of 1991 through 1996 of 3.5km segments of the Ganges River, upstream and downstream of the Farakka Barrage, and in a 3km segment of the feeder canal.

Year	Season*	Dolphins upstream of barrage	Dolphins downstream of barrage	Dolphins in feeder canal
1991	Post-monsoon	7	4	4
1992	Winter	2	0	2
1992	Summer	4	0	0
1992	Post-monsoon	0	3	0
1993	Winter	2	1	0
1993	Summer	0	1	0
1993	Post-monsoon	0	3	0
1994	Winter	7	2	0
1995	Summer	0	0	0
1995	Monsoon	10	5	0
1996	Winter	0	0	0
1996	Monsoon	9	4	0

* Post-monsoon (October–November), winter (January–March), summer (April–June), and monsoon (July–September).

Table 3. Number of dolphins observed during surveys of the entire Farakka feeder canal in 1995 and 1996.

	No. of dolphin groups	H - L - B*	Mean group size	SD	Range
Apr. 95	16	20 - 14 - 20	1.25	0.45	1–2
Aug. 95	8	15 - 13 - 14	1.75	2.10	1–7
Mar. 96	8	17 - 13 - 14	1.75	1.70	1–6
Sep. 96	8	22 - 18 - 21	2.60	2.00	1–7

*High-Low-Best estimates (see Smith and Reeves, this volume).

During four surveys of the entire feeder canal, we observed 8–16 dolphin groups for a total of 13–22 dolphins (Table 3). Dolphins were concentrated downstream of bridge pilings, at the convergence of the feeder canal and the Bhagirathi River, and downstream of a submersible weir, located approximately 20km below the head-regulator.

Physical and ecological conditions

The reservoir, especially in the middle and near the right bank, became increasingly shallow and occupied by macrophytes and filamentous algae over the duration of the surveys. Due to the higher water velocity, the left channel remained free of macrophytes while the right channel became completely blocked in 1996. In 1994, an island emerged close to the right bank. By 1996, this island was approximately 300m long and 35m wide, and was partially covered with wild grasses and cultivated rice. The blockage of the right channel and emergence of a mid-channel island was caused by the sluggish flow upstream of the barrage and the particularly high sediment loads carried by the Ganges in this river segment. The Kosi River, which joins the Ganges 125km upstream of Farakka, carries one of the highest sediment loads of rivers in Asia.

During the low-water season in 1993, flow through the barrage fell to as little as 258cms (m^3/second), compared to a minimum flow of 2,058cms before construction of the barrage (Patel 1996). When the barrage was open during the monsoon season, downstream flow was constrained into a series of smaller channels, causing bank erosion.

Fishes and fisheries

Intensive fishing was observed throughout the year, upstream and downstream of the barrage and for 3km downstream of the head-regulator in the feeder canal. During the monsoon season, when the gates of the barrage were open, approximately 500 fishing boats operated within one km of the barrage. During the night fishing occurred close to the two fish ladders of the barrage, reportedly with the collusion of barrage personnel.

Seine nets (*konajal*), purse nets (*shanglajal*), drift gill nets (*beenjal*), monofilament gill nets (*naginjal*), and multifilament gill nets (*phansajal*) were used extensively to catch large and medium-sized fish. Occasional accidental killing of susus from entanglement in gill nets in the feeder canal and the mainstem close to the barrage was reported by fishermen.

In the reservoir, many fishermen used mosquito nets (*kapda jal*) to capture small fishes, such as *Chanda ranga*, *Chela laubuca*, *Nangra* sp., as well as the fingerlings of larger species which have been recorded in the diet of the dolphins (see Sinha *et al.* 1993). During the low-water season, this type of net was also used below the barrage.

Table 4. Commercially important fish species sampled in the 3.5km segments of river upstream and downstream of the Farakka Barrage.

Name of species	Upstream Farakka	Downstream Farakka
Hypolophus sephen (Fors.)	-	+
Hilsa ilisha (Ham.)	+	+++
Catla catla (Ham.)	+++	+
Labeo rohita (Ham.)	++	-
L. calbasu (Ham.)	++	+
Cirrhinus mrigala (Ham.)	+++	+
Puntius phutunio (Ham.)	+	-
P. sarana sarana (Ham.)	+	-
Tor tor (Ham.)	+	-
Amblypharyngodon mola (Ham)	+	-
A. microlepis (Bleeker)	+	-
Rasbora rasbora (Ham.)	+	-
Garra annandalei (Hora)	+	-
Botia lohachata (Chaudhuri)	+	-
Aoriichthys aor (Ham.)	+++	++
A. seenghala (Sykes)	+++	++
Mystus cavasius (Ham.)	++	+
M. menoda (Ham.)	+	-
Ompok bimaculatus (Bloch)	-	+
O. pabda (Ham.)	+	++
Wallago attu (Schneider)	+++	+
Ailia coila (Ham.)	++	+
Clupisoma garua (Ham.)	++	+++
Silonia silondia (Ham.)	+	+++
Pangasius pangasius (Ham.)	+	+++
Bagarius bagarius (Ham.)	+	++
B. yarrelii (Sykes)	+	++
Erethistes pussilus (Mull & Tros.)	+	-
Chaca chaca (Ham.)	-	+
Clarias batrachus (Linneaus)	++	+
Heteropneustes fossilis (Bloch)	++	+
Chanda spp.	+++	+
Johnius coitor (Ham.)	+++	++
Rhinomugil corsula (Ham.)	++	+
Sicamugil cascasia (Ham.)	++	+
Anabas testudineus (Bloch)	++	+
Colisa fasciatus (Schneider)	++	-
Channa marulius (Ham.)	++	+
C. punctatus (Bloch)	++	+
C. striatus (Bloch)	++	+
Anguilla bengalensis (Gray)	+	+
Mastacembelus armatus (Lacépède)	+++	++

+ Rarely available; + + Available in good amount;
+ + + Abundant; - Absent

Air-breathing fishes and other species most often associated with a lentic environment (e.g. *Clarias batrachus*, *Heteropneustes fossilis*, *Anabas testudineus*, *Channa marulius*, *C. punctatus*, and *C. striatus*) were commonly caught upstream of the barrage. In contrast, fishes most often associated with lotic conditions (e.g. *Hilsa ilisha*, *Silonia silondia*, *Pangasius pangasius*, *and Bagarius bagarius*) were recorded from catches downstream of the barrage (Table 4).

Discussion

High siltation and luxuriant growth of macrophytes reduce the availability of dolphin habitat, especially counter-currents where the animals are most commonly found (see Kasuya and Haque 1972, Smith 1993, Smith *et al.* 1998). The marked variation of fish composition, from mostly lentic species upstream of the barrage to mostly lotic species downstream of the barrage, may indicate at least a local decline of suitable dolphin prey. Intensive fishing near the barrage, especially using *kapda jal*, threatens dolphins with accidental entanglement and may have also reduced their prey.

The environment downstream of the Farakka Barrage, at least for the 3.5km surveyed, is largely unsuitable for sustaining dolphins. This is because of the lack of water during the low-water season and the extremely high fishing pressure during the high-water season. The suitability of dolphin habitat in the 3.5km segment upstream of the barrage has been compromised by heavy siltation and luxuriant growth of macrophytes.

The direct and indirect effects of the Farakka Barrage, as well as the low number of dolphins observed near the barrage, indicate a high probability that dolphin abundance has declined. The feeder canal may support a viable population because these dolphins can mix freely with others in the Bhagirathi and Hoogly rivers.

The high water velocity in the feeder canal, especially below the head-regulator, probably does not allow dolphins to move up into the reservoir. A few dolphins were observed swimming against the current in the feeder canal, but they were unable to approach the head-regulator due to the fast current.

Water quality in the feeder canal is affected by the discharge of pollution from the Farakka township and the Super Thermal Power Plant. During the survey of the feeder canal in August 1995, oil, grease, and fly ash were noticed floating on the surface. The power plant authorities informed our team that oil and grease had leaked into the canal while the plant boilers were being recharged. During this survey, dolphins were not seen in this segment of the canal.

Intensive fishing throughout the year near the head of the feeder canal and during the monsoon season at the two fish ladders below the barrage is detrimental because these activities target species migrating upstream for breeding purposes. This situation may lead to a decline in dolphin prey and the collapse of important fisheries for migratory species. The Farakka Barrage has already nearly eliminated the hilsa fishery above the barrage (Jhingran 1982, Sinha 1997) and dramatically reduced the catch of Indian major carps (*Labeo rohita, L. calbasu, Catla catla* and *Cirrhinus mrigala*; Sinha 1997).

Recommendations

Conserving susus near the Farakka Barrage will require collaboration among barrage and water development authorities. The first step should be to raise awareness of the status and importance of conserving river dolphins. Research should address siltation, nutrient enrichment, and luxuriant growth of macrophytes behind the barrage. Information is needed from long-term studies of the morphological, hydrological, and ecological impacts of the barrage. Fishing below the barrage, especially during the rainy season, should be prohibited for 3km downstream. The entire feeder canal should be established as a protected area. Commercial fishing and the discharge of pollutants into the feeder canal should be prohibited, and regulations must be enforced. Alternative employment for fishermen, which could include aquaculture in the lentic water bodies on the right side of the feeder canal, should be promoted. The use of chemical fertilizers and organochlorine pesticides on farms located on the mid-channel island and right bank of the reservoir should be prohibited.

Acknowledgments

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Chapter 3

Yangtze River Dolphin, or Baiji (*Lipotes vexillifer*)

Baiji (*Lipotes vexillifer*): Travel and Respiration Behavior in the Yangtze River

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Abstract

So few baiji (*Lipotes vexillifer*) survive, and opportunities to observe them in the wild are so rare, that the rudimentary data gathered during three brief encounters in 1987 and 1989 were considered worth analyzing and reporting. It must be acknowledged, however, that these observations may not be representative of the animals' natural behavior, as would have been observed in earlier times when they were much more abundant and widespread in the Yangtze River. Groups of two, two, and three (briefly four) baiji were observed on 18 November 1987, 22 March 1989, and 30 March 1989, respectively, for a total of about seven hours of concentrated study. The group on 30 March was joined briefly by a group of five finless porpoises (*Neophocaena phocaenoides*). All of the baiji appeared to be travelling for the entire time of observations, with no indication of social interactions or feeding. The mean respiration rate of the 30 March group was 1.21 ± s.d. 0.106 per minute during seven recording bouts. This group, followed for almost ten hours, crossed the river five times, apparently to minimize resistance as they travelled upriver against the current. Their minimum average ground speed was 2.4 km/hr in a current of about 2–3 km/hr, making their actual speed about 5 km/hr. Respiratory behavior of the wild baiji was similar to that of a captive male baiji during its daytime, non-feeding mode of behavior.

Introduction

The Chinese river dolphin, or baiji (*Lipotes vexillifer*), is suffering a chronic and possibly irreversible decline largely due to human use of the Yangtze River (Chen and Hua 1989, Leatherwood and Reeves 1994, Wang *et al.* 1998, Zhou *et al.* 1995, 1998). It is classified as Critically Endangered by the IUCN (IUCN 1996) and has been declared a national treasure "of the first order" by the People's Republic of China (Wang 1989).

While the baiji has generated considerable international and Chinese national attention (e.g. Zhou and Zhang 1991, Chen and Liu 1992), surveys for population estimates as well as studies of behavior have been generally unsystematic and of short duration (Zhou *et al.* 1998). The lone baiji in captivity, the adult male "Qi-Qi" at the Wuhan Institute of Hydrobiology, has been studied far more intensively than wild baiji in the river (e.g. Liu and Wang 1989, Liu *et al.* 1994, Yang *et al.* 1997).

In autumn 1987 and again in spring 1989, we were fortunate to observe baiji at two disparate locations in the middle and lower reaches of the Yangtze River, enabling us to describe their basic patterns of behavior. While we had hoped to build on these data in a long-term study of baiji behavior, now – about 10 years later – it appears unlikely that much additional information will be obtained, given the present scarcity of sightings. We therefore present what information we have, compare it to the behavioral descriptions of the lone baiji in captivity (Yang *et al.* 1997), and discuss how our limited data might be extrapolated.

Methods

Searching for baiji was carried out visually with the aid of x7 to x10 power binoculars, variably from the river bank, a 15m long vessel, and 5 to 7m wooden fishing vessels (the latter driven by single-cylinder outboard engines, capable of moving the vessel at 5 to 7km/hr). Fishermen hired by the researchers worked together to search for dolphins, often from as many as 15 vessels. They reported sightings either by shouting from boat to boat, waving flags, or in a few instances using marine-band (VHF) hand-held radios.

Baiji behavior was described on three sighting days: 18 November 1987 and 22 and 30 March 1989. Baiji were also seen (by fishermen, not by us) on 19 and 20 November 1987. In 1987, we followed two baiji to describe behavior from a 7m wooden vessel; on 22 March 1989, our river boat was tied to shore while two animals were observed passing by; and on 30 March 1989, we again followed three and briefly four baiji from a 7m wooden fishing vessel. During follows, we tended to be 100 to 300 meters behind and slightly to the side of the travelling animals. Thus, we did not have clear views to distinguish individual baiji except briefly when the vessel was close or alongside the animal. Observations were made by naked eye from the fishing vessels but with nine power binoculars from the stationary platform near shore on 22 March 1989. In all cases, a primary observer dictated behavioral descriptions into a portable tape recorder. At the same time, one secondary observer photographed the dolphins when possible, and a third observer recorded weather, location, and other observations on data sheets.

In the laboratory, observer voice recordings were transcribed; and respiration data were entered into a computer spreadsheet and graphed. Statistical analyses were not attempted because of small data sets and the realization that our several days and only about seven hours of observations may present a biased, uncharacteristic view of the species.

Results

In 1987, baiji were seen on three of four census days on the river, within 10km of the city of Chenglingji, not far from Dongting Lake, and about 1,287km from the Yangtze River mouth at Shanghai. We followed two baiji for 44 minutes on 18 November; and one and three were seen briefly by fishermen working for the research crew, on 19 and 20 November, respectively. Unfortunately, we do not know whether any of these represented repeat sightings.

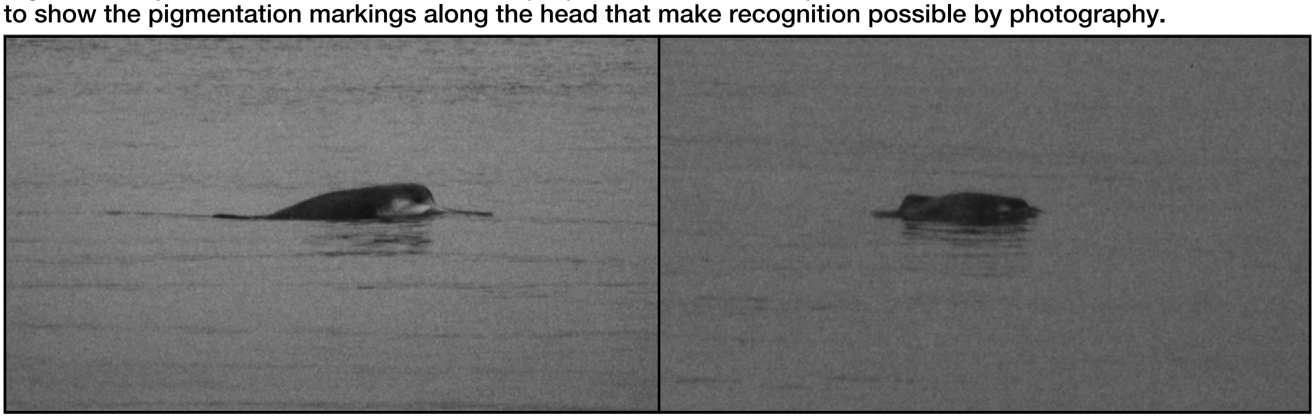
On 18 November, the two apparently adult baiji travelled downriver (with the current), 15.16–16.00h local time. They moved within about 200m of one side of the river, which was 600–800m wide in this area. Our observation vessel, a 7m wooden fishing boat with a one-cylinder outboard motor, followed generally 150–200m behind the dolphins. Travel was judged to be "medium speed," with no whitewater along the flanks of the animals as they surfaced, estimated to be about 4km/hr (which made distance covered 7–8km/hr because of the generally swift currents of the area). The first surfacing after each longer-than-60 second dive tended to be with head and rostrum exposed, so we could clearly distinguish facial markings and a variably dark "brush-like" shading behind the eyes of one individual (Fig. 1).

In general, we were not able to dictate the fishing vessel's movements to suit our research interests, and stayed too far behind the dolphins for reliable surfacing data. However, short sequences when we were briefly closer revealed the following, with dives longer than 60 seconds underlined: Animal "A" surfaced and respired in second intervals of 12, 7, 15, 15, 68, 13, 18, 22, 17, 16, 79, 18, 20, 15, and 13 before we lost sight of it. Animal "B" surfaced and respired in second intervals of 16, 12, 14, 25, 82, 25, 28, 17, 14, 72, 22, 18, and 15 before it, too, was lost. Short "inter-dive" respiration intervals were between 7 and 28 seconds, and there were three to five of these between the four longer dives. Dolphin "A" exhibited a short dive mean of 15.5 $\pm$ s.d. 3.82sec (n=13), and Dolphin "B" showed a mean of 18.7 $\pm$ s.d. 5.39 seconds (n=11). Both animals were lost from view when they dived abruptly approximately eight meters in front of a fast-moving barge.

On 22 March 1989, two baiji were encountered travelling upriver past a mid-river island. Observations were made from a stationary vessel on shore, from a distance of about 200m. The location was at Yubanzhou, in a channel of the mainstem of the river, almost exactly 600km from the mouth of the river at Shanghai. This set of observations was the only one without an observation vessel moving with the animals, and thus may represent the "least-disturbed" baiji encounter described in this note.

The two baiji were observed from 13.23.11 (hours, minutes, seconds, local time) to 14.03.34, or for 40.4min. They travelled approximately 75 to 100m apart, with one dolphin ("A") in front and the other one ("B") almost directly behind. Travel was again "medium speed", or about 4km/hr. However, because the dolphins were travelling

Figure 1. Dolphin "A" of 18 November, 1987 (left); and a different Dolphin "A" of 22 March 1989; in both cases to show the pigmentation markings along the head that make recognition possible by photography.

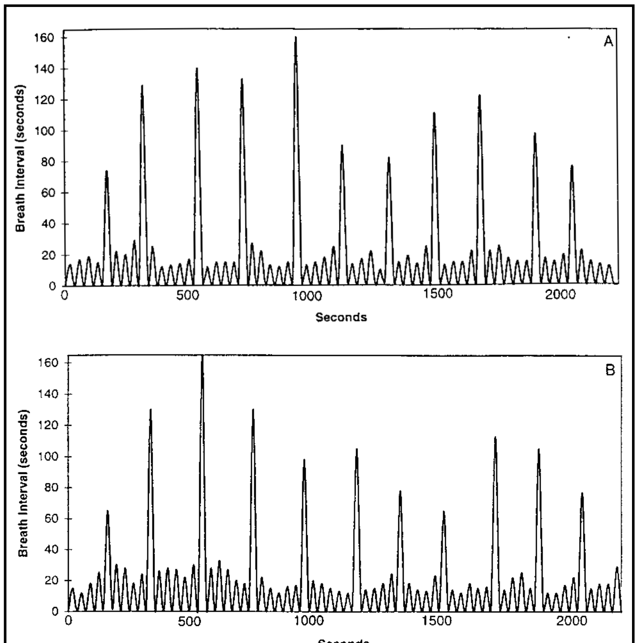


upriver into a current of about 1–3km/hr, they made slow progress, covering only about one kilometer along the mid-river island during the 40.4min of observations. This explains why we were able to watch the traveling dolphins for so long from a stationary viewing site.

As in 1987, surfacings after a long dive tended to be with head and rostrum exposed. Again, we were able to distinguish animals by markings on the head and back. Baiji "A" was slightly smaller than "B" and had a lighter head and back, with heavy criss-cross scarring on its back. Baiji "B" was less scarred and appeared to be darker overall.

The surfacing/respiration pattern for both animals is summarized in Figure 2. While long dives were always greater than 60 seconds ("A" mean = 110.4 ± s.d. 28.70sec, n=11; "B" mean = 102.8 ± s.d. 31.02sec, n=11), there were three to five shorter respiration intervals between them, all lasting less than 35 seconds ("A" mean = 17.2 ± s.d. 5.79sec, n=49; "B" mean = 19.3 ± s.d. 5.79sec, n=53). Figure 2 shows the remarkable consistency in surfacing/dive patterns for the approximately 37 minutes of observation of each dolphin, with the unproved possibility of "bouts" of several long and several short dives by both baiji (compare the longer dives around 500 and 1,700 seconds for both dolphins with shorter dives at the beginning, middle, and end of observations. Overall, the respiration rates were 60 respirations per 34.26min, or 1.75/min, for dolphin "A"; and 64 respirations per 35.88min, or 1.78/min, for dolphin "B".

Figure 2. Surfacings and dives, which were correlated fully with respirations, for two dolphins observed for slightly longer than one-half hour, 22 March 1989. Note the high regularity of short respiration intervals and longer dives.



On 30 March 1989, dolphin researchers from the Wuhan Institute of Hydrobiology observed a group of three, briefly four, baiji from 07.15 to 17.00, or for almost ten hours. During that time, the animals travelled mainly upstream, with occasional meandering, for a total distance of 24km, or at a minimum average speed of approximately 2.4km/hr. Since the current was estimated at about 2–3km/hr for that area (Chen Peixun, pers. observ.), the dolphins may have travelled at a speed of about 5km/hr.

Several of us travelled with the baiji from 09.45 to 15.00, and described respirations of three, briefly four, animals during seven bouts when we could count all respirations. Unfortunately, our distance of generally 100–300m from the dolphins only occasionally allowed us to differentiate them, and we were forced to count all surfacings during these bouts of better observations, and – for overall estimates of numbers of blows per individual – divide by the three (briefly four) animals present in the group. These data are presented in Table 1, and they show a mean of 1.21 ± s.d. 0.106 respirations/min (n=7 bouts).

Three dolphins travelled together, generally within 5 to 15m of each other, throughout the day. A smaller individual, possibly a subadult, travelled close beside a larger dolphin, and a second even larger one was generally ahead of the two, by up to 15m. From at least 12.23 through 12.38 (see Table 1), these three were joined by another large animal. This large individual travelled in the lead, and while it was present, the other three dolphins bunched closely together, trailing behind. We did not see the large "newcomer" approach or leave, but are certain from at least one almost synchronous set of surfacings that there were four individuals in the group for at least 15 minutes.

Table 1. Surfacing data on baiji travelling upriver on 30 March 1989. Because we could not clearly distinguish between individual dolphins from our vantage point almost directly behind them, we logged all surfacings during seven unequivocal bouts of data gathering, and calculated mean respirations per minute by dividing by the number of dolphins present.

Time	Number of Minutes	Number of Baiji	Number of Respirations	Respirations/ Minute
10.06.53–10.14.49	7.93	3	30	1.26
10.42.32–11.04.49	22.28	3	86	1.29
11.20.54–11.48.40	27.75	3	86	1.03
12.00.39–12.11.39	11.00	3	40	1.21
12.23.14–12.38.13	14.98	4	68	1.13
12.49.10–13.06.45	17.58	3	71	1.35
14.15.28–14.33.17	17.80	3	64	1.20

The three "primary" dolphins crossed from one side of the river to the other on at least five occasions. At times, this crossing took place abruptly, apparently bringing the dolphins into the lee of currents at the far side of a river bend, and away from forceful or swift currents just before a river bend. However, our observations of crossovers are not numerous enough to "prove" that the baiji use a particular travelling strategy consistently.

Baiji were seen with finless porpoises (*Neophocaena phocaenoides*), at least briefly, during all but the 22 March 1989 encounter. On 18 November 1987, at least five finless porpoises appeared to join the two travelling baiji for approximately five minutes. There was no sign of change in headings, speed, or behavior of the baiji. During the long 'follow' of 30 March 1989, two to five finless porpoises accompanied the three "primary" baiji on four occasions, staying with them for two min. to as long as 25min. Again, it was our impression that the finless porpoises approached the baiji, while the baiji did not appear to change their travel direction or speed. The baiji in two other sightings reported to us by fishermen (on 19 and 20 November 1987) were also said to have had finless porpoises near or with them, but we obtained no further information on this point.

Discussion

The baiji described here were all in groups of two to three, with one brief grouping of four. Chen and Hua (1989) reported that during a survey between November 1985 and February 1986, most of the groups observed were larger than five, with some of them containing up to nine to 16 animals. The small groups that we encountered may not represent the optimal group size for this species. The fact that three dolphins stayed together for at least 10 hours while they travelled several dozen kilometers indicates some degree of fidelity among adults. In the present cases, however, we are ignorant of sex, age, and possible kinship among the group members.

All three of the groups that we observed were travelling, with no indications of socializing, playing, or resting. The dolphins may well have been feeding while travelling, but we did not see fish or other prey in their mouths, and have no further information on this point. Swimming speeds and surfacing/dive/respiration patterns were remarkably consistent among groups, among animals within a group, and for individuals over time. We are reluctant to call the behavior of baiji "consistent," however, because we appear to have observed them only during the one behavioral mode of travel. At any rate, the two dolphins of 18 November 1987 averaged surfacing intervals of 15 to 19 seconds, and dives of somewhat more than one minute. Interestingly, the two animals observed on 22 March 1989 exhibited very similar average surfacing intervals, but with long dives considerably longer than those of the 1987 dolphins (103 and 110sec). Respiration rates of the latter two animals swimming upriver were about 1.75/min. This is much higher than those of the three to four dolphins of 30 March 1989, which averaged only 1.21/min during their travel, also upriver.

The respiration rates of the two baiji of 22 March 1989 were remarkably similar to that of Qi-Qi, at 1.77/min (Yang *et al.* 1997). Furthermore, surfacing intervals and long dives of 22 March were quite similar to Qi-Qi's daytime "general" (non-feeding) surfacings and dives.

Multiple river crossings by the three dolphins of 30 March 1989 were of particular interest. This kind of movement pattern has been observed quite often when animals were travelling upstream (Wang Ding, pers. observ.), and the crossings suggest that the animals were attempting to shorten the distance to be covered, to swim in areas of least current, or both. It is also possible, however, that these crossings of the river were prompted by other factors not related to distance or current. It is even possible that the abrupt changes in direction and river side were related to searching for or following prey. Interactions between the baiji and finless porpoises would also be interesting to study further. Our brief observations suggested a curiosity of finless porpoises toward baiji, but not the reverse. There was no obvious indication of aggressive or competitive interactions.

Finally, we do not wish to attribute too much significance to these brief observations of baiji. They would hardly be worth reporting if there were a reasonable chance to gather more data on swimming, surfacing/diving, and inter-individual affiliations and interactions during different behavioral modes and in different kinds of habitat. Alas, such data may not be easily gathered on this highly endangered species. We hope that the baiji will survive and increase in number, so that our data can serve as a baseline of information from snapshots of the species' bleakest times.

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Chapter 4

Ganges River Dolphin, or Susu (*Platanista gangetica*)

Status and Distribution of the Ganges Susu (*Platanista gangetica*) in the Ganges River System of India and Nepal

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Abstract

Although comprehensive surveys for Ganges river dolphins, or susus (*Platanista gangetica*), have not been conducted throughout the entire Ganges river system, an informed assessment can be made of their status in certain areas. Susus are particularly threatened in the upstream reaches of smaller tributaries, where populations are often isolated behind barrages and are more vulnerable to human activities because of the reduced area of their habitat. Perhaps the most endangered populations are in Nepal, with only remnant groups in the Karnali and Sapta Kosi rivers. Other tributaries where dolphins are especially threatened include the Sone River, upstream of the Indrapuri Barrage, and the Sind and Betwa tributaries of the Yamuna River. In the Ganges mainstem, the dolphin's upstream range has declined by approximately 100km – no dolphins occur above the Bijnor Barrage. Animals below the barrage may be at increased risk from industrial pollution at Kanpur because of the reduced dilution capacity of the river. This situation will worsen once construction of the Kanpur Barrage is complete. The new barrage will also add to the problem of population fragmentation. Areas where surveys are particularly needed include the Burhi Gandak tributary of the Ganges, the Kamla tributary of the Kosi, small tributaries of the Mahananda River, and the Yamuna River between Delhi and the confluence of the Chambal River. Dolphins in the Ganges River system appear to be sufficiently numerous for timely conservation action to be worthwhile.

Introduction

The Ganges river dolphin, or susu (*Platanista gangetica*), was historically distributed throughout the Ganges/Brahmaputra/Megna and Karnaphuli river systems of India, Nepal, and Bangladesh (Anderson 1878, Kasuya and Haque 1972, Jones 1982, Mohan 1989, Reeves and Brownell 1989, Shrestha 1989, Reeves *et al.* 1993). Its range has been reduced, however, and abundance has declined in many areas where the animals still occur (Reeves and Leatherwood 1995). IUCN–The World Conservation Union recently revised the threatened status of the susu from Vulnerable (Klinowska 1991) to Endangered (IUCN 1996).

The susu's survival in the Ganges River is threatened by: (a) accidental killing through entanglement in fishing gear, most often nylon gill nets; (b) deliberate killing, generally for dolphin oil used as a fish attractant and for medicinal purposes; (c) water development (e.g. water abstraction and the construction of barrages, high dams, and embankments), which fragments populations, interrupts the movement of migrating prey, and alters the ecological features that make river channels suitable for sustaining dolphins; (d) increasing levels of chemical pollution, such as chromium from tanneries, sulfur from paper mills, fly ash from thermal power plants, butyltins from the manufacture and disposal of PVC pipe, paints, and plastic bags, PCBs from the disposal of transformers and other electrical appliances, and organochlorine pesticides used for agriculture and vector control; (e) increasing levels of other forms of pollution, such as city sewage and noise from vessel traffic; and (f) over-exploitation of prey, mainly due to the widespread use of non-selective fishing gear, especially mosquito nets, during fish breeding migrations and early juvenile growth.

This paper reviews the status and distribution of susus in the Ganges river system and identifies areas where research and conservation activities are most needed. We emphasize that quantitative data for assessing river dolphin abundance are lacking for most of the Ganges river system.

We also acknowledge that the abundance estimates reported in this paper were generally obtained without rigorous application of a well-defined survey design. As a result, the estimates lack measures of precision and are biased in unknown ways (see Smith and Reeves, this volume a). The reported data should therefore be interpreted only as providing an indication of dolphin occurrence and *approximate* population levels. We include data from published sources and our own unpublished observations.

Status and distribution by river or system

Ganges Mainstem

A comprehensive survey of the entire Ganges mainstem (Figure 1) has not been conducted. Anderson (1878) reported that the susu's 19th century range in the Ganges extended from the delta region of the Sundarbans upstream to Haridwar.

From 8–11 December 1996, Sinha and G. Sharma conducted a survey from Haridwar to 10km upstream of the Narora Barrage (approximately 255km). They saw 26 groups for a total of 28–35 dolphins (overall best estimate 28, mean group size 1.1, SD=0.39, range=0–2). All dolphins were located downstream of the Bijnor Barrage (approximately 156km). Local fishermen reported that they had not seen dolphins upstream of the Bijnor Barrage in the previous 5–6 years.

During 1993–95, Rao (1995) recorded 22 dolphins between the Bijnor and Narora barrages (approximately 166km). During 25 January – 2 February 1998, Behera conducted a survey between the Bijnor and Narora barrages. He saw 35 dolphins. The largest concentration of animals was located at Bridgeghat where he saw eight dolphins.

During January–March 1978, Gupta (1986) conducted 27 visits to scattered locations between Allahabad and Calcutta. He counted 52–55 dolphins and observed the greatest concentration at Munger. During 11–22 October 1995, Sinha and G. Sharma conducted a survey from Allahabad to Patna (approximately 600 km). They observed 117 groups for a total of 198–265 dolphins (overall best estimate=237, mean group size=2.0, SD=1.2, range=1–9). During 7–16 October 1997, Sinha, Prasad, and G. Sharma conducted another survey from Allahabad to Patna. They observed 186 groups for a total of 285–365 dolphins (overall best estimate=333, mean group size=1.8, SD=1.1, range=1–7).

On 9–18 February 1988, 7–15 May 1989, and 6–14 August 1989, Ali (1992) conducted surveys from Buxar to Sirigat [Bhagalpur] (approximately 463km) and counted 88, 28, and 159 dolphins, respectively. He recorded the greatest concentration of dolphins in the river segment from Munger to Bhagalpur.

Sinha and G. Sharma conducted surveys of nine discrete segments of various lengths, ranging from 10–35km and totaling 120–125km, of the Ganges River between Buxar and the Farakka Barrage. Eight surveys of the nine segments were conducted during the post-monsoon

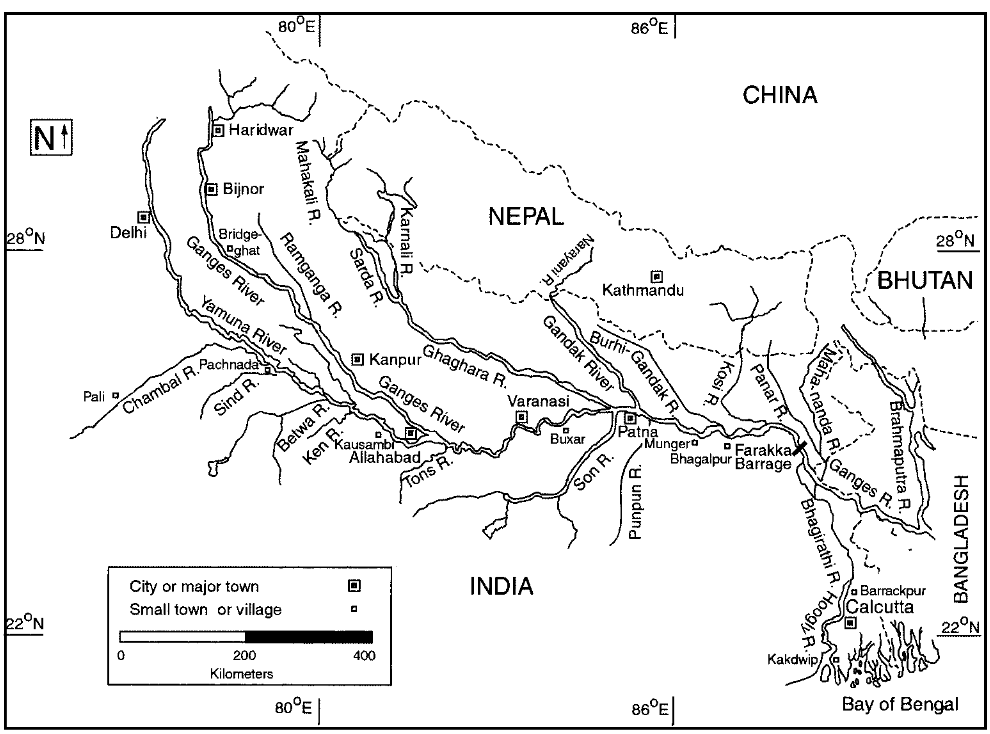

Figure 1. Map of the Ganges River system in Nepal and India showing locations referred to in the text.

(October–November), winter (January–March), and summer (April–June) seasons of 1991 through 1994 (Table 1). Each segment was a continuous stretch of the river, except at Farakka, where 3.5km was surveyed on each side of the barrage and 3km of the feeder canal was surveyed (see Sinha, this volume). Data for the three portions are combined to represent the Farakka segment in Table 1. During the post-monsoon surveys in 1991, 1992, and 1993, Sinha and Sharma counted 217, 115, and 109 dolphins, respectively. During the winter surveys in 1992, 1993, and 1994, they counted 198, 106, and 96 dolphins, respectively. During the summer surveys in 1992 and 1993, they counted 116 and 48 dolphins, respectively.

During 26–29 April 1998, Sinha, Prasad, and G. Sharma conducted a survey from Patna to Sultanganj, located 35km upstream of Bhagalpur (approximately 250km). They observed 83 groups for a total of 144–161 dolphins (overall best estimate=146, mean group size =1.76, SD= 1.41, range=1–9).

During 11–18 November 1994, Sinha and G. Sharma conducted a survey from Patna to the Farakka Barrage (approximately 460km). They observed 161 groups for a total of 207–270 dolphins (overall best estimate=224, mean group size=1.4, SD=1.3, range=1–9). During 10–19 October 1996, Sinha and Sharma conducted a second survey from Patna to the Farakka Barrage. They observed 50 groups for a total of 103–130 dolphins (overall best estimate=112, mean group size=2.2, SD=2.3, range=1–10).

On 7 January 1996, Sinha conducted a survey between Sultanganj and Kahalgaon (located 25km downstream of Bhagalpur), the upstream and downstream limits of the Vikramshila Gangetic Dolphin Sanctuary. He observed at least 92 dolphins. On 30 November and 2 December 1998, Sinha, G. Sharma, and Smith conducted upstream surveys of the sanctuary (Bhagalpur to Sultanganj=35.3km and Kahalgaon to Bhagalpur=25.0km). They observed 63 groups for a total of 81–108 dolphins (overall best estimate=95, mean group size=1.5, SD=1.5, range=1–9, encounter rate=1.6 dolphins/km). On 1 December 1998, the same investigators conducted a downstream survey of the same area. They observed 33 groups for a total of 47–56 dolphins (overall best estimate=49, mean group size=1.5, SD=0.6, range=1–12, encounter rate=0.9 dolphins/km). The difference in the number of animals observed during upstream and downstream surveys was probably related to the faster average speed of the survey vessel while traveling downstream (9.6km/hr vs. 5.2km/hr).

In general, surveys in the Ganges mainstem have found particularly high concentrations of dolphins: (1) at the convergence of the Yamuna and Ganges rivers at

Table 1. Results of dolphin surveys in nine segments of the Ganges River during post-monsoon (PM), winter (W), and summer (S) seasons.

Survey stations	Year	Survey Distance (km)	Number of dolphins observed PM	W	S	Dolphins per km PM	W	S
Buxar	1991–92	25	17	29	10	0.7	1.2	0.4
	1992–93	25	10	6	3	0.4	0.2	0.1
	1993–94	25	21	11	ND*	0.8	0.4	ND
Koilwar	1991–92	10	10	11	9	1.0	1.1	0.9
	1992–93	10	ND	ND	ND	ND	ND	ND
Patna	1991–92	35	53	85	45	1.5	2.4	1.3
	1992–93	35	30	30	14	0.9	0.9	0.4
	1993–94	35	25	25	ND	0.7	0.7	ND
Mokama	1991–92	10	36	36	14	3.6	1.9	1.4
	1992–93	10	12	12	6	1.2	1.9	0.6
	1993–94	10	11	11	ND	1.1	0.4	ND
Munger	1991–92	10	27	27	16	2.7	2.0	1.6
	1992–93	10	16	16	4	1.6	1.0	0.4
	1992–94	10	13	13	ND	1.3	1.0	ND
Sultanganj	1991–92	10	39	39	2	3.9	0.5	0.2
	1992–93	10	21	21	6	2.1	1.0	0.6
	1993–94	10	5	5	ND	0.5	0.5	ND
Kahalgaon	1991–92	15	ND	ND	ND	ND	ND	ND
	1992–93	15	10	3	8	0.7	0.2	0.5
	1993–94	15	20	16	ND	1.3	1.1	ND
Rajmahal	1991–92	10	20	25	11	2.0	2.5	1.1
	1992–93	10	13	24	6	1.3	2.4	0.6
	1993–94	10	11	17	ND	1.1	1.7	ND
Farakka	1991–92	10	15	4	4	1.5	0.4	0.4
	1992–93	10	3	4	1	0.3	0.4	0.1
	1993–94	10	3	0	ND	0.3	0.9	ND

* ND = not done

Allahabad; (2) at the convergence of the Tons and Ganges rivers at Sirsa; (3) at the convergence of the Ghaghara and Ganges rivers at Doriganj; (4) at the convergence of the Gandak and Ganges rivers at Patna; (5) in large counter-currents created by the intrusion of a bedrock formation at Bateshwarsthan (8km downstream of Kahalgaon) and Sultanganj (the main course of the river has recently changed so that this area no longer supports such a high concentration of dolphins); (6) in the vicinity of the three rock islands at Kahalgaon; (7) at the convergence of the Kosi and Ganges rivers 20km downstream of Kahalgaon; and (7) below sharp meanders and mid-channel islands scattered throughout the river course.

Farakka feeder canal

The Farakka feeder canal carries water from the Ganges River to the Bhagirathi River, which ultimately flows into the Hoogly River. The water is diverted to allow navigation to the Calcutta Port. The feeder canal is 38km long. During four surveys of the feeder canal, on 3 April 1995, 20–21 August 1995, 10 March 1996, and 25 September 1996, Sinha (this volume) observed 16 groups for a total of 14–20 dolphins (overall best estimate=20, mean group size=1.2, SD=0.4, range=1–2), eight groups for a total of 13–15 dolphins (overall best estimate=14, mean group size=1.7, SD=2.1, range=1–7), eight groups for a total of 13–17 dolphins (overall best estimate=14, mean group size 1.7, SD=1.7, range=1–6), and eight groups for a total of 18–22 dolphins (overall best estimate=21, mean group size=2.6, SD=2.0, range=1–7), respectively. Dolphins were concentrated downstream of bridge pilings and a submersible weir, and at the convergence of the feeder canal and Bhagirathi River.

Bhagirathi River

During 3–9 April 1995, Sinha (1997) conducted a survey of the Bhagirathi River from the Jangipur Barrage (near the convergence of the Farakka feeder canal) to Tribenighat, where the river's name changes to the Hoogly (approximately 320km). He observed 86 groups for a total of 104–132 dolphins (overall best estimate=119 dolphins, mean group size=1.4, SD=0.8, range=0–5). Dolphins were concentrated at the confluence of the feeder canal and below sharp meanders scattered throughout the length of the river.

Hoogly River

During 9–11 April 1995, Sinha (1997) conducted a survey of the Hoogly River from Tribenighat to the Calcutta Botanical Gardens (approximately 100km). He observed 10 groups for a total of 10–16 dolphins (overall best estimate=12 dolphins, mean group size 1.2 dolphins, SD=0.8 range=0–2). The 18km segment between Barrackpur and the Howrah Bridge at Calcutta was covered during the night so this segment was not, in effect, surveyed. Dolphins were concentrated downstream of the Bandel and Howrah bridges. On 12 April 1995, Sinha (1997) also sighted a single dolphin in the mouth of the Hoogly Delta at Kakdwip.

Large tributaries

Yamuna River

Anderson (1878) reported that susus were present throughout the year in the Yamuna River as far upstream as Delhi. The only recent record of dolphins this far upstream was a dolphin caught in a fisherman's net in 1967 and brought dead to the Delhi Zoo (K.S. Sankhla, pers. com.).

During 3–7 January 1997, R.K. Sharma conducted a survey in the Yamuna River from the confluence of the Chambal River to Hamirpur (approximately 250km). He observed 25–40 dolphins. During June 1998, R.K. Sharma and Behera observed 48 dolphins in this same segment of river.

During 9–11 October 1995, Sinha and G. Sharma conducted a survey of the Yamuna River from Kausambi to Allahabad (approximately 90km). They observed seven groups for a total of 16–21 dolphins (overall best estimate=18, mean group size=2.6, SD=3.3, range=1–10). Dolphins were concentrated at the confluence of the Yamuna and Ganges rivers at Allahabad, where 8–11 animals were observed. These animals were included in the data for the Yamuna survey, rather than the Ganges, due to the greater effect that this river has on creating the large counter-current at the confluence where the dolphins were seen.

Chambal River

From the results of surveys conducted in 1982–1985, Singh and Sharma (1985) estimated that 45 dolphins inhabited the approximately 305km segment of river between Batesura and the confluence of the Yamuna River at Barhi (although the abstract of the published paper reports this same number for the river segment from Batesura to Pachhnada – see below). During February 1988, Rao *et al.* (1989) conducted a survey in the Chambal River from Batesura to Pachhnada and counted "around 50 dolphins." Pachhnada is located in the Yamuna River approximately 15km downstream from the Chambal confluence, so we assume that these observations include some dolphins in the Yamuna. During 12 February–2 March 1993, Sharma (1993) conducted a survey from Pali to Barhi (approximately 370km). He observed 30 dolphins. During 25 January–12 February 1994, Sharma *et al.* (1995) conducted a survey between Pali and Barhi and observed 29 dolphins.

Ghaghara River (Karnali in Nepal)

During September 1982 and January 1983, Shrestha (1989) surveyed the Karnali River between Solta and the Nepal/India border at Kotiaghat. He reported counts of 12 and 20 dolphins, respectively, all downstream of Kachali.

During 21–25 January and 4–17 April 1990, Smith (1993) conducted upstream and downstream surveys from Kachali to Kotiaghat and observed 5–6 dolphins. No dolphins were observed downstream of Ghostighat, which is approximately 40km downstream of Kachali.

During 19–25 February 1993, Smith *et al.* (1994) conducted upstream and downstream surveys between Kachali and the Girijapuri Barrage (approximately 20km downstream of the Nepal/India border). They observed 23–30 dolphins, only two of which were observed upstream of the Nepal/India border.

During 22–23 February 1998, Smith conducted a survey from Kachali to Kotiaghat. He observed four groups for a total of six dolphins. On 27 February 1998, Smith surveyed from Chisapani to Kotiaghat and observed three groups for a total of 5–6 dolphins. During both surveys, the farthest upstream that dolphins were observed was at Golaghat, approximately 35km downstream of Kachali.

During surveys for gharials (*Gavialis gangeticus*) conducted by the Uttar Pradesh Forest Department in 1992, dolphins were observed throughout the river segment between the Girija Barrage and the Ganges mainstem (D. Basu pers. comm.). Sinha and G. Sharma normally see 1–3 dolphins throughout the year at Revilganj (approximately 20km upstream of the confluence of the Ghaghara and Ganges rivers) while monitoring water quality there.

Gandak River (Narayani in Nepal)

In June 1986, Shrestha (1989) reported seeing five dolphins in the Narayani River of Nepal. During 12–18 March 1993, Smith *et al.* (1994) conducted upstream and downstream surveys of the Gandak River, from the upstream limits of dolphin distribution at Devghat (evidenced by high-velocity rapids and rocky barriers) to the Gandak Barrage at the Nepal/India border. They observed 1–2 dolphins. During a more informal 'floatdown' of the same river segment in March 1994, Smith was unable to find a single dolphin. During 12–17 January 1995, Sapkota conducted an intensive survey of the Gandak River from the confluence of the Rapti River at Amaltari to the Gandak Barrage. He could not find a single dolphin. We consider it likely that the susu has been extirpated from this segment of river.

During surveys in January and May 1992, Choudhury was unable to find dolphins between the Gandak Barrage and Bagaha (approximately 50km). However, a forest officer and several fishermen reported that dolphins were frequently seen in the area. No surveys have been conducted in the river segment between the Gandak Barrage and the confluence of the Ganges mainstem at Patna. Sinha and G. Sharma frequently observe one to two dolphins, and occasionally as many as six, throughout the year at Hajipur (5km upstream of the confluence), while monitoring water there. During November 1995, Sinha interviewed fishermen in Vaishali (approximately 50km upstream of the convergence of the Gandak and Ganges rivers) who said that they see dolphins in this area throughout the year and that the animals are occasionally caught in their fishing nets.

Kosi River (Sapta Kosi in Nepal)

In July 1986, Shrestha (1989) reported sighting eight dolphins in the Kosi River above the Kosi Barrage at the Nepal/India border. During 26 March–3 April 1993, Smith *et al.* (1994) conducted upstream and downstream surveys of the Kosi River, from the confluence of the Arun and Sun Kosi rivers, where rocky barriers and strong currents prevent dolphins from swimming farther upstream, to the Kosi Barrage. They observed a maximum of three dolphins.

During 26–27 May 1994, G. Sharma conducted a survey of a 60km stretch of river below the Kosi Barrage. He observed 22–32 dolphins (overall best estimate of 26 dolphins, mean group size 3.2, SD=3.2, range=1–10).

On July 1991, Sinha conducted a one-day survey of approximately 15km of the Kosi River on both sides of the Dumri Bridge (approximately 150km downstream of the Kosi Barrage). He observed 2–3 dolphins. Fishermen reported that they frequently observed dolphins approximately 100km farther downstream at Naugachhia.

Mahananda River

In February 1993, Sinha and G. Sharma received a carcass of a pregnant female dolphin that reportedly had been caught accidentally in a gill net in the Mariadhar tributary of the Panar River, which is a tributary of the Mahananda. An adult female was also killed on 25 January 1993 in the Lohandra River, a tributary of the Bhalwa River, which is also a tributary of the Panar (S. Sahay, pers. comm.).

Small tributaries

Sarda (Mahakali in Nepal)

In September 1986, Shrestha (1989) reported seeing four dolphins in the Sarda River upstream of the Nepal/India border. During 1–3 March 1993, Smith *et al.* (1994) surveyed the segment of the Sarda River flowing through Nepal and found that there was insufficient water to sustain dolphins (maximum depth of 20cm in some channel cross-sections). The Sarda Barrage, located near the northwest border of Nepal and India, diverts flow from the Sarda for irrigation purposes.

On 17–23 March 1994, Sinha, G. Sharma, and Smith conducted upstream and downstream surveys of the Sarda River, from the Sarda Barrage to the farthest upstream limit of dolphin distribution, evidenced by insufficient water, near the southern border of Nepal and India. No dolphins were observed during the surveys, although local people reported that dolphins could be seen during the monsoon season. If dolphins do indeed occur in the Sarda River, above the Sarda Barrage, this would require that the animals swim past the gates of the barrage when they are open during the monsoon season. This situation is unlikely but not impossible. Another explanation is that dolphins move downstream from the Ghaghara River, through the link canal located on the west side and upstream of the Girijapuri Barrage. Sharma returned to the Sarda River on 11–15 April and 4–6 September to investigate whether dolphins were passing through the barrage while the gates were open; the gates are normally opened during monsoon floods and for a short time in April to supply water for religious bathing. He was unable to find evidence of dolphins occurring in the reservoir behind the barrage or in Ghaghara link canal. However, local people reported catching one dolphin a few years ago in an irrigation canal carrying water from the Sarda River.

On the basis of surveys conducted during March–April (summer season) and July–August (monsoon season) of 1989–1993, Choudhury estimated that the Suheli and Mohana tributaries of the Sarda River supported approximately 10 dolphins during the monsoon season and that these animals moved into the Sarda during the dry season. He also estimated that the segment of the Sarda River within the Dudhwa Tiger Reserve (approximately 80km in length) supported 10–20 dolphins during both monsoon and summer seasons.

Sone

During March 1994 and September 1995, Sinha conducted an informal survey (walking) from the Indrapuri Barrage to the confluence of the Sone and Ganges rivers. No dolphins were observed. Except during the monsoon (July to September), the river below the Indrapuri Barrage does not contain sufficient water to support dolphins. Local people reported that a few dolphins migrate as far upstream as the Bansargar Barrage (see Smith *et al.* this volume) during the monsoon season. R.K. Sharma surveyed a 130km segment of the Sone River between Bichhi to Banjari (upstream of the Indrapuri Barrage) in June 1998 and observed 10 dolphins.

Sind

In June 1998, R.K. Sharma and Behera surveyed a 110km segment of the Sind River upstream of the confluence with the Yamuna and recorded five dolphins. Two of these were observed at the confluence, and two were observed approximately 60km upstream of the confluence.

Kumari

In June 1998, R.K. Sharma and Behera surveyed a 100km segment of the Kumari River from the confluence with the Sind River and observed no dolphins. Local people reported seeing dolphins during the monsoon season.

Betwa

In June 1998, R.K. Sharma and Behera surveyed an 84km segment of the Betwa River from the confluence of the Yamuna at Hamirpur to Orai. They observed six dolphins.

Ken

In June 1998, R.K. Sharma and Behera surveyed a 30km segment of the Ken River from the confluence of the Yamuna at Chilla to Sindhan Kala village. They observed eight dolphins.

Punpun

Local people reported to Sinha that, prior to the construction of embankments in 1975, dolphins were frequently seen during the monsoon season as far upstream as Shripalpur (approximately 35km upstream of convergence of the Punpun and the Ganges). During the monsoon season of 1991, Sinha and G. Sharma surveyed the Punpun River between Gaurichak and the confluence with the Ganges (approximately 20km). No dolphins were observed, but local people reported that a few animals were occasionally seen in this area during the monsoon. During the same survey, two dolphins were seen at the Ganges confluence.

Burhi Gandak

During fish surveys of the Burhi Gandak River conducted during 1989–1993, Prakesh *et al.* (1996) reported that they occasionally observed dolphins in deeper portions of the river during the monsoon season.

Bagmati, Rapti, Babai, and Tinnau

Sapkota conducted foot and jeep surveys of the Bagmati, Rapti, Babai, and Tinnau rivers of Nepal on 10–14, 16–21, 23–26, and 29–31 August 1995, respectively. He did not observe dolphins in these rivers, but local people reported that a few were occasionally seen in the Bagmati River at Samanpur and Pipra, and in the Rapti River near Kachnapur, during the monsoon season.

Discussion

Although there is insufficient information to estimate the total abundance of susus in the Ganges system, we can make informed assessments of their status in specific areas. The most critically endangered populations appear to be those located in the upstream reaches of the smaller tributaries. Dolphins inhabiting these areas are more vulnerable to human-induced effects because of the restricted nature of their habitat, especially during the low-water season, when channel width is reduced and fishing activities are intensive. Furthermore, dolphins in tributaries are often isolated behind barrages, which affects their migratory and dispersal patterns, as well as movements of their prey (Smith and Reeves, this volume b, Reeves and Smith 1999).

Perhaps the most endangered populations of susus are those in the tributaries of Nepal. The only river in Nepal that supports an even questionably viable population is the Karnali upstream of the Girija barrage. We believe that this population will soon go extinct in the absence of conservation action on both sides of the Nepal/India border (see Smith 1993, Smith *et al.* 1996). Other small tributaries of India where dolphins are particularly threatened include the Sone tributary of the Ganges, upstream of the Indrapuri barrage, and the Sind and Betwa tributaries of the Yamuna. Information is needed on the status of dolphins in the Burhi Gandak tributary of the Ganges, the Kamla tributary of the Kosi, and the Bhalua and Panar tributaries of the Mahananda River, as well as the Mariabhar tributary of the Panar.

The current upstream limit of the range of dolphins in the Ganges mainstem appears to be below the Bijnor Barrage. This means that the total linear extent of their distribution in the Ganges has declined by approximately 100km since the 19th century (Anderson 1878). Population fragmentation, water abstraction, and pollution pose particular threats to dolphins inhabiting the Ganges mainstem downstream of the Bijnor Barrage until the convergence of the Yamuna River at Allahabad. In addition to reducing the amount of available habitat, water abstraction decreases the ability of the river to dilute pollutants. A paint factory, located between the Bijnor and Narora barrages, releases large quantities of suspended solids and organotins, and several tannery industries at Kanpur release chromium into the river. This situation will worsen once construction of the Kanpur barrage is complete (see Smith *et al.* this volume). The river segment between Allahabad and the Bijnor barrage warrants special conservation attention.

The status of dolphins in the entire tidal zone of the Ganges/Hoogly Delta is uncertain. There is an urgent need to survey the delta because we suspect that dolphins in this area are particularly threatened by the extensive use of non-selective fishing gear, the large volume of ship traffic, and the enormous discharge of urban and industrial pollutants in Calcutta.

The status of dolphins in the segment of the Yamuna River between Delhi and the confluence of the Chambal River is also uncertain. Large-scale water abstraction for agricultural, industrial, and urban uses has severely reduced dry-season flow in the area. We suspect that dolphins are absent from this area during the low-water season but that the river may provide important habitat during the monsoon season.

In conclusion, we believe that the number of dolphins remaining in the Ganges river system is sufficient for their continued survival if conservation measures are implemented soon. Another closely related platanistoid dolphin, the baiji (*Lipotes vexillifer*) in the Yangtze River of China, is on the verge of extinction (Zhou *et al.* 1998). The baiji population has declined due to many of the same factors that threaten susus. The greatest lesson of the baiji may be that early conservation action is required before a metapopulation has reached an irreversible threshold of decline. One promising development in the Ganges was the designation by the State of Bihar in 1991 of the Vikramshila Gangetic Dolphin Sanctuary. A project is currently being implemented by Sinha, G. Sharma, and Smith to transform the sanctuary from one that exists only on paper to one that provides effective protection to dolphins.

To ensure that future surveys contribute toward conservation goals, we recommend that methods be standardized among researchers. Survey reports should include detailed descriptions of methods, search effort, environmental conditions, and dolphin sightings, so that the data can be properly evaluated and future surveys can be designed for comparability (see Smith and Reeves, this volume a).

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Water Development and the Status of the Shushuk (*Platanista gangetica*) in Southeast Bangladesh

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Abstract

The Ganges river dolphin, or shushuk (*Platanista gangetica*), occurs in unknown, but probably small numbers in the Halda, Karnaphuli, and Sangu rivers of southeast Bangladesh. The species has also been recorded in Kaptai Lake, a large reservoir located behind a high dam on the Karnaphuli River. The barrier effects of the dam isolate dolphins living in the lake from others downstream in the Karnaphuli. The shushuk may also occur in the Feni River/Reservoir, and Matamuhuri and Bagkhali rivers, but its presence in these water systems has not been confirmed. Dolphins occurring in freshwater bodies of southeast Bangladesh are presumably isolated by the saltwater barrier of the Bay of Bengal from the majority of individuals of the species inhabiting the Ganges/Brahmaputra/Meghna river system. The animals in southeast Bangladesh are of special conservation significance because they probably comprise one or more discrete stocks. A rigorous survey program is needed to assess the status of dolphins in these rivers. The possibility that dolphins move between the Sangu and Karnaphuli rivers, via a connection provided by the Sikalbaha-Chandkhali Canal, should be investigated. The Sangu River deserves special consideration for protective measures due to its relatively undisturbed status.

Introduction

The Chittagong, Cox's Bazaar, Khagrachari, Rangamati, and Bandarban districts of southeast Bangladesh are drained by the Feni, Halda, Karnaphuli, Sangu, Matamuhuri, and Bagkhali rivers (Figures 1 and 2). These rivers are independent of the Ganges/Brahmaputra/Meghna system. They are characterized by numerous braided channels and tributary junctions, extensive lateral erosion, and low flow during most of the year, but they become torrential during the high-intensity and short-duration rains of the monsoon season. Most of the Feni River is contained behind a closure dam, and the upstream reaches of the Karnaphuli River are contained behind the Kaptai Dam.

This paper reviews the status of river dolphins and water development in southeast Bangladesh. It is hoped that this information will serve as a basis for implementing research and conservation activities.

Summary of rivers and reservoirs

Muhuri River and Feni River/Reservoir

The Feni River rises from the hills of the Tripura State of India. It flows southwest, marking the India/Bangladesh border, until reaching Aliganj, where it emerges from the hills onto the Chittagong Plains. Construction of a closure dam and regulator near the mouth of the river was completed in June 1986 as part of the Muhuri Irrigation Project (see Smith *et al.,* this volume). The Feni Reservoir was designed for normal and minimum pool elevations of 3.8m and 2.6m, respectively, with approximately 27 million m^3 of storage capacity. River flows were measured from January 1983 to June 1986 and were lowest in February–March [5–13cms (m^3/second)] and highest in July–August (64–126cms; Ameen 1987). The convergence of the Muhuri River and the reservoir is near the closure dam. All water in the reservoir is diverted into irrigation canals except during high flows when spillage occurs over the top of the dam. The river/reservoir, navigable by small boats, is approximately 116km long and 80.5km wide. It is uncertain whether shushuks currently occur, or historically occurred, in the Muhuri River or Feni River/Reservoir.

Halda River

The Halda River rises from the Badnatali Hills and flows south into the Karnaphuli River at Kalurghat. Its total length is 80.5km, of which 29km are navigable by large boats and an additional 16–24km by small country boats. Turbulent tributaries flow into the river from the Chittagong and Pakshimimura hills.

On 20 July 1995, fishermen from Raozan brought a live shushuk to the Chittagong Zoo. The dolphin was reportedly found entangled in a fishing net set in the Halda River. It was placed in a fish tank at the zoo but died the next day. The carcass was stuffed for display but later discarded due to poor preservation of the hide.

A young dolphin, probably from the Halda River (A.K.M. Aminul Haque, pers. comm.), was shown in Reeves and Brownell (1989). Pelletier and Pelletier (1986) refer to this specimen as captured on 17 June 1978 in the vicinity of Chittagong and then released back into the capture site on 17 July 1978. A photograph from the Bangladesh Observer, 6 June 1990, shows a shushuk,

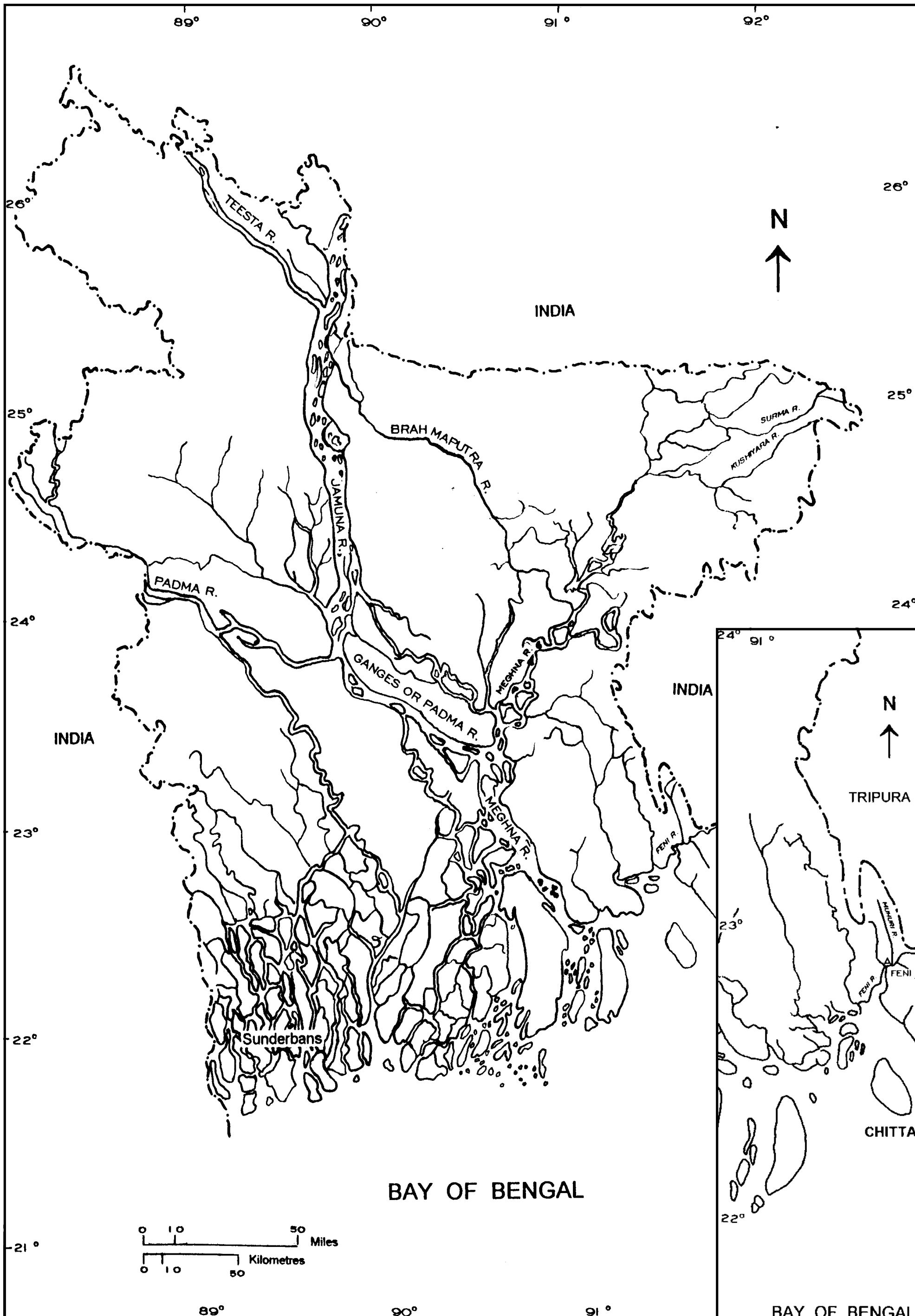

Figure 1 (left). Map showing the major rivers of Bangladesh.

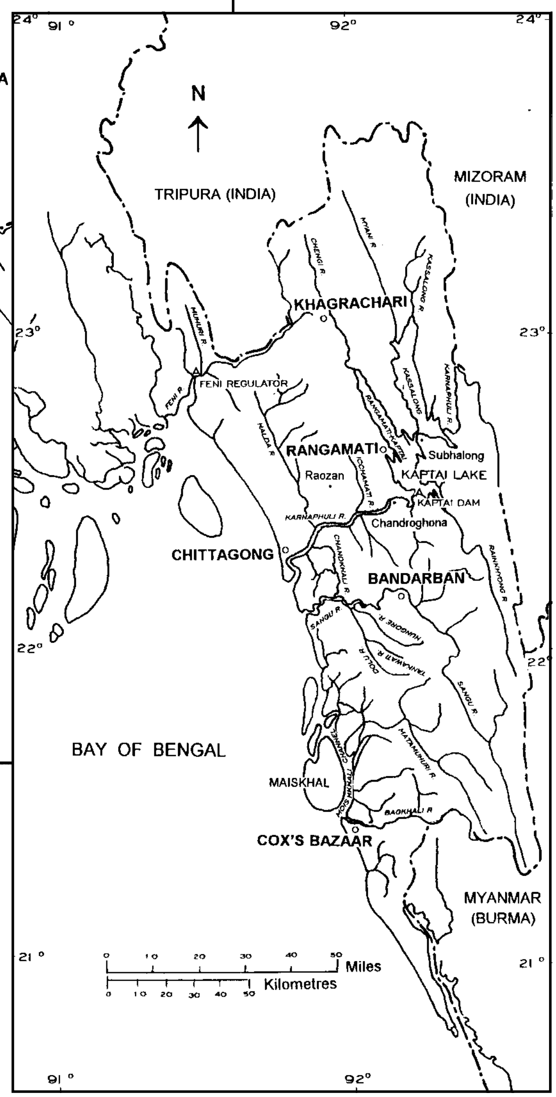

Figure 2 (below). Map showing the major rivers, their tributaries and distributaries in southeast Bangladesh.

reportedly caught in the Halda River, which was on display at the French Ambassador's residence in Dhaka. Reeves *et al.* (1993, p. 22) refer to both of these captures, indicating only that they occurred in the Karnaphuli system.

On 3 April 1998, a team from the University of Chittagong (including the author) surveyed a 19.4km segment of the Halda River, from the Sattarghat Bridge, on the Rangamati road, downstream to the confluence of the Karnaphuli River. Following the procedure used by Smith *et al.* (1994) and recommended in Smith and Reeves (this volume, a), we stopped at all *kooms* (small counter-currents) for at least 15 minutes to avoid missing submerged animals. We had seven sightings of dolphin groups for a total of 13–16–12 dolphins (ordered according to the sum of best-high-low estimates of group size; mean group size = 2.3, range = 1–4). Two small juveniles were seen. The channel was meandering and generally less than 100m wide. Human activity was minimal, with occasional motorized vessel traffic and fishing with gill nets and with hooks and lines. Fishing activity was conducted in *kooms* located downstream of meanders.

Karnaphuli River and Kaptai Lake

The Karnaphuli River, known locally as Kynsa Khyong, is the most important river in southeast Bangladesh. Its source is in the south Lushai Hills of the Mizoram State of India. It follows a southwesterly course through the hills before flowing onto the Chittagong Plains at Chandroghona. The river then flows west before emptying into the Bay of Bengal. In the plains, the Icchamati River meets the Karnaphuli at Kodala and then, downstream, the Halda River meets it at Kalurghat. Although these rivers are of considerable depth, turbulent rapids and sharp meanders render them unnavigable by large vessels during the monsoon season.

A high dam was constructed 88.5km upstream of the mouth of the Karnaphuli River (see Smith *et al.* this volume). The dam, completed in 1961, was built primarily for hydroelectric power generation, but it also stores water for irrigation and helps control flooding. The surface area of the reservoir, popularly known as Kaptai Lake, was estimated to be 68,800 and 58,300 hectares by Ali (1985) and ARG (1986), respectively, making it the largest man-made freshwater body in southeast Asia (Fernando 1980). The lake extends northwest to southwest in an 'H' shape with the two long portions joined by a narrow gorge near Shubhalong. The eastern portion of the lake is called Kassalong and receives flow from the Kassalong and Myani rivers to the north and the Karnaphuli River to the southeast. The western portion is called Rangamati-Kaptai and receives flow from the Chengi River to the north and the Rainkhyong to the southeast. The shoreline of the reservoir is irregular, with many indentations.

Electricity generated from the dam has accelerated industrial and agricultural development in the region. The Karnaphuli Paper and Rayon Complex at Chandroghona and a number of other large and small industries discharge toxic wastes directly into the river. Oil spills from ships are also a significant source of pollution. The University of Chittagong is carrying out an investigation into the effects of pollution on aquatic life. Water quality is monitored routinely by the Department of Environment under the Ministry of Environment and Forest.

Kaptai Lake has an organized fishery operated by the Bangladesh Fisheries Development Corporation at Rangamati. This fishery contributes substantially to the country's commercial catch. Surveys of the lake have been impossible due to civil strife.

Reliable sources informed the author about the sighting of two dolphins, one large and one small, in the western arm of Kaptai Lake on 28 July 1992 (see Reeves *et al.* 1993, p. 11). The Fisheries Research Institute Sub-station at Rangamati reported finding a dead shushuk floating in the western arm of Kaptai Lake, near the Baradam hills, opposite Tabalchhari Bazaar at Rangamati. A fishing rope was found twisted around its body. The dolphin measured 247cm in length and weighed 110kg. The skeleton is kept at the sub-station museum. It is unknown if dolphins in Kaptai Lake constitute a reproducing and potentially self-sustaining subpopulation or, alternatively, are old individuals that became cut off from the river when the dam was built (Smith and Reeves, this volume b).

The only published information on dolphins in the Karnaphuli below the Kaptai Dam is in Pelletier and Pelletier (1980), who reported seeing shushuks frequently, in groups of three or four, three kilometers from the mouth of the river, at both low and high tides.

The University of Chittagong conducted a study of shushuks in the Karnaphuli River during July–August and November–December 1992. A 20km segment of the river was surveyed from Sadarghat, located 18km from the river mouth, upstream to Bhandaljuri. A large number of dolphin surfacings were recorded, but no estimate was made of the number of animals present. Dolphins were concentrated in the downstream and deeper portions of the study area.

On 4 April 1998, the author and two colleagues conducted an informal survey of a 19.3km segment of the Karnaphuli River, downstream from Sadarghat. The channel was approximately two km wide and relatively straight, but with one sharp meander. The segment included a major sea port and much of the right bank was taken up by dock facilities. Large container ships, tankers, and fishing trawlers were the dominant vessels. A *swampan* (small rowboat) was used for the survey, so a view of the entire channel was not possible. The observations reported below should, therefore, be considered an incomplete count. We had nine sightings of dolphin groups for a total of 35–42–26 dolphins (ordered according to the sum of best-high-low estimates; median of group sizes = 2, range = 1–20). The largest group, estimated to be 20–25–15 animals, was located in a *duar* (large counter-current), downstream of the one sharp bend. Most of the other sightings were in the tidal lee of anchored vessels.

Sangu River

The Sangu River is 287km long, making it the longest river in southeast Bangladesh. Its source is in the Arakan hills of Myanmar (formerly Burma) where it is known as the Sabot Khyong. The river flows north while in the hills then turns west and becomes the Rigray Khyong. It meets the Chittagong Plains at Dohazari, where it is known as the Sangu until it empties into the Bay of Bengal. The Sangu is 91–136m wide in the hills and 305–610m wide in the plains. Depths range from 1.7–3.0m, sometimes increasing during heavy rains. Major tributaries are the Dolu, Tankawati, and Hungore rivers. Downstream, the Sikalbaha-Chandkhali canal (sometimes referred to as the Chandkhali River) diverges from the Karnaphuli River at Bridgeghat and connects with the Sangu in an approximately 30km long and 20–60m wide meandering waterway.

The Sangu is relatively undisturbed, with no shoreline industry or organized fisheries. Oar- and sail-powered country boats are the most common vessels. Shallow water prevents large motorized boats entering the river.

A brief study of artisanal fisheries in the Sangu conducted by the University of Chittagong between March and June 1995 found rich fish resources and recorded 30 commercially valuable species. Dolphins were observed in deep areas of the river. Local people were aware of the dolphins and reported no directed killing. They appeared to have little interest in using dolphin products. The only reported accidental catch was said to have occurred some 30 years ago.

The author obtained a photograph of a dead shushuk on the bank of the Sangu River. According to local people, the dolphin was found stranded in the mud and was killed by villagers (see Reeves *et al.* 1993, p.11).

On 4 May 1998, a team from the University of Chittagong conducted upstream and downstream surveys for dolphins in an approximately 30km segment of the Sangu River, from Bajalia to the confluence of the Chandkhali River. We used a single oar-powered dinghy. The channel was meandering and less than 50m wide from Bajalia to Dohazari, and between 100m and 200m from Dohazari to the confluence. Human activity was minimal. Vessel traffic was limited to a few large bamboo rafts and small oar- and motor-powered vessels. Fishermen were using gill nets and hooks and lines in *kooms* located downstream of meanders and the Chandkhali confluence. The team stopped at all *kooms* and at the confluence for 15 to 20 minutes, following the same procedure as described above for the Halda River survey. We had four sightings of dolphin groups during the upstream survey for a total 11–15–9 dolphins, ordered according to best-high-low estimates of group size (range of group sizes = 1–5), and two sightings of dolphin groups during the downstream survey for a total of 4–6–4 dolphins (range of group sizes = 1–3). Sightings were concentrated in the downstream section below the confluence of the Dolu River. Three and two small juveniles were seen during the upstream and downstream surveys, respectively.

On 14 May 1998, the University's team also conducted upstream and downstream surveys for dolphins in the Sikalbaha-Chandkhali canal from Bridgeghat to the Sangu confluence. We had seven sightings of groups during the downstream survey for a total of 25–31–24 dolphins (median of group sizes = 2, range = 1–7). We had only three sightings of groups during the upstream survey for a total of 3–5–3 dolphins; this lower count may have been related to the fact that we did not stop at *kooms* as we had done for the downstream survey. Sightings were concentrated in sections of the canal relatively close to the Karnaphuli divergence and the Sangu confluence, with no dolphins seen in the middle section of the canal. Nine young juveniles were observed during the downstream survey and one during the upstream survey. We also had one sighting of 2–4–2 dolphins in the Sangu River below the canal confluence. Human activities were limited to occasional oar- and motor-powered boat traffic, a few ferry crossings, and gill net fishing.

Matamuhuri River

The Matamuhuri River, or Moree Khyong, is a shallow river in the far south of Bangladesh. It originates in the hills that divide Arakan and Chittagong. The river is 161km long and follows a course roughly parallel to that of the Sangu. A broad delta forms where the Matamuhuri meets the Bay of Bengal. Local residents reported that dolphins occur in the river and are usually seen during heavy monsoon rains. It is unclear if this report refers to shushuks or, instead, a marine species that sometimes ranges up rivers (e.g. Irrawaddy dolphins, *Orcaella brevirostris*; see below).

Bagkhali River

The Bagkhali River flows north out of the hills that divide Chittagong and Arakan before turning west and emptying into the Moishkhali Channel, opposite Maiskhal Island in the Bay of Bengal. Dolphins have been reported to occur in this river, but the descriptions given by local people are more reminiscent of the Irrawaddy dolphin than the shushuk. The author found a dead Irrawaddy dolphin in December 1980, not far from the mouth of the river near Sonadia. Smith *et al.* (1997) recorded sightings of Irrawaddy dolphins in the Kalidan River, Myanmar, approximately 180km to the south.

Discussion

Shushuks have been confirmed as occurring in the Halda, Karnaphuli, and Sangu rivers, as well as in Kaptai Lake. They may also occur in the Matamuhuri and Bagkhali rivers, but their presence has not been confirmed there. River dolphins in southeast Bangladesh are of special conservation importance because they represent the only population(s) of shushuks inhabiting waters outside the Ganges/Brahmaputra/Meghna river system. The saltwater barrier of the Bay of Bengal presumably blocks movement between the two drainages. This discontinuous distribution raises interesting zoogeographical questions. How much, if any, dispersal occurs during the flood season in the freshwater plume of the lower Meghna entering the Bay of Bengal? Or are dolphins in the Karnaphuli and other rivers of southeast Bangladesh genetically isolated from those farther north? If so, how long have they been isolated?

Although the need for systematic surveys of the rivers and reservoirs of southeast Bangladesh has been recognized by the Asian River Dolphin Committee (see Reeves and Leatherwood 1995, Smith and Reeves this volume b), no such surveys have been conducted due to lack of funds. The relatively small size of these rivers means that the number of dolphins living in them is likely to be small, and there is a correspondingly high risk of extirpation, whether due to natural catastrophes or human activities. Dolphins in Kaptai Lake are the only known example of a reservoir-entrapped cetacean population that might provide insight about adaptation to conditions in an artificial lake (Smith and Reeves, this volume b). One important question is whether animals move between the Sangu and Karnaphuli rivers via the Sikalbaha-Chandkhali Canal. The relatively pristine conditions of the Sangu River may make it an important refuge for the dolphins. Protective measures for this area should be considered. Another important issue is whether Irrawaddy dolphins share habitat with shushuks in any segments of these rivers. Both species have been observed in the mouth of the Meghna River in the Sundarbans region of Bangladesh, sometimes swimming within a few meters of each other (B.D. Smith and R.R. Reeves, pers. comm.)

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Chapter 5

Yangtze River Population of Finless Porpoises (*Neophocaena phocaenoides*)

Report of the Workshop to Develop a Conservation Action Plan for the Yangtze River Finless Porpoise, Ocean Park, Hong Kong, 16–18 September 1997

Randall R. Reeves, Thomas A. Jefferson, Toshio Kasuya, Brian D. Smith, Wang Ding, Wang Peilie, Randall S. Wells, Bernd Würsig, and Zhou Kaiya

Abstract

The population of finless porpoises (*Neophocaena phocaenoides*) that inhabits China's Yangtze River is unique. All other known populations of the species are distributed principally in marine waters. This population is also one of the few geographical populations of cetaceans (whales, dolphins, and porpoises) listed as Endangered in the *1996 IUCN Red List of Threatened Animals*. Chinese scientists report that Yangtze finless porpoises are rapidly declining and that, in response, officials within China wish to stock "semi-natural reserves" and other facilities with porpoises. This approach to conservation was adopted several years ago with the explicit objective of preventing the extinction of baiji (*Lipotes vexillifer*). Although the baiji rescue effort has been unsuccessful so far, it appears that the same approach is now being taken to conserve the finless porpoise, with no rigorous advance consideration of its appropriateness.

A workshop was convened at Ocean Park, Hong Kong, in September 1997 to review information on Yangtze River finless porpoises and develop recommendations concerning their conservation. Participants included experts from China, Japan, Hong Kong, Taiwan, the United States, and Canada. Planning and execution were done jointly by Ocean Park Conservation Foundation and the IUCN/SSC Cetacean Specialist Group.

Wang Ding, of the Wuhan Institute of Hydrobiology (WIH), summarized recent research and management activities in the upper reaches of the Yangtze. A population estimate of 2,700 porpoises was made, referring to the period 1978–91. More recent surveys provided indices pointing to a dramatic decline in abundance since then. Thirty-six finless porpoises have been removed from the Yangtze and placed in the Shishou semi-natural reserve since March 1990. Nine porpoises have been born in the reserve, including one that is known to have been conceived there. Losses, due mainly to escape and accidental killing, have resulted in a current population of five porpoises in the reserve. Two outstanding problems with the reserve were noted: (1) a barrier to prevent animals from escaping during the flood season has not been completed, and (2) fishing within the reserve continues to pose a threat to the porpoises and their food supply. Additional porpoises have been brought into captivity at the WIH, where two animals presently reside.

Zhou Kaiya, of Nanjing Normal University, summarized work on a life table and population dynamics of finless porpoises in Chinese waters, as well as recent survey work in the lower reaches of the Yangtze. Although some concerns were expressed about possible bias from the ways specimens were obtained, the life table analyses generally reinforce the conclusion from surveys that there is a serious conservation problem with finless porpoises, not only in the Yangtze River, but also in coastal marine waters. Surveys in 1990–92 suggested a total porpoise population of about 700 porpoises in a 421km segment of the lower reaches. Results of these surveys also support the hypothesis that porpoises occur in greater abundance and in larger groups in river reaches characterized by numerous bends and sandbars, relatively slow water flow, rich fish resources, and relatively little vessel traffic.

Threats to finless porpoises in the Yangtze River include incidental mortality from entanglement in passive fishing gear, electric fishing, collisions with powered vessels, and exposure to explosives used for harbor construction. Much of their habitat has been severely degraded, due to the damming of Yangtze tributaries and the intensive use of the river as a transportation corridor. The effects of pollution and reduced availability of prey species are not well documented, but they represent serious additional concerns. Numerous topics were formally discussed by the group before formulating conclusions and recommendations. The workshop's principal conclusions were:

1. The finless porpoise population in the Yangtze River is likely to continue declining unless serious efforts are made to protect the animals and their habitat (including prey resources).

2. The ultimate goal of conservation efforts must be to maintain a viable wild population of porpoises in the river, and any *ex-situ* conservation strategy (e.g. establishment of "semi-natural reserves," maintenance of porpoises in captivity) can only be justified if it contributes to that goal.
3. Even more important than creating new "natural reserves" or expanding existing ones is the need to educate people about, and strictly enforce, regulations concerning the use of destructive fishing gear or methods.
4. A deliberate, step-by-step approach should be taken in evaluating any proposal for *ex-situ* conservation of Yangtze finless porpoises. In the specific case of Shishou semi-natural reserve, it should be acknowledged that a porpoise "population" already exists there. Thus, an initial requirement is that all harmful fishing be eliminated and the barrier fence be completed to improve the safety and security of those five animals. A critical review of available information is needed to provide advice on the required size and composition of a founding stock of finless porpoises. Water quality and sediment in the reserve need to be rigorously evaluated and monitored on an ongoing basis. A program of studying the animals presently in the reserve should be initiated, including marking (e.g. freeze-branding) and a sampling regimen of some kind. These steps should be taken prior to any consideration of further captures to stock the Shishou reserve.
5. The Tongling facility is best used, for the present, as a rehabilitation center for sick or injured porpoises (and dolphins) rather than being stocked with additional deliberately caught animals.
6. Like the five animals already present in Shishou reserve, the two animals already in captivity at the WIH constitute a small existing captive "population." Strenuous efforts should be made to improve the quality of their environment and to advance knowledge by observing and experimenting with these porpoises. Collaboration in these endeavours with experts from Hong Kong, Japan, and elsewhere is highly desirable.
7. Among the types of additional research that are needed to support conservation efforts are: tracking and marking studies in the wild and possibly also inside the Shishou Reserve; site-specific studies in key areas to investigate aspects such as the nature of threats, local movements by groups or individuals, and habitat preferences; and studies of genetics and contaminant levels using tissues from salvaged carcasses or from biopsies (e.g. skin scrapings) from live animals.
8. A scientific presence should be established and maintained in and near the Xin Luo Natural Reserve for baiji, with at least two primary objectives: (1) to provide a means of evaluating the effectiveness of protective measures and (2) to obtain information that can be used to guide management decisions in the future (e.g. changes in the reserve boundaries).

Introduction

Chinese scientists have concluded from survey and other data that the finless porpoise (*Neophocaena phocaenoides*) population in the Yangtze River has been declining for at least several decades. The reasons for the decline are not entirely clear, but it is assumed that incidental take, pollution, vessel traffic, and habitat degradation have all contributed. This finless porpoise population was listed as Endangered in the *1996 IUCN Red List of Threatened Animals*. Also, Chinese authorities are in the process of upgrading the finless porpoise's status from the Second to the First Order of Protected Animals in China, which will mean that the species is given full protection under the law. A workshop was held at Ocean Park, Hong Kong, 16–18 September 1997, to begin development of a long-range conservation strategy for this endangered population.

T.A. Jefferson, co-director of the Ocean Park Conservation Foundation (OPCF) and the workshop convenor, welcomed participants and outlined the objectives and agenda. He dedicated the workshop to the memory of Steve Leatherwood, founding director of OPCF, who died in January 1997. Josephine Woo, co-director of OPCF, offered additional remarks concerning the foundation's ongoing commitment to cetacean conservation in Asia and expressed hope that the recommendations from this workshop would lead to significant progress in conserving Yangtze finless porpoises.

Three background documents were provided by Chinese participants (Wang Ding 1997; Zhou *et al*. 1997; Yang *et al*. 1997; see later). In addition, an English translation of Zhang *et al*. (1993) was kindly provided by Mientje Torey, and a partial bibliography of the Yangtze finless porpoise was prepared for the workshop by Jefferson.

R.R. Reeves, chairman of the IUCN/SSC Cetacean Specialist Group (CSG), summarized events leading up to the workshop. During discussions at the Asian River Dolphin Committee meeting in Bangladesh in February 1997 (Smith and Reeves 1997), it had been evident that Chinese authorities intended to capture more finless porpoises to stock the Shishou Semi-natural Reserve and the captive-maintenance facilities at the Wuhan Institute of Hydrobiology. The semi-natural reserve and the tanks at Wuhan were originally developed as part of a strategy to conserve the baiji (*Lipotes vexillifer*) (Perrin and Brownell 1989; Ellis *et al*. 1993; Kasuya 1997). The implicit assumption seems to have been that the *ex-situ* measures taken to prevent the baiji's extinction were also appropriate for the Yangtze River population of finless porpoises. Although porpoises remain much more abundant in the

Yangtze system than the sympatric baiji, they are thought to be experiencing a rapid decline (Zhang *et al*. 1993; Zhou *et al*. 1997; Wang Ding *et al*. 1997). In view of this situation, it was felt that a workshop was needed to explicitly address the question of whether further collections of finless porpoises were appropriate, either for translocation into semi-natural reserves or for long-term captive maintenance.

It was agreed that Jefferson would act as chairman of the workshop, B.D. Smith would act as rapporteur, and Reeves would take primary responsibility for drafting recommendations and writing the workshop report. The workshop agenda is attached as Appendix 1 and the list of participants as Appendix 2.

In addition to the primary financial and in-kind support provided by Ocean Park and OPCF, important contributions were made by the Chicago Zoological Society and the CSG. Hiedi Chan (OPCF) and Irene Wong and Josephine Woo (Ocean Park) facilitated many aspects of the workshop's planning and execution. Also, Mientje Torey and Isabel Beasley helped with logistics, and Mary Felley served as a translator for Wang Peilie.

Summary of oral presentations

Formal presentations were made by Wang Ding and Zhou Kaiya, based on background documents prepared for the workshop (Wang Ding *et al*. 1997; Yang *et al*. 1997; Zhou *et al*. 1997). The contents of these presentations are summarized below:

Population Status and Conservation of the Yangtze Finless Porpoise – Wang Ding

Surveys of baiji and finless porpoises from 1978 to 1991 resulted in an average estimate of 2,700 for the total population of finless porpoises in the Yangtze during this period (Zhang *et al*. 1993). Additional surveys were conducted in segments of the Yangtze from 1991 to 1996 (Wang Ding *et al*. 1997). Results of these surveys were interpreted to indicate a drastic decrease in numbers. For example, encounter rates in the middle reaches of the river declined from 0.14 to 0.07 porpoises/survey kilometer (km), and from 8.62 to 2.7 porpoises/survey day, between spring 1991 and spring 1992. Moreover, in spite of improved observation methods (i.e. more vessels and more observers), this trend continued in later years, with rates of 0.55 porpoises/survey km in spring 1994, 0.29 in spring 1995, and 0.12 in spring 1996, or 4.35, 3.69, and 2.13 porpoises/survey day, respectively, at the same one-year intervals. Although fewer data were available for the lower reaches, the "trend" there appeared similar. Taken at face value, these results confirm the impression held by Chinese scientists from several different institutions that porpoises are becoming much scarcer in parts of the Yangtze River than they were as recently as the 1970s and even the 1980s. No quantitative analysis of the survey data was conducted to assess the significance of apparent trends, however. Also, no attempt was made to provide a new estimate of absolute abundance from the 1991–96 survey data. Areas with particularly high densities of porpoises included: the section from the mouth of Poyang Lake to Balijiangkou, Sanjiangkou, Xintankou, Tianxinzhou, Luxikou, Chibi, Chenlingji, and Sunliangzhou. Also, animals were often present in Poyang and Dongting lakes.

The Shishou semi-natural reserve (see Figure 1), situated 360km upriver from Wuhan (250km by road), is a 21km long oxbow (see Perrin and Brownell 1989: their Appendix 9). It is connected with the main river during the five month summer flood season (approximately June–October) by a 100 to 150m wide channel. During the rest of the year, there is only a small amount of flow and

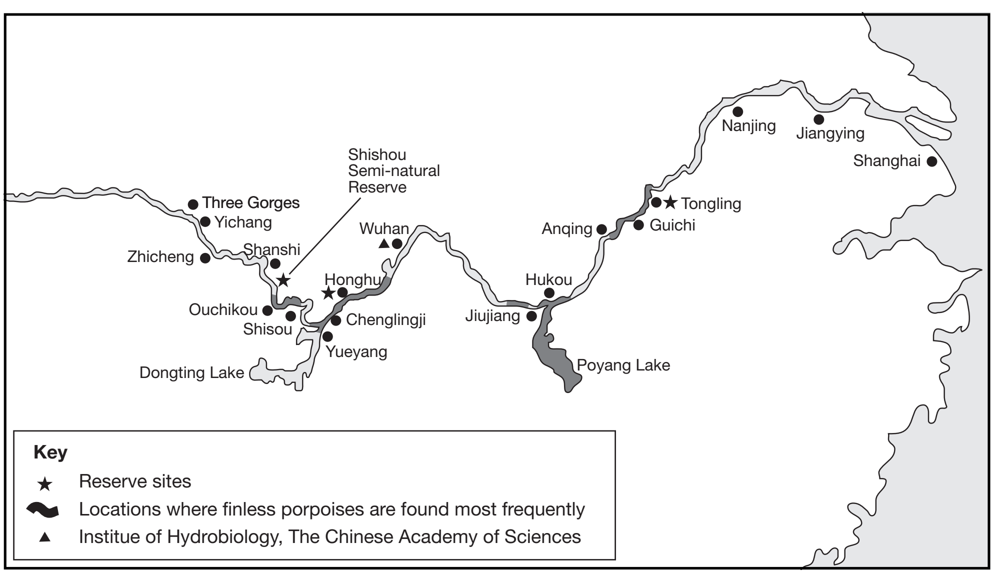

Figure 1. Areas of concentration of the Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*).

seepage into the river, and it is impossible for cetaceans to enter or leave the reserve. Between March 1990 and December 1996, a total of 36 finless porpoises (17 females, 19 males) were translocated into the Shishou reserve and nine porpoises were born there. Of the 45 animals, 11 died, 14 escaped into the Yangtze River during the 1996 flood season, and 15 were released because of concerns about fishing activity within the reserve. Of the 11 deaths, seven occurred accidentally during capture operations for radio-tagging in October 1993; two animals were killed by rolling hook longlines; one died from capture-related injuries within a few weeks after being brought to the reserve; and one was a premature birth caused by capture operations. Thus, five animals, of uncertain age and sex, are currently living in the reserve. At least one of the porpoises born in the reserve was conceived there, but most, if not all, of the others were conceived prior to capture.

Assessments of fish production in the reserve have consistently shown that there is adequate food to support breeding colonies of both baiji and finless porpoises. However, there are two outstanding difficulties. First, construction of a permanent artificial barrier at the mouth of the reserve has not yet been completed. This barrier is needed to prevent escape of cetaceans during the flood season. Until it is constructed, no additional porpoises (or baiji) should be introduced. Second, fishing activity in the reserve needs to be stopped. At least two of the finless porpoises that died in the reserve were killed by rolling-hook longlines. Also, the reason given for releasing 15 porpoises back into the Yangtze in spring 1997 was that they were competing with fishermen. Thus, local people have clearly not accepted the idea that cetaceans should have first priority in using the reserve's resources. About 600 people continue to depend on fishing in the reserve for their livelihood.

Wang Ding and his colleagues continue to believe that the potential problem of competition between finless porpoises and baiji (see Perrin and Brownell 1989; Ridgway *et al*. 1989; Leatherwood and Reeves 1994; Reeves and Leatherwood 1995) is unimportant and should not impede ongoing efforts to stock the reserve with both species.

Wang Ding *et al*. (1997) conclude that the degradation of the Yangtze River is bound to continue and therefore that the best hope for saving the Yangtze finless porpoise population from extinction is by establishing *ex-situ* breeding colonies. The Shishou semi-natural reserve is proposed as a model for the maintenance and breeding of porpoises. These authors also suggest that "natural reserves" be established for protecting porpoises in areas of the river known to be frequented year-round. A pair of porpoises (an adult male and a juvenile female) are being kept in a tank at Wuhan for study of reproductive behavior and physiology. A third animal (juvenile female) was released after it was noted that she could not feed normally.

Life Table and Population Dynamics of Finless Porpoises in Chinese Waters – Zhou Kaiya

Static life tables were constructed for three populations of finless porpoises: Yangtze River, Yellow Sea, and South China Sea. Specimen totals used in the analyses were 107, 122, and 45, respectively. Most of the specimens either stranded or were salvaged after being taken incidentally in fishing gear. Age estimates for these specimens were derived in four ways, either: (1) by counting dentinal growth layer groups, (2) from Zhang (1992), (3) by inference from porpoises of similar body length and weight whose teeth had been sectioned for growth-layer counting, or (4) by inference from age-length curves (Gao and Zhou 1993). The porpoise specimens were grouped into age classes at two year intervals. Survivorship, mortality, and death-rate curves were derived from the life tables, and intrinsic rates of increase were calculated for the three populations.

The survivorship curves were L-shaped, indicating poor survival in the 0–2 and 2–4 age classes. Deaths peaked in the 0–2 age class for all three populations, and the peak extended into the 2–4 age class for the Yellow Sea and South China Sea populations. The mortality rate of the Yangtze River population was lower than those of the other two populations for most age classes, with the notable exception of the 8–10 age class.

For calculating intrinsic rates of increase, it was assumed that the maximum reproductive rate (m_x) was 0.7. It was further assumed that m_x was 0 for the first two age classes (0–2 year and 2–4 year), and the third as well (4–6 yr) in the case of the Yangtze River population, in which females do not attain sexual maturity until six years of age (Gao and Zhou 1993). The m_x for the 4–6 age class in the Yellow Sea and South China Sea populations was assumed to be 0.35 because female sexual maturity is reportedly attained at an average age of five years in those populations (Gao and Zhou 1993). Females as old as 23 years were assumed to be reproductively active, based on Shirakihara *et al*. (1993). However, since all animals older than 16 years were assigned to a single age class, presumably some of them would be reproductively senescent, so the m_x for this age class was assumed to be 0.35. Thus, only the animals between 6 and 16 years old were assumed to have an m_x of 0.70.

For all three populations, the net reproductive rate and finite rate of increase were less than 1, and the instantaneous rate of increase was less than 0. This analysis therefore indicates that all three populations are declining. Although the authors (Yang *et al*. 1997) acknowledge that a dynamic, rather than static, life table would have provided more reliable results, and that their sample sizes were relatively small (especially for the South China Sea population, for which n=45), they consider this exercise the best that could be done with the data available. During the discussion, it was noted that the samples may be biased because of the ways in which the specimens were obtained. Nevertheless, the life table analyses reinforce the conclusion from surveys that there is a serious conservation problem with finless porpoises, not only in the Yangtze River but in Chinese marine coastal waters as well.

Abundance and Distribution of Yangtze Finless Porpoises in the Nanjing-Hukou Section of the Lower Reaches of the Yangtze River – Zhou Kaiya

No verbal presentation was made at the workshop; an earlier version of the manuscript had been presented at the meeting of the Asian River Dolphin Committee in February. The main results are summarized here from the written document tabled in Hong Kong.

Six surveys of the Yangtze River between Nanjing and Hukou were organized and conducted by staff of Nanjing Normal University between 1989 and 1992. The field and analytical methods were essentially the same as those reported by Zhang *et al.* (1993) and Wang Ding *et al.* (1997). Estimates of absolute abundance from the four surveys with complete coverage of the 421km segment of river averaged 697 ± 47 individual porpoises. A comparison of results from this study and that by Zhang *et al.* (1993) suggests a decline in average porpoise density and abundance between the period December 1984–June 1991 and the period March 1990–March 1992. The 1990–92 survey results support the hypothesis that porpoises occur in greater abundance and in larger groups in river reaches characterized by numerous bends and sandbars, relatively slow flow, rich fish resources, and relatively little vessel traffic. Zhang *et al.*'s (1993) conclusion that finless porpoises in the lower Yangtze River make annual long-distance migrations to the Yellow Sea in summer and fall is not supported. Rather, Zhou *et al.* (1997) suggest that the increased size of groups seen in the Yangtze River during winter and spring (December–April) is best explained by the more clumped distribution of porpoises in these seasons.

Summary of discussion of agenda items

In this section highlights of the group discussion under each agenda item are summarized. For additional details, the reader is referred to Smith and Reeves (1997) as well as the cited literature.

Background on Yangtze finless porpoises

What is known about Yangtze finless porpoise life history (reproduction, feeding, etc.)?

Attention was called to the question of whether the supposed difference in average age at sexual maturity in Yangtze females (six years) compared to females in other populations (four years) (Yang *et al.* 1997, as summarized above) is real, or an artifact caused by sampling or methodological inconsistencies. An exchange of sectioned teeth or slides between laboratories might be appropriate for evaluating and reconciling any differences in methods or interpretations. According to Wang Ding (pers. comm., see Zhang 1992), Yangtze porpoises normally reach sexual maturity at four years of age, so in his view, they do not differ in this respect from the porpoises in Chinese marine waters.

The subject of feeding behavior and food preferences was discussed mainly in the context of how it might relate to the role of prey depletion as a causative factor in the finless porpoise's decline in the Yangtze River. The prevailing view is that finless porpoises generally prey on smaller organisms than those taken by baiji. Some overlap in diet is recognized, with respect to both the sizes and species of organisms taken. Assuming that the depletion of fish resources in the Yangtze has followed the typical pattern, with the larger species and the larger individuals within species affected earliest and most severely, the impact on baiji would be expected to be more immediate than that on finless porpoises. An implicit assumption is that finless porpoises have been better able to respond to the effects of overfishing. However, it was agreed that too little is known about the energy budgets and food habits of either species to reach definitive conclusions. It was suggested that food-preference studies using the porpoises currently in captivity might be useful.

Is there more than one Yangtze finless porpoise stock?

This question was divided into two: first, are the Yangtze River porpoises reproductively isolated from those in the Yellow Sea? Second, is there more than one porpoise population within the Yangtze system?

While it was acknowledged that some evidence can be interpreted as suggesting seasonal movements by Yangtze animals into the estuary (see Zhang *et al.* 1993), the balance of opinion is that the porpoises in the Yangtze are reproductively isolated and therefore constitute a discrete population. A clear definition of the boundary between it and the marine population, however, must await further research.

Although there are high-density zones within the river, separated by areas in which porpoises are rarely seen, no actual gaps in distribution have been identified. The question of subpopulations within the river must remain open for the present.

What are the main threats to the Yangtze finless porpoise population?

The group had considerable difficulty addressing this question. Although porpoises were often killed deliberately for oil and meat in the past (e.g. Liu 1991), particularly perhaps during the "Great Leap Forward" beginning in autumn 1958 (Zhou and Zhang 1991:32–33), they are said to have been "well protected" since the 1980s (Liu 1991). In any event, no evidence is available to suggest that direct exploitation is occurring on a significant scale at present.

Incidental mortality certainly occurs in passive fishing gear such as rolling hook longlines (some of which are illegal in the Yangtze) and encircling gillnets (Zhou and Wang 1994). Electric fishing, a practice that has become widespread in the Yangtze system during the past ten years, even though it is illegal, could be a major cause of porpoise mortality (and also damage their prey resources).

Collisions with powered vessels and deaths from explosives used for harbor construction are among the documented sources of mortality for the baiji (Zhou and Zhang 1991), and it was generally agreed that they probably affect finless porpoises as well.

The Yangtze River has been severely degraded as habitat for cetaceans and other wildlife. Some 1,300 small lake systems that were once connected to the Yangtze have been cut off by dams, and the Gezhouba Dam interrupts the natural flow in the mainstem. Besides affecting the sediment budget and hydrology of the river, such damming blocks fish (and porpoise) movements and probably causes a net decrease in fish production in the river. The amount of habitat suitable for finless porpoises to forage, rest, and carry on other vital activities has undoubtedly diminished, and this process is continuing unabated. Vessel traffic is rapidly increasing, and it is reasonable to suppose that porpoises are experiencing disturbance and, perhaps, physical damage from exposure to artificial noise. The potential for serious effects from chronic exposure to underwater noise cannot be dismissed, even though documentation is lacking.

Considerable discussion was devoted to the subject of pollution. Although several publications have documented levels of organochlorines and heavy metals in the tissue of finless porpoises in Chinese waters (e.g. Zhou K. *et al.* 1994; Zhou R. *et al.* 1993a, 1993b; Zhang H. *et al.* 1993, 1995, 1996), nothing exceptional has been identified that might help explain the Yangtze population's precipitous decline. Nevertheless, the same caution applies here as stated above in reference to noise: the absence of documentation cannot be taken to mean that serious health effects are not occurring.

Is the finless porpoise less vulnerable to bycatch than the baiji?

This question was raised initially at the Asian River Dolphin Committee meeting in the context of trying to explain why the baiji has declined to a much lower level of abundance than the Yangtze finless porpoise. If the finless porpoise is less vulnerable to bycatch, then it might be better able than the baiji to survive in the wild, without requiring *ex-situ* conservation measures to prevent its extinction.

In general, Wang Ding and Zhou Kaiya believe that baiji are more susceptible to entanglement in rolling hook longlines, while finless porpoises are at least as susceptible as baiji to capture in gillnets. Active gillnets used in shallow nearshore waters represent a serious threat to finless porpoises, which show a strong preference for such areas.

It is impossible to make a proper comparison of the two species' vulnerability for several reasons. Until recently, and perhaps still, the probability that porpoise carcasses will be reported is much lower than is the case for baiji carcasses. This is, in part, because the baiji is held in much higher esteem by fishermen and the general public (regarded as a "national treasure"), while the smaller, less conspicuous finless porpoise has no special status. Reporting and carcass salvage are not carried out on a systematic basis, so it is not possible to relate the frequency of documented mortality to the amount of effort made to obtain such information. Unless effort can somehow be standardized, any comparison will remain questionable.

Is there evidence that the Yangtze River mainstem can no longer support finless porpoises?

If the Yangtze finless porpoise population has been declining, as indicated by survey results and life table analyses (see above), then the ability of the river to continue to support this species is certainly in doubt. Human use of the river and its resources is expected to intensify for many decades into the future. Considering that present use is unsustainable, the porpoise population will probably continue to decline. Nevertheless, it is important to recognize that animals live-captured in recent years have been judged to be in good health and condition, and the porpoise population's reproductive output is not known to have declined. It is therefore appropriate to vigorously pursue measures to protect the porpoises from direct harm (e.g. incidental capture, vessel strikes, exposure to explosives, etc.), maintain as many natural qualities of the ecosystem as possible, and investigate factors causing the species' decline. While it may be true that substantial portions of the population's historic range are no longer suitable, there is no reason to abandon the hope of arresting the decline in at least a few carefully-selected areas.

How can we determine if there is competition between finless porpoises and baiji?

Two points were made during the brief discussion of this question. First, in spite of the fact that baiji generally eat larger fish than finless porpoises, competition could occur if both were eating different age classes of the same species. In other words, heavy predation by finless porpoises on the younger age classes of a given species could reduce the availability of larger individuals of that species to baiji. Second, Jefferson noted the almost completely allopatric distribution of finless porpoises and Indo-Pacific hump-backed dolphins (*Sousa chinensis*) in Hong Kong waters. Even though these two species might be considered sympatric on a regional scale, and indeed they are seen occasionally in the same areas, competitive exclusion is a reasonable hypothesis for explaining their allopatric distribution at a local scale. In the case of baiji and Yangtze finless porpoises, competition may operate in a subtle way and thus be difficult to detect and describe.

If this research problem is ever to be addressed empirically, it will require that animals in the reserve be captured regularly, or at least handled (possibly after training) to assess their health condition. But this assumes that baiji will be caught and introduced to the reserve alongside finless porpoises, and that repeated capture and handling within the reserve could be done without jeopardizing the animals' survival. Such a scenario is very unlikely in the foreseeable future.

The potential role of semi-natural reserves

Is the Shishou Reserve currently a safer place for individual porpoises than the Yangtze mainstem? What about Tongling Reserve?

The basic design and conditions of Shishou Reserve were outlined by the Baiji Research Group in 1986 (Perrin and Brownell 1989: their Appendix 9). The concrete posts intended to support the chain-link fence across the mouth of Shishou Reserve are in place, but the fence is not yet available. Thus, at the present time, movement by cetaceans into and out of the reserve is possible for about five months each year. Until fencing is completed, the reserve cannot be regarded as a secure environment for long-term maintenance of either baiji or finless porpoises.

A second major problem is that the fishing families living on the banks of the reserve continue to depend on the fish stocks within the reserve for their livelihood. Thus, cetaceans in the reserve are vulnerable to bycatch in fishing gear, and they may well be competing with humans for food resources. Illegal fishing methods have been used within the reserve in recent years: at least two finless porpoises were killed by rolling hooks, including as recently as May 1992 (Wang Ding *et al*. 1997). Until some arrangement has been made to substantially reduce human pressure on the reserve's biological resources, and to guarantee the safety of cetaceans from direct harm by fishing gear, it cannot be considered safer for individual porpoises than the Yangtze mainstem.

On the positive side, vessel traffic in the reserve is minimal, with only one or two ferries operating. Two motorboats are available for use by the reserve's staff of 24. Presumably, the presence of the staff deters at least some of the illegal fishing that would take place (e.g. with rolling hooks or electricity) in their absence. Pollution levels in the reserve are reportedly no worse than in the Yangtze despite the fact that the only significant water input during much of the year is runoff from adjacent rice paddies. The apparent exceptions to this are that sulfide and coliform bacteria levels are anomalously high (Zhang *et al*. 1995), suggesting inadequate flushing.

A major obstacle to getting the fence completed, the fishing families relocated, and the reserve properly protected from illegal fishing is that the finless porpoise does not have nearly the same revered status as the baiji. This difference in perceived value means that local people are less concerned about harming the porpoises and that officials are less prepared to invest resources in development of the reserve than they would be if it were stocked with baiji. Some change can be expected once the finless porpoise is upgraded to a First Order protected animal. However, entrenched views, based on centuries of folklore and tradition (e.g. see Zhou and Zhang 1991; Wang Ding 1993), will only be changed through increased public education and awareness. There may be a role here for the international community, but, until this workshop, no outside financial investment in conservation efforts targeted explicitly at the Yangtze finless porpoise had been made.

Wang Ding pointed out that Three Gorges Dam is expected to reduce the extremes of flow in the middle reaches of the Yangtze. His expectation is that high flows will be lower and low flows higher once the dam is functioning, with the net effect that "escape" of animals back into the Yangtze will be less likely. Even if this "beneficial" effect of the dam were to occur, however, the artificial barrier would still be necessary. Also, the major anticipated change in flow regime, caused by Three Gorges Dam, could have offsetting negative effects, such as decreased flushing of the oxbow, leading to increased levels of organic and inorganic pollutants in the reserve. It is important to emphasize that as long as human communities live along the shores of the reserve, there will be a danger of point-source pollution within what is a largely lentic system for much of the year.

Tongling Reserve presents a quite different situation from that at Shishou. The scale is much smaller and the conditions much less natural (see Perrin and Brownell 1989: their Appendix 8). Fish production is inadequate to support cetaceans, so there is no fishing in Tongling Reserve. Much less investment has been made in development of Tongling Reserve, and it was generally agreed that, without considerable further assessment of water quality there, as well as completion of the infrastructure outlined by Zhou Kaiya in 1986 (Perrin and Brownell, as above), this reserve cannot be considered safer than the Yangtze River for finless porpoises.

Should the Shishou Reserve be a single-species reserve? If so, for which species?

Consensus was not reached on how this question should be answered. Those who considered the baiji translocation initiative to be a failed approach that should be abandoned, took the position that Shishou was, if anything, a de facto reserve for finless porpoises already. Those who believed that efforts to collect baiji should continue supported the idea of stocking the reserve with both species.

Should finless porpoises be placed in the reserve at Tongling?
Most of the discussion of this question centered on use of the concrete tank, rather than the "semi-natural" reserve, at Tongling. A large investment has been made in the facilities and trained staff at Tongling. There was general agreement that the most suitable use of the Tongling establishment would be as a rehabilitation center for sick or injured cetaceans.

If live-captures are required, what techniques should be used?
Wang Ding summarized the technique used in the past to capture finless porpoises (and baiji) in the Yangtze River. Areas with slow current and shallow water are preferred as capture sites. Six small fishing boats (maximum ground speed approximately 5km/hr, travelling against the current) are used to trap the animals against the shore, using a specially-made large-mesh net. A smaller-mesh net is used once the animals are well herded inside the first net. Team members often have to enter the water to stop the animals entangling. Of 36 finless porpoises collected for the Shishou facilities since 1990, none have been killed outright, but one died later from injuries sustained during the capture operations (Wang Ding *et al*. 1997).

R. Wells compared the technique initially described by Wang Ding with that used routinely to capture, study, and release bottlenose dolphins (*Tursiops truncatus*) near Sarasota, Florida, USA. Wells and associates use their own adaptation of the seine-net technique described and illustrated by Asper (1975; also see Wells 1991). Areas with little current and shallow water are preferred. Depths at the capture site in Florida are often about 1.5m, in contrast to 4m or deeper in the Yangtze. In Florida, the animals are captured in the open without the benefit of a shoreline, but a major difference is that fast speedboats are used to corral the dolphins. Optimally, as many as ten boats and 30–50 people are used in the capture effort. The goal, in order to maximize safety for the animals, is to capture fewer than five individual dolphins at a time.

The technique used in the Yangtze was judged adequate for capturing finless porpoises. It was stressed, however, that at least one and preferably two faster boats would make the operations more efficient and safer for both the animals and the people involved.

The group also wished to emphasize the importance of having a protocol for collecting animals of particular age and sex classes. This protocol, which should be prepared in advance of further capture attempts, would need to be developed on the basis of a plan for achieving explicit demographic and other goals for the captive population such as re-creating natural social groupings (e.g. see Ralls 1989).

Should captive breeding and artificial insemination play a role?
The possibility that captive breeding and artificial insemination will need to play a role in the conservation of Yangtze finless porpoises cannot be discounted. However, the record, to date, of using captive porpoises (within China) to improve knowledge about breeding requirements and to develop ways of applying new technologies in their propagation is not promising. While several births have been reported in the Shishou semi-natural reserve since 1990 (Wang Ding *et al*. 1997), nothing seems to have been learned from these events about the animals' reproductive behavior and biology. Before considering the collection of additional animals to stock reserves and artificial environments, it is important to establish research protocols and husbandry programs with the animals that are already available in the reserve and holding pool.

A partial list of tasks that can or should be completed with the available group of animals, starting immediately, might include:

1. The animals in the reserve need to be marked in some way so that they can be identified individually through time. The feasibility of freeze-branding should be tested with these animals.
2. Tooth extraction is the only means of obtaining reliable age estimates for porpoises older than about 4 years (the age-length relationship is not necessarily reliable for adults). (Any tooth extraction should only be attempted when a person with experience in the procedure is involved.)
3. Body weights should be monitored on a regular basis.
4. Ultrasound examinations can provide valuable information on blubber thickness (an index of condition), fetal development, and stage of maturation.
5. Blood profiles are essential for monitoring health and reproductive cycles.
6. Blowhole swabs provide opportunities to evaluate and monitor microbial fauna.
7. Small skin scrapings or blood can be used for genetic analyses.

Should public viewing and "ecotourism" be allowed or encouraged at the reserves(s)?

An Earthwatch program was conducted in the Shishou reserve for two years but has been discontinued. There is a small reserve for Pere David's deer (*Elaphurus davidianus*) nearby which provides a supplementary tourist attraction.

Discussion of this question was brief and inconclusive.

Protection in the natural habitat

What techniques should be used for population assessment and stock structure studies?

Wang Ding summarized plans for a large-scale, system-wide survey of baiji and finless porpoises in the Yangtze, scheduled for November 1997. This survey was intended to involve numerous vessels and hundreds of people, with the intention of achieving complete, non-overlapping coverage of the entire range of both species in one week. The methods of data collection and analysis described by Zhang *et al.* (1993) were to be used.

It was generally agreed that future monitoring surveys for population assessment should emphasize standardization of procedures. This proviso applies not only to the design and methods of observation, but also to the timing of the surveys. Time should be judged by water level rather than date. The goal should probably be to obtain index values rather than estimates of absolute abundance, although this would depend on the management objectives being served by a given survey program. If the intention is to obtain an estimate of the actual number of porpoises present in the river, it is essential to use a sampling technique, such as line or strip transect, and to achieve representative coverage of the entire width of the channel, even though porpoises have a strong tendency to inhabit waters within several hundred meters of shore (Zhang *et al.* 1993). If, on the other hand, an index is sought, two boats travelling in tandem on opposite sides of the river may be adequate.

Studies of stock structure can be pursued using several different approaches. Genetic and other studies (e.g. of contaminant or parasite loads, morphometrics, etc.) can take advantage of stranded animals, animals obtained from fishermen (bycatch), samples already in storage, and skin scrapings or blood from captive porpoises. Movements by individual porpoises can be tracked through freeze-branding (after testing with captive animals or animals in the semi-natural reserve) or radio telemetry. Although there is no reason to expect there to be local stocks of porpoises within the Yangtze system, a comprehensive recovery or conservation plan requires that the degree of mixing among areas be well understood.

Can we define and designate critical habitat for finless porpoises in the Yangtze?

Finless porpoises, like other river cetaceans (see Zhou and Li 1989; Hua *et al.* 1989; Smith 1993), tend to congregate in areas of interrupted flow where counter-current eddies provide hydraulic refuge and good foraging opportunities. In this respect, their habitat preferences can be said to be broadly similar to those of baiji. Bars or sandbanks, sharp bends, and confluences often create suitable conditions for cetaceans. As mentioned previously, porpoises occur mainly in shallow water near shore (Zhang *et al.* 1993). The mouths of Poyang and Dongting lakes are recognized as areas where porpoise density is consistently high, with the animals moving freely into and out of the lakes (Figure 1). Such tributaries are also centers of fishing activity and vessel traffic. Areas with relatively high numbers of survey observations are easy to identify (e.g. see previous summary of Wang Ding *et al.* 1997), but more needs to be known about seasonal movements, individual home ranges, and turnover rates at specific sites before "critical" habitat can be defined and designated. One way of answering this need might be by initiating long-term site-specific studies in several of the areas shown by survey data to be suitable for year-round observation.

Should additional radio-tracking be undertaken?

Much useful information can be obtained from radio tracking. Limited experience with vest-mounted tags suggests that such tracking can be done safely and efficiently (Zhang *et al.* 1996). Conventional radio tags are good for ranges only up to about 50 km. For tracking over greater distances, a satellite link will be necessary. There is a need for more development and testing before a satellite tag that is appropriately small and unintrusive can be considered for use on these small finless porpoises.

There was no disagreement about the desirability of having more telemetry work done with Yangtze finless porpoises. It was emphasized, however, that the danger of injuring or killing animals by accident is ever-present. Thus, any radio-tracking activity needs to be carefully justified and well planned. Much progress has been made in recent years by American, European, and Japanese scientists in developing and field-testing telemetry devices for small cetaceans, including harbor porpoises (*Phocoena phocoena*), which are only somewhat larger than finless porpoises. Incorporation of this international expertise into any tagging program in the Yangtze could be expected to improve efficiency and reduce the risks to animals.

How can public awareness of the finless porpoise best be increased?

The Yangtze finless porpoise's local name means "river pig," and it is associated in traditional mythology with ugliness, cruelty, and foolishness (Wang Ding 1993). Unlike the baiji, it receives no benefit from existing cultural bias. On the contrary, transforming the porpoise into a national treasure will be an enormous challenge to scientists and conservationists. Its upgrading to a First Order protected animal should improve the porpoise's status, but the Yangtze population's global significance as the only known freshwater population of its species needs to be publicized at every opportunity through every available forum. This must be done in the face of widespread disillusionment caused by the failed campaign to save the baiji. It is hoped that the baiji's rapid decline, apparently irreversible at this stage, will be seen as a lesson and a warning. Having done too little, too late, for the baiji, immediate action must be taken to slow, and reverse, the degradation of the Yangtze ecosystem before yet another member of its unique fauna becomes extinct. It is always important to emphasize that cetaceans are not fish. The usual "quick fix" of using hatchery programs to replace, maintain, or enhance wild stocks does not apply to cetaceans. Only genuine protection of the animals and respect for their needs can ensure a viable population in the long term.

How can existing measures to protect baiji be modified to also benefit finless porpoises?

The need to enforce regulations against destructive and unsustainable fishing practices is obvious. If the Yangtze's fish resources have been damaged and destroyed, despite the calls to safeguard them on behalf of human communities, and recently to prevent the baiji's extinction, it seems unlikely that calls to protect them for the benefit of finless porpoises will have much effect. The same might be said about calls to reduce pollution and traffic congestion in the river.

Most of the discussion centered on the Xin Luo Natural Reserve for baiji, a 135km segment of the Yangtze centered at Honghu City and stretching upriver to a point about 20km below the mouth of Dongting Lake. A staff of 15–17 people, equipped with a motorboat and based in Honghu City, is entrusted with providing strict protection for baiji and enforcing fishing regulations. One way in which the fishing regulations differ inside and outside the reserve is that rolling-hook longlines are prohibited within the reserve, while outside it, only certain sizes of hooks on longlines are banned.

Wang Ding urged that the boundary of Xin Luo Reserve be extended upstream to encompass the mouth of Dongting Lake, an area long recognized as having a high density of finless porpoises. He also urged that the official mandate of the reserve be expanded to include the finless porpoise under its mantle of protection. Other participants were supportive of these gestures, in principle. However, they were very concerned about two aspects of the proposal.

First, it was unclear whether the basis for designating this particular area as a finless porpoise reserve was grounded in scientific understanding of the survival needs of the animals, or instead in administrative convenience. In other words, is there any evidence that the type of protection afforded by the reserve, if extended to include the mouth of Dongting Lake, would actually contribute to the conservation of finless porpoises? Second, there was considerable doubt as to whether enforcement of regulations had been effective in protecting the baiji within the existing reserve boundaries. Without a mechanism for assessing and monitoring effectiveness, an increase in size and an expansion of the mandate of a protected area would seem at best pointless and at worst counter-productive.

Both of these concerns might be addressed by a scientific presence in the region. A long-term site-specific study at the mouth of Dongting Lake, for example, would provide a better understanding of what features of this area are important to finless porpoises. This, in turn, would make officials better able to judge what types of protective measures are needed.

What realistic measures can be taken to protect finless porpoises in the Yangtze?

This question had been addressed, at least implicitly, in the previous discussions.

Conclusions and recommendations

General conclusions:

Chinese scientists have concluded that conditions in the Yangtze River will continue to deteriorate in the foreseeable future and that the decline in the finless porpoise population will therefore continue. The establishment of one or more captive populations in semi-natural reserves obviously represents one possible conservation strategy, following the same logic that was outlined for the baiji in the Wuhan workshop report in 1986 (Perrin and Brownell 1989). The situation of the finless porpoise, however, differs from that of the baiji in several respects. First, there are more finless porpoises in the Yangtze River today than there were baiji in 1986 (Liu 1991; Liu *et al.* 1997). Second, there is already a relatively long history of holding finless porpoises in captivity, especially in Japan but also in China. Third, five finless porpoises are already being kept in the Shishou Semi-natural Reserve (age and sex uncertain) and two (one adult male and one juvenile female) in a tank at the Wuhan Institute of Hydrobiology. In other words, a small captive population of Yangtze finless porpoises already exists. Finally, experience has shown that finless porpoises are much easier to capture than baiji, and that they can be handled and trained.

As a working principle, the group wished to emphasize that the ultimate goal must always be to maintain a viable wild population of porpoises in the Yangtze River and that all measures endorsed or recommended here are intended to serve that goal. Moreover, it is necessary to bear in mind at all times when considering *ex-situ* approaches that any removal of animals from the wild has a negative effect on the wild population. This "cost" must be weighed against the potential benefit to the wild population that might eventually be realized through reintroduction or restocking. The long-term maintenance of a captive population in either a semi-natural reserve or an aquarium tank does not, by itself, constitute a conservation strategy. It is only justified, in conservation terms, if it contributes to the maintenance of the wild population at some future time.

Conservation of finless porpoises in the wild (*in situ*):

1. Even more important than creating new reserves or expanding existing reserves is the need to educate people about, and strictly enforce, regulations restricting the use of destructive fishing gear within the currently protected area for baiji. The finless porpoise should be included, along with the baiji, as an intended beneficiary of any protected area of the Yangtze River. Effectiveness should be monitored and evaluated by regular surveys of illegal fishing and other harmful human activities.
2. Together with efforts to make the existing baiji reserve safe for cetaceans, the desirability and feasibility of extending protective measures to additional areas explicitly for the benefit of finless porpoises should be explored.
3. There is a need for long-term monitoring of population trends throughout the river, and the current baiji reserve should be a focal area for such monitoring. The most critical feature of the monitoring program is that the methodology and survey procedures are standardized and constant. A sighting survey, using two boats travelling along opposite sides of the river, within a specified distance from shore, might be suitable for sampling and monitoring trends in abundance, calf production, etc. Regardless of the financial and logistical constraints, however, the methodology should conform to a standard sampling technique, such as line or strip transect, that allows rigorous estimation of numbers or evaluation of trends.
4. Tracking and marking studies are a high priority because of the potential for learning about individual movement patterns, home ranges, site fidelity, seasonal movements, social affiliations, etc. If possible, three to five individuals should be radio-tagged, with only large and healthy adults selected for tagging. The attachment method should incorporate a timed-release mechanism. A preferred tagging locality would be somewhere inside an existing or proposed reserve (e.g. Xin Lou Baiji Reserve).
5. Whenever animals are captured, a full suite of morphometric data and biological samples should be collected before release. Capture should only be undertaken when trained veterinary personnel are present.
6. At least one site-specific study of the behavior and distribution of the porpoises and the nature of local threats to these animals should be initiated. Ideal locations for such studies would be areas within existing or proposed reserves, with the studies preferably involving one or more graduate students based in the area.
7. Genetic and morphometric studies would be useful for determining broad-scale exchange between the middle and lower reaches of the Yangtze River and between the riverine and marine populations.
8. Studies of contaminant levels in the tissues of finless porpoises and their prey are important and should be encouraged.

Conservation of finless porpoises in semi-natural reserves (*ex situ*):

The security fence to prevent escape from the Shishou Semi-natural Reserve is not complete; harmful human activities (e.g. fishing in ways known to result in incidental mortality of cetaceans) continue inside the Reserve; and questions remain concerning the quality of the water in the Reserve. Thus, at present, the Shishou Semi-Natural Reserve is not a safe environment for either baiji or finless porpoises. In view of the scarcity of baiji and the difficulty of finding and collecting them, efforts to collect and translocate this species into the reserve should be suspended. Even if conditions in the Reserve were improved, e.g. by completing the security fence and eliminating dangerous fishing practices inside the Reserve boundaries, it would be very difficult, perhaps impossible, to find and collect a sufficient number of baiji to establish a viable captive population (following the guidelines provided by Ralls 1989).

In combination, the circumstances described above can be interpreted to mean that a deliberate, step-wise approach should be taken in evaluating any proposal for using *ex-situ* management to conserve the Yangtze finless porpoise. The group agreed that the following steps should be taken, in the stated order, before any decision is made concerning the further collection of Yangtze finless porpoises.

1. Conditions in the Shishou Semi-natural Reserve must be improved to ensure the safety of the existing captive population of finless porpoises. This means the elimination of all fishing with harmful methods (e.g. electricity, explosives, rolling hooks, gillnets, etc.) inside the reserve. It also means that the barrier to prevent the animals' escape into the Yangtze River during the flood season must be completed.
2. A critical review and summary of knowledge is needed which synthesizes all information available, published and unpublished, concerning the reproduction, social behavior, and husbandary requirements of finless porpoises. This review also needs to integrate genetic and demographic factors and to provide advice on the required size and composition of a founding stock, integrating as much information as possible on the behavior and social structure of finless porpoises (see previous Recommendation No. 4, under *in situ*).
3. Rigorous evaluation of water quality and sediment in the Reserve must be completed, including measurement of fecal coliform levels during the dry season when flushing is at a minimum. Organochlorine, organotin, and heavy metal levels inside the Reserve should be compared with levels in the Yangtze mainstem. Contaminant levels should be measured in at least one

of the porpoise's prey species inside the Reserve. Some of the environmental evaluations need to be done only once, but some aspects of water quality and sediment conditions will need to be monitored on an ongoing basis.
4. The five animals inside the Reserve should be marked to facilitate long-term management and research. Freeze-branding is probably the best method available, and it should be done in collaboration with someone who already has experience with the technique (e.g. R. Wells).
5. A behavioral conditioning regime should be established with the five finless porpoises so that they can be handled and examined routinely. Among other things, their blood chemistry and hematology can then be compared with those of captive and wild porpoises (e.g. see Sweeney *et al*. 1995; Wells *et al*. 1995; Hansen *et al*. 1995, for bottlenose dolphins).

Conservation of finless porpoises in captivity (*ex situ*):
The two porpoises currently in captivity at the Institute of Hydrobiology present opportunities for certain kinds of research that could benefit future captive breeding efforts. Among the actions that should be completed with these animals are:
1. Establish collaborations with people at Japanese and Hong Kong aquaria to develop procedures for training, ultrasound examinations, blood profiling, tissue collection and preservation for use with new or future reproductive technologies, etc.
2. Some experimentation with tools to be used for research on wild porpoises and on porpoises in the semi-natural reserve would be of great benefit. For example, these animals could be used to test techniques for age estimation, to test harnesses to be used for radio-tag attachment, or to refine and evaluate freeze-branding techniques. At present, however, given the very poor water quality in the tanks, such experimentation is probably too dangerous. The value of the animals in tanks would be enhanced if the water quality were improved.
3. Conduct food-preference trials to learn something about porpoise feeding habits.
4. A focused study of female and male reproduction, based on the monitoring of hormone levels and behavior of the captive animals, would be worth continuing and publishing.

It is hoped that the recommendations outlined here will be useful to researchers and conservationists both within and outside China. With this "blueprint" to guide decisions about how funds should be invested, as well as a renewed commitment to the conservation of China's wildlife, it may be possible to prevent the finless porpoise from following the tragic path of the baiji.

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Appendix 1: Workshop Agenda

Developing a Conservation Action Plan for the Yangtze River Finless Porpoise Population

Day 1 (Tuesday, 16 September)

10.00 Welcomes and introductions

10.30 Presentation – Wang Ding
Recent work on Yangtze finless porpoises by Wuhan Institute of Hydrobiology

11.00 Presentation – Zhou Kaiya
Recent work on Yangtze finless porpoises by Nanjing Normal University

11.30 Questions and Discussion

11.50 Break for lunch

14.00 Group Discussion – Background on Yangtze Finless Porpoises
1. What is known about Yangtze finless porpoise life history (reproduction, feeding, etc.)?
2. Is there more than one Yangtze finless porpoise stock?
3. What are the main threats to the Yangtze finless porpoise population?
4. Is the finless porpoise less vulnerable to bycatch than the baiji?
5. Is there evidence that the Yangtze River mainstem can no longer support finless porpoises?
6. How can we determine if there is competition between finless porpoises and baiji?

18.00 Break for dinner

Day 2 (Wednesday, 17 September)

09.00 Group Discussion – The Potential Role of Semi-Natural Reserves
1. Is the Shishou Reserve currently a safer place for individual porpoises (than the mainstem)? What about the Tongling Reserve?
2. Should the Shishou Reserve be a single-species reserve? If so, for which species?
3. Should finless porpoises be placed in the reserve at Tongling?
4. If live-captures are required, what techniques should be used?
5. Should captive breeding and artificial insemination play a role?
6. Should public viewing and "ecotourism" be allowed or encouraged at the reserve(s)?

13.00 Break for lunch

14.00 Group Discussion – Protection in the Natural Habitat
1. What techniques should be used for population assessment and stock structure studies?2) Can we define and designate critical habitat for finless porpoises in the Yangtze?3) Should additional radio-tracking be undertaken?
4. How can public awareness of the finless porpoise best be increased?
5. How can existing measures to protect baiji be modified to also benefit finless porpoises?
6. What realistic measures can be taken to protect finless porpoises in the Yangtze?

18.30 Break for dinner

Day 3 (Thursday, 18 September)

09.00 Group Discussion – Agreeing on Wording of Recommendations for action plan

11.45 Closing remarks

12.00 Break for lunch and boat trip to observe finless porpoises

17.00 Return to pier

Appendix 2: List of Participants

Invited Experts:
Thomas A. Jefferson, Ocean Park Conservation Foundation
Toshio Kasuya, Mie University
Randall R. Reeves, Okapi Wildlife Associates
Brian D. Smith, Aquatic Biodiversity Associates
Wang Ding, Wuhan Institute of Hydrobiology
Wang Peilie, Liaoning Marine Fisheries Research Institute
Randall S. Wells, Chicago Zoological Society
Bernd Würsig, Texas A&M University
Zhou Kaiya, Nanjing Normal University

Observers:
Lien-siang Chou, National Taiwan University
Mary Felley, Ecosystems, Ltd.
Reimi Kinoshita, Ocean Park Corporation
Mark Shea, Hyder Environmental Ltd.

Status and Conservation of the Yangtze Finless Porpoise

Wang Ding, Liu Renjun, Zhang Xianfeng, Yang Jian, Wei Zhuo, Zhao Qingzhong, Wang Xiaoqiang.
Institute of Hydrobiology, The Chinese Academy of Sciences, Wuhan, Hubei 430072, China

Abstract

During 1991–1997, five and three surveys were conducted in the middle and lower reaches, respectively, of the Yangtze River. The target species of the surveys included both the baiji (*Lipotes vexillifer*) and the finless porpoise (*Neophocaena phocaenoides asiaeorientalis*). Results indicate that the finless porpoise population has declined in recent years. To conserve finless porpoises in the Yangtze River, the following actions are recommended: 1) a breeding group should be established in the Shishou Baiji Semi-natural Reserve; 2) natural reserves should be established in areas most frequented by the animals; and 3) research on captive breeding should be intensified.

Introduction

The finless porpoise (*Neophocaena phocaenoides*) is distributed widely in Chinese waters, including coastal waters of the South China Sea, East China Sea, Yellow Sea, and Bohai Sea, as well as the middle and lower reaches of the Yangtze River (Reeves *et al.* 1997, Parsons and Wang 1998, Kasuya 1999). Some animals may occasionally migrate into other large rivers, such as the Pearl and Yalu (Gao and Zhou 1995, Wang 1993, Zhang *et al.* 1993). Wang (1992) proposed three subspecies of finless porpoises: *Neophocaena phocaenoides phocaenoides* from the South China Sea and Indian Ocean; *N. p. sunameri* from the Yellow Sea, Bohai Sea, and Japanese coastal waters; and *N. p. asiaeorientalis* from the East China Sea and the Yangtze River. He considered porpoises from the Yangtze River to constitute a separate geographical population. Gao and Zhou (1993, 1995) also proposed three subspecies, but they considered animals from the East China Sea and Yellow Sea to belong to *N. p. sunameri* and the Yangtze finless porpoise to be a separate subspecies *N. p. asiaeorientalis*. Zhang *et al.* (1993) roughly estimated the population of Yangtze finless porpoises to be 2,700 animals, based on surveys conducted during winter 1984 through 1991. Conservation measures were discussed in Liu and Wang Ding (1996) and Liu *et al.* (1996, 1997). This paper summarizes the distribution, relative abundance, and habitat of finless porpoises in the Yangtze River. A description of the porpoises translocated to the Shishou Baiji Semi-natural Reserve is included. Conservation measures are recommended (also see Reeves *et al.*, this volume).

Methods

During 1991–1997, while conducting surveys for Yangtze river dolphins or baiji (*Lipotes vexillifer*), we also investigated the population and habitat of the Yangtze finless porpoise. Five surveys were conducted in the middle reaches of the Yangtze River from Wuhan to Xinchang (826km), and three surveys of various lengths (560–2038km) were conducted in the lower reaches of the Yangtze River from Wuhan to Liuhekou (Figure 1). Surveys were normally

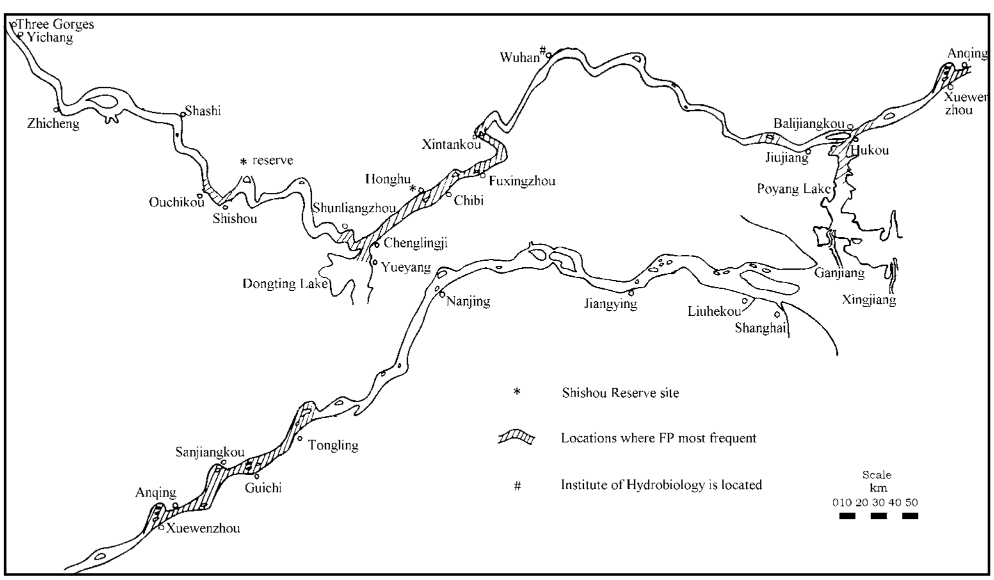

Figure 1. Distribution of the Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*).

conducted from a 31m motorized vessel, *Shuisheng No. 1* or *Kekao No. 1,* or a 20m motorized vessel, *Baiji No. 1*, and several or many 5m fishing boats with small outboard motors. While surveying downstream, all of the boats oriented in one to three lines across the river channel, depending on the number of fishing boats participating in the survey. The distance between each line was 1–3km, and the boats were spaced 300–500m apart. The larger vessel served as a commander ship. While surveying upstream, the commander ship followed a path in the middle of the channel, and the fishing boats travelled along the sides where the current was not so strong, spaced 500–1000m apart. The average speed of the vessels was 5–8km/h during both upstream and downstream surveys. Two observers searched for porpoises from the large vessel while one observer searched from each fishing boat. Communication between vessels was maintained using hand-held radios and flag signals. Information on the habitat where porpoises were observed was also recorded.

Results

Distribution and abundance

During all seasons surveyed, a particularly high density of porpoises was found in the mouth of Poyang Lake and in the adjacent river segment at Balijiangkou. Other segments of river with relatively high densities of porpoises included Sanjiangkou, Xuewenzhou, Xintankou, Fuxinzhou, Chibi, Chenglingji, Sunliangzhou, and Ouchikou. Data from surveys in the middle reaches upstream of Wuhan are presented in Figure 2, while data from surveys in the lower reaches downstream of Wuhan are presented in Figure 3.

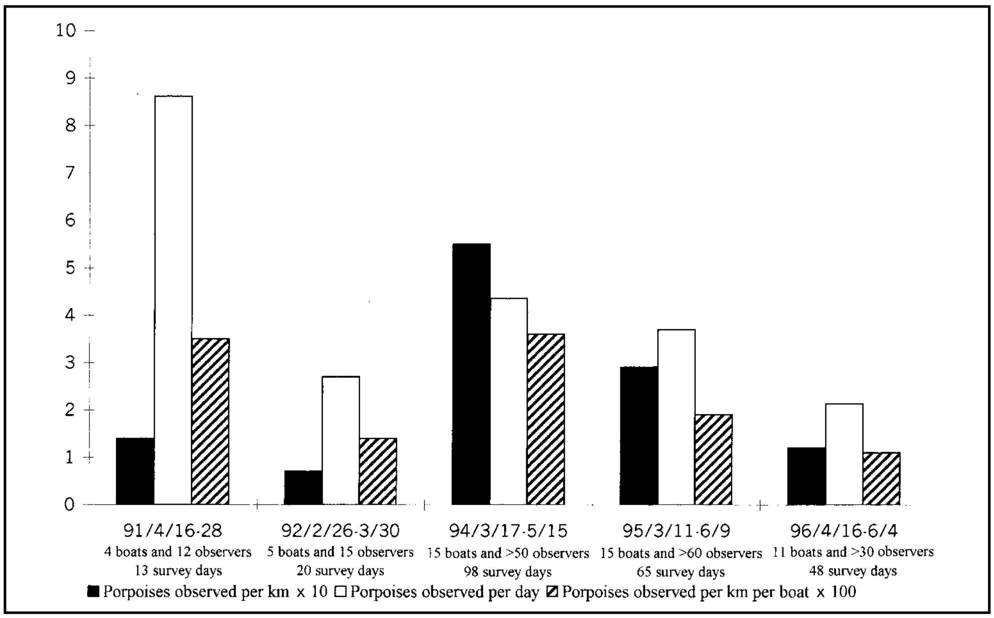

Figure 2. Encounter rates for finless porpoises observed during surveys of the middle reaches of the Yangtze River from Wuhan to Xinchang (826km) in spring seasons from 1991 to 1996.

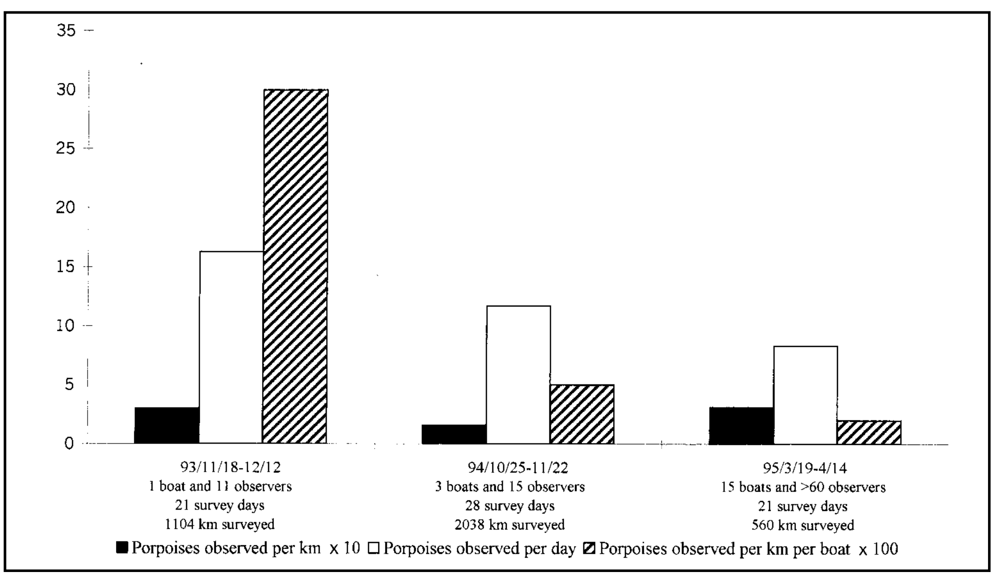

Figure 3. Encounter rates for finless porpoises observed during surveys of various lengths in the lower reaches of the Yangtze River downstream from Wuhan in spring and winter seasons from 1993 to 1995.

Habitat characteristics

Finless porpoise habitat in the Yangtze River had one or more of the following characteristics: (1) location at the convergence of a tributary or connecting channel of an appended lake, or near sand bars downstream of a channel meander; (2) relatively low water velocity, estimated at 0–0.5m/sec; (3) two or more currents meeting in different directions and with different velocities forming counter-current eddies; (4) water depth of 3m with a gently sloping bed; (5) mud bottom substrate rich with organic matter and plankton; (6) relatively high abundance of small fish; (7) feeding ground for gulls, wild ducks, herons and other water birds; (8) presence of fishermen using fixed box and small-mesh nets; and (9) relatively high abundance of riparian vegetation. Porpoise habitat frequently shifted location, changed channel form, and increased or decreased in size during different water stages of the survey period.

Translocation of finless porpoises to the Shishou Baiji Semi-Natural Reserve

A program was initiated to translocate finless porpoises into the Shishou Baiji Semi-natural Reserve. The initial aim was to use the finless porpoise as a surrogate species for testing the suitability of the reserve for baiji. During 1990, we translocated five finless porpoises into the reserve and another five in 1993 (Table 1). In 1990, one male died soon after arrival from injuries suffered during capture. In 1992, another male was accidentally killed by rolling hooks. The other eight porpoises survived. Five of them were pregnant females, two of which were near term when taken from the wild. The calves from those two females were found dead (one killed by rolling hooks and one from premature delivery, probably due to the stress associated with capture). The other three females, also pregnant at the time of capture, gave birth successfully. One other calf, conceived in the reserve, was born in spring 1992. It survived.

During capture attempts for a radio-tracking study in 1993 (see Wursig *et al.* this volume), seven porpoises in the reserve were killed because of an inexperienced catching team. The five remaining animals consisted of three adult males, one juvenile female, and one animal of unknown age and sex, possibly an adult female.

Between May 1995 and April 1996, we translocated 12 additional porpoises into the reserve. Three calves that were conceived in the wild were born in the reserve and survived. Fourteen porpoises escaped into the mainstream of the Yangtze River during the flood season in June through August 1996. Of the six remaining animals, at least one was a juvenile and one a neonate. In December 1996, we translocated another 14 porpoises into the reserve, including five males (three adults and two juveniles) and nine females (six adults and three juveniles). Adults and

Table 1. Details on the translocation, breeding, escapes, mortalities, and releases of Yangtze finless porpoises in the Shishou Baiji Semi-natural Reserve from 1990 to 1998.

Dates	Segment of river where porpoises were captured	Number of porpoises translocated	Females	Males	Number of porpoises born in the reserve	Deaths, escapes and releases	Porpoises remaining in the reserve
March 2 – April 25, 1990	Chenglingji	5	3	2	2+	One infant was killed by rolling hooks, one male died on April 25, 1990 from injuries during capture.	5
May 28, 1992						One male was killed by rolling hooks.	4
Spring 1992					1++		5
April 1993	Chenglingji	5	3	2	3+	One infant was found dead on April 26, 1993, born prematurely due to capture.	12
October 18, 1993						Seven killed accidentally.	5
May 23, 1995	Chenglingji	3	1	2	1+		9
December 6, 1995	Chenglingji	4	2	2			13
April 20, 1996	Jianli	5	3	2	2+		20
June – August 1996						Fourteen escaped from the reserve.	6
December 1996	Chenglingji and Shishou	14	5	9			20
Spring 1997						Fifteen were released.	5
Autumn 1997					2++		7
Spring 1998					1++		8
Total		**36**	**17**	**19**	**12**		

\+ Conceived in the Yangtze River
++ Conceived in the Reserve

juveniles were distinguished on the basis of body length (see Zhang 1992).

In spring 1997, 15 porpoises were released from the reserve into the Yangtze River to reduce competition for fish between the animals and local fishermen. Two porpoises were born in autumn 1997, and another one in spring 1998. All three were conceived in the reserve. As of spring 1998, there were eight porpoises remaining in the reserve, consisting of at least three adult females, three calves, and two of uncertain age and sex.

Discussion

Although no statistical analysis of our data was possible because of variable survey methods and small sample sizes, we believe that our results indicate a marked decline in porpoise abundance. When methods were kept consistent, during surveys in spring 1991 and 1992, the sighting rate in the segment of river between Wuhan and Xinchang declined from 0.14 porpoises/km to 0.07 porpoises/km. After the 1992 survey, we increased the number boats and observers. Although our encounter rate increased to 0.55 porpoises/km during the next survey in spring 1994, it declined to 0.29 porpoises/km in spring 1995 when survey methods were, again, kept relatively constant. During spring 1996, we recorded an encounter rate of only 0.12 porpoises/km, although this could be at least partly due to the fact that fewer boats and observers participated in this survey. Encounter rates downstream of Wuhan decreased from 0.30 porpoises/km in winter 1993 to 0.16 porpoises/km in winter 1994, despite an increase in the number of boats and observers used for the survey.

Despite evidence of a decline in abundance, the range of finless porpoises in the Yangtze River has apparently remained constant. During our most recent survey in winter 1997, finless porpoises were observed in Yichang at their farthest reported upstream range (see Fraser 1935), and 60km upstream of the river mouth at Liuhekou. This is in contrast to baiji, which were historically sympatric with finless porpoises throughout their range in the Yangtze River. The baiji is now observed no farther upstream than Sashi and no farther downstream than Jiangying. This represents a loss of 148km from the baiji's upstream range which reportedly extended to Yichang (Liu and Wang 1996, Liu *et al*. 1996, authors' unpublished data) and 134km from its previously recorded downstream range which reached to Liuhekou (Lin *et al*. 1985, Zhou *et al.* 1977). The difference in the ability of the finless porpoise and baiji to maintain their respective historic ranges presents an interesting research problem, with important conservation implications.

The Shishou Baiji Semi-natural Reserve encompasses an area 21km long and 1–1.5km wide. Zhang *et al.* (1995) and Liu *et al.* (1998) estimated the standing biomass of fish in the reserve as 400,000–500,000kg. Fish are restocked naturally each year when the reserve reconnects to the Yangtze mainstem for approximately five months during the flood season. We believe that the large size of the reserve and its abundant fish resources should allow it to support breeding groups of both baiji and finless porpoises.

While a single adult female baiji occupied the reserve from 19 December 1995 to 23 June 1996 (the animal was found dead, entangled in the barrier net), we observed the dolphin swimming with finless porpoises with no obvious competitive interactions (see Liu *et al.* 1998). All 11 animals that died in the reserve were killed accidentally (Table 1). Their deaths were not caused by the natural environmental conditions of the reserve but by inexperienced capture teams and by fishing activities that will be prohibited once the reserve has been fully established. Our experience with porpoises in the reserve indicates that they can survive, conceive, and give birth in this semi-natural habitat.

Environmental degradation is severe and widespread in the Yangtze River. This situation will worsen with increasing development. We believe that Yangtze finless porpoises will continue to decline if urgent conservation action is not taken.

We propose to:

1. Establish a breeding group of finless porpoises in the Shishou Baiji Semi-natural Reserve. Several measures must be taken first. A safe permanent barrier must be constructed across the mouth of the reserve to stop the animals escaping into the mainstem during the flood season. Fishermen should be relocated, and fishing must be prohibited in the reserve. After sufficient information is obtained on the population genetics, life history, and demography of an established breeding group, the Shishou Reserve could then serve as a model and possibly provide founder animals for additional breeding groups in other parts of the country. Translocation of the porpoises back into the river would be possible if the semi-natural reserve was operating successfully.
2. Establish natural reserves. Since the population size of the porpoise is still relatively large (at least in comparison to that of the baiji) and the animals congregate in specific segments of river year round, it may be helpful to establish natural reserves in one or more of these segments. Two potential areas are the mouths of Poyang and Dongting lakes and adjacent waters in the Yangtze River.
3. Carry out breeding programs in captivity. Breeding programs in captivity may be effective for preserving an *ex-situ* population of Yangtze finless porpoises. Toba Aquarium in Japan has bred finless porpoises in captivity to the third generation (Teruo Kataoka, pers. comm.). Two Yangtze finless porpoises (one male and one female, approximately three years old) have been living in our pools since December 1996 and have exhibited

sexual activity. We plan to carry out research on their reproductive biology.

In summary, Yangtze finless porpoises are unique. No other population of this species is known to live entirely in fresh water. The lesson from our experience with baiji is that conservation action should be taken well before a crisis develops. If we do not act promptly to conserve the finless porpoises in the Yangtze River, we may lose them forever.

Acknowledgments

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A Preliminary Study on the Variability of the Mitochondrial DNA Control Region in Populations of Finless Porpoises (*Neophocaena phocaenoides*) in Chinese Waters

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Abstract

The mitochondrial DNA control region of 12 finless porpoises (*Neophocaena phocaenoides*) from the Yangtze River, Yellow Sea, and South China Sea, was amplified. Two portions, 317 and 245 base pairs, respectively, were directly sequenced to characterize the amount of genetic variation of finless porpoises in Chinese waters. No haplotype was shared among the Yangtze River population, the Yellow Sea population, and the South China Sea population. The phylogenetic trees using the two nucleotide sequences, as well as a longer sequence (562bp) formed by combining the former two sequences, clustered the haplotypes into three clades corresponding to the three geographical populations. The levels of genetic differentiation within each population were much lower than those between populations, indicating that the populations have diverged and are probably reproductively isolated. Because of the obvious genetic differentiation among the three populations, they should be regarded as different population units in their conservation and management.

Introduction

Population identification and genetic variation of the finless porpoise (*Neophocaena phocaenoides*) have been studied using mainly morphological and life history data (Amano *et al.* 1992, Gao and Zhou 1993, Gao and Zhou 1995a,b,c). Comparisons of external characters, skull measurements, and life history characteristics have suggested that there are three populations in Chinese waters: the Yangtze River population in the middle and lower reaches of the Yangtze River, the Yellow Sea population in the Yellow/Bohai Sea and the northern part of the East China Sea, and the South China Sea population in the South China Sea and the southern part of the East China Sea (Gao and Zhou 1995a). However, molecular genetic variation of these populations has not previously been reported except for a brief restriction fragment length polymorphism (RFLP) analysis by Gao (1991).

In recent years, molecular techniques, especially the polymerase chain reaction (PCR) and PCR-directed DNA sequencing (Rao 1994), have greatly facilitated the ability to sequence, compare, and analyze DNA segments from a large number of samples in a short time (Rosel *et al*. 1995a, Wang and Zhou 1996). Such techniques have been widely used in phylogenetic and population genetic analyses (Rosel *et al*. 1995a, b; Árnason and Gullberg 1996). In such analyses, the control region, which constitutes the most rapidly evolving and hypervariable portion of mitochondrial DNA (mtDNA) (Cann *et al*. 1984, Aquadro and Greenberg 1982), has proven to be a good marker for intraspecific and/or intrapopulation genetic variation analyses (Rosel *et al.* 1995a, Avise 1994, Taberlet 1996).

In the present study, the control region of finless porpoises from the Yangtze River, the Yellow Sea, and the South China Sea was amplified. Two portions of this region were sequenced and then used to assess the degree of population variation among the three populations.

Materials and methods

Samples

Tissue samples of skeletal muscle collected from 12 incidentally caught finless porpoises were used in this study (Table 1, Fig. 1). These specimens had been assigned to different populations prior to the genetic analyses, using discriminant analyses of skeletal and external measurements (see Gao and Zhou 1995a, b, for details) and without reference to the geographical positions of collections.

Table 1. The samples used in the present study.

Population	Number of samples	Specimen number NJNU[a]	Locality
Yangtze River	2	0372	Zhenjiang City, Jiangsu Province
		0374	Tongling City, Anhui Province
Yellow Sea	5	0327, 0362, 0368, 0369, 0370	Lusi Port, Jiangsu Province
South China Sea	5	0297, 0317, 0384, 0386, 0389	Dongshan Port, Fujian Province

[a]: NJNU, Nanjing Normal University

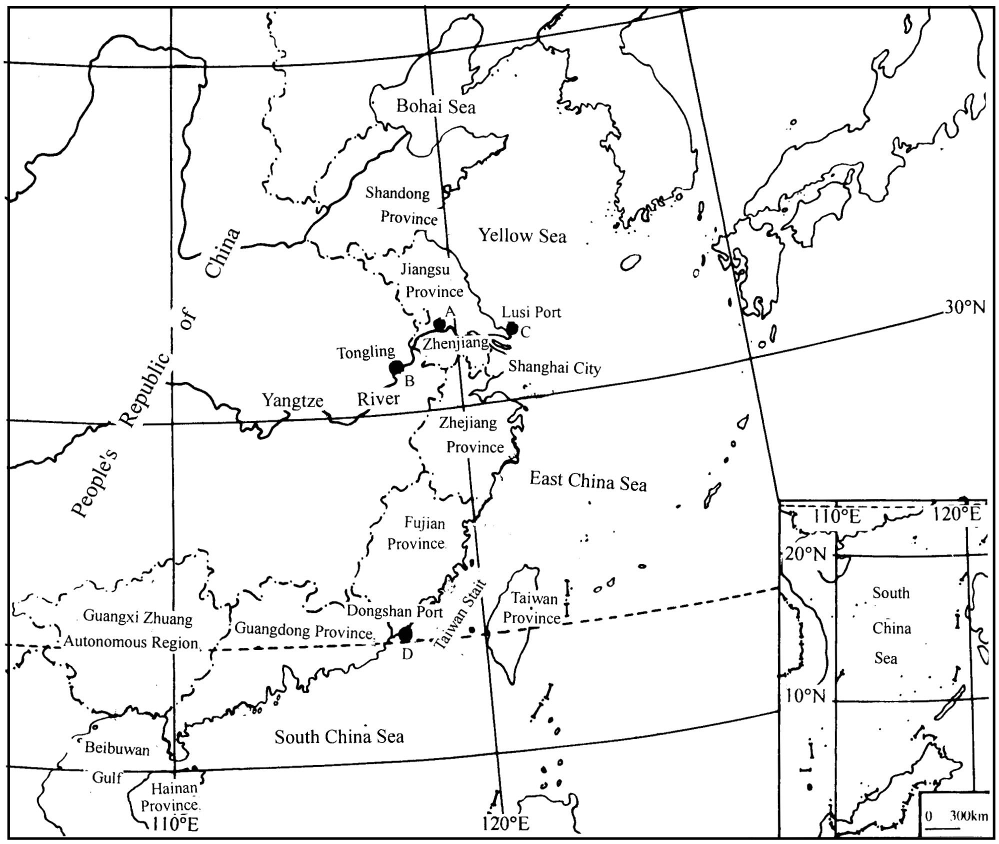


Figure 1. Sample localities in the present study. A: Zhenjiang, locality of sample 0372 (Yangtze River population); B: Tongling, locality of sample 0373 (Yangtze River population); C: Lusi Port, locality of samples 0327, 0362, 0368-0370 (Yellow Sea population); D: Dongshan Port, locality of samples 0297, 0317, 0384, 0386, 0389 (South China Sea population).

Extraction of total genomic DNA

Total genomic DNA was extracted from skeletal muscles following a protocol of protease digestion and phenol extraction (McPherson *et al.* 1991).

PCR amplification and DNA sequencing

Double-stranded amplification reactions were performed in 100 µl volumes containing 10-100 ng of extracted DNA template, 10 mM of Tris-HCl (pH8.3), 50 mM KCl, 2.5 mM $MgCl_2$, 150 µM of each dNTP (dATP, dGTP, dCTP, and dTTP), 0.01% gelatin, 3 units of Taq DNA polymerase (Promega, MADISON, WI), and 0.3 µM of each primer. The sequences of two primers were:
L5'-GAATTCCCCGGTCTTGTAAACC-3'
(hereafter primer I), and
H5'-TCTCGAGATTTTCAGTGTCTTGCTTT-3'
(hereafter primer II) (Hoelzel *et al.* 1991).
The reactions were cycled on a Gene Amp PCR system 2400 (Perkin Elmer) for 35 cycles at 95°C for 40sec, 55°C for 1min, and 72°C for 2min after a 2min predenaturation at 95°C. After the last cycle, a 7min extension was performed at 72°C.

The amplification products were about 1,000 base pairs (bp) long, including a flanking tRNA sequence at the 5'-end. The products were sequenced directly using the silver-staining technique following the standard protocol described in Promega (1995). Because the silver-staining sequencing usually produced less than 350-bp sequences for a single primer, it was not possible to obtain the total sequence of the control region using the two primers used in the amplification reaction. For this reason, two separate portions contained in the region, a 317 bp portion at the 5'-end (hereafter CON1) (including the above-mentioned flanking tRNA sequence) and a 245 bp portion at the 3'-end (hereafter CON2) of the L strand, were sequenced. The CON1 region was sequenced from the 5'-end of L-strand using primer I, thus the resultant sequences could be compared directly with homologous sequences of other cetaceans. However, the CON2 region was sequenced directly from the 5'-end of H-strand using primer II, and was translated into the 3'-end sequence of the L-strand according to the base complementary pairing rule (i.e. A to T, and G to C) for the subsequent analyses. Each region of every individual was sequenced at least twice to verify the sequence.

Analysis of population genetic variation

The sequences were aligned using the program PCGENE version 6.70 (Bairoch 1992) and corrected by hand. Unique haplotypes were defined by the sequence variation and then used to reconstruct the phylogenetic trees of the three populations using the unweighted pair-group method with arithmetic means (UPGMA) with a Tamura-Nei evolutionary model and a gamma correction (a=0.5) in the program MEGA (Kumar *et al.* 1993). We also tried to reconstruct the phylogenetic trees using the neighbor-joining (NJ) algorithm. However, the NJ trees were very different from the UPGMA trees. Moreover, the NJ trees were very difficult to explain according to the ecological distribution of haplotypes. Thus, the NJ trees were excluded from the paper. The percentage of variable sites in the combined CON1 and CON2 fragments (percent neucleotide diversity) was calculated and used to estimate within- and between-population differentiation.

Results

Haplotypes defined by variable sites in control region sequences and their distribution in three populations

Each population had its specific haplotypes, and no shared haplotypes were found among the three populations. Within the region of CON1, four variable sites were found, defining five unique sequences (haplotypes) in 12 finless porpoises (Table 2). Of the five haplotypes, CON1A was present only in the Yangtze River population. CON1B and CON1C were present in the Yellow Sea population, with CON1B the more prevalent. CON1D and CON1E were present in the South China Sea population, with CON1D the more prevalent. Rosel *et al.* (1995b) sequenced the control regions of two finless porpoises from the Yangtze River population. Their sequences overlapped with, and were identical to, the two sequences of finless porpoises from the Yangtze River population in the present study.

Table 2. Haplotypes defined by the variable sites within CON1 of 14 finless porpoises.

	Variable sites					
Haplotype	Site 108	Site 111	Site 161	Site 264	Sample number	Source
CON1A	T	A	C	G	4[a]	YR
CON1B	C	G	•	•	4	YS
CON1C	C	G	T	•	1	YS
CON1D	C	G	•	A	4	SS
CON1E	C	G	T	A	1	SS

The dot indicates that the corresponding site has the same nucleotide as the first haplotye; [a] including 2 individuals sequenced by Rosel et al. (1995b); YR: Yangtze River population; YS: Yellow Sea population; SS: South China Sea population.

Table 3. Haplotypes defined by the variable sites within CON2 of 12 finless porpoises.

	Variable sites			Sample	
Haplotye	Site 38	Site 44	Site 237	number	Source
CON2A	C	G	C	2	YR
CON2B	G	A	•	5	YS
CON2C	•	A	T	5	SS

Note: See Table 2 for explanation of symbols and abbreviations.

CON2 revealed three variable sites defining three haplotypes (Table 3), each of which was distributed in one of the three populations. Like the haplotypes defined by CON1, no haplotypes were shared among the three populations.

When CON1 and CON2 were combined, a single sequence of 562 bp was obtained. The combined sequence contained seven variable sites defining five haplotypes. Of the five haplotypes, one (HAP1) was distributed in the Yangtze River population; two (HAP2 and HAP3) were distributed in the Yellow Sea population, with HAP2 the more prevalent; and the remaining two (HAP4 and HAP5) were distributed in the South China Sea population, with HAP4 the more prevalent (Table 4).

CON1 contained 76 bp of flanking tRNA sequences. However, the inclusion or exclusion of this portion from CON1 had no effect on the number of variable sites and haplotypes.

Phylogenetic relationships among the three populations

Phylogenetic analyses of the three finless porpoise populations were performed by the UPGMA method in the program MEGA, using haplotypes defined by CON1 and CON2 sequences separately and combined (Figures 2, 3, 4). The phylogenetic analysis of CON1 used the harbor porpoise (*Phocoena phocoena*) as the outgroup. However, because the homologous sequence of CON2 from the harbor porpoise and other phocoenids was unavailable, homologous sequences from the beluga (*Delphinapterus*

Table 4. Haplotypes defined by the variable sites in the combined control region sequence.

	Variable sites								
Haplotype	CON1 108	CON1 111	CON1 161	CON1 264	CON2 38	CON2 44	CON2 237	Sample number	Source
HAP1	T	A	C	G	C	G	C	2	YR
HAP2	C	G	•	•	G	A	•	4	YS
HAP3	C	G	T	•	G	A	•	1	YS
HAP4	C	G	•	A	•	A	T	4	SS
HAP5	C	G	T	A	•	A	T	1	SS

Note: See Table 2 for explanation of symbols and abbreviations.

leucas) and killer whale (*Orcinus orca*) were used as outgroups in the phylogenetic analysis of CON2. Further, because the corresponding tRNA sequence flanking the 5'-end of the control region was unavailable from the beluga and the killer whale, this portion was excluded when CON1 and CON2 were combined into a single sequence. That is to say, the combined sequence (486 bp) in the subsequent phylogenetic analyses included 241 bp of CON1 and 245 bp of CON2, and the phylogenetic analysis of this region used the beluga and the killer whale as outgroups.

Figure 2. Phylogenetic tree of CON1 haplotypes reconstructed using UPGMA with Tamura-Nei evolutionary model and a gamma correction (a=0.5), with *Phocoena phocoena* as the outgroup. Numbers are bootstrap values derived from 2000 iterations.

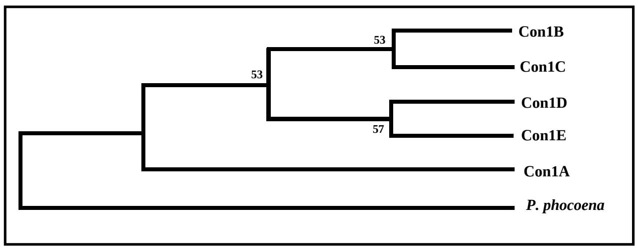


Figure 3. Phylogenetic tree of CON2 haplotypes reconstructed using UPGMA with a Tamura-Nei evolutionary model and a gamma correction (a=0.5), with the beluga *Delphinapterus leucas* and killer whale *Orcinus orca* as the outgroups. Numbers are bootstrap values derived from 2000 iterations.

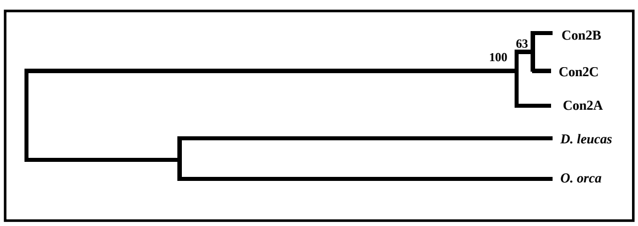
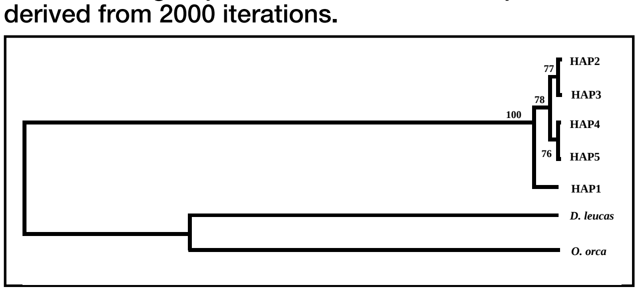


Figure 4. Phylogenetic tree of haplotypes of combined control region sequences, reconstructed by UPGMA with a Tamura-Nei evolutionary model and a gamma correction (a=0.5), using the corresponding sequences of the beluga and killer whale as outgroups. Numbers are bootstrap values derived from 2000 iterations.



All three phylogenetic trees clustered the haplotypes into three clades corresponding to the geographical populations. Two populations inhabiting coastal waters clustered together before they clustered with the Yangtze River population, indicating a closer relationship between the Yellow Sea and South China Sea populations than those between either of these populations and the Yangtze River population. The structure of the tree in Figure 4 was identical to those in Figures 2 and 3; however, bootstrap values in Figure 4 were higher than those in Figures 2 and 3.

Variation within and between populations

Comparison of DNA sequence variation between and within populations (percentage of variable sites, i.e. percent sequence diversity) (Table 5) revealed that the population genetic variation of the Yangtze River population was the lowest when compared to the Yellow Sea and South China Sea populations. No sequence divergence was detectable from the two individuals of the Yangtze River population and the two individuals reported in Rosel *et al.* (1995a). Although within-population variation was detectable for the Yellow Sea and South China Sea populations, the level was much lower than the between-population variation. This point is illustrated by the trees in Figures 2, 3, and 4, in which all within-population haplotypes clustered together before they clustered with haplotypes from other populations.

Table 5. Percent nucleotide diversity of control region sequences within (along diagonal) and among (below diagonal) finless porpoise populations.

	YR	YS	SS
YR	0		
YS	0.76	0.07	
SS	0.72	0.58	0.07

Note: See Table 2 for explanation of symbols and abbreviations.

Discussion

The number of variable sites and haplotypes found in the present study was very small compared with those found in some other marine mammals, e.g. harbor porpoises (Rosel *et al.* 1995a) and humpback whales (*Megaptera novaeangliae*) (Baker *et al.* 1993). This may be due to the small sample sizes and limited sampling of the total range of the finless porpoise. The sample size in this study was only 12 – smaller than the samples used in most other similar studies. It is possible that more variable sites and haplotypes would be detected and defined with a larger sample size and more sampling localities. For this reason, we recommend that the population genetic variation of finless porpoises, especially those in the Yangtze River, be studied further. Nevertheless, two factors make us believe that the true amount of population genetic variation of finless porpoises in Chinese waters is low. Firstly, Rosel *et al.* (1995a) reported 12 variable sites and 10 haplotypes among 15 harbor porpoises sampled from the North Atlantic (Bay of Fundy, Gulf of Maine, coastal Denmark, and Norway). Thus, the harbor porpoise, a species closely related to the finless porpoise, exhibited higher sequence diversity than finless porpoises in Chinese waters. Secondly, the sequences from the control region of two Yangtze finless porpoises analyzed by Rosel *et al.* (1995b) overlapped with the CON1 sequences of the two Yangtze porpoises in the present study. In other words, the addition of the two individuals in Rosel *et al.* (1995b) to those in the present study in effect increases our sample size to 14, which is nearly equal to the harbor porpoise sample from the North Atlantic used by Rosel *et al.* (1995a). Even considering the 14 specimens, we could not detect as many variable sites or haplotypes as were detected in the harbor porpoise.

No haplotypes were shared among the three finless porpoise populations studied, and within-population genetic variation was lower than that between populations. These results suggest that the populations are reproductively isolated and that there is a lack of individual exchange and gene flow. This is consistent with the results obtained by morphological studies. It has been shown that obvious external differentiation exists among finless porpoise populations in Chinese waters, and a specimen can be identified to population based on two external characters (Gao and Zhou 1995a). Although it is more difficult to distinguish populations on the basis of skeletal morphology, we can clearly distinguish the population of a finless porpoise by discriminant analysis of skull characters (Gao and Zhou 1995b, 1995c). There are also differences in growth and reproduction that support the hypothesis that these populations are isolated to some degree. For the above reasons, it is unlikely that finless porpoises migrate between the Yangtze River and the sea as suggested by Zhang *et al.* (1993). The three populations should be regarded as different population units in their conservation and management

In conclusion, our results suggest that isolation exists across the three populations of finless porpoises, and that each population's level of genetic variation is low. In particular, the four individuals from the Yangtze River, including the two reported in Rosel *et al*. (1995b), had only a single haplotype, indicating a very low level of genetic variation in this population. The Yangtze finless porpoise is the only population of finless porpoises living permanently in fresh water, and it has been recognized as a subspecies, *N. p. asiaeorientalis* (Gao and Zhou 1995a). A proposal was submitted in 1995 to the Bureau of Fisheries, Ministry of Agriculture of China, that the Yangtze population be recognized as separate from the other two subspecies and be declared a Grade 1 National Key Protected Animal when the List of National Key Protected Animals was revised. The Yangtze population of finless porpoises is listed as Endangered in the *1996 IUCN Red List of Threatened Animals* (IUCN 1996).

Although the List of Grade 1 National Key Protected Animals has not yet been revised, the conservation of the Yangtze finless porpoise has attracted increasing attention from biologists and some relevant administrative officials in China. A comprehensive survey of the Yangtze River was conducted in 1997 to collect data on the population status of the baiji and finless porpoise. Some other studies on the activities, behavior, and molecular genetic variation of finless porpoise are also ongoing in China.

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Abundance and Distribution of Finless Porpoises in the Nanjing-Hukou Section of the Lower Yangtze River

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Abstract

Survey results from 1989 to 1992 were interpreted as indicating that about 700 finless porpoises (*Neophocaena phocaenoides*) inhabited the section of the lower Yangtze River between Nanjing and Hukou. The number of individuals seen per kilometer searched (NIPK) was stable in certain river subsections and variable in others. The highest NIPK was in the subsection between Huayang and Hukou. Eighty-nine percent of recorded distances of porpoises from the river bank were 500m or less, indicating that porpoises tend to inhabit the near-bank waters. Our abundance estimate was lower than that from previous surveys, but the suggested decline was not shown to be statistically significant.

Introduction

The finless porpoise (*Neophocaena phocaenoides*) is found throughout coastal Indo-Pacific waters (Reeves *et al.* 1997, Kasuya 1999). In China, it is distributed in coastal waters and the middle and lower reaches of the Yangtze River. The Yangtze finless porpoise (*N. p. asiaeorientalis*) (Gao and Zhou 1995a) shares its riverine habitat with the baiji (*Lipotes vexillifer*), an endemic and critically endangered dolphin. The IUCN has classified the Yangtze finless porpoise as Endangered (IUCN 1996), but only one report on its population status has been published previously (Zhang *et al.* 1993). The purposes of the present study were to obtain abundance estimates for finless porpoises in the lower reaches of the Yangtze River and thus to provide a basis for monitoring trends in abundance through time.

Methods

From 1989 to 1992, six surveys were conducted in the 421km river section between Nanjing (32°03'N, 118°47'E) and Hukou (29°45'N, 116°20'E) (Fig. 1). Four to eight 7m fishing boats with outboard engines of 4–12hp were chartered for the surveys. Two trained fishermen served as operators/observers on each boat. In addition, one or more researchers were aboard two of the boats. All vessels travelled on a path parallel to the bank, spaced at distances of 100–200m, with the goal of achieving 100% coverage of the river surface. The boats travelled at higher speeds heading downstream, but the intention for all surveys was to maintain a constant slow speed (approximately 7–8 km/hr with respect to the bank). Contact among the crews was maintained by radio and signal flag. Observers scanned for cetaceans with their naked eyes or with hand-held binoculars, depending on the circumstances. When porpoises were spotted, the time, locality (with respect to landmarks and a map), number of individuals, distance from the boat, distance from the river bank, and behavior of the animals were recorded independently by the researchers on the two boats. Usually one of the two boats was near the northern bank and the other near the southern bank. The animals sighted by researchers on one of the two boats usually were not in the visual range of the researchers on the other boat, and the two teams of researchers did not communicate sighting information to each other during the survey. The distance from the vessel to the animals was visually estimated. Each day's total survey distance was used as the measure of effort. If two boats were surveying a segment of river for six hours, and they covered 40 linear km of river during that time, the day's effort was 6 hr and 40km (not 12 hr and 80km). Repeated upstream and downstream surveys were conducted in some river segments. For example, the survey in March 1989 included a downstream leg from subsection No. 3 to No. 1, an upstream leg from subsection No. 1 to No. 5, and a downstream leg from subsection No. 5 to No. 1. In addition, the surveys were repeated in particular parts of subsections No. 2 and No. 4. Therefore, the surveyed distance in each subsection was longer than the length of the subsection. Weather conditions were noted each morning (e.g. clear, rainy, windy, foggy). When they were judged unfavorable for detecting porpoises, survey effort was suspended until the weather improved.

The river section between Nanjing and Hukou was divided into seven subsections for analyses of porpoise distribution and habitat preference. The seven subsections

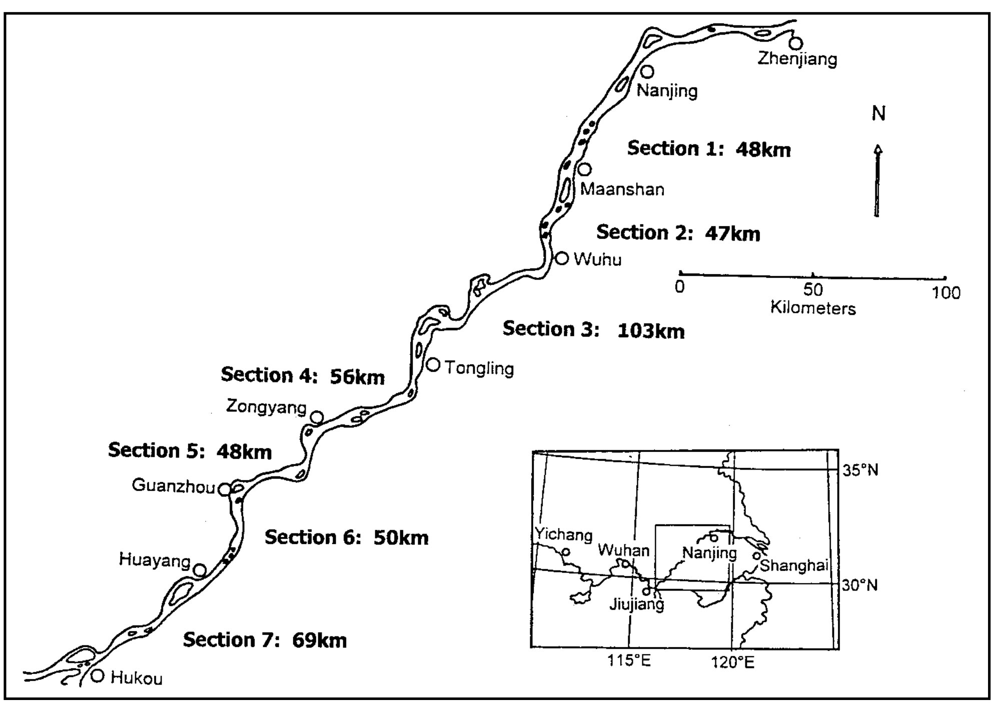

Figure 1. Sketch map of the Yangtze River between Nanjing and Hukou.

and their lengths were: 1. Nanjing-Maanshan (48km), 2. Maanshan-Wuhu (47km), 3. Wuhu-Tongling (103km), 4. Tongling-Zongyang (56km), 5. Zongyang-Guanzhou (48km), 6. Guanzhou-Huayang (50km), and 7. Huayang-Hukou (69km).

The number of porpoises seen in each subsection was ascertained after subtracting duplicate sightings. Duplicates were identified through consultations between the researchers on the two boats. The corrected numbers were used to calculate number of individuals per kilometer searched (NIPK).

The habitat preferences of porpoises were analyzed by comparing NIPK in the subsections.

Results

NIPK comparisions

Data from the six surveys are summarized in Tables 1 to 6. Coverage in two of the surveys was incomplete: the area between Guanzhou and Hukou (subsections No. 6 and 7) was not covered in March 1989 (Table 1), and that between Nanjing and Wuhu (subsections No. 1 and 2) was not covered in March 1991 (Table 4).

A comparison of NIPK between surveys implies stability in certain subsections and variability in others (Table 7). The number of individuals per kilometer was

Table 1. Summaries of data collected in the survey in March 1989.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]	230	115	390	225	80		
Porpoises counted	61	44	218	16	13		
NIPK[3]	0.2652	0.3826	0.5590	0.0711	0.1625		

1. Length of river in that subsection.
2. Total distances surveyed by all the survey vessels as a single unit, not combined.
3. Number of individuals per kilometer searched.

Table 2. Summaries of data collected in the survey in March 1990.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]	88	207	286	199	111	89	155
Porpoises counted	32	65	104	79	37	36	72
NIPK[3]	0.3636	0.3140	0.3636	0.3969	0.3333	0.4044	0.4645

Note: See Table 1 for explanation of superscripts.

Table 3. Summaries of data collected in the survey in March and April 1990. This survey also included the river section from Nanjing to Zhenjiang (50km). There were 43 porpoises, NIPK of 0.1866, in this section.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]	155	125	185	210	80	120	145
Porpoises counted	41	47	65	72	26	30	88
NIPK[3]	0.2645	0.1680	0.3513	0.3428	0.3250	0.1382	0.6069

Note: See Table 1 for explanation of superscripts.

Table 4. Summaries of data collected in the survey in March 1991.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]			110	235	75	115	105
Porpoises counted			11	35	18	35	61
NIPK[3]			0.1000	0.1489	0.2400	0.3043	0.5809

Note: See Table 1 for explanation of superscripts.

Table 5. Summaries of data collected in the survey in November and December 1991. This survey also included the river section from Nanjing to Zhenjiang (50km). There were 46 porpoises, with NIPK of 0.2000, in this section.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]	240	195	210	235	127	218	185
Porpoises counted	23	25	29	57	37	77	241
NIPK[3]	0.0750	0.1282	0.1380	0.2425	0.2913	0.3432	1.3027

Note: See Table 1 for explanation of superscripts.

Table 6. Summaries of data collected in the survey in March 1992.

No.	1	2	3	4	5	6	7
Subsection	Nanjing-Maanshan	Maanshan-Wuhu	Wuhu-Tongling	Tongling-Zongyang	Zongyang-Guanzhou	Guanzhou-Huayang	Huayang-Hukou
Length (km)[1]	48	47	103	56	48	50	69
Surveyed distance (km)[2]	90	120	255	250	158	118	84
Porpoises counted	19	18	65	89	38	55	56
NIPK[3]	0.2111	0.1500	0.2549	0.3560	0.2405	0.4611	0.6667

Note: See Table 1 for explanation of superscripts.

Table 7. Comparisons of NIPK between subsections and between periods.

Period	1 Nanjing-Maanshan	2 Maanshan-Wuhu	3 Wuhu-Tongling	4 Tongling-Zongyang	5 Zongyang-Guanzhou	6 Guanzhou-Huayang	7 Huayang-Hukou
March 1989	0.2652	0.3826	0.5590	0.0711	0.1625		
March 1990	0.3636	0.3140	0.3636	0.3969	0.3333	0.4044	0.4645
April 1990	0.2645	0.1680	0.3513	0.3428	0.3250	0.1382	0.6069
March 1991			0.1000	0.1489	0.2400	0.3043	0.5809
Nov. to Dec. 1991	0.0750	0.1282	0.1380	0.2425	0.2913	0.3432	1.3027
March 1992	0.2111	0.1500	0.2549	0.3560	0.2405	0.4611	0.6667

consistently highest in the Huayang-Hukou subsection (No. 7). It was also comparatively high in the Zongyang-Huayang subsections (No. 5 and 6), where it exceeded 0.3 porpoises/km for most of the surveys. NIPK in the Wuhu-Tongling (No. 3) and Tongling-Zongyang (No. 4) subsections fluctuated markedly, with highest values of 0.5590 and 0.3969 and lowest values of 0.1 and 0.0711 porpoises/km, respectively.

Distances from river bank

Most of the surveyed river was about 1.5km wide. In some areas, it narrowed to about 1km, and in others it widened to about 2km. Distances of porpoises from the river bank were recorded for 2,190 individuals sighted. Of this number, 1,143 were within 100m (52.2%), 162 between 100 and 200m (7.4%), 338 between 200 and 300m (15.4%), 157 between 300 and 400m (7.2%), and 145 between 400 and 500m (6.6%). A total of 1,945 sightings (88.8%) were judged to be within 500m of the bank.

Discussion

Habitat preferences

We believe that the patchiness of the distribution of porpoises along the river can be explained by the heterogeneous distribution of suitable habitat within the river system. The confluence of Poyang Lake and the Yangtze mainstem is opposite Hukou. The river channel from Hukou downstream to Huayang has numerous sandbars (e.g. Shanhaozhou, Yazihaozhou, and Gupaizhou). Its course is winding, the flow rate is relatively slow, and the fish resources are abundant in this portion of the river. Also, human activity (i.e. vessel traffic) is notably less than in subsections further downstream. The NIPK was higher in the Huayang-Hukou subsection (No. 7) than in any other part of our study area (Table 7), and Zhang *et al.* (1993) also found the largest groups of porpoises in this subsection.

The subsections between Maanshan and Huayang have numerous bends and some sandbars and eddy areas, but they also have considerable vessel traffic and human activity. We found NIPK values in these parts of the study area to be somewhat variable (Table 7). The subsection from Maanshan downstream to Nanjing has few bends and sandbars, and it is strongly influenced by vessel traffic. NIPK there tended to be low.

The porpoises observed in our surveys were mainly within 500m of the river bank. This finding is consistent with that of Zhang *et al.* (1993). We consider it reasonable to infer that porpoises tend to inhabit near-bank waters rather than the center of the river channel. However, we cannot exclude the possibility that our observations were biased by the tendency of porpoises to flee toward shore as the survey vessel approached.

Seasonal changes in porpoise distribution and abundance

Zhang *et al.* (1993) reported higher "relative densities" of finless porpoises in the Yangtze River in winter and spring than in summer and autumn. From this, they inferred that the porpoises make annual long-distance migrations, moving into marine waters in summer and autumn and returning upriver in winter and spring. However, only three of their 13 surveys took place in summer and autumn, and all of their surveys were limited to specific segments of the river. An alternative explanation of the observed seasonal differences in "relative density" could be that the distribution of porpoises within the river is dynamic, involving short-range movements but not necessarily long migrations into and out of the sea as proposed by Zhang *et al.* (1993).

Our survey data indicate pronounced differences in NIPK between areas, corresponding to hydrologic and orogenic features of the river channel, fish abundance, and intensity of human activity. Moreover, in a given reach of river the NIPK of porpoises can be quite variable, not only between seasons, but also between years in the same season (Table 7). This variability means that great care must be taken in making inferences about long-distance migrations or about trends in overall porpoise abundance.

Phylogenetic evidence argues against the hypothesis of regular annual migrations by Yangtze porpoises to marine waters. Yangtze animals and those found in the East China and Yellow seas are clearly different based on external morphology, skull characteristics, and growth patterns (Gao and Zhou 1993, 1995a, 1995b, 1995c) and mtDNA sequences (Yang and Zhou this volume). There was no shared haplotype between the Yangtze porpoises and the porpoises from Chinese coastal marine waters. If finless porpoises migrated annually out of the Yangtze into the sea and back, it would be difficult to explain these differences.

We cannot rule out the possibility that some individuals from the Yangtze population enter the sea, or that individuals from coastal populations sometimes move into the lower reaches of the river. In fact, coastal finless porpoises are known to enter fresh water occasionally. Such movement is most likely to occur in the Yangtze in February and March, when spring tides can cause seawater to penetrate as far upstream as Zhenjiang, about 260km from the mouth of the Yangtze. Documented instances of marine cetaceans moving far into Chinese rivers include: a dolphin (*Sousa chinensis*) that stranded on a sandbank 220km from the mouth of the Yangtze in February 1987 (Zhou 1991, Zhou *et al.* 1997), one false killer whale (*Pseudorca crassidens*) seen at the same distance upstream in February and another 300km upstream in March (Zhou *et al.* 1995), and at least two finless porpoises and a false killer whale found in the Qiantang River (Zhou *et al.* 1982, Gao and Zhou 1995a, Wang 1991). Such movements, however, are far from typical.

Further study of the ecology and molecular biology of finless porpoises in China can be expected to clarify further the nature and extent of exchange between freshwater and marine environments.

Comparison with results of earlier surveys

Zhang *et al.* (1993) used an *ad hoc*, non-standard method to estimate absolute abundance from NIPK data. Their NIPK values were 0.15 and 0.25 for the two single-boat surveys and 0.19 for the one multiple-boat survey. They used a conversion factor, R, to estimate absolute abundance from NIPK, such that N (absolute abundance) = NIPK/R. Their R value was 0.108 for single-boat surveys and 0.216 for multiple-boat surveys. Applying this crude formula to their data for the segment of the river that we surveyed gives an abundance estimate of about 774 porpoises. Using their R value of 0.216 for multiple-boat surveys with the NIPK values from our four surveys gives an average abundance estimate of about 700 in the study area during the period 1989-92. The suggested decline cannot be considered significant because of the many uncertainties involved in estimating absolute abundance. Two of the three surveys by Zhang *et al* (1993) that covered our study area used single boats and the other used multiple boats. Moreover, their NIPK values were derived from a longer river section than that covered in the present study, and our surveyed river sections only partially overlapped theirs. Thus, it is of little meaning and inappropriate to directly compare their NIPKs, or their absolute abundance estimate, with ours. It is important to recognize also that Zhang *et al.* based their estimates on data from 13 surveys conducted between December 1984 and June 1991, so there is some overlap in the timing of their surveys and ours.

It is clearly inappropriate to make any definite conclusions about trends in the Yangtze finless porpoise population from the available survey data. However, all evidence suggests that the total population is no more than several thousand individuals. Scientists working in the region have the impression that the population is declining (see Reeves *et al.* this volume). Therefore, it is important that surveys be conducted at regular intervals using standard techniques, with the main emphasis being to obtain index values that can be compared through time. NIPK is probably the best index to use.

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Chapter 6

Methods for Studying Freshwater Cetaceans

Survey Methods for Population Assessment of Asian River Dolphins

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Abstract

Methods used to survey Asian river dolphins have generally been simple and *ad hoc*. This paper is an attempt to develop a rigorous, standardized methodology. We suggest that group-size estimates should include three values – best, high, and low. If possible, independent estimates by multiple observers should be obtained. In narrow channels, direct counts can be used to estimate absolute abundance. Accuracy is improved in direct-count surveys by spending extra time searching for dolphins in counter-current areas and at sighting locations. Wide channels require a sampling approach, and estimation of absolute abundance is much more difficult. Surveys in wide channels should focus on obtaining an index of relative abundance. No stops should be made during these surveys. The vessel should follow a ladder-type transect design, with transects oriented parallel to the bank, interrupted at standard intervals by transects across mid-channel. Density sampling, modified from standard line or strip transect methods, may be applicable in the future. However, resultant estimates of absolute abundance will be meaningful only if better information becomes available on diving behavior and habitat preferences. Modifications will need to consider the difficulties of (a) estimating sighting distances and (b) following random or systematic transect lines in the complex environments where these animals typically occur. The introduction of more sophisticated methods must be accompanied by efforts to provide Asian researchers with appropriate data-collection and analytical resources.

Introduction

Asian river dolphins have disappeared from much of their historic range and are believed to be declining rapidly in many areas where they still occur (see Smith and Reeves this volume). Of the three species of "obligate" or true river dolphins inhabiting Asian waters, the baiji (*Lipotes vexillifer)* is classified as Critically Endangered and the susu (*Platanista gangetica*) and bhulan (*Platanista minor*) as Endangered in the *1996 IUCN Red List of Threatened Animals* (IUCN 1996). The action plan of the IUCN/SSC Cetacean Specialist Group calls attention to the need for range-wide population assessments in support of conservation efforts for these species (Reeves and Leatherwood 1994).

Surveys of river dolphins have generally been conducted without rigorous application of a well-defined survey design. As a result, virtually all available population estimates lack measures of precision and are biased in unknown, or at least unquantified, ways. Modified line transect, cue counting, and simultaneous multi-platform survey methods have been recommended (Perrin and Brownell 1989) but have rarely been used. Unless survey methods are standardized and made more rigorous, it will remain difficult or impossible to detect trends in population abundance (Reeves *et al.* 1993).

The objectives of this paper are to review methods of population assessment, to discuss the appropriateness of their use in surveys of river dolphins, and to provide practical guidance to researchers in Asia for the design and implementation of survey programs. These researchers face difficulties that do not generally apply to surveys of marine cetaceans. Certain problems are related to the complex morphology of freshwater systems, which tends to concentrate dolphin distribution in microhabitats associated with specific hydrological features (Hua *et al.* 1989, Smith 1993) and limits the ability of survey vessels to follow random or systematic search patterns. Annual flood cycles of variable intensity add a strong seasonal element to dolphin distribution and constantly alter the structure of the animals' alluvial channel habitat. These factors complicate attempts to conduct repeated surveys that are consistent with respect to coverage and sighting conditions. Such consistency is a requirement for detecting population trends.

Asian researchers must also deal with logistical difficulties that are either absent or less extreme in many of the areas where standard survey methodologies have been developed and applied previously. Fiscal realities of conservation programs in developing countries dictate that surveys will, for the foreseeable future, be mostly low-budget and often dependent on foreign funds. In many instances, field scientists in Asia have limited experience with the analytical methods of population sampling and statistical theory. Moreover, they do not always have ready access to the computer software and hardware needed to analyze large volumes of numerical data. Both economy and simplicity are therefore important when developing survey protocols.

The primary focus of this paper is on the use of sighting surveys to estimate dolphin abundance in narrow- and wide-channel environments. Mark-recapture methods using photo-identification are discussed briefly. Ancillary objectives related to habitat assessment and investigating life history characteristics are also considered.

The proposed survey methods emphasize Asia's "obligate" river dolphins, but they can generally be applied to surveys of "facultative" river cetaceans. The latter species, normally associated with coastal marine and estuarine environments, range far upstream in some large rivers of Asia, making it important to distinguish between species in areas of sympatric distribution. On several occasions, we have observed susus swimming within a few meters of Irrawaddy dolphins (*Orcaella brevirostris*) in the Sundarbans of Bangladesh. In the Yangtze river of China, baiji are sympatric with a freshwater population of finless porpoises (*Neophocaena phocaenoides*), and the two species sometimes swim in close proximity (Zhou *et al.* 1998, Würsig *et al.* this volume).

Besides being useful for surveys of both obligate and facultative river cetaceans in Asia, the methods proposed here should be applicable, at least to a limited extent, for surveys of South American river dolphins, the boto (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*). However, some of the environmental conditions where these dolphins are found (e.g. large lakes, complex lagoon networks, and flooded forests and grasslands) are unlike those where Asian river dolphins are typically found. Thus, extensive modifications to the survey methods proposed here, or perhaps different ones altogether, will be needed for surveys of South American river dolphins.

Survey design

Defining abundance

Before designing a cetacean survey program, the term "abundance" must be defined in relation to the population being surveyed (e.g. the bhulan population between the Guddu and Sukkur barrages in the Indus River). Researchers must also consider if their primary goal is to obtain an estimate of absolute abundance (e.g. total number of susus in the Ganges River) or to detect and monitor population trends with an index of relative abundance (e.g. percent decline or increase in the population of susus in the Ganges River over a 20 year period). Survey methods for accomplishing both goals are broadly similar. Estimating absolute abundance, however, requires that surveys be designed to maximize precision and minimize bias (in the field or by analytical inference). Estimating relative abundance, on the other hand, only requires that surveys be designed to maximize precision; biases are tolerable as long as they are consistent from one survey to the next (Figure 1).

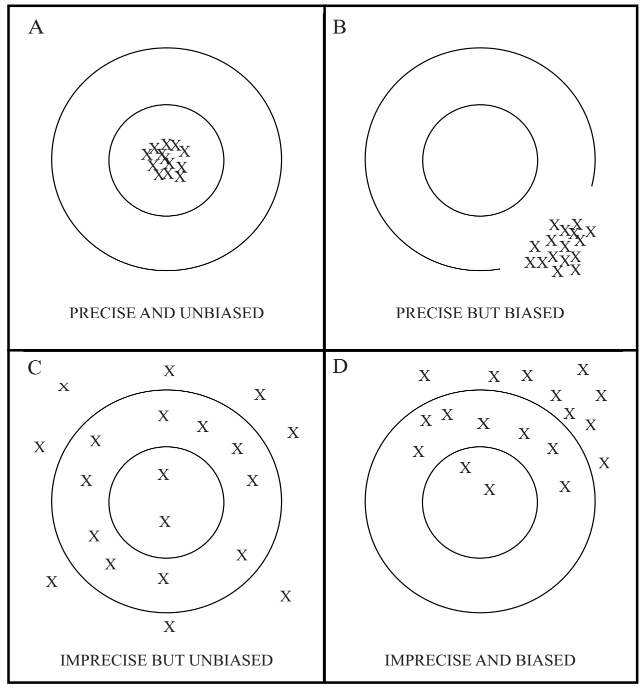

Figure 1. Archery targets illustrating the difference between precision and bias (from White *et al*. 1982). Problems with estimating the abundance of river dolphins can generally be characterized by situation "D" (imprecise and biased). Absolute abundance surveys attempt to move from situation "D" to situation "A" (precise and unbiased). Relative abundance surveys need only to move from situation "D" to situation "B" (precise but biased), which can often be accomplished with less effort and expense than the former.

In practical terms, bias and precision are not independent. Effort to reduce bias usually improves precision, and vice-versa. For example, if the speed of the survey vessel is reduced, more dolphins will probably be seen, so precision is increased and bias reduced.

Surveys of absolute abundance

Surveys of absolute abundance are intended to provide estimates of the total number of dolphins in a specific segment of river. Such estimates can be used to detect population trends over time, assess the viability of populations, and evaluate the relative urgency, and thus priority, of conservation efforts. Credible estimates of absolute abundance are particularly important for formulating conservation strategies for highly endangered populations or species.

Estimates of absolute abundance are frequently biased downward, because under most circumstances some unknown proportion of the population is not detected. Sighting biases are related to dolphin availability (most animals are underwater at any given time, and, when they are at the surface, they generally show little of their body) and observer perception (all surfacings are not necessarily noted because observers may be inattentive, distracted, fatigued, or focused on a different location; see Marsh and Sinclair 1989). Estimates can also be biased upward if, when estimating group size, multiple surfacings by the same individuals are attributed to more animals than are actually present. Clearly defined methods to reduce bias and quantify variability should be incorporated into survey designs.

The density of animals in an area may affect the probability of detection. For example, if dolphins are more quiescent and spend more time underwater while with other animals, detectability could be inversely proportional to density. The possibility that abundance is not proportional to availability points to the importance of conducting detailed behavioral studies under a variety of environmental and group-size circumstances.

Other issues to be considered when designing surveys to estimate absolute abundance include: (1) the difficulty of achieving complete or "representative" coverage of the entire study area, (2) double counting animals that follow the survey vessel (vessel attraction), and (3) missing animals that move away from the transect line in response to the vessel's approach (vessel avoidance).

Surveys of relative abundance

In many situations, population trends can be monitored with less effort and expense with an index of relative abundance. Indices of relative abundance are normally expressed in terms of sightings per unit of time (e.g. hour), area of water surface (e.g. km^2), or length of river (e.g. km).

The rigid requirements of surveys to estimate absolute abundance can be relaxed as long as the "efficiency" of observers remains the same (i.e. a constant fraction of the actual population is detected) throughout the survey program. The ability of observers to detect animals can be influenced by environmental conditions, dolphin behavior, sighting platforms, vessel speed, or observer experience, eyesight, interest, psychological state, or fatigue.

Analytical procedures for detecting a trend in abundance

To assess population trends, it is imperative that researchers investigate whether differences (or similarities) in the results of a series of surveys can be explained by random variation in sighting probabilities rather than actual differences (or similarities) in abundance. This is accomplished by regressing a series of absolute or relative abundance estimates obtained during a survey program conducted over a period of several years.

Because populations typically grow or decline at an exponential rate, the natural logarithm of a series of relative or absolute abundance estimates should be regressed against time (i.e. the chronologically ordered series of surveys). If a regression analysis shows a significant relationship between abundance estimates and the time series of surveys, a trend in abundance can be estimated according to the slope of the regression line. The 95% confidence interval (CI) for the slope is the range of possible index values that can be explained by the trend with 95% certainty. The CI is calculated from the standard error and gives the upper and lower confidence limits of the regression equation for describing the trend. The coefficient of variation (CV) is equivalent to the residual variance in the abundance estimates that cannot be explained by the regression equation and is calculated as one minus the coefficient of determination (r^2). An in-depth summary of regression analysis is beyond the scope of this paper. Detailed treatments can be found in Zar (1984) and Hampton (1994).

Scientists generally use the standard statistical significance level (α) of 0.05 to avoid rejecting a null hypothesis when it is in fact true (Type 1 error). In other words, they tolerate only a <5% probability of concluding that there was a trend in abundance when in fact the appearance of a trend was simply due to random variation in the proportion of animals seen during the surveys.

Conservation biologists have argued that, when evaluating trends for endangered species or populations, it is equally important to consider the probability of failing to reject a null hypothesis of no significant trend when it is in fact false (Type 2 error). This is especially critical when the failure to detect a trend could lead to an unwarranted decision that no conservation action is necessary. The problem of ignoring Type 2 errors is greatly magnified when the small size of the surveyed population means that few sightings are made during a given survey. Small sample sizes cause low precision in the estimates, making it almost impossible to achieve statistical significance with inter-survey comparisons (Taylor and Gerrodette 1993).

Statistical power depends on: (1) the number of surveys conducted, (2) the magnitude of trend that the researcher wishes to detect, (3) the precision of the abundance estimates, and (4) the α probability level that the researcher is willing to accept of erroneously rejecting a null hypothesis of no trend (Type 1 error; Gerrodette, 1987, Gerrodette 1993, Taylor and Gerrodette 1993).

Statistical power can best be understood in terms of a simple example. Consider a hypothetical case in which a dam has been built and a conservation authority wishes to know if the altered river conditions are affecting dolphin abundance. A series of surveys is conducted over a 5 year period, and a regression analysis of the results indicates "no significant trend in abundance." A conservation biologist takes the research a step further and asks, "If the population has been declining at 10% per year, what is the probability that a trend could be detected with these data?"

The number of years and surveys required depends on the degree of change that one wishes to detect and the level of certainty desired. For instance, a 20% change is more difficult to detect than a 50% change at the same level of certainty. Detecting a change with 95% certainty that a Type 1 error has not been made (significance level = 0.05) is more difficult than detecting a change with only 90% certainty that a Type 1 error has not been made (significance level = 0.10). The power of a statistical test to detect change increases if the researcher is willing to accept a higher probability of inferring a trend when none is actually present (Type 1 error).

In a simulated survey of the vaquita (*Phocoena sinus*), a critically endangered porpoise in the Gulf of California, Mexico, Taylor and Gerrodette (1993) found that the ability to detect statistically significant declines in abundance required more frequent surveys over a longer period of time as the population size decreased. They concluded that the species would probably go extinct before researchers could detect a statistically significant decline (at $\alpha = 0.05$), even with an intensive survey program. In assessing abundance of harbor porpoises (*Phocoena phocoena*) off California, U.S.A., Forney *et al.* (1991) found that, although no trend could be detected, the power to detect one using the conventional $\alpha = 0.05$, or even $\alpha = 0.10$, probability level was poor. They concluded that "if the cost of failing to detect a change in abundance is high relative to the cost of falsely detecting a trend for a stable population, the traditional significance level of 0.05 may be inappropriate."

Appropriate probability levels should be based on the relative costs of committing Type 1 and Type 2 errors (Rotenberry and Wiens 1985, Peterman 1990, Forney *et al.* 1991, Taylor and Gerrodette 1993). Considering that the absolute sizes of all Asian river dolphin populations are known or presumed to be small (several tens to a few thousand), the appropriate probability level for Type 1 errors should probably not be less than 0.10.

High statistical power should be fundamental to survey design, but this can only be attained relative to an explicit management goal (e.g. to detect a 50% drop in population over a 10-year period). Parameters used for power analyses (percentage of area searched, proportion of dolphins seen, rate of detectable decline, and probability levels of Type 1 and Type 2 errors) can be modified according to the population being surveyed and the resources available for the survey program. Appendix 1 uses a hypothetical scenario to demonstrate how a power analysis can be used for designing a survey and evaluating the results. Free software is available for conducting power analyses (see Gerrodette 1993).

Survey techniques

Direct counts

Direct counting has rarely been used to estimate the abundance of marine dolphins. Most dolphin populations are so widely dispersed that coverage of their total range would require an unrealistic amount of searching effort. Estimating absolute abundance from direct counts is further complicated due to the unknown number of animals that are missed because of sighting biases.

Only when the entire range of a population is searched and sighting biases are reduced to insignificant levels can direct counts be used to accurately estimate absolute abundance. Modifying search effort so that areas where dolphins are known to congregate are surveyed more intensively (i.e. by stratifying effort) can reduce sighting biases. Correction factors derived from paired rigorous and standard counts or dive time/sighting distance probabilities can also be applied to the data, if the factors are shown to be statistically significant and appropriate to the field situation (see Correction Factors, below).

Density sampling

Surveys intended to estimate dolphin density in "representative" (usually meaning randomly or systematically determined) areas generally use a finite sampling method (strip transects) or a distance sampling method (line transects). The density estimate can itself be used as an index of relative abundance, or multiplied by the total area inhabited by the sampled population to obtain an estimate of absolute abundance. In either case, it is assumed that the density of animals in the sampled area is representative of the density of animals in the total study area.

Strip transects are long, narrow survey plots whose width is determined by the assumption that all animals within the strip are detected during the survey or accounted for by analytical inference. Sightings of dolphins outside the strip are not included in strip transect calculations. The assumption that 100% of the animals within the survey strip are counted makes the strip transect model inappropriate for calculating unbiased absolute abundance estimates unless a statistically tested correction factor is applied to compensate for sighting biases.

Line transect methods are similar to strip transect methods. Instead of determining the strip width before the survey begins, however, an "effective strip width" is empirically derived from the probability distribution of sighting distances evaluated from the transect line ($f(0)$). The parameter $f(0)$ estimates sighting efficiency and is derived by fitting a mathematical detection curve to the frequency distribution of sightings as a function of perpendicular distance from the transect line (Burnham *et al.* 1980, Buckland *et al.* 1993).

When feasible, line transect surveys are preferred to strip surveys because in the former, one assumes only that all animals are detected on the transect line, whereas in the latter, one assumes that all animals are detected within the entire strip. Biases related to the efficiency of observers in detecting dolphins at increasing distances from the transect line are at least partially integrated into the calculation of $f(0)$. The problem of failing to detect animals on the transect line, for example, because they are below the surface when the survey vessel passes, can be addressed to some extent by reducing the vessel's speed, but this may accentuate problems of vessel avoidance.

Accurately estimating sighting distances is a problem in both strip transect and line transect surveys. The ability of observers to accurately estimate distances can be improved by practicing on objects located at a known distance. A laser or optical range finder can also be used to calibrate estimates of distance to floating objects.

River morphology creates an array of constraints that confound standard strip and line transect procedures. For example, observers cannot always view the main river channel unhindered by mid-channel islands, and the pilot cannot always maintain a predetermined course or constant vessel speed, both of which are necessary for following random or systematic transects. The natural (and often safest) inclination is to follow the most efficient course according to water currents, bars, etc. This may cause the vessel to transit within a few meters of one bank or the other, or to crisscross the river from one counter-current (located downstream of convergent channels or meanders, or upstream or downstream of mid-channel islands) to another. These areas often contain a proportionally high density of dolphins (see Chen and Hua 1989, Hua *et al.* 1989 for baiji; Pilleri and Zbinden 1974, Bhatti and Pilleri 1982 for bhulans; Kasuya and Haque 1972, Smith 1993, Smith *et al.* 1998 for susus; Lloze 1973, Smith *et al.* 1997 for Irrawaddy dolphins; Magnusson *et al.* 1980, Vidal *et al.* 1997, Leatherwood *et al.* this volume for botos). Disproportionate representation of such areas in survey coverage would lead to an overestimation of overall density and, in turn, abundance. Variable survey speeds would also be expected to cause artificial heterogeneity in sighting rates.

Vidal *et al.* (1997) conducted line and strip transect surveys for botos and tucuxis along approximately 120km of the Amazon River bordering Colombia, Peru, and Brazil. They found "zigzag" line transects to be seriously deficient because most sightings were made within 200m of the riverbank and were, therefore, concentrated near the apexes of the V-shaped track segments. Partway through the survey, they switched to a strip transect technique, following a search path parallel to the bank. Although they found that this method generally worked better, because it was far easier to direct the survey vessel on a path parallel to shore than on zigzag transect lines, the primary assumption of strip transect, that all individuals within the survey strip are counted, was not met. The problem of missed animals due to submergence is a problem for both line and strip transects, but the researchers suggested that this bias is not likely to change over time.

An in-depth summary of line and strip transect methods is beyond the scope of this paper. Detailed treatments can be found in Eberhardt (1978), Eberhardt *et al.* (1979), Burnham *et al.* (1980), Hiby and Hammond (1989), Barlow (1988), and Buckland *et al.* (1993).

Correction factors

If the goal is to obtain an estimate of absolute abundance, a raw estimate of abundance (density times area) can be adjusted, or "corrected," to account for missed (undetected) animals. Several approaches have been used to develop "correction factors" to account for availability bias and perception bias in surveys of marine mammals (e.g. Marsh and Sinclair 1989, Barlow and Sexton 1996, Kingsley 1996, Laake *et al.* 1996).

Leatherwood (1996) and Vidal *et al.* (1997) suggested that the minimum number of animals missed while surveying for river dolphins could be determined by using two independent sets of observers. One or more rear-facing observers could record sightings missed by the forward-looking observers. Alternatively, concurrent independent counts could be made from the shore or another vessel.

Another method would be to pair intensive surveys (generally requiring more effort and expense) with systematic or randomized surveys of the same area using standard techniques (generally requiring less effort and expense). The ratio between the counts obtained from the two types of survey could then be used as a correction factor. For instance, if the number of animals sighted during the standard survey (n) is 50% of the number sighted during the intensive survey (N), the raw estimate would be multiplied by N/n or two. Several paired surveys would need to be conducted before a regression analysis could be used to evaluate the relationship between the two different survey methods. Intensive surveys could include increasing the number of observers searching for dolphins (on a single vessel or using additional vessels) and using land-based observers located at a sufficiently high elevation to obtain a better view of the survey area than that of observers in the survey vessel (e.g. see Laake *et al.* 1996; Leatherwood 1996). Correction factors based on paired counts can only be applied to abundance estimates obtained from surveys conducted using the same methods and under the same sighting conditions.

Moran and De'ath (1992) used paired intensive and standard surveys to obtain indices of starfish and coral abundance. They found that more accurate estimates of absolute abundance could be obtained by correcting relatively imprecise surveys of the total population than by intensively surveying "representative" areas and extrapolating to the entire area. The advantages of using correction factors were particularly obvious when the spatial distribution of the target organisms was highly variable.

Another method was used by Kasuya and Nishiwaki (1975) to correct counts of Indus river dolphins between the Guddu and Sukkur barrages in Sindh, Pakistan. They used a regression analysis of the total number of dolphins seen plotted against the number of surfacings observed for each individual to estimate the number of animals missed. The Y-intercept of zero surfacings was used to estimate the number of missed animals. The sum of the number of dolphins actually seen and the estimated number of dolphins missed was then divided by the total number of surfacings observed to obtain a correction factor. This correction factor was applied to the number of surfacings observed to estimate the number of dolphins present. Kasuya and Nishiwaki (1975) recognized that their correction factor might have been positively biased because of the tendency of observers to pay more attention to a particular patch of water after initial detection of a dolphin. This tendency would lead to over-representation of multiple surfacings by a single animal. The approach developed by Kasuya and Nishiwaki anticipated the "cue-counting method" later advocated for large-scale surveys of whales (Hiby and Hammond 1989).

Mark-recapture estimation using photo-identification

Photo-identification of individuals has been used to estimate the abundance of some marine cetaceans (Hammond *et al.* 1990). Natural markings, such as nicks, scars, scratches, and pigmentation features, generally located on or in the region of the dorsal fin of dolphins, are used to identify individuals from photographs. Photo-identification can provide estimates of population size using mark-recapture methods. The basic principle behind these methods is that for a surveyed population, $N = Mn/m$, where N is the population size, M is the number of animals or groups "captured" and marked (photo-identified) during the first survey, n is the number of animals or groups "captured" and marked (photo-identified) during the second survey, and m is the number of previously marked animals that are "recaptured" (photoidentified during both surveys). More complex mark-recapture models are based upon multiple photographic surveys and take account of whether photographs are of the right or left side of the animal's body (see Hammond 1986, Hammond *et al.* 1990).

Little information is available on the use of photographic techniques to identify individual river dolphins. Hua *et al.* (1990) took approximately 1,000 photographs of baiji in the Yangtze River but were unable to positively identify any individuals. Zhou *et al.* (1998) took 1,178 photographs of baiji and identified seven individuals from 84 high quality images. Using a mark-recapture model, they estimated that there were approximately 30 dolphins between Zhenjiang and Hukou. No variance for the abundance estimate was given. Trujillo Gonzalez (1994) took 3,600 photographs of botos and tucuxis in the Amazon region of Peru and Colombia and was able to identify 22 individuals, mainly on the basis of notches and scars on the dorsal fin, but also from pigmentation patterns on the bodies of some botos. Of these identified animals, eight were photoidentified during two different sessions and five were photoidentified during three or more different sessions. Smith (unpublished data) took almost 1,200 photographs of Ganges susus in the Karnali River, Nepal. He had minimal success in identifying individuals because: (1) they were visible for extremely short periods of time; (2) surfacings were sometimes extremely quiescent, with only a small portion of the body exposed; (3) surfacing intervals were variable; (4) movements were generally unpredictable; and (5) few good marks could be distinguished. No serious attempt has yet been made to photoidentify large samples of Ganges susus in other parts of the species' range, nor has any attempt been made with the bhulan.

One possible strategy to increase the precision of mark-recapture estimates in a population with few "identifiable" animals is to divide a set of good quality photographs into "identifiable" and "non-identifiable." The abundance of the former can be estimated with a mark-recapture method and the abundance of the latter by the proportion of "non-identifiable" photographs versus "identifiable" ones.

Preliminary indications are that sighting surveys will provide better coverage with fewer biases and greater precision. It is important to emphasize, however, that efforts to photo-identify river dolphins are still justified. The ability to re-identify individuals, even if one is successful only occasionally, and the requirements of mark-recapture models cannot be met, opens up possibilities to learn about seasonal movements, changes in behavior and morphology as the animals mature, social affiliations, and population turnover at specific localities. Würsig and Jefferson (1990) suggested that high-resolution video could be used to overcome some of the problems with taking still photographs of dolphins that are only briefly and unpredictably available at the surface.

Data collection

Mapping

Before field surveys begin, a detailed map of the area to be surveyed should be obtained or created. Generally, the only printed maps that are suitable for use in rigorous surveys of river dolphins are those derived from satellite imagery or from satellite positioning on the ground.

Adequate satellite imagery probably exists for all areas inhabited by river dolphins. However, a researcher may have difficulty gaining access to such imagery, whether because it is classified for security reasons or is prohibitively expensive. Moreover, on a given image, cloud cover may obscure critical portions of the study area. Another factor is that annual flood cycles can change river morphology, often in a manner dramatic enough to have a strong influence on survey conditions. It is therefore necessary to ensure that any published or satellite map used to design a survey is relatively recent. Ideally, a map should be prepared during the same year and season in which the dolphin survey is conducted. Seasonal differences in the amount of water surface available to the dolphins can be at least as relevant as inter-annual differences in channel features.

If a suitable satellite image is available, the river outline can be traced by hand and a scanner used to create a computer file of the base map. During field use, the map can be modified as necessary, and missing details can be added from ground observations.

In the absence of a satellite map or a recently published map derived from satellite imagery, a global positioning system (GPS) can be used to create a map of the river from location coordinates recorded in the field. The most basic approach is to follow both banks of the river while recording frequent waypoints taken from the GPS (see Vidal *et al.* 1997, Leatherwood *et al.* this volume). Once plotted, the waypoints can be connected to create an outline of the river. The mapping vessel must travel as close to the shore as possible. For logistical and safety reasons, it is usually necessary to maintain a separation distance of at least several meters from the shoreline. Whatever this distance may be for a particular area, it should be kept as constant as possible and corrected for when the final map is drawn.

A related but much coarser approach can be used in situations when the more costly and time-intensive method described above proves infeasible. In such cases, the vessel can travel as closely as practical along the centerline of the river while an observer records GPS positions. The distance to each bank can be estimated, using a laser or optical range finder or a hand-held inclinometer, whenever a position is recorded. If an inclinometer is used, the shoreline should be sighted from as high an elevation as possible on the survey vessel. The range is determined according to the product of the tangent of the incline angle and the elevation height of the inclinometer measured from the water surface. An outline of the river margins can then be made by connecting the plotted points along each bank.

Survey timing

Surveys for population assessment should not be conducted during times of migration. Directional movements of dolphins are thought to occur during rising and falling water stages (e.g. Kasuya and Haque 1972, Pilleri and Tagliavini 1982, Singh and Sharma 1985). Surveys intended to estimate absolute abundance would ideally be conducted at the lowest water stage of the low-water season.

Search effort

The quality of survey results depends on observers searching for dolphins in a conscientious and consistent manner. Also, the careful recording of search effort and relevant variables affecting search efficiency is essential. If experienced observers are not available, time and expense should be invested in a training program.

Observers frequently sight dolphins after being alerted by cues – e.g. water disturbances caused by submerged or shallow-surfacing animals, fish driven to the surface by foraging dolphins, or the presence of circling or diving birds (e.g. Mohan *et al.* 1997). The sounds of a dolphin respiring can also call attention to its presence. All cues need to be confirmed by direct observation of animals before being recorded as sightings. Upon closer inspection, some cues will turn out to have been caused by something other than dolphins (e.g. fish surfacing, ducks diving, water buffaloes snorting). Observers should not be timid about alerting fellow members of the survey team when a cue has been noted. For each sighting, the cue that initiated the sighting should be recorded.

We recommend that at least three observers be used to search for dolphins. Two should search from 90º off the right and left beam of the vessel, respectively, forward to 10º past the straight-ahead position. The rear observer should search 180° behind the survey vessel. A fourth observer, if available, should have the task of recording effort and sighting data (see appendices 2–4); otherwise, the rear observer should record data for the two forward observers. A schedule for rotating through the three positions can help reduce fatigue, but extra care should be taken to ensure that dolphins are not missed during rotations. Mandatory rest breaks at reasonable intervals should be incorporated into the survey design. For long days, it can help to have a fourth person in the rotation to provide additional rest breaks for the observer team (e.g. observers rotate into each position for 30 minute watches, then into a resting position for 30 minutes). During multi-day surveys, search effort should be stopped in areas of low abundance at the end of the survey day to reduce the probability of re-counting the same animals the next day.

Stopping or slowing the survey vessel in river reaches that have physical and ecological characteristics preferred by dolphins may reduce downward bias in estimates of absolute abundance. For example, Chen and Hua (1989) found baiji most often in the vicinity of sand bars or banks, and they concentrated their search effort in areas of fishing activity and where gulls and ducks were present. Hua *et al.* (1989) described the preferred habitat of baiji as being within the boundaries of counter-current eddies. Kasuya and Haque (1972) reported that susus in Bangladesh occurred immediately downstream of shallow areas or tributary junctions. Smith (1993) found susus in the Karnali River, Nepal, most often in "primary habitats" where convergent streams created eddy counter-currents in the mainstream flow. Less often, the dolphins were found in "marginal habitats" where sharp upstream bends created a similar, but smaller counter-current. In the single narrow channel of the Kushiyara River, Bangladesh, Smith *et al.* (1998) observed all dolphins located within the eddy boundaries of obvious counter-currents, with large counter-currents containing more dolphins than small ones. In the wide channels of the Jamuna River, Bangladesh, Smith *et al.* (1998) found dolphins generally located within the boundaries of large counter-currents, but their movements were not as limited to these areas as was the case in narrow channels.

Potential problems arise from stopping in high-density areas. What might be gained by reducing bias may be lost by the inability to ensure consistency in effort and coverage between surveys. It is difficult to make consistent judgments about what are "high-density areas" and how much time to spend in them. If the survey design includes spending additional time searching for animals in certain areas, it is important to: (1) rigidly standardize the amount of time spent in them, (2) precisely define the criteria for determining what is a high-density area, and (3) record the positions of stops so that they can be replicated during subsequent surveys.

The position and heading of the vessel, observer positions, and any change in sighting conditions (e.g. wind, cloud cover, sun glare, and visibility) should be recorded regularly (at least every 30 minutes). The time and position should be noted when survey effort begins, ends, and resumes, as well as when dolphins are sighted. Sample effort logs and sighting forms are provided in appendices 2–4.

Sighting conditions

Surveying when environmental conditions are suboptimal can lead to an under-estimation of abundance. In Asian rivers, rain, high winds, sand or dust storms, sun glare, and severe heat (causing inattention and fatigue) can impair sighting efficiency. The best way of dealing with this problem is to suspend survey effort whenever environmental conditions are below a certain threshold of acceptability. It is important to keep a record of the conditions under which any survey is conducted. The survey report should include a description of environmental conditions and give the basis for determining the threshold of acceptability for initiation or continuation of survey effort.

Species identification

In areas inhabited by only one species of river cetacean, the observer need only to establish that he has seen a dolphin, rather than, say, an otter, a large fish, a turtle, or a diving bird. However, in some areas (e.g. the Yangtze River and delta areas of the Sundarbans), at least two cetacean species are known to occur. When surveying such areas, observers need to be able to distinguish and record the diagnostic characteristics of each species. Observers should refrain from guessing at identification if sufficient diagnostic features were not seen. It is better to include an "unidentified" category in the sighting record rather than to include animals that were misidentified.

Defining dolphin groups

A sighting is an event, and the focus of the event is the animal group. However difficult it may be in some circumstances to define and recognize a dolphin group, collecting sighting data on the basis of groups, rather than individuals (although a single individual can in some circumstances be considered a "group"), confers flexibility when it comes to analysis. It allows for abundance to be evaluated in terms of a range of estimates, rather than an "absolute count," which does not reflect the inherent uncertainty about the actual number of animals present. For line transect surveys, the way the term "group" is defined is critical because line transect theory assumes that each sighting is an independent event. Since detection of groups of more than one animal usually begins with the detection of an initial animal, the estimated detection distance of this animal is applied to the entire cluster. Solving the problem of independence between sightings depends upon the ability of observers to estimate the location and size of groups without bias, a difficult task if clusters are poorly defined (Buckland *et al.* 1993).

Defining a group of river dolphins can be difficult. Even though the animals are often found in relatively close proximity to each other, they may not be interacting in a way that makes it obvious that they belong to a social unit. With the exception of mother-young pairs, the attracting force for a group of river dolphins may be more related to the patchy distribution of prey resources and of hydraulic refuge in fluvial systems rather than to survival or reproductive advantages gained by maintaining close social affiliations.

If the hydrological boundaries of preferred patches of riverine habitat can be precisely defined and consistently recognized, the number of animals present within a river reach, so defined and recognized, might be used to define a group. A reach is defined as a relatively homogeneous stretch of river flowing between reasonably obvious breaks in channel slope, local side slopes, tributary confluences, riparian vegetation, and bank material (Frissel *et al.* 1986, Kellerhalls and Church 1989). The definition of a reach in meandering streams will be analogous to the distance from the outer edge of a bend on one bank to the outer edge of a bend on the opposite bank (one half the meander wave-length), and in braided streams to the distance between the upstream origin of a mid-channel bar or depositional island to the next bar, island, or outer edge of a channel meander (or vice-versa). The assumptions necessary to use a definition of dolphin groups based on river reaches can probably be met when surveying narrow channels but not when surveying wide channels.

Defining dolphin groups is a greater problem in wide channels because of difficulties in consistently recognizing the physical features that define a reach and because the large size of a river reach may encompass a greater area than can be searched from a single location. Under these circumstances, a useful definition of a dolphin group is the "cluster" of animals that would have undoubtedly been seen from the location where the dolphins were initially seen, a distance probably not exceeding a few hundred meters of channel length. Applying this definition will require an unavoidably subjective judgment because the survey vessel will probably drift downstream from the initial location of the sighting while observers are estimating group size. Complete objectivity in defining dolphin groups may be impossible to achieve, but, again, the challenge is to be consistent.

Estimating group size

Group sizes should be estimated using best, high, and low estimates, as suggested by Smith *et al.* (1994). High and low estimates are used to reflect the confidence of observers in the accuracy of the best estimate. The low estimate should be considered a minimum count and the high estimate a maximum count. Identical best, high, and low estimates indicate a high level of confidence in the best estimate. Sightings that cannot be substantiated by subsequent surfacings or confirmation by a second member of the survey team can be given a best and low estimate of zero and a high estimate of one. Distinctive physical characteristics of individual animals (e.g. scarring, pigmentation patterns, length of the rostrum relative to height of the melon, and body size) and the location of surfacings relative to shoreline features and other animals can be used to assist observers in making group-size estimates. Estimates should be agreed upon by a consensus of the research team. If observers do not agree, the lowest estimate by any team member should be used for the low, the highest estimate for the high, and the best estimate by either the observer with the most experience or the observer who first sighted the animal(s) for the best.

An alternative approach is for each observer to make independent estimates of group size (recorded secretly). This approach reduces the likelihood that one observer's bias will influence decisions by the others. It is also essential for calculating variance in group-size estimates. A problem, however, is that observers may find it difficult to avoid discussing the number of animals seen, especially while making other observers aware of the location of sighted dolphins to make their estimates.

Habitat information

An ancillary objective of any survey of freshwater dolphins should be to collect data on the physical and ecological characteristics of the study area, including information on human activities. Recording habitat information should be integrated into survey design so that it does not interfere with sighting effort. Environmental variables, letter-coded to simplify recording, can be noted at standard intervals and at dolphin sightings. Data collected in this manner can be used to test for differences in dolphin density between different types of habitat, or among highly disturbed, moderately disturbed, and undisturbed habitats. These data can also be useful for helping to explain a decline in dolphin abundance caused, for example, by a reduction in the amount of woody debris, changes in river-channel morphology, or depletion of prey resources.

Life-history information

Some information on life history can be obtained during sighting surveys. The presence of neonates signifies the calving season(s) and establishes approximately where calving occurs. Adults and juveniles can sometimes be distinguished. A record of the location and number of juvenile, adult, and unclassified individuals might prove useful for identifying differences in seasonal movements and habitat use. The sex and age of animals cannot be determined routinely from sightings alone. Field data accompanied by complete age and sex classifications should be regarded with suspicion.

Recommendations for abundance surveys

Narrow-channel habitat

We define narrow-channel habitat to be where the main channel is narrow enough to be surveyed as one or two strips. In other words, it is assumed that 100% of dolphin surfacings within a strip could be detected from the survey vessel as it travels along the main axis of the river. Practical constraints (e.g. in regard to platform height) could make it necessary to use two survey vessels, traveling in tandem and covering parallel but non-overlapping strips. A less desirable variant would be to have a single vessel survey the two strips, one after the other. Obvious problems arise, however, when coverage is not simultaneous. Animals may move from one side of the river to the other, causing either under-counting or double counting. When two vessels are used, or when one vessel is used to cover two strips, it is important to exercise discipline to ensure that dolphins sighted outside the survey strip are not counted.

When the entire channel is treated as a single strip, the survey vessel should travel as close as possible to the centerline. When two vessels are used to cover two parallel strips, they should travel approximately one quarter of the channel width offshore from the respective riverbanks. In braided systems, all channels with enough water to support dolphins should be searched by at least one vessel even though this may require some back-tracking. In many cases, the vessel's course will necessarily be influenced by navigational considerations such as shallow water, variable flow velocities across the channel, and man-made or natural obstructions. During upstream surveys, vessels may need to travel close to the shore and cross back and forth from one counter-current to another. These navigational constraints should be considered when defining habitat as narrow or wide.

During multi-vessel surveys, observer teams should maintain radio contact or use whistle or flag signals to coordinate search effort and dolphin sightings. When powered vessels are used, observers should monitor dolphin behavior for responses such as avoidance, increased dive times, and more cryptic surfacings. This information can be incorporated into the data analysis, or at least used to qualify the results.

Some sighting biases can be reduced by using one or more rear-facing observers or by stopping in high-density areas (see Search Effort). The amount of time to be spent searching in these areas needs to be standardized before the survey program begins. Survey time series are useful only if comparable methods are used from one survey to the next. The benefits of bias reduction gained from stopping at high-density sites need to be balanced against the possibility that previously counted dolphins will move into the area while the vessel is stationary. In most circumstances, 15 minutes is probably an appropriate amount of time to spend in a prime sighting area (see Smith *et al.* 1994, Vidal *et al.* 1997). We also recommend that observers stop for a standard amount of time (e.g. 15 minutes) at sighting locations to obtain more precise group-size estimates and to guard against the possibility that surfacing intervals of individuals change under different density circumstances.

The sum of "best" group size estimates for all sightings should be used as the best estimate of absolute abundance. The sum of high estimates and the sum of low estimates should be used to give the range.

Wide-channel habitat

Habitat is wide-channel when the river is too wide to be covered by a single survey strip (one vessel) or two strips (two vessels). This is a functional definition that depends upon the height of the survey platform and the morphology of the river channels.

An ideal survey design for estimating absolute abundance in wide-channel habitat would involve some kind of modified density-sampling method (i.e. line or strip transect; see Vidal *et al.* 1997). We believe, however, that the many practical problems of surveying Asian river dolphins, summarized in this paper, preclude the use of such methods, at least for the present.

Until we have a better understanding of dolphin diving behavior and habitat preferences, and all of the tools necessary for carrying out standard line or strip transect surveys of wide-channel environments are reliably available to researchers in Asia, we consider it more appropriate to opt for relatively simple approaches. At present population trends should be investigated by reference to indices of relative abundance. The most appropriate index is, in most cases, simply the sum of "best" estimates of group size for all sightings in a survey. This sum also provides an estimate of minimum absolute abundance, which can be useful in many management contexts (as long as it is referenced to effort, e.g. total kilometers surveyed).

Procedures for surveying wide channels are broadly similar to those for surveying narrow channels. However, the vessel should follow a ladder-type track, with transects oriented parallel to the bank, interrupted at standard intervals (30–60 minutes) by transects across the channel (Figure 2). Since it is more important to increase precision than to reduce bias in this instance (the goal being to obtain an index of relative abundance), we recommend

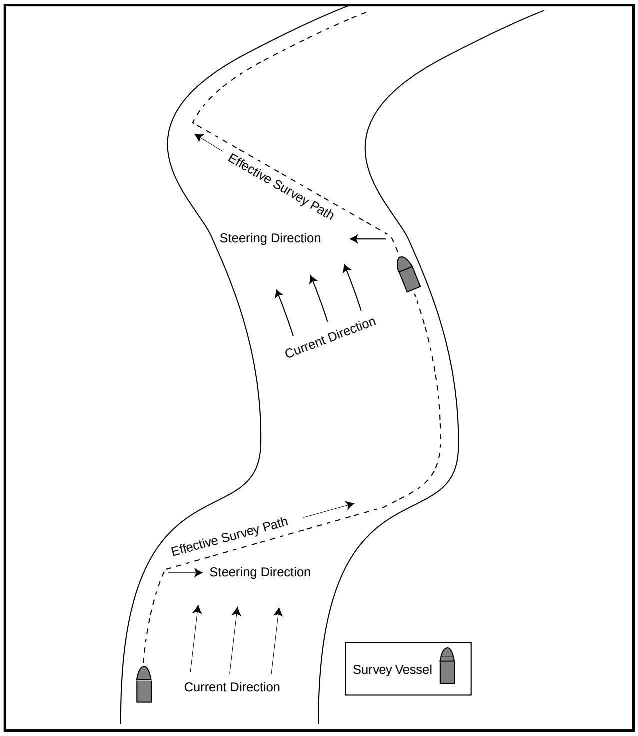

Figure 2. Illustration of a ladder-type survey path for surveys of relative abundance in wide channels. The survey path follows the approximate route of the deepest downstream flow, a requirement to avoid becoming grounded in many wide channels. This path also takes the observers from one counter-current (caused by flow deflection of the channel meander) to another, thereby biasing any density-sampling technique used (because dolphins are often concentrated in these areas) but increasing sample size, and therefore the precision (situation "B" in Figure 1) of relative abundance estimates.

that there are no stops to search for submerged animals or to obtain more precise group-size estimates.

Recommendations for dive-time studies and sighting-distance experiments

Dive-time studies and sighting-distance experiments are required before a density-sampling method can produce credible estimates of absolute abundance. A dive-time study should include the recording of surfacing intervals (i.e. dive times) of individual dolphins in a variety of circumstances. The goal would be to obtain a representative sample of observations. Thus, observations need to be made of groups that are feeding, socializing, resting, or travelling, and group sizes must include numbers from one to several. Sampling sessions should last for a standard period (e.g. 30 minutes).

Dive-time studies are fraught with difficulties. For example, it is hard to be certain that an apparently long dive time is not really just an artifact of the observer's overlooking one or more surfacings. When more than one dolphin is under observation, it is essential that the observer be able to distinguish individuals consistently. It may often prove necessary to concentrate observations on a focal animal within a group and to use only the data referring to that individual's behavior. We recommend that dive-time data be collected from an observation site on shore, located high enough above the water surface to view the entire reach where the dolphins are likely to remain during the sampling session. Size differences, distinctive body marks, and the locations of surfacings can be used to differentiate individuals and judge the number of animals in the group. A tape recorder can be a useful tool for improving the efficiency of dive-time studies.

If it proves impossible to differentiate between the individual dolphins in a group, important information can still be collected on the mean surfacing interval of all animals in the group. If t = total time of the sampling session, n = total number of dolphins in the sampled group, and s = total number of surfacings observed, then the mean surfacing interval (SI) for that session equals $t*n/s$. A series of SI estimates can be used to test the null hypothesis of no significant difference in surfacing (diving) behavior between different-sized groups. Failure to reject this null hypothesis is an important assumption for using correction factors based on dive times and may affect the ability to detect trends in abundance from estimates of relative abundance.

An experiment can be conducted to evaluate the accuracy of sighting-distance estimates. Accurate estimation of sighting distances is a prerequisite for conducting surveys using density-sampling methods. The experiment requires observers on board a survey vessel to estimate the distances to sightings, while at the same time a team on shore estimates the positions of the vessel and surfacing dolphins using a theodolite (surveyor's transit). The theodolite tracking should be done from a site well above the water surface (i.e. on a bridge or high tower). Observers in the survey vessel should use a hand-held radio to communicate the moment and approximate location of dolphin sightings to the person taking the theodolite fix. The range to the dolphin (RD) and the vessel (RV) from the theodolite base station can be calculated from the tangent of the azimuth angle multiplied by the elevation of the theodolite above the water. If the horizontal angle between the dolphin and the survey vessel equals X, then the distance of the dolphin from the survey vessel, $(DV) = SQRT(RD^2 + RV^2 - 2*(RD)*(RV)*Cos(X))$. A paired t-test can be used to test the null hypothesis of no significant difference between estimated distances and actual distances.

A much simpler experiment can be conducted by having observers estimate the distance to various objects, then obtaining the "true" distance by using a laser or optical rangefinder. A drawback of this type of experiment is that there may be a difference between estimating the distance to a stationary or floating object and that to an "instantaneous event" like a dolphin surfacing.

Conclusions

Although this paper provides guidance for developing and implementing a survey program, it is not intended to be an authoritative "manual." Survey designs will need to take account of the constraints imposed by local circumstances. For the sake of brevity and simplicity, we have left out important details, especially relating to analytical procedures. We strongly recommend that anyone planning to conduct surveys of river dolphins submit a detailed plan to one or more experts before beginning the program. Peer review of survey plans can be accomplished through the IUCN Species Survival Commission's Cetacean Specialist Group. Once survey plans have been thoroughly reviewed, the most important considerations are that data be collected in a consistent manner and that effort and observations be painstakingly documented.

We also caution that the lack of data on abundance, and the ongoing difficulty of obtaining such data, should not prevent us pursuing conservation measures to protect Asian river dolphin populations. Common sense dictates that such measures are necessary if there is to be any hope of curbing obvious, immediate, and extensive threats, such as high mortality in fishing nets, directed catches in some areas, high pollutant levels, and the habitat degradation and population fragmentation associated with dams and other water developments. Population assessments are a valuable component of the conservation process but should not be considered a prerequisite for judicious action.

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Appendix 1. Power analysis for estimating trends in abundance

A power analysis of hypothetical survey scenarios can be used to investigate, *a priori*, under what circumstances a significant population trend would be detected.

All combinations were modeled[1] for surveys conducted under the following scenarios: (1) where 60% and 90% of the dolphins present along the survey transect were observed; (2) of four population sizes: 200, 400, 800, and 1,600; and (3) where three different proportions of the study area were searched: 20%, 40%, and 80% coverage. For each combination, 10,000 simulated population abundance estimates were calculated.

The mean abundance estimate for each combination was what would be expected: proportion observed * actual abundance (e.g., for the combination of 60% observed and N = 200, the mean estimate of all simulations was 119, which is equal to the product of the two). The difference between combinations was in the precision of the estimates, as measured by the CV; precision dramatically declined with a decreasing population size.

The CVs were then used to calculate statistical power[2] for a survey design which planned to cover 20% of the total range of the population, and which was intended to detect a 5% per year decline at $\beta = 0.95$ (i.e., only 5% probability of making a Type 2 error) and $\alpha = 0.05$ (i.e., only 5% probability of making a Type 1 error). The stringent requirements for α and β were chosen to illustrate the decline in actual population size needed before a statistically significant decline could be detected at traditional levels ($\alpha = 0.05$).

	Proportion observed = 60%			Proportion observed = 90%		
Starting Abundance	Ending Abundance	Surveys Required	Percent Remaining	Starting Abundance	Surveys Required	Percent Remaining
200	99	14	49.5	115	11	57.5
400	243	10	60.8	255	9	63.8
800	536	8	67	564	7	70.5
1,600	1,185	6	74.1	1,264	5	77.9

Note that a population decline of more than 50% will have to occur in an already small population of 200 before a survey program conducted under the conditions described above would be able to detect a 5% annual decline. This scenario is unacceptable if abundance estimates are expected to contribute to conservation planning.

The power of sighting surveys to detect trends in abundance can be improved by conducting more surveys, increasing survey coverage, or increasing the proportion of animals seen (e.g., by increasing the number of observers and decreasing the speed of the survey vessel). From an analytical viewpoint the most significant factor is the choice of α probability level.

1 Program for computing CVs written by Barbara Taylor, Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92093, U.S.A.

2 Program for power analysis written by Tim Gerrodette, Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92093, U.S.A.

Appendix 2a. Effort log for river dolphin surveys

DATE	PAGE #	TOTAL PGS	SURVEY TIME	SURVEY DISTANCE

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

EVENT	TIME BEGAN	TIME END	START POSITION	END POSITION	OBSERVERS			ODOMETER READING
					LEFT	REAR	RIGHT	
SIGHT #	LEFT DIST.	RIGHT DIST.	CHANNEL TYPE		WIND	GLARE	RAIN/FOG	HUMAN ACT.

SURVEY EVENTS: B = BEGIN SEARCH EFFORT, D = DOLPHIN SIGHTING, CT = CHANGE IN CHANNEL TYPE R = ROTATION OF OBSERVER POSITIONS, SC = CHANGE IN SIGHTING CONDITIONS DUE TO WIND, GLARE, OR RAIN/FOG, AND HS = HABITAT STOP TO SEARCH FOR DOLPHINS MORE INTENSIVELY

CHANNEL TYPE: NSS = NARROW (< 200 m) SINGLE STRAIGHT, WSS = WIDE (> 200 m) SINGLE STRAIGHT, NSM = NARROW SINGLE MEANDERING, WSM = WIDE SINGLE MEANDERING, NB = NARROW BRAIDED, WB = WIDE BRAIDED, CBI = BETWEEN CHANNEL BANK AND ISLAND. OTHER CODES CAN BE ADDED: F = FORESTED, FP = FLOODPLAIN, CB = CONTAINED IN BANKS, U = URBAN, R = RURAL and P = PRISTINE, ETC.

WIND, GLARE, RAIN/FOG: 0 = NONE, 1 = SMALL EFFECT, 2 = LARGE EFFECT.

HUMAN ACTIVITIES: BTH = BATHING, BS = BOATS ON SHORE, MFC = MOTORIZED FERRY CROSSING, OFC = OAR-POWERED FERRY CROSSING, GNF = GILLNET FISHING, TF = TRAP FISHING, HLF = HOOK AND LINE FISHING, AG = AGRICULTURE, IND = INDUSTRY, and SM = SAND MINING, ETC.

Appendix 2b. Instructions for entering data in search effort log

Description of form

The search effort log records information on survey coverage and conditions. Both effort logs and sighting forms (see Appendix 3a/3b) should be used during dolphin surveys. Each box of the effort log is used to record data for a survey event (see below). The duration of each event includes only the time actually spent searching for dolphins. It does not include stops at dolphin sightings to estimate group sizes (during narrow-channel surveys) or time spent for resting, photography, etc. A new event begins when the observers resume search effort or to record a change in environmental conditions or observer positions. All items of each box should be completed for each survey event. Codes are used for efficient recording.

Each page begins with a header for recording:

DATE – Year/month/day.

PAGE # – Sequential page number for the survey day.

TOTAL PAGES – Total number of pages used for the survey day.

TOTAL SURVEY DISTANCE – Total distance in kilometers surveyed for the day.

TOTAL SURVEY TIME – Total time in minutes surveyed for the day. This is equal to the sum of the duration of all events.

Each box has 15 items to record:

EVENT – Survey events include: begin search effort, dolphin sightings, changes in channel type, rotation of observer positions, changes in sighting conditions due to wind, glare, or rain/fog, and habitat stops to search more intensively for dolphins. Codes are provided at the bottom of the effort log.

TIME BEGIN – Time event begins. Use 24hr clock.

TIME END – Time event ends. Use 24hr clock.

BEGIN POSITION – The latitude and longitude recorded from a GPS at the beginning of the event. Generally it is only necessary to record the position to the nearest minute or tenth of a minute.

END POSITION – The latitude and longitude recorded from a GPS at the end of the event.

OBSERVERS – Initials of observers in the left, rear, and right searching positions.

ODOMETER READING – Odometer reading from the GPS at the beginning of the survey event.

SIGHT # – Sequential sighting number from beginning of the survey day. Make a line through this box if the event ended for a reason other than a dolphin sighting.

LEFT DIST. – Estimated distance in meters to the shoreline left of the survey vessel. If the distance is too far to estimate, use >500m.

RIGHT DIST. – Estimated distance in meters to the shoreline right of the vessel.

Codes are provided at the bottom of the effort log to complete the following items:

CHANNEL TYPE – Channel types include narrow (<200m) single straight, wide (>200m) single straight, narrow single meandering, wide single meandering, narrow braided, wide braided, between channel bank and island. This box can also be used to describe other channel characteristics such as forested, floodplain, contained within banks, urban, rural, and pristine. Additional codes can be added according to local conditions.

WIND – The effect of wind on sighting conditions.

GLARE – The effect of glare on sighting conditions.

RAIN/FOG – The effect of rain or fog on sighting conditions.

HUMAN ACTIVITIES – Human activities include: bathing, boats on shore, motorized ferry crossing, oar-powered ferry crossing, gillnet fishing, hook-and-line fishing, trap fishing, agriculture, industry, and sand mining. Additional codes can be added according to local conditions.

Appendix 3a. Sighting form for river dolphin surveys in wide channels

DATE ______________ PAGE NUMBER ______ TOTAL NUMBER OF PAGES ________ STARTING POINT ____________ END POINT ________________

SIGHT #	TIME	OBSERVER	NUMBER OF DOLPHINS			NUMBER IN EACH SIZE CLASS				NAME OF AREA	POSITION LAT/LOG	DIST. FROM SHORE	CHANNEL TYPE	HUMAN ACTIVITY	ODOMETER READING
			BEST	HIGH	LOW	ADULT	SUBADULT	NEONATE	UNCLASS.						

CHANNEL TYPE: NSS = NARROW (< 200 M) SINGLE STRAIGHT, WSS = WIDE (> 200 M) SINGLE STRAIGHT, NSM = NARROW SINGLE MEANDERING, WSM = WIDE SINGLE MEANDERING, NB = NARROW BRAIDED, WB = WIDE BRAIDED, CBI = BETWEEN CHANNEL BANK AND ISLAND.
OTHER CODES CAN BE ADDED: F = FORESTED, FP = FLOODPLAIN, CB = CONTAINED IN BANKS, U = URBAN, R = RURAL, P = PRISTINE, ETC.

HUMAN ACTIVITY: BTH = BATHING, BS = BOATS ON SHORE, MFC = MOTORIZED FERRY CROSSING, OFC=OAR-POWERED FERRY CROSSING, GNF = GILLNET FISHING, TF = TRAP FISHING, HLF = HOOK AND LINE FISHING, AG = AGRICULTURE, IND = INDUSTRY, SM = SAND MINING, ETC.

Appendix 3b. Sighting form for river dolphin surveys in narrow channels

DATE __________ PAGE NUMBER _________ TOTAL NUMBER OF PAGES __________

SIGHT #	TIME	OBSERVER	SIGHTING POSITION	AREA NAME	CHANNEL TYPE	ASSOC. FAUNA

ESTIMATED NUMBER OF DOLPHINS			NUMBER IN EACH SIZE CLASS				DIST. TO SHORE	DIST. TO DOLPHINS
BEST	HIGH	LOW	ADULT	SUBADULT	NEONATE	UNCLASS.		

PHOTOGRAPHS	HUMAN ACTIVITIES	NOTES

SIGHT #	TIME	OBSERVER	SIGHTING POSITION	AREA NAME	CHANNEL TYPE	ASSOC. FAUNA

ESTIMATED NUMBER OF DOLPHINS			NUMBER IN EACH SIZE CLASS				DIST. TO SHORE	DIST. TO DOLPHINS
BEST	HIGH	LOW	ADULT	SUBADULT	NEONATE	UNCLASS.		

PHOTOGRAPHS	HUMAN ACTIVITIES	NOTES

SIGHT #	TIME	OBSERVER	SIGHTING POSITION	AREA NAME	CHANNEL TYPE	ASSOC. FAUNA

ESTIMATED NUMBER OF DOLPHINS			NUMBER IN EACH SIZE CLASS				DIST. TO SHORE	DIST. TO DOLPHINS
BEST	HIGH	LOW	ADULT	SUBADULT	NEONATE	UNCLASS.		

PHOTOGRAPHS	HUMAN ACTIVITIES	NOTES

SIGHT #	TIME	OBSERVER	SIGHTING POSITION	AREA NAME	CHANNEL TYPE	ASSOC. FAUNA

ESTIMATED NUMBER OF DOLPHINS			NUMBER IN EACH SIZE CLASS				DIST. TO SHORE	DIST. TO DOLPHINS
BEST	HIGH	LOW	ADULT	SUBADULT	NEONATE	UNCLASS.		

PHOTOGRAPHS	HUMAN ACTIVITIES	NOTES

CHANNEL TYPE: NSS = NARROW (< 200 M) SINGLE STRAIGHT, WSS = WIDE (> 200 M) SINGLE STRAIGHT, NSM = NARROW SINGLE MEANDERING, WSM = WIDE SINGLE MEANDERING, NB = NARROW BRAIDED, WB = WIDE BRAIDED, CBI = BETWEEN CHANNEL BANK AND ISLAND. OTHER CODES CAN BE ADDED: F = FORESTED, FP = FLOODPLAIN, CB = CONTAINED IN BANKS, U = URBAN, R = RURAL AND P = PRISTINE, ETC.

HUMAN ACTIVITY: BTH = BATHING, BS = BOATS ON SHORE, MFC = MOTORIZED FERRY CROSSING, OFC = OAR-POWERED FERRY CROSSING, GNF = GILLNET FISHING, TF = TRAP FISHING, HLF = HOOK AND LINE FISHING, AG = AGRICULTURE, IND = INDUSTRY, AND SM = SAND MINING, ETC.

Appendix 3c. Instructions for entering data in river dolphin sighting forms for wide and narrow channels

Description of forms

Sighting forms are provided for surveys in both wide and narrow channels. The sighting form for wide channels (Appendix 3a) is designed so that data can be entered quickly while maintaining search effort. The sighting form for narrow channels (Appendix 3b) includes extra boxes for recording information on photographs, distance to the dolphins, associated fauna, and notes. During narrow channel surveys, the recorder should have time to complete these boxes, assuming the survey protocol includes stops at dolphin sightings. Boxes for channel type and human activity are also larger in this form to encourage recording additional details. The wide channel survey form can be used for narrow channel surveys when stops are not made at dolphin sightings.

Data should be entered in each box of the form at the time of a dolphin sighting. Additional notes can be added at the end of the day. Codes are used to efficiently record sighting data. Boxes are labeled the same in wide and narrow channel sighting forms.

Each page begins with a header for recording:

DATE – Year/month/day

PAGE # – Sequential page number for the survey day.

TOTAL PAGES – Total number of pages used for the survey day.

STARTING POINT – Location where the survey begins.

END POINT – Location where the survey ends.

Boxes in both sighting forms include:

SIGHT # – Sequential sighting number from beginning of the survey day. The number should match the sighting number recorded in the effort log.

TIME – Time of sighting. Use 24-hour clock.

OBSERVER – Initials of the observer who initially sighted the dolphins.

NUMBER OF DOLPHINS – Best, high, and low estimates of the total number of dolphins in the observed group.

NUMBER IN EACH SIZE CLASS – Includes boxes for the number of adult, subadult, neonate, and unclassified dolphins in the group. The sum of the four boxes should equal the best estimate of group size. Observers should not hesitate to categorize dolphins as unclassified if there is any doubt.

NAME OF THE AREA – Local name(s) given to the area where the dolphins were observed.

POSITION LAT/LOG – The latitude and longitude, recorded from a GPS, where the dolphins were located. The recorder should wait until the survey vessel arrives at the approximate location where the dolphins were initially seen before recording the position. Generally it is only necessary to record the position to the nearest minute or tenth of minute.

DISTANCE FROM SHORE – Estimated distance in meters of the dolphin group from shore.

Codes are provided at the bottom of the sighting form to complete the following items:

CHANNEL TYPE – Description of channel characteristics, same as used in the effort log (see Appendix 2b), where the dolphins were observed.

HUMAN ACTIVITIES – Description of human activities, same as used in the effort log, where the dolphins were observed.

ODOMETER READING – Odometer reading where the sighting was made.

Additional boxes included in the narrow channel sighting form include:

ASSOC. FAUNA – Associated aquatic animals and shorebirds.

DISTANCE TO DOLPHINS – Estimated distance in meters of the dolphin group from the survey vessel.

PHOTOGRAPHS – Record of photographs taken of the dolphins or their habitat. Information should include the initials of the photographer and roll and frame numbers. Can also include information on film ASA, shutter speed, f-stop, and side of the dolphin(s) photographed (important for photoidentification purposes).

NOTES – Additional notes can be recorded on: (1) the cue used for detecting the animals, (2) vessel avoidance or attraction behavior, (3) characteristics peculiar to individual dolphins, (4) behavioral state (e.g., vigorous, moderate, or quiescent), (5) interactions between dolphins and human activities, (6) patterns of habitat use, (7) interspecific behavior, (8) difficulties in estimating group size, etc. Objective observations should have priority. Subjective interpretations can be added later and should be clearly labeled.

Radio Tracking Finless Porpoises (*Neophocaena phocaenoides*): Preliminary Evaluation of a Potential Technique, with Cautions

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Abstract

Three finless porpoises (*Neophocaena phocaenoides*) from the Yangtze River were fitted with cotton cloth vests and small radio transmitters. They were tracked for 2.6, 11.0, and 14.6 days in the Swan Oxbow adjacent to the mainstem of the Yangtze River. The porpoises showed no adverse effects of the vests and appeared to feed normally. They dove for periods of 40 seconds to 4.03 minutes, interspersed with two to six surfacings of less than 40 seconds. As in captivity, the longest dives of three to four minutes, suggestive of feeding behavior, occurred during the day. Also, rapid movement (estimated at faster than 5km/hr) occurred during the day, never at night. All three tags fell off as predicted, the one with the quickest-release mechanism (lightly sewn) falling off earliest and the one with the most durable (heavily-sewn) attachments lasting the longest. Although this short-term tagging was successful in the relatively shallow (30m) oxbow, it is important to emphasize that longer-term vest attachments in deeper waters have not been demonstrated to be safe. Hence, other techniques must be investigated before re-considering vest attachments, which can lead to entanglement and cause abrasions if not applied properly.

Introduction

For effective management, we need to know as much as possible about a species' population size, habitat use patterns, social organization, and life history parameters. However, the mere gathering of data can disrupt the animals' lives and bias results of research, so the research techniques employed should be as non-invasive and benign as possible. For marine mammals, life history strategies have been studied mainly from animals killed *en masse* in fisheries (e.g. Kasuya and Marsh 1984, Amos *et al.* 1993). While it is important to take scientific advantage of dead whales and dolphins, data from living animals can give similarly robust information. Individual recognition of whales and dolphins in nature, using photo-documentation, can provide much information about site fidelity, social organization, and population patterns [e.g. Katona *et al.* 1979 for humpback whales (*Megaptera novaeangliae*); Bigg *et al.* 1990 for killer whales (*Orcinus orca*); Würsig and Würsig 1977 for bottlenose dolphins (*Tursiops truncatus*)]. Skin samples for genetic analyses can be collected by biopsy of live animals (Amos and Hoelzel 1991), or by swabbing skin from bow-riding individuals (Harlin *et al.* 1999).

Radio tracking, another method of studying live animals, has been used regularly by cetacean researchers since the early 1970s (Evans 1971, 1974; Scott *et al.* 1990 provide a summary). This can be accomplished with a small tag attached to the dorsal fin (e.g. Würsig and Lynn 1996, Wells *et al.* 1998) or fixed onto the back with the aid of a suction cup for hours (Baird and Goodyear 1993) to days (Goodyear 1989). It can also be accomplished by pinning a tag onto the back of an animal that has only a low dorsal ridge and no fin, for example white whales (*Delphinapterus leucas*) (Martin *et al.* 1993) and Amazon river dolphins (*Inia geoffrensis*) (Martin and da Silva 1998, da Silva and Martin this volume).

The finless porpoise (*Neophocaena phocaenoides*) occurs in shallow coastal waters of the Indo-China region: from the Arabian (Persian) Gulf and Arabian Sea in the west to the Yellow Sea and central Sea of Japan in the northeast (Reeves *et al.* 1997). A separate, morphologically distinct population occurs in the Yangtze River, where it is largely sympatric with the Yangtze river dolphin, or baiji (*Lipotes vexillifer*) (Zhou and Zhang 1991). The baiji is critically endangered (Wang Ding 1993, Zhou *et al.* 1998, Wang Ding *et al.* 1998). Although the finless porpoise also appears to be declining in the environmentally degraded Yangtze River (Zhou Kaiya *et al.* this volume, Wang Ding *et al.* this volume, Reeves *et al.* this volume), it is not too late to identify habitat-use patterns in the hope that such information will facilitate protection strategies. Their small size, habit of avoiding vessels, and lack of a distinguishing dorsal fin or other easily-identifiable markings, make finless porpoises particularly difficult to study in the wild. In this paper, we describe a radio-tag attachment device that was made possible by the availability of very small radio transmitters and by the use of a light harness which did not require puncturing the body for attachment. The device worked well on a test group of three finless porpoises in a 21km-long oxbow isolated from the mainstem of the Yangtze River (Zhang *et al.* 1996). With modifications, it might serve as a non-harmful tool for collecting information on habitat use, behavior, and social-affiliation patterns of this species in the Yangtze River. However, the fact that it was successful in the present study does not guarantee that this radio-tag attachment technique is the best for finless porpoises.

More experimental work is necessary before sending porpoises into the mainstem of the river carrying vest-attached radio tags. As well, experimental work with other techniques, such as skin/blubber attachment pins, must be carried out before a particular method of radio-tag attachment is chosen.

Materials and methods

The tags were 8cm long by 1.6cm diameter aluminum tubes with an in-air weight of 50gm (Telonics Model 050). Two small metal tabs brazed onto each end allowed the tag to be sewn onto an oval plastic plate (cut from the lid of a one-gallon plastic ice cream container) with a short axis of 10cm and a long axis of 14cm. The tag had a 39cm long and 0.1cm diameter metal antenna projecting from its front end at a 45° angle to the longitudinal axis of the transmitter. The tag/plastic plate assembly was mounted so that the antenna projected up from the dorsum of the animal and pointed backward at that 45° angle (Figures 1 and 2). This orientation was intended to reduce resistance and minimize the possibility of entanglement in nets or debris. The antenna was tipped with a 0.3cm diameter metal sphere to reduce the possibility of injuring other porpoises.

The tag/plastic plate assembly was sewn onto a cotton cloth vest (made from thin men's undershirt material) designed to fit around the front part of the animal's body. Flipper openings ensured that the vest would not rotate around the animal, thus keeping the transmitter on the mid-back at all times. The vest was closed with 2cm by 5cm velcro fasteners and by cotton button-sewing thread known to tear easily. Our intention was to make sure that the vest and transmitter would readily fall off the animal if they became entangled in a net or a rolling-hook longline (see Fig. 2 of Zhang *et al.* 1996 for vest size and configuration details). Vaseline was spread around the front part of the animal's body to prevent the skin from being abraded. Vests were closed around the animals with varying amounts of end-knots of the sewing thread (Table 1). They were color-coded with red, striped-black, and white indelible ink, for porpoises #1–3, respectively. In this way, the individuals could be distinguished quickly in the field.

The vest was tested, without a radio transmitter, on a captive porpoise in the aquarium of the Institute of Hydrobiology (9 September 1993). Swimming and diving of the test animal was found to be unhampered in this artificial environment (Zhang *et al.* 1996). However, in our opinion, this brief test did not indicate that the vest technique would work properly in the wild.

The radio tags were programmed to project signals at 148–150MHz, bandwidth 16.2Hz, pulse frequency 90/min, pulse length 40msec, and power output approximately 15mw per pulse. The 3v lithium batteries were capable of powering each tag for up to 6 weeks, although the vests were expected to last only for 1–3 weeks. While tag signal reception was expected to vary according to the altitude of the receiving antenna above water level, in practice the signal was received strongly at a distance of less than 10km, less strongly at 10–20km, and variably and much more weakly when the porpoise and transmitter antenna were below the water surface. A test demonstrated that a 5–element Yagi-Uda antenna (Uda and Mushiake 1954), at an altitude of 20m above the water, could receive the signal from a radio transmitter that was 3km away and submerged 0.7m below the surface. This meant that porpoises could be tracked for some distance when they

Figure 1. **Porpoise #3, with white cotton vest, posing with Professor Liu Renjun of the Wuhan Institute of Hydrobiology. Note that the antenna, tipped with a small metal sphere, projects just beyond Prof. Liu's right temple. Future tags can be better-streamlined than this experimental model, and the antenna could be a soft wire one emanating from the back of the transmitter. The whitish coloration to the sides of the vest is caused by an ample layer of vaseline applied to the animal's body before the vest was fastened.**

Figure 2. **Porpoise #1, with red cotton vest, swimming in the holding pond just before release, 25 October 1993.**

were just below the surface; however, the clarity of the signal was greatly enhanced when the animal surfaced. Thus, surfacing/breathing could be distinguished from sub-surface swimming by characteristics of the signals received.

Tracking was accomplished with Telonics Model TR-2 receivers connected to 2- to 5-element Yagi-Uda antennas that were physically rotated for obtaining directional information (Würsig *et al.* 1991, Würsig and Lynn 1996). Our triangulation protocol followed those of Mech (1983) and Lehner (1996). When clear signals were obtained, porpoise surfacing and dive times were recorded, on a schedule of 30 minutes per four hour period, day and night.

The three tagged porpoises were released simultaneously in the enclosed 21km waterway of the U-shaped Swan Oxbow of the Yangtze River (Shishou City, Hubei Province, China, 29°N, 112°E). Boat approaches were made with a 3.5m rubber inflatable vessel with a 15Hp outboard engine.

Results

Ten finless porpoises had been captured in three groups from the mainstem of the Yangtze River in early 1990 and early 1993 (Wang Ding *et al.* this volume). They were kept in the Swan Oxbow and allowed to acclimatise to their new surroundings for several months to several years. On 18 October 1993, five males and two females out of the 12 animals available (two of them were born in the oxbow; see Wang Ding *et al.* this volume) were recaptured with nets. Unfortunately, two males and two females died during capture, apparently because the mesh of the fishing net used was too fine, and because the captures were made in water too deep (20m) for animal safety. The three remaining males were transferred to a pond adjacent to the oxbow (for more information on these animals, see Zhang *et al.* 1996). We decided to proceed with the radio-tracking experiment despite the obvious social disruption caused to the animals by the disastrous capture operation.

On 25 October 1993, vests with radio transmitters were fitted on the porpoises. They were observed in the pond for five hours and appeared to be swimming normally, even catching live fish introduced to the pond. They were released into the oxbow in the afternoon of the same day and tracked for 2.6, 11, and 14.6 days (Table 1). Small scratches and other features made it possible to identify all three porpoises. With practice, they could be distinguished by eye at close distances (within about 10m). However, these markings were not adequate for consistent identification from a greater distance or by photography.

When the porpoises were released into the Swan Oxbow, they swam immediately and rapidly to one end of the oxbow, turned and swam to the other end. They covered approximately 25km in three hours, for an average speed of 8.3km/hr during the afternoon of their release. Although the porpoises were separated by up to 1km for periods of 10–20 min, they tended to stay together as a group for the entire 2.6 days during which all three were being tracked. We were able to approach the group on all days, with approach attempts on 25–29 October. During each approach, three porpoises were together (with one not identified but suspected to be #3 after the morning of 28 October, as #3's vest had fallen off by then). During approaches, the porpoises tended to stay about 150m from the research vessel, generally maintaining that distance but not fleeing beyond it. On 26 October, one day after release, the three were within approximately 300m of another group of two porpoises, indicating the potential for some social affiliation with untagged conspecifics. While rapid movement from one to the other end of the oxbow occurred sporadically throughout the tracking time, rapid movement, estimated at greater than 5km/hr for one hour or more, occurred only during the day between 06.00 and 22.00, 10 times within the 14.6 days of tracking.

Table 1. Three porpoises tracked in the Swan Oxbow. **The designation "knotted" refers to whether the ends of threads had knots in them; if unknotted, they could unthread more easily over time, or when entangled with underwater objects (e.g. nets, lines, etc.). Note the apparently inverse correlation between amount of tracking time and amount of knotting – the porpoise outfitted with a vest with no threads knotted held the vest for only 2.6 days, while the porpoise with all thread ends knotted held the vest for 14.6 days. These suggestive data are, however, too few for statistical analysis.**

Porpoise	Length (cm)	Track time (days)	Sewing Type
#1	153.0	14.6	vests sewn and knotted
#2	143.0	11.0	vests sewn and one end knotted
#3	161.5	2.6	vests sewn but not knotted

Surfacings were correlated with breaths with 100% accuracy during several days of observation of the test animals in the holding pond before release into Swan Oxbow (Liu Renjun, Wuhan Institute of Hydrobiology, pers. comm.). Radio-track data showed that porpoises dove from 40sec to 4.03min, interspersed with 2–6 short surfacings of less than 40sec each. Long dives of 40sec or more occurred throughout day and night with about equal frequency, but there were slightly more short surfacing intervals at night, from 22.00 to 06.00, than during the day (Chi-Square = 4.258, n = 2 for comparison, chosen from 10-each 30min sessions at night and during the day, $p < 0.05$). The 30 longest dives of 3–4min duration all occurred during daytime.

All three vests are known to have fallen off the porpoises, as the animals were seen without them on several occasions after the study. For example, they were re-identified, together as a group, immediately after the radio-tracking period in autumn 1993, as well as three times during 6–13 June 1994. The tag of porpoise #2 was recovered, still operating, approximately 10m below the surface (with radio transmission received when a receiver came within about 100m of this submerged tag). The vest had separated after 11 days on the animal. It is not known whether the vest opened up and disengaged due to entanglement with an underwater obstruction, or instead opened up due to the purposeful flimsiness of the vest's thin-thread attachment. The two other tags/vests were not recovered. For further tracking and tag recovery details, see Zhang *et al.* (1996).

Discussion

Porpoises appeared to use the entire length of the Swan Oxbow, and showed no particular habitat preference for the two weeks of study. The sporadic rapid movements from one end of the oxbow to the other immediately after release gave the impression that the animals were responding to the vests that they were being forced to carry, although similar rapid movements have been observed under normal situations, without vests (Wang Ding, pers. observ.). Observations of the animals during and after the study indicated that they were probably feeding "normally" and unhampered by the vests, since they showed no apparent ill effects of slowed movement or thinning bodies. However, the possible lack of tagging effect should be explored rigorously and over a longer tagging period.

While porpoises exhibited less than 40 second dives both day and night, the very long dives approaching four minute duration occurred only in the day. This correlated broadly with rapid movements of greater than 5km/ hr during day. Our general impression was that the porpoises were foraging and possibly more socially active during day than at night, but this requires much more observational data. As well, night-time radio signals were often heard between short as well as some greater than 40 second dives (not sufficiently well documented for statistical analysis). This indicates that many night dives were shallow, some probably no deeper than 0.7m. Taken together, these observations suggest more resting at night than during the day, a finding similar to observations of porpoises in captivity at the Wuhan Institute of Hydrobiology (Zhang *et al.* 1996). If this behavior should prove to be a general one for porpoises in the mainstem of the Yangtze River, it might suggest that they are more susceptible to fishing-gear entanglement during daytime while they travel greater distances and dive longer and perhaps deeper. However, entanglement could also occur if animals are less aware of their surroundings during rest at night than during potentially more alert activity in the daytime.

The vest-attachment system used in the present study provided a non-constraining and apparently safe tagging/tracking technique for an animal that does not have a dorsal fin. The thin sewing thread used to tie the vests onto the body allowed the vests to fall off after some time. The thread that did not have a knot at the ends fell off in the shortest time, while that knotted for all seams stayed on the longest. Nevertheless, anything attached to the animals could increase their chances of becoming entangled in the heavily-fished and badly-polluted Yangtze River.

The present experimental radio tag/harness was not as streamlined as it could have been, and future tags should have no protrusions that could catch on nets or lines. Future tags should also have a flexible (braided-wire) instead of rigid antenna, for less drag and less chance of becoming entangled. While the vest was worn well in the Swan Oxbow, which has a maximum depth of only about 30m, porpoises in the Yangtze mainstem or in the ocean probably dive deeper. Because of lung and rib-cage collapse, the vest is not likely to fit as well at depth as at the surface (Evans *et al.* 1972), and it could even become displaced from the flipper hold-fast position. For this reason, and because of the drag that vests are likely to create, we strongly recommend that other attachment techniques be tried as well, such as pins through the skin and blubber. Perhaps such a system could be developed by modifying the tags now being used with other species without dorsal fins. If it is strongly indicated that the vest tag is the least harmful candidate for tracking finless porpoises, and this is agreed on by experienced marine mammal radio-tracking researchers, we recommend investigating a harness system with several centimeters of girth variability, possibly by including elastic material. We recommend that any further tagging/tracking attempts be made only after more detailed laboratory tests of the capability of vests to release when confronted by moderate pressure, such as from a net. The "vest" technique holds promise for finless porpoise studies, but it should not be considered safe until there has been further exploration of its function in shallow and deep waters, and under a variety of conditions. As part of testing, it is imperative that detailed behavioral research be carried out before, during, and after the wearing of a vest tag. Evaluations should also include physiological measurements, such as blubber thickness, blubber quality, and blood hormone levels, for indications of stress.

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A Study of the Boto, or Amazon River Dolphin (*Inia geoffrensis*), in the Mamirauá Reserve, Brazil: Operation and Techniques

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Abstract

A multi-disciplinary study of the boto (*Inia geoffrensis*) was initiated in flooded forest habitat in the central Brazilian Amazon in 1994. The study is intended to span at least a decade. This paper discusses progress made during the first five years of fieldwork. Research has been carried out on life history, behavior, ecology, physiology, and movements. Observational work continued year-round, but three weeks in each low-water season were dedicated to a capture-release program which allowed close examination, marking, and sampling of up to 35 dolphins annually. This element of the study also permitted the deployment of VHF radio transmitters. Linked with a network of automatic receivers positioned above the forest canopy, these transmitters yielded detailed information on individual animal movements for up to 13 months. Marking techniques included freeze-branding, which in most cases facilitated long-term recognition, and the attachment of colored plastic tags, which normally lasted two to six months. Methodology was developed for counting and remotely observing botos, and the latter provided behavioral data unaffected by the presence of the researcher. More than 130 botos were handled during the first five years of work, some in more than one year. The proportion of marked dolphins in the study area at any one time was usually in the range 0.2–0.4. The ability to recognize such a high proportion, and to know their sex and size, greatly enhanced the observational work. Although the research has targeted one particular species of river dolphin in its characteristic habitat, much of the methodology may also be relevant to work with other river dolphins in Asian environments.

Introduction

The only numerous and relatively secure platanistoid species is the boto or Amazon river dolphin (*Inia geoffrensis*), which is widespread in both the Amazon and Orinoco drainage basins of tropical South America (Best and da Silva 1989a, b). Despite its extensive distribution and familiarity to river-dwelling people in several countries, the boto remains poorly studied. The species occurs in high densities in many areas, is usually tolerant of boats, and is relatively easy to observe. For these reasons, it is amenable to close study, which facilitates the development of research methods suitable for cetaceans in riverine habitat. Although the South American species and its environment differ in some respects from those in Asia, the similarities are striking. Research experience gained in one region may well be relevant in others.

In 1991, we visited areas west of Manaus in the Brazilian Amazon to investigate possible sites for a long-term study of a boto population. An area of *várzea* (seasonally-flooded forest) was chosen, and fieldwork began there in January 1994.

Detailed studies of movements, behavior, social structure, and life history depend on the researcher's ability to readily identify individual animals. In many cetacean species, natural marks such as scars or pigmentation patterns, often combined with characteristics of dorsal fin shape, carry sufficient "information" to allow animals in a population to be identified individually. The usefulness of these characters is normally enhanced by the observer's ability to photograph the animal or view it clearly through binoculars by anticipating where it will surface. Most botos are sufficiently scarred by tooth rakes from conspecifics to theoretically allow them to be recognized visually in this way. In practice, however, only the small proportion bearing large wounds or scars can be reliably identified. The reasons for this are twofold. Firstly, the opacity of the water makes it impossible to follow the dolphins below the surface. Secondly, in central Brazil at least, botos surface very briefly, rarely twice in quick succession, and almost never in a predictable position. Consequently, momentary views are usually all that can be obtained. The eye cannot discriminate tooth-rake scars rapidly and efficiently enough to permit unambiguous identifications on a routine basis. Furthermore, although photographs can sometimes be taken (Trujillo Gonzalez 1994), photo-identification techniques as used with some marine cetaceans (Shane and McSweeney 1990, Würsig and Jefferson 1990) fail because too small a proportion of animals can be photographed in any encounter.

It became evident early in our study that artificial marks would be needed to permit the necessary rapid recognition of our study animals by eye. The application of such marks would require a capture program, with its attendant costs of time, manpower, extra equipment, and stress to the animals. However, the ability to examine, measure, and sample botos would add greatly to the breadth and depth of what could be learned about the population. Additionally, capture would permit the deployment of miniature radio transmitters. These promised to dramatically increase our understanding of animal movements and behavior, especially if used in conjunction with a network of automatic receiving stations to track dolphins day and night throughout the study area.

The objectives of this paper are to describe the study area and the study animal, and to discuss the development and application of our research methodology. Lessons learned in the early stages of this project may help reduce the start-up time needed for similar work on river dolphins elsewhere.

Study area

The study site is at 3°20'S, 64°54'W, some 500km west of Manaus, Amazonas, Brazil, and some 2,500 river kilometers from the mouth of the Amazon. It is situated within the Mamirauá Sustainable Development Reserve (MSDR), an area of 11,000km^2 between the Solimões and Japurá rivers (Figure 1). The Mamirauá Reserve is flat, low-lying, and covered by *várzea* intersected by lakes and channels. The dominant feature of *várzea* is that it lies in the Amazon floodplain and incurs seasonally cyclic water levels with a range of 10–12m. At low water, most of Mamirauá is dry land, but rising floodwaters gradually inundate the forest until, at high water, the whole reserve is submerged to a depth of several meters. This annual transformation has a major influence on both the wildlife and people of the region (SCM 1996). Water levels peak in May and June, and reach their lowest levels between September and early November. The speed with which the water rises or recedes is variable, but it can reach up to 20cm per day (Ayres 1993). Rainfall is greatest from January through April, with monthly records of 60mm to 450mm. Annual rainfall in Mamirauá is estimated to range from 2,200 to 2,400 mm/yr. Highest temperatures are reached during the low-water period (October and November), with monthly averages ranging from 30° to 33°C. Average minimum temperatures oscillate between 21° and 23°C (SCM 1996).

The study was centered on an area of some 210km^2 in the southeast corner of the reserve. During the dry season, the waterways here comprise some 45km of channels and lakes known as the Mamirauá System. Mamirauá Lake is the largest waterbody, some 10km long, with an average width of 400m. In all but the driest month, the lake is connected to the Japurá River by the Cano and the Paraná do Mamirauá, a channel of approximately 20km and average width of 100m. For approximately six months, additional access to the lake is provided by the narrow Paraná do Apara (Figure 2), a very shallow channel approximately 15km long which is impossible to navigate during the low-water season. At this time, the depth of water in various parts of the Mamirauá System varies from zero (dry) to a maximum of 22m. Two very different types of water occur within the study area, each supporting different fish fauna. Opaque "white" water is laden with

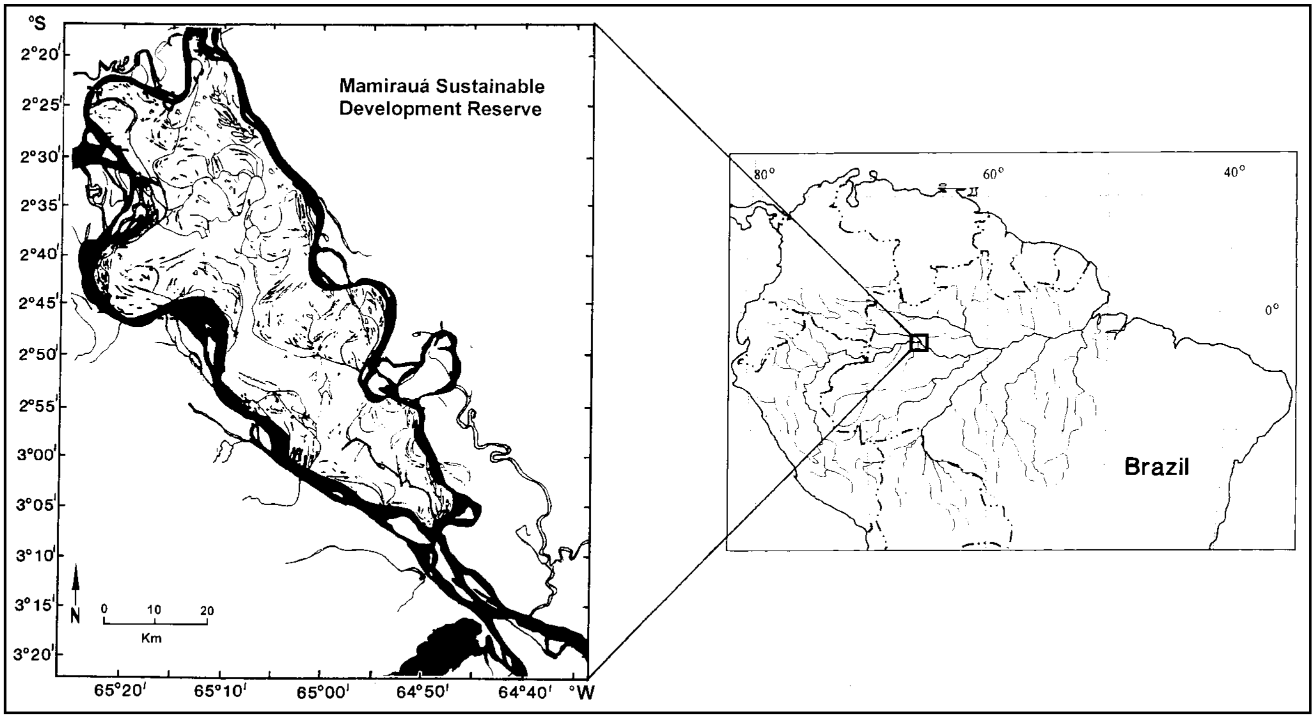
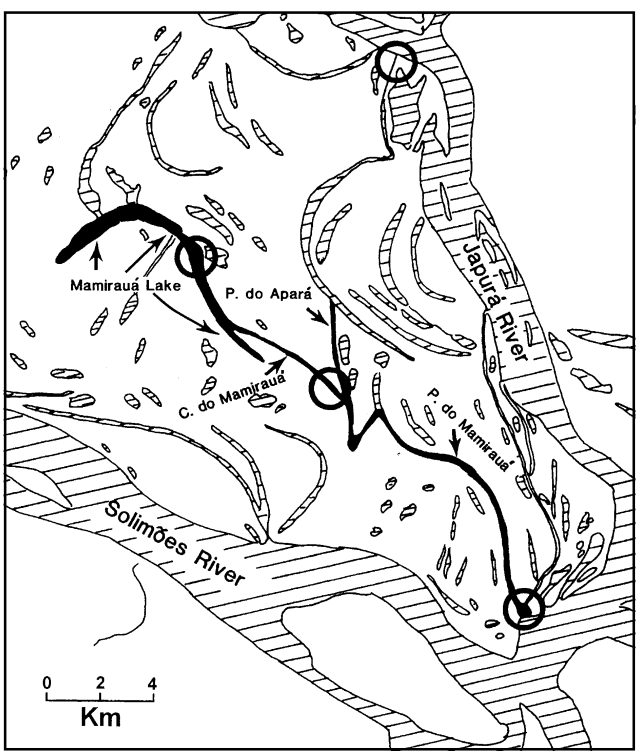


Figure 1. Location of the study area, the Mamirauá Sustainable Development Reserve in Amazonas State, Brazil.

sediments and is brought from the Andes by the main rivers, while clearer, acidic, "black" water is derived locally from drainage of the forest and is colored by tannin from the breakdown of vegetation. Water inside the lakes is black year round, while that in the *paranás* or channels varies with water level. Water in the Paraná do Apara is always white because it is supplied from the Japurá River. The Paraná do Mamirauá is black at low water but becomes white as water levels rise and Japurá water begins to flow though the Paraná do Apara. This variation in the level and type of water, and the topographical relief of the area, provide a large number of different aquatic habitats, from permanent open waters to temporary pools. The area holds extremely high densities, and a great diversity, of fish and other aquatic animals (SCM 1996).

Figure 2. Map of the study site. The waterways shown in black form the core area for the research, and the circles denote sites of the automatic VHF receivers.



The boto

The boto, or Amazon river dolphin, is the most abundant river dolphin species. Its density varies across a wide geographical range, which encompasses both the Amazon and Orinoco watersheds. The species is vulnerable to human-induced habitat changes and suffers some incidental mortality in fisheries, but it has not yet been depleted to anything like the extent of its Asian counterparts. Consequently, its current distribution may be little different from that in pre-settlement times (Best and da Silva 1989a). The boto is the largest member of the superfamily Platanistoidea, with adult males measuring approximately 2.25–2.50m and 120–180kg, and adult females 1.80–2.20m and 80–120kg in this study.

The boto (Figure 3) has a long beak (11 to 13% of the body length), with numerous teeth in the upper and lower jaws (range 24–34 teeth per row). Unlike other dolphins,

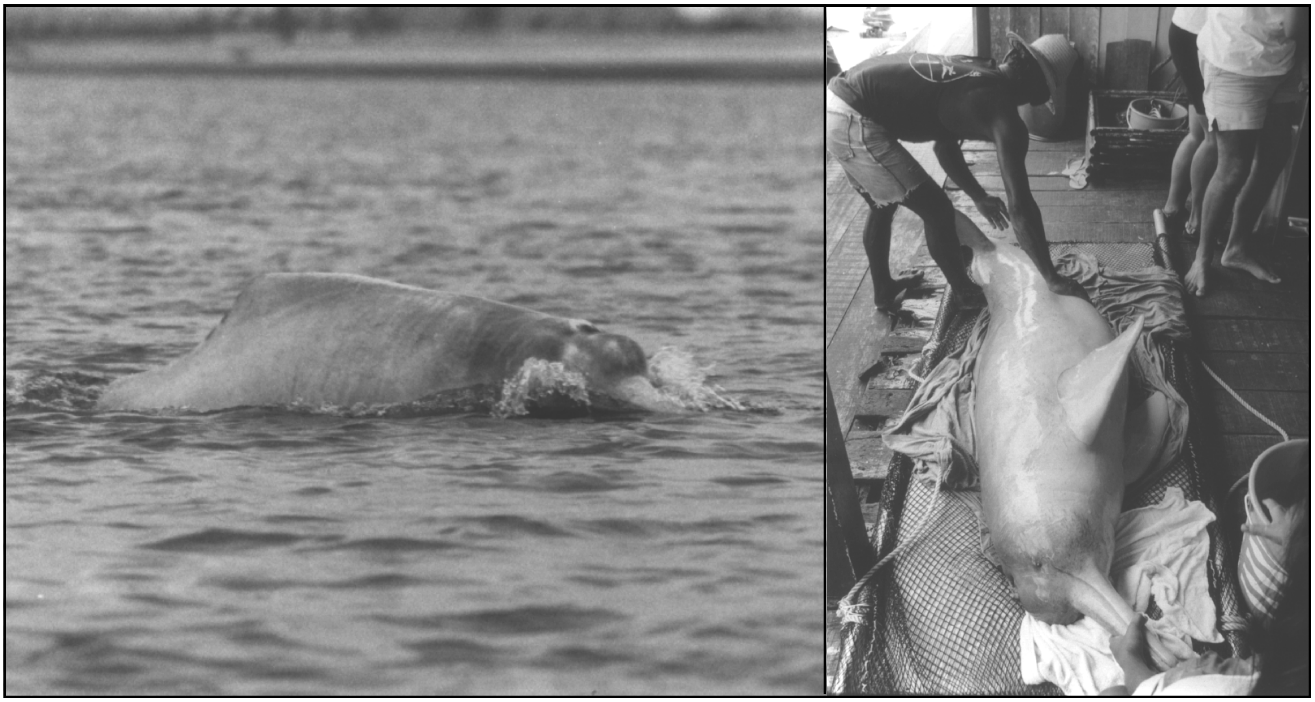


Figure 3. (a) Adult boto in Mamirauá; (b) captured adult boto immediately after arriving at the processing station.

botos have teeth of two types: conical in the anterior section of the jaws and molar-like posteriorly, allowing the animal to crush and consume armored prey such as catfish. The boto is exceptionally flexible and maneuverable, permitting it to swim in confined and shallow areas, and among trees in the flooded forest (Layne 1958, Best and da Silva 1989a). This is due to a number of physical features: broad flippers capable of independent rotational movements, unfused cervical vertebrae allowing great flexibility of the neck, separated lumbar and caudal vertebrae that allow body flexibility, and a low and long dorsal fin. Although small, the eyes of the boto are functional, and their vision is good (Phillips and McCain 1964).

The boto is also known as the pink dolphin due to the body color of adults. Although fetuses, calves, and immature animals are always gray, adults are pink on the flanks and ventral areas, and either pink, blotched pink, or gray dorsally. The color of adults can also become lighter or darker depending on their activity and the type of water in which they live (Best and da Silva 1989a, b).

Methodology

Definitions

Two types of dolphin association were recognized. A "group" was a number of individuals in close association and essentially involved in the same activity. An "aggregation" was defined as two or more groups of botos in the same small area (usually <400m across) but not necessarily interacting or engaging in the same activity. An aggregation could occur naturally, often on a waterway bend where fish density was high, or artificially, for example by dolphins being attracted toward a boat. When the attraction faded, the animals usually dispersed in small groups again. Where possible, the composition of groups and aggregations was recorded by animal size and appearance: adults, sub-adults/juveniles, and calves. Calves were defined as small animals closely associated with what was apparently an adult female. Mature adult males, which were usually distinguishable by a combination of size (longer and more massive), shape (proportionally higher dorsal fin), and color (invariably deep pink), were recorded as such.

Capture, handling, and routine sampling

Various techniques were tested to establish which were most effective for this species in this habitat. The following is a description of the protocol used during the most recent capture work (November/December 1998).

Botos were captured by net when water levels were low, and water channels were consequently narrow (<80m in places). Netting areas needed to have little or no current and no submerged trees or branches. One net (stretched mesh 120–150mm) was used to completely block a channel (maximum 10m deep). When a group of dolphins swam up to this net, a second net was swiftly laid across the channel about 100m from the first to prevent their escape. Usually, the isolated area was further subdivided by the deployment of more nets. Botos were invariably calm when the trap was closed, and rarely became enmeshed at this stage. As a precaution, however, several small manned boats were stationed around the nets to extract any entangled dolphins very rapidly, and netting crews maintained high levels of vigilance at all times. No motors were used during capture operations.

The usual method for bringing the dolphins to hand was to “seine” them onto a gradually-shelving shoreline with a separate, small-mesh net. The seining technique allowed us to select particular dolphins from a trapped group. In most cases, only one dolphin was handled at a time. Once an animal was secured, no attempt was made to take another from the netted area until the first had been processed and released. The only exception to this was in the case of mother-calf pairs, when both were handled together so that they could be released at the same time. Once at hand, the animals were transferred immediately to a covered raft where they could be securely and comfortably handled. During the time out of water, all dolphins were carefully monitored for signs of respiratory or other distress, and their skin and eyes were liberally irrigated to prevent desiccation or overheating.

Each individual was weighed, measured, uniquely freeze-branded, tagged (see below), and given an appropriate intra-muscular dose of long-acting antibiotic (oxy-tetracycline derivative) to reduce the chances of infection from the tagging procedures. This type of antibiotic also has the advantage of being an important tool in age-estimation studies because it leaves a marker in the hard tissues, including teeth. When the tooth is sectioned, this marker is visible as a fine line under ultra-violet light and can be used to calibrate the rate of dentinal and cemental layer formation. Skin and blood samples were routinely collected for genetic, hematological, and biochemical studies. Skin was collected as a by-product of tagging procedures (preserved in DMSO (Dimethyl Sulfoxide) or 95% ethyl alcohol), and blood was taken from a sub-dermal vessel on the ventral surface of the tail stock. These samples were used to assess the health, growth, and genetic structure of the population. Samples of milk were collected from lactating females and stored deep-frozen.

Techniques for marking individual animals

Plastic tags

We used different sizes, shapes, and colors of flexible plastic tags (originally designed as cattle ear-tags; Dalton Supplies Ltd, Nettlebed, Henley-on-Thames, Oxfordshire, UK). Adults and juveniles received large and medium-size tags, respectively. Calves were given 2.5cm-diameter circular tags. The tags were attached in pairs, one on each side of the dorsal fin, and positioned low on the trailing edge of the fin just above the body. They were secured with a single 6mm-diameter threaded nylon pin. The procedure involved making a clean hole through the tissue at the chosen site using a sterile thin-walled stainless-steel borer, applying an antiseptic cleanser, and inserting the pin. Nylon nuts at each end of the pin were adjusted to ensure a good fit, neither loose enough to allow movement nor tight enough to cause abrasion or pressure wounds.

Freeze-brands

Freeze-brands were applied using characters of 70mm height on brass blocks of 1kg mass. The blocks were cooled in liquid nitrogen for about two minutes, when the nitrogen had ceased to boil, then applied to the skin with firm pressure for 20–25 seconds (Figure 4). During the first capture trip (January 1994), the brand was applied on each flank, just below the dorsal fin. To improve visibility, brands were applied to the second (November ’94) and third (November ’95) groups of captured botos on the highest part of the dorsal fin. The fourth to sixth (November ’96–’98) batches of brands were applied both on the dorsal fin and on the flanks of each individual.

Figure 4. A freeze–brand being applied to an adult female boto in November 1994. This dolphin has been re-sighted every year since its capture.

Notches

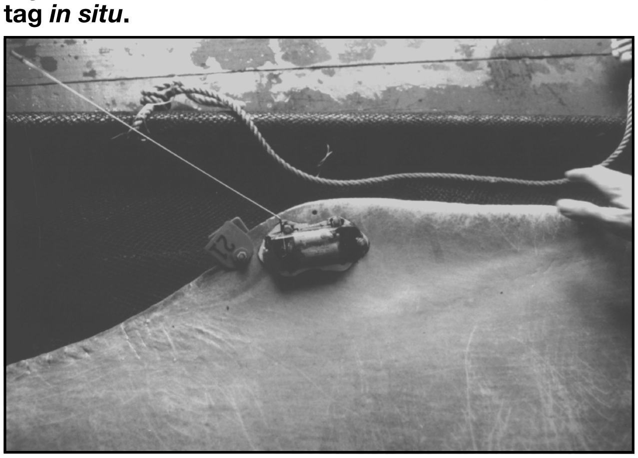
Other marks used experimentally were notches cut on the trailing edge of the tail fluke or on the very top of the dorsal fin. These were triangular or semi-circular in shape, the latter applied with a cattle ear-notcher. Wounds were cold-cauterized and treated with local antibiotic.

Radio telemetry

Two types of radio transmitter were deployed, both constructed by the Sea Mammal Research Unit (SMRU, UK): a VHF unit (173–174 MHz) designed for local reception, and a satellite–linked UHF unit (401.65 MHz). These units were potted in either urethane or epoxy-molded blocks, fitted with stainless-steel whip antennas, and powered by 1 or 2 AA-sized lithium batteries. The packages had a mass of 100–130g in air (25–35g in water) and were approximately 150 x 50 x 20mm or 100 x 45 x 20mm in size.

The VHF transmitters had an output of 1mW and transmitted for 20ms with a repetition interval of either 1000ms or 1500ms. The units operated continuously, with neither duty cycling nor disabling below the surface, and used either Mariner Radar (Bridleway, Camps Heath, Lowestoft, Suffolk, UK) or ATS (Box 398, Isanti, MN 55040, USA) RF stages. Nominal tag longevity was 6 and 12 months, respectively. The satellite-linked transmitters were registered with the ARGOS data collection and location system, which provides Lat/Lon locations using two or three polar-orbit NOAA satellites (Fancy *et al.* 1988). They were fitted with wet/dry sensors to prevent transmissions below the water surface and had a minimum inter-transmission interval of 40sec. All transmitters were attached to a piece of 1mm-thick flexible belting which was tailored to fit snugly on the dorsal fin, either in a wrap-around fashion with the battery on the side of the fin and the antenna following the leading edge, or with the transmitter as a single unit on the side (Martin and da Silva 1998) (Figure 5). The units were held in place with two or three 6mm-diameter nylon pins which passed through the fin within 4cm of the leading edge and were secured with nuts and washers, as described above.

Figure 5. Side-mounted VHF transmitter and plastic tag *in situ*.



The animals with VHF transmitters were tracked by hand, usually from a small outboard-powered aluminum boat, and also automatically using tracking stations atop towers or tall trees. Automatic stations (model PRX900 manufactured by TELEVILT International AB, Box 53, S-711 22 Lindesberg, Sweden; for more information see Martin and da Silva 1998) were placed at strategic points within the study area at approximately 10km spacing. Five stations were set up for the study, each with two yagi antennas 4–10m above the forest canopy. Each receiver polled the two antennas alternately, scanning each programmed frequency in turn. A new line of data was logged whenever a transmitter was detected, comprising a record of the strength, duration, and repetition rate of the signal and the direction of the antenna involved. Periodically, stored data were downloaded to a laptop computer from the tracking-station memory (Martin and da Silva 1998).

In order to correctly interpret data from the automatic stations, the range of signal reception was tested at each site. This was done by placing transmitters at or just below the water surface at locations up to 8,000m from the receiving stations. Four antenna orientations, simulating conditions likely to occur when botos surface to breathe, were tested at each point: fully submerged, 50% submerged vertical, above the surface vertical, and above the surface at 45° to the vertical.

Visual observations

Three visual-observation methodologies, with different objectives, were developed and standardized. Each took into account boto behavior, habitat constraints, and the types of observation platforms available to the project.

Animal abundance

The measure used here was a "minimum count." Counts were made in the same way each time, using a small outboard-motor-powered aluminum boat and two or three experienced observers. The objective was to travel the entire length of the study area as rapidly as possible, but slowly enough to allow each dolphin present to be seen. Boat speed was therefore varied as necessary to ensure that all areas of water were in view ahead of the observers long enough (minimum two minutes) for any dolphin present to surface at least once. Stops were only made when the size of a group or aggregation could not be determined while the boat was in motion, and even then only in areas of low boto density. Botos were very mobile and often difficult to detect, so observers had to be keenly aware of the spatial distribution of all groups within visual range and to ensure that the boat moved sufficiently fast to avoid being overtaken by botos already counted. This was normally only a problem in areas of high dolphin density, and particularly when animals were attracted to the boat and able to keep pace with it at low speeds.

The boat travelled in mid-channel at around quarter speed (8–10km/hour) in straight waterways and at minimum speed around the outer edge on tight bends. When it was necessary to stop, the boat either circled slowly or moved up-sun to avoid water glare and idled. Circling sometimes encouraged botos to approach the boat and show themselves, but at other times animals were more easily seen from a quieter boat. When only two observers were available, the primary observer looked forward, using 7x binoculars on long straight sections, while the second looked for animals near and behind the boat. With three observers, one looked only forward, one only behind, and one both recorded data and helped monitor individual dolphins in areas of high density. The critical information required for each sighting was simply the number of animals involved; auxiliary data such as animal size, marks, and behavior were recorded as opportunity allowed, but not at the expense of completing the count as effectively and rapidly as possible. Counts were only carried out in good sighting conditions (calm water, no rain), and during the first and last four hours of daylight when botos were more active and visible.

Observations of marked animals

The principal means of gaining information on life history, habitat use, home range, social behavior, activity patterns, and habitat use was observation of recognizable individuals. The objective here was to locate as many marked botos as possible and to record the location, group size, habitat, and activity and to identify (if possible) and note the size of associated animals. This type of work could be carried out less rigorously and more opportunistically than the counts mentioned above, in that it did not require a fixed amount of time and could be undertaken from any platform.

Focal animal

The third observational technique was to unobtrusively follow a single radio-tagged animal and to record details of its activity, movements, and social behavior for as long as possible. The main objective was to gain an understanding of a dolphin's activity during a normal day, while minimizing the risk of altering the animal's behavior by virtue of its being aware of the observer's presence. This type of work was greatly enhanced by having the focal animal radio-tagged, for two related reasons. Firstly, it was almost impossible to maintain continuous and distant contact with a particular boto in rainforest habitat by purely visual means. A radio tag ensured that the dolphin could not "escape." Secondly, the confidence of knowing that the animal could not move away undetected allowed the observer to remain further away than would otherwise be the case, so the risk of altering the focal animal's behavior was much reduced.

Results and discussion

The inclusion of capture and marking in this study, based on an early and rather tentative decision, yielded greater benefits than anticipated. It both broadened the scope of the research and substantially increased its productivity and effectiveness in many different ways. The first of these was animal recognition. Only 11 botos in the study population had visibly recognizable marks before the branding work was begun. This represented no more than 5% of the local population, a proportion too small to allow any meaningful analysis based on known individuals. Having a marked sample of more than 100 dolphins, allowing recognition of almost half of those encountered, transformed our ability to piece together the lives of known individuals. Another benefit was the close examination of study dolphins. As with most cetaceans, it was extremely difficult to accurately judge the size of botos in the field, or in most cases to determine their sex. Capturing them permitted the unambiguous determination of the age class and sex of all marked animals; this was critical information for many aspects of the study, including the interpretation of social behavior and the calculation of age- and sex-specific life history parameters such as birth and mortality rates. The third area of benefit was tissue sampling, which allowed investigation of animal health and physiology, and provided genetic information. The latter should reveal the degree of relationship between animals and between populations, throwing light on social structure and behavior, and the level of mixing between Mamirauá botos and those elsewhere. A fourth advantage of the capture program was the ability to deploy radio transmitters, which provided information on, for example, movements round the clock every day of the year, habitat use, and levels of association between individuals.

Capture, handling, and routine sampling

Concerns about the ability of botos to withstand the stress of capture and to behave normally after tagging were fortunately misplaced. During the first five years of the study, 133 botos were captured and marked, 19 of these on two separate occasions, and the species proved to be among the most resilient of all cetaceans when being handled. The handling time of animals in this study ranged from 5–30min, but 10–15min was typical for adults. Young calves were always processed quickly, usually being kept out of water for seven minutes or less.

Almost all of the captured botos were monitored for months or years after release, and none have been found dead. Obvious post-capture changes in behavior, if they occurred at all, were limited to the first minutes after release. Lactating mothers captured with or without their calves were always immediately reunited with the calf on release, and the pairs left the area swimming side by side. Observation of many radio-tagged and freeze-branded botos in the first week after release did not reveal any outwardly abnormal social activity or other behavior. They were seen swimming and surfacing as usual, and interacting normally with the observation boat, including playing in the wake.

A word of caution is appropriate here. Although botos were amenable to capture and handling, this may not necessarily be the case for other platanistoids. We would urge researchers considering similar studies of any cetacean species to start very slowly and cautiously, as we did, allowing experience to guide the speed and direction of the work. Successful and safe dolphin capture demands great care and vigilance, expert guidance, and considerable resources of skilled manpower.

Techniques for marking individual animals

The longevity of the different plastic tags on botos, the first river dolphin species to be marked in this way, were variable according to tag size, the smaller ones generally lasting longer. In this study, plastic tags normally migrated out of the dorsal fin within six months of attachment, although one tag remained in place on a juvenile male for almost two years. Loss of the tag usually resulted in a notch, which proved helpful as a permanent indicator that the individual had been marked if the brand was not clear or, as in the case of a few calves, the animal had not been branded. The greatest use of the plastic tag was that it provided an immediate marker, in particular one that was effective at least until the brand became clear (usually two to four weeks). Plastic tags were first used on small cetaceans by Evans (1967) and Norris and Pryor (1970) on rough-toothed (*Steno bredanensis*) and pantropical spotted (*Stenella attenuata*) dolphins, respectively. More recently, they have been deployed on the bottlenose dolphin (*Tursiops truncatus*) (Irvine *et al.* 1981, Odell and Asper 1990, Scott *et al.* 1990b) and have been effective for individual identification in this species for up to three years.

With the exception of a few very small calves at the beginning of the study, when we were still unsure about the resilience of this species to handling, all botos captured were freeze-branded. This type of mark proved to be an effective way to recognize individuals on a long-term basis, and it appeared to have no harmful side-effects. In most cases, the brand had a well defined outline once the affected skin tissue had stabilized, with a light pink color that contrasted with the dark pink or gray of the dorsal area of the body. Resightings and recaptures of marked botos showed that re-pigmentation of the brand was normally slow and that it might remain visible indefinitely in many animals. Certainly, a high proportion of the oldest brands (4–4.5 years old) remained bright and clear. The intensity and quality of brands were variable, however, reflecting both differences in individual morphology and in marking effectiveness. Brand contact on smaller animals (where the fin or body had a smaller radius of curve) was often less effective than on larger ones, and the affected tissue on some dolphins noticeably thawed more quickly than on others. This variability likely affected subsequent brand quality. Brands on the flanks generally retained their contrast for longer than those on the dorsal fin, due largely to a lower rate of repigmentation. The same result was described for bottlenose dolphins in Florida, where the longevity of freeze-brands was reported to be over eight years (Odell and Asper 1990) or up to 11 years (Scott *et al.* 1990b). Indeed, in almost every respect, our results on botos were very similar to those obtained on bottlenose dolphins by those authors.

In some cases, brands were of good quality on one side of the body and of poor quality on the other. In others, only a partial mark remained on both sides. In a small number of cases, the brands became so poor that they would not be noticed during a normal visual encounter. With time, this will be the case for an increasing number of branded animals. For this reason, the brands of recaptured dolphins were re-touched if any repigmentation of the mark had occurred, and flank brands were added to those animals that were not originally given them.

Radio telemetry

During the first four years of this study, 37 adult botos were fitted with radio transmitters – 34 of the VHF type and three satellite-linked (Martin and da Silva 1998). In conjunction with the network of automatic tracking stations, the VHF transmitters provided excellent data on both hour-by-hour and longer-term movements. Figure 6 illustrates the type of information gained from the tracking station network. Animal reaction to carrying a transmitter appeared to be negligible. We were not able to detect any behavioral difference between botos with and without transmitters, and there was positive evidence (e.g. in observations of tagged lactating mothers and their calves) that social relationships were unaffected. No radio-tagged animals were observed trying to knock or brush off their transmitter pack, and three packs recovered after being shed by the dolphin showed no indication of abrasion or damage consistent with such behavior. Animals were tracked, and their behavior recorded, for up to 13 months after tagging.

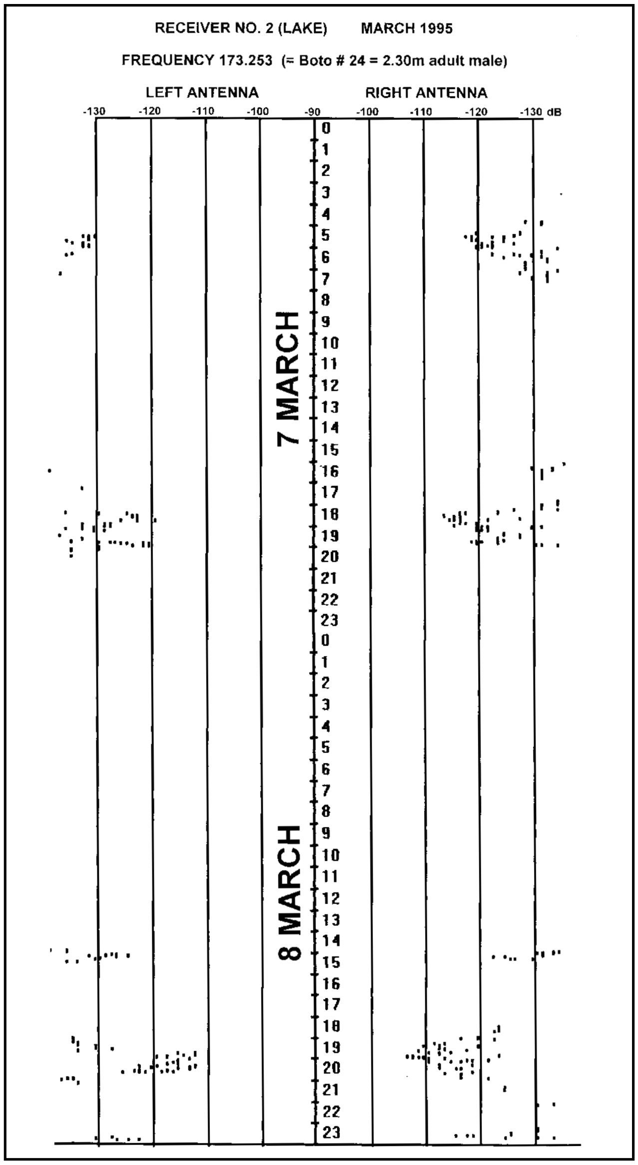


Fig. 6. Representation of data received by the automatic VHF receivers.
This chart shows signals detected from animal # 24 by the receiver situated on the lake in the northwest sector of the study area. Time proceeds down the page, and the chart covers 48 hours in early March 1995. Signals received by the left antenna (pointing southeast) are shown as dots on the left of the chart; those received by the right antenna are on the right. Signal strength (measured in dB) decreases with increased distance from the centre line, so a transmission from a distant dolphin appears as a dot near the edge of the chart. The chart shows that the dolphin spent this period in the upper part of the lake, approaching the receiver on several occasions but never passing it. The closest approach was on March 8th at 20.00 (when it was probably less than 200m from the receiver), after which the dolphin once again swam away to the northwest. At no time during this period of two days did the left antenna receive stronger signals than the right, which it would have done if the dolphin had swum past the receiver. This animal remained in the lake until the end of the month, then was detected passing two other receivers as it moved down the reserve before being seen on the main river in June.

Radio-tag longevity was variable, usually in the range 3–9 months. However, longevity improved as greater experience led to improved transmitter design and attachment. One individual was still located by its radio signals 13 months after capture, and routine transmitter functionality for a full 12-month cycle is a reasonable objective for future deployments.

The three satellite-linked transmitters were deployed experimentally to determine whether such devices could operate effectively in conditions that appeared to be sub-optimal (low latitudes and no visible horizon). Results were indeed poor compared to those from marine cetaceans at high latitudes (e.g. Martin *et al.* 1993), but it was at least possible to follow botos on a daily, though not hourly, basis. These devices would be used again if animals were likely to travel long distances. The less expensive VHF transmitters are clearly preferable for use with animals which remain in or near Mamirauá year-round.

Tags were released from the animal when the retaining pins either broke or migrated through the tissue. The dorsal fins of more than 20 radio-tagged botos were examined subsequent to release of the transmitter, either by close observation of the swimming dolphin or, in many cases, at recapture a year or more after tag deployment. Evidence that the animal once carried a transmitter varied from nothing (complete healing with no scars) to notches on the leading edge of the dorsal fin, corresponding to the sites where the pins migrated out of the tissue. In a few cases, these notches appeared to be as deep as the initial pin site, but in most animals healing had occurred behind the line of pin migration, leaving either a white line or no trace. Even the deepest notches were not associated with any sign of infection or tissue necrosis, however, and healthy skin always grew back over the pin sites.

The range of detection of VHF signals was variable from 100 to 6,000m, depending on the amount of intervening vegetation and the orientation of the transmitter antenna. In ideal conditions, an animal could be detected at 6km with the receiving equipment at 43m above water level. With dense, wet forest between transmitter and receiver, the range diminished to some 600m with a receiver at 35m above the water level. Submergence of the transmitter antenna diminished the strength of the received signal, but, even on the river bed in several meters of water, transmitters produced signals that could be detected 100m or more away.

Visual observations

Neither line transects nor strip transects, the usual methodologies for estimating cetacean abundance, were applicable in Mamirauá because assumptions of the models would have been violated. In particular, the waterways were so twisted, and bankside vegetation so dense, that the probability of seeing an animal at any given distance from the trackline was variable with time. For these reasons, it was necessary to devise another method of estimating boto numbers within the study area. The "minimum count" approach was attractive because it required no assumptions other than that the level of accuracy was similar between counts, so they could be used to provide a time series of comparable figures. Although, theoretically, all botos present in the waterways should be countable using our techniques, we know that some were missed because, for example, sometimes the forward-looking observer saw a group that was missed by the rear-facing one, and vice-versa. The level of under-counting has not yet been quantified, but repeat counts and examination of between-observer differences gave the impression that the error was likely to have been less than 20%. A record was kept of which observer saw which groups, and how many animals each observer saw in those groups. Correction factors can therefore be calculated to account for the effect of variations in the data-collection protocol, for example when a dedicated rear-facing observer was unavailable.

Boats of different sizes were tried for the various observational tasks, from paddled wooden dug-out canoes to 20m-long diesel-powered riverboats. We concluded that the 4m-long aluminum skiffs, powered by 15HP outboard motors, were the most universally useful craft from which to observe and count botos in the reserve. This was because of their small size and maneuverability and the fact that dolphins were habituated to them. Dug-out canoes were sometimes preferred when there was a particular need to be silent as, for example, during observations of focal animals. Although small craft were most appropriate in small waterways, there is little doubt that larger boats would be more suitable for estimating dolphin density and abundance in the main river channels (Vidal *et al.* 1997).

Conclusions

Botos proved to be robust to capture and handling procedures, and they showed no apparent reaction to carrying small VHF radio transmitters or plastic tags. Detection ranges of VHF signals from botos in dense forest were lower than for cetaceans in the open sea, but transmitter longevity exceeded anything yet published for other cetacean species. Overall, the VHF-tracking element of this study was successful and added greatly to the information that could be gained using other means.

The study of botos is hindered by their remote location and forested habitat, the turbid water in which they live, and their erratic surfacing behavior. However, a suite of research techniques has now been developed to address many fundamental questions about their biology, ecology, and behavior. Some of these techniques are novel, while others are adaptations of methodology that has been used successfully in studies of marine cetaceans (e.g. Odell and Asper 1990, Irvine and Wells 1972, Scott *et al.* 1990a, Scott 1990). Each was modified in a step-by-step process to meet the special requirements of Mamirauá and its botos, but this experience and methodology could also be applicable to the study of river dolphins in other areas.

Acknowledgments

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Habitat Preferences of River Dolphins in the Peruvian Amazon

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Abstract

The distribution, relative abundance, and habitat use of two river dolphin species (*Inia geoffrensis* and *Sotalia fluviatilis*), were studied in the Peruvian Amazon between 1991 and 1993. Sighting surveys were carried out in two types of riverine habitat: (1) large, turbid ("white water"), relatively straight, fast-flowing rivers (Amazonas and Marañón) and (2) narrow, non-turbid ("black water"), meandering rivers (Samiria and Yanayacu Grande). For coarse-grained analyses, the main axes of all four rivers were classified, by kilometer, according to the presence or

absence of a confluence. Dolphins of both species showed significant attraction to confluences. While there was no clear seasonal difference in this affinity for confluences in the Amazon-Marañón, there was a strong suggestion that the association with confluences disappears in the blackwater rivers during the flood, or high-water, season. For fine-grained analyses, a Geographic Information System was used to classify habitat in the Samiria and Yanayacu Grande rivers, by area, according to the "zones of influence" of confluences, sandbanks, and sharp channel bends. Again, confluences appeared to strongly influence the distribution of dolphins. The deep pool areas created by scouring in confluences, opposite sandbanks, and on the outer edges of sharp bends may provide benefits to dolphins, but the nature of such benefits remain ill-defined.

Introduction

Two kinds of river dolphin inhabit the Amazon River system in South America. *Inia geoffrensis* (de Blainville, 1817), the boto, is an obligate freshwater species that occurs throughout the entire system below the Andean foothills (Best and da Silva 1989a, 1989b). *Sotalia fluviatilis* (Gervais, 1853), the tucuxi, is sympatric with the boto in much of the Amazon (da Silva and Best 1994). The two species are not closely related, and they have many conspicuous differences in morphology and behavior. Nevertheless, their overlapping ranges mean that observational research targeted at both species can be conducted simultaneously and comparatively.

A study by Magnusson *et al.*(1980) in the Brazilian Amazon provided insights about habitat preferences, "territoriality," and group size for these two dolphin species (also see Schnapp and Howroyd 1992). In a recent study of dolphins in the Peruvian Amazon, we investigated many of the same questions as Magnusson *et al.* (1980). Our study, however, had the benefit of including more than one biotope. The work of Magnusson *et al.* (1980) was done exclusively within a 550km segment of the mainstem of the Solimões (Amazon) River upriver from Manaus. Ours encompassed two dissimilar types of river system. We studied dolphins in the mainstems of the Amazonas, Marañón, and Ucayali rivers in Perú. These "whitewater" rivers (see below) are essentially like the Solimões: wide, deep, fast-flowing, and turbid. We also worked in the Samiria River and its associated streams and *cochas* or *tipishcas* (oxbow lakes). The Samiria is a "blackwater" system, characterized by narrow, winding waterways (see below). Thus, in our study we were able to compare habitat preferences not only between the two species, but also between two different types of environment. In addition, we conducted surveys at different stages in the annual hydrological cycle and thus obtained some insight into seasonal effects on habitat preferences. It is important to emphasize, however, that sampling was limited to only five months of the year (March, April, June, July, and August) and that no data were available for the season of low water levels.

In the literature on river dolphins of Asia and South America, it is frequently alleged that these animals show preferences for particular types of riverine habitat. For example, Best and da Silva (1989a) reported that *Inia* inhabit "all types of micro-habitat, i.e. rivers, small channels, lakes, etc." and that they seem more concentrated at river mouths and just below rapids, "where there is more fish movement and the currents may help disorient fish schools, making them easier prey for the dolphins." Similar conclusions were reached by Kasuya and Haque (1972) after surveying Ganges River dolphins (*Platanista gangetica*) in Bangladesh and by Meade and Koehnken (1991) from their surveys of *Inia* in the Orinoco River of Venezuela. The latter authors also noted, citing da Silva (1986), that "*Sotalia* prefer the deeper parts of the river channels whereas *Inia* are more prevalent in the shallows." Da Silva and Best (1994) emphasized that *Sotalia* show a "distinct preference" for confluences and avoid rapids and small channels where maneuverability is restricted. In Nepal, Smith (1993) found Ganges dolphins primarily just below confluences, where eddy counter-current systems provided ecologically rich and energetically efficient microhabitats (also see Pilleri and Zbinden 1974; Pilleri and Bhatti 1980; Chen and Hua 1989; Zhou and Li 1989; Hua *et al.* 1989).

The central question addressed in this paper is whether the distribution of *Inia* and *Sotalia*, in the two biotopes where we studied them in Perú, suggests preferences for particular types of habitat. Specifically, we examine how observed dolphin "densities" (i.e. encounter rates) varied between microhabitats, defined as areas with confluence zones, sandbanks, or sharp bends; areas with two or more of these features; and areas with none of these features.

Study area

Iquitos is located about 3,700km from the mouths of the Amazon. The Samiria River drains into the Marañón, an Amazon formant, 232km upriver from Iquitos (Figure 1). This region is in the humid-tropical forest life zone (Bayley *et al.* 1992), where the land ranges between 80 and 400m above sea level and the annual precipitation is generally less than 3,000mm per year (Peñaherrera del Aguila 1989). The lack of relief causes secondary rivers to follow meandering courses, flow relatively slowly, and frequently form oxbows.

Annual rainfall is strongly seasonal with the highest precipitation in April and the lowest in July. In general, the rainy season spans the months of November through May; the dry season, June through to October. Although

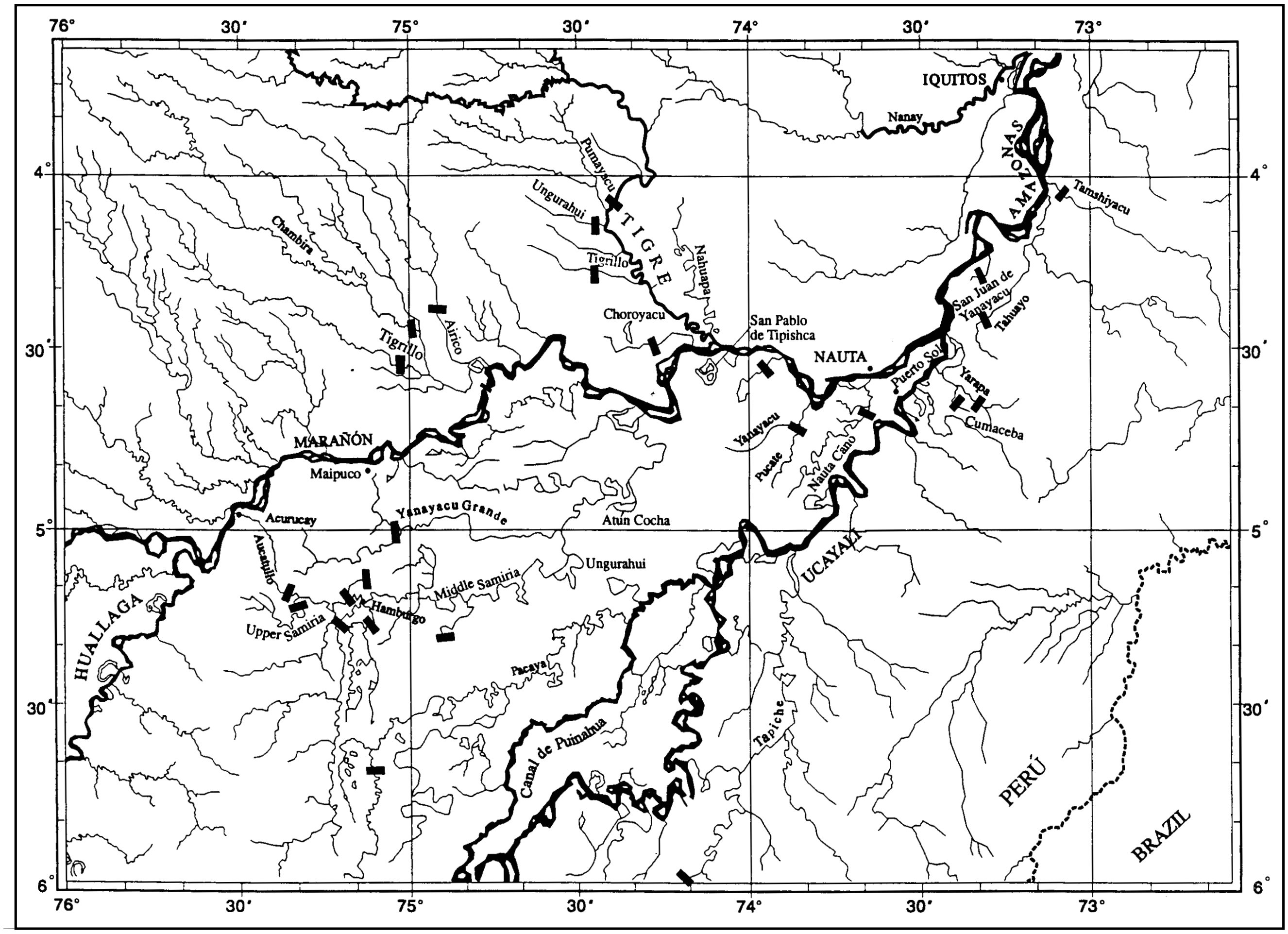


Figure 1. The study area in Peru, with bars across river channels indicating upstream limits of surveys. Only the survey data from the Amazonas, Marañón, Samiria, and Yanayacu Grande rivers were used in this paper.

air temperatures can reach as low as 10°C and as high as 35°C (FPCN *et al.* 1993), temperatures less than 16°C are rare.

The timing of extreme seasonal changes in water level is generally predictable. The average annual amplitude of water level flux is 7-8m at Iquitos, where it is influenced primarily by Andean runoff and the different timing of floods from north and south of the equator (COREPASA 1986). Swamps and floodplains have a strong moderating effect on the hydrology of low-elevation areas outside the large, deep river channels (Bayley *et al.* 1992).

The three conventionally recognized water types in the Amazon region are: whitewater rivers that carry large amounts of suspended matter and have a yellowish brown color; clearwater rivers with relatively high transparency due to a lack of organic acids and suspended matter; and blackwater areas, which are grayish black in color, apparently due to high concentrations of dissolved organic humic acids (Sioli 1984). All three water types are represented in our study area, but only the observations made in whitewater and blackwater systems are analyzed here. The rivers in our study area are bordered mainly by either *igapó* (forested land that is seasonally flooded by acidic, nutrient-poor black water) or *várzea* (floodplain that is seasonally inundated by nutrient-rich white water).

The Samiria River has a total length of about 346km and a drainage area of about 8,400km^2 (Bayley 1981). Although some of our surveys extended farther upriver, the blackwater-system data used for the present analyses were collected only in the lower 142km of the Samiria (i.e. downriver from Ungurahui) and in the lower 73km of its major tributary, the Yanayacu Grande (Fig. 2). The maximum flux in the Samiria's water level documented during our surveys was 4.6m, measured at the Ungurahui ranger station between early April ("high water") and late July 1993 ("medium low water"). This was a year of exceptionally heavy flooding, so the annual average high-low flux might be in the range of 4–5m. The maximal width of the Samiria (defined as forest edge to forest edge) is 180m, and it is much narrower than this in many areas.

The Samiria River follows a serpentine course, and it is surrounded and dominated by vast, continuous *igapó*. Almost the entire Samiria system is contained within the Pacaya-Samiria National Reserve, a 2,080,000 hectare

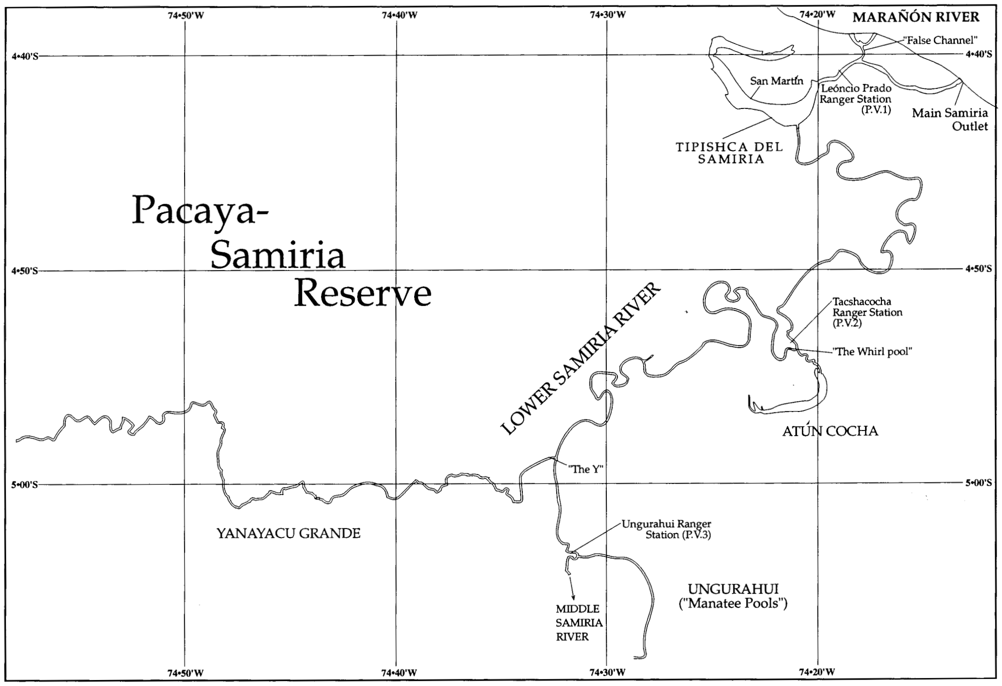


Figure 2. Detail of the Samiria and Yanayacu Grande rivers generated by the Geographic Information System based on GPS data from the field.

area managed, partly, to protect a brood stock of paiche (*Arapaima gigas*), a popular osteoglossid food fish in Perú (COREPASA 1986), and, partly, to meet the basic needs of some 70,000 humans living along the reserve borders (Francisco Estremadoyro, pers. comm., February 1998). Although the extent and degree of human disturbance are relatively low by most standards, the areas near the Reserve boundaries, including the large lake Tipishca del Samiria, are intensively settled and used by people, many of whom regularly travel by dugout canoe deep inside the Reserve to fish and hunt for paiche, river turtles, monkeys, and large cats (F. Estremadoyro, pers. comm., February 1998). Overt signs of human disturbance are generally scarce in the center of the Reserve. There are only scattered patches and strips of secondary forest at sites of abandoned settlements, occasional remnants of oil exploration activity (see Neville *et al.* 1976), and seasonal fishing camps.

Methods of data collection and analysis

Collecting data on dolphins

The data used in this study were all collected upriver from Iquitos during 11 one or two-week expeditions between July 1991 and August 1993 (Table 1). Ninety-eight days were spent on the rivers making observations, principally from aboard multi-decked river boats designed to navigate shallow water and provide living accommodation for 20 or more passengers. The boats were powered by inboard diesel engines. Eye height of observers was usually about 7m above water level.

The usual procedure was to travel on the rivers in survey mode, with at least two primary observers (experienced cetacean biologists) maintaining a constant watch ahead of the vessel. These observers were often accompanied by one or several secondary observers whose level of experience and training, as well as intensity of vigilance, was highly variable. The pattern of observation was to scan, with the unaided eye, an arc of 180° ahead of the moving vessel, with the goal of detecting all dolphins within viewing range. The search area was generally partitioned into left and right quadrants, with perhaps 15–30° of overlap directly ahead. In the large rivers, 10-power binoculars were frequently used for scanning, as the objective was to detect as many animals as possible. In the narrow rivers, scanning was generally done with the unaided eye, and binoculars were used only when necessary for identification and counting.

Data were recorded by hand on standard forms. An observation of one or more dolphins was logged as a sighting, and the time, position, species, and number of individuals in the sighted "group" were noted. Dolphins that were swimming within approximately five body lengths of each other, or that appeared to be associated because of their synchronous surfacing and common heading, cooperative feeding, or other interactive behavior, were considered a group. This judgment was necessarily subjective and often difficult, especially for *Inia*. Positions were normally taken from a hand-held Global Positioning System (GPS) receiver. Less than 5% of sighting positions were estimated by reference to landmarks on a map or by interpolating between good satellite fixes.

Despite the obvious differences in morphology, behavior, and general appearance of the two species, it was not always easy to distinguish botos and tucuxis under field conditions. Sightings recorded as "unidentified" were not used in analyses of distribution or habitat preferences.

Collecting data on environmental features

Data were collected on three environmental features that were considered particularly relevant to this study: water level or stage, river dimensions and configuration, and water depth.

All data on sightings and effort were assigned to appropriate water-level categories. Although it proved impractical to schedule expeditions during the low-water season, when many of the blackwater tributaries are inaccessible, our coverage included water stages ranging from "medium low" to "high" water. Each of the 11 expeditions was assigned to one of five categories, based on subjective information provided by local informants and on our own assessment of watermarks on trees, steepness of mudbanks, etc. (Table 1).

Published maps and charts from Peruvian sources and the United States Defense Mapping Agency (DMA) were used for plotting data in the mainstems of the Amazon and Marañón rivers. For plotting effort and sightings in the Samiria and Yanayacu Grande, we used six DMA charts, with scales of 1:100,000 (J632-1859-61, 1959–61, and 2059–61). The maps and charts were photographically enlarged by four times to allow us to plot the sighting locations and effort more precisely. Effective scales were 1:31,250 for the Amazon-Marañón and 1:6250 for the Samiria-Yanayacu Grande.

For finer-scale analyses of habitat preferences in the Samiria-Yanayacu Grande (see below), we created our own charts from data obtained in late July 1993, when the water level was judged to be "medium high." Two of us (SL and RR) travelled in a skiff at high speed as close as possible to the shores of the lower Samiria (between the Marañón confluence and the first sandbank upriver from Ungurahui ranger station; Fig. 2). GPS positions were logged automatically into a computer (AST Advantage NB-SX25) at 10-sec intervals. The resulting files were edited to remove spurious positions, and a map was produced on a Geographic Information System (GIS) at Texas A&M University, using the computer program ARC/INFO (Figure 2; see Leatherwood 1996 for more detail). This GIS-generated map was corrected to account for the fact that the skiff travelled at a safe distance from the exact shoreline. When overlain on a LANDSAT image, our map was an essentially perfect match. We used a somewhat cruder method to chart the lower 73km of the Yanayacu Grande. Positions recorded at irregular intervals during an upstream and downstream transect were used to plot a line, which we considered to represent the center axis of the river. This line was then "buffered" (30.35m added to each side) using ARC/INFO.

Depth measurements were used to gain some perspective on the underwater topography of the various habitat categories within the Samiria system (see below). Two methods of measurement were used. A marked sounding line was used at a few locations during some of the earlier expeditions. This method is obviously crude as it is difficult to account for the incline of the sounding line caused by downstream current (slow though it is in the Samiria). In July 1993, we (SL and RR) used a fathometer (Apelco XCD241 Fish Finder Sonar) to obtain a series of systematic measurements in selected river reaches. Our measurements were referenced to the maximum depth for the particular reach, determined from water lines on trees or man-made objects along the bank. From aboard a slow-moving skiff, we measured depths on zig-zag transects across the river. The slowness of the current in the sampled areas ensured that downstream drift was negligible. Measurements were taken at sufficient frequency to produce statistical characterizations of depth in sample sections of sharp bends, confluences, and conspicuous sandbank areas where prolonged observations of dolphins were made, as well as in one long area of "unclassified"

Table 1. Timing of surveys in the various river systems.

Expedition dates	Water stage[1]	Amazonas dates	Marañón dates	Samiria dates	Yanayacu Grande dates
10–15 Mar 91	B	10–15	11–12	-	-
23–28 Jun 91	D	23,28	-	-	-
14–19 Jul 91	E	14,19	-	-	-
21–26 Jul 91	E	21,26	23,26	23–25	-
28 Jun–3 Jul 92	D	28,3	29,3	29–30,1–2	-
5–10 Jul 92	D	10	9	5–9	7
26 Jul–7 Aug 92	E	26,5–7	27,30,3–4	27–30	28
21 Mar–2 Apr 93	A	21,2	22,1	23–28	26
4–16 Apr 93	A	4,16	5,15	6–14	12
28 Jun–8 Jul 93	C	28–30,8	30,7	1–7	4–5
18–30 Jul 93	C	18–19	19	20–23,25–28	24–25

[1] Water stages: A, high; B, medium high rising; C, medium high declining; D, medium declining; E, medium low declining.

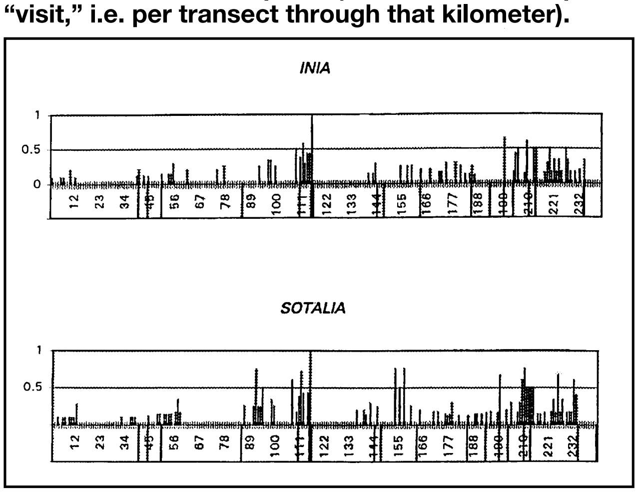
river (see below for details on habitat classification). Depths (from the fathometer) and GPS positions were logged into the computer at intervals of approximately 5–10 seconds. The skiff was navigated bank to bank but turned away before becoming grounded. Therefore, the shallowest depths are under-represented in the depth-profile data. As the samples were taken from a skiff travelling at constant speed, the measured depths can be regarded as true cross-sectional representations of the depths in the sampled habitats.

Coarse-grained analyses

Each river was subdivided at 1km intervals, starting with Kilometer 0 at the mouth (except in the case of the Amazon, which began with Kilometer 0 at Iquitos). Effort and sightings were assigned to the appropriate kilometer by hand. The lower Samiria and Yanayacu Grande were also treated using GIS to (1) plot areas of all "classified habitats" (see below), (2) plot all survey effort and dolphin sightings, and (3) characterize densities of dolphins, by various types of habitat.

A simple, coarse-grained habitat-classification system was applied to both the Amazon-Marañón data and the Samiria-Yanayacu Grande data for what we call "kilometer-wise analysis." The question to be addressed was: Are dolphins more likely to be observed in segments of river containing one or more confluences than in segments without confluences? Each linear kilometer of river was assigned to one of two categories: with a confluence (denoted as "confluence kilometers") or without a confluence (denoted as "non-confluence kilometers"). The 17 confluences in the 232km Amazon-Marañón transect (Figure 3) were identified by reference to three

Figure 3. Schematic representation of surveyed portions of the Amazonas and Marañón rivers, showing locations of confluences (below the horizontal line) and "densities" of dolphins (animals observed per "visit," i.e. per transect through that kilometer).



sources: (1) our own field observations, (2) published maps (DMA Chart TPC M-25C), and (3) a LANDSAT image. The 49 confluences in the lower Samiria and Yanayacu Grande rivers (Figures 4 and 5) were identified by direct observation. Effort was defined by whether the survey vessel did or did not pass through the kilometer in on-effort mode during a given survey. All sightings were assigned to their appropriate kilometer. "Density" was defined as the number of groups or individuals observed, by species, divided by the number of on-effort passes through that kilometer. The effort and sighting data were divided into three water-level classes: High (A), Medium High (B,C), and Medium-Medium Low (D,E) (see Table 1 for overall effort and water levels).

Fine-grained analyses

Apart from serving as potential exchange points for dolphins moving between adjoined channels, one of the most obvious characteristics of confluences is complexity of flow. This complexity distinguishes confluences, and certain other sites as noted below, from straight, undifferentiated riverine habitat. A confluence is typically marked by swirls and counter-current eddies, the size and extent of which depend at least partly on the volume and velocity of the convergent waters. Similar complexity occurs at sharp bends, below islands, on and near sandbanks or bars, and at sites where woody debris obstructs flow.

There are no islands in the mainstem of the Samiria River. Its channel, however, is sinuous, with numerous C-curves and S-curves. Also, prominent sandbanks form in some reaches, occasionally even where the main channel is relatively straight. These banks become most evident when the water level is well below flood stage. In our analyses, we considered confluences, sharp bends, and sandbanks to be essentially stable features even though, in retrospect, we recognize that all of them, but especially sandbanks, might be more labile than we initially supposed. These relatively conspicuous features were, in any event, used as independent variables for testing dolphin habitat preferences.

We (SL and RR) classified the Samiria and Yanayacu Grande main channels during our downstream survey of 27–28 July 1993, when the water level was judged to be medium-high and declining (Figure 5). The basis for our classification scheme was as follows:

Confluences: For each tributary, we noted its position (latitude and longitude), the bank of the main river through which it flowed (left or right), the estimated or measured width (5m or less, > 5–15m, > 15–30m, > 30m), and the estimated flow rate (slow, medium, fast – an entirely subjective judgment). The latter two parameters were used to define two classes of confluence: "major" (> 15m wide with fast or high-volume flow) and "minor" (< 15m wide with slow or moderate flow). All tributaries were judged to be affluents. The "zones of influence" of confluences were considered to extend upstream, downstream, and offshore for standard distances in calculating habitat areas. These distances were derived empirically from a sample of positions taken in April or July, at high or medium-high water levels. A skiff was driven along the boundaries of mixing plumes, demarcated by visible color differences and current swirls. The positions taken in the field were later plotted on the master GIS map to position, and subsequently measure, habitat areas. The few dimensions with no measurements were estimated by interpolation.

In describing mixing zones in the mainstem of the Orinoco, Meade (1992) noted that hundreds of kilometers of downstream transport could be required before the different water types and their suspended sediments were completely mixed. Our estimated zones of influence in the Samiria system, however, basically correspond to the areas of strong visual contrast which, in the Orinoco examples cited by Meade (1992), persist for only a few kilometers downriver. It is important to acknowledge that the Samiria River system is extremely dynamic and that any fixed values, such as those used to define zones of influence in this study, are largely arbitrary and depend very much on the stage of the hydrological cycle.

Sandbanks: Sandbanks that extend into the river channel can significantly disrupt water flow. Most sandbanks that we observed formed along the inner bank of a bend, and depth was always greatest in the scoured channel on the side of the river opposite the sandbank. We noted the positions of the upstream and downstream ends of such sandbanks, then estimated the zone of influence based on the observed locations of changes in water flow relative to the start and end of the sandbank. We standardized the procedure by considering the zone of influence to extend from the upstream end of the sandbank downstream to a point 1.5 times its total length.

Bends: Sharp bends in a river alter the direction and speed of flow. We noted the positions at the beginning and end of all single turns greater than 90° and of all river segments with multiple 90° bends. In instances when depth was measured, the deepest water was always in the outer part of the curve, presumably due to scouring. The depth gradient was even more pronounced in areas where a tributary entered the river along the outer part of the curve (e.g. at The Whirlpool). The zone of influence for a bend was estimated to extend half the length upstream and half the length downstream of the bend's start and end points, respectively.

Six habitat classes were defined, as follows: 0 = none of the recognized features were present, 1 = sandbank, 2 = sharp bend, 3 = sharp bend in combination with a sandbank or confluence, 4 = minor confluence, 5 = major confluence. Throughout our discussions, we refer to class 0 as "unclassified" and classes 1–5 as "classified" habitats.

Using the GIS, the sighting and effort data were overlain onto the rivers with the classified habitats plotted. In this way, we calculated amounts of survey effort (in km^2), by habitat class, as well as numbers of dolphins and densities of dolphins (individuals/km^2), by habitat class, for each survey replicate and for each water level.

Hypotheses tested

Appropriate statistical tests were applied to the data to test the following hypotheses:

1. Dolphin densities differed between kilometers of river with and without confluences (Amazon-Marañón and Samiria-Yanayacu Grande tested separately and comparatively).
2. Dolphin densities differed between "classified" and "unclassified" habitats in the Samiria and Yanayacu Grande.
3. Habitat preferences of each species varied seasonally (i.e. by water level).

Based on our own preliminary observations of river dolphins and on statements in the literature (see Introduction), we expected dolphin distribution to be non-random and non-uniform, with higher densities in or near confluences, sharp bends, exposed sandbanks with large, gently sloping, submerged components, and possibly other interruptions of flow, than in the straighter, simpler (i.e. "unclassified") reaches.

Results

Coarse-grained analyses, Amazon-Marañón

The sighting data consisted of 156 *Inia* groups (258 individuals) and 150 *Sotalia* groups (352 individuals).

Inia were significantly attracted to confluence kilometers [48.1% of all individuals, while confluences represented only 6.8% of overall linear kilometers of river ($z = 26$, $P < 0.00001$); 44.9% of all groups vs. 6.8% of linear kilometers of river ($z = 19$, $P < 0.00001$)]. There was no statistically significant evidence that attraction to confluence kilometers depended on season, i.e. water level (individuals: Chi Square = 4.8, df = 2, $P = 0.14$; groups: Chi Square = 3.1, df = 2, $P = 0.21$). The same inferences apply to *Sotalia*: 23% of both individuals and groups were seen in confluence kilometers, while only 6.8% of river length consisted of confluence kilometers (individuals: z = 2.2, $P < 0.00001$; groups: z = 8, $P < 0.00001$); and for attraction to confluence kilometers by season, Chi Square = 4.9, df = 2, $P = 0.09$ (individuals); Chi Square = 0.9, df = 2, $P < 0.65$ (groups).

Coarse-grained analyses, Samiria-Yanayacu Grande

The same tests were applied to 573 sightings in the Samiria and Yanayacu Grande (*Inia* 382 groups, 628 individuals; *Sotalia* 191 groups, 469 individuals), with the following conclusions:

- Overall, *Inia* groups and individuals were more likely to be found in confluence kilometers than would be expected by chance ($z = 5.8$, $P < 0.00001$; and $z = 6.5$, $P < 0.00001$, respectively). However, there was strong seasonal (i.e. water-level) variation in the degree of their affinity for confluence kilometers. A 95% confidence interval for the proportion of *Inia* individuals found in confluence kilometers at high water (CI = 5.7%–17.5%), although not conclusive, suggests that the preference by *Inia* for confluence zones weakens or disappears at high water (at medium-high and medium-medium low water, 31% and 33%, respectively, of the *Inia* individuals were observed in confluence kilometers; Leatherwood 1996: his Table 24). Among the more plausible explanations for this tendency is that the animals move into the smaller appended water bodies, and possibly also the flooded forest, when the water level is high (see below).
- *Sotalia* also showed a strong affinity, overall, for confluence kilometers ($z = 3.3$, $P < 0.001$, and $z = 3.1$, $P < 0.001$ for groups and individuals, respectively). Again, however, there was a strong seasonal effect, with the greatest affinity for confluence kilometers at medium high water and no significant association with confluence kilometers at high water.

Coarse-grained analyses, comparing the two datasets

Some differences may exist in the way dolphins use confluence areas in the Amazon-Marañón vs. those in the Samiria-Yanayacu Grande. Confluences appear to attract dolphins of both species, at all water stages, in the Amazon-Marañón. Although we did not survey during the low-water season, we suspect that confluences become even more attractive to dolphins then, providing concentrated prey resources and safety from stranding. The attractiveness of confluences to dolphins in the Samiria and Yanayacu Grande seems to diminish, and may even vanish, at the high-water stage. This could be explained in a number of ways. At this time, the dolphins have maximal access to lakes, small tributaries, and the flooded forest. Any foraging benefits provided by confluences (e.g. as areas where prey are concentrated or made catchable at less energy cost) might be diluted during high water as fish disperse outside the main river channels (see Goulding 1980). The hydraulic refuge provided by counter-currents at confluences may be reduced, especially if the main channel has a proportionally greater flow than the tributary during high water. Moreover, the difference in depth between the scour hole of the counter-current and the adjacent river channel may be less during high water, and this could wash out the hydraulic refuge effect (B.D. Smith, pers. comm.). It is also possible that the dolphins in confluences are less easy to detect and count during high water, whether because they remain submerged longer or because of increases in turbulence and water surface area.

Dolphin densities, displayed opposite the positions of confluences along the Samiria (Figure 4), suggest some clustering but also a more consistent use of the entire river length than is the case for the Amazon-Marañón (compare with Figure 3).

Fine-grained analyses, Samiria and Yanayacu Grande

The same 573 sightings of 1097 dolphins were included in the detailed analyses of habitat preference using the GIS.

The proportions of dolphins of both species within confluence zones were significantly greater than expected by chance for all of the water levels that were sampled (*Inia*: high, $z = 6.4$, $P < 0.00001$; medium-high, $z = 10.7$, $P < 0.00001$; medium-medium low, $z = 9.7$, $P < 0.00001$; *Sotalia*: high, $z = 7.9$, $P < 0.00001$; medium-high, $z = 2.6$, $P < 0.01$; medium-medium low, $z = 4.3$, $P < 0.00001$). The densities in non-confluence areas were approximately the same as the overall densities, which is not surprising since most of the river area was non-confluence habitat. The densities in confluence areas, by contrast, were much greater (by two to six times) (Table 2).

Table 2. Dolphin "densities" (individuals counted/km²) in Samiria-Yanayacu river system in confluence and non-confluence areas.

	Density					
	Inia			*Sotalia*		
Habitat	High	Medium High	Medium-Medium Low	High	Medium High	Medium-Medium Low
Confluence areas	23.35	20.95	14.71	30.54	5.99	7.06
Non-confluence areas	4.31	4.71	2.29	5.09	2.97	2.08
All areas combined	4.76	5.23	2.72	5.69	3.07	2.25

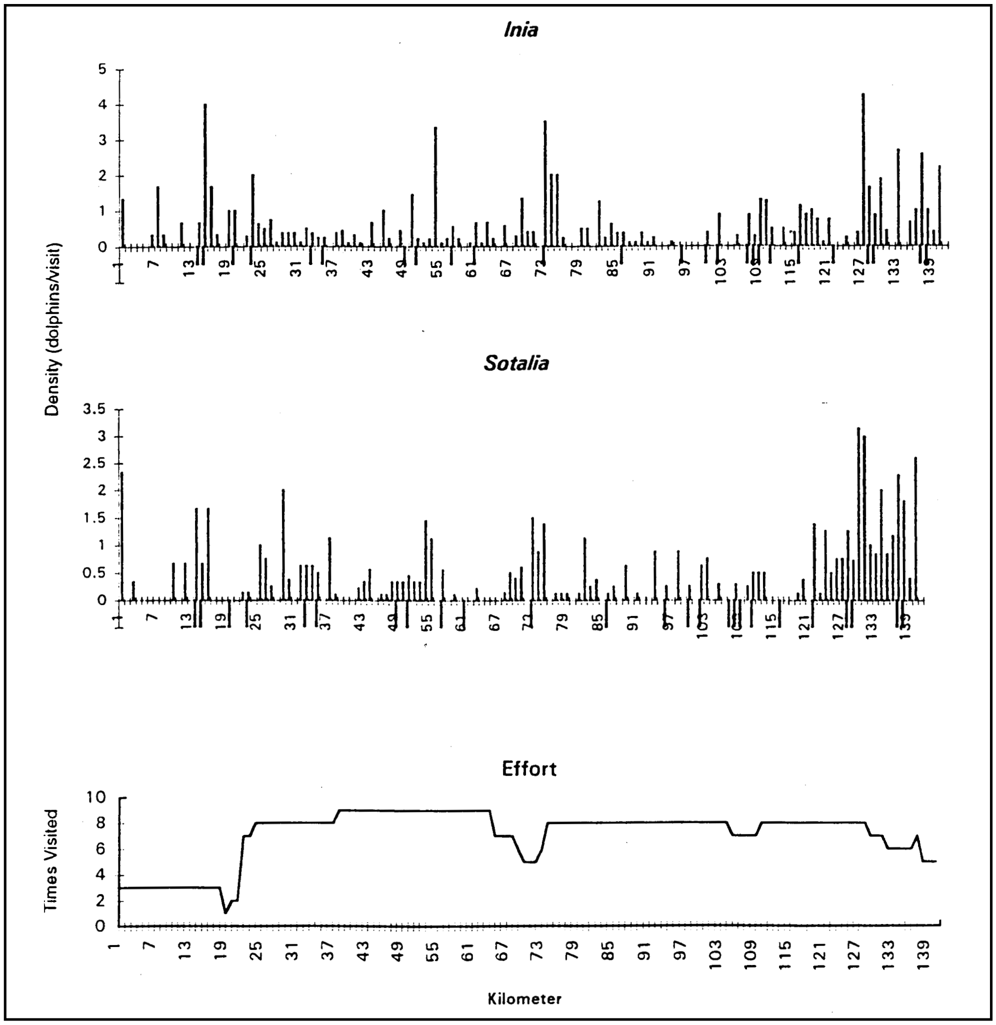


Figure 4. Schematic representation of surveyed portion of the Samiria River, showing locations of confluences (below the horizontal line) and "densities" of dolphins (animals observed per "visit," i.e. per transect through that kilometer).

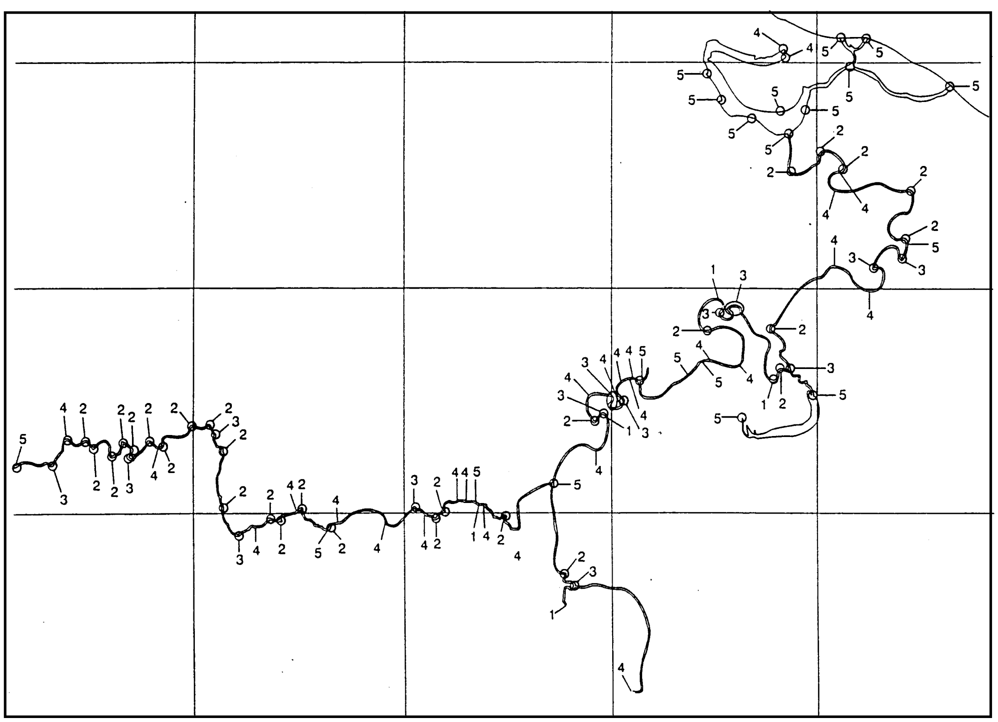
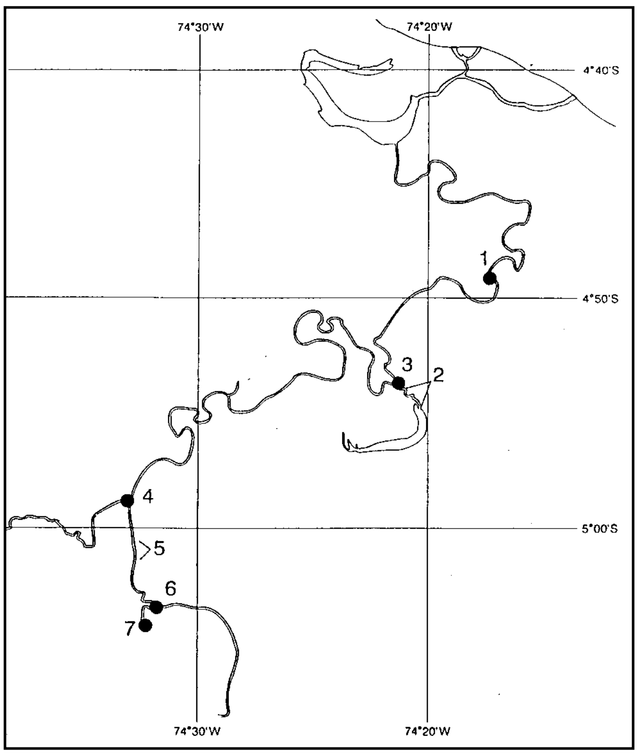


Figure 5. GIS map of the Samiria and Yanayacu Grande rivers, showing locations of classified habitats based on observations on 27–28 July 1993, when the water level was medium-high and declining: 1, sand bank; 2, one or more sharp river bends; 3, one or more sharp bends with a sandbank or a confluence (or both); 4, minor confluence; 5, major confluence (see text for definitions).

Influences of water depth

To investigate the possibility that water depth might help explain the habitat preference of dolphins, we compared the distribution of depths in a sample of "classified" and "unclassified" habitats (Figure 6 and Table 3). Not only were the absolute depths in all of the measured classified habitats (except one) greater than those in the measured unclassified river segment, but also the distributions of depths in classified habitats were significantly different from that in unclassified habitat (ANOVA, F = 2.101, df = 6, $P < 0.0001$). In other words, the classified habitats offered deeper holes and higher volumes of water per unit of surface area than a typical straight reach of river with no confluence or sandbank along its course.

Figure 6. Sites ("habitats") where depths were measured in July 1993, when the water level was medium-high and declining: unclassified, 3 and 5; sandbank, 7; confluence, 4; bend with – sandbank, 1, confluence, 2, and both sandbank and confluence, 6.



One dramatic exception to the tendency of dolphins to remain in the deeper portions of classified habitats was noted. On 24 July 1991, one of us (SL) observed 13 *Inia* (including at least five small calves) and four to five *Sotalia* in a sharp bend with a sandbank. During 85 minutes of continuous observation, the *Sotalia* came and went in mid-river, while the *Inia* appeared to follow a pattern. Calves circled slowly over the shallow water on the sandbank side, alone or in pairs. The larger *Inia*, some of which were presumed to be the calves' mothers, dived and surfaced in deep water near mid-river for up to four minutes, then returned to the shallows, each joining one of the calves. After a brief reunion with the calves, the larger animals would return to the deep water. There was no suggestion that fish were being brought to the shallows so that the adults could introduce the calves to solid food. Rather, this scenario seemed to represent a kind of "nursery," with the microhabitat partitioned to accommodate the needs of both the adults and the very young, dependent calves.

Discussion

Relative importance of water type

Best and da Silva (1989a) stated that *Inia* are not limited in their overall distribution to waters with particular qualities of acidity and transparency, as has sometimes been alleged (Pilleri and Gihr 1977; Pilleri and Pilleri 1982; Tagliavini and Pilleri 1984; Grabert 1984). Da Silva and Best (1994) affirmed that *Sotalia*, also, occur in all three types of Amazonian waters and that "physical factors such as visibility and pH appear not to affect their distribution directly."

The implication by Best and da Silva (1989a) that densities of *Inia* are likely to be lower in the oligotrophic blackwater rivers than in the more nutrient-rich whitewater and clearwater rivers is not borne out by our data from

Table 3. Comparison of distribution of depths in classified and unclassified habitats. All measurements were made at medium-high water in July 1993. "Height below maximum" refers to the amount below the maximal water level in 1993, estimated from persistent water marks on trees and structures.

Site (numbers refer to Fig. 6)	Habitat class	N (no. of depth measurements)	Mean of depth measurements (m)	Height below maximum (m)
Elder Hostel Bank (1)	Bend with sand bank	542	9.13	4.88
Whirlpool (2–3)	Bend with confluence	582	9.31	4.57
Ungurahui (7)	Sand bank	709	8.11	–
Ungurahui-Samiria (6)	Bend with sand bank and confluence	226	6.31	4.95
Ungurahui to Yanayacu Grande (5)	Unclassified	542	6.12	4.80
Yanayacu Grande-Samiria (4)	Confluence	408	8.62	4.88

Perú (see Leatherwood 1996). We found no clear correlation between the density of dolphins and the chemical characteristics of water, although admittedly we did not conduct any rigorous analyses to address this topic. If anything, densities of both *Inia* and *Sotalia* may be higher in some blackwater systems than in whitewater and clearwater habitats (Leatherwood 1996). The paradox of "rich life in poor water" probably applies to the Pacaya-Samiria system as it does, for example, to the Rio Negro in Brazil (Goulding *et al.* 1988). While both *Inia* and *Sotalia* use waters of all types, much of their activity in large whitewater rivers, *Inia*'s in particular, seems to be directed swimming, as though the animals were transiting between patches of preferred habitat (e.g. confluences and possibly the lower ends of sandbars and islands). Meade and Koehnken (1991) also found no correlation between the chemical characteristics of water and the distribution of *Inia* in the Orinoco River system.

Relative importance of water flow characteristics

Magnusson *et al.* (1980) used data from two survey days in a 290km segment of their study area to analyze the effects of tributaries and turbulence on group size and number of groups for *Inia* and *Sotalia*. Their study was conducted at a time when the Solimões was judged to be one-third of the way through its seasonal decline of about 10m (equivalent to our medium-high declining, or water level C; see Table 1). The number of groups of *Sotalia* in the Solimões was significantly higher at the mouths of tributaries than would be expected by chance (Chi Square = 5.33, $0.025 < P < 0.05$), and this relationship approached the level of statistical significance for *Inia* (Chi Square = 3.44, $0.05 < P < 0.10$). Magnusson *et al.* stated that it was their "subjective opinion" that *Inia* occurred at higher densities in areas of increased turbulence. The clear tendency of *Sotalia* and probable tendency of *Inia* to congregate at the junctions of tributaries was thought to be related to food availability (Magnusson *et al.* 1980; also see Meade and Koehnken 1991). While acknowledging that *Inia* occur in "nearly all types of micro-habitat", Best and da Silva (1989a:25) noted that these dolphins occur at highest densities in confluences, just below rapids, and in smaller channels running parallel to the main river. They accounted for the increased densities at confluences and below rapids by suggesting that there would be "more fish movement" in such areas and that the currents might "help disorient fish schools, making them easier prey for the dolphins" (also see da Silva 1983, 1986).

We did not collect data on "turbulence" and therefore cannot make direct comparisons with the findings of previous authors concerning this factor. Our habitat data from the Amazon and Marañón relate only to the presence or absence of confluences. It is therefore only in regard to this factor that we have any basis for comparing habitat preferences of dolphins in our study area to those in the Solimões. If anything, our data support, even more strongly than those of Magnusson *et al.* (1980), the hypothesis that both species of Amazonian dolphin are attracted to confluences. Henningsen (1998) found a similarly strong attraction of both species to confluences in the Samiria, Pacaya, and Tapiche rivers. He also found a secondary attraction to sharp bends in these rivers, especially bends of more than 90°.

It has often been stated that *Sotalia* have a greater affinity for "open" areas (river channels and lakes) than *Inia*, and that only the latter tend to enter flooded forests, swampy areas, flooded grasslands, and shallow or constricted waterways (da Silva 1983, Best 1984). Da Silva (1986) advocated the hypothesis that *Inia* and *Sotalia* manage to live in partial sympatry by a combination of character divergence and resource partitioning. *Inia* are considerably larger and have much longer beaks, larger flippers, and greater neck mobility. They also have sensory vibrissae on the rostrum and differentiated teeth. These features distinguish them from *Sotalia* and may make them more versatile predators. A comparison of the prey species found in the stomachs of 22 *Inia* and 29 *Sotalia* sampled in Brazil indicated a more diverse diet for *Inia*: 43–45 vs. 28 species (da Silva 1983, Best 1984). There was some overlap (14 prey species are shared), but the *Sotalia* contained primarily pelagic, schooling fishes, while the *Inia* had consumed substantial amounts of benthic, solitary species as well (Best 1984).

We obtained little evidence that either *Inia* or *Sotalia* move far into flooded forests, except via the small rivulets, or secondary channels, that are often obstructed by living vegetation, leaf litter, or woody debris, making them difficult to penetrate with powered skiffs. Although we have heard dolphins blowing and splashing in the forest on a few occasions, it is our impression that most of their time is spent within or near the borders of rivers and lakes as defined by the edge of high forest. On those few occasions when dolphins were heard in the forest, the water was high and the dolphins were in or near tributary streams. Thus, the animals may have been using channels, albeit now deeply submerged and unapparent to a human observer, rather than venturing randomly onto the floor of the flooded forest.

Depth preferences

Published evidence for depth preferences of river dolphins is mainly anecdotal and qualitative. Few attempts have been made to measure and compare depths in areas where dolphins were observed with those in areas without dolphins. It has been claimed that *Platanista* and *Lipotes* remain in deep water except when chasing fish or moving between deep pool areas (Reeves *et al.* 1993). Pilleri and Gihr (1977) claimed that *Inia* prefer deep, calm river reaches, and Best and da Silva (1989b) acknowledged that *Inia* might be restricted to deep channels during the low-water season. *Sotalia* in the Brazilian Amazon are said to prefer the main channels of rivers and to enter lake systems only during high water (da Silva and Best 1994).

Initially, we had the impression that both *Inia* and *Sotalia* favored the deeper portions of confluences, bends, and sandbank areas, judging by bank slopes and surface characteristics of water flow. We also suspected, and later confirmed, that these areas contained relatively deep pools, formed by scouring driven by the centrifugal force, or sheer, at sharp bends and confluences.

If the preference of Amazonian dolphins for "classified habitats" is related to water depth, i.e. water volume per unit of surface area, as suggested by the findings of this study, it is appropriate to ask what it is about this feature that makes it attractive. Does the extra three-dimensional space provide greater security? If so, from what? Predators? Stranding? Or is the effect indirect? For example, are prey animals more abundant or more easily caught in deeper waters? And if so, why is that? Is the ultimate cause of an area's attractiveness related to nutrient dynamics or hydraulics rather than to animal behavior, *per se*? It is always possible, of course, that depth is an incidental feature of areas to which dolphins are attracted, and that deeper water has little or no bearing on the appeal of such sites. For example, it may be the hydraulic refuge provided by counter-currents and eddies that attracts dolphins, and the increased depth (itself the result of scouring action by the counter-currents and eddies) may be irrelevant. The increased availability of prey might, then, be an additional, or secondary, benefit of spending time in a confluence. Alternatively, confluences might be important to dolphins mainly because of the array of options that they offer, most notably that of access to other waterways and microhabitats.

Conclusions

The Samiria River system provides diverse aquatic microhabitats: slow-flowing lakes, fast-flowing stream channels, mixed convergence zones, sharp river bends with their associated eddies, sandbanks, and deeply scoured troughs, as well as the seasonally-flooded floor of the high forest (see Bayley *et al.* 1992). While many physical features of these habitats are fairly homogeneous (e.g. water temperature, acidity, color, clarity), they are also dynamic because of the extreme within-year and between-year variation in water levels. To assess the relationship between dolphin distribution and fine-scale habitat characteristics, it would have been necessary to make a suite of measurements (e.g. current speed and direction, surface and deep water temperature, dissolved oxygen, pH, suspended sediment/clarity/turbidity, conductance) during each survey replicate, in areas with high densities of dolphins and in an equivalent sample of randomly selected locations. Repeated sampling of fish availability (for example, by netting, hook and line, or sidescan sonar) would have been a useful adjunct to other environmental measurements.

The habitat features used in the present study were mainly coarse-grained. We began with the assumption that the critical effect was the interruption of the river current and the creation of eddies and swirls (see Smith 1993). We also assumed that areas of interrupted flow could be detected from visible signs. With further knowledge, it should be possible to find more meaningful (quantitative) and inclusive definitions of "habitats" for comparisons.

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Genetic and Demographic Considerations for the Conservation of Asian River Cetaceans

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Abstract

The survival of Asian river cetaceans is threatened most obviously and tangibly by habitat degradation, pollution, and direct and indirect human-induced mortality. These animals face an additional suite of potentially serious problems that are often overlooked, perhaps because they are not so obvious. The genetic and demographic consequences associated with very small population size can result in extinction even when effective measures are in place to protect the animals and their habitat. Small populations tend to harbor less genetic variation than large populations. In addition, small populations are more strongly affected by processes of genetic drift and inbreeding, both of which can further reduce genetic variability. Genetically depauperate populations may have lower fitness, a reduced ability to adapt to changes in their environment over time, and decreased evolutionary potential. Finally, small populations may also be more vulnerable to demographic stochasticity, which can accelerate the process of extinction. Awareness of the genetic and demographic consequences of small population size should be integral to planning for conservation of endangered river cetacean species and populations. This paper attempts to define these processes, explain their importance, and provide guidelines for investigating genetic and demographic questions. The goal is to provide a sound basis for making decisions about translocation and other types of intervention for conservation.

Introduction

Four primary factors have generally been recognized as contributing to recent species extinctions: habitat degradation (encompassing fragmentation and loss), overkill (intentional or not), non-native species introductions, and pollution (Primack 1993, Frankham 1995a). These factors can reduce population sizes and greatly increase the probability of extinction due to chance events. Stochastic perturbations can cause a population to go extinct even in an environment that seems favorable for the population's continued existence (Shaffer 1981).

At least three of the four factors identified by Frankham (1995a, above) – habitat degradation, overkill, and pollution – are playing a role in the decline of Asian river cetaceans, intended here to include the baiji (*Lipotes vexillifer*), the bhulan or Indus dolphin (*Platanista minor*), the susu or Ganges dolphin (*Platanista gangetica*), the Irrawaddy dolphin (*Orcaella brevirostris*), and the finless porpoise (*Neophocaena phocaenoides*) (Perrin and Brownell 1989, Reeves *et al.* 1993, Leatherwood and Reeves 1994). The baiji is classified as Critically Endangered, and the Indus and Ganges dolphins and the Yangtze River population of finless porpoises as Endangered, in the *1996 IUCN Red List of Threatened Animals* (IUCN 1996). The Irrawaddy dolphin and the marine populations of finless porpoises have been classified by IUCN as Data Deficient, meaning that too little is known about them to assess the risks of extinction.

All three platanistoids (baiji, bhulan, and susu) have small populations that are artificially fragmented by dams and barrages, although the segment of its historical range presently occupied by the baiji is continuous. The most abundant of them, the susu, is believed to number in the low thousands (authors' judgment from the literature), the bhulan in the hundreds (Reeves and Chaudhry 1998), and the baiji in the tens (see Liu *et al.* 1997, Zhou *et al.* 1998). In addition, these animals have relatively low reproductive capabilities in comparison to many mammal species, and their geographic ranges are restricted, with little or no possibility of dispersal. This latter point is a crucial aspect to consider for river dolphin conservation. Because these species have narrow ranges and specialized habitats, they are limited in their ability to disperse to new areas should their current habitats be degraded or destroyed. As a result, adaptive change is the chief means by which these species can respond to changes in their environment, whether man-made (e.g. pollution, habitat fragmentation) or natural (e.g. climate change). Genetic variability is the basis for adaptive change, and hence, conservation of genetic variability in these species should be of utmost concern.

In this paper, we identify and discuss some of the genetic and demographic problems associated with small population size, with explicit reference to the river cetaceans of Asia. We also consider what types of genetic information could be obtained that would inform discussions of management strategies. Our overall aim is to underscore the importance of maintaining relatively large population sizes and expansive distributions to minimize the risks of extinction.

The role of random events in extinction

As mentioned above, habitat degradation and loss, exploitation, species introductions, and pollution can reduce populations to levels at which stochastic processes significantly affect their viability. Such stochastic processes include: environmental uncertainty (unpredictable or random variations in competitors, predators, parasites, disease, food supply, and climate, or changes in habitat quality); demographic uncertainty (random variations in survival and reproductive success of members of a population); natural catastrophes (floods, fires, droughts, typhoons, etc.); and random changes in genetic composition (loss of genetic variability, inbreeding, and genetic drift) (Shaffer 1981). The importance of these stochastic processes in causing extinctions increases as population size decreases. In particular, very small populations (10s–100 animals) are extremely vulnerable to random fluctuations in reproductive success of the breeding adults, and the genetic consequences of small population size can also be severe. These random processes are not mutually exclusive, so several of them may be acting on a population simultaneously. For example, a decrease in habitat quality or quantity can result in a decrease in the size of the population that can successfully reside in that habitat. The decrease in population size in turn may make the population more susceptible to further disturbances, including stochastic environmental events. This in turn can further reduce population size, resulting in a negative spiral of population viability. This type of downward spiralling has been termed an extinction vortex (Gilpin and Soulé 1986) and can rapidly lead to extinction. Habitat destruction and fragmentation, overharvesting, inbreeding and genetic drift, and environmental and demographic stochasticity can all contribute to an extinction vortex.

The extinction of the heath hen (*Tympanuchus cupido cupido*) illustrates the interactions and effects of these stochastic processes (here paraphrased from Shaffer 1981). European settlement during the 1800s precipitated the decline of this bird, which had been fairly common in eastern North America from New England to Virginia. By 1900, the heath hen was found only on an island off the coast of Massachusetts, and the population was estimated at approximately 100 individuals. With protection from predators, by 1916 the population had increased to approximately 800. However, a fire (natural catastrophe) that year destroyed most of the nests and much of the species' habitat. The following winter the population experienced unusually high predation (environmental stochasticity), which reduced the number of birds to 100–150. In 1920, disease (environmental stochasticity) reduced the population to fewer than 100 birds. The population continued to decline and experienced increasing sterility and an increase in the proportion of males (genetic and demographic stochasticity). The last bird died in 1932.

Why is genetic variation important?

This question is central to any discussion of the potential genetic problems faced by small populations. Genetic variability occurs as a result of individuals having different forms of a gene, known as alleles. Genetic variability can be considered on two levels – that of the individual and that of the population or species. Heterozygous individuals have two different alleles of a gene and are genetically more variable than individuals with two copies of the same allele of that gene (homozygotes). This measure becomes particularly significant when considered across multiple genes. Heterozygosity, or genetic variability, at the level of the individual is important because it has been positively correlated with fitness (Soulé 1980, Frankel and Soulé 1981, Soulé 1986, but see also Charlesworth 1991). In a heterozygote, each allele may perform optimally under different conditions, so an individual bearing two different alleles of a gene may function optimally over a broader range of conditions than a homozygous individual. Heterozygous individuals tend to have higher survival, disease resistance, growth rates, and reproductive success (Soulé 1986). At the level of the population or species, heterozygosity can be measured as the proportion of heterozygous individuals within the population, and it can also be measured in terms of allelic diversity, i.e. the number of different alleles present at a locus or loci within the population. Genetic variability at this level is important because it provides that population or species with evolutionary potential or flexibility. The larger the population, the more genetic variability it is likely to harbor (Frankham 1996). The more genetic variability a population has (heterozygosity of allelic diversity, for example), the better it may be able to cope with, and adapt to, natural or human-caused changes in its environment over time (Soulé 1980, Frankel and Soulé 1981, Allendorf and Leary 1986, Gilpin and Soulé 1986). For species like obligate river dolphins (*sensu* Leatherwood and Reeves 1994) that generally cannot disperse and colonize new habitat, adaptive change is the primary means of coping with changes in the environment.

Why are small populations especially prone to lose genetic variation?

One reason that small populations are at increased risk of extinction is that they are especially susceptible to loss of genetic variation. Processes that can reduce genetic variation and have particularly strong effects on small populations include genetic drift and inbreeding, and bottlenecks and founder events. All four processes are relevant to conservation efforts aimed at Asian river cetaceans. Before discussing them, however, it is necessary to distinguish between total population size and effective population size.

The concept of effective population size

Population size (N) usually refers to the total number of animals in the population (i.e. population abundance), which is often estimated from sampling surveys or direct counting (see Smith and Reeves, this volume). Not all members of a population are breeding at a given time, however, so N may not be representative of the number of animals that pass on their genes to the *next* generation. Discussions of population size, in the context of population genetics, usually concern the effective population size, or N_e. N_e is defined as the number of individuals in a theoretical "ideal" population experiencing the same amount of random changes in allele frequencies (genetic drift) as the real population of size N. An "ideal" population is one in which there are non-overlapping generations, a constant population size, an equal sex ratio, random mating, no immigration or emigration, no selection, and no mutation. Few, if any populations of diploid, sexually reproducing individuals conform to these assumptions. Hence, corrections must be made to accurately model the changes in genetic variation that occur in a population through time. Calculating N_e corrects for the complications of the natural world. At its most basic level, N_e may be considered an estimate of the members of a population that are contributing genetically to the next generation. These are the individuals most important to the viability and persistence of a population through time. The rate of loss of genetic variability and inbreeding in a population is estimated based on N_e rather than on N.

In an "ideal" population, N_e is equal to N. As mentioned above, one feature of this ideal population is that it consists of randomly mating individuals with a sex ratio of 1:1. Also, the number of offspring per family has a Poisson (i.e. random) distribution. Under most circumstances, N_e is smaller than N, particularly for mammal populations. Frankham (1995b) suggested that N_e may be an order of magnitude lower than N, although other authors have suggested that it more likely lies between $0.25N$ and $0.75N$ (Nunney and Elam 1994, Waite and Parker 1996). Nunney (1993b) suggested that for organisms with long generation times, N_e converges on $N/2$. Waite and Parker (1996) took Nunney's work one step further and concluded that his result applied particularly to taxa in which the age to sexual maturity (M) is short relative to total reproductive lifespan (A), as is true of most mammals. Overall, for discussion of insular cetacean populations, it is important to bear in mind the relationship between N and N_e. Although there may be 100–150 animals in a segment of river between two dams or barrages, the number contributing to the genetic diversity of the next generation (N_e) could be as low as 25 individuals. This is a critically low number, and it is such values that raise concern about the loss of genetic variability in small populations.

Effective population size can be influenced by several factors. N_e will be smaller than N if the sex ratio of breeding adults is unequal. For example, in a monogamous species existing as an isolated population of 2 males and 10 females (N=12), the effective population size is only 4 (2 males and 2 females), leaving 8 reproductively mature females unable to contribute to the next generation at that time. N_e is also affected by variations in reproductive output among individuals in a population. When this variation is high, N_e is lower than N, again because a limited number of individuals are making a disproportionately large contribution to the genetic composition of following generations. Finally, N_e is affected by fluctuations in population size over time. Thus, a single generation that includes a drastically reduced population size will lower N_e. The most significant loss of genetic variation will occur if the population size is small for several generations (Amos 1996).

Loss of genetic variation in small populations

The amount of genetic variation maintained within an isolated population is determined by the interactions of genetic drift, mutation, and selection. Genetic drift is defined as the random change in gene frequencies in a population due to chance alone (Meffe and Carroll 1994). Passing genes from one generation to the next involves the random sampling of gametes. As with any random process, the sampling error involved increases with decreasing sample size. For example, if you tossed a coin 500 times, you would expect to see approximately 250 heads and 250 tails. If you only performed five tosses, the likelihood of seeing all heads or all tails would be much larger, simply as a result of your small sample size. Similarly, in small populations, gene frequencies change from one generation to the next due to statistical sampling error in the process of "choosing" gametes or genes from the available gene pool during reproduction. This is called genetic drift. Random changes in gene frequencies generally result in a gradual decrease in heterozygosity in a population, and can result in fixation of alleles. Because small samples frequently do not represent the entire range of variation within a species, genetic drift causes more dramatic changes in gene frequencies in small populations than in large populations. Isolated populations lose a percentage of their original genetic variability at a rate of $1/(2N_e)$ per generation due to genetic drift (Soulé 1980). The smaller the population, the more significant this loss becomes. For example, a population of $N_e = 1000$ individuals will lose on average 0.05% of its genetic variability per generation, while a population of $N_e = 50$ individuals will lose 1% per generation. This becomes significant when the loss is compounded over multiple generations. For example, because heterozygosity is lost each generation, over 25 generations an effective population of 50 individuals will contain less than 82% of the genetic variability found in the original population, while an effective population of 1000 will retain over 99% of its original genetic variability. Inbreeding (see below) will exacerbate this effect.

If genetic drift is not countered, the result can be the total loss of heterozygosity in a population. Countering drift requires the introduction of new genetic variability. This can be achieved through either genetic mutations or gene flow, i.e. immigration from other populations. Mutation rates are generally not high enough to counter the effects of genetic drift in small populations. Hence, the movement of animals among subpopulations may provide the best means of maintaining genetic diversity within a metapopulation consisting of two or more small subpopulations. Artificial exchange may be necessary, as in the case of the Florida panther, a critically endangered subspecies of *Puma concolor* (Seal 1994, Hedrick 1995).

Inbreeding is also of concern in small populations. It involves the mating of individuals who are likely to share some genes because they have one or more recent ancestors in common. As the population size decreases, the total number of possible parents in the population also decreases, resulting in an increase in the probability of inheriting alleles that are identical by descent. Inbreeding results in a decrease in heterozygosity, within individuals and within the population. It can also result in an increase in the frequency and possible fixation of deleterious alleles. In a very small population, adults may have no choice but to breed with close relatives. The effects of inbreeding are manifested as "inbreeding depression," which can include decreased fecundity and reproductive success, smaller offspring size, slower growth rates, and reduced survivorship (Ralls *et al.* 1986).

Inbreeding depression has been documented in both small captive (Ralls and Ballou 1986) and small wild populations (see Frankham 1995b). Inbred lines of mice are more frequently lost (i.e. go extinct) than outbred mice, and inbred lines that do survive over several generations show an increase in fitness if they are crossed with each other or with outbred lines (Bowman and Falconer 1960). These findings support the concept that inbreeding can lead to extinction. More controversial is whether inbreeding contributes to extinction in wild populations. The sample sizes, in the form of known matings, required to document inbreeding depression are usually not obtainable in studies of wild populations. For example, Lacy (1997) estimates that the sample sizes required to detect a 1% decline in survival for a 1% increase in inbreeding in prairie dogs *Cynomys ludovicianus* ranges from 128 half-sibling matings to 500 first-cousin matings, plus an equal number of non-inbred matings. Clearly, such numbers are extremely difficult to achieve in studies of wild populations. Nevertheless, a few studies of mammals in natural habitats have documented the deleterious effects of inbreeding. Stockley *et al.* (1993) found that shrews (*Sorex araneus*) from inbred matings were smaller at weaning and less likely to survive to maturity than non-inbred shrews. Jiménez *et al.* (1994) found that inbred white-footed mice (*Peromyscus leucopus noveboracensis*) produced from brother-sister matings were less likely to survive in a woodland habitat than non-inbred mice. Finally, Saccheri *et al.* (1998) effectively demonstrate that inbreeding can contribute to extinction in wild populations of butterflies. While it may be next to impossible to demonstrate that inbreeding is directly responsible for the extinction of wild populations of cetaceans, the loss of genetic variation that accompanies inbreeding certainly decreases a population's ability to adapt to changes in its environment, a situation that can itself lead to extinction.

Given the negative consequences of decreased genetic variation, including inbreeding depression, decreased fitness, and decreased evolutionary potential or adaptability of a population or species, the maintenance of genetic variability should be one of the goals of any conservation program for river cetacean populations.

How many individuals are required?

This is an extremely important question in any conservation strategy, but it is difficult to answer. Despite considerable work on the topic (Soulé 1987a, Nunney and Campbell 1993), it is not possible to establish a universally applicable "minimum viable population size." There are several reasons. First, non-biological factors influence the estimation of a minimum viable population size. Consideration must be given to the length of time into the future that we wish for the population to persist (e.g. tens of years, centuries, longer), and to the level of risk that we are willing to accept with respect to the population's extinction. For example, should a minimum viable population be one with a 50% probability of persisting for 100 years, or a 95% probability of surviving for 1,000 years? Second, each species or population experiences different environmental and genetic conditions. This makes it virtually impossible to ascertain a universally applicable value for minimum viable population size. Soulé (1987b) suggests that a minimum viable population should be one with a "95% expectation of persistence without loss of fitness for several centuries." He concedes that this is a "risk-averse" definition, appropriate to the conservation of the last population of an endangered species, and that higher levels of risk may be acceptable for individual subpopulations.

Populations of fewer than 100 individuals, regardless of the species, are "extremely vulnerable" to loss of evolutionary potential and accumulation of deleterious genetic mutations (Lynch 1996). Berger (1990) studied the persistence of bighorn sheep populations (*Ovis canadensis*) in southwestern North America. He found that 100% of those with 50 or fewer individuals went extinct within 50 years, while those with more than 100 individuals persisted for up to 70 years. Unfortunately, there was insufficient data to follow the populations for more than 70 years. Franklin (1980) and Lande and Barrowclough (1987) suggested that, from a genetic perspective, an effective population size of at least 500 animals is necessary to ensure the long-term viability of any population. Given the relationship between N and N_e, this would translate into a total abundance of at least several thousand individuals. More recently, Lande (1995) has suggested that an N_e of 5000 is required to retain evolutionary potential. Again, however, it is necessary to emphasize that a universal number is not adequate because the conditions experienced by each population and species are unique.

Demographic stochasticity

In addition to considering genetic factors that affect small populations, it is important to recognize that such populations are sensitive to demographic stochasticity, i.e. random variation in birth rates, mortality rates, and sex ratios. As population size decreases, the role of demographic variation becomes increasingly important in determining the viability of the population. In populations of fewer than 50 individuals, demographic stochasticity can significantly contribute to the process of extinction (Shaffer 1987, Lande 1988, Meffe and Carroll 1994). For example, consider an effective population of four dolphins consisting of two breeding pairs, a scenario that may not be unrealistic in river reaches upstream of some dams or barrages (Reeves *et al.* 1991, Smith *et al.* 1994). There is a 25% probability that the first calf from both females will be male, and if each female produces only two surviving calves in her lifetime, there is a greater than 6% probability that the next generation will be all males (or all females). While this is an extreme example, it is not without precedent. For example, the last five surviving dusky seaside sparrows (*Ammodramus maritimus nigrescens*) were male (Primack 1993).

Future considerations

If one's goal is to reduce an endangered species' susceptibility to the genetic and demographic problems discussed above, two measures might be considered. First, effective population size should be maintained at a high level to minimize the risks posed by demographic variation and genetic problems. Individuals, therefore, need to be protected to the greatest extent possible. Second, careful consideration should be given to the question of whether it is better to maintain a single large population or multiple small subpopulations. The advantage of a single large population is that the demographic and genetic problems discussed above can be more readily avoided. However, if environmental stochasticity or rare catastrophic events are important risk factors, as they may be for freshwater cetaceans in Asia, then multiple subpopulations, individually large enough to keep demographic and genetic risks reasonably low, may be favored.

If the maintenance of several subpopulations is deemed the preferred option, a second question arises: How much mixing of individuals among subpopulations should be supported? If the subpopulations are kept completely isolated, the amount of genetic diversity of the species, overall, might be maintained as the separate populations diverge from one another through time. This strategy could then be seen as maximizing the evolutionary potential of the species as a whole. However, each isolated subpopulation is likely to maintain less and less of its genetic variability (i.e. become more homozygous) through time, due to inbreeding and genetic drift. The effect will be to increase that subpopulation's risk of extinction. Efforts to ensure mixing, whether through translocations or by providing dispersal corridors, offer a means of preserving the genetic variability within each subpopulation even though the total genetic variability within the species may still decrease. Demographic arguments suggest that several subpopulations linked by dispersal may promote persistence (Burkey 1989). On the other hand, negative consequences may result from the mixing of animals adapted to their particular local environments (Lynch 1996). Such negative effects may not become apparent for two or more generations following the movement of animals, by which time it will be too late to reverse the process.

Research directions

The ongoing fragmentation and deterioration of freshwater habitat in Asia (e.g. Dudgeon 1992), and the continued population declines of Asian river cetaceans, intensify the need for biological information to aid in planning conservation strategies. The following research questions address issues that are important to formulating strategies for the conservation and management of wild populations of these species.

Question 1: How genetically distinct are the fragmented populations (i.e. subpopulations)? Are some populations more or less differentiated than others?

Question 2: How closely related are individuals within the small isolated populations?

Question 3: What are the breeding system(s) and social structure(s) of these species?

These questions are directly relevant to strategies that involve the human-mediated movement or translocation of animals. *Translocation* has been defined as the deliberate and mediated movement of living organisms from one part of their range to another (IUCN 1998). Three types of translocation are viewed as potentially useful for conservation. *Re-introduction* represents an attempt to re-establish a species in an area where it was indigenous before being exterminated by human activities or a natural catastrophe. Of course, re-introduction only makes sense if there is reason to believe that the factors which led to the species' disappearance in the first place either have been removed or are being reliably managed. *Reinforcement* or *supplementation* refers to efforts to add individuals to an existing population of conspecifics. Finally, *conservation/benign introduction* would be an attempt to establish a species in an area outside its recorded distribution – a last-resort measure that might be used when there is no longer any possibility of re-introduction (IUCN 1998).

For translocations to be successful, particularly those that involve the augmentation of existing populations with animals from elsewhere (reinforcement or supplementation), the translocated individuals must breed and produce viable offspring in their new environment. Several factors may inhibit the successful interbreeding of translocated animals with animals in a recipient population, including outbreeding depression or the species' breeding system. Answering the research questions above should help in deciding whether translocation will be of benefit or not.

Question 1 concerns the degree of genetic relatedness, on an intraspecific level, among the isolated subpopulations. It addresses the issue of genetic population structure within the species. This line of investigation is intended to help determine which subpopulations are genetically most closely related and, therefore, which of them may be appropriate candidates, from a genetic perspective, for translocation. It will also provide estimates of the amount of genetic exchange occurring between or among populations. Such information may be useful for testing the hypothesis of unidirectional downstream movement by dolphins past barrages during flood seasons, as proposed by Reeves *et al.* (1993). If this hypothesis proved correct, it would suggest that the maintenance of viable upstream populations of dolphins over the long term requires human-mediated movement of animals back upstream.

The mitochondrial DNA (mtDNA) molecule offers a useful tool for studying population structure and for measuring levels of genetic variability in populations of cetaceans (Baker *et al.* 1993, Rosel *et al.* 1999). Furthermore, this molecular marker is more sensitive than nuclear DNA to reductions in population size because the effective population size of mtDNA is one-quarter that of nuclear DNA (Birky *et al.* 1989, Birky 1991). Examination of mtDNA should enhance our understanding of the population genetics of Asian river dolphins, and it is currently being used to study finless porpoise populations (Yang and Zhou, this volume).

We can also examine the relatedness of individuals within a population (Question 2, above). Such information would be useful for situations in which, for example, only a few individuals remain upstream of a dam or barrage. Given the extremely small population size, one might want to seriously consider translocating these animals. Whether they are translocated together into one recipient population, or split among several different recipient populations, might depend on their relatedness. In addition, by examining the degree of relatedness among individuals in a population, we can determine which animals are reproducing and thus evaluate the extent of inbreeding. Nuclear microsatellite markers are the molecular tool best suited for questions of parentage and relationships among individuals. These highly polymorphic markers can be used in a manner similar to DNA fingerprinting. By "fingerprinting" individuals, it may be possible to determine parentage, and sibling relationships.

Finally, microsatellite markers are proving useful for elucidating the breeding system and social structure of some species (Ellegren *et al.* 1991, Amos *et al.* 1993, Bruford and Wayne 1993, Queller *et al.* 1993, Richard *et al.* 1996a, Taylor *et al.* 1997). Knowledge about breeding systems (Question 3, above) is always helpful, if not critical, in making decisions about translocation. Again, from a genetic and demographic standpoint, rescuing animals from an extremely small population is only useful if the translocated individuals breed in their new environment. Some social or breeding systems may prevent introduced animals from breeding and thus passing on their genes. It is clearly useful to have an understanding of such systems before any individuals are moved.

Obtaining and caring for samples

Standard molecular techniques have been used to address questions similar to those raised here but pertaining to other cetacean species (Amos *et al.* 1993, Baker *et al.* 1993, Rosel *et al.* 1995, Richard *et al.* 1996a). To provide meaningful information for freshwater cetaceans, it is essential to have sufficient sample sizes from each population, and to sample as many different populations as possible from each river system in which the species occurs. Fresh tissues are best. These may be small skin samples, biopsies ($0.5cm^2$), or blood. Pieces of skin, either scraped from the animal's body or sloughed naturally (Richard *et al.* 1996b), can also be used. Other sources of tissue, in descending order of usefulness for DNA studies, include dried skin, teeth, bone, and formalin-fixed tissues preserved in ethanol, the last of these being quite unpredictable as a source of DNA (Vachot and Monnerot 1996, France and Kocher 1997). It is extremely important to avoid cross-contamination of the samples. Thus, instruments used to collect tissues must be taken from sterile containers or be carefully cleaned between samples, using a minimum of soapy water and a rinse in ethanol. Such precautions are also warranted to avoid infections when taking biopsies from live animals. Complete information on the sample, including collection date, collection location, sex if known, and name of the collector must accompany each sample. It may also be useful to contact the laboratory or person who will be analyzing the samples to determine if any other protocols need to be followed. Generally, fresh skin or tissue samples are best stored and transported in small plastic (easier to transport) or glass vials containing saturated sodium chloride in a 20% (volume to volume) solution of dimethyl sulfoxide in water. This solution preserves the DNA in good condition and eliminates the necessity of keeping tissue samples frozen. Ethanol can also be used. Blood should be collected in sodium citrate or EDTA tubes and must be refrigerated. Dried skin samples may simply be placed in clean plastic bags and kept dry. They need not be frozen. Similarly, teeth or bone samples should be kept dry and stored in plastic bags, each sample in its own bag.

Conclusions

Studies of the genetics of threatened and endangered populations can play a valuable role in conservation planning. At their best, such studies provide insights about inter- and intra-population relationships, movement of individuals, population demography, interactions among individual animals, and the nature of social and breeding systems. This kind of information enhances the quality of decision making. Interventionist approaches, such as those involving translocation or the linking of separate populations with corridors to facilitate dispersal, should be critically evaluated before embarking on them. Genetic data can add important information with respect to the desirability and feasibility of these approaches.

We wish to emphasize that even the most scientifically elegant genetic analyses do not, by themselves, constitute conservation. Insight about genetic variability, relatedness, and breeding or social systems does not reduce the risks of extinction. Only hard choices, understood and embraced by large numbers of people, can give meaningful protection to habitats and organisms, without which conservation measures are doomed. The twin goals of preserving high-quality habitat and maintaining large numbers of individual animals must remain at the top of any list of priorities. Without them, gene conservation will degrade into little more than "museum curation of a genetic library" (Meffe and Carroll 1994).

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