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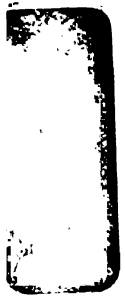
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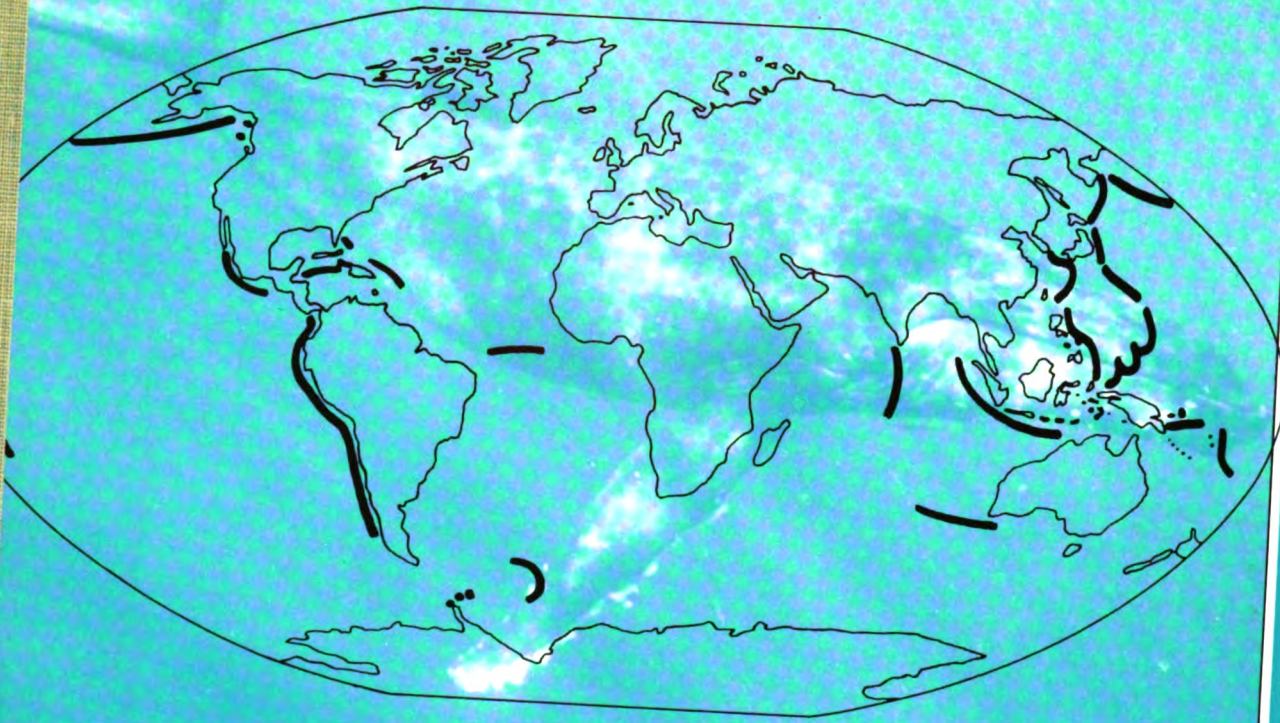
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# Ocean Trench Conservation



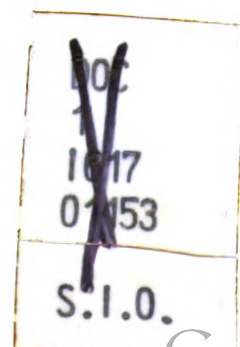
*By Dr. M. V. Angel, chairman  
of the Working Group on Ecology of the Oceans  
of the IUCN Commission on Ecology*

**Commission on Ecology Papers Number 1**



**International Union for Conservation of Nature  
and Natural Resources**

**1982**



### IUCN Commission on Ecology

The Commission on Ecology of the International Union for Conservation of Nature and Natural Resources (IUCN) is a scientific commission of an independent, international, non-governmental organization. IUCN was founded in 1948 by Unesco and the French Government. The Union comprises today 57 governments as state members, 118 government agencies, and 315 non-governmental national and international organizations. This membership represents 111 countries.

The Commission on Ecology was established in 1954 and reconstituted in 1979. At present it has 140 members from 43 countries in all the continents, carefully selected for their national and international scientific status and expertise.

IUCN's Commission on Ecology provides scientific information and advice to ensure that action directed towards the sustainable use and conservation of natural resources, i.e. the implementation of the World Conservation Strategy, makes the best use of current ecological knowledge. The World Conservation Strategy, launched in 1980, provides an overall plan for action in this direction.

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- ecological problems of the open oceans,
- continental seas,
- coastal areas,
- mangrove ecosystems,
- coral reefs,
- inland waters,
- arid lands,
- tropical rainforests.

It is concerned with problems relating to:

- oil pollution,
- environmental pollutants,
- ecological assessment,
- (re)introductions, animal migrations,
- mountain and river basin management.

The Commission is also active in the field of human ecology, particularly in rural development and traditional life styles.

For further information please contact: Executive Officer, IUCN Commission on Ecology, Av. du Mont Blanc, 1196 Gland, Switzerland.

# Ocean Trench Conservation

*By Dr. M.V. Angel, chairman  
of the Working Group on Ecology of the Oceans  
of the IUCN Commission on Ecology*

**Commission on Ecology Papers Number 1**

*With the support of  
The Netherlands Government  
The Australian National Parks and Wildlife Service  
The French Government*



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## PREFACE

Considerable concern has been recently expressed in conservation circles about the potential threat to oceanic trench ecosystems. Here, the geological origin in environmental characteristics and biological significance of the trenches are reviewed.

Each trench provides a unique and isolated habitat, consequently endemism has been found to be high at the specific level in each trench that has been adequately studied. However, the remoteness from primary food sources greatly reduces the richness of the fauna.

The physical instability of trench habitats deriving from their high level of seismic activity, will result in the organisms being pre-adapted to mechanical disturbance. The main threats are either direct through poisoning by toxic chemicals or indirect through the decoupling of the trench habitat from its primary food source, or reduction in oxygen levels caused either by eutrophication or reduction in flushing rates.

Only direct threats are considered as being at all dangerous, and any incident would be restricted to a single trench system. These threats could be reduced by rerouting vessels carrying toxic cargoes and by improving the effectiveness of the London Dumping Convention.

The internationally agreed criteria for the selection of sites for any proposed seabed disposal of radioactive waste exclude the use of trenches for this purpose.

## INTRODUCTION

Numerous recent publications and ongoing activities have emphasized the urgency with which the natural resources of the Earth need to be assessed as to their vulnerability to irreversible change resulting from exploitation, pollution, and all the other pressures derived from Mankind's burgeoning population. Oceans cover 70.8% of the Earth's surface, 70% of this coverage being with water that is 3,000–6,000 m deep (Fig. 1). The vast volume of this salt water, estimated at  $1,379 \times 10^6$  km<sup>3</sup>, has resulted in all manner of wastes being disposed of in it, whose dilution together with the natural cleansing processes have relieved the grosser effects of pollution in a global context though not, of course, in localized areas, especially in such shallow and largely enclosed seas as the Mediterranean and the Baltic.

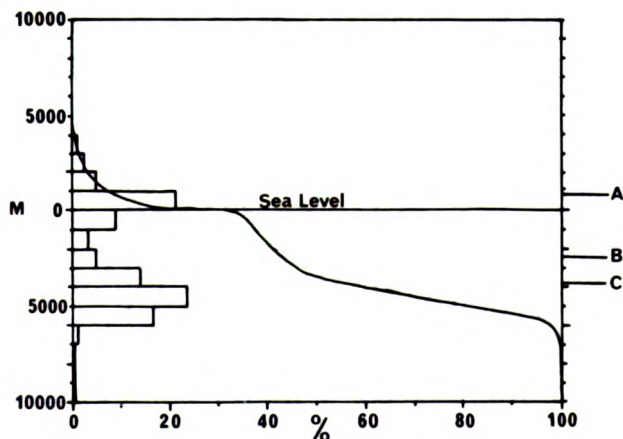


Fig. 1. Hypsographic curve showing the percentage of the Earth's surface above or below a given elevation or depth, with the percentage frequency distribution for each 1,000 m interval. Also shown is the mean height of the land mass of 840 m (A), the mean global depth of 2,440 m (B), and the oceans' mean depth of 3,800 m (C). (Modified from Neumann & Pierson, 1966).

The oceans contain relatively few species of plants and animals compared with terrestrial environments—probably because there is an absence of clear internal boundaries within them, and the structure of their biotopes and ecosystems is generally far simpler. However, their relative remoteness and the difficulties involved in sampling organisms in very dilute concentrations, means that our knowledge of oceanic faunas and floras, and the way in which their communities are structured and function, is still rather limited. It is, therefore, extremely difficult to identify which species are endangered and which ecosystems are either threatened or so fragile as to make them extremely susceptible to even tiny perturbations. Concern has been expressed about the vulnerability of oceanic-trench ecosystems, and this paper attempts to examine their vulnerability and assess to what extent they are at risk.

## GEOLOGICAL AND OCEANOGRAPHIC BACKGROUND

The recent development of the theory of plate tectonics has produced an explanation for the relative youthfulness of the rocks comprising the 'crust' underlying the oceans, as compared with the far greater age of many of the rocks that constitute the continental land-masses. The oldest oceanic crust existing under the Atlantic is about 250 million years of age, whereas radioactive dating techniques suggest that some rocks found in adjacent Greenland may be as much as 3,000 million years old. Along the central axis of most oceans runs a chain of submarine mountains known as 'mid-oceanic ridges'. A 'Rift valley', typically about a kilometre deep, runs down the centre of each ridge, and it is within the axes of these rift valleys that new oceanic

crust is continually being formed. As new crust is formed, the older crust is pushed out—away from the axis of the rift valley—in a process known as ‘sea-floor spreading’. The spreading becomes fractured and faulted because of the stresses and strains imposed on it by the solid geometry of the globe.

Where the ocean crust impinges on a continental margin, it may push the continent aside, providing the mechanism for ‘continental drift’ that is so basic to our understanding of terrestrial biogeography. Alternatively, if the continental mass is unyielding, an ‘active margin’ is formed with the oceanic crust buckling downwards and being destroyed within the hot interior of the Earth. It is along these active margins, where such ‘subduction’ is occurring, that trench systems are formed. As oceanic crust ages, it cools and becomes both denser and stiffer. As a result, the older the subducting crust is, the more the angle of subduction steepens and the forming trench deepens. The oldest known oceanic crust occurs along the western edge of the Pacific, so it is along the edges of the ‘island arcs’ of that region that the deepest series of trenches occur.

Ocean trenches are geologically young, and because subduction is a jerky—rather than a smooth and continuous—process, they are seismically highly active. This seismic activity results in the trenches offering a relatively unstable and unpredictable habitat in comparison with the great environmental stability of the abyssal plains. In general, the ocean trenches occur close to continental land-masses and island arcs (Fig.

2). This has two important environmental implications, the first being that sedimentation rates tend to be relatively high (Jumars and Hessler, 1976). The dominant sources of these sediments are of terrigenous origin, being either wind-borne aeolian dusts or suspended material from river wash-out. Much of this terrigenous material consists of inert mineral particles, but a significant proportion is organic and provides an important food input for the trench (or ‘hadal’) communities. For example, observations show that waterlogged wood and plant debris from for example Turtle-grass (*Thalassia testudinum*) and land plants constitute the main food for many species of molluscs and a variety of other benthic organisms (Wolff, 1976, 1979). Clearly the volume of terrigenous input will vary significantly with the geographical location of the trench system: for example, there will be relatively little such input off island arcs, whereas in contrast the Peru Trench will receive relatively small inputs from river run-off (because of the lack of any major river system on the western coast of South America), but will receive a comparatively high wind-borne input of dust from the desert fringe carried by the prevailing off-shore winds.

The second important influence of the proximity of land-masses is that several trenches underlie upwelling zones, or zones of high productivity caused by the wake effect of the islands on the physical structure of the ocean. Coastal upwelling generally occurs where the prevailing winds push the surface water offshore, the surface water being then replaced from below the ther-

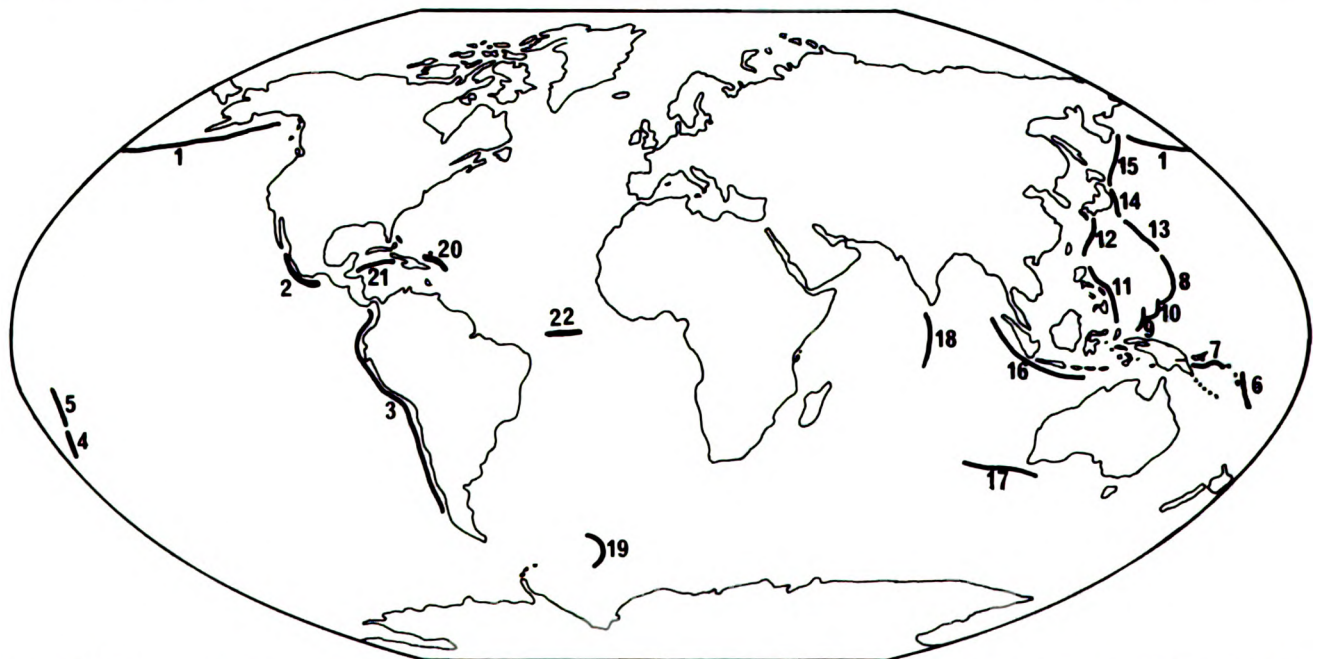


Fig. 2. Sketch-map indicating geographical distribution of the major trench systems in the World's Oceans. The numbering of the trenches identifies each trench in Table I. (Modified from Neumann & Pierson, 1966.)

TABLE 1. The main ocean-trench systems and their physical dimensions. (The numbering locates their positions on Fig. 2.)

Number on Fig. 2	Name	Maximum depth (m)	Length (km)	Mean width (km)	km**
1	Aleutian	7,820	3,700	50	50
2	Middle American	6,662	2,800	40	120
3	Peru-Chile	8,055	5,900	100	80
4	Kermadec	10,047	1,500	60	120
5	Tonga	10,800	1,400	55	90
6	New Hebrides	9,165	1,200	70	40
7	New Britain	8,320	750	40	-
8	Marianas	11,022	2,550	70	110
9	Paulau	8,054	400	40	-
10	Yap	8,527	700	40	-
11	Philippines	10,540	140	60	90
12	Ryukyu	7,507	2,250	60	90
13	Idzu-Bonin	9,810	800	90	120
14	Japan	8,412	800	100	120
15	Kurile-Kamchatka	10,542	2,200	120	90
16	Java	7,450	4,500	80	140
17	Diamantina*	8,230	2,160	30	-
18	Chagos*	5,408	2,450	70	-
19	South Sandwich	8,428	1,450	90	100
20	Puerto Rico	8,385	1,550	120	40
21	Cayman	7,093	1,450	70	50
22	Romanche*	7,856	300	20	-

\*There are examples of transverse trenches formed by extensive faulting across mid-ocean ridges or other features.

\*\*Minimum distance of land from 6,000 m.

mocline (usually from around depths of 100 m) with cold water that is relatively rich in mineral nutrients. These high nutrient levels stimulate intense blooms of phytoplankton, which in turn support massive populations of herbivorous zooplankton and attendant carnivores.

Some of the World's richest fisheries occur in these ocean upwelling zones. Thus the uniquely long Peru-Chile Trench (Fig. 2 and Table I) is close to the Peruvian upwelling zone which until recently was the site of the World's largest fishery and where, on the offshore islands, vast populations of seabirds had dropped rich deposits of guano which have been exploited for gunpowder manufacture in the past and for fertilizers more recently. The Peru-Chile Trench, and others such as the Aleutian Trench, receive substantial inputs of organic fallout from the richly productive surface waters. On the other hand, trenches underlying poorly-productive, oligotrophic waters receive very little locally-produced organic input.

### THE HADAL ENVIRONMENT

The hadal environment (i.e. of deep-ocean trenches) is normally assumed to be where oceanic depths exceed 6,000 m (Table I). As can be seen in the hypsographic curve in Fig. 1, only about 1% of the Earth's surface is covered with water of hadal depths. However, not all features with geological properties of trenches are quite so deep, nor do all soundings in excess of 6,000 m occur in conjunction with features

that constitute trenches. The world's total volume of water at depths exceeding 6,000 m is probably of the order of  $6 \times 10^6 \text{ km}^3$ . In terms of fresh-water environments this is a massive figure, but in terms of the oceans it is tiny.

Trenches, as might be expected from their origins, are long linear features (Fig. 3). Each trench system is isolated from other trench systems. If depth is a sufficient barrier to the downward movement of animals, then each trench would be expected to have evolved a unique fauna, derived from a similar suite of parental species inhabiting the surrounding abys-

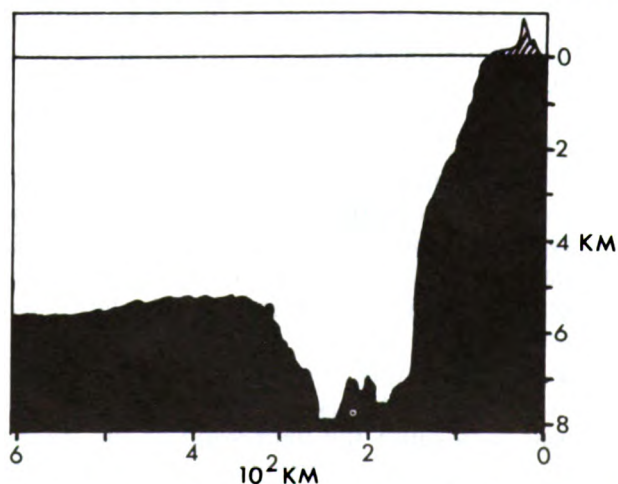


Fig. 3. Cross-section of the Puerto-Rico Trench showing the island of San Juan to the east and the Nares Abyssal Plain to the west. Note the precipitous sides and the flat, sediment-filled 'valleys'. Measurements of sea-surface levels made with altimeters carried on satellites show a depression in sea-level of 10-15 m, caused by the increased pull of gravity over the trench.

sal plains. It is tempting to draw an analogy with the endemicity of the faunas and floras of the isolated high-alpine peaks in tropical Africa. Thus each trench might be expected to show a high degree of endemicity at specific and sub-specific levels, but at generic and family level there would be great similarity between trenches in the same system and within the same zoogeographic province.

The existence of an environmental barrier at around 6,000 m depth is still a matter of controversy. For shallow-living organisms, the hydrostatic pressure at such depths (about 600 times atmospheric pressure) is more than sufficient to change protoplasm from the gel to the sol phase, and to reverse various vital biochemical reactions. A freshwater *Amoeba*, when subjected to increasing pressure, initially shows an increase in respiration rate, but then rounds up into an immobile sphere (MacDonald, 1975). If the pressure is then lowered, the organism recovers; but if it is raised further, the animal is killed.

Deep-sea organisms must have physiological adaptations for them not only to survive but also to function under such high pressures. The few measurements of respiration rates that have been made of animals living at relatively shallow depths of 1,000 m, show that deep-living animals have metabolic rates about an order of magnitude lower than their surface-dwelling counterparts (e.g. Torres *et al.*, 1979; Smith and Laver, 1981). These adaptations are not at all well understood, but are the subject of intense research effort—not only because of the commercial need for a deep-living capability in Man, but also because many of the effects of high pressures parallel the physiological effects of anaesthetics, which may be produced by changes in the permeability of cell membranes because of changes in calcium metabolism.

The water within ocean trenches is normally derived from the surrounding 'bottom water'. Oceanic water-masses can be defined by their conservative properties of temperature and salinity. By mapping these properties, the general flow-patterns within the oceans can be followed. 'Bottom waters' are formed at high polar latitudes—mostly in the Southern Ocean, as the Arctic Ocean is effectively hemmed-in by shallow shelves. Sea-water forms sea-ice at  $-1.9^{\circ}\text{C}$  (the dissolved salts cause the depression of the freezing point; also it is important to remember that salt water does not reach a maximum density at  $4^{\circ}\text{C}$  as does fresh water). When sea-water freezes, much of its salt content 'freezes out'; accordingly, sea-ice contains relatively little salt, and the surface-water, besides being very

cold, also increases in salinity. This cold, more-salty water becomes denser than the underlying water and 'slides down' off the Antarctic shelf into abyssal depths forming 'bottom water'.

Being derived from cold surface-water, the 'bottom water' is extremely well oxygenated. Furthermore, because the oxygen demand in very deep water is so very low, the flushing rates of the deep ocean are sufficient to ensure that hadal biota rarely experience stress from low oxygen levels. There are, however, some exceptions to this—such as the Cariaco Trench, which is a very shallow trench in the Caribbean Sea, off the north coast of Venezuela and not shown on our map. It is enclosed by quite shallow sills and underlies a local upwelling region. The oxygen demand created by the high input of organic material causes its deeper water to become anoxic. The activities of sulphur Bacteria in oxidising sulphate ions to sulphide result in high concentrations of hydrogen sulphide accumulating in the deep water, making it totally inimical to most other life (Baird *et al.*, 1973; Broecker *et al.*, 1980).

In typical oceanic conditions, as the 'bottom water' spreads slowly towards lower latitudes, it follows the lowest topography, though the rotational forces derived from the spin of the Earth makes it hug, in the Southern Hemisphere, the western boundary of the basin in which it lies. Thus bottom water formed in the Weddell Sea, Antarctica, flows northwards up the deep abyssal trough that lies between the eastern slope of South America and the mid-Atlantic Ridge (Broecker *et al.*, 1980). At the Equator it branches, with one branch flowing north-west into the deep basins of the North-west Atlantic, and the other branch flowing *via* the Romanche Deep through the mid-Atlantic Ridge to flow in part northwards and in part southwards into the deep basins of the eastern Atlantic.

The 'bottom water' on the eastern side of the South Atlantic spills out into the Cape Basin, but its northerly flow is blocked by the submarine Walfish Ridge, which joins South-West Africa with the Mid-Atlantic Ridge. The distance that the 'bottom water' flows and its rate of spread are significant, because it is gradually warmed from its initial temperature of less than  $-1^{\circ}\text{C}$  to more than  $+2^{\circ}\text{C}$  by the heat-flux from the Earth. However, trenches with sills that are deep enough for 'bottom water' to flow into them, contain water that is extremely stable in temperature and salinity.

The series of photographs published by Lemche *et al.* (1976) from five different trenches have one feature that is common to all the

pictures—the absence of ripple and scour marks and the apparent ‘fossilization’ of tracks. The water currents are probably extremely gentle except for when some seismic event triggers-off turbidity-flows of vast boluses of sediment-laden water. These flows are probably as destructive to the deep environments as the violence of the dust-laden winds that wreaked such havoc to the forests surrounding Mount St Helens in the north-western US during the 1980 eruption. The path of one such ‘slide’ has been traced south of the Canary Islands from the slope of the African mainland over 500 nautical miles (1000 km) out across the abyssal plain, thus forming a great deltaic fan (Embley and Jacobi, 1977). Such catastrophic flows are probably as common in the seismically active trenches as anywhere in the oceans.

One of the most important boundaries in the deep ocean is the ‘carbonate compensation depth’ (CCD). This is the depth at which the chemical equilibria, that render calcium carbonate virtually insoluble at shallow depths, reverse so that the carbonate dissolves. Sediments at depths deeper than the CCD are totally devoid of all carbonates which are derived from the calcareous skeletons of microplanktonic organisms such as Foraminifera and coccolithophorids and of larger planktonic forms such as the pteropod molluscs. Even the silicious skeletons of diatoms remineralize (i.e. the mineralogy of the silica alters so that it dissolves). These deep-water sediments are composed mainly of red clays, mostly of aeolian origin, but in the case of trenches they are mostly of more terrigenous origin. In the Atlantic the depth of the CCD is around 4,500 m, but it tends to be somewhat shallower in the Pacific.

The factors controlling the depth of the CCD are not fully understood, but are probably influenced by a combination of pressure and temperature. Palaeontological evidence (Shackleton, 1978) suggest that around 60 million years ago, before the Australasian continental land-mass became detached from the Antarctic Continent, the ‘bottom water’ was prevented in some way from flowing out into the main oceans. Deep-water temperatures were generally in excess of 10 °C, and the CCD was then at a much shallower depth of around 1,500 m. The opening of the deep-water channel between Antarctica and Australasian continental land-masses may either have created or coincided with the advent of the conditions whereby cold ‘bottom water’ formed. This may then have been followed by a cooling of the deep water in the main oceans and a deepening of the CCD. Thus deep-sea environments may have undergone slow but quite

major changes, and so do not have as long a geological history of physical stability as some terrestrial habitats (such as the Amazonian tropical rain-forests).

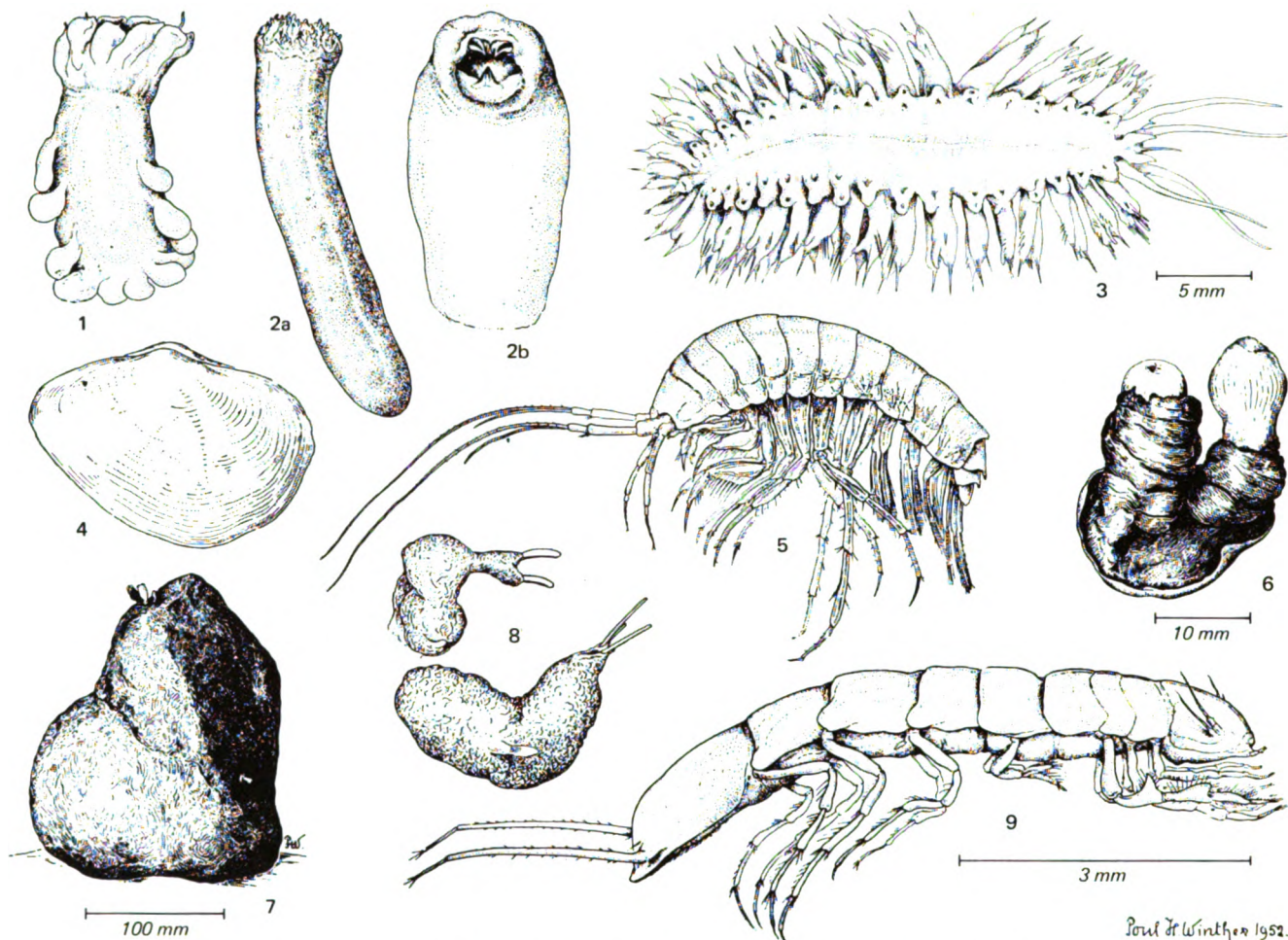
#### FOOD SUPPLY TO HADAL FAUNAS

In the total darkness of the trench environment, the nearest source of primary production is at or close to the surface, 6 km or more above. So the biota are very remote from their primary supplies of energy. A variety of sources have been postulated: (a) dissolved organic material; (b) chemosynthesis, mostly based on the reduction of sulphate to sulphide by microorganisms; (c) the ‘rain’ of very fine phytoplankton and other detrital material sinking from the surface layers; and (d) the fall of ‘large lumps’, including the carcasses of very large species which, when once they die, sink very rapidly to the sea-bed before either scavengers have time to exploit them or bacterial breakdown can cause appreciable deterioration.

It is generally assumed that the levels of concentration of dissolved organic compounds, while possibly providing a supplementary source of energy for a few organisms, are insufficient to maintain the benthic populations (Stephens, 1981). The curious group of worm-like Pogonophora were considered until recently to be the most likely candidates for this method of nutrition, because they completely lack any sort of gut, and experiments to demonstrate their ability to absorb dissolved organic compounds from the surrounding sea-water were equivocal. However, recent evidence has shown that some species probably contain symbiotic Bacteria that are capable of chemosynthesis (Figs. 4, 5, 6, 7).

The initial observations on the possible importance of chemosynthesis in deep-living populations, came from the extraordinarily rich and abundant populations of giant bivalve molluscs, vestimentiferan worms, and other rather bizarre organisms, found inhabiting the immediate environs of hot vents on the Galápagos and East Pacific Rises (e.g. Enright *et al.*, 1981). The water issuing from the vents is believed to have circulated deep within the Earth’s crust, where it had been superheated, and helps to cause diagenesis\* of the minerals in the crust. Water temperatures in the Galápagos vents are in the region of 23 °C, but in the east Pacific Rise vents they are around 350 °C. The vent waters are loaded with metalliferous and sulphide

\*Diagenesis is the physical and chemical changes that occur in sedimentary deposits and includes compaction, cementation, recrystallisation and replacement.



Poul & Winkler 1952.

Fig. 4. The first recorded animals from the hadal zone (Philippine Trench July 1951, 9820-10210). 1, 2a and 2b, the sea cucumbers *Scotoplanes galatheae* Hansen, *Myriotrochus bruuni* Hansen; 3, the bristle worm *Macellicephalo hadalis* Kirkegaard and its gullet; 4, the bivalve *Yoldiella hadalis* Knudsen; 5, the amphipod *Pardaliscooides longicaudatus* Dahl; 6, two sea anemones *Galatheanthemum hadale* Carlgren of the hadally endemic family *Galatheanthemidae*; 7, other specimens attached to a large stone; 8, fragments of an echiurid worm *Vitjazema* sp.; 9, the isopod *Macrostylis galatheae* Wolff. (after Galathea Rep. 2, 8, and 11).

ions, and it is the oxidation of the latter to sulphate ions that is the main energy-source of several of the microorganisms. Viewed from a submersible vessel the vent waters of the Galápagos region look milky, because of suspended Bacteria at concentrations of  $10^8$ - $10^9$  per ml. Many of the vent species filter-feed on Bacteria. The vestimentiferans have no guts, so cannot consume food, instead it seems that they rely on symbiotic sulphur bacteria for their energy input.

Enright *et al.* (1981) have argued that chemosynthesis may not be the sole source of productivity available to the vent populations. They postulate that the convection 'cell' set up by the plume of hot water concentrates the organic matter, which sediments out into the immediate vicinity of the vents. Vent conditions are highly localized, each vent being surrounded by a circle of rich animal populations about 25 m in diam-

eter. But as the vents occur only at intervals of about 50 km, chemosynthesis seems unlikely to provide a significant energy input for hadal ecosystems as a whole. Pogonophorans may also exploit chemosynthetic Bacteria, but they tend to occur in abundance only where the sediments have a high organic content.

The 'rain' of fine materials from at or near the sea's surface is believed to provide the major energy input into abyssal and also hadal environments. The rate at which particles sink is related to their size. Small clay particles sink extremely slowly, at rates of less than a metre per 24 hours. Any labile organic compounds that may be associated with such particles are likely to be utilized by microorganisms long before the particle reaches the sea-bed. Recent sediment-trap experiments have suggested that the main flux of organic materials down through the water-column is in the form of faecal pellets.

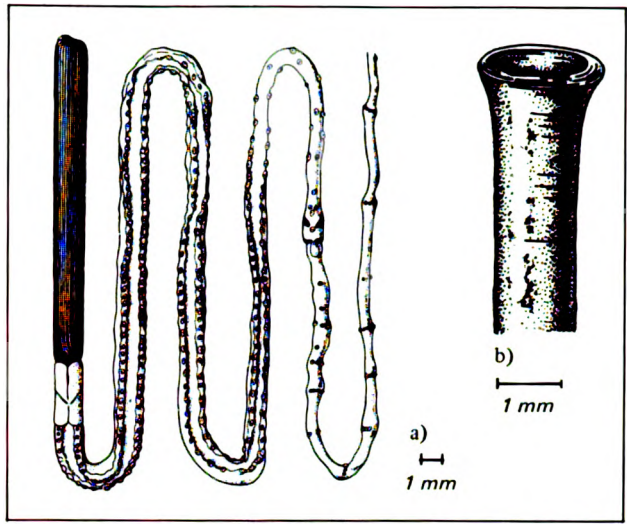
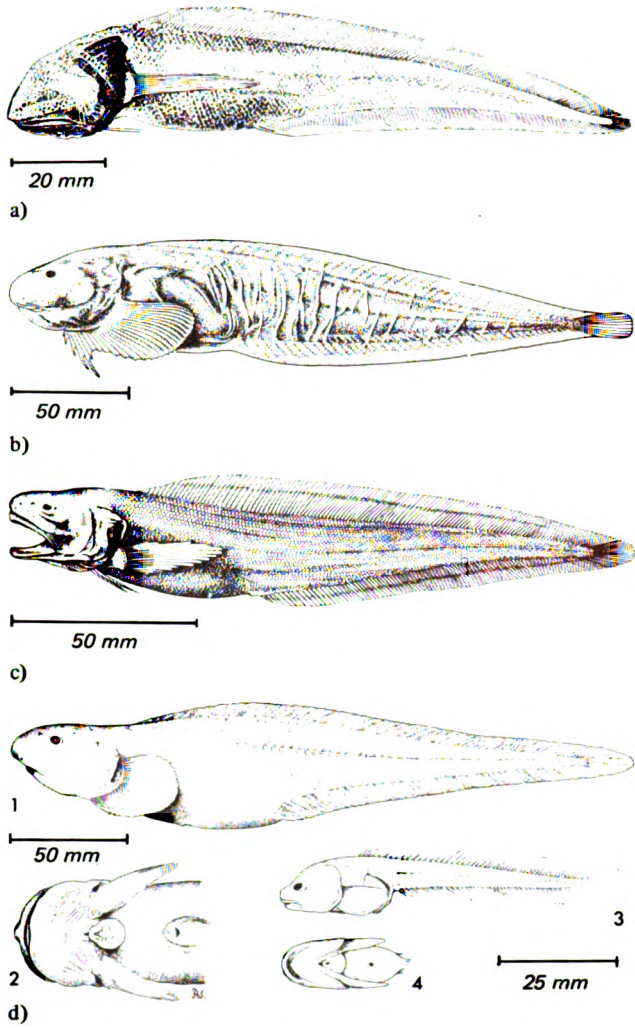


Fig. 6. Anterior end of the Pogonophoran *Spirobrachia bekle-mischevi* Ivanov and its tube, Kurile-Kamchatka Trench, 9000–9050 m. (after Zool. Jb. Syst. 85).

◀ Fig. 5. The four hadally recorded fish species: A. *Abyssobrotula galathea* Nielsen (*Brotulidae*). Worldwide distribution (13 recordings) between 40°N and 40°S at depths between 3100 and 8370 m, the latter recording from the Puerto Rico Trench, (after Galathea Rep. 14). B. *Careproctus (Pseudoliparis) amblystomopsis* Andriashev (*liparidae*), Kurile-Kamchatka Trench, 7230 m. (after Trud. Inst. Okeanol. 12). C. *Bassogigas profundissimus* Roule (*Brotulidae*), Java Trench and Central Atlantic Ocean, 5600–7160 m. (after Galathea Rep. 7). D. *Careproctus kermadecensis* Nielsen (*Liparidae*), Kermadec Trench, 6660–6770 m. (after Galathea Rep. 7).

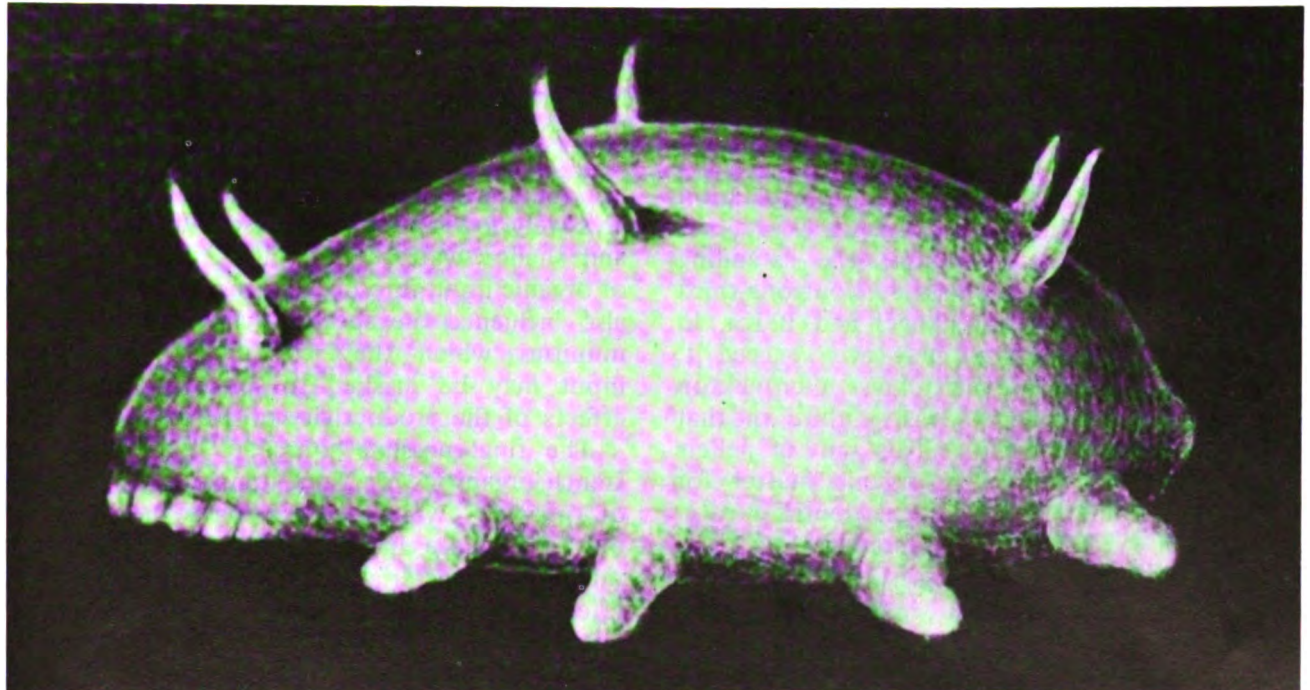


Fig. 7. *Elpidia sundensis* Hansen from the Java Trench, 6900–7160 m, belongs to a genus of sea cucumbers with at least 10 hadal species. (after Galathea Rep. 2, Poul H. Winther del.).

Crustaceans secrete a peritrophic membrane as a lining to their guts, and as a result of this their faeces are produced in the form of a pellet ensheathed in a membrane. The pellet produced by an average-sized copepod such as *Calanus finmarchicus* is cylindrical ( $600 \times 70 \mu\text{m}$ ), and sinks at a rate of 200 m per 24 hours. Under rich feeding conditions, a copepod may produce 100–200 pellets in 24 hours. At warm temperatures the membrane enclosing the pellet is rapidly broken down by Bacteria (in 3–4 hours at  $20^\circ\text{C}$ ), but at cold temperatures it remains intact for days on end (20 days at  $5^\circ\text{C}$ ) (Honjo and Roman, 1978). Rupture of the membrane soon leads to disintegration of the pellet; consequently the deeper and cooler a pellet is produced, the greater will be its chance of reaching the sea-bed intact.

Crustaceans are not alone in producing membrane-ensheathed faecal pellets; salps—free-swimming thaliacean tunicates which ‘automatically’ feed as they swim—also produce them (Silver and Bruland, 1981). When once salps are satisfied in their feeding, their ingestion efficiency tends to decrease and they produce pellets full of phytoplankton which is undigested and even viable. Massive swarms of salps, such as occur regularly off the northeastern coast of the United States (Wiebe *et al.*, 1978), probably provide a substantial but short-lived flux of detritus to the deep-water communities.

Sediment-trap experiments (e.g. Hinga *et al.*, 1979) indicate that about 1% of surface primary production sinks to depths of 3,000–4,000 m in the form of faecal pellets. However, these sediment-traps underestimate the flux of pellets produced by micronektonic organisms which produce much larger pellets. The large pellets sink more rapidly than small ones, and are much less susceptible to either bacterial degradation or scavenging by mid-water organisms.

In the total water-column, the ‘standing crop’ of micronekton biomass is about one-third of that of the plankton (Angel and Baker, *in press*), and in deep water may even exceed it. So the flux of organic matter *via* micronekton faecal pellets may be at least a third of that *via* plankton faecal pellets. This rain of pellets is also a major source of organic matter for mid-water communities living at depths greater than 1,000–1,500 m. The standing crop of mid-water organisms decreases at a constant rate with the logarithmic increase in depth (Fig. 8) (Wishner, 1980; Angel and Baker, *in press*). This decrease is probably related to the decrease in food supply, and such a relationship between depth and standing crop may provide

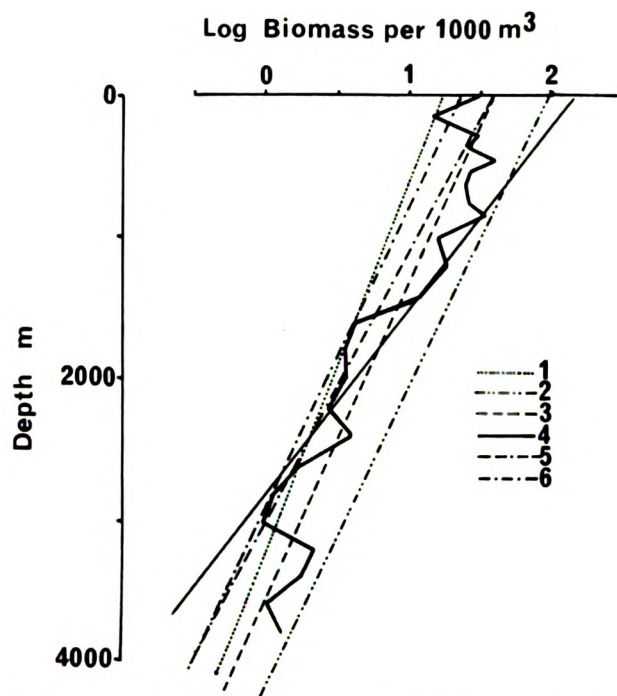


Fig. 8. Regression lines for the profiles of plankton and micronekton at three positions in the North-east Atlantic.

a useful method of estimating the flux of organic material to the sea-floor.

At low latitudes there is relatively little variation in surface productivity, but at high latitudes there is marked seasonality. This will probably be reflected in the seasonal pulsing of detrital fall-out to the deep-sea, and evidence is beginning to accumulate of seasonality in the breeding of some benthic organisms (Tyler and Gage, 1980) at high latitudes. Constancy of environmental parameters or their high level of predictability is generally regarded as an important factor in controlling the diversity of communities. It is probably an important factor in determining the familiar increase in species richness at progressively lower latitudes that occurs in terrestrial and shallow-water communities. The seasonality of organic input into ocean trenches will probably also influence the species richness of the communities which they contain. However, this input may be masked to some extent by the effects of the productivity of the surface waters.

The final possible source of food for ocean trench organisms are ‘large lumps’—the carcasses of organisms which are too big to be exploited by near-surface living scavengers, and sink too rapidly for bacterial degradation to have much effect. The first indication that such a source might be significant came from the evidence for the unexpected abundance of benthopelagic scavenger-carnivore populations revealed by the use of baited camera systems (Isaacs and



Schwartzlose, 1975) and the use of deep-drop line techniques (Foster, 1964) at abyssal depths. Initially, it was thought that these 'large lumps' could be the major source of organic input to deep benthic communities, but the latest estimates suggest that, globally, they might account for only around 0.01% of surface primary production (e.g. Haedrich and Rowe, 1977) and thus be two orders of magnitude less than the input from faecal pellet fall-out. However, a large carcass will have a considerable local influence, and there are regions, such as beneath whale or Blue-fin Tuna (*Thunnus thynnus*) migration routes, or beneath spawning grounds, where 'large lumps' could be far more important. In general, however, large organisms tend to follow their food supply and so to be more abundant in regions of high productivity than elsewhere. This may account for the very large numbers of scavenging amphipods which have been attracted to the baits of free-fall cameras both in trenches, underlying richly productive waters i.e. the Peru Trench, and underlying poorer waters such as the Philippine Trench (Hessler, 1978).

Wolff (1976) has clearly demonstrated the importance of larger plant remains either from shallow waters (such as eel-grass [*Zostera*] fragments) or from terrestrial sources, in providing the food supply for a rich fauna of wood-boring and other organisms in such ocean-trench ecosystems. Rowe and Staresinic (1979) estimated that members of the algal genus *Sargassum* could provide as much as 0.4 g carbon per sq. cm per year to the deep Western Atlantic which is equivalent to 10% of the input from faecal pellets.

## TRENCH FAUNAS

The data available on the quantity of standing crops of hadal communities have been collected by such a diversity of techniques that comparisons are sparse and often questionable. Trenches underlying richly productive regions have been observed to have several grammes of living organisms per square metre of surface—e.g. 8.8 g per sq. m at 6,875 m in the South Sandwich Trench (Vinogradov *et al.*, 1974) and 3.44 g per sq. m at 6,938 m in the Kurile–Kamchatka Trench (Belyaev, 1972). By contrast, trenches underlying oligotrophic waters are poorer by several orders of magnitude—e.g. 0.008 g per sq. m in the Marianas and Tonga Trenches (Vinogradov *et al.*, 1974).

The number of organisms observed depends very much on the sampling technique employed. Thus for example Belyaev (1972) observed a

concentration of megafaunal individuals of 35–100 per sq. m, whereas Jumars and Hessler (1976) found meiofaunal concentrations to be 1,270 per sq. m in the same trench. In the Peru–Chile Trench Frankenberg and Menzies (1968) observed 60 megafauna individuals per sq. m, but more extraordinary were the immense swarms of amphipods that were attracted to baited camera systems—swarms reminiscent of the clouds of flies attracted to corpses in the tropics (Fig. 9).

The composition of these populations is unusual, compared with abyssal plain faunas, in that they tend to be dominated by deposit-feeders. According to Wolff (1970) in the Kurile–Kamchatka Trench, 54% of the bottom megafauna consists of holothurians (mostly *Elpidia* but also *Peniagone* and *Scotoplanes*). Other groups, present in large numbers, are bivalve molluscs (19%), polychaetes (7%), peracarid crustaceans (5%), ophiuroids (2%), and pogonophorans (11%). Wolff (1977) gave comparative data from the group composition of abyssal and hadal bottom faunas (Table 2) which, despite the biases introduced by the different sampling techniques used, do indicate that substantial differences exist.

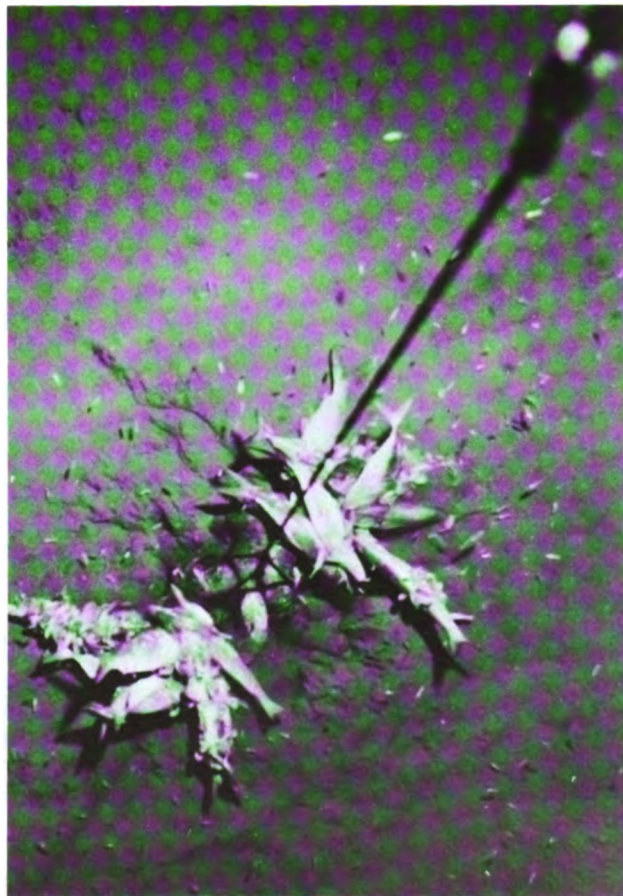
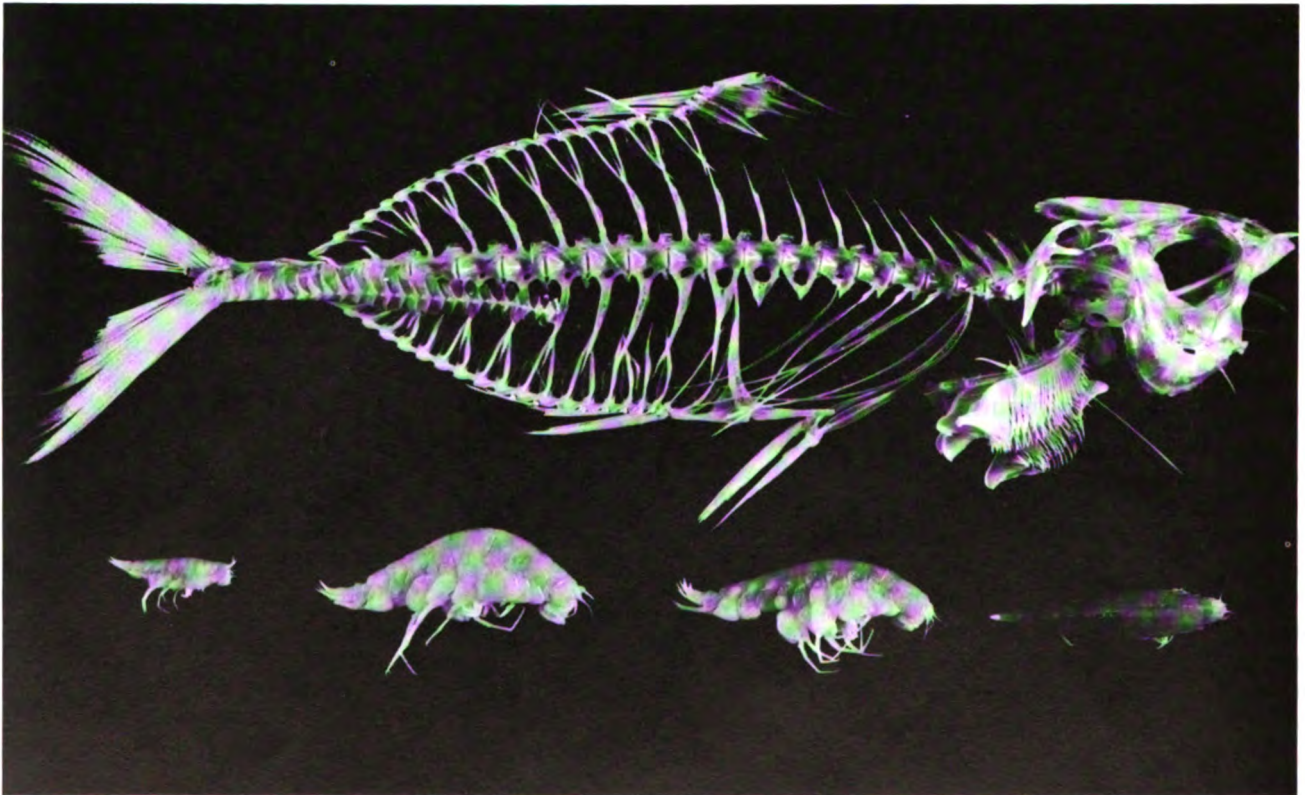


Fig. 9(a)



(b)



(c)

Fig. 9. Time-lapse photographs from the Philippine Trench, 9600 m. (a) 2.15 h after reaching the bottom, showing bait (about 14 shallow water fishes) and rather few attracted amphipods. (b) 10 h later, showing almost devoured bait and multitudes of amphipods. (c) one skeletonized bait fish and three of the 5 cm long, marauding amphipods, *Hirondellea gigas* Birstein & Vinogradov (also recorded hadally in the Kurile-Kamchatka Trench). (a + b) Courtesy of R. R. Hessler, Scripps Inst. of Oceanography; (c) T. Wolff, Copenhagen.

TABLE 2. Composition of bottom macrofauna (% of total number of individuals) from trawl samples from trenches (Kurile–Kamchatka, Japan, Kermadec, and Java) compared with samples from abyssal depths in the Atlantic and Pacific (after Wolff, 1977)

	Trenches	Central N. Pacific	N.W. Atlantic	N.W. Atlantic
	Trawl	Anchor dredge	Anchor dredge	Epibenthic sledge
Sampler depths (m)	6,200–10,000	5,600	4,400–5,000	4,700
Polychaetes	7	55	55	8
Peracarid Crustacea (total)	5	24	33	32
Tanaidacea	<1	18	19	1
Isopoda	4	6	12	18
Amphipoda	<1	0	2	5
Bivalvia	19	7	4	47
Echinodermata (total)	57	1	1	2
Ophiuroidea	2	<1	<1	2
Holothuroidea	54	<1	0	0
Others	11	11	8	11
Number of individuals	21,589	287	681	3,737

Jumars and Hessler (1976) reported on the organisms from a single 0.25 m<sup>2</sup> box-core sample collected from the Aleutian Trench. They found that the megafauna consisted mostly of polychaetes (49%), bivalve molluscs (11.5%), aplousophoran molluscs (10%), hemichordates (8%), and echinoids (3%). The meiofauna was dominated by allogrominiid foraminiferans, nematodes, and harpacticoid copepods. They found that the species diversity was low in comparison with other deep benthic communities, and suggested that the relatively poor contribution to the community by polychaetes in the Aleutian Trench of only 49% is due to the combined influence of rapid sedimentation and high seismic activity. The need to survive sediment flows and turbidity currents probably favours the survival of species with weed-like life-styles, having the ability to invade rapidly and exploit new areas of unoccupied sea-bed.

### ENDEMISM IN TRENCHES

Professor G. M. Belyaev, a leading authority on hadal faunas, wrote recently: (pers. comm. October 1980): 'The endemism of hadal faunas constitute [commonly some] 57–60%. There are no endemic species [occurring] throughout this zone because each trench tends to have its own specific endemic fauna. 50–90% of the fauna of each trench is endemic. The Banda Trench [in the Banda Sea in eastern Indonesia] has the lowest level of endemism—33%. The fauna is related to the shallower-living fauna of the Indo–Malaysian region. This trench is probably the youngest geologically.

'There are not only endemic species, but also endemic genera and families. There are 25 endemic hadal genera [representing some] 10–25%

of all hadal genera. However, there are only two known endemic hadal families—Galatheanthe- midae (Actinaria), which has been recorded in 40 samples from many trenches at depths of 6,000–10,700 m, but only in three samples at shallower depths of 5,500–5,900 m on the slopes of the Kermadec and South Sandwich Trenches. Probably this family was formerly more widely distributed on the abyssal floor of the World Ocean. The second endemic hadal family is Gigantapseudidae (Crustacea: Tana- idacea), which contains a single species—*Gigant- apseudes adactylus*—the largest tanaid known, which has only been taken at two stations in the Philippines Trench at depths of 6,300 m and 7,880 m (Fig. 10).

'At present, 500 species of Metazoa have been identified from hadal depths plus around 100 species of Foraminifera, but in time this number is likely to exceed 1,000. Representatives of 33 classes, 150 families, and about 240 genera, are known from depths greater than 6,000 m.

'The greatest number of species known from a single trench are the 200 (only 150 determined to species level so far) from the Kurile–Kamchat- ka Trench, whereas only 10 are known from Ryukyu and Marianas Trenches. However, the faunas of many trenches have either been insuf- ficiently studied or have not been studied at all (e.g. San-Cristobal Trench in the West Pacific and the newly-discovered Amirante Trench to the west of the Seychelles which is over 9 km in depth).

One comment is worth adding: Until recently it was believed that deep-sea Bacteria are all very slow-growing and have extremely slow population doubling-rates. Hence it was believed that microorganisms play only a minor role in degradation and recycling of organic material



Fig. 10. Examples of gigantism in the hadal zone is exhibited by e.g. isopods and tanaids. The two largest known tanaids are hadal, this one (female and male of *Herpotanais kirkegaardii* Wolff) being from the Kernadec Trench, 7150 m. (after Galathea Rep. 2).

in deep seas. However, Yayanos *et al.*, (1979) have found a deep-sea Bacterium in the guts of amphipods which can grow at rates similar to those of shallow-living microorganisms—provided the cultures are maintained at low temperatures and high pressures. Could such microorganisms perhaps be important in the biology of some of the scavenging deep-sea amphipods?

### REPRODUCTIVE STRATEGIES

There are generally considered to be two basic types of life-history and reproductive strategy. The first seeks to maximize the intrinsic rate of increase (r-selected); in this type the organisms are short-lived, produce single broods of very large numbers of young with great potential for dispersion, of which each individual receives only a minimum investment of reserves, though its growth and metabolic rates tend to be rapid. This type of reproductive strategy is common in 'weed' species and is common in highly productive and in unpredictable habitats. The second (K-selected) strategy involves organisms that are long-lived, develop slowly, produce repeated small broods of young in each of which is made a big investment of reserves to optimize survival rates despite low dispersive potential;

also, brooding of the young is common. This latter strategy is common in species living in highly predictable, low-productivity environments such as primary tropical rain-forest trees and abyssal benthic communities.

In benthic communities, naturally occurring radio-isotopes have been used to estimate the possible ages of abyssal bivalve molluscs. The estimates are subject to wide errors and assumptions (e.g. that the organisms use elements in the same isotopic proportions in their shells as occur in the surrounding sea-water). However, for some species estimates of a hundred years have been obtained; for example, recent estimates for the age of *Calyptogena magnifica* shells from hydrothermal vents were between 6.5 and 830 years (Turekian *et al.*, 1979). These giant clams have been shown by Boss and Turner (1980) to have large yolky eggs. The abyssal environment is characterised by its stability, predictability, and low productivity. But as has been emphasized above, ocean trenches are far less stable, and so hadal species should have greater ability to disperse than abyssal ones.

The closest abyssal analogy to trench conditions may be those that occur in the vicinity of the hydrothermal vents. Vents have been studied along the Galápagos and East Pacific

Rises, and it is now believed that they occur in all oceans. Each vent area is an oasis of faunal abundance in the vast desert of the almost barren abyssal floor. The high-abundance area is of very limited extent (*see above*), and the vents are separated by long distances.

At first sight it would seem advantageous for species living in vent communities to have larvae that undergo direct development, rather than planktonic larvae that may get swept away into the surrounding impoverished areas. Initial studies suggested that for several species this was indeed the case. However, geophysical evidence indicates that the vents may only be active for about a hundred years. When the water-flow from the vent dies away, the animals living in its environs soon die. Several old vents surrounded by the shells of large clams have been found. Vent species must have the capability for long-distance dispersal, probably as planktonic larvae, and this is confirmed by the high similarity between the faunas of the two regions where vents have been located.

The observed faunal differences between the vent communities of the Galápagos and East Pacific Rise seem more likely to result from geochemical differences of the water issuing from the vents than from any inability of the species to disperse. The vents on the East Pacific Rise are called 'black smokers' because as the water, superheated to 350 °C, issues from the vent, it is rapidly cooled to the temperature of the surrounding water and precipitates black plumes of sulphides.

In marked contrast to the ability of vent species to colonize new sites some tens of kilometres away from their original site, abyssal plain species show a remarkable inability to disperse over even short distances. Using a submersible vessel, Woods Hole, Massachusetts, scientists have been able to remove all large animals from small areas on the abyssal plain in the northwestern Atlantic. Even after several years, there are no signs of the experimental areas being recolonized by the original set of species. Instead, occupation of the site has been restricted to a few, otherwise rare, species (Grassle, 1977). Similarly, sampling of the vast 'mud slide' to the south of the Canary Islands in 1979 showed that the slide is almost totally devoid of benthic organisms. The slide was originally recorded by Embley and Jacobi (1977), and although its exact age is uncertain, recolonisation of the slide is proceeding extremely slowly.

Thus the dispersal capabilities of organisms inhabiting the vents and abyssal plains are very

different, and appear to relate to the long-term stability of their habitats. Little is known about the reproductive strategies of hadal species, but depending upon the degree of environmental instability and unpredictability produced by their seismic activity, they may well be forced to adopt strategies that increase their ability to disperse.

## SIGNIFICANCE OF TRENCH FAUNAS AND MICROFLORAS TO WORLD CONSERVATION

World conservation should have three principle aims: (a) to maintain ecological processes, (b) to maintain renewable resources, and (c) to maintain ecological diversity. Ocean-trench systems are probably never going to provide biological or mineral resources that Man will be able to exploit economically, but may nevertheless be damaged environmentally through negligence and ignorance. The small size of the trenches, combined with the very sparse densities of the inhabitants, means that the populations of all the endemic species are very small. Although they are likely to be adapted to severe localized disturbance caused by seismic events, they must be considered vulnerable to trench-wide disturbance. Therefore, the scale of disturbance must be kept small relative to the overall size of the trench system. Although the level of endemism is high, the actual numbers of endemic hadal species known are small in terms of the total ocean fauna and microflora, and will probably remain so even when our knowledge becomes more comprehensive. Similarly, there are probably no important ecological processes involving the general oceanic biomes and component ecosystems that are in any way dependent on the integrity of the hadal faunas.

However, these faunas and microfloras are important for physiological studies in learning how living processes adapt to the extreme conditions of high hydrostatic pressure. The similarity between pressure effects and the physiological effects of anaesthetics could be the key to important medical advances.

The various trench ecosystems form a series of 'natural experiments' in which the principal physical environmental parameters are kept constant and the food supply is varied in quantity and in the degree to which it is seasonally pulsed. These ecosystems could provide a variety of test-beds for the critical assessment of ecological theories developed by studying terrestrial habitats and communities. Such theories are fundamental to the ways in which we should seek to manage

and conserve the World's ecosystems. Whereas there have been pragmatic statements as to why natural biota and communities must be conserved for the good of Mankind, it is also immoral to damage needlessly a remote and largely unknown assemblage of organisms—even if they are out-of-sight, out-of-mind, and apparently of little importance to the general ecological processes in the ocean—through negligent and ignorant abuse of the oceans.

## POTENTIAL THREATS

Environmental threats to the hadal faunas may be *via* direct damage to the animals themselves, such as through pollution by the dumping or accidental loss of toxic chemicals, or by direct mechanical interference by ocean-floor mining, or even by excessive scientific investigation. Alternatively, the threat may be indirect: for example, if the surface productivity is either significantly decreased or decoupled from the deep-water column by overexploitation, or increased so much that eutrophication leads to the development of anoxic conditions in deep water. This latter process occurs naturally in the tropical Eastern Pacific and the Black Sea, but has been induced by Man in enclosed seas such as the Baltic Sea and some fjords.

The geographical separation of the various ocean-trench systems should limit the threat to just one of them, unless the threat is global (such as the uncontrolled use of persistent toxic chemicals). Any such global threat would be recognized in other environments long before its influence would be noticed in trench faunas. Indeed, so little is known about trench faunas and microfloras, and so high is the cost and time involved in their study, that it is doubtful if changes in the faunas would be noticed even if they were quite drastic.

The purposeful or accidental introduction of large quantities of toxic substances into an ocean-trench system would create the conditions for a catastrophic disruption of its ecosystem. Far too little is known of current velocities or diffusion rates within trenches to be able to predict how extensively the damage would be spread; indeed, far too little is known even to guess as to how fast the system would recover if it was partly destroyed, or even if it would be able to recover at all. Purposeful dumping of toxic substances in the sea is limited by International Convention (Norton, 1976). Assuming that the Convention continues to be effective, dumping offers no threat. However, one type of disposal is being actively considered

and research is being done in an attempt to assess its feasibility, namely the sea-bed disposal of high-level radioactive waste (i.e.  $\alpha$ -emitting radioisotopes with long half-lives).

World energy demands will in time exhaust many reserves of fossil fuels. There is little evidence that the technology of exploiting renewable resources is likely to be advanced enough to bridge the energy-gap, nor does it seem likely that sufficient energy will be generated from such sources in the foreseeable future. Nor is it by any means certain that the full development of such resources will be environmentally acceptable: the prospects of vast areas of land surface being covered with sugar-cane and windmills, and every estuary being used to generate tidal energy, are scarcely compatible with our hopes for the world's future. The development of nuclear power is probably important for the political stability of the world, and hence to conservation interests, so long as adequate safeguards can be developed. But one of the major problems is how to dispose of the wastes. There are two methods of disposal that are considered practical—disposal in geologically stable crystalline rocks on land, and disposal in (or possibly on) the deep sea-bed.

Whereas land disposal is generally considered to be the safer in the long term, nuclear power agencies in several countries have local opinion violently opposed to their even carrying out preliminary site-investigations. Therefore, the feasibility and safety of sea-bed disposal is being actively investigated. For this, the waste materials will be converted into a highly refractory form—such as a vitrified glass—and encapsulated in a resistant alloy casing. Alloys are being developed that should resist corrosion in the deep oceanic environment for at least 1,000 years, after which period reprocessed waste would have a radiation level as low as that of the original ore from which it was extracted. Unreprocessed fuel, however, will always maintain higher levels of radioactivity. The cannisters containing the waste would probably be buried several tens of metres down in sediment, but some countries consider this to be an unnecessary safeguard.

Site criteria which have been laid down for possible dump-sites are that they should be (1) tectonically stable, (2) climatically stable, (3) remote from areas exploited for resources, and (4) highly predictable over geological time-scales (Anderson, 1979). It is clear from the geological background of ocean trenches that they fail to fulfil two if not three of the site criteria. The naïve attraction of disposal within trench systems is that subduction would lead to the

movement of isotopes down towards the Earth's centre and so out of the Biosphere. However, the average subduction rates of 2–6 cm per year are too slow for effective removal. The accidental sinking of a vessel loaded with cannisters being transported to a disposal site is unlikely to have any more than a very localized effect (e.g. Hessler and Jumars, 1979; Cohen, 1980), particularly as levels of natural radiation are so high on the sea-bed that hadal organisms are likely to be pre-adapted to withstand moderate levels of radiation.

At present there are no reports of mineral deposits within trench systems which suggest that they are never likely to be economically viable for exploitation. Manganese nodule deposits of commercial size tend to occur along the edges of the highly productive equatorial zones, well clear of the trench systems. Metal-rich brines, such as occur in the Red Sea or are discharged from hydrothermal vents (e.g. Edmond, 1981), tend to occur in close association with spreading centres at the mid-ocean ridge axes. These vents pose a much more critical conservation problem, but geographically they are sufficiently remote from trench systems not to merit further discussion here. Furthermore, any sediment plumes produced by mining activities would have sunk out of the photic zone by the time they drifted over trenches, and so would not threaten the organic input into the hadal communities.

Direct interference by Man by the emplacement of instruments or cables on the trench floor, whether for peaceful purposes or otherwise, is unlikely to be on a scale to produce more than minor disturbance. Another form of direct interference is by sampling from research vessels. Multiple-repeated tows with trawls or dredges over long distances across a trench floor would cause mechanical disturbance, particularly if the gear were so badly operated that the trawl warp dragged along the sea-bed in front of the sampler. The scouring and resuspension of sediment may cause mechanical damage and the clogging of the filters of filter-feeding organisms. However, the time and expense of deep trawling will probably never permit oceanographers the luxury of being able to sample trenches at an intensity that could cause serious damage to them. Moreover monitoring the extent and frequency of scientific sampling in trenches should not present any difficulties because, through the international exchange of data, the information is readily available from the major oceanographic data-centres.

A greater danger to an individual trench-system would be the accidental sinking of a vessel carrying a large load of highly toxic substances. In the relatively small volume of an ocean trench-system, especially if there is a low flushing-rate, catastrophic poisoning of a large part of the system could ensue. In shelf-seas, removal of toxins from the ecosystem occurs by biodegradation, and by chelation or absorption onto particles which sediment out. In trenches, microbial activity is at a relatively low level and the microorganisms do not appear to be able to adapt quickly to new substrates. When the submersible 'Alvin' was recovered from the sea-bed several months after it had been accidentally flooded and sank, sandwiches left inside were unaffected by biodeterioration (Jannasch and Wirsen, 1973). There is an argument as to whether this indicated low microbial activity or merely that bologna sausage with preservatives was an unsuitable substrate for deep-sea Bacteria (Yayanos *et al.*, 1979) although later experiments have suggested that the preservatives were not responsible for the inhibition of bacterial growth. However, the observation does indicate a low ability of these microorganisms to adapt quickly to unusual substrates, and so they would be unlikely to play a major role in detoxification. Similarly, although sedimentation rates in trenches are very high in comparison with those over abyssal plains, they are still slow relative to those in shelf-seas. So removal of toxic substances by chelation and absorption onto particulates will also be slow. The routing of vessels carrying such toxic loads so that they do not run along the axes of ocean trenches, would minimize the risk of serious accidental pollution of the latter.

## CONCLUSION AND SUMMARY

Ocean trenches provide a series of isolated and specialized environments containing a specialized fauna and microflora with a high degree of endemism. The physical environmental parameters are highly stable, but the seismic activity and the high sedimentation rates create a much less stable environment than is offered by the abyssal plains. Consequently, the communities inhabiting ocean-trenches are likely to prove less fragile to environmental disturbance than communities inhabiting more stable habitats.

The trenches are very difficult of access and offer no known exploitable mineral resources, so direct human interference is unlikely to create conservation problems. However, because

of their small dimensions, a research programme concentrated on even a single trench-system could prove disastrous for a single system. The disturbance and ecological disruption.

Most indirect threats to trench ecosystems will first affect other, shallower ecosystems, so hopefully any serious damage can be averted. However, the sinking of a vessel with a highly toxic cargo into a trench with a low flushing-rate, could prove disastrous for a single system. The chance of such a disaster destroying a trench ecosystem would be minimized by routine vessels carrying toxic cargoes at right-angles to trenches if it is not possible to steer clear of them completely.

Three of the four basic criteria, laid down by the International Atomic Energy Agency, for site selection for the disposal of high-level radioactive waste in or on the deep-sea bed, are not fulfilled by deep-ocean trenches. Such trenches are, and must continue to be, excluded from any considerations of deep-sea disposal of high-level radioactive waste, or indeed for the dumping or disposal of any materials permitted (or not permitted) under the present international dumping agreements.

So little is known about trench faunas and microfloras, and so high is the cost and time involved in their study, that it is doubtful if changes in them would be noticed, even if they were quite drastic. Monitoring of trench ecosystems with present-day technology is neither feasible nor likely to detect changes induced by Man's activities.

With our present knowledge and technology, the unique faunas and microfloras of ocean trenches would not seem to be in any critical danger. Conservation agencies do not need to take any immediate action for their conservation, but should maintain a watching brief in case any future developments might increase the vulnerability of these remote and unique systems.

## REFERENCES

Anderson, R. D. (1979) *Nuclear Waste Disposal in Subseabed Geologic Formations: The Seabed Disposal Program*. Sandia Report 78-2211, Sandia Laboratories, Albuquerque, New Mexico, USA, 31 pp.

Angel, M. V. and Baker, A. de C. (in press). Vertical distribution of the standing crop of plankton and microneckton at three stations in the Northeast Atlantic. *Biological Oceanography*.

Baird, R. C., Wilson, D. F. and Milliken, O. M. (1973) Observations on *Bregmaceros nectabanus* Whitley in the anoxic sulfurous water the the Cariaco Trench. *Deep-Sea Res.*, 20, pp. 503-4.

Belyaev, G. M. (1972) *Hadal Bottom Fauna of the World Ocean*. Instituta Okeanology Nauk Moscow: Israel Programme of Scientific Translations, Jerusalem, Israel: 281 pp.

Broecker, W. S., Takahashi, T. and Stuiver, M. (1980) Hydrography of the central Atlantic, II: Waters beneath the two-degree discontinuity. *Deep-Sea Res.*, 27 (6A), pp. 397-420.

Boss, K. J. and Turner R. D. (1980) The giant White Clam from the Galapagos Rift, *Calyptogena magnifica* species novum. *Malacologia*, 20 (1), pp. 161-94.

Cohen, B. (1980) Ocean dumping of high-level waste—an acceptable solution we can 'guarantee'. *Nuclear Technology*, 47, pp. 163-72.

Edmond, J. M. (1981) Hydrothermal activity at mid-ocean ridge axes. *Nature* (London), 290, pp. 87-8.

Embley, R. W. and Jacobi, R. D. (1977) Distribution and morphology of large sediment slides and slumps on Atlantic continental margins. *Mar. Geotech.*, 2, pp. 205-28.

Enright, J. T., Newman, W. A., Hessler R. R. and McGowan, J. A. (1981) Deep-ocean hydrothermal vent communities. *Nature* (London), 289, pp. 219-20.

Foster, G. R. (1964) Line-fishing on the continental slope. *J. Mar. Biol. Ass. U.K.*, 44, pp. 277-84.

Frankenberg, D. and Menzies, R. J. (1968) Some quantitative analyses of deep-sea benthos of Peru. *Deep-Sea Res.*, 15, pp. 623-6.

Grassle, J. F. (1977) Slow recolonisation of deep sea sediment. *Nature* (London), 265, pp. 618-9.

Haedrich, R. L. and Rowe, G. T. (1977) Megafaunal biomass in the deep sea. *Nature* (London), 269, pp. 141-2.

Hessler, R. R., Ingram, C. L., Yayanos, A. A. and Burnett, B. R. (1978) Scavenging amphipods from the floor of the Philippine Trench. *Deep-Sea Res.*, 25, pp. 1029-47.

Hessler, R. R. and Jumars, P. A. (1979) The relation of benthic communities to radioactive waste disposal in the deep sea. *Ambio* (special report No. 6), pp. 93-6.

Hinga, K. R., Sieburth, J. McN. and Heath, G. R. (1979) The supply and use of organic material at the deep-sea floor. *J. Mar. Res.*, 37 (3), pp. 557-79.

Honjo, S. and Roman, M. R. (1978) Marine copepod faecal pellets: Production, preservation and sedimentation. *J. Mar. Res.*, 36, pp. 469-92.

Isaacs, J. D. and Schwartzlose, R. A. (1975) Active animals of the deep sea floor. *Scient. Am.*, 233 (4), pp. 84-91.

Jannasch, H. W. and Wirsén, C. O. (1973) Deep-sea microorganisms: *in situ* responses to nutrient enrichment. *Science*, 180, pp. 64-73.

Jumars, P. A. and Hessler, R. R. (1976). Hadal community structure: Implications from the Aleutian Trench. *J. Mar. Res.*, 34, pp. 547-60.

Lemche, H., Hansen, B., Madsen, F. J., Tendal, O. S. and Wolff, T. (1976). Hadal life as analysed from photographs. *Vidensk Medd. Dansk naturh. For.*, 139, pp. 263-336.

Le Pichon, X. (1968) Sea floor spreading and continental drift. *J. Geophys. Res.*, 73, pp. 3661-87.

MacDonald, A. G. (1975) *Physiological Aspects of Deep Sea Biology*. Cambridge University Press, Cambridge, England, UK: xii + 450 pp., illustr.

Neumann, C. and Pierson, W. J. Jr. (1966) *Principles of Physical Oceanography*. Prentice-Hall, Englewood Cliffs, NJ, USA: xii + 545 pp., illustr.

Norton, M. G. (1976). The operation of the Dumping at Sea Act 1974. *Chemistry and Industry*, 19, pp. 829-34.

Rowe, G. T. and Staresinic, N. (1979) Sources of organic matter to the deep-sea benthos. *Ambio* (special report No. 6), pp. 19-23.

Shackleton, N. J. (1978) Evolution of the Earth's climate during the Tertiary Era. Pp. 49-58 in *Evolution of Planetary Atmospheres and Climatology of the Earth*. Centre National d'Etudes Spatiales, Toulouse, France.

Shepard, F. P. (1978) Geological oceanography, evolution of coasts, continental margins, and the deep sea floor. Heinemann, London: xii + 214 pp., illustr.

Silver, M. W. and Bruland, K. W. (1981) Differential feeding and fecal pellet composition of salps and pteropods and the possible origin of the deep-water flora and olive-green 'cells'. *Mar. Biol.*, 62, pp. 263-73.

Smith, K. L. and Laver, M. B. (1981) Respiration of the bathypelagic fish *Cyclothone acclinidens*. *Mar. Biol.*, 61, pp. 26-36.



- Stephens, G. C. (1981) The trophic role of dissolved organic material. Pp. 271-91 in *Analysis of Marine Ecosystems* (Ed. A. R. Longhurst). Academic Press, London & New York: 741 pp.
- Torres, J. J., Belman, B. W. and Childress, J. J. (1979) Oxygen consumption rates of midwater fishes as a function of depth of occurrence. *Deep-Sea Res.*, 26 (2A), pp. 185-8.
- Turekian, K. K., Cochran, J. K. and Nozaki, Y. (1979) Growth rate of a clam from the Galapagos Rise hot spring field using natural radionuclide ratios. *Nature* (London), 280, pp. 385-7.
- Tyler, P. A. and Gage, J. D. (1980) Reproduction and growth of the deep-living brittle-star *Ophiura Ljungmani* (Lymann). *Oceanologica Acta*, 3, pp. 177-85.
- Vinogradov, N. G., Kudinova-Pasternak, R. K., Moskalev, L. I., Muromtseva, T. L. and Fedikov, N. F. (1974) Some regularities of quantitative distribution of bottom fauna of the Scotia Sea and the deep-sea trenches of the Atlantic sector of the Antarctic. *Tr. Inst. Okeanol. SSSR*, 98, pp. 157-82.
- Wiebe, P. H., Madin, L. P., Haury, L. R., Harbison, G. R. and Philbin, L. M. (1978) Diel vertical migration by *Salpa aspera*: Potential for large-scale particulate organic transport to the deep-sea. *Mar. Biol.*, 53, pp. 249-56.
- Wischner, K. F. (1980) The biomass of the deep-sea benthopelagic plankton. *Deep-Sea Res.*, 27 (2A), pp. 203-16.
- Wolff, T. (1970) The concept of hadal or ultra-abyssal fauna. *Deep-Sea Res.*, 17, pp. 983-1003.
- Wolff, T. (1976) Utilization of seagrass in the deep sea. *Aquat. Bot.*, 2, pp. 161-74.
- Wolff, T. (1977) Diversity and faunal composition of the deep-sea benthos. *Nature* (London), 267, pp. 780-5.
- Wolff, T. (1979) Macrofaunal utilization of plant remains in the deep sea. *Sarsia*, 64, 117-36.
- Yayanos, A. A., Dietz, A. S. and Boxtal, R. Van (1979). Isolation of a deep-sea barophilic bacterium and some of its growth characteristics. *Science*, 205, pp. 808-10.
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