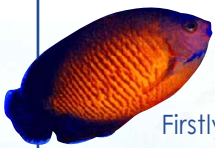




INTRODUCTION TO THE DEEP SEA ENVIRONMENT

In this essay we shall discuss several aspects of the deep sea environment. The main focus will be on the environment below the Mesopelagic Zone that extends down to 2000 meters below sea level with an emphasis on the environment in the Bathypelagic and Abyssalpelagic Zones. We will examine the sources of evidence for a discussion of this deep sea environment by looking at some of the techniques man uses to gather information there. This will be followed by a description of some of the determining conditions in these regions with a note on geology, sediments, a brief discussion of the deep water masses, a description of marine life to be found in the deep sea environment, its adaptations and challenges with a special note on hydrothermal vents (although at an average depth of 2100 meters they are just within our discussion zone), hydrocarbon seeps and a final conclusion about the overall importance of the deep sea environment for mankind.



Firstly, why study the deep sea environment at all? The abyssal plains are dark and seem devoid of life or interest but nothing could be further from the truth. Abyssal areas represent over 90% of the benthos and over 80% of ocean lies below 3000 meters. New discoveries are being made and these could greatly influence our future. The deep sea is a repository of scientific information and resources that can influence us in the fields of medicine, chemistry, physics, biology, feeding the world's expanding population and conservation. The deep sea is in fact the largest ecosystem on Earth. Let us first examine the methods of evidence collection.

THE COLLECTION OF EVIDENCE

There are many techniques and devices that have been used to explore the depths and gather information ranging from the days of dropping lead weights (line sounding) over the side of ships, to echo sounding since World War I, to the invention of scuba gear (not useful at our depths under discussion), to the use of Geological Long Range Inclined Asdic (GLORIA). Sidescan sonar and continuous seismic surveying methods do give us a wealth of information. In addition a range of simple devices give us information such as thermometers, water bottles and current meters for measuring the physical and chemical properties of the water, dredges, corers, heat probes and cameras for studying

bottom sediments and bottom life. However, for centuries the only evidence we had of marine life in the deep sea was extremely scarce.

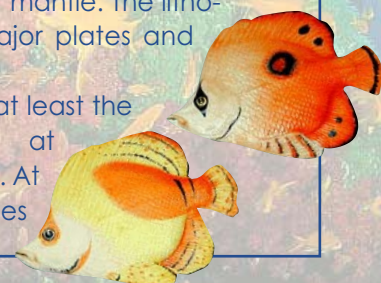
The area we are discussing has rarely been visited. Diving using atmospheric suits (JIM) can only cope to around 450 meters currently. We need different equipment to explore the depths we are discussing. In 1964 Alvin made the first successful scientific deep sea manned submersible dive on behalf of the Woods Hole Oceanographic Institute. Later updated versions have been able to dive to 6,000 meters. Alvin was the first to discover hydrothermal vents and explore a small section of the mid oceanic ridge. We will return to this environment later. For depths below this we rely on remote operated vehicles or ROVs. Cutting edge research is being conducted using ROVs by Woods Hole OI and also Monterey bay Aquarium Research Institute. Man has even visited the lowest point. In January 1960 Piccard and Walsh descended in the Trieste II (a bathyscaphe) to the deepest known point on Earth, the Mariana Trench at 10,915 meters.

Despite the overall paucity of evidence and the fact that the vast majority of the seabed remains to be explored we can discuss the deep water environment in a dynamic way. New discoveries are being made frequently in this field. Let us now look at the geological basis of the deep sea environment.

GEOLOGY

The Ocean lithosphere is approximately 100 km thick (therefore significantly thinner than the continental lithosphere) and this refers to the crust and the upper part of the mantle. The lithosphere is composed mainly of peridotite. The upper part of the lithosphere is the crust which is made up mainly of lighter granitic rock. The oceanic crust is thinner and denser than the continental crust and made up mainly of basaltic rock. The entire lithosphere (oceanic and continental) sits on top of the viscous lower layer called the asthenosphere which forms part of the upper mantle. The lithosphere is composed of 7 major plates and 6 minor ones.

New oceanic lithosphere, or at least the oceanic crust, is formed at constructive plate boundaries. At sea floor spreading ridges



the asthenosphere wells up and cools and forms the oceanic floor on either side of the boundary. The Mid Atlantic Ridge is a classical example of this. Destruction of the oceanic lithosphere occurs in the subduction zones.

The subducted plate descends into the hot mantle and is destroyed as it melts. The coast of Japan offers an example of this. It should be noted that the environment is dynamic over geological time as the process of subduction destroys the ocean floor. As new ocean floor is formed it pushes the floor on either side away and this may eventually enter a subduction zone and be destroyed.

It is possible to date the ocean crust as the plates move apart and spread over the abyssal plain as they take on the polarity of the Earth's magnetic field. This work was described by Matthews and Vine. Also generally speaking the older the ocean crust the further away from the spreading ridges it will be. The denser material also sinks further away from the surface of the sea. Given the age/depth relation the age of the ocean crust can also be estimated. The main "landform" features of the ocean basins are perhaps a Mid Ocean Ridge with an abyssal plain on either side of this ridge, constructive plate margins or destructive plate margins with a deep ocean trench at the edges of the deep sea environment with pelagic sediments covering the floor. Naturally there are many variations to this pattern but this brings us to a consideration of sedimentation.

SEDIMENTS IN THE DEEP SEA ENVIRONMENT

In the true deep sea environment we are really only concerned with deep sea sediments. However, there are two main types of sediment, terrigenous and bioclastic and less widespread types of sediment from volcanic and hydrothermal vent activity. Sediments can also be classified as pelagic or deep sea sediments. If we look at terrigenous sediments first, these are the result of erosion from continental rocks. The material eroded is deposited on the continental shelves by runoff or other physical actions and advances the continental shelf seawards by deposition of sediments. Submarine fans may form e.g. the giant Ganges Fan and currents eventually move sediments off the continental shelf and into the abyssal plain. Therefore this brief discussion of terrigenous sediments is useful as they do eventually enter our discussion remit. The ocean shifts the coarser material in turbidity currents and there are occasional sudden movements e.g. 1929 Grand Banks in North America turbidity event.

Bioclastic sediments are the result of biological activity and include the dead remains of pelagic plants and animals that have sunk. Pelagic bioclastic sediments are also called oozes and may be composed of calcareous or siliceous materials. Calcareous ooze is composed of chalky remains of foraminifera and

pteropods, and forms the deep ocean red clays. The siliceous material is derived from shells of radiolarians and diatoms and found mainly in tropical and polar seas. The distribution of ooze reflects primary production taking place near the surface. The thickness of the sediments also reflects the age of the ocean crust with thickness increasing as we move away from mid ocean ridges for example.

Volcanic ash from eruptions can also travel large distances and end by being deposited on the ocean floor, thus contributing to sediments. Finally around hydrothermal events we have unique sediments with metalliferous muds. It should also be noted that sediments on the abyssal plains are not completely static as currents, earthquakes and tectonic activity can move them. An understanding of sediments in the deep sea environment is vital when we discuss life in this region.

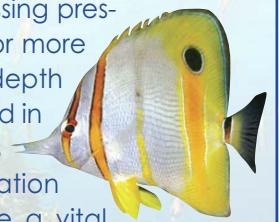
DEEP WATER CONDITIONS

Deep water is isolated from the effects of wind below the Ekman spirals which only influence down to 100 meters. However, changes at the surface can result in the movement of deep water with changes in temperature, density and salinity. Cold, dense water sinks and moves very slowly along the depths of the ocean, requiring many hundreds of years to move through an ocean basin. There is no daily or seasonal variations effectively and this creates a very stable environment. Below 3,000 meters the area is isothermal effectively except for areas around hydrothermal vents. The regions under discussion in this essay are mainly the Bathypelagic and Abyssalpelagic Zones so here the waters are dark, limited in nutrition, cold and at great pressure. For every 10m increase in depth pressure increases by one atmosphere so we are discussing pressures of 200 to 600 atmospheres or more in our region since the average depth of the deep sea is 4,000 meters and in some cases goes to 11,000 meters in the trenches. A consideration of deep water conditions will be a vital underpinning to our section of life in the deep water environment.

LIFE IN THE DEEP SEA ENVIRONMENT

Despite the apparent difficulties and challenges of life in the deep sea environment organisms have managed to exploit these regions. We shall take a look at some of the main groups of inhabitants, some of the difficulties they face and finally some of the adaptations they have evolved to cope with life in the deep sea.

Firstly we should discuss briefly the presence of microorganisms in the deep sea. In fact most organisms in the deep sea are microorganisms. These microbes are able to tolerate high pressure (barotolerant) and others actually depend on high pressure (barophilic). In the Mariana Trench there are extreme barophiles.



Most of these microbes are also psychrophilic i.e. they like cold conditions. Bacteria at these levels have specially adapted enzymes and membranes. However, much research remains to be done in this area and results can sometimes be inconclusive or at least very surprising. For example in 1996 the Japanese submersible Kaiko scooped mud from the bottom of the Challenger Deep in the Mariana Trench and when the many thousands of organisms were examined none of them were barophilic, halophilic or acidophilic but surprisingly alkaliphiles and even thermophiles so we should be careful in making generalization in the hadal zone. However, other samples taken around the same time did result in the successful isolation of some extreme barophiles related to the genera *Shewanella*, *Moritella* and *Colwellia*. However, as we shall see not only microbes live in these zones.

ANIMALS OF THE DEEP SEA ENVIRONMENT

The deep sea is home to most phyla of animals but changes in abundance of different animals with increasing depth. Research in the Kurile-Kamchatka shows that sponges are dominant down to 2000 meters but we are focussed on the deeper regions. Sea cucumbers are the commonest animals found below 4000 meters and polychete worms make up a large percentage of benthic or bottom dwelling animals. Sea cucumbers and seapigs (Holothuroidea) are often the most common animal in deep dredges. Seapigs have been caught at 10,000 meters deep in the Kermadec Trench. These feed by ploughing the deep sea mud and digest bacteria and organics. Some can swim above the ooze though.

Starfish have been found down to 7,000 meters. Brittle and basket stars (Ophiuroidea) are found. Small crustaceans such as amphipods and isopods, as well as molluscs (such as clams) and sea anemones have been found at great depths. There were relatively few crabs and fish found at these depths but this may have been more to do with the sampling methods used. On the ocean bed deposit feeders predominate with sea cucumbers and worms at the deepest levels. There are in fact many species of smaller infaunal animal here. Some estimates reckon close to a million different species of benthic invertebrates in the deep sea sediments. This shows why our above consideration of sediments is so fundamental to a discussion of the deep ocean environment. However, the number of individual animals decreases from the surface to the deep hadal trenches.

We stated that there were relatively few crabs and fish found at great depth but they are represented. Lets us take three species as examples. Firstly a fish that is often ignored because of its more spectacular rivals the - Rattail Fish or Grenadier fish. This is termed benthopelagic or demersal because they swim just above the bottom. This relative of cod

is in fact the most common fish found in the abyssal depths. The deepest Rattail observed lives down to 6500 meters. These belong to the family Macrouridae and have large heads and tapering bodies and feed by both hunting and scavenging. They are being fished commercially. Secondly we have the Hatchet fish (*Argyropsaleus olfersi*). They are camouflaged with silvery bodies, a flattened body for reduced silhouette and photophores that match the downwelling light so they are difficult to see. They search the waters above with their tubular eyes. We shall consider these adaptations in the next section. Thirdly we have the Lantern fish (*Ceactoscopelus warmingii*), which are about 5 to 15 centimeters long, have numerous photophores and migrate daily upwards to feed. We have space here only to discuss a few of the many species in the deep sea environment. Other species include sea urchins, crinoids, Tripod fish, gulper eels, sponges and seapens. Some are permanent dwellers in this environment such as deep sea cucumbers and others are visitors to our region such as the large Greenland shark (*Somniosus microcephalus*) down to 2,200 meters and the six gilled Hexanchus down to 2,500 meters but all have some adaptations to cope with the deep sea environment. These and other adaptations to life in the deep sea environment will now be discussed in more detail.

DEEP SEA CHALLENGES TO ANIMALS AND THEIR ADAPTATIONS

Lets us select five main categories to discuss as follows: adaptations to pressure, temperature, food availability, lack of light, and reproduction.

Pressure and temperature

Animals adapt to pressure in a variety of ways e.g. sperm whales have lungs that can compress to 1% of their normal volume, angler fish have reduced skeletons and other fish have reduced muscle mass. Sea cucumbers have bodies largely composed of water and others have proteins and enzymes adapted to work at pressure. Sharks have oily livers instead of swim bladders to cope with extremes of pressure. It is also difficult to produce calcium carbonate shells due to pressure and temperature issues. As pressure increases and temperature decreases calcium carbonate becomes soluble making it difficult for creatures to secrete shells. The depth when no calcium carbonate present is called the carbonate compensation depth or CCD. Today the CCD in the Pacific ranges from 4,200 meters to 4,500 meters deep and in the Atlantic 5,000 meters deep. Many species have dispensed with shell formation below the carbonate compensation depth. In these ways we see that there are physiological and chemical adaptations to cope with increased pressure. Secondly we have a brief discussion of temperature. The deep sea is largely isothermal with very stable temperatures prevailing that need few adaptations. Hydrothermal vents are an exception to this rule and we will discuss these in more detail later in the thesis.



Food availability

As far as food availability is concerned there are many adaptations animals use to cope ranging from predatory and scavenging behavior, opportunistic feeding on whale carcasses to vertical migration strategies. Let us look at these in more detail now: Basically food availability decreases with depth as does species diversity. The supply of food to the deep sea depends on primary production in the photic zone (except for hydrothermal vent areas). However, it has been estimated that just 2% of phytoplankton sink to the bottom as they are mainly consumed above or on the way down. Since food is relatively scarce the marine organisms have a number of ways of coping.

We can loosely categorize these as

- 1) Energy conservation adaptations e.g. slow movements, slow metabolisms, and some fish with relatively low muscle mass compared to fish in shallower seas.
- 2) Related to energy conservation some fish are ambush predators e.g. deep sea Angler fish, using bioluminescent lures.
- 3) Dwarfism and gigantism are methods of coping with food availability e.g. tiny nematode worms at one extreme and large amphipods (up to 28cm) at the other.
- 4) Physiological adaptations also include distended stomachs and hinged jaws in some species to cope with the rare chances of feeding e.g. angler fish and gulper eels but even bivalves in the deep ocean have been found to have longer guts to take full advantage of food availability.
- 5) Related to this opportunistic feeding but perhaps in a class of its own we have the animals adapted to feed on dead whales. These are very important and provide many year's food supply to an area of the ocean floor in one moment. 43 species have been found on one whale carcass e.g. sharks, hagfish, bone eating zombie worms, snails, limpets, clams and anaerobic bacteria. Since there are many similarities with organisms found round hydrothermal vents these carcasses may have acted as stepping stones from vent to vent.
- 6) Deposit feeders. Since the deep sea floor is dominated by loosely compacted biogenic ooze it is dominated by deposit feeders like the deep sea cucumber (Scotoplanes). Deposit feeders may make up to 80% of the species on the sea floor. Most of the sea bed is covered in soft clays or mud like oozes made of skeletons of tiny sea animals and fecal material. The ooze in the abyss can reach several hundred meters thick. Some animals walking along the bottom have very long legs to avoid stirring the mud up e.g. deep sea spider. These are not true spiders but belong to the pycnogonids. Other species grow anchored to the sea bed and have long stems to keep feeding structures clear of the ooze.
- 7) Vertical migration. Some fish move upwards to feed

and have replaced swim bladders with fatty deposits in order to cope with the vast differences in pressure. The Rattail fish mentioned above is a good example of this travelling up to 1,700 meters upwards in a night to feed. This is just a brief cross section of the ways in which animals cope with limited food supplies.

Lack of light

Lack of light perhaps creates some of the most interesting adaptations. Eyes of fish in the deep sea tend to be generally larger than their counterparts above, although below 2000 meters eyes again grow smaller or are absent. Eyes contain a higher density of rods in the retina or tubular eyes are common e.g. hatchet fish. Where eyes are useless in the total darkness other methods have developed to sense the environment. Lateral lines are well developed to sense vibrations and antennae may also be used e.g. in hairy angler fish. Bioluminescence is another adaptation with 60 to 70% of deep water animals possessing this ability. Organs called photophores, sometimes using bacteria as a light source are found in many fish e.g. lantern fish. Simple photophores either produce light or retain light producing bacteria such as *Vibrio* or *Photobacterium* in a symbiotic relationship. Since bacteria produce light continuously the host animals develop ways to control emissions e.g. reflective layers, flaps and lenses. Squid have the most spectacular abilities in this area. Bioluminescence can be used as a lure for food or for defence. Areas of photophores in the angler fish are for lures. The hatchet fish uses light for camouflage and the squids for defense as a burst of unexpected light can distract an attacker.

Since the dominant sense in the deep sea is hearing we should discuss this in a little more detail. Many invertebrates detect sound by cilia. Fish detect by sensory hairs in the otolith organ in the inner ear. Lateral line systems also enable fish to detect sound vibrations, movements of prey and fish in schools and changes in ocean currents. Animals around the hydrothermal vent systems may rely on this to avoid the vents themselves but we will return to a discussion of vents later. When we consider vision there are also a variety of systems in use. There are relatively simple systems such as eyespots e.g. polychete worms to the spherical lens systems of fish which allow them to have light perception beyond the capabilities of man as we have mentioned above. Next we should consider the sense of orientation in marine animals. Several species can detect the pull of gravity with organs known as statocysts. In vertebrates the semicircular canal in the ear performs this function. Next we come to chemoreception covering the senses of taste and smell. The sense of smell (olfaction) is extremely well developed in sharks. and these do venture down into the regions we are discussing. Electroreception is another sense used by sharks and some other predatory fish who possess electrosensory organs.



In sharks these are known as ampulla of Lorenzini. Finally there is the sense of magnetoreception and magnetite crystals have been found in fish that may enable them to navigate over long distances. Much research remains to be done in this area it seems, particularly in relation to deep sea species.

Reproduction

Finally we have adaptations in reproduction in the deep sea with eggs with large yolks to combat lack of food, long lived species with slow sexual maturity may also help in this area. The relative difficulty of finding isolated mates may also have led to high degrees of hermaphroditic behavior. For example tripod fish have both male and female sex organs. The tripod is unusual in that male and female organs may reach maturity at the same time thus allowing the fish to fertilize its own eggs. Perhaps it is so sparsely distributed that one fish may not find a mate at the right time. The famous adaptation of the tiny parasitic male in angler fish is another adaptation to this isolation. The tiny male clamps onto the female and is even partially absorbed by her thus ensuring a source of fertilization at the right time. Deep sea species tend to be slow growing, late maturing and low in reproductive capacity. Many deep water fish species live 30 years or more and the orange roughy can live up to 150 years. These are just some of the adaptations to the deep sea. If we look in more details at certain unique communities in the deep sea environment we can observe other adaptations

A NOTE ON HYDROTHERMAL VENTS AND HYDROCARBON SEEPS

Hydrothermal vents systems are one such unique community. These have been of interest really since the Alvin discoveries in 1977 in the Galapagos Rift Zone. Hydrothermal vent systems develop at depths of several kilometers in the oceans in mid ocean spreading centers where there is hot upwelling lava. Sea water percolates and is vented back at hot temperatures, full of minerals, as either warm seeps, black or white "smokers". White smokers are only slightly cooler than black smokers and because they are rich in zinc have a white tinge. Animals here must have a unique set of adaptations. Since they are far from the photic zone the inhabitants rely on bacteria such as *Beggiatoa* to produce food from chemosynthesis of caustic compounds such as hydrogen sulphide. These bacteria sometimes form mats near the vents and are in turn grazed upon by limpets and gastropod molluscs. Other communities of bacteria live in symbiosis with the giant tube worms (*Riftia pachyptila*) for example. *Riftia* can grow up to 1.5 meters long and have unique adaptations to the deep sea environment in that they can carry both oxygen and hydrogen sulphide in their blood to supply the bacteria. The clams (*Calyptogena magnifica*) near the vent systems have similar techniques. So far scientists have discovered over 236 species around the vent systems. 223 of these were

new to science and many of them endemic to vent systems. More vent systems have now been explored e.g. Hole to Hell and Hanging Gardens on the East Pacific Rise, the Snake Pit on the Mid Atlantic Ridge and the Rose Garden in the Galapagos Rift Zone. How these species developed and spread from system to system is a matter of interest and one theory suggests they may use whale carcasses as stepping stones.

There are also many theories about how life may have originated around these vents and in fact these areas may even have been where photosynthesis first developed as there is a faint haze around these vents. There are animals here with extreme UV sensitivity such as huge shrimp with massive numbers of photoreceptors in their eyes. The vent systems are highly dynamic and unstable environments but they do support uniquely adapted communities of marine life which are an important part of the discussion the deep sea environment

In addition to this perhaps we should also consider another unique deep sea environment namely Hydrocarbon seeps. These fall within our study as some of these seeps are more than 2000 meters down. Marine hydrocarbon seeps are cold (as distinguished from hydrothermal vent activity) and have two major sources, biogenic (bacterial production of gases) and petrogenic i.e. relates to subsurface petroleum reservoirs that leak to the surface. Some seep gasses arise from CH₄ hydrate dissociation, a water ice that is stable at great depths and low temperatures. Hydrocarbon seepage produces asphalt volcanism, brine pools, gas hydrates and authigenic carbonates. Hydrocarbon seepages are a feature in the Gulf of Mexico and we know from research done at the Chapopote site what minerals are involved. According to one study by the University of Texas communities of chemosynthetic fauna that depend on seeping oil and gas have been found at over 45 sites in the Gulf of Mexico so far down to the 2200 meters below sea level. The dominant fauna consist of species within four groups: tube worms, seep mussels, epibenthic clams, and infaunal clams. The development of these communities is closely linked to the geological and geochemical processes of seepage. Temperatures varied between 5 and 9 degrees Celsius. The full consequences and importance of both hydrothermal vents and hydrocarbon seepages has perhaps not yet been sufficiently realized or fully researched but these are fascinating and vital parts of the deep sea environment.

CONCLUSION

We have briefly discussed the geology, sedimentation, water mass and life forms and their adaptations in the deep sea environment. Until relatively recently the relevance of this environment to man was little studied and perhaps not regarded as particularly relevant for the future of man on Earth. In this summary we should touch upon seven key areas we have selected that link



the deep sea environment with man's future. The first topic regards biodiversity. Of the estimated 500,000 to 10 million species living in the deep sea, the majority are yet to be discovered. There could be no clearer illustration of the value of the world's deep sea environments. Approximately 98% of the world's species live in or just above the floor of the sea. (This includes some areas strictly outside our remit). Many of these species are related to seamounts for example. However, the unique environments harbor a breathtaking array of species with high rates of endemism. Each unsampled trench, vent and seep is a potential source of numerous undiscovered species. In addition two thirds of all known coral species live in waters that are deep, dark and cold, down to over 3000 meters deep, which belongs to our area under discussion. Some of these cold water corals are 5-8,000 years old or more and over 35 meters high. These and other habitat forming organisms provide protection from currents and predators, nurseries for young fish, and feeding, breeding and spawning areas for hundreds of thousands of species and therefore are a critical feature of the Earth's biodiversity.

Secondly we should consider the feeding of the world's ever expanding population. Commercially important deep water fish and crustacean populations found in the high seas include crabs, shrimp, cod, Pacific cod, orange roughy, armorhead, grenadier, Patagonian toothfish (also known as Chilean sea bass), jacks, snappers, porgies, sharks, groupers, rockfish, Atka mackerel and sablefish.

Thirdly, we have the medical uses and implications of the deep sea environment. For example Gorgonian corals produce antibiotics. Compounds found in certain deep sea sponges are powerful immunosuppressive and anti-cancer agents. In addition some corals contain the pain killing compounds known as pseudopterosins. Seafans contain high concentrations of posaglandins used to treat asthma and heart disease.

Our fourth point concerns energy and mineral resources. The deep sea environment harbors unexplored deposits of oil, gas, and many minerals. Seismic surveys have so far only detected a fraction of available reserves. A resource hungry world will need to exploit these reserves at some point in its future and the more we know about the deep sea environment the better we can use these reserves and hopefully lessen the impact.

Fifthly, we need to consider the relationship of the deep sea environment to our immediate environment. At first it appears there is little direct connection between the abyssal depths and our own world. However, according to one study at the University of Indiana deep sea hydrothermal vents may play an important part in regulating the temperature and chemical balance of the oceans. Before the discovery of hydrothermal vents scientists believed that the chemical

balance of the oceans was determined primarily by run off from the continents. Now hydrothermal vent (and hydrocarbon seep) influence is seen as important. In fact the university describes the hydrothermal circulation systems with wide ranging effects. Effects of pollution and deep sea circulation systems are vital to an understanding of the Earth's environment.

Sixthly, we need to consider the purely scientific importance of the deep sea environments. It is a treasure house of untapped discovery and resource. For example ancient deep sea corals provide valuable records of climate conditions that may assist our understanding of global climate change. Studies of this environment are making contributions to almost every branch of science from climatology to the search for the origins of life itself and in fact the deep sea is often seen as an extreme environment comparable to conditions prevailing on other planets.

Finally we will always be aware of the commercial attractions of the deep. These commercial considerations range from the exploitation of hydrocarbon reserves, mineral reserves, deep sea fishing to the deep sea communities, particularly of corals and sponges which are untapped sources of natural products with enormous potential as pharmaceuticals (mentioned above) enzymes, pesticides and cosmetics. By harvesting the deep sea environment responsibly we can contribute to a more balanced and prosperous world but by overexploiting we can cause global chaos. For all these reasons an understanding of the deep sea environment is pivotal to mankind's future.

SOURCES

Deep Sea Conservation Coalition

Indiana University studies on hydrothermal circulation

Texas University studies on hydrocarbon seeps

Monterey Bay Aquarium Research Institute

New Scientist

Simon Harding

Chairman of COBERON - CHRONOS GROUP