DEMERSAL SPECIES FISHERIES

K. Brander, International Council for the Exploration of the Sea (ICES), DK, Denmark

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Introduction

Demersal fisheries use a wide variety of fishing methods to catch fish and shellfish on or close to the sea bed. Demersal fisheries are defined by the type of fishing activity, the gear used and the varieties of fish and shellfish which are caught. Catches from demersal fisheries make up a large proportion of the marine harvest used for human consumption and are the most valuable component of fisheries on continental shelves throughout the world.

Demersal fisheries have been a major source of human nutrition and commerce for thousands of years. Models of papyrus pair trawlers were found in Egyptian graves dating back 3000 years. The intensity of fishing activity throughout the world, including demersal fisheries, has increased rapidly over the past century, with more fishing vessels, greater engine power, better fishing gear and improved navigational and fish finding aids. Many demersal fisheries are now overexploited and all are in need of careful assessment and management if they are to provide a sustainable harvest.

Demersal fisheries are often contrasted with pelagic fisheries, which use different methods to catch fish in midwater and close to the water surface. Demersal species are also contrasted with pelagic species (see relevant sections), but the distinction between them is not always clear. Demersal species frequently occur in mid-water and pelagic species occur close to the seabed, so that 'demersal' species are frequently caught in 'pelagic' fisheries and 'pelagic' species in demersal fisheries. For example Atlantic cod (*Gadus morhua*), a typical 'demersal' species, occurs close to the seabed, but also throughout the water column and in some areas is caught equally in 'demersal' and 'pelagic' fishing gear. Atlantic herring (*Clupea harengus*), a typical pelagic species, is frequently caught on the seabed, when it forms large spawning concentrations as it lays its eggs on gravel banks.

Total marine production rose steadily from less than 20 million tonnes (Mt) in 1950 to around 100 Mt during the late 1990s (**Figure 1**). The demersal fish catch rose from just over 5 Mt in 1950 to around 20 Mt by the early 1970s and has since fluctuated around that level (**Figure 2**). The proportion of demersal fish in this total has therefore declined over the period 1970–1998.

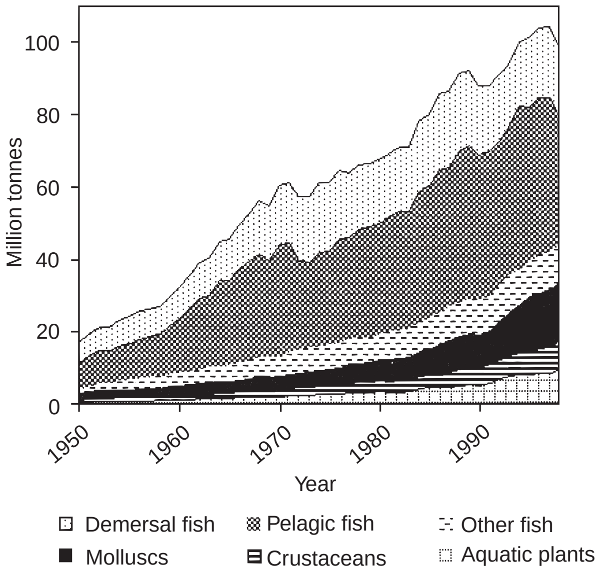

Figure 1 Total marine landings.

The products of demersal fisheries are mainly used for human consumption. The species caught tend to be relatively large and of high value compared with typical pelagic species, but there are exceptions to such generalizations. For example the industrial (fishmeal) fisheries of the North Sea, which take over half of the total fish catch, are principally based on low-value demersal species

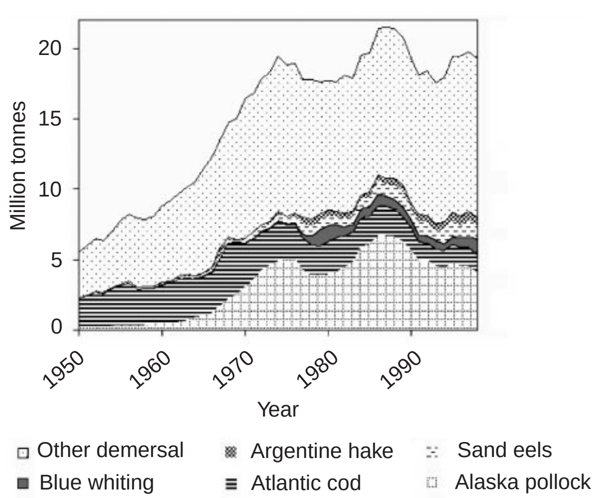

Figure 2 Total demersal fish landings.

which live in or close to the seabed (sand eels, small gadoids).

Demersal fisheries are also often known as groundfish fisheries, but the terms are not exact equivalents because 'groundfish' excludes shellfish, which can properly be considered a part of the demersal catch. Shellfish such as shrimps and lobsters constitute the most valuable component of the demersal trawl catch in some areas.

Principal Species Caught in Demersal Fisheries

For statistical, population dynamics and fisheries management purposes the catch of each species (or group of species) is recorded separately by FAO (UN Food and Agriculture Organization). The FAO definitions of species, categories and areas are used here. FAO groups the major commercial species into a number of categories, of which, the flatfish (flounders, halibuts, soles) and the shrimps and prawns are entirely demersal. The gadiforms (cods, hakes, haddocks) include some species which are entirely demersal (haddock) and others which are not (blue whiting). The lobsters are demersal, but most species are caught in special fisheries using traps. An exception is the Norway lobster, which is caught in directed trawl fisheries or as a by-catch, as well as being caught in traps.

The five demersal marine fish with the highest average catches over the decade 1989–98 are Alaska (walleye) pollock, Atlantic cod, sand eels, blue whiting and Argentine hake. These species all spend a considerable proportion of their time in mid-water. Sand eels spend most of their lives on or in the seabed, but might not be regarded as a typical demersal species, being small, relatively short-lived and of low value. Sand eels and eight of the other 20 top 'species' in fact consist of more than one biological species, which are not identified separately in the FAO classification (**Table 1**).

The vast majority of demersal fisheries take place on the continental shelves, at depths of less than 200 m. Fisheries for deep-sea species, down to several thousand meters, have only been undertaken for the past few decades, as the technology to do so developed and it became profitable to exploit other species.

The species caught in demersal fisheries are often contrasted with pelagic species in textbooks and described as large, long-lived, high-value fish species, with relatively slow growth rates, low variability in recruitment and low mortality. There are so many exceptions to such generalizations that they are likely to be misleading. For example tuna and salmon are large, high-value pelagic species. Three of the main pelagic species in the North Atlantic (herring, mackerel and horse mackerel) are longer lived, have lower mortality rates and lower variability of recruitment than most demersal stocks in that area (**Table 2**).

Table 1 Total world catch of 20 top demersal fish species (averaged from 1989–1998)

Common name	*Scientific name*	*Tonnes*
Alaska pollock	*Theragra chalcogramma*	3 182 645
Atlantic cod	*Gadus morhua*	2 317 261
Sand eels	*Ammodytes* spp.	1 003 343
Blue whiting	*Micromesistius poutassou*	628 918
Argentine hake	*Merluccius hubbsi*	526 573
Croakers, drums nei	Sciaenidae	492 528
Pacific cod	*Gadus macrocephalus*	425 467
Saithe (=Pollock)	*Pollachius virens*	385 227
Sharks, rays, skates, etc. nei	Elasmobranchii	337 819
Atlantic redfishes nei	*Sebastes* spp.	318 383
Norway pout	*Trisopterus esmarkii*	299 145
Flatfishes nei	Pleuronectiformes	289 551
Haddock	*Melanogrammus aeglefinus*	273 459
Cape hakes	*Merluccius capensis, M. paradox*	266 854
Blue grenadier	*Macruronus novaezelandiae*	255 421
Sea catfishes nei	Ariidae	242 815
Atka mackerel	*Pleurogrammus azonus*	237 843
Filefishes	*Cantherhines* (=*Navodon*) spp.	234 446
Patagonian grenadier	*Macruronus magellanicus*	230 221
South Pacific hake	*Merluccius gayi*	197 911
Threadfin breams nei	*Nemipterus* spp.	186 201

Table 2 The intensity of fishing is expressed as the average (1988–1997) probability of being caught during the next year. The interannual variability in number of young fish is expressed as the coefficient of variation of recruitment. Species shown are some of the principal demersal and pelagic fish caught in the north-east Atlantic

	Probability of being caught during next year	*Coefficient of variation of recruitment*
Demersal species		
Cod	33–64%	38–65%
Haddock	19–52%	70–151%
Hake	27%	33%
Plaice	32–48%	35–56%
Saithe	29–42%	45–56%
Sole	28–37%	15–94%
Whiting	47–56%	41–61%
Pelagic species		
Herring	12–40%	56–63%
Horse mackerel	16%	40%
Mackerel	21%	41%

Fishing Gears and Fishing Operations

A very wide range of fishing gear is used in demersal fisheries (*see* **Fishing Methods and Fishing Fleets**), the main ones being bottom trawls of different kinds, which are dragged along the seabed behind a trawler. Other methods include seine nets, trammel nets, gill nets, set nets, baited lines and longlines, temporary or permanent traps and barriers.

Some fisheries and fishermen concentrate exclusively on demersal fishing operations, but many alternate seasonally, or even within a single day's fishing activity, between different methods. Fishing vessels may be designed specifically for demersal or pelagic fishing or may be multipurpose.

Effects of Demersal Fisheries on the Species They Exploit

Most types of demersal fishing operation are nonselective in the sense that they catch a variety of different sizes and species, many of which are of no commercial value and are discarded. Stones, sponges, corals and other epibenthic organisms are frequently caught by bottom trawls and the action of the fishing gear also disturbs the seabed and the benthic community on and within it. Thus in addition to the intended catch, there is unintended disruption or destruction of marine life (*see* **Ecosystem Effects of Fishing**).

The fact that demersal fishing methods are nonselective has important consequences when trying to limit their impact on marine life. There are direct impacts, when organisms are killed or disturbed by fishing, and indirect impacts, when the prey or predators of an organism are removed or its habitat is changed.

The resilience or vulnerability of marine organisms to demersal fishing depends on their life history. In areas where intensive demersal fisheries have been operating for decades to centuries the more vulnerable species will have declined a long time ago, often before there were adequate records of their occurrence. For example, demersal fisheries caused a decline in the population of common skate (*Raia batis*) in the north-east Atlantic and barndoor skate (*Raia laevis*) in the north-west Atlantic, to the point where they are locally extinct in areas where they were previously common. These large species of elasmobranch have life histories which, in some respects, resemble marine mammals more than they do teleost fish. They do not mature until 11 years old, and lay only a small number of eggs each year. They are vulnerable to most kinds of demersal fishery, including trawls, seines, lines, and shrimp fisheries in shallow water.

The selective (evolutionary) pressure exerted by fisheries favors the survival of species which are resilient and abundant. It is difficult to protect species with vulnerable life histories from demersal fisheries and they may be an inevitable casualty of fishing. Some gear modifications, such as separator panels may help and it may be possible to create refuges for vulnerable species through the use of large-scale marine protected areas. Until recently fisheries management ignored such vulnerable species and concentrated on the assessment and management of a few major commercial species.

In areas with intensive demersal fisheries the probability that commercial-sized fish will be caught within one year is often greater than 50% and the fisheries therefore have a very great effect on the level and variability in abundance (**Table 2**). The effect of fishing explains much of the change in abundance of commercial species which has been observed during the few decades for which information is available and the effects of the environment, which are more difficult to estimate, are regarded as introducing 'noise', particularly in the survival of young fish. As the length of the observational time series increases and information about the effects of the environment on fish accumulates, it is becoming possible to turn more of the 'noise' into signal. It is no longer credible or sensible to ignore environmental effects when evaluating fluctuations in demersal fisheries, but a considerable scientific effort is

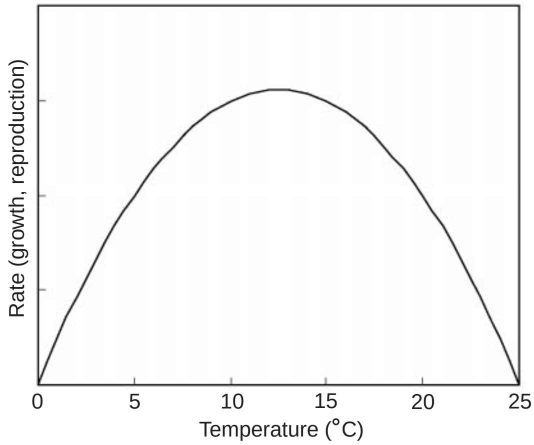

Figure 3 The relationship between temperature and many rate processes (growth, reproductive output, mortality) is domed. The optimum temperature is species and size specific.

still needed in order to include such information effectively.

Effects of the Environment on Demersal Fisheries

The term 'environment' is used to include all the physical, chemical and biological factors external to the fish, which influence it. Temperature is one of the main environmental factors affecting marine species. Because fish and shellfish are ectotherms, the temperature of the water surrounding them (ambient temperature) governs the rates of their molecular, physiological and behavioral processes. The relationship between temperature and many of these rates processes (growth, reproductive output, mortality) is domed, with an optimum temperature, which is species and size specific (**Figure 3**). The effects of variability in temperature are therefore most easily detected at the extremes and apply to populations and fisheries as well as to processes within a single organism. Temperature change may cause particular species to become more or less abundant in the demersal fisheries of an area, without necessarily affecting the aggregate total yield.

The cod (*Gadus morhua*) at Greenland is at the cold limit of its thermal range and provides a good example of the effects of the environment on a demersal fishery; the changes in the fishery for it during the twentieth century are mainly a consequence of changes in temperature (**Figure 4**). Cod were present only around the southern tip of Greenland until 1917, when a prolonged period of warming resulted in the poleward expansion of the range by about 1000 km during the 1920s and 1930s. Many other boreal marine species also extended their range at the same time and subsequently retreated during the late 1960s, when colder conditions returned.

Changes in wind also affect demersal fish in many different ways. Increased wind speed causes mixing of the water column which alters plankton production. The probability of encounter between fish larvae and their prey is altered as turbulence increases. Changes in wind speed and direction affect the transport of water masses and hence of the planktonic stages of fish (eggs and larvae). For example, in some years a large proportion of the fish larvae on Georges Bank are transported into the Mid-Atlantic Bight instead of remaining on the Bank. In some areas, such as the Baltic, the salinity and oxygen levels are very dependent on inflow of oceanic water, which is largely wind driven. Salinity

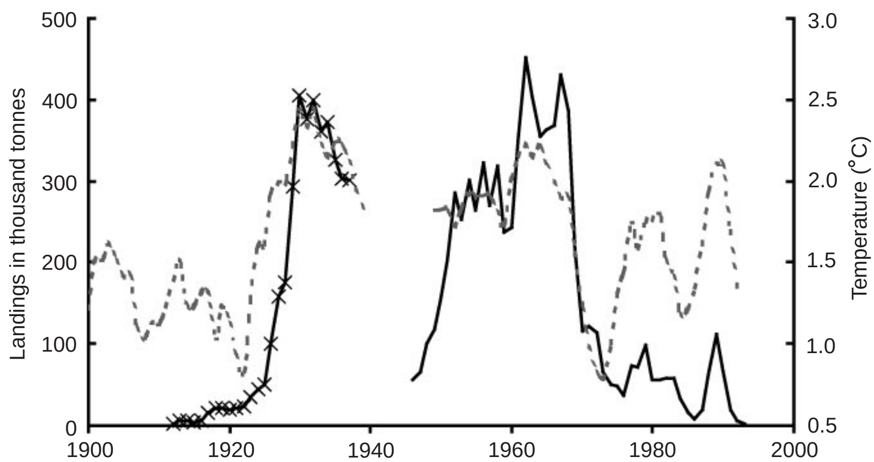

Figure 4 Cod catch and water temperature at West Greenland. Temperature is the running five-year mean of upper layer (0–40 m) values. ×, local catch × 20; —— international catch; – – –, temperature.

and oxygen in turn affect the survival of cod eggs and larvae, with major consequences for the biomass of cod in the area. These environmental effects on the early life stages of demersal fish affect their survival and hence the numbers which recruit to the adult population.

World Catches from Demersal Fisheries and the Limits

Demersal fisheries occur mainly on the continental shelves (i.e., at depths less than 200 m). This is because shelf areas are much more productive than the open oceans, but also because it is easier to fish at shallower depths, nearer to the coast. The average catch of demersal fish per unit area on northern hemisphere temperate shelves is twice as high as on southern hemisphere temperate shelves and more than five times higher than on tropical shelves (**Figure 5**). The difference is probably due to nutrient supply. The effects of differences in productive capacity of the biological system on potential yield from demersal fisheries are dealt with elsewhere (*see* **Ecosystem Effects of Fishing**).

Demersal fisheries provide the bulk of fish and shellfish for direct human consumption. The steady increase in the world catch of demersal fish species ended in the early 1970s and has fluctuated around 20 Mt since then (**Figure 2**). Many of the fisheries are overexploited and yields from them are declining. In a few cases it would seem that the decline has been arrested and the goal of managing for a sustainable harvest may be closer.

A recent analysis classified the top 200 marine fish species, accounting for 77% of world marine fish production, into four groups – undeveloped, developing, mature and declining (senescent). The proportional change in these groups over the second half of the twentieth century (**Figure 6**) shows how fishing has intensified, so that by 1994 35% of the fish stocks were in the declining phase, compared with 25% mature and 40% developing. Other analyses reach similar conclusions – that roughly two-thirds of marine fish stocks are fully exploited or overexploited and that effective management is needed to stabilize current catch levels.

Fish farming (aquaculture) is regarded as one of the principal means of increasing world fish production, but one should recall that a considerable proportion of the diet of farmed fish is supplied by demersal fisheries on species such as sand eel and Norway pout. Fishmeal is also used to feed terrestrial farmed animals.

Management of Demersal Fisheries

The purposes of managing demersal fisheries can be categorized as biological, economic and social. Biological goals used to be set in terms of maximum sustainable yield of a few main species, but a broader and more cautious approach is now being introduced, which includes consideration of the ecosystem within which these species are produced and which takes account of the uncertainty in our assessment of the consequences of our activities. The formulation of biological goals is evolving, but even the most basic, such as avoiding extinction of

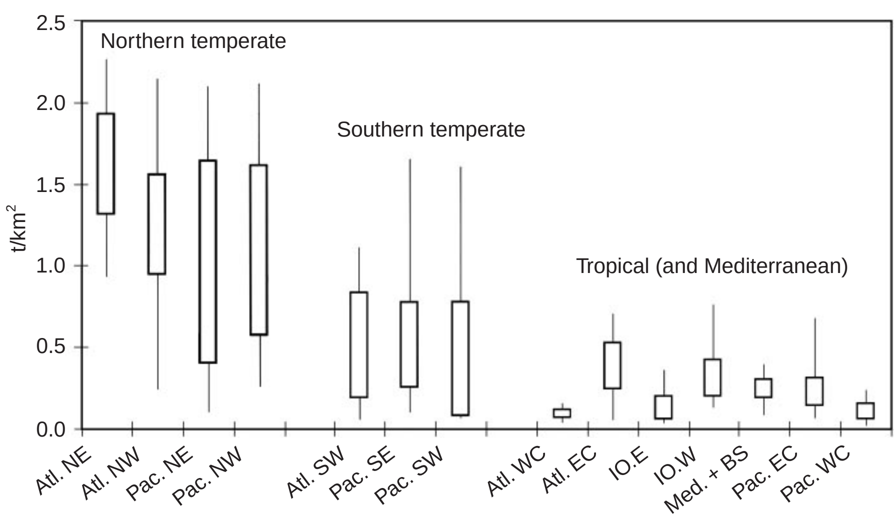

Figure 5 Demersal fish landings per unit area of continental shelf < 200 m deep for the main temperate and tropical areas. The boxes show the spread between the upper and lower quartiles of annual landings and the whiskers show the highest and lowest annual landings 1950–1998. Atl, Atlantic; Pac, Pacific; IO, Indian Ocean; Med, Mediterranean; BS, Black Sea.

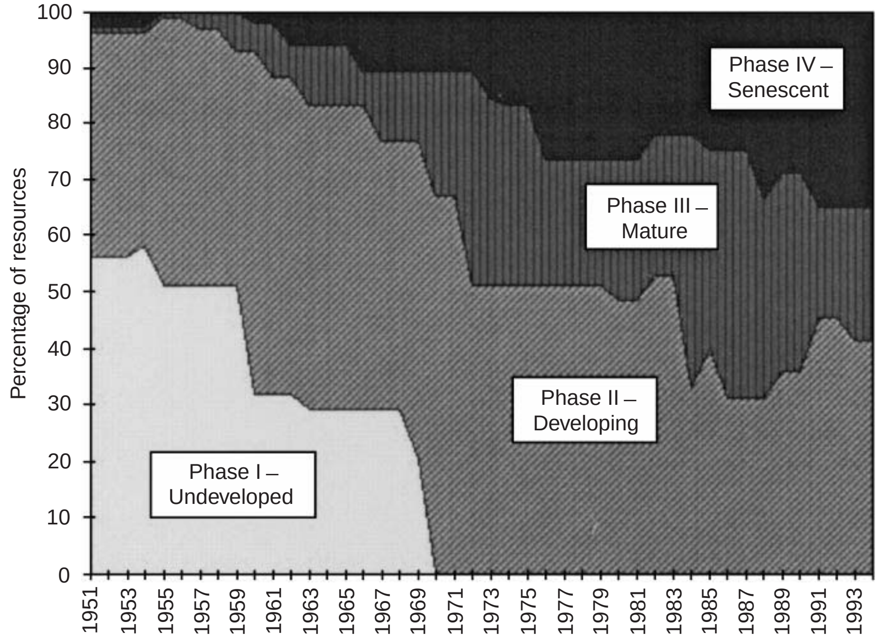

Figure 6 Temporal change in the level of exploitation of the top 200 marine fish species, showing the progression from mainly undeveloped or developing in 1951 to mainly fully exploited or overexploited in 1994.

species, are not being achieved in many cases. At a global level it is evident that economic goals are not being achieved, because the capital and operating costs of marine fisheries are about 1.8 times higher than the gross revenue. There are innumerable examples of adverse social impacts of changes in fisheries, often caused by the effects of larger, industrial fishing operations on the quality of life and standard of living of small-scale fishing communities. Clearly there is scope for improvement in fisheries management.

From this rather pessimistic analysis of where fisheries management has got us to date, it follows that a description of existing management regimes is a record of current practice rather than a record of successful practice.

Biological management of demersal fisheries has developed mainly from a single species 'yield-per-recruit' model of fish stocks. The output (yield) is controlled by adjusting the mortality and size of fish that are caught. Instruments for limiting fishing mortality are catch quotas (TAC, total allowable catch) and limits on fishing effort. Since it is much easier to define and measure catch than effort, the former is more widely used. In many shared, international fisheries, such as those governed by the European Union, the annual allocation of catch quotas is the main instrument of fisheries management. This requires costly annual assessment of many fish stocks, which must be added to the operating costs when looking at the economic balance for a fishery. Because annual assessments are costly, only the most important species, which tend to be less vulnerable, are assessed. For example the US National Marine Fisheries Service estimate that the status of 64% of the stocks in their area of responsibility is unknown.

The instruments for limiting the size of fish caught are mesh sizes, minimum landing sizes and various kinds of escape panels in the fishing gear. These instruments can be quite effective, particularly where catches are dominated by a single species. In multispecies fisheries, which catch species with different growth patterns, they are less effective because the optimal mesh size for one species is not optimal for all.

There are two classes of economic instruments for fisheries management: (1) property rights and (2) corrective taxes and subsidies. The former demands less detailed information than the latter and may also lead to greater stakeholder participation in the management process, because it fosters a sense of ownership.

The management of demersal fisheries will always be a complex problem, because the marine ecosystem is complicated and subject to change as the global environment changes. Management will always be based on incomplete information and understanding and imperfect management tools. A critical step towards better management would be to monitor performance in relation to the target objectives and provide feedback in order to improve the system.

One of the changes which has taken place over the past few years is the adoption of the precautionary approach. This seeks to evaluate the quality of the evidence, so that a cautious strategy is adopted when the evidence is weak. Whereas in the past such balance of evidence arguments were sometimes applied in order to avoid taking management action unless the evidence was strong (in order to avoid possible unnecessary disruption to the fishing industry), the presumption now is that in case of doubt it is the fish stocks rather than the short-term interests of the fishing industry which should be protected. This is a very significant change in attitude, which gives some grounds for optimism in the continuing struggle to achieve sustainable fisheries and healthy ecosystems.

Demersal Fisheries by Region

The demersal fisheries of the world vary greatly in their history, fishing methods, principal species and management regimes and it is not possible to review all of these here. Instead one heavily exploited area with a long history (New England) and one less heavily exploited area with a short history (the south-west Atlantic) will be described.

New England Demersal Fisheries

The groundfish resources of New England have been exploited for over 400 years and made an enormous contribution to the economic and cultural development of the USA since the time of the first European settlements. Until the early twentieth century, large fleets of schooners sailed from New England ports to fish, mainly for cod, from Cape Cod to the Grand Banks. The first steam-powered otter trawlers started to operate in 1906 and the introduction of better handling, preservation and distribution changed the market for fish and the species composition of the catch. Haddock became the principal target and their landings increased to over 100 000 t by the late 1920s. The advent of steam trawling raised concern about discarding and about the damage to the seabed and to benthic organisms.

From the early 1960s fishing fleets from European and Asian countries began to take an increasing share of the groundfish resources off New England. The total groundfish landings rose from 200 000 t to 760 000 t between 1960 and 1965. This resulted in a steep decline in groundfish abundance and in 1970 a quota management scheme was introduced under the International Commission for Northwest Atlantic Fisheries (ICNAF). Extended jurisdiction ended the activities of distant water fleets, but was quickly followed by an expansion of the US fleet, so that although the period 1974–78 saw an increase in groundfish abundance, the decline subsequently continued. Most groundfish species remain at low levels and, even with management measures intended to rebuild the stocks, are likely to take more than a decade to recover.

The changes in abundance of 'traditional' groundfish stocks (cod, haddock, redfish, winter flounder, yellowtail flounder) have to some extent been offset by increases in other species, including some elasmobranchs (sharks and rays). However, prolonged high levels of fishing have resulted in severe declines in the less resilient species of both elasmobranchs (e.g. barndoor skate) and teleosts (halibut, redfish). This is covered more fully elsewhere (*see* **Ecosystem Effects of Fishing**).

The second half of the twentieth century saw major changes in the species composition of the US demersal fisheries. By the last decade of the century catches of the two top fish species during the decade 1950–59, redfish and haddock, had declined to 0.6% and 2.3% of their previous levels, respectively. Shellfish had become the main element of the demersal catch (**Table 3**).

Demersal Fisheries of the South-West Atlantic (FAO Statistical Area 41)

The catch from demersal fisheries in the SW Atlantic increased steadily from under 90 000 tonnes in 1950 to over 1.2 Mt in 1998 (**Figure 7**). The demersal catch consists mainly of fish species, of which Argentine hake has been predominant throughout the 50-year record. The catch of shrimps, prawns, lobsters and crabs is almost 100 000 t per year and they have a relatively high market value.

Thirty countries have taken part in demersal fisheries in this area, the principal ones being Argentina, Brazil, and Uruguay, with a substantial and continuing component of East European effort. A three year 'pulse' of trawling by the USSR fleet resulted in a catch over 500 000 t of Argentine hake and over 100 000 t of demersal percomorphs in 1967. The fisheries in this area are mostly industrialized and long range. As the stocks on the continental shelf have become fully exploited, the fisheries have extended into deeper water, where they take pink cusk eel and Patagonian toothfish. The main coastal demersal species are whitemouth croaker, Argentine croaker and weakfishes.

The Argentine hake fishery extends over most of the Patagonian shelf. It is now fully exploited and possibly even overexploited. Southern blue whiting

Table 3 Average US catch from the north-west Atlantic region

Species	*Scientific name*	*Average catch (t)*	
		1950–59	*1989–98*
Atlantic redfishes nei	*Sebastes* spp	77 923	518
Haddock	*Melanogrammus aeglefinus*	64 489	1487
Silver hake	*Merluccius bilinearis*	47 770	16 469
Atlantic cod	*Gadus morhua*	18 748	24 112
Scup	*Stenotomus chrysops*	17 904	3846
Saithe (=Pollock)	*Pollachius virens*	11 127	6059
Yellowtail flounder	*Limanda ferruginea*	9103	5085
Winter flounder	*Pseudopleuronectes americanus*	7849	5700
Dogfish sharks nei	Squalidae	502	17 655
Raja rays nei	*Raja* spp.	73	10 304
American angler	*Lophius americanus*	41	19 136
American sea scallop	*Placopecten magellanicus*	77 650	81 320
Northern quahog (=Hard clam)	*Mercenaria mercenaria*	52 038	25 607
Atlantic surf clam	*Spisula solidissima*	43 923	160 795
Blue crab	*Callinectes sapidus*	28 285	57 955
American lobster	*Homarus americanus*	12 325	29 829
Sand gaper	*Mya arenaria*	12 324	7739
Ocean quahog	*Arctica islandica*	1139	179 312

and Patagonian grenadier are also close to full exploitation. Hake and other demersal species are regulated by annual TAC and minimum mesh size regulations.

Conclusions

Demersal fisheries have been a major source of protein for people all over the world for thousands of years. World catches increased rapidly during the first three-quarters of the twentieth century. Since then the catches from some stocks have declined, due to overfishing, while other previously underexploited stocks have increased their yields. The limits of biological production have probably been reached in many areas and careful management is needed in order to maintain the fisheries and to protect the ecosystems which support them.

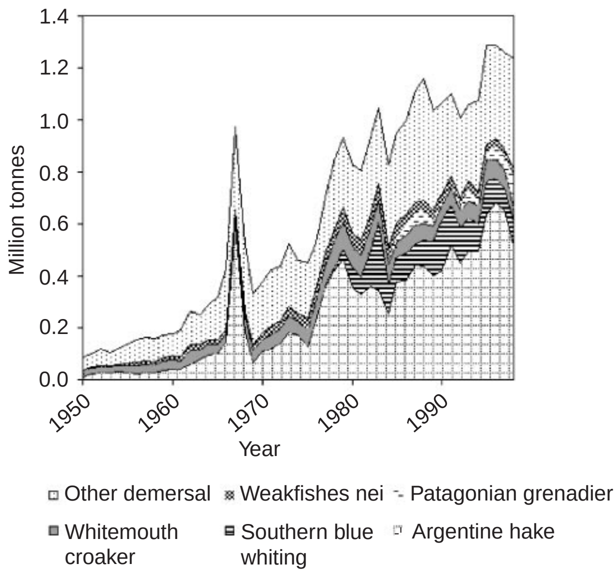

Figure 7 Total demersal fish landings from the south-west Atlantic (FAO Statistical area 41).

See also

Ecosystem Effects of Fishing. Fishing Methods and Fishing Fleets.

Further Reading

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