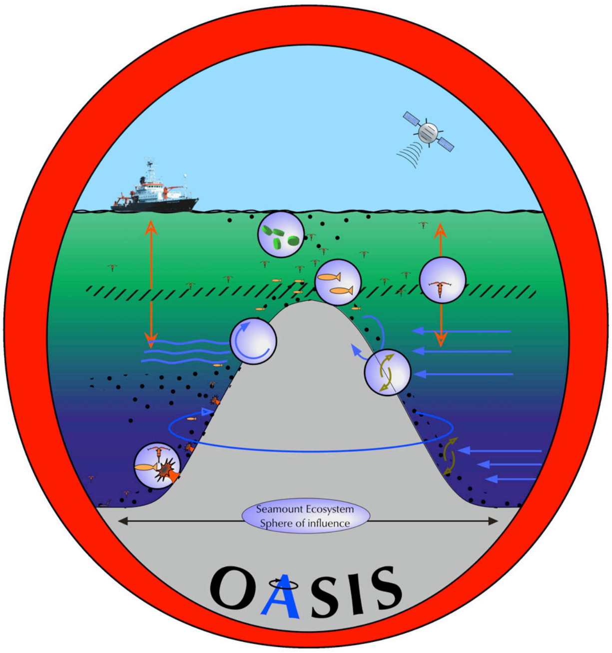
Seamounts of the North-East Atlantic



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Preface

Although there are tens of thousands of seamounts spread throughout the world's oceans, these undersea features are still little-known environments with regard to their biodiversity, their ecology and the short and long-term effects of human impacts. However, it has become clear in recent years that seamounts host very special ecosystems which are at risk from intensive exploitation of their natural resources.

Most studies on seamounts have been conducted in the Pacific. Although some North East Atlantic seamounts were studied already in the 1970s, the knowledge base is very limited and information is scattered through various disciplines, and many scientific results are unpublished. The EU-funded OASIS project (Oceanic Seamounts: An Integrated Study) aims to provide a holistic, integrated assessment of seamount ecology in the NE Atlantic using two sites as case studies. It is the first NE Atlantic seamount survey integrating physical, biogeochemical and biological studies and applying the scientific knowledge to develop possible options for sustainable management.

This report is one of the first products of the OASIS project and seeks to establish a baseline of published information on seamounts in the North East Atlantic by 2002, including a summary of management activities and legal issues. Although some geological information is included, the report focusses mainly on oceanographic and ecological aspects. It is envisaged to update the report in 2005, reflecting the project results and other ongoing research activities in the North Atlantic.

Dr. Bernd Christiansen
OASIS project coordinator

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Executive Summary

Seamounts are generally isolated, typically cone shaped undersea mountains rising relatively steeply at least several hundred meters from the surrounding deep sea floor.

There are at least some 800 major seamounts in the North Atlantic, mostly occurring associated with the Arctic Mid-Ocean Ridge, the Mid-Atlantic Ridge (MAR), and the Greenland-Iceland/Iceland-Faeroe Rise, large features which dominate the topography of the seabed. However, there are also clusters of seamounts some distance from the MAR such as those along the south west of the Rockall Bank and west of Portugal on the Madeira-Tore Rise.

Water mass circulation is characterized by the warm North Atlantic Drift setting northeastwards, seasonal upwelling off southeastern Europe and North Africa, and cold deep water formation off Greenland which then prevails in the North Atlantic deep sea. At the Mid Atlantic Ridge, and in particular around the islands of the Azores, currents, water masses and species of different biogeographic origin meet and mix - shallow seamounts often acting as stepping stones for cross-Atlantic dispersal of species, including wide-ranging migratory species. Reproductive isolation between seamount and ridge systems may also lead to elevated numbers of endemic benthic species, however this cannot yet be confirmed based on the limited data available.

Because of their volcanic origin and steep slopes amplifying the prevailing currents, hard substrata are common on seamounts and may be formed into a terrain interrupted by faults, fissures, down-dropped blocks, canyons, caves and hummocks. Softer substrata may also be present and include biogenic sediments such as foraminiferan sands, lithogenic sediments transported from the continental margin, and authigenic sedimentation, principally from the precipitation of ferromanganese oxides

There is a paucity of information on the benthos, illustrated by the fact that a century of study has resulted in the identification of just 596 invertebrate species from all seamounts explored up to the late 1980's. The enhanced currents that sweep around the seamounts and the exposed rock surfaces provide ideal conditions for suspension feeders, and it is these that often dominate the benthos. Cold water corals can be particularly abundant with gorgonian, scleractinian and antipatharian corals, some or all recorded from a number of seamounts at several hundred meters depth.

Studies of the pelagic communities above seamounts reveal qualitative and/or quantitative differences when compared to the surrounding water. The higher biomass of planktonic organisms over seamounts constitutes an important basis for the diet of fish, squid and top predators such as sharks, rays, tuna and swordfish. Small and large cetaceans, and turtles also aggregate at these biologically productive hydrographic features.

The fish communities found around seamounts have evolved a suite of morphological, ecological, life-history and physiological features that enable them to successfully exploit an environment with enhanced currents and greater flux of organic matter than much of the deep sea. Many are adapted for strong swimming performance, deep-bodied and with relatively high rates of metabolism and food intake. They may also be exceptionally long-lived with a slow growth rate. Some are also subject to extremely high recruitment variability, with successful recruitment occurring on approximately decadal time scales. Such species include the teleosts like orange roughy, oreos, pelagic armour head, and *Sebastes* spp., as well as various species of sharks and skates. Deep sea fish which form spawning aggregations on North East Atlantic seamounts include the orange roughy (*Hoplostethus atlanticus*), roundnose grenadier (*Coryphaenoides rupestris*) and oreosomatids – smooth oreo and black oreo (*Pseudocyttus maculatus* and *Allocyttus* niger).

The most significant threat in terms of geographic spread and scale of impact is commercial fishing. Commercially important species known to occur on seamounts in the NE Atlantic include tusk (*Brosme brosme*), blue ling (*Molva dipterygia*), morid cod (*Mora mora*), orange roughy (*Hoplostethus atlanticus*) and the shovel nosed shark (*Deania calceus*). They have been the targets of intensive exploitation using longlines, mid-water trawls and bottom trawls that can operate at depths of more than 1500 m. The search for new locations and potentially marketable deep-water fish on seamounts is a continuous process, fuelled by the depletion of shallow water stocks and the unsustainability of exploitation of deep water stocks.

The effects of fishing on seamount fishstocks are difficult to distinguish from the effects of deep-sea fisheries in general because catch statistics are pooled for relatively large areas. There is also extensive incomplete reporting of deep water catches and landings from international waters. In most cases fishing has taken place before there is a reasonable understanding of the biology of the species being targeted, and in the absence of formal stock assessments or quotas. The result has been over-exploitation and major crashes in the different stocks, *i.e.* of orange roughy and blue ling. Another cause for concern is the high rate of discards of ecologically vulnerable deep sea species associated with deep water fishery in general, with one ton of fish discarded for every ton of fish landed.

Fishing activity is also known to have had a massive impact on the benthos of seamounts in other areas of the world ocean, However, for the North East Atlantic data on impacts are missing due to lack of scientific studies.

Next to demersal fisheries, which have rapidly driven some deep-sea fish stocks to commercial extinction and depleted previously abundant fishing grounds, the use of longlines, driftnets and purse seines are known to have taken many thousands of seabirds, cetaceans, and turtles between them as “incidental catch", Recreational fishing, while not as widespread in these environments, adds to pressure on the biodiversity on some of the shallower offshore banks and reefs where top predators such as sharks are targeted.

Other threats, though less imminent, are pollution-associated high contamination levels of top predators, threats associated with the dumping of litter, deliberate discharge of oily and chemical wastes, accidental spills, leakage from sunken ships, noise pollution and, possibly, from the exchange of large volumes of ballast water. More localised threats include those associated with the deep-sea disposal of wastes, mineral extraction and bio-prospecting.

The habitat and associated species on seamounts have been identified as being particularly vulnerable, and there have been calls for measures, such as the establishment of Marine Protected Areas, to safeguard the biodiversity of these features and their associated wildlife, and to provide opportunities to learn more about them.

In recent years, several political initiatives are seeking to address the conflict between human impact and conservation requirements on a global, North East Atlantic regional and national level:

- The UN General Assembly called for urgent coordinated action to integrate and improve the management of seamounts and other underwater features in 2002,
- The need for conservation action in the high seas, *i.e.* by establishing high seas Marine Protected Areas is recognized by various fora (*i.e.* the Convention on Biodiversity)
- The OSPAR Ministerial Meeting agreed in 2003 on a regional priority list of species and habitats, including seamounts, for developing conservation action.
- The European Union Natura 2000 network of protected areas will include seamounts, selected as reef-like habitats under EU Habitats Directive Annex I. The first seamount protected is in Azores (Portugal) waters.

Methods and experiences gained with the management of human activities at seamount Marine Protected Areas in other parts of the world are complied in the final chapter.

1. Introduction

Seamounts are undersea volcanoes which are typically cone shaped, rising relatively steeply from the seabed. Some definitions limit them to features which do not emerge above the surface and to circular or elliptical features of volcanic origin (Epp & Smoot, 1989). In other cases height is a defining factor with seamounts considered to be features more than 1000m high with limited extent across the summit (Baker *et al.,* 2001). Seamounts can be very large features, not only in terms of their elevation but also in area, as some are more than 100 kilometres across at their base.

Some of the earliest reports on the occurrence of seamounts were made in the late 18th century and the first to be termed a seamount was possibly the Davidson Seamount off the California coast in 1933. Only in the last century has there been a focused interest in the natural and physical characteristics of these features as well as in the exploitation of associated resources.

As knowledge of these systems and exploitation of their resources has grown, so has concern about their condition and an awareness of the need to manage activities taking place around them to safeguard their biodiversity. One outcome has been the designation of a number of seamounts, which lie within Exclusive Economic Zones as Marine Protected Areas (eg. the Tasmanian Seamounts Marine Reserve 170km south of Hobart, Tasmania). There is also interest in similar action being taken for some seamounts on the High Seas although no such areas in the High Seas have such protected status as yet (e.g. Probert, 1999; WWF 2003).

The 3rd United Nations Open-ended Informal Consultative Process (which deals with matters on the High Seas and the UN Law of the Sea Convention) noted at its May 2002 meeting that seamounts are one of the underwater features on the High Seas that have high levels of endemic species and constitute a large, as yet unevaluated, reservoir of biological diversity that may be threatened by human activities in these areas. The meeting called on the UN General Assembly to invite international and regional organizations to urgently consider how to integrate and improve, on a scientific basis, the management of risks to seamounts within the framework of UNCLOS, and to make suggestions on appropriate management actions. This was subsequently endorsed by the General Assembly who called for urgent coordinated action to integrate and improve the management of seamounts and other underwater features (UNGA, 2002- A/57/L/48).

Interest in conservation and management of seamounts and associated resources can also be seen at a regional level. In the NE Atlantic, the OSPAR Commission has been developing guidelines for the selection and management of offshore Marine Protected Areas, and its Biodiversity Committee has discussed how this might relate to seamounts (OSPAR, 1999). There is also an initial OSPAR list of threatened and/or declining habitats and species for which action needs to be taken. Seamounts are on this list, as agreed at the recent OSPAR Commission meeting in June 2003, with a proviso that a search for further information on threats and their status will be conducted (OSPAR, 2003).

At a national level, some Member States of the European Union are considering options for seamount conservation through the EU Habitats & Species Directive. The Directive lists ‘reefs’ as one of a number of marine habitats whose favourable conservation status should be achieved through the establishment of ‘Special Areas of Conservation’ (SACs). Seamounts are covered by the definition of reefs, and Portugal (Azores) is the first EU country with proposals for seamount SACs under this category.

Interest in the conservation and exploitation of seamounts and their associated biological communities in the NE Atlantic has highlighted a need to improve understanding of seamount ecosystems and the threats that face them, as well as considering the management of activities that take place around them. These are little known environments, like much of the deep sea, both in terms of their biodiversity and the short and long-term effects of exploitation. Several initiatives are seeking to address these questions.

In 1997 an international research programme known as the "Census of Marine Life" was set up with the aim of assessing and explaining the diversity, distribution and abundance of marine organisms throughout the world's oceans. A key objective was to focus on poorly known ecosystems and/or communities such as the vast oceanic areas off the continental shelves. The ecosystems of the mid-oceanic ridges and the mesopelagic zone were highlighted as being of particular interest. A specific project under this programme is MAR-ECO (Patterns and Processes of the Ecosystems of the Northern Mid-Atlantic), which aims "to describe and understand the patterns of distribution, abundance and trophic relationships of the organisms inhabiting the mid-oceanic North Atlantic, and identify and model the ecological processes that cause variability in these patterns"[1]. This project and the respective programme mentioned above are an important focus for the collection and dissemination of information about seamounts.

A more recent initiative, agreed in 2002, seeks to gather information and improve understanding of seamounts in the NE Atlantic. The OASIS project (Oceanic Seamounts: an Integrated Study), funded by the European Union under its Fifth Framework Programme, aims to provide a holistic, integrated assessment of seamount ecology in the NE Atlantic using two examples as case studies - **Sedlo Seamount**, north of the Azores, and **Seine Seamount** north-east of Madeira: There are five work packages, one of which is to develop a common understanding of seamount ecosystems and their conservation and sustainable use[2].

This report is being prepared as a contribution to the OASIS project. It is intended to provide an up-to-date summary of scientific knowledge on seamount ecosystems, the impacts of human activity on these ecosystems, and approaches to the management of seamount resources with particular reference to seamounts in the NE Atlantic.

1.1 The North East Atlantic

The North East Atlantic, as defined by the OSPAR Maritime Area, extends from the North Pole to the Straits of Gibraltar, and from the coasts of mainland Europe eastwards to the Mid-Atlantic Ridge (Figure 1). The physical, biological and chemical characteristics of the region have been described in a series of Quality Status Reports prepared by OSPAR (OSPAR, 2000a-e) and are summarised briefly below.

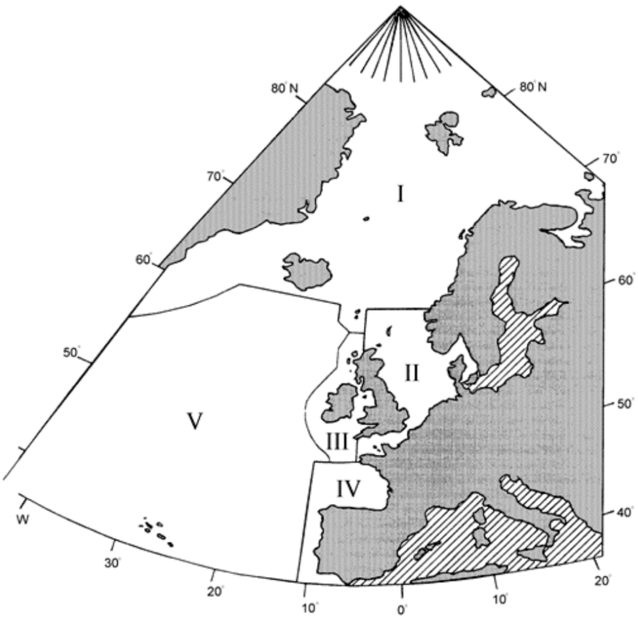

Figure 1: The OSPAR Maritime Area and Regions

Large topographic features such as the Arctic Mid-Ocean Ridge, the Mid-Atlantic Ridge, and the Greenland-Iceland/Iceland-Faeroe Rise dominate sections of the seabed in this part of the Atlantic. There are also extensive relatively flat and featureless areas, such as in the Porcupine Abyssal Plain and Iberian Abyssal Plain, and deep channels like the Norwegian Deep and Rockall Trough (Figure 2). The Continental Shelf is relatively narrow in most places. The exceptions are around the British Isles and north-western France where it forms the shallow seabed of the North Sea, Irish Sea, Celtic Shelf and the Northern Bay of Biscay. The habitat diversity created by features such as these is apparent on many scales; as underwater mountain chains, seamounts, hydrothermal vents, rocky seabed and as micro-variations in sediment type.

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[1] http://mareco.imr.no

[2] http:// www.rrz.uni-hamburg.de/OASIS

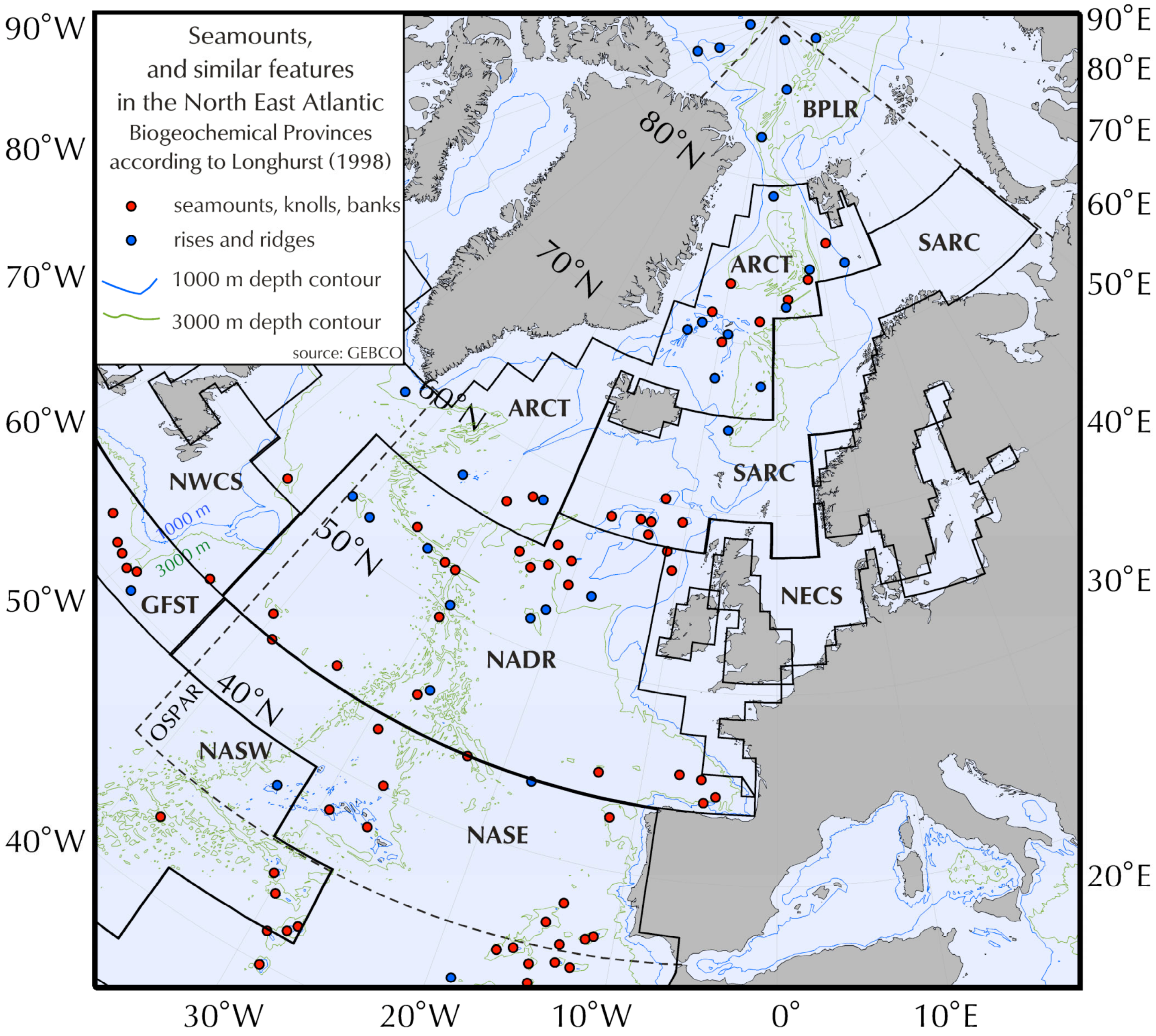

Figure 2: Bathymetry of the Northeast Atlantic and biogeochemical provinces redrawn after Longhurst (1998). Map by Bernd Christiansen (source GEBCO)

There are a number of clearly identifiable water masses and circulation patterns in the North East Atlantic. To the South and South-East of Greenland, for example, the cold temperature and relatively high salinity of the seawater causes it to sink. This water then flows southwards through the narrow channel between Greenland and Spitzbergen creating what is known as the North Atlantic Deep Water, which extends over much of the abyssal plain (Figure 3).

The North Atlantic current, on the other hand, carries warm water from low latitudes on the western side of the Atlantic to the western coasts of Europe Off the coast of Portugal the effects of wind on seawater circulation can be observed.

The consistent northerly winds which blow during the summer months move surface water offshore to such an extent that deep cool water is drawn to the surface creating a seasonal upwelling.

Other hydrographic features include gyres, eddies and frontal boundaries which persist for varying periods of time and can be a on a scale of a few centimetres to many kilometres across.

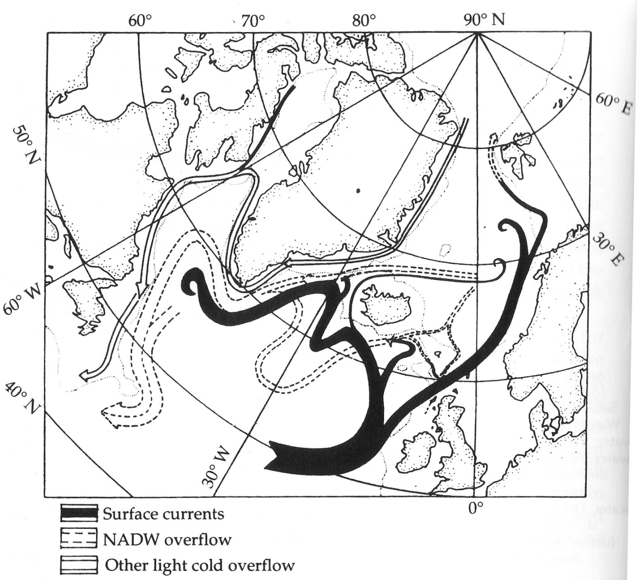

Figure 3: Formation and track of dense cold deep water (NADW) in the Norwegian Sea and subpolar N. Atlantic. (from McCartney & Tallex, 1994, 1984; in Gage & Tyler, 1996)

In the mid-Atlantic, the isolated volcanic islands of the Azores are influenced by a complicated current regime with different elements dominating at different times of the year (Santos *et al.,* 1995). The large scale oceanic circulation is dominated by the Azores Current which flows from west to east but the marine fauna and flora have more affinities with those of the eastern Atlantic. The islands have been described as being at a crossroads where representatives of shallow marine fauna and flora of different origins meet. Eddies from western Africa and the Atlantic coasts of Europe transport eggs and fish larvae to the Azores. Shallow –topped seamounts may serve as stepping-stones for dispersal of some species. The islands are also on the migration path for the sperm whale and the blue whale (Silva *et al*., 2003), sharks (eg. the whale shark and the blue shark), and turtles (eg. loggerhead turtles born in Florida live in the region of the Azores until maturity (Bolten *et al.,* 1998).

The characteristics of the different water masses in the NE Atlantic support a wide diversity of marine life. This is reflected in that fact that the region includes several biogeographical zones. Dinter (2001) reviewed the scientific literature on this subject and proposed biogeographic classifications for the NE Atlantic. Twenty-five different regions were identified relating to benthic and pelagic fauna of the shelf, upper continental slope and deep sea. This included work specifically on the deep sea (eg. Vinogradova, 1997) and on pelagic systems (eg. Longhurst, 1998; see Fig. 2). The biogeographical context of seamounts is complicated by the need to consider benthic and pelagic fauna and the fact that the features themselves can extend from the deep sea to near surface.

Limited information makes it difficult to draw conclusions about the biogeography of species found on seamounts. One example is the work by Kukuev (2002) on the fish associated with the Mid-Atlantic Ridge (MAR) and adjacent areas, including seamounts, based on about 200 species collected from the mid-1970s to the late 1980s. He concluded that the peaks of seamounts east of the MAR are inhabited by demersal fish associated with the European and North African shelf. On the Rockall Plateau boreal and boreo-tropical European species prevailed. On the seamounts south of the Azores, north-subtropical, boreo-subtropical and tropical East-Atlantic species typical of the southern European shelf and NW Africa predominated. At depths greater than 500m the pattern of the zoogeographic structure changed. The fish fauna was similar irrespective of geographic location on the MAR, westwards or eastwards of it. At these depths common tropical amphi-Atlantic and boreo-subtropical species dominated.

Work is underway to provide a habitat classification for the NE Atlantic. Joint workshops on this subject have been held by OSPAR/ICES/EEA (OSPAR Commission, International Council for the Exploration of the Sea/European Environment Agency) with the aim of developing a system that will be consistent with the marine classification of the European Nature Information System (EUNIS). One benefit of this work will be to show how seamount habitats and their associated wildlife relate to other habitats and marine communities in the NE Atlantic.

1.2 Seamounts in the North East Atlantic.

There are many thousands of seamounts on the ocean floor. Their formation is linked to past and present volcanic activity so they are generally found around mid-ocean ridges or associated with “hotspots” in the deep mantle, where plumes of molten rock have melted through the overlying tectonic plate and brought magma up to the seabed. Chains of seamounts can form when a moving plate passes over a hotspot as has happened in the Azores. Where hotspots interact with a mid-ocean ridge, volcanoes can form on the ridge as in the case of the **Iceland Seamount**. The origin of isolated seamounts on much older oceanic crust is not clear. When plate tectonics processes move a seamount-formed island away from the mid-ocean ridge, the ocean crust sinks and pulls the island beneath the surface. These so-formed, submerged, often flat-topped seamounts are known as guyots.

An analysis of narrow beam bathymetric data collected by the US Naval Oceanographic Office between 1967 and 1989 revealed more than 800 seamounts in the North Atlantic (Epp & Smoot, 1989). This was considered to be an underestimate because of the omission of small features from the analysis, but it does indicate the abundance of these features in the region. The majority lie along the Mid-Atlantic Ridge (MAR) between Iceland and the Hayes Fracture Zone. In the North East Atlantic there are also clusters of seamounts some distance from the MAR such as those along the south west of the Rockall Bank and west of Portugal on the Madeira-Tore Rise. The greatest concentrations of seamounts in the NE Atlantic are found between the Charlie-Gibbs Fracture Zone and on the latitude of the Azores (Figure 4).

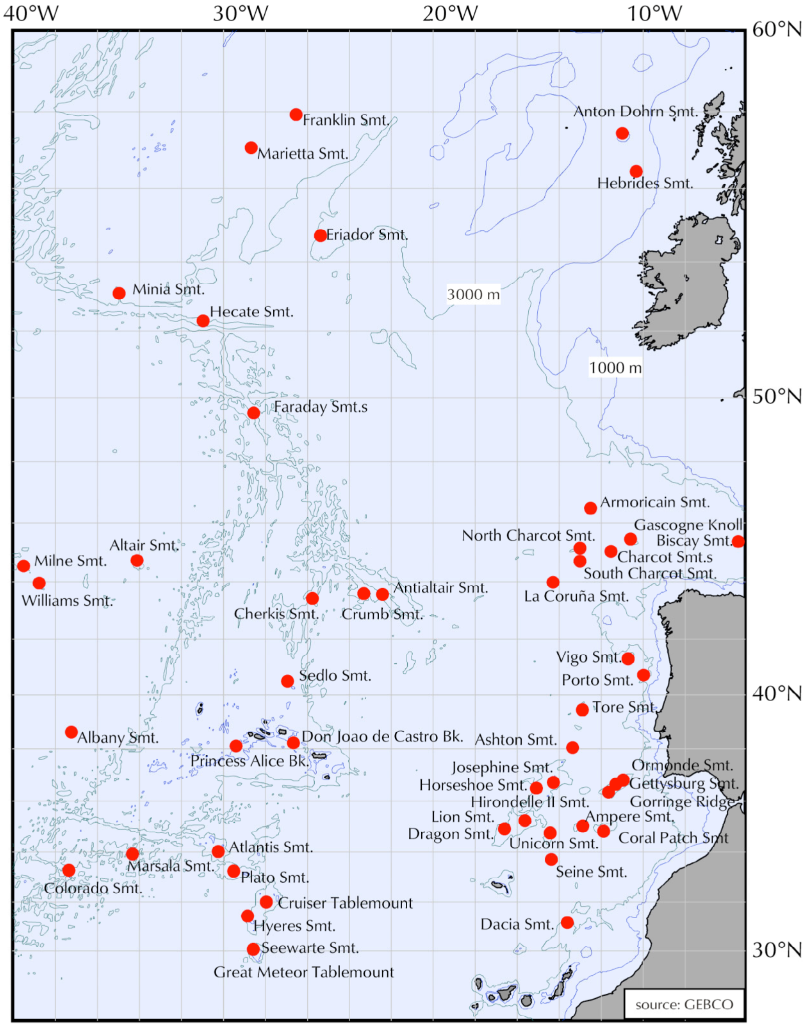

Figure 4: Distribution of known seamounts in the NE Atlantic. Map by Bernd Christiansen, source: GEBCO

2. Scientific Knowledge

Scientific knowledge about seamounts, including those in the NE Atlantic, is much sparser than for many other marine habitats and there is a clear need for more information about these features given the many questions being raised about them by scientists, managers, regulators and the public. These questions range from seeking a better understanding of the influence of seamounts on adjacent pelagic systems, to a desire for detailed information on specific seamounts. This includes details about their diversity, the endemism of their fauna and the impacts of fishing on their biodiversity.

The current interest in exploitation and conservation of marine resources associated with seamounts brings with it an opportunity to improve scientific knowledge of these features. The OASIS project, with its programme of work on the **Sedlo** and **Seine Seamounts** is an example, and the findings will contribute to our knowledge and understanding of seamounts in the North East Atlantic.

This section of the report gives an overview of the existing state of scientific knowledge on various aspects of seamounts in the NE Atlantic. Locations in the NE Atlantic are used to illustrate particular points wherever possible, and full use has been made of the information compiled for an inventory of reefs in the NE Atlantic (Rogers, 2001; WWF, 2001).

2.1 Physical characteristics

Bathymetric charts reveal seamounts as distinctive features that can be distinguished from the surrounding seabed by their physical characteristics. Many are several kilometres high and cover a large area of the seabed. For example, the **Ampere Seamount** which is located between the Seine and Horseshoe Abyssal Plains is more than 4,700m high, and extends over an estimated area of 3,600km^2, while the **Vesteris Seamount** in the Greenland basin, is more than 3,800m high and around 500km^2 in extent. The dramatic profiles of these features when compared to the surrounding seabed is particularly well illustrated by the **Great Meteor Seamount** and the two ancillary seamounts in its immediate vicinity, **Small Meteor Seamount**, and **Closs Bank** which lie approximately 1,500km west of the Canary Islands and 1,000km south of the Azores (Figure 5).

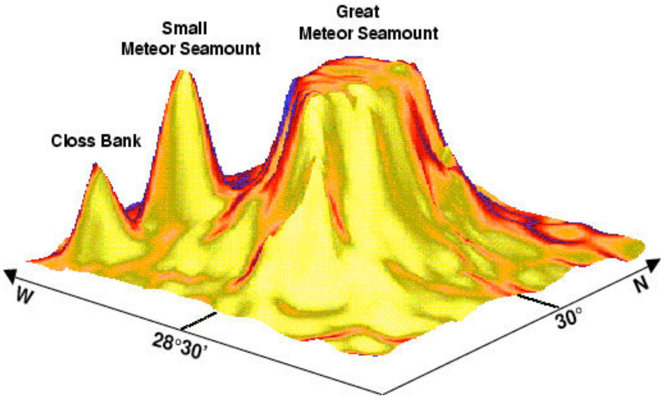

Figure 5: Topography of Great Meteor Seamount (© Mohn & Beckmann).

The shapes of individual seamounts can vary from simple cones to stellate forms, and are influenced by factors such as the height and the depth of the top of magma chambers which can promote flank collapse via groundwater heating or creating steep unstable slopes (Mitchell, 2001). In the NE Atlantic examples of this topographical variety can be seen by comparing the conical shape of **Rosemary Bank**, the **Tore Seamount** which is unusual in having a deep basin in its centre, the elongated form of the **Gettysberg Peak** and **Ormonde Peak,** which make up the **Gorringe Ridge** and the truncated cone shape of the guoyot **Anton Dohrn** (Figure 6).

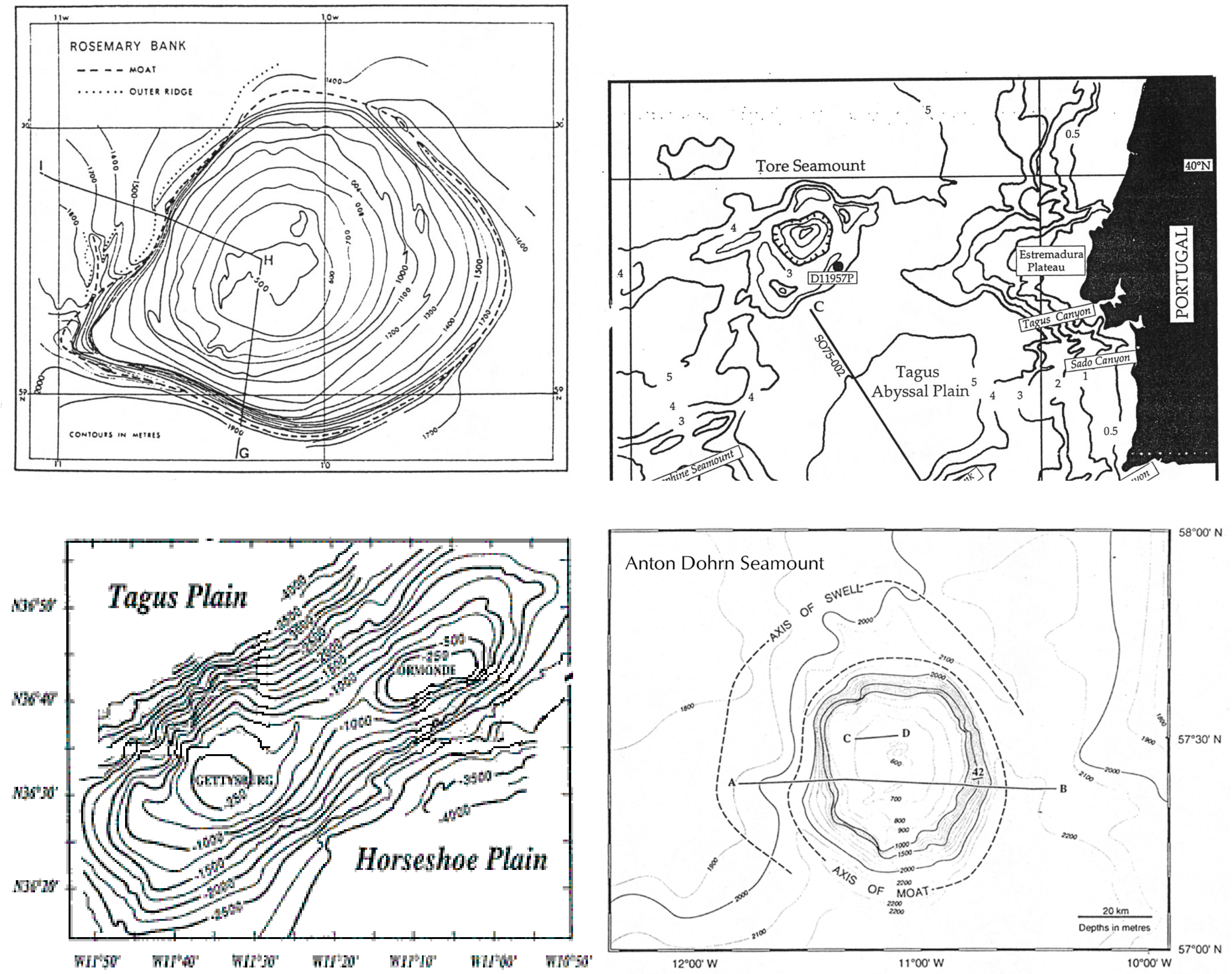

Figure 6: Examples of the varying topography of seamounts in the NE Atlantic (Rosemary Bank, from Roberts et al., 1974; Tore Seamount, from Lebreiro et al., 1996; Gorringe Ridge, from Girardeau 1998; and Anton Dohrn Seamount, from Jones et al. 1994)

In many situations seamounts occur in chains or clusters associated with seafloor hotspots where magma is brought up to the seabed. The **Horseshoe Seamounts** range is an example in the NE Atlantic. The Canary and Madeira hotspots are probably responsible for their formation, as these hotspots are believed to have passed through the Madeira-Tore Rise and Horseshoe **seamounts** area. The Africa/Eurasia plate boundary also passes through the **Horseshoe Seamount** area so some of the seamounts may have been formed by hotspot interaction with the plate boundary (Epp & Smoot, 1989).

The profile of seamounts, with slopes at angles of up to 60º, is in marked contrast to much of the surrounding seafloor (Rogers, 1994). The **Great Meteor Seamount** rises steeply from more than 4500m to less than 300m and has a typical slope of around 29% at depths of more than 3,000m, although exceeding 40% in some places. The **Ampere Seamount**, which is part of the Horseshoe Seamounts chain, rises from 4,800m to 60m below the surface. The eastern and southern flanks are extremely steep and nearly vertical for several hundred meters in places. The western and northern flanks have a gentler gradient, but are interrupted by short steep slopes giving a stepped or terraced structure (Kuhn *et al.,* 1996; WWF, 2001).

Because of their volcanic origin, hard substrata are common on seamounts and may be formed into a terrain interrupted by faults, fissures, down-dropped blocks, canyons, caves and hummocks.

On a scale of tens of metres, side scan sonar images have revealed distinct and diverse morphologies with both hummocky (bulbous) and smooth lava flows providing different surface textures (Smith & Cann, 1990).

Softer substrata may also be present and include biogenic sediments such as foraminiferan sands, lithogenic sediments transported from the continental margin, and authigenic sedimentation, principally from the precipitation of ferromanganese oxides (Rogers, 1994).

The following examples illustrate something of the variety of substrata of seamounts in the NE Atlantic:

- The surface of the **Gorringe Ridge** is composed of recent conglomerates and lava flows with some areas of exposed carbonate rock (Girardeau *et al.,* 1998).
- **Josephine Bank** has a current swept summit covered in a wide diversity of surface types including basaltic rock, limestone, biogenic and gravel sand (von Rad, 1974; Gage & Tyler, 1991)
- The **Anton Dohrn** seamount is capped by a sedimentary layer approximately 100m thick which lies on the erosion surface of the guyot

Hydrothermal sediments may also be found on some younger and active seamounts, where they form crusts, mounds and chimneys (Levin & Nittrouer, 1987). The **Vesteris Seamount** is an example where there are signs of recent hydrothermalism, and the **Joao de Castro Bank** is one of the few known sites where hydrothermal venting takes place at intermediate depths.

Seamounts interrupt the flow of water and therefore affect the hydrography and current system in their immediate vicinity as well as further afield. Tides can be amplified creating fast currents, and eddies may form and be trapped over seamounts in closed circulations known as Taylor columns. Other effects include locally enhanced turbulent vertical mixing and the creation of jets where seamounts interact with ocean currents (eg. Kunze & Sandford, 1993; Noble & Mullineaux, 1989; Eriksen, 1991; Dower *et al.,* 1992).

Effects such as these have been reported through observation, numerically modelling and a combination of both techniques at a range of scales in the immediate vicinity of the seamount and further afield.

At the **Great Meteor Seamount** direct observations and numerical modelling suggest that the dominant process is due to tidally forced bottom trapped diurnal waves and internal waves, and a system of horizontal and vertical circulation cells (Kaufmann *et al.,* 2002). A dome of cold, less saline and dense waters (isopycnal doming) is present, although this is relatively small when compared to other seamounts. In the near surface layers, the positive density anomaly associated with the doming at the outer rim generates a large-scale anticyclonic recirculation with typical velocities of 6cms^{-1}. A closed circulation cell develops to the south west of the summit plain and the effects of the substantial amplification of tidal currents can be seen some 20-40km from the seamount (Mohn & Beckmann, 2002) (Figure 7).

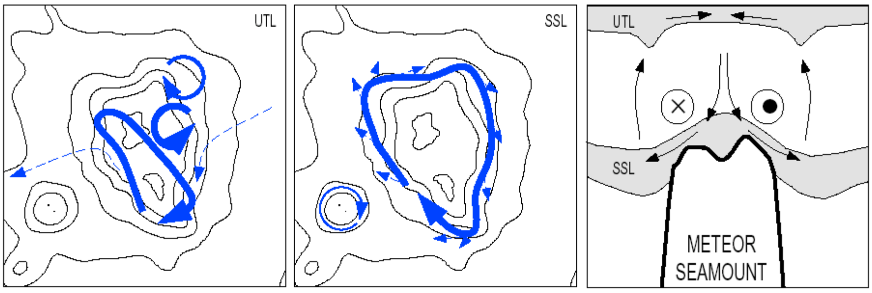

Figure 7: Great Meteor Seamount: Schematic view of the time-mean circulation in the upper thermocline layer UTL (left), and seamount summit layer SSL (middle), as well as the vertical overturning motion. (from Mohn & Beckmann, 2002)

Studies around the **Gorringe Ridge** also show some of the effects of seamounts on water movement. A hydrodynamic model applied to circulation and primary production around the ridge points to the development of a large anticyclonic eddy and associated upwelling of deep nutrient rich water. This appears to be consistent with field observations (Coelho & Santos, 2002). On a macroscale, the Ridge acts as a barrier to the flow of Meddies (closed rotating bodies of Mediterranean Waters) and tends to deflect them to the west (Bower *et al.,* 1995). Further north on the **Hatton Bank**, semi-permanent or permanent eddies have been observed in a line north-west of, and parallel to, the bank as a result of the North Atlantic Current impinging on the southern edge of the bank (Martin *et al.*, 1998).

2.2 Benthic biodiversity

The practical difficulties and limited attention given to sampling the benthic fauna of seamounts in the last century means there is a paucity of information on the benthos. Those data that are available also tend to be from a limited number of locations. The scale of the task ahead is put in perspective by noting that a century of study has resulted in the identification of just 596 invertebrate species from all seamounts explored up to the late 1980's (Wilson & Kaufman, 1987). This compares to more than 850 macro and mega faunal species from directed surveys on 25 seamounts in the Tasman Sea since the 1980's (Richer de Forges *et al.,* 2000). Somewhere between 29-34% of species collected during the 23 cruises to the region are believed to be new to science and potentially endemic to these seamounts, and the rate of discovery of new species has not yet reached an asymptote, even in this limited study area (Richer de Forges *et al.,* 2000).

The enhanced currents that sweep around the seamounts and the exposed rock surfaces provide ideal conditions for suspension feeders, and it is these that often dominate the benthos (Rogers, 1994) (Figure 8). Corals can be particularly abundant with gorgonian, scleractinian and antipatharian corals all recorded on seamounts:

- Le Danois (1948) recorded an abundance of the coral *Dendrophyllia cornigera* between 400-500m on the eastern, southern and south-western parts of the **Le Danois Bank** which abuts the slopes of the continental shelf of northern Spain. The Bank is also the type locality for two other species of coral *Aulocyathus atlanticus* and *Balanophyllia thalassae* (Zibrowius, 1980).

- Little is known of the biology of **Lousy Bank** but there are many records of the occurrence of the coral *Lophelia pertusa* from 200-700m on the bank. The coral is probably present because of the vigorous currents flowing around the seamount (Wilson, 1979; Frederiksen *et al.,* 1992).

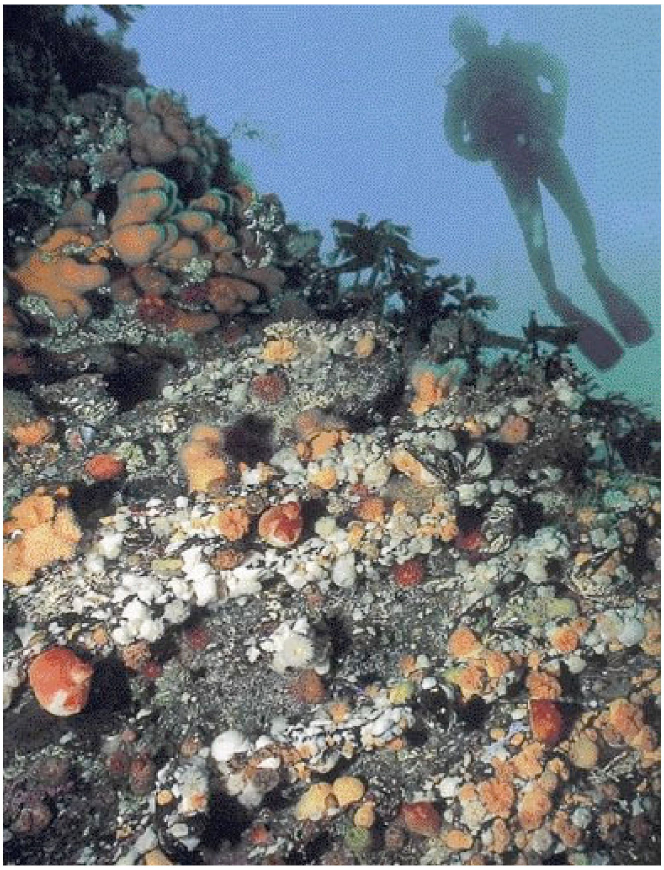

Figure 8: Suspension feeders such as different gorgonians and scleractinian coral species on Banco Gorringe. © Erling Svensen

Other suspension feeders sometimes found in abundance on seamounts are sponges, hydroids and ascidians. crinoids, asteriods, ophiuroids, holothurians, molluscs and decapods have also been reported

(Heezen & Hollister, 1971; Genin *et al,* 1986; Koslow & Gowlett-Holmes, 1998). The **Vesteris Seamount** in the Greenland Sea, for example, is reported to have a rich fauna including a build up of sponges and bryozoans in an area characterised by seasonal ice-edge plankton blooms (Henrich *et al.,* 1995) while the hard substrates below the summit of the **Ampere Seamount** show growths of large sponges (Heezen & Hollister, 1971).

Analysis of a series of photographs taken at different depths on the **Great Meteor Seamount** revealed that the most prominent megafaunal taxa were sponges (eg. *Haliclonia* sp). Gorgonain species (eg. *Elisella flagellum*), antipatharian and madreporarian corals (eg. *Antipathes glabberima* and *Dendrophyllia* cf.*cornigera*) and sea urchins (*Cidaris cidaris*). Statistical analysis revealed three distinct faunistic zones; the Slope (>450m), a Southern Plateau (290-300m) and a Northern Plateau (290-470m). This corresponds well with the distribution of gyres over the seamount that would locally augment primary production, sedimentation and hence, food supply to the benthos (Piepenburg & Mueller, 2002).

There have been few studies on the fauna of soft substrata on seamounts. While it is difficult to generalise, a comparative study on seamounts, a study in the North Pacific suggests that the epibenthos can differ markedly from area to area depending on the substratum availability, local current regime, nutrient availability, bioturbation, and depth (Kaufmann *et al.,* 1989). In the NE Atlantic

- The ascidian *Seriocarpa rhizoides* has been collected from some areas of sandy substrate on **Josephine Bank.** This species was thought to be endemic but has since been found on other seamounts in the area (Monniot & Monniot, 1992).

2.3 Plankton

Studies on the planktonic communities in the vicinity of seamounts are important in revealing another aspect of the biodiversity in these areas. Material collected in warm and cold years around seamounts to the south of the Azores included some 30 species of fish eggs and larvae of 16 fish families. Myctophidae and Gonostomatidae larvae predominated in both seasons (Arkhipov *et al.,* 2002).

Many studies of the plankton around seamounts report qualitative and quantitative differences between pelagic communities over the seamounts and those in surrounding oceans (Rogers, 1994). Observed effects include increases, decreases and patchiness in the planktonic communities around seamounts. In the NE Atlantic, the best studied seamount in this regard is probably **Great Meteor Seamount** (GMS). For example:

- Nellen (1973) recorded a concentration of the larvae of neritic fish species and a lower abundance of migrating mesopelagic fish larvae and plankton over the GMS compared with surrounding waters.
- Schnack-Schiel & Mizdalski (2002) carried out two transects across GMS and determined that the zooplankton population was dominated by copepods at all stations (80-95% of total numbers) and that within them the calanoids contributed the largest fraction. The genus Clausocalanus dominated the assemblage at all stations with *Clausocalanus furcatus* and *C. paululus* the most abundant of species that could be identified. All species except *C. paululus* occurred in higher numbers over the seamount than in surrounding oceanic waters.
- Martin & Nellen (subm.) found strong diurnal differences in the vertical distribution of copepods and euphausiids, with high abundances close to the bottom during daytime. These dense layers of plankton are much likely to interact with the near-bottom fauna, probably playing a significant role in maintaining the fish stocks at the Great Meteor Bank (see also chapter 2.4)
- Isolated patches of picoplankton recorded above the summit of GMS linked to the existence of closed circulation cells (Kaufmann *et al.,* 2002)

Two main hypotheses that have been put forward to explain the increased concentration of plankton around seamounts: 1) localised upwellings which bring nutrients to the surface encouraging primary production, and 2) trapping of advected plankton in circulation cells (Taylor columns) on seamounts (Rogers, 1994). Models of Beckmann and Mohn (2002) suggest that passive particles are retained in Taylor columns over the plateau of the **Great Meteor Seamount.** This could explain the higher abundance of copepod exoskeletons above the plateau as compared to the flanks of the seamount (Martin & Nellen, subm.).

On the **Great Meteor Seamount** passive tracers indicate a substantial degree of isolation of the body of water above the seamount, whereas areas on the flanks of the **Ampere Seamount** are subject to dynamic upwelling.

2.4 Fish

Koslow *et al.,* (2001) describe the fish communities found around seamounts as being derived from a number of different families and orders, but having evolved a suite of morphological, ecological, life-history and physiological, features that enable them to successfully exploit an environment with enhanced currents and greater flux of organic matter than much of the deep sea. Many are adapted for strong swimming performance, deep-bodied and with relatively high rates of metabolism and food intake. They may also be exceptionally long-lived with a slow growth rate. Some are also subject to extremely high recruitment variability, with successful recruitment occurring on approximately decadal time scales (Leaman & Beamish, 1984; Clark, 1995). Such species include the orange roughy: Trachichthyidae, Beryciformes; oreos: Oreosomatidae, Zeiformes; pelagic armour head: Pentacerotidae, Perciformes; *Sebastes* spp: Scorpaenidae, Scorpaeniformes) (Box 1).

Erich (1977) studied the fish community at the Great Meteor Seamount and found at least three autochthonous populations. Generally the fish community at the seamount was very similar to that of the African shelf.

Trawl catches of planktivorous fish around seamounts to the south of the Azores took 51 species of fishes from 38 families. In summer catches the majority were *Trachurus trachurus* (blue jack mackerel) and *Scomber japonicus* (chub mackerel), spawning *Beryx splendens* (Lowe's beryx), *Lepidopus caudatus* (silver scabbard fish) and *Antigonia capros* (deep-bodied boarfish). In winter catches spawning *Trachurus trachurus* and *Scomber japonicus*, *Beryx splendens*, and *Lepidopus caudatus* predominated. The maximum diversity of fish plankton as well as the greatest catches of adults were on the **Erving Seamount**, one of the largest in the area and characterised by complicated oceanographic features (Arkhipov *et al.*, 2002).

Box 1. Examples of fish species found on seamounts in the NE Atlantic.

- The orange roughy, *Hoplostethus atlanticus*, is a benthopelagic species found in deep waters, over steep continental slopes, ocean ridges and seamounts. It is a slow growing species and one of the longest lived fish species known with an estimated life span of more than 130 years (Allain & Lorance, 2000). Their occurrence in the NE Atlantic includes seamounts in the Azores.
- The black scabbard fish (*Aphanopus carbo*) occurs on both sides of the Mid-Atlantic Ridge around underwater rises. Concentrations around seamounts such as **Ampere, Lion, Seine,** & **Susan** have supported a Madeiran based fishery for many years (Martins & Ferreira, 1995).
- Fish species recorded from the **George Bligh Bank** include the Great Lantern Shark (*Etmopterus princeps*), cat shark (*Galeus* sp), and the shovel-nosed shark (*Deania claceus*) (Rogers, 2001).
- **Bill Bailey Bank** is the type locality for the deep water skate *Malacoraja kreffti*, which is known from very few other localities (Stehmann, 1993).

There are various ideas on why large concentrations of fish occur around seamounts including the possibility of increased primary production caused by upwelling or because diurnally migrating plankton are trapped during their daytime descent by predators living near the bottom (Rogers, 1994) (Figure 9). The studies of Hesthagen (1970) about the distribution of near-bottom organisms at the **Great Meteor Seamount** and **Josephine Seamount** support the latter hypothesis. Fock et al. (2002) studied diets of four dominant fish species at the **Great Meteor Seamount** and concluded that diurnally migrating mesopelagic organisms contributed significantly to the maintenance of these fish stocks.

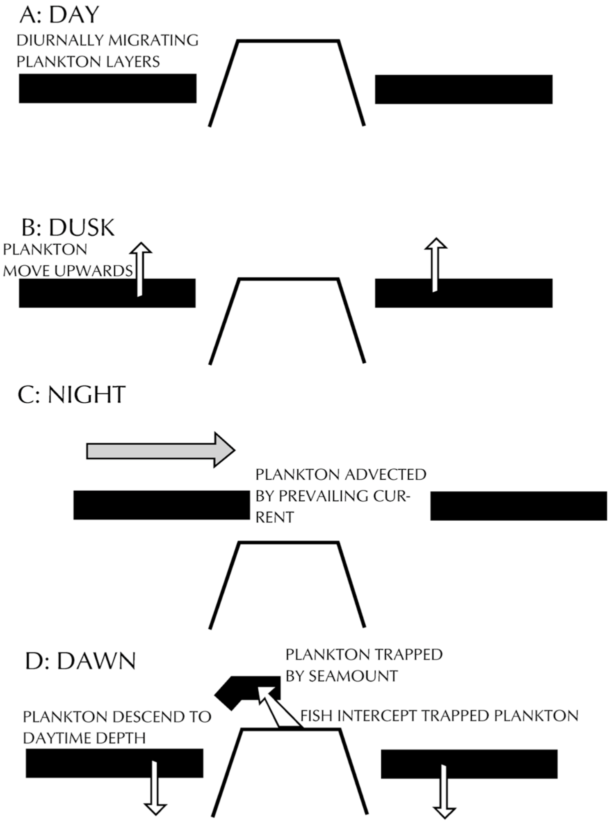

Figure 9. Diagram representing how seamount fish populations might feed on diurnally migrating layers of plankton (Fig 3 from Rogers, 1994).

The reproductive behaviour and life history of fish species may also help explain the aggregations, especially if seamounts are used as spawning grounds. This is known to be the case for blue ling, for example, which are known to spawn on seamounts south of the Westman Islands on the south coast of Iceland (Magnússon & Magnússon, 1995).

2.5 Seamounts as “hotspots” and “stepping stones”

One of the extensively debated questions about the biodiversity importance of seamounts is whether they are “hotspots” and/or “stepping stones” for marine fauna.

The distribution of seamount species and levels of endemism are likely to be determined largely by plate tectonic history and the degree to which ridge systems and seamount chains provide ‘stepping stones’ between areas (Butler *et al.,* 2001). Reproductive isolation between seamount and ridge systems appears to result from the flows around the seamounts and submarine ridges, combined with reproductive strategies with limited larval dispersal (Lutjeharms & Heydorn, 1981; Mullineaux & Mills, 1997) (Figure 10).

The high level of endemism and the considerable diversity of species at some seamounts makes them “hotspots” for biodiversity in the ocean. This is supported by the retention of larvae in the vicinity of seamounts and the subsequent attraction of predators to take advantage of the higher primary production in these areas compared with other parts of the abyssal plain or pelagic zone in the open ocean. The ecological importance of seamounts for top predators is emphasised by the fact that some far ranging pelagic species concentrate their mating and spawning on seamounts. An example from the NE Atlantic is the **Formigas Bank** which appears to attract groups of small cetaceans such as bottlenose and common dolphin, and spotted dolphins and pilot whales.

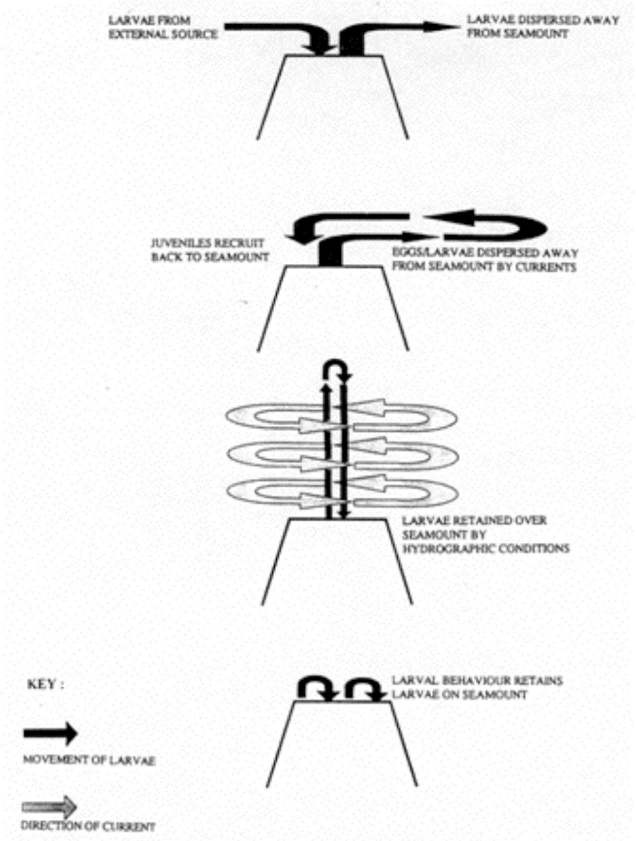

Figure 10: Models for recruitment to populations of species living on seamounts (Fig 4. from Rogers, 1994)

Deep sea fish which form spawning aggregations include the orange roughy (*Hoplostethus atlanticus*), roundnose grenadier (*Coryphaenoides rupestris*) and oreosomatids – smooth oreo and black oreo (*Pseudocyttus maculatus* and *Allocyttus* niger) and such aggregations have been observed on seamounts (Merrett & Haedrich, 1997). They include;

- Blue ling on a small seamount near the Westman Islands and in a southerly area of the Reykjanes Ridge. (Magnusson & Magnusson, 1995)
- Roundnose grenadier on the Hatton Bank (ICES, 2002)
- Orange roughy (*Hoplostethus atlanticus*) on some seamounts in the Azores archipelago (Melo & Menezes, 2002; Barceloss *et al*, 2002)

The idea of seamounts as "stepping stones" is more relevant where seamounts lie close to the continental shelf or occur in chains. Under these circumstances species may gain a foothold in the open ocean and deep sea and, by relatively small steps of larval dispersal, extend their distributions.

The potential role of seamounts as stepping stones and hotspots is illustrated by work on the **Great Meteor Seamount**. Information from benthic sampling during a cruise to this area in 1998 showed that typical NE Atlantic fauna dominated the invertebrate community (64%), with lower contributions from African (30%) and endemic species (6%). The suggestion is that the **Great Meteor Seamount** is in the North Atlantic gyre and in the centre of the Mediterranean Water. These water masses transport larvae from shelf seas either directly, or indirectly over the other seamounts and islands into the Great Meteor region (Benke, 2002).

Investigation of the diet and morphology of *Macroramphosus* spp. (Snipefishes) on **Great Meteor Seamount** suggests local speciation where selection pressures favour the evolution of two ecologically divergent species (Matthiessen, 2002).

Sampling of benthic copepods on the plateau and surrounding deep sea shows high level of endemism (George & Schminke 2002). A study of the Harpacticoida (copepods) fauna on **Great Meteor Seamount** revealed a very diverse meiofauna typical of deep-sea meiobenthos. The seamount was considered to resemble an "island" for the colonisation by meiofauna or a "stepping stone" for large-scale dispersal but there are still many uncertainties about this view and it remains to be tested (Gad & Schminke, 2002).

3. Threats to Seamount Biodiversity

Much has been written in recent years about the threats to the biodiversity of seamounts e.g. Rogers (1994), Gubbay (1999), Butler *et al.,* (2001); & Koslow *et al.,* (2001). The most significant threat in terms of geographic spread and scale of impact is undoubtedly commercial fishing. This section of the report describes various seamount fisheries and associated impacts with reference to the NE Atlantic wherever possible.

3.1 Seamount fisheries

The concentration of commercially valuable fish species around seamounts is well documented (eg.

Gerber, 1993; Gordon, 2001; Vinnichenko[2]). These and other biological resources such as shellfish and corals have been the targets of intensive exploitation using longlines, mid-water trawls and bottom trawls that can operate at depths of more than 1500m.

Baited longlines are probably the earliest technique to be used and have been deployed around the islands of Madeira since early in the 17th century. The extent and intensity has however changed dramatically over the years. Today, longlines may extend for more than 50km, and involve the setting of more than 1000 hooks on a single line (Figure 11).

Modified Granton trawls with nets up to 60% larger than the standard Granton trawl and considerably heavier are used for bottom trawling. The foot rope of nets on these trawls can be 120m long and the floating headline 70m with the net weighing up to 800kg. The rockhopper gear on the foot rope which helps the net stay on the bottom while at the same time allows it to move over rocky ground, can weigh an additional 4,800kg. The large otter boards that spread the mouth of the trawl can weigh up to 4,000kg each (Merrett & Haedrich, 1997).

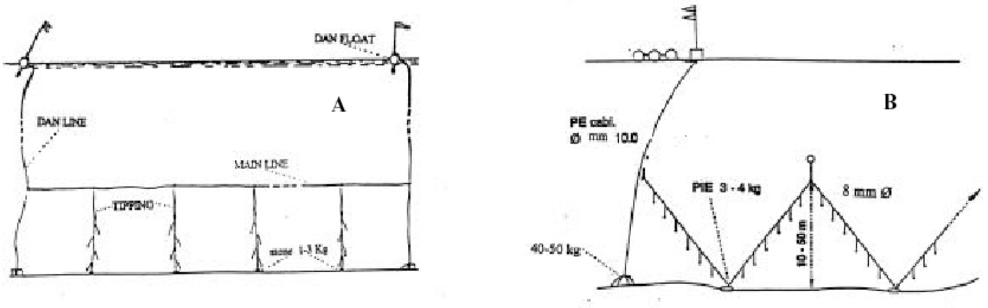

Fig 11: Longline gear directed at deep water sharks and deep-water teleosts during exploratory fishing on the Galicia Bank (EC FAIR, 1999).

Rogers (1994) lists more than 70 commercially valuable stocks of fish and shellfish that are known to occur on seamounts. They include the pelagic armourhead (*Pseudopentaceros wheeleri*), alfonsin (*Beryx splendens*), argentine (*Glossanodon* sp.), rockfish e.g. *Sebastes rosaceous, S.variegatus* & *S.jordani*, blue whiting (*Micromesistius poutassou*), tuna e.g. yellowfin (*Thunnus albacares*) skipjack (*Katsuwonus pelami)*; bigeye (*Parathunnus obesus*); crustaceans e.g. rock lobster (*Jasus tristani*) and deep-sea red king crab (*Lithodes couesi*). Distinct groups dominate different major biogeographic provinces of the world ocean; orange roughy and oreos (eg.smooth oreo *Pseudocyttus maculatus*) in the temperate South Pacific; alfonsino (*Beryx* spp.) in the tropics and sub-tropics, Patagonian toothfish (*Dissostichus eleginoides*) in the subantarctic Southern Ocean; pelagic armourhead (*Pseudopentaceros wheeleri*) in the open North Pacific; and several species of *Sebastes* (*Scorpaenidae*) along the continental slope of the North Pacific and North Atlantic (Koslow *et al.,* 2001). Commercially important species known to occur on seamounts in the NE Atlantic include tusk (*Brosme brosme*), blue ling (*Molva dipterygia*), morid cod (*Mora mora*), orange roughy (*Hoplostethus atlanticus*) and the shovel nosed shark (*Deania calceus*) (Reinert, 1995; Magnusson & Magnusson, 1992).

Russian scientists sampling the NE Atlantic continental slope and seamounts in the mid 1970's considered that the most abundant and promising species for deep-sea fisheries were from the families *Macrouridae, Berycidae, Alepocephalidae, Moridae, Gadidae, Trachichthyidae, Squalidae, Scorpaenidae* and *Lophiidae*. (Troyanovsky & Lisovsky, 1995). Their surveys revealed that species such as the roundnose grenadier, *Sebastes mentella*, alfonsino, orange roughy and tusk were most frequently observed near underwater rises, interacting with water masses and quasi-stationary currents. At that time there was a casual Russian fishery for alfonsino, orange roughy and black scabbard fish around the southern seamounts of the Mid-Atlantic Ridge, a fishery for blue ling (*Molva dypterygia*) and ling (*Molva molva*) on **Lousy Bank** in

1977-79, and an experimental long-line fishery for tusk (*Brosme brosme*) on seamounts of the Mid-Atlantic Ridge as far south as 48° N. Some of the species targeted by Azorean fisheries are shown in Figure 12.

Hoplostethus atlanticus © FM Porteiro / ImagDOP

Aphanopus carbo © Peter Wirtz / ImagDOP

Beryx splendens © Peter Wirtz / ImagDOP

Figure 12: Illustrations of some of the species taken by Azorean fisheries on seamounts

The search for new locations and potentially marketable deep-sea fish on seamounts is a continuous process. During 1997 & 1998 deep-water surveys carried out by two commercial longliners from the Spanish Fishing fleet explored the resources of the **Galicia Bank** with one targeting deep-water sharks, fishing at depths of >900m, and the other targeting teleosts, sampling down to about 900m (Figure 13).

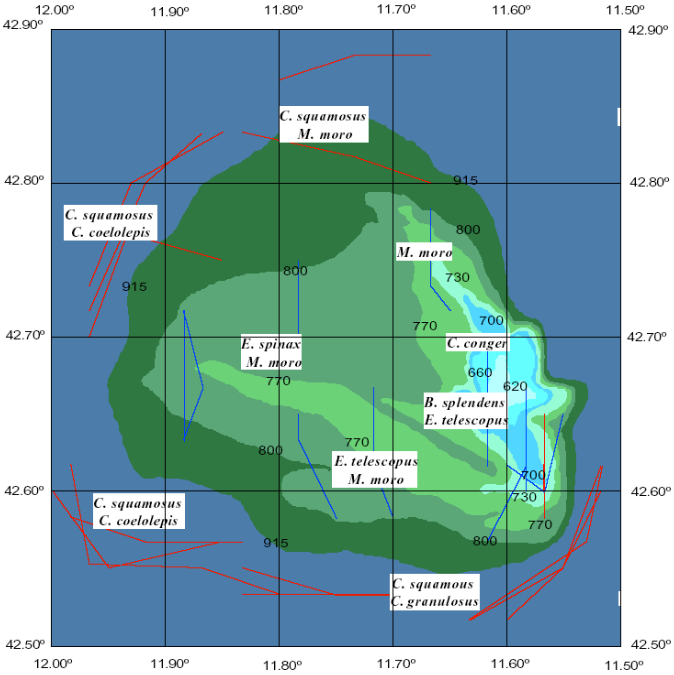

Figure 13: Position of hauls and the general distribution of the most important species captured on the Galicia Bank during exploratory long-line fishing (EC FAIR, 1999)

During 1998-1999 exploratory fishing on **Galicia Bank** by two Spanish trawlers resulted in catches of 106 species made up of 70 teleosts, 11 sharks, 3 rays, 2 chimaeras, 11 crustaceans, 6 molluscs and 3 echinoderms. The most important species captured were teleosts: *Hoplostethus mediterraneus*, *Mora moro, Lepidion eques, Alepocephalus bairdii, Epigonus telescopus, Trachyscorpia crustulata echinata* and *Lophius piscatorius*, followed by deep water sharks: *Dalatias licha*, *Deania calceus* and the crustacean *Chaecon affinis*. (EC FAIR, 1999). In 2000 exploratory fishing by Russian trawlers took blue ling, velvetbelly shark, chimaera, roundnose grenadier, redfish and black scabbard fish at depths of 870-950m on **Hatton Bank**. On **Bill Baileys Bank**, their catches at a depth of 750-1,200m constituted 1.5-4t of deep-water sharks with a bycatch of roundnose grenadier, blue ling, rabbitfish and smoothhead (ICES, 2002). Species taken on **Hatton Bank** and **Faraday Seamount** in 2000 are listed in Table 1.

Table 1: Species taken on **Faraday Seamount** and **Hatton Bank** during experimental trawling by Spain in spring 2000 (ICES, 2001)

Area	**701-800m**	**801-900m**	**901-1000m**	**1001-1100m**
Faraday Seamount		*Etmopterus pusillus* *Coryphaenoides rupestris* *Hoplostethus atlanticus*	*Etmopterus princpes* *Alepocephalus rostratus* *Coryphaenoides rupestris* *Lepidion eques* *Hoplostethus atlanticus* *Aphanopus carbo*	
Hatton Bank	*Galeus melastomus* *Centroscymnus crepidater* *Deania clacea* *Hydrolagus miriabilis* *Brosme brosme* *Molvea dypterygia* *Micromesistius poutassou* *Lepidion eques* *Mora moro* *Aphanopus carbo* *Todaropsis sagittatus*	*Galeus melastomus* *Apristurus sp.* *Centroscymnus coelolepis* *Centroscymnus crepidater* *Deania calcea* *Hydrolagus miriabilis* *Argentian silus* *Coryphaenoides rupestris* *Brosme brosme* *Molva dypterygia* *Micromesistius poputassou* *Lepidion eques* *Mora moro* *Aphanopus carbo* *Lophius piscatorius* *Todaropsis sagittatus*	*Centroscymnus coelolepis* *Alepocephalus bairdii* *Coryphaenoides rupestris* *Molvadypterygia* *Lepidion eques* *Aphanopus carbo*	*Centroscymnus coelolepis* *Centroscymnus crepidater* *Alepocephalus bairdii* *Coryphaenoides rupestris* *Trachyrhynchus trachyrynchus* *Molva dypterygia* *Lepidion eques* *Aphanopus carbo*

Commercial fisheries on seamounts in the North East Atlantic include the following target species:

- black scabbard fish (*Aphanopus carbo*) from seamounts around Madeira (Merrett & Haedrich, 1997)
- monkfish (*Lophius piscatorius*) taken by tangle netting on **Lousy Bank** and **Bill Bailey Bank** (Reinert, 1995)
- blue ling and red fish (*Sebastes* spp) from the **Hatton Bank** (McCormick, 1992, ICES, 1995)
- Slickhead (*Alepocephalus bairdii*), roundnose grenadier (*Coryphaenoides rupestrius*) and the deep-water shark *Centroscymnus coelolepis* in multi-species trawl fisheries on the **Hatton Bank** (EC FAIR, 1999)
- roundnose grenadier (*Coryphaenoides rupestris*) around the Mid-Atlantic Ridge seamounts (Vinnichenko, 2003)
- longline and handline multispecific fisheries on the slopes of the islands, offshore banks and seamounts of the **Azores** taking at least 50 species including blackspot seabream (*Pagellus bogaraveo*), bluemouth rockfish (*Helicolenus dactylopterus dactylop*terus) and forkbeard (*Phycis phycis* and *P.blennoides*) (Santos *et al*., 1995).

Exploration continues with previously unfished areas being considered for new fisheries such as the experimental trawl fishing for orange roughy around seamounts in the Azores which started in the winter of 2001 (Morato *et al*., 2001). The increase in effort and fishing activity further offshore has put considerable pressure on the demersal fish assemblages in these areas (Santos *et al.,* 1995) and increasing effort in established areas such as the **Hatton Bank** (ICES, 2001). In 2000, for example, boats from the Spanish fleet spent the equivalent of 1,363 days fishing on **Hatton Bank** and 1,627 days in 2001. This corresponds to 22,202 and 26,123 estimated hours of trawling respectively and was mainly at depths between 800-1600m (ICES, 2002).

3.2 Effects of fishing on seamounts

The effects of fishing on seamounts are difficult to distinguish from the effects of deep-sea fisheries in general because catch statistics are pooled for relatively large areas. There is also extensive incomplete reporting of deep water catches and landings from international waters, including from areas around **Hatton Bank** and the south-west part of **Lousy Bank** and the Mid-Atlantic Ridge north of the Azores (ICES, 2002).

In most cases fishing has taken place before there is a reasonable understanding of the biology of the species being targeted, and in the absence of formal stock assessments or quotas. The result has been over-exploitation and major crashes in the different stocks. The best known examples are the crash in populations of the rock lobster *Jasus tristani* on the **Vema Seamount** due to a combination of overfishing and unpredictable larval recruitment; fishing of the pelagic armourhead *Pseudopentaceros wheeleri* over the southern **Emperor Seamounts** and seamounts in the northern Hawaiian Ridge drove the species to commercial extinction within 10 years of their discovery; and the orange roughy *Hoplostethus atlanticus* fishery on seamounts off the coast and New Zealand and Australia where new discoveries of stocks are typically fished down to 15-30% of their initial biomass within 5-10 years. (Clarke, 1999, Koslow *et al.*, 2001).

The fact that fleets move from area to area adds to the difficulty of distinguishing effects on particular locations. Landings of *Sebastes* spp. in the NE Atlantic (which include fish taken on seamounts) have fluctuated between 150,000 and 300,000 t since the early 1950's but this masks a shift in the fishery. In the early 1980s 40% of the redfish catch was the shallower *S. marinus* (Koslow *et al.*, 2001). This was gradually replaced by the deeper and more oceanic *S. mentella* in the 1990s so that *S. marinus* is now less than 20% of the catch. Major inshore stocks have been overexploited (Anon., 1997), and more offshore and deeper fishing grounds appear to support smaller stocks that can be quickly fished down.

In terms of the target stocks ICES has made a first attempt to rank deep-water species according to "vulnerability to fishing" as determined from available information on life history strategies. These rankings should be viewed in the context of: 1) a lack of data for many species and parameters, and 2) an awareness that the numbers given may have been estimated by different methodologies, have wide confidence intervals or apply to local areas or environments. The ranking according to longevity is shown in Table 2. All the species listed are known to be taken in seamount fisheries.

Table 2: Vulnerability of deep water species ranked according to longevity (from ICES, 2002).

RANK	SPECIES	LONGEVITY (Yrs)
1	Orange roughy	125
2	Roundnose grenadier	>60
2	Deepwater squalid sharks	
	Centroscymnus coelolepis	-
	Centrophorus squamosus	60-70
3	***Sebastes***	45-50
3	Blue ling	~30
3	Great silver smelt	~35
4	Greenland halibut	15-20
4	Ling	~20
4	Tusk	~20(?)
4	Black scabbardfish	8, 12 from whole otoliths, ~25 from sections
4	Red (Blackspot) seabream	16
4	Greater forkbeard	15?
5	Broad alfonsin	13
5	Alfonsin	11

Rank 1 is assigned to species for which the sustainable catch level should be the lowest fraction of the virgin biomass. Species with similar vulnerability are given the same rank. All these species are known to be taken during fishing over various seamounts in the NE Atlantic

Of particular concern are species such as the orange roughy that are known to form dense aggregations around seamounts and are therefore relatively easily targeted, by trawlers. Because of the pooling of catch statistics it is not clear which seamounts have been targeted but the overall effect has been a rapid fishing down of this species (Lorance & Dupouy, 2001) (Table 3 & Figure 14).

Table 3: Total catch (Tonnes) of orange roughy by the three major fleets of French trawlers in the NE Atlantic (Table 4 from Lorance & Dupouy, 2001)

ICES Sub-area	1991	1992	1993	1994	1995	1996
V	36	4	1	0	1	2
VI	2190	1297	429	179	74	116
VII	1135	2628	1175	1408	829	879
Total	3361	3929	1605	1587	904	997

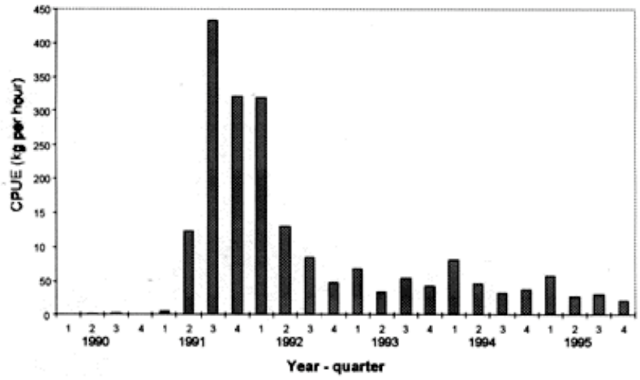

Figure 14: Clear declining trend in Catch per Unit Effort (CPUE) for French industrial trawlers taking orange roughy to the west of the British Isles representing 45-65% of the annual catch (in years where statistics were complete). (Fig 4.1.1 from EC FAIR, 1999)

The blue ling fishery is another example. This is mainly a bycatch fishery for the Icelandic fleet linked to the deep-sea redfish fishery, but blue ling were occasionally targeted when spawning aggregations were located, for example during 1980-1984 and in 1993. The basis of the fishery in the 1980's was the discovery of a spawning area at a very restricted locality near the Westman Islands, on and around a small steep hill near the base of the slope, mostly in depths of 500-800m (Figure 15). In 1993 spawning concentrations were found on another small seamount in a southerly area of the Reykjanes Ridge and took place mainly at depths of 800-900m.

Icelandic catches of blue ling increased rapidly and reached 8,000 tonnes in 1980 (the highest catch of blue ling ever landed from Icelandic grounds). This then decreased rapidly after 1983 returning to the low by-catch level (Figure 16). No significant accumulations of spawning blue ling have since been observed in the area that supported the fishery in the 1980's (Magnuśson & Magnuśson, 1995; EC FAIR, 1999).

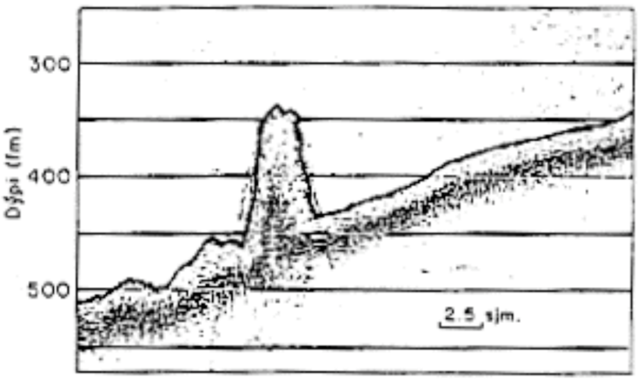

Figure 15: Profile of an unidentified seamount that was a spawning location for blue ling south of the Westman Islands and targeted by a blue ling fishery. (Fig 21 from Magnuśson & Magnuśson, 1995).

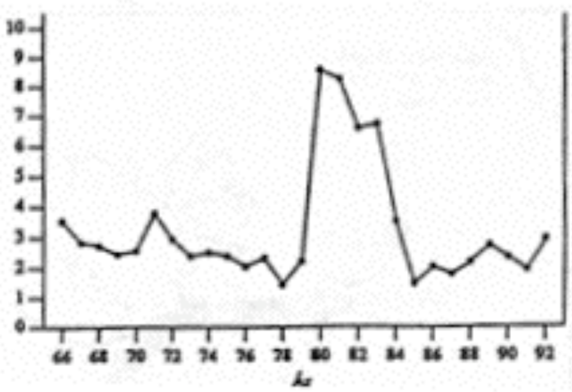

Figure 16: Total Icelandic catch of blue ling (1966-1992) showing the peak associated with fishing the spawning aggregations on a seamount south of the Westman Islands. (Fig 22 from Magnuśson & Magnuśson, 1995)

The ability of vessels to move to new locations also makes it difficult to determine effects. In the early 1990s, for example, one Faroese trawler fished continuously on **Hatton Bank** for 5-6 years. During the first quarter of the year blue ling were targeted and in the second quarter black scabbardfish with roundnose grenadier of increasing importance. This vessel has now changed to fishing on the shelf but no reasons are given in the report that would describe this shift (ICES, 2002).

Discards are also a consideration although it is difficult to distinguish effects associated with deep-sea fisheries in general from catches around seamounts. Analysis of landings and discards related to French deep-sea trawlers in 1996, for example, identified three species, *Deania calceus* (Figure 17), *Coryphaenoides rupestris* and *Alepocephalus bairdii* as dominant in the discards and estimated that for every ton of fish landed, approximately one ton of fish is discarded (EC FAIR, 1999). Estimated retained catch and discards by the Spanish fishery on **Hatton Bank** is shown in Table 4.

Experimental longlining on seamounts around **Madeira** identified species which might be subject to commercial fishery. They took 16 other species including the Porbeagle (*Lamna nasus*), Granulose shark (*Centrophorus granulosus*), leafscale gulper shark (*C.squamosus*) and the Siki/Portuguese shark (*C.coelolepis*)

Illegal/unreported fishing is also known to take place around seamounts such as those to the north and south of the **Azores**. Vessels engaged in such activity often use unmarked monofilament gill nets and small drift nets which are abandoned when they are detected (Morato *et al.*, 2001).

Recreational fisheries on shallow seamounts may also be an issue. In the NE Atlantic this is particularly relevant around seamounts of the Azores. The **Princess Alice Bank**, for example, is just 35m below the surface at its shallowest point. Fish species sought by recreational fishermen visiting the area include skipjack tuna, blue marlin (*Makaira nigricans*) and wahoo (*Acanthocybium solandri*).

Fishing activity is also known to have had a massive impact on the benthos of some of the seamounts. The substrate of heavily fished seamounts off Tasmania is now mostly either bare rock or coral rubble and sand, unlike the situation on lightly fished or unfished seamounts that were also investigated (Koslow *et al.,* 2001). The abundance and species richness of the benthic fauna on heavily fished seamounts was markedly reduced.

Fishing is clearly the most significant current threat to the biodiversity of seamounts but not the only one. Pollution effects are not really known on seamount fauna however it is interesting to note that during experimental fishing on **Hatton Bank** in 1992 commercial quantities of shark were caught but were difficult to sell because the maximum permitted levels of mercury in the fish were exceeded (Olsen, 1992). Heavy metal contamination is probably not unusual for top predators even when they are species that live in the open ocean. Any impacts on the fauna and flora of **Galicia Bank** from oil spilt by the tanker *MV Prestige* has still to be determined. The incident does however show that the biodiversity on the shallower parts of some seamounts can be vulnerable pollution associated with shipping accidents in much the same way as some benthic communities on the continental shelf.

In terms of future risks there is the possibility that seamounts may be targeted by mining companies for ferromanganese crust and polymetallic sulphides (Sarma *et al.*, 1998) which would have a direct physical impact as well as effects on the associated communities in the area of exploitation as well as further afield due to potentially increased turbidity and sedimentation in downstream areas.

Figure 17: Daenia calceus © Luis Quinta / ImagDOP

Table 4: Spanish Fishery on **Hatton Bank**. Estimated retained catch and discards by species and year.

Year 2000			Year 2001 (preliminary)		
Species	**%R**	**%D**	**Species**	**%R**	**%D**
Blue ling	100	0	Blue ling	100	0
Mora	100	0	Greenland halibut	100	0
Portuguese dogfish	100	0	Portuguese dogfish	99	1
Greenland halibut	100	0	Black scabbardfish	98	2
Black scabbardfish	99	1	Baird’s smoothhead	97	3
Cataetix laticeps	97	3	Cataetix laticeps	95	5
Leafscale gulper shark	97	3	Roundnose grenadier	93	7
Longnose velvet dogfish	95	5	Deep water sharks various	90	10
Roundnose grenadier	93	7	Mora	89	11
Baird’s smoothhead	92	8	Lanternsharks	74	26
Smoothhead n.s.	88	12	Rabittfishes	61	39
Blackdogfish	60	40	Blackdofish	61	39
Grenadiers various	60	40	Longnose velvet dogfish	59	41
Lanternsharks	59	41	Leafscale gulper shark	59	41
Rabittfishes	58	42	Skates	52	48
Birdbeak dogfish	40	60	Smoothheads	48	52
North Atlantic codling	33	67	Lophius sp.	44	56
Skates	28	72	Bird beak dogfish	43	57
Fishes various spp.	3	97	Wolffishes	35	65
Roughsnout grenadier	1	99	N.Atlantic codling	33	67
Catsharks	0	100	Grenadiers various	18	82
Blue antimora	0	100	Fishes various	6	94
Wolffishes	0	100	Roughsnout grenadier	1	99
Orange roughy	0	100	Greenland shark	0	100
Deep water shark various	0	100	Catsharks	0	100
Tusk	-	-	Blue antimora	0	100
Cardinalfish	-	-	Orange roughy	0	100
Lophius sp.	-	-	Tusk	0	100
Greenland shark	-	-	Cardinalfish	0	100

%R=% retained, %D=%discarded (ICES, 200

Composition of discards in weight (ICES,

Baird’s smoothhead	28	Roundnose grenadier	31
Roughsnout grenadier	17	Baird’s smoothhead	11
N.Atlantic codling	5	N.Atlantic codling	4
Other species	14	Other species	20

4. Management of activities around Seamounts

The case for conservation of the High Seas, deep-sea environments, and offshore areas has been made in many international fora in the last few years (e.g. UNCLOS, OSPAR). The most obvious, widespread and extensively documented threat to the biodiversity of these environments is commercial fishing in its many forms. Bottom trawling has disrupted deep- sea sediment structure and damaged benthic communities even when the seabed is more than 1km below the surface. Demersal fisheries have also rapidly driven some deep-sea fish stocks to commercial extinction and depleted previously abundant fishing grounds.

The use of longlines, driftnets and purse seines are known to have taken many thousands of seabirds, cetaceans, and turtles between them as “incidental catch” (Gubbay, 2003). Recreational fishing, while not as widespread in these environments, adds to pressure on the biodiversity on some of the shallower offshore banks and reefs where top predators such as sharks are targeted.

Shipping is another activity that needs to be considered when assessing threats to marine biodiversity in the offshore environment and deep sea.

The risk of accidents as a result of collisions and grounding are less likely than in coastal waters, but there are threats associated with the dumping of litter, deliberate discharge of oily and chemical wastes, accidental spills, leakage from sunken ships, noise pollution and, possibly, from the exchange of large volumes of ballast water. More localised threats include those associated with the deep-sea disposal of wastes, mineral extraction and bio-prospecting.

The habitat and associated species on seamounts have been identified as being particularly vulnerable and there have been calls for measures, such as the establishment of Marine Protected Areas, to be taken to safeguard the biodiversity of these features and their associated wildlife, and to provide opportunities to learn more about them (e.g. Santos et al., 1995; Probert, 1999; Koslow, 2001; WWF, 2003; IUCN, 2003) (Box 2).

BOX 2. Reasons for putting forward seamounts as priority habitats/ecosystems for MPAs on the High Seas (from Gubbay, 2003):

- The high species diversity at these locations including many species new to science, and the likelihood that the number of species present is far greater than the number currently recorded
- The highly localised distribution of many seamount species with a large percentage of potentially endemic species
- The functionally critical nature of seamounts for certain species that congregate in these areas for spawning/mating
- The demonstrable link between human activity and decline in biodiversity on seamounts
- The apparently limited dispersal between seamounts, the extreme longevity and slow recruitment of many species, and the limited fixed habitat, making seamount fauna sensitive to the impacts of fishing and the likelihood of very long time scales for recovery, if damaged
- The high level of threat to seamount faunas from fishing activity and the unregulated nature of such activity on seamounts in the High Seas.

In common with marine conservation in general and MPAs in coastal waters, any measures will need to target the activities taking place around the seamount ecosystems rather than the features themselves. Identification of what can and what needs to be done, and how it might be done, can be drawn from the failures and successes of fisheries management and from the management of existing MPAs.
Examples of actions taken include:

- The designation of the Elizabeth & Middleton Reefs in the Coral Sea east of Australia (in 1975) with restrictions on commercial and recreational fishing and permits for commercial activities including fishing and diving.
- The designation of the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico (in 1992) with a zoning scheme that includes a “no activity zone”.
- Protection from bottom trawling at the Sula Reef (in 2002) and Røst Reef (in 2003) to protect deep water coral reefs off the coast of Norway.
- The designation of the Endeavour Hydrothermal Vents MPA by the Canadian government in 2003

There are also examples of proposed and designated protected areas around seamounts in territorial waters, EEZs and the High Seas. (Box 3).

This section of the report gives an overview of the management experience to date on seamount ecosystems from around the world. This is based on the management plans for the Lord Howe Island Marine Park, the Tasmanian Seamounts Marine Reserve, and the draft management plan for the Bowie/Sgaan Qintlas Seamount Marine Protected Area Management Plan all of which include the entire area of the seamount within the proposed protected area boundary. It should be borne in mind that even the agreed plans are at the early stages of implementation and therefore still need to be fully tested. It should also be noted that many of the issues are common to MPAs which have been established around other features in both coastal and offshore waters.

Box 3. Examples of existing and proposed protected areas around seamounts and associated islands

Existing seamount protected areas

- Saba National Marine Park, established in 1987, circling the entire island from the High Water mark to a depth of 60m.
- The Cordell Bank National Marine Sanctuary, on the edge of the California continental shelf, declared in 1989 (management plan currently undergoing revision)
- A pilot MPA on the **Bowie/ Sgaan Qintlas Seamount** in the Pacific EEZ of Canada, declared in 1998
- The Tasmanian Seamounts Marine Reserve, declared in 1999
- Lord Howe Island Marine Park declared in 2000 with a boundary that roughly corresponds to the 1800m depth contour that follows the seamounts that underlie Lord Howe Island and Ball's Pyramid
- The **Formigas Islets & Dollabarat Bank Nature Reserve** established in 1988 in the Portuguese (Azores) EEZ.

Proposed seamount protected areas

- An extension of the Northern Marianas Islands Conservation Area where a marine section that extends 1km seaward of the four northern islands has been proposed under the Commercial Fisheries Act of 2002
- Inclusion of the **Balleny Seamount** in an existing Special Protection Area in the Antarctic
- Candidate Special Areas of Conservation for the **Formigas Islets & Dollabarat Bank** in the Portuguese (Azores) EEZ
- **D. Joaõ de Castro**, a SCI for the Macaronesian biogeographical region as agrred in December 2001, and a cSAC in the Azores
- Proposals for MPAs to be established around the **Josephine Seamount, Galicia Bank** and **Gorringe Ridge** , prepared by WWF for consideration by OSPAR.

4.1 Boundaries

Many early MPAs, with the exception of the Great Barrier Reef Marine Park, covered relatively small areas and were often only fringing coastal protected areas. Since then there has been a distinct shift in the approach with large areas being recognised as necessary for the management of biodiversity on an ecosystem scale. This is particularly true in the case of seamounts which are generally large features, extending through a considerable depth of the water column and whose influences extend for tens of kilometres into the surrounding ocean. ICES, for example, noted that in order to prevent the depletion of local populations the proper management of species that form local aggregations around seamounts should be at "seamount" scale (ICES, 2002).

At Lord Howe Island, the Park encompasses a large proportion of the shelf area (approximately 3-6nm wide) and extends well beyond the drop-off zone that, at about 200m falls off very steeply to depths greater than 2,000m (Figure 18) (Commonwealth of Australia, 2002a). In the Tasmanian Seamounts Reserve the potential for trawling outside the reserve to devalue the benthic communities was a consideration in the design of the Reserve and the boundaries have been located to minimise the possibility of indirect impacts (Commonwealth of Australia, 2002b).

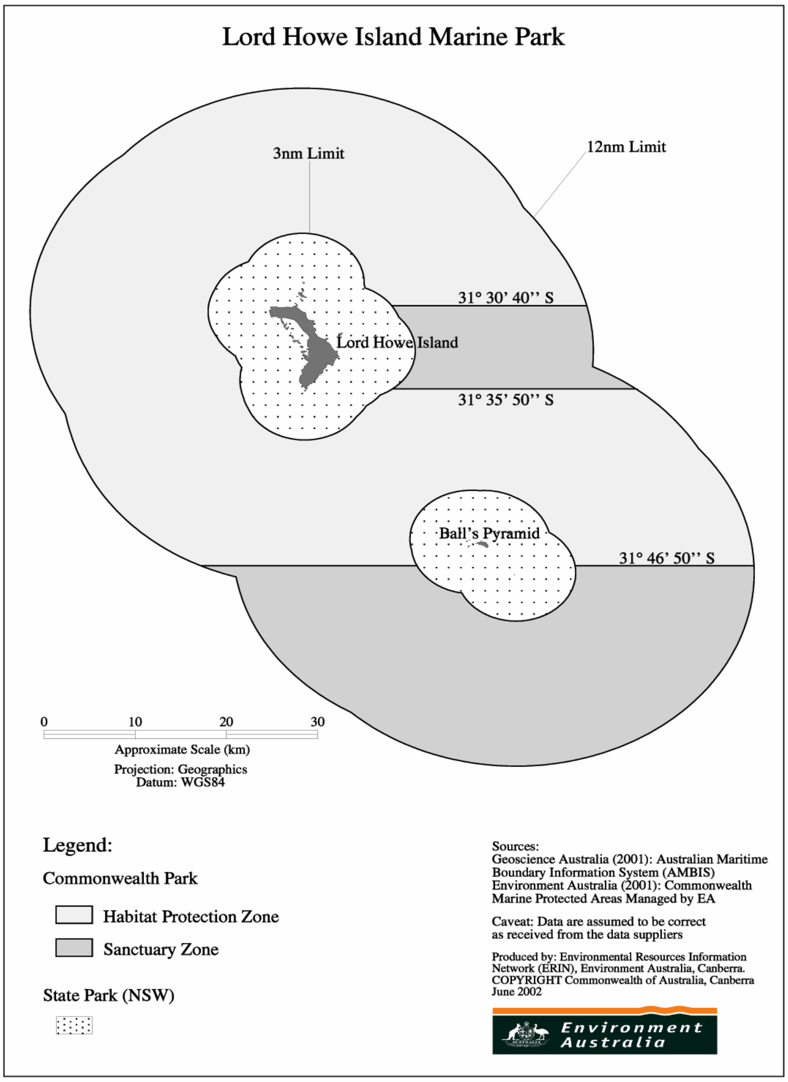

Figure 18: Boundaries and zoning of the Lord Howe Island Marine Park (Commonwealth of Australia, 2002a).

In the case of the proposed **Bowie**/ **Sgaan Qintlas Seamount** MPA the proposed boundary includes the nearby seamounts of **Hodgkins** and **Davidson**. Including the connected deep seamounts is considered to “best achieve an ecosystem approach” to the management of the area (FOC, 2001). A report, commissioned by WWF-Canada which comments on these MPA Management Proposals supports the idea of including these nearby seamounts because of the topographical and potentially oceanographic linkages between them and the **Bowie**/**Sgaan Qintlas Seamount** and because it would make the MPA sufficiently large and oriented to consider the continental offshore dynamics such as mesoscale eddies (WWF Canada, 2003).

4.2 Management Zones

Both vertical and horizontal zoning schemes have been introduced for seamount MPAs and management options ranging from strict protection to multiple-use. These differences can be seen in the management plans for the Tasmanian and Lord Howe Island reserves, both of which have a Highly Protected Zone (equivalent to the IUCN Category 1a) and Managed Resource Zones (equivalent to IUCN Category IV).

Horizontal zoning is a familiar and standard practice in many MPAs, giving both flexibility and responsiveness to a range of activities that are likely to be undertaken in the protected area. Vertical zoning is a newer idea and the only example to date is the Tasmanian Seamounts Marine Reserve (Figure 19). This is possible and desirable in that particular case because of the considerable depth of the protected area (the seabed is some 1000-2000m below the surface) and the fact that activities taking place in the shallow waters (pelagic fisheries) are not believed to have a major impact on the seamount fauna as the seamounts peak is at 660-1,940m although there is still some debate about this. This is also a far more practical approach than drawing a boundary at depth and it retains the option of being able to control more indirect effects from activities taking place in shallower waters over the seamounts at a later date if the need arises.

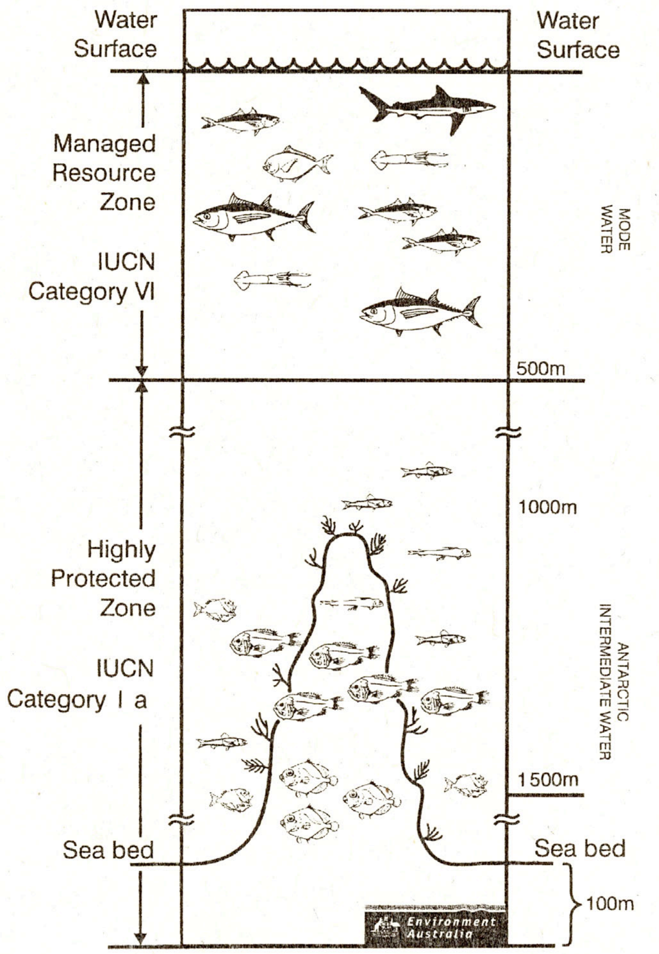

Figure 19: Vertical Management zones in the Tasmanian Seamounts Marine Reserve (Commonwealth of Australia, 2002b).

In the case of the **Bowie/Sgaan Qintlas Seamount**, there are proposals for regulations to prohibit activities such as non-renewable resource exploration and extraction, dredging, dumping and other activities that damage, disturb or alter the habitat within the area. Activities such as research, fishing, recreation, and tourism may be permitted if it is deemed that they would not result in damage, disturbance or alteration of the habitat within the area.

A Harvest Refugia (no-take zone) is also being proposed, with three possible boundaries put forward for consideration including the possibility that the entire MPA should be treated as Harvest Refugia where there would be additional regulations to prohibit commercial and non-commercial fisheries (FOC, 2001).

Another idea which has come up during the consultation on the draft management plan for **Bowie/ Sgaan Qintlas** is for an Experimental Research Area to be established as a “strictly-controlled living laboratory as a basis for developing ecosystem-based management approaches and protected ecosystem function (Beamish & Neville (in prep) in WWF Canada, 2003).

4.3 Legislation & Management Measures

Protection of seamounts within territorial waters is relatively straightforward in a legal sense as most countries have MPA programmes, backed by statute, that enable them to make the designation. A similar situation applies in EEZs but beyond this, on the High Seas, there is no specific legal mechanism for the designation of protected areas although UNCLOS includes the obligation to protect and preserve the marine environment, to conserve natural resources, and to cooperate with other states in this regard. (Young, 2003). In the NE Atlantic, an MPA programme, which is likely to include seamounts, is being developed by OSPAR but it is still not clear how this will be implemented. At a global level, the idea is being promoted by groups such as WWF/IUCN through the UN.

Regardless of the location of the seamount MPA, management measures will need to be interdisciplinary.

Control of shipping and fisheries will have an international legal element and may therefore also have to be considered at this level if action is to be taken to restrict or prohibit such activities. In the case of shipping, action needs to be supported by the IMO and there is the possibility of establishing Particularly Sensitive Sea Areas around such sites. Fisheries measures are more complicated. In the NE Atlantic they involve the Member States of the EU, non-EU abutting countries, the European Commission, the North East Atlantic Fisheries Commission (NEAFC), the advice of ICES and all other countries interested in fishing in the region. Fishing is the activity that is most likely to require regulation in any seamount protected areas and it should be noted that such regulation already takes place both within and outside seamount protected areas (Table 5).

Table 5. Examples of measures used for the management of a number of seamount fisheries both within and outside protected areas (from table 4, WWF-Canada 2003)

Seamount	**Fisheries Management**
Tasmanian Seamounts Marine Reserve	• Trawling and Danish seining closures on selected seamounts • Non-trawl fishing within vertically zoned area managed by TAC & ITQ
Cordell Bank National Marine Sanctuary	• No specific commercial Fisheries Management Plan • Regional fisheries management prohibiting gillnetting, managed by season length, quotas, depth restrictions and gear modification
Hawaiian Seamount Fisheries	• Groundfishing closures on selected seamounts • Permit system for bottom fishing • Management by catch limits, size limits, area and seasonal closures, fishing effort limitation, gear restrictions and access limitation
Azores Fisheries	• No deep-sea trawling within the EEZ • Tuna fisheries limited to pole and line • No fisheries around deep-sea hydrothermal vent fields.

Within the two Australian seamount MPAs (Tasmanian & Lord Howe) the management prescriptions include:

- Total prohibition of fishing in areas
- Total prohibition of mining throughout the reserve
- Prohibition of certain types of fishing (eg. trawling) in some areas.
- Commercial fishing allowed subject to various specified conditions (eg. methods, effort, use of catch)
- Research to be carried out in accordance with permits that will be issued by the relevant authorities

Proposed actions to support these include;

- Education of users in the conservation values and location of the reserve
- Development of enforcement strategies
- Monitoring the efficacy of protection through a follow up survey (not planned so far, s. previous comment)
- Development of codes of conduct and permit conditions in consultation with stakeholders
- Joint working between Environment Australia and other groups to address by-catch and pollution issues in the reserve
- Joint research and monitoring programmes will be developed

Indicators to measure success include;

- The health of benthos
- Water quality
- Vessel movements
- Catch records and bycatch records
- Presence of fishing debris on seamounts
- Number of commercial tour operator permits issued
- Community observations of fishing vessels in the park
- The number of targeted research programmes
- Number of violations detected (VMS data)
- Number of successful prosecutions
- Frequency of website and pamphlet updates

Experiences todate suggests that seamount MPAs are likely to cover large areas although there may be management zones within them, with different degrees of regulation. A mix of regulatory measures will be required and are being brought together in the framework of management plans even though the majority are concerned with fisheries and could therefore be dealt with by fisheries regulators. Such an approach helps to keep the overall objectives of these protected areas in mind, not just the management of commercial fisheries but to conserve and protect the productivity and diversity of seamounts and their associated communities.

5. Future Direction: Threats & Opportunities

The resources around seamounts are being exploited, often in advance of sufficient knowledge to determine whether such exploitation is sustainable or has likely impacts on non-target species and habitats. As a consequence stocks are known to have become depleted in particular areas and other impacts on the biodiversity, such as habitat damage, have been observed.

The pressure on these resources shows no signs of reduction, and indeed the ongoing exploratory fishing on seamounts by many nations suggests that it will increase at least in geographic extent and in the species that are targeted. Many seamounts may already be depleted. Myers & Worm (2003) report surprisingly consistent and rapid declines in predator biomass of open ocean communities targeted by Japanese pelagic longline fisheries (who have the most widespread longline operation and who operate on seamounts as well as other areas). Catch rates fell from 6-12 down to 0.5-2 individuals per 100 hooks during the first 10 years of exploitation. Rates of decline were consistently highest in temperate regions in all three oceans. Some of these formerly productive areas, such as the Mid-Atlantic Ridge have since been abandoned. Crashes in some exploited fish stocks have also been reported around specific seamounts (eg. blue whiting, orange roughy, pelagic armourhead, rock lobster)

One of the options being considered by a number of countries and international organisations to safeguard the productivity and diversity of these systems is the establishment of Marine Protected Areas. These would act as a focus for the protection and integrated management of these areas, bringing together fisheries and other management measures in a concerted effort to safeguard their biodiversity interest. The legal framework already exists to introduce MPAs in the territorial waters and EEZs of most countries, and mechanisms to do so on the High Seas are being considered by various fora (eg. OSPAR, IUCN).

The threats to seamounts are considerable. The most widespread and serious of these at the present time are commercial fisheries because of their impact on target species, as well as on other wildlife associated with seamounts. The pressure to open up new areas and target new species for exploitation is significant, and the risks to biodiversity are high as such activity is likely to take place before any management measures have been introduced or even before it has been determined whether it is possible to have sustainable and economically viable fisheries in such areas. The prohibition of all fisheries on some seamounts should therefore be considered as pro-active management and one of a spectrum of measures to safeguard the biodiversity of these areas.

The opportunities that lie ahead are considerable. They include;

- Improving our scientific knowledge and understanding of seamount ecosystems
- Safeguarding the biodiversity of these rich and productive areas
- Working for sustainable fisheries in the offshore environment, using seamount fisheries as a model
- Having highly protected areas in the offshore environment as an insurance against the unrelenting depletion of resources by fisheries
- Raising awareness of the richness, and productivity of ocean environments and fostering a fascination and appreciation of the biodiversity of the oceans
- Safeguarding some of the last great wilderness areas on Earth.

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