account of wider environmental impacts including depletion of seabird prey species and implications for ecosystem function, and actions which minimise the risk of pollution incidents at sea. All these measures are relevant to seabird conservation in the OSPAR maritime area.

2.10 DEEP SEA FISH

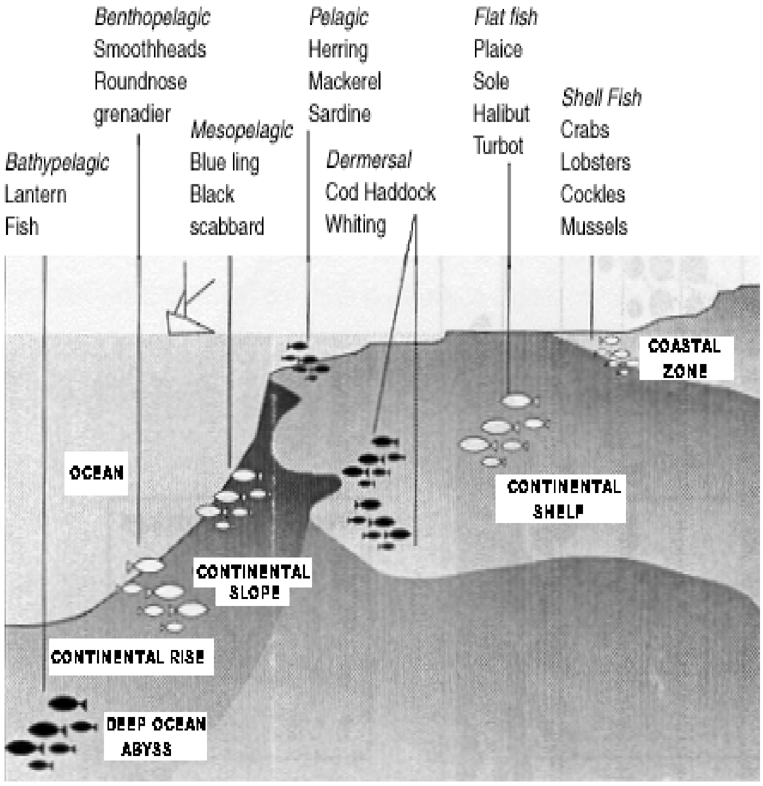
This section of the report is principally concerned with deep sea benthopelagic fish. These are species that are associated with, or live close to, the sea-bed and that are found in the deepest parts of the ocean, the bathyal and abyssal zones (below depths of 1,000m) where sunlight does not penetrate. Reference is also made to some mesopelagic species, that occupy a twilight zone between 150m-1,000m which extends from the edge the continental shelf to the bathyal zone (figure 33).

Box 6: Examples of marine birds occurring in the OSPAR maritime area which are species or European Conservation Concern and/or are listed on Annex I of the EU Birds Directive (from BirdLife, 1999).

Note: Species are listed in order of increasing conservation concern on SPEC ranking
'T' indicates that a species registers for any given ranking
EC Birds 1 = Annex 1 of EU Birds Directive
SPEC 1-4 = Species of European Conservation Concern

Common Name	EC Birds 1	SPEC 1	SPEC 2	SPEC 3	SPEC 4
Steller's eider		T			
Fea's petrel	T	T			
Zino's petrel	T	T			
Cory's shearwater	T		T		
Manx shearwater			T		
Storm petrel	T		T		
Gannet			T		
Common gull			T		
Sandwich tern	T		T		
Black guillemot			T		
Puffin			T		
White-faced storm petrel				T	
Red-throated diver	T			T	
Black-throated diver	T			T	
Bulwer's petrel	T			T	
Little shearwater	T			T	
Leach's storm-petrel	T			T	
Madeiran storm-petrel	T			T	
Scaup				T	
Velvet scoter				T	
White-tailed eagle	T			T	
Little gull				T	
Gull-billed tern	T			T	
Caspian tern	T			T	
Roseate tern	T			T	
Little tern	T			T	
Shag					T
Great skua					T
Mediterranean gull	T				T
Lesser black-backed gull					T
Great black-backed gull					T
Razorbill					T
Great northern diver	T				
Slavonian grebe	T				
Red-necked phalarope	T				
Common tern	T				
Arctic tern	T				
Guillemot (Iberian race)	T				

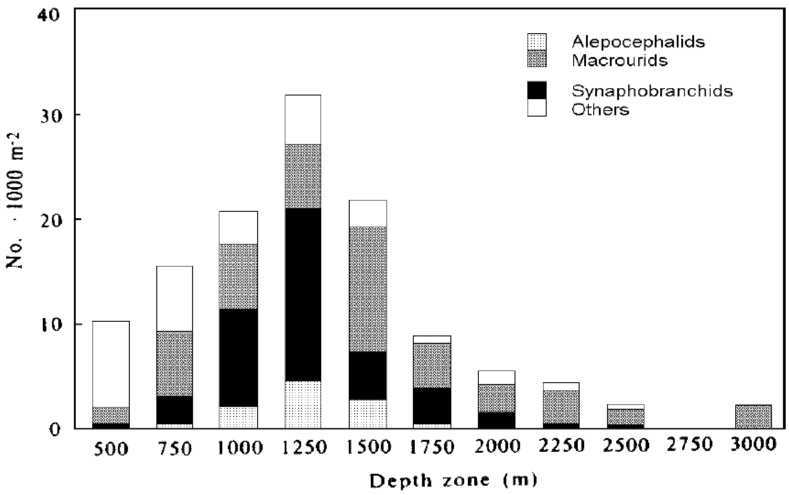
Figure 33: Diagram of fish species on continental shelf continental rise and deep-ocean abyss (from Greenpeace 1997)



Nearly 1,000 species of bottom-dwelling fishes are known as a result of trawling the deep sea bottom (Gage & Tyler, 1991). They include hagfishes, gulper eels, grenadier fish, tripodfish, skates and species of bony fish such as the flatfish and angler fish. The relative abundance of the different groups varies with depth with the macrourids (rat-tails & grenadiers) often the most abundant and, like many benthopelagic fish, being most diverse and numerous on the continental slope, particularly in middle to low latitudes (Gage & Tyler, 1991).

Changes in abundance of different groups of deep sea fish with depth is particularly well illustrated by the work of Gordon & Mauchline (1990) who studied the three main groups of bottom-living fish in the Rockall Trough. Their analysis of the numbers and biomass of alepocephalids (smoothheads, slickheads), macrourids (grenadiers, rat-tails) and the synaphobranchids (arrowtooth eels, cut-throat eels) shows a peak in the numerical abundance of fish as 1,250m (mostly due to the presence of the deep sea eel, *Synaphobranchus kaupi*) and a peak in biomass in the same depth zone but, in this case, mostly due to the presence of the smoothhead *Alepocephalus bairdii.* (figures 34 & 35). The vertical distribution of deep-water species in the water column is nevertheless still poorly understood.

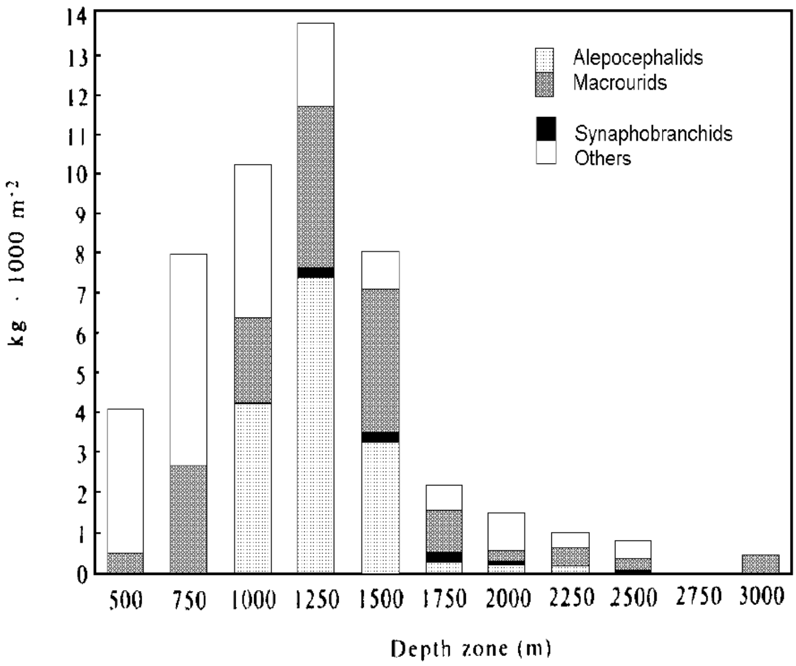
Figure 34: Estimated abundance of fish in different depth zones of the Rockall Trough (from Gordon & Mauchline, 1990).



Many deep-water fish tend to be long-lived and slow growing with a relatively high age of maturity. Orange roughy, *Hoplostethus atlanticus*, for example, are believed to live more than 120 years, maturing after 25 years, and the roundnose grenadier, *Coryphaenoides rupestris* maturing at around 10 years with a longevity of around 60 years (summary table from Koslow *et al.*, in press). Adaptations to the deep sea environment include elongate body forms, neutral buoyancy, long-based dorsal and anal fins sustained by many fin rays, overall darkening in body colour by black or red pigmentation, and reduced metabolic rates (Marshall, 1972; Merrett & Haedrich, 1997). Deep sea fish also exhibit a variety of feeding strategies such as scavenging, active predation, or ambushing prey in what is generally a food-poor environment . Some species, such as the roundnose grenadier feed on migrating zooplankton as they descend during the day and so, although a benthopelagic species, take pelagic prey.

The main components of the diet of deep sea bottom-living fish in the north-east Atlantic are generally species which live close to or on the sea-bed rather than the benthic infauna. They include other fish, copepods, amphipods, decapods, euphausiids and cephalopods. The most numerous prey items for bottom-living fish at nine depth zones between 500m and 3,000m in the Rockall Trough, for example, tended to be fish in the upper levels (500m, 800m & 1,000m), while unidentified material was important at greater depths (figure 35) (Gordon & Mauchline, 1990). The importance of fish in the diet can be accounted for by the abundance of the fish eating *Aphanopus carbo* and the increase in the importance of copepods in the 750mm zone, mainly due to the dominance of the roundnose grenadier *Coryphaenoides rupestris*, which has a very diverse diet. Although fish and copepods remain important dietary components in the 1,000m zone, unidentified material is increased: about 80 per cent attributed to Baird's smoothhead, *Alepocephalus bairdii* being the dominant species in this zone, of which a significant part may be salps and or ctenophores. The dominant species at the 2,250m zone is *Coryphaenoides guentheri* which accounts for most of the copepods consumed while the prey composition in the 3,000m zone reflects the typically diverse diets of macrourid fishes which were most abundant in this zone.

Figure 35: Estimated biomass of fish in different depth zones of the Rockall Trough (from Gordon & Mauchline, 1990).

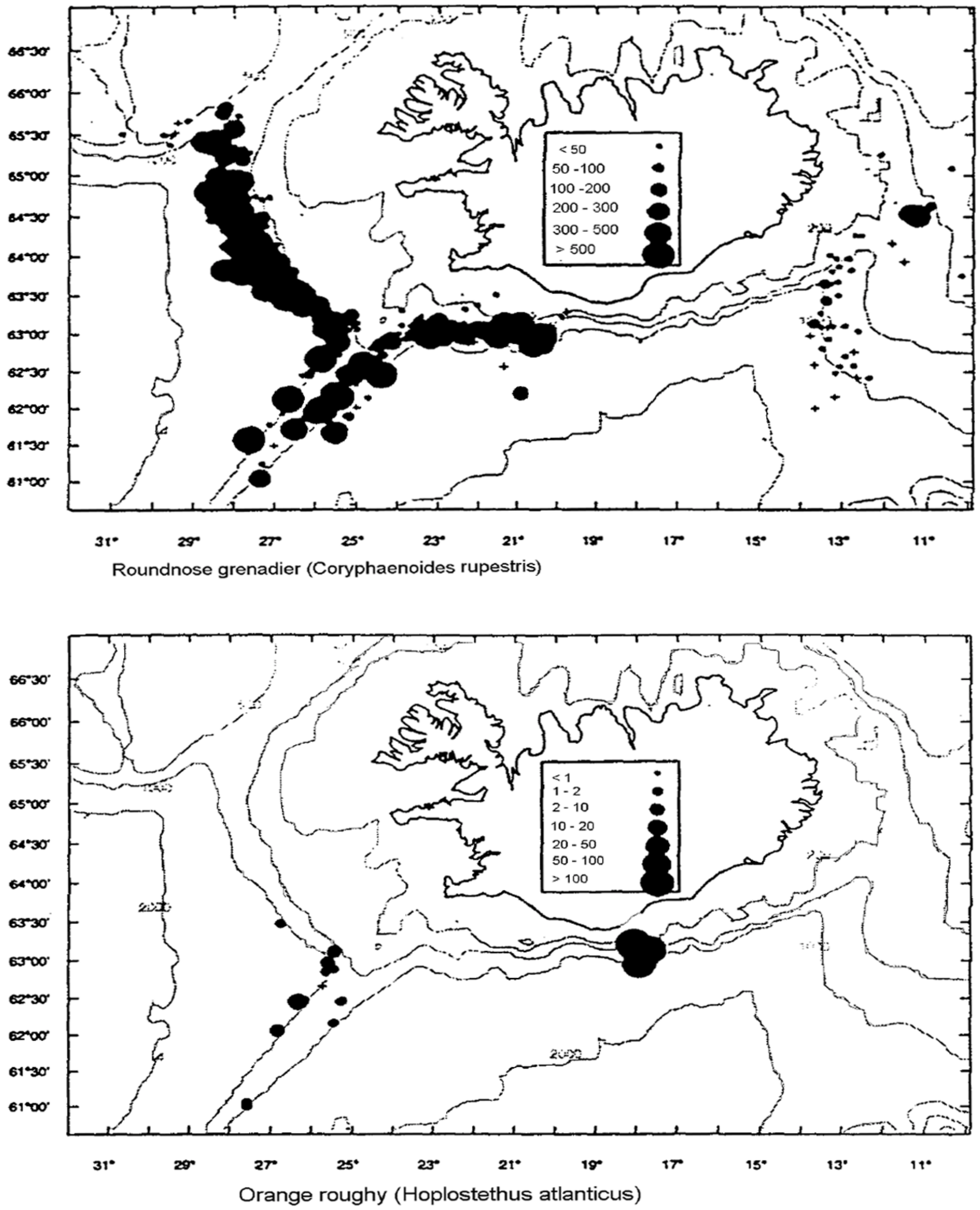


2.10.1 Distribution in the OSPAR maritime area

Detailed knowledge about the distribution of many deep-water species remains poor but some areas, such as the continental slopes of the North Atlantic have been well studied. They reveal both geographic and depth distribution patterns for deep sea fish.

The Norwegian Basin is very cold (0°C or less below 500m) but quite productive with the deep-water fish in this area most similar to those reported off Iceland and the Rockall Trough. Characteristic species include *Raja hyperborea*, *Macrourus berglax*, *Anarchichas denticulatus*, *Cottunculus microps*, *Careproctus reinhardti*, *Reinhardtius hippoglossoides* and *Lycodes* spp. which have been identified as part of an Arctic deep-water fauna off Iceland (Merrett & Haedrich, 1997). The Iceland-Faeroe Ridge, which separates the Norwegian Basin from the Iceland Basin, acts as a major faunal barrier for deep-water fish to the extent that none of these species range widely outside the immediate area of the Norwegian Sea and the majority of the small number of macrouridae from this basin appear to be endemic (Gordon, 1986; Rass *et al.*, 1975 in, Merrett & Haedrich, 1997).

Figure 36: Distribution of roundnose grenadier and orange roughy around Iceland (from Magnusson & Magnusson, 1995).



Around Iceland the Reykjanes Ridge area appears to be particularly significant because of its importance as a spawning and nursery ground for several species of deep sea fish (Magnusson & Magnusson, 1995). The macrouridae are common in the deep waters around Iceland with the roundnose grenadier widely distributed and common off the south and west coasts of Iceland as well as being common on the western slope of the Iceland-Faroe Ridge. The area off the south-west coast, particularly from the Reykjanes Ridge north to 64°N and between the Westman Islands and the Reykjanes Ridge is thought to be a nursery ground for this species and the ridge a spawning ground for blue ling (*Molva dypterygia*), and black scabbard fish (*Aphanopus carbo).* In contrast, the orange roughy (*Hoplostethus atlanticus*) has a very localised distribution (figure 36).

Further south, the Rockall Trough lies at the northern end of the range of a faunal region which may extend to around 20°N where the Mediterranean outflow and proximity to the region of the West African upwelling are major influences (Gordon, 1986). The deep sea fishes of the Rockall Trough include rays, smooth-heads, lizardfish, spiny eels, grenadiers and cuskeels (box 7). The dominant species on the slope is the roundnose grenadier *Coryphaenoides rupestris*, but there are also large numbers of the deep sea eel *Synaphobranchus kaupi* and alepocephalids especially Baird's smoothhead (*Alepocephalus bairdii*) (Gordon, 1986; Gordon & Mauchline, 1990). The Porcupine Sea Bight has a number of species which are exclusive to the area or very rare in the Rockall Trough like the macrourid *Trachyrincus trachyrincus*, and increased diversity of alepocephalid fishes possibly related to the greater influence of Mediterranean water in the Porcupine Sea Bight (Gordon & Mauchline, 1990).

Around the archipelago of the Azores, the most recent checklist of fishes covers 460 species (Santos *et al.,* 1997). This includes epipelagic, meospelagic and bethopelagic species such as grenadiers (for example, *Coryphaenoides guentheri*, *Nezumia aequalis*), smooth-heads (for example, *Alepocephalus rostratus*, *Bellocia koefoedi*), arrowtooth eels (for example, *Histiobranchus bathybius*, *Synaphobranchus kaupi*) and roughy (*Hoplostethus atlanticus*, *H.mediterraneus*).

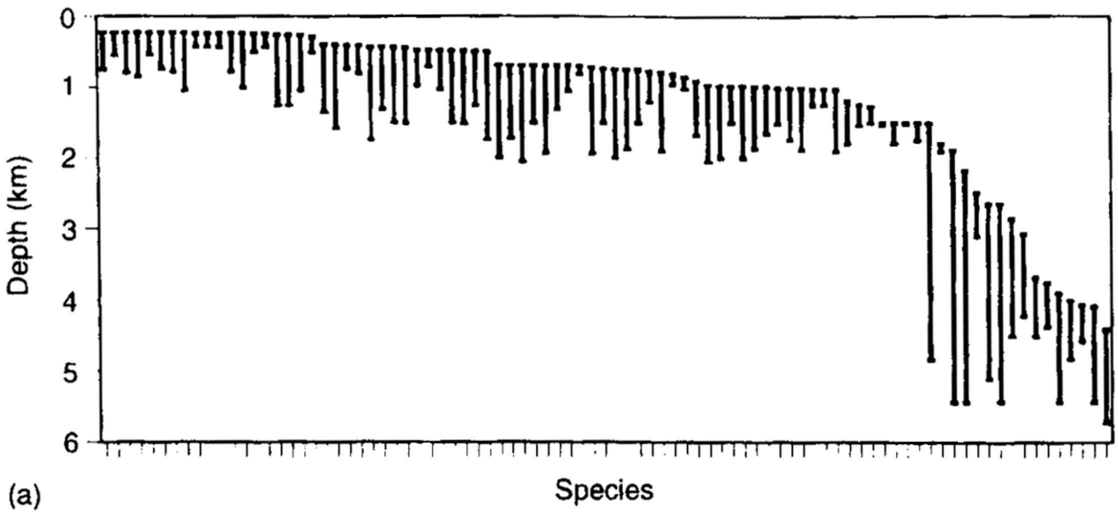
Apart from the Iceland-Faeroe Ridge, the southern boundary of the OSPAR maritime area may also be an important biogeographic boundary for deep sea fishes. Analysis of data available in the late 1980s by Merrett (1987) suggested a distinct change in abyssal demersal fish between 34°N and 41°N. Further sampling confirmed a northerly abyssal fish assemblage in latitudes of 41-49°N and another group between 31-38°N (Merrett, 1992). More recent analysis with additional fish records suggests that the northerly group of stations remain relatively discrete but coalesces with a group of stations from intermediate latitudes (Merrett & Haedrich, 1997). Other studies support the hypothesis that this is a zone of transition. It corresponds with an area where there is a marked change in the depth of winter mixing for example, which will affect the seasonality of production in the water column. As with many aspects of deep sea biology, this is clearly a subject which will needs ongoing assessment as more records become available.

All well as differences in geographic distribution, individual species are also known to occur over bathymetric ranges from a few hundred to thousands of metres (figure 37).

Box 7: Species of demersal fish occurring at the 2200, 2500 and 2900m hathymetric zones in the Rockall Trough (from Gordon, 1986)

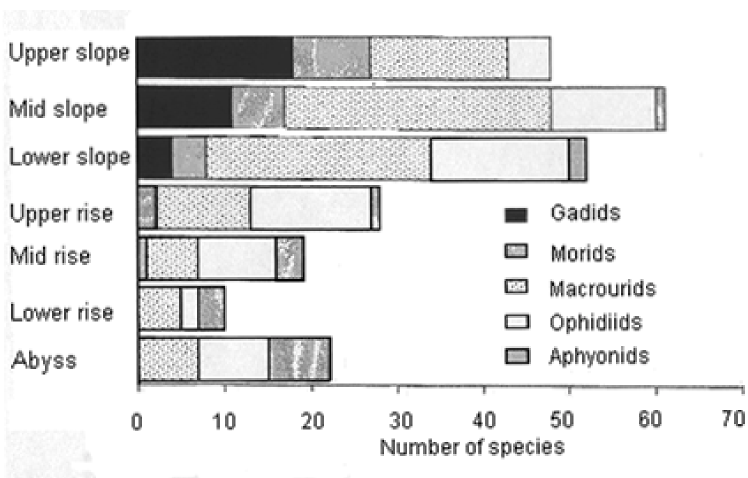
	2200	2500	2900
Rajidae			
Raja (Amblyrqia) sp.	+		
Raja (Rajelia) bigelowi Stehmann, 1976	+		
Bathyraja pailida (Forster, 1967)	+		+
Alepocephalidae			
Alepocephalus agassizi Goode & Bean, 1883	+	+	
Alepocephalus bairdii Goode & Bean, 1879	+		
Synodontidae			
Bathysaurus agassizi Goode & Bean, 1883			
Bathysaurus mollis Gunther, 1878		+	+
Synaphobranchidae			
Svnaphobranchus kaupi Johnson, 1862	+	+	
Histiobranchus bathybius (Gunther, 1877)		+	+
Halosauridae			
Halosauropsis macrochir (Gunther, 1878)	+	+	+
Notacanthidae			
Polycanthonotus rissoanus (Filippe & Verany, 1859)	+	+	
Polycanthonotus africanus Gilchrist & Von Bonde, 1924	+		
Macrouridae			
Coryphaenoides guentheri (Vaillant, 1888)	+	+	
Nematonurus armatus (Hector, 1875)	+	+	+
Chalinura brevibarbis Goode & Bean, 1883	+	+	+
Chalinura leptolepis (Gunther, 1879)	+	+	
Chalinura mediterranea Giglioli, 1893	+	+	
Lionurus carapinus (Goode & Bean, 1883)	+	+	+
Moridae			
Antimora rostrata	+	+	+
Zoarcidae			
Lycodes atlanticus Jensen, 1902	+		
Lycodes sp.	+		
Ophidiidae			
Spectrunculus grandis (Gunther, 1877)	+		
Bythitidae			
Cataetyx laticeps Koefoed, 1927	+		
Liparidae			
Paraliparis bathvbius (Collett, 1879)	+		

Figure 37: Individual bathymetric ranges of deep demersal fish species on the slope and rise of the Porcupine Sea Bight and Abyssal Plain (from Merrett & Haedrich, 1997)



The gadids are fishes of the shallow depths with numbers declining across the slope and none in deeper waters of the Atlantic Basin (figure 38). The alepocephalidae, macrouridae and ophidiidae are the dominant families at all depths and although most species within these groups have a limited depth distribution, some range over thousands of metres. The cut-throat eel *Synaphobranchus kaupi* is one such example as it is known to occur from depths of 230m to more than 2,000m (Merrett & Haedrich, 1997).

Figure 38: Number of species in different families over different depth zones in the North Atlantic Basin (Merrett & Haedrich, 1997)



2.10.2 Conservation issues

Commercial fisheries have been targeting deep sea species since the 1950s with global landings after the initial period of rapid expansion generally varying between 800,000 to one million tons (FAO figures from Koslow *et al.,* in press). In the last two decades, the serious impacts of this activity on fish stocks have become particularly apparent with a shift in focus of the fisheries to different species as stocks or areas have become depleted. The bycatch associated with bottom trawl fisheries and discards of unwanted fish are another concern as is the fact that many of these fisheries take place in international waters making it difficult to regulate and enforce any management measures.

The life-history characteristics of many of the species targeted by deep sea fisheries make them particularly vulnerable to over-exploitation. These are generally low growth rates, later maturity, extreme longevity, highly episodic recruitment and often an aggregating habit on restricted topographic features. As a result, deep sea fisheries have been referred to as analogous to a mining operation where an ore body is exploited to depletion and then new sources are sought (Merrett & Haedrich, 1997). It has also been stated that most of the targeted species are already overfished or in danger of depletion (Koslow *et al.*, in press). Another area of concern is about possible shifts in species composition caused by taking out species that are dominant in mid-to upper trophic levels. There is no evidence for this at the moment but because of the longevity, slow growth and later maturation of many deep-water species, it may be too early to assess whether this is taking place (Merrett & Haedrich, 1997; Koslow *et al.*, in press). What has been seen, however, is a downward shift in the size structure of deep sea fish assemblages which is a classic sign of fishing pressure on a stock. There have also been declines in landings and shifts in the species caught as stocks become depleted.

In the north-east Atlantic, for example, 40 per cent of the landings of the redfish *Sebastes* spp. in the 1980s was *S.marinus* but this has largely been replaced by the deeper and more oceanic *S.mentella,* while roundnose grenadier *Coryphaenoides rupestris* catches in the north-east Atlantic peaked in 1971 at over 80,000 tones then declined quickly to only a few hundred tons in 1997 (Koslow *et al.*, in press). Other species in the north-east Atlantic which are particularly vulnerable are smoothheads (*Alepocephalidae* spp.) which can make up a large percentage of catches on the continental slope to the west of Scotland but which are discarded, argentine (*Argentina silus*) where a crash in catches in the Irish directed deep-water fishery in an area west of the Hebrides was reported in 1990, blue ling (*Molva dypterygia*) which are fished while aggregating during the spawning season, black scabbard (*Aphanopus carbo*) which are caught west of the British Isles in bottom trawls but for which there is a lack of basic life-history information, and deep-water sharks, some of which are bycatch and others the specific target of fisheries (Greenpeace, 1997).

2.10.3 Conservation actions

The vulnerability of many deep sea fish stocks to over-exploitation, lack of information about the biology of most species, rapid declines in landings of even relatively recently exploited stocks, pressure to discover and exploit new stocks, and poor regulation of existing deep sea fisheries have led to an increasing number of calls to slow-down and, in some cases, to stop deep sea fisheries. Options which have been discussed include the establishment of deep sea reserves in areas where species aggregate to spawn (Koslow *et al.*, in press), an interim suspension of deep sea fishing while information is collected on which to base a management regime (House of Lords, 1996) and a total ban on deep-water fisheries to the west of the British Isles to protect the remaining highly vulnerable species (Greenpeace, 1997). Merrett & Haedrich (1997) suggest that the only possible deep sea fisheries that might be viewed as continued and sustainable operations are those that operate on a small scale with searching done very locally and which take a very small volume of high-quality fish. They refer to the black scabbard fishery in Maderia as an example of such an operation.

It has been said that the success of any management scheme can only be measured after the passage of several fish generation times which could be at a minimum of 150-200 years for deep sea fish (Merrett & Haedrich, 1997). Clearly it is therefore essential that such fisheries should only proceed under very conservative regimes, if at all.

2.11 Xenophyophores

Deep sea samples often contain sediment balls, faecal pellets, and concretions of foraminiferan tests, spicule balls and organic detritus. Since the last century it has been known that some of these structures contain animals but it is only in recent years that they have been studied in any detail. One such group of animals is the xenophyophores. They were described in a monograph in the early 1970s (Tendal, 1972), and include species such as *Maudammina arenaria, Galatheammina calcara, Psammina globigerina, Reticulammina labyrinthica* and *Cerelasma massa*.

Xenophyophores are unusually large protozoans. Individuals can grow to more than 20cm in diameter and, although they are often fragile, their relatively large size has made them easier to study when compared to other protozoans found in the oceans. Their size also means that they can be categorised as part of the macrofauna of the deep sea. Most species have been observed on the surface of the sea-bed where they form part of the benthos but at least one species, *Occultammina profunda*, is known to consist of branching tubes buried 1-6cm deep in the sediment (Gage & Tyler, 1991).

A characteristic feature of xenophyophores is that they glue together sediment particles and other materials such as the tests for foraminiferans, to form a test which protrudes above the sea-bed. This contains the protoplasm but also extensive accumulations of faecal pellets known as stercomes. Particles are collected from the environment, accumulated in loose masses of ‘ingested material’, then gradually transferred into stercomes which are present as strings or masses (Tendal, 1979). These are deposited outside the plasma but within the test and are enclosed by membranes. It is this characteristic of agglutination of sediment particles to form large tests which has resulted in the name xenophyophore, derived from the Greek meaning “bearer of foreign bodies”. They are thought to feed using pseudopodia, which collect food from the surface of the sediment or by trapping particles suspended in the water column.

The colour and shape of xenophyophore tests varies a great deal. Using photographs of specimens taken at depths of between 1,000-4,000m, Tendal & Gooday (1981) described a number of different growth forms. These could be categorised into branched, reticulate, platy, and various intermediate forms. Some of the differences were thought to be due to local conditions, which would determine the composition and grain size of the sediment particles used to form the test for example.