

to understand better how the single biological variable we can reasonably hope to measure synoptically and globally – the biomass of phytoplankton – is forced by regional oceanographic processes.

## See also

**Diversity of Marine Species. Large Marine Ecosystems. Ocean Gyre Ecosystems. Polar Ecosystems. Primary Production Processes. Upwelling Ecosystems.**

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# PELAGIC FISHERIES

See **OPEN OCEAN FISHERIES FOR LARGE PELAGIC SPECIES; SMALL PELAGIC SPECIES FISHERIES**

# PELAGIC FISHES

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## Introduction

In the economy of the sea pelagic fish play a central part. The simplest food chain comprises phytoplankton, copepods and pelagic fish. They spend their lives in the midwater of coastal seas and oceans. Much of our knowledge about them comes from the fisheries that exploit them, which yield very large catches. The three groups, clupeoids, tunas and mackerels live in all parts of the ocean and many of them migrate across the seas for considerable distances. The clupeoids include such fishes as herring, sardines and sprats which have supported large fisheries since the earliest times. Anchovies are widespread and the Peruvian anchoveta once supported a very large fishery. Herring are caught in the North Atlantic and North Pacific; sardines are taken in the upwelling areas and sprats

are mainly caught in the North Sea. Herring can migrate for up to 2000 km each year and their stocks (or populations) have yielded annual catches of as much as one million tonnes, wet weight. They are smallish fish ranging in length from about 12 cm (sprats) to 20 cm (sardines) and 25–30 cm or longer (herring).

The tunas are larger fishes, one or two meters in length and each year they make transoceanic migrations. They include yellowfin, albacore, bigeye and bluefin. Catches amount to about a million tonnes each year and they are taken at many places in the world ocean, but particularly in upwelling areas and at fronts. Mackerels are larger than herring (up to 40 cm in length) and they also migrate across considerable distances. The common mackerel in the North Atlantic and the cosmopolitan Spanish mackerel are typical examples; horse mackerels (in a different suborder) are also widely distributed. The pelagic fish spend their lives in the near-surface layers of the ocean and they swim steadily for long periods. From their central position in the marine ecosystem they control the passage of energy up

the food webs from the algal cells and copepods to fish.

## Clupeoids

### Herring: a Case Study of a Pelagic Fish

Herring live in the North Atlantic (*Clupea harengus* L.) and in the North Pacific (*Clupea pallasii* Val.). The edges of the scales on the belly of the Atlantic herring are rough, but in the Pacific herring they are smooth. Atlantic herring are found in the east from the Bay of Biscay to Spitzbergen and the Murman coast and in the west from Greenland and Labrador to Cape Hatteras on the eastern seaboard of the United States. The Pacific herring is found off British Columbia, off Hokkaido in Japan and off Kamchatka. Although they live in the midwater, both species lay their eggs on the seabed; the Atlantic herring usually lay their eggs at depths of 40–200 m and in some cases intertidally on gravel and small stones and the Pacific herring spawns on seaweeds between tidemarks. Both species spawn on narrow strips; for example that near the Sandettié Bank not far from Dover is 3000 m long and 300–360 m wide.

Herring are small fish, the adults being about 25–30 cm in length; Baltic herring (*Clupea harengus/membras*) are smaller and the Norwegian herring are somewhat larger. North Sea herring live for about twelve years and Norwegian herring for about twenty years. They mature at about three or four years of age and their annual fecundity amounts to 40 000–100 000 eggs. Throughout life the total fecundity would be about ten times greater and only two survivors are needed to replace the stock. Hence the annual mortality each year of the eggs, larvae and juveniles is high; indeed, it is approximately the inverse of the annual fecundity. The natural mortality of the adults is that sustained under predation in the absence of fishing and, as might be expected, it is rather difficult to establish; that of the herring might be about 10–20% of numbers per year. They live and swim in large shoals, each of which may be many kilometers across. They migrate towards the surface at night and then the shoals tend to disperse. They make long migrations each year from spawning ground to feeding ground and back, distances of up to 2000 km. To do this they usually swim down tide or current. Herring feed on *Calanus* among other plankton animals. They grow quite quickly particularly during the first year of life, but as adults they grow relatively slowly, as more energy is devoted to reproduction. The herring of any spawning group spawn at the same

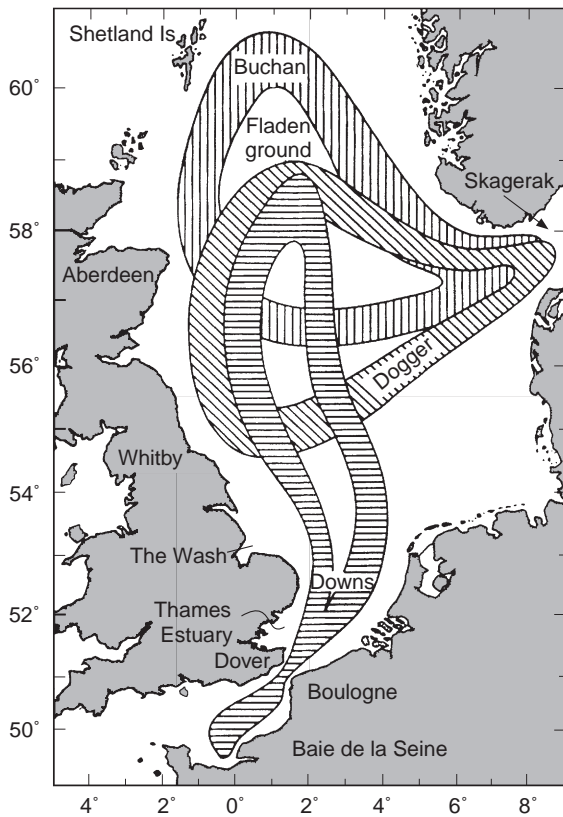
season each year to within about a week. It is likely that they return to the grounds on which they were spawned, although this cannot be shown decisively.

In the Northeast Atlantic there are a number of spring spawning stocks: Norwegian, Murman, Shetland and Faroe Islands. The Icelandic spring spawners may no longer exist, but the Icelandic summer spawners flourish. There are some small stocks in the Skagerak and there are very small local stocks that spawn at the mouths of certain rivers such as the Elbe. In the North Sea there are two autumn spawning stocks, Buchan and Dogger in the northern and central North Sea and a winter spawning stock, the Downs, in the southern North Sea. The Buchan group spawns off the northeast coast of Scotland; the Dogger group spawns off Whitby and around the Dogger Bank. The Downs stock spawns in the English Channel off Dover and in the Baie de la Seine off northern France. There is another winter spawning stock in the western English Channel. Icelandic summer spawners lay their eggs on three grounds off the north coast of the island. The Norwegian herring spawn in spring between Egersund and Bergen, between Bergen and Kristiansund and off Lofoten and Westeralen. The North Sea herring migrate in a clockwise circuit in the North Sea (Figure 1). The Norwegian herring migrate from the Norwegian coast across to Iceland and then northwards to Jan Mayen and the Barents Sea before returning to their spawning grounds on the Norwegian coast (Figure 2). The Icelandic herring stocks migrate round the island in a clockwise direction.

In the Northwest Atlantic there are a number of herring stocks: off Labrador, the southern and western coasts of Newfoundland, the Scotian Shelf, Georges Bank, and to the south of Georges Bank. Most of these stocks are spring spawners, but after 1950, off the south and west of Newfoundland the migrations of the stock on the Scotian Shelf are quite limited but the reason for this difference is not known.

In the Pacific there are two main groups of stocks, that off British Columbia and that in the Far East. The British Columbian fishery is established off Vancouver Island, and off Queen Charlotte Is. There are four major stocks in the east, the Sakhalin-Hokkaido (a spring spawner), the Kamchatka herring, the Kora Karazynsk herring and the Okhotsk herring. Each stock migrates from feeding ground to spawning ground over distances of about 1200 km, for the first three stocks and about 500 km for the Okhotsk herring (Figure 3).

In the North Sea herring have been caught from the earliest times by drift net off Shetland, off the northeast coast of Scotland, off northeast England



**Figure 1** The migration circuits of the three groups of spawners in the North Sea: Buchan, Dogger and Downs.

and off East Anglia. Later, they were caught by trawl on the Fladen Ground northeast of Aberdeen, off the Dogger Bank and on the narrow grounds not far from Dover and Boulogne. In the Norwegian Sea herring were originally caught by drift net in the fiords and later by purse seine. Finally, when the purse seine could be worked in the open sea, herring were caught there off southern Norway and also north of the Lofoten Is. Off Iceland, drift nets were also replaced by purse seines worked in the open sea. Nowadays most herring are caught by purse seine and midwater trawl.

In the Northwest Atlantic the traditional fishery took place in the Gulf of Maine and in the Bay of Fundy. In recent years, trawl fisheries have been developed on Georges Bank and purse seine fisheries off Nova Scotia. There were fisheries also off Newfoundland and in the Gulf of St Lawrence. Catches were converted into fish meal and oil. In the Far East, the major fishery was that for the Hokkaido spring herring which were caught by offshore gill nets. The fishery peaked between 1895 and 1905 after which it declined to low levels. Since 1950, the offshore gill nets have been replaced by trawlers. Off Sakhalin and in the Sea of Okhotsk herring have been caught by gill nets for a long time.

The global catches of herring have amounted to several million tonnes. In the North Sea the Downs stock was overexploited in the late 1950s by trawling on the spawning grounds and the two other groups, Buchan and Dogger, suffered from overfishing by purse seiners in the late 1960s. The Norwegian spring spawning stock of herring was overexploited by the offshore purse seiners in the early 1970s. In the Northwest Atlantic the fishery on Georges Bank became too heavy in the 1970s. It is possible that the Hokkaido stock suffered from overfishing but this cannot be shown decisively.

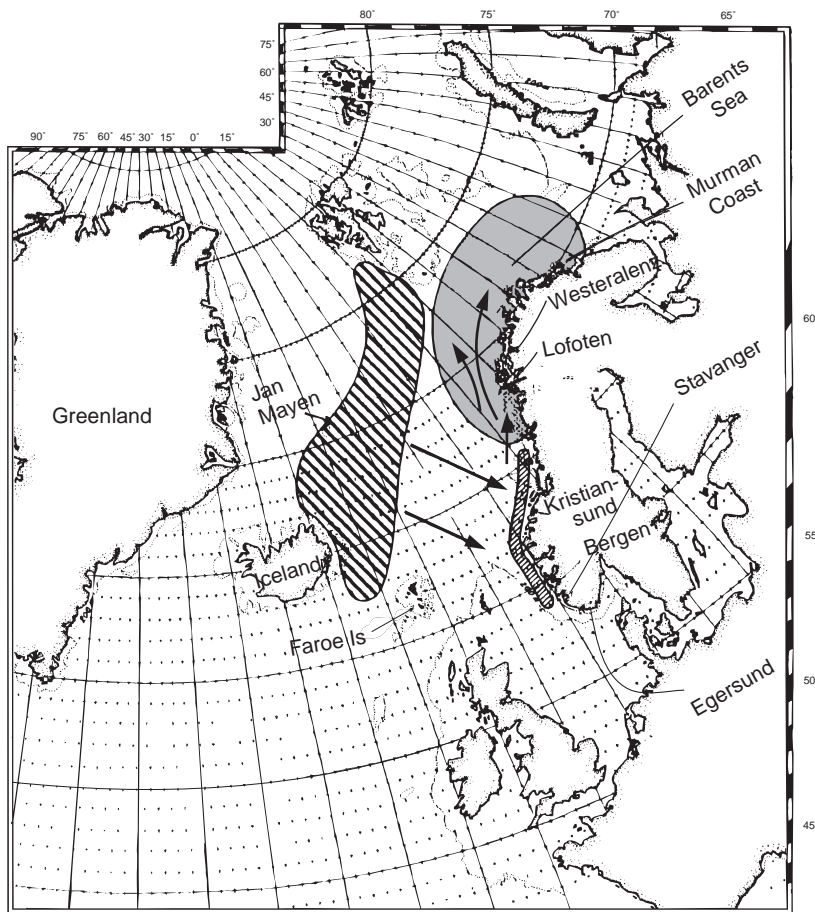
### Sprats

Sprats, *Clupea sprattus* (L.), are small clupeoids about 10–13 cm in length. They live for about five to seven years, but the most abundant age group is the third. Like other clupeoids, they feed on copepods and other plankton animals. They spawn in spring and summer, but in the northern Adriatic they spawn between December and March. They mature from the end of their second year to the end of their third year and they lay between 10 000 and 40 000 eggs each year. The natural mortality is probably high. There are major spawning grounds in the southern North Sea and in the southern Norwegian fiords. The eggs, larvae and juveniles are fully pelagic.

Sprats are found in the Baltic, in the North Sea, in the northern Adriatic and off Romania in the Black Sea. Fisheries were established in the Scottish firths, between Bergen and Stavanger in Norway, off Brittany in France and around the English coast, particularly in the Wash and in the Thames estuary. In the main, these are winter fisheries worked with drift nets and stow nets, i.e. bag nets hung from fixed poles in the tidal streams.

### Sardines

There are a number of sardines and related species: *Sardina pilchardus* Walb in European waters, *Sardinops caeruleus* (Girard) off California, *Sardinops ocellatus* (Pappé) off South Africa, *Sardinops melanostictus* (Schlegel) off Japan and *Sardinella aurita* Val. off West Africa. The pilchard (*S. pilchardus*) lives in the English Channel, in the Bay of Biscay and off the Iberian peninsula. Elsewhere, sardines live mainly in the upwelling areas in subtropical oceans. An upwelling area is an extensive region along western coasts in the subtropical ocean both north and south of the equator. The four main regions lie off California, off Peru and Chile, off southern Africa and off northwest Africa. There are also lesser upwellings off the west coast of the Iberian peninsula, off Ghana, off southern Arabia and



**Figure 2** The migration circuit of the spring spawning Norwegian herring; the spawning ground lies off the Norwegian coast, the nursery ground spreads north into the Barents Sea and the feeding ground lies between Iceland and Spitzbergen.

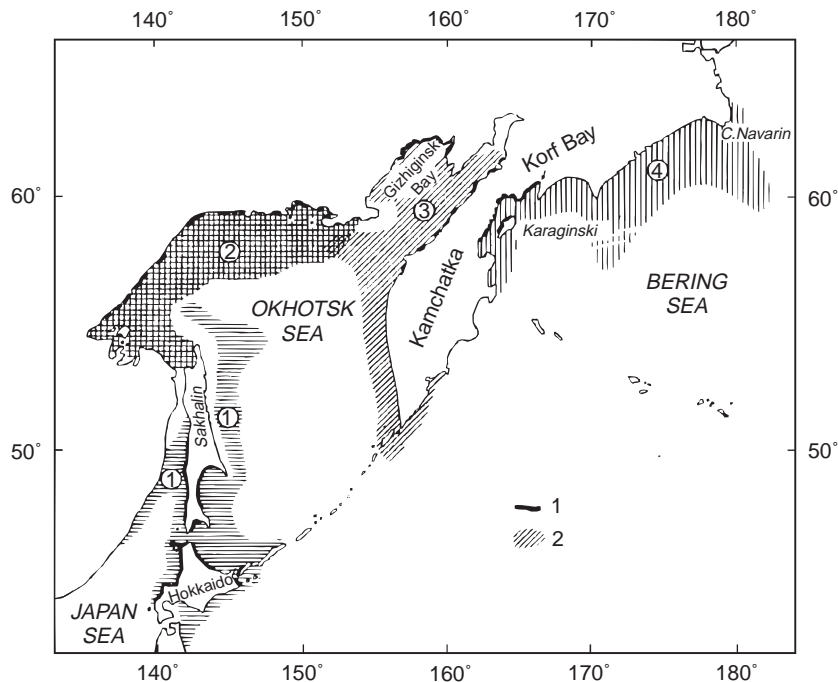
off the Malabar coast of India. In an upwelling area the wind blows towards the equator. Water advects offshore and the nutrient-rich replacement is drawn up from below and in it production starts. In these rich areas sardines flourish in large populations.

Sardines are smaller than herring with an average length of just over 20 cm. They live up to ten years but the abundant year classes peak at about four or five years of age. An average year class of *Sardinops caeruleus* off California might comprise about a billion fish. The natural mortality of the sardine is high because they are eaten by a wide range of predators. They spawn in spring and fall off Baja California; within the Baja they spawn in late winter. Their fecundity may amount to about 40 000 eggs year<sup>-1</sup>. Shoals lie along the line of the tide or current and, like herring shoals, they are much longer than they are wide. Sardines do migrate within an upwelling area, but their movements are restricted. They feed on copepods; the larvae eat copepod nauplii and the larger fish feed on adult copepods. They tend to spawn in winter and spring in both hemispheres, perhaps a little

before the upwelling strengthens (but off southern California, they can also spawn in the fall). Eggs, larvae and juveniles are all pelagic.

Records of sardine catches off Japan go back to the fifteenth century. The rich periods lasted from twenty to seventy years, for example, from 1660 to 1730, 1818 to 1864 and 1917 to 1939. From five to seven local groups were recognized but they tended to flourish or decline together. One of the most remarkable events is the trend in catches peaking between the 1930s and the 1950s, off California, off Spain and in the northern Adriatic. Catches of the Japanese sardine (*Sardinops melanostictus*) rose to a peak of about 2 500 000 tonnes in 1935–36 and then declined to very low levels between 1945 and 1972. With the year classes, 1977 and 1980, catches recovered to over 4 000 000 tonnes each year by 1985. Subsequently catches again declined. These events occurred at places far apart and there is, as yet, no explanation for the fact that the catches rose and declined together.

Pilchards were caught by drift net off Brittany and by ring net off Cornwall. In the upwelling



**Figure 3** The stocks of *Clupea pallasii* in the Far East. 1, Sakhalin-Hokkaido herring; 2, Okhotsk herring; 3, Gyzhigynsk-kamchatka herring; 4, Korto-karagynsk herring. Bold line, spawning grounds; Hatched areas, feeding grounds.

regions purse seines were used. Catches reached a peak quite quickly and then declined and the fishermen would switch to another pelagic stock. Off South Africa sardines were replaced by anchovies and off Peru, the anchoveta was replaced by sardines. The sardine stock off California collapsed and was replaced by the stock of the northern anchovy (*Engraulis mordax* Girard) which was subsequently exploited further south by Mexican fishermen.

Off northwest Africa sardine catches remained fairly steady in the north off Cap Ghir but further south between Cap Blanc and Cap Bojador catches reached very high levels before a sudden collapse. The fisheries for sardines and anchovies were very large and they supplied a market for fish meal and oil. Anchovies (*Engraulis* spp.) are small fishes and they live not far from the coast. They are caught in small fisheries in European waters. Off India, a rather larger fishery was practiced on *Rastrelliger kanagurta* (Cuvier) and a much bigger fishery has been that for the Peruvian anchoveta (*Engraulis ringens* Jenyns). At its peak it was the largest fishery in the world, yielding about eleven million tonnes each year.

## Tuna

The tunas are large pelagic fish which grow to up to 2 m in length. The principal species are the yellowfin

(*Thunnus albacares* Bonaterre), bigeye (*Thunnus obesus* Lowe), skipjack (*Katsuwonus pelamis* L.), albacore (*Thunnus alalunga* Bonaterre) and bluefin (*Thunnus thynnus* L.). They are, in the main, subtropical animals and are distributed across each of the oceans making transoceanic migrations. The natural mortality of the tunas is probably rather high because they do not appear to live very long. Catches of each species amount to about 100 000 or 200 000 tonnes each year; for all tuna species total catches amount to about one million tonnes each year.

Tuna larvae are found all over the subtropical ocean at nearly all seasons which means that spawning is widespread and continuous, but they are also found in the upwelling areas. In three years the bluefin tuna grows to 50 kg. The yellowfin is most abundant in the divergences and convergences of the equatorial system. There is a spawning migration into the Mediterranean and tuna have been caught in small traps and sighted from vedette (look-out posts) in Dalmatia, on the Roussillon coast of France and off Algeria. Bluefin are caught in the tonnare di corsa (spawning migration) in Spain, Portugal, France, Sardinia and Sicily. The tonnara is a complex structure; that off Trapani in Sicily was manned some years ago by ninety-three men. Porters, stevedores, cooks, boxmakers and coopers supported such operations. The fish were herded into the mattanza or 'death room' with white palm

leaves and as the nets were brought towards the surface the tuna were killed with lances.

Off Brittany, albacore are caught with hooks on long rods. The fish are most abundant at the shelf edge, associated with 'heavy swells' perhaps where internal waves ride from south to north. Off California, tuna are caught either by pole and line with live bait or with purse seine in the equatorial region and there is also a sport fishery off the coasts of the United States. Yellowfin are prominent in the catches perhaps because they tend to live in stocklets just north of the North Equatorial Current. Albacore tagged off California can be recovered off Japan for the fish may live right across the North Pacific gyre. The larger fish live in the North Equatorial Current and spawn east of the Philippines.

## Mackerels

There are a number of mackerels together with their relatives. The Atlantic or common mackerel, *Scomber scombrus* L., lives in the Atlantic off the North American coast and in European waters. The chub mackerel, *Scomber japonicus* Houttuyn, is cosmopolitan. The Indian mackerel is *Rastrelliger kanagurta* (Cuvier). The common horse mackerel, *Trachurus trachurus* L., lives in the Atlantic; the Pacific form is *Trachurus japonicus*. The Atka mackerel of the North Pacific is a scombrid, *Pleurogrammus azonus* Jordan and Metz. The Spanish mackerel, *Scomberomorus commerson* Lacépède, is a larger animal.

Mackerels are larger than herring, reaching as much as 40 cm in length or more. They spawn in the midwater in productive seas where the larvae and juveniles grow up, and they spend the rest of their lives there. They feed on copepods and other plankton animals. They swim quickly and some of the larger ones are predatory. The natural mortality of the mackerels is perhaps high, up to 30% of numbers per year. They do not shoal as herring do but there may be small and transient aggregations.

In the Northeast Atlantic annual catches of mackerel have reached as much as one million tonnes from two stocks, one in the North Sea and the other to the west of the British Isles. They are found in the Mediterranean but catches have only amounted to about 30 000 tonnes each year. Considerable catches of the Atlantic mackerel have been made off

the eastern seaboard of the United States. The stock of Atka mackerel in the Northwest Pacific yielded annually about 100 000 tonnes. The Pacific mackerel yielded large catches for a period, after which they declined. Tens of thousands of tonnes of *Rastrelliger* are taken each year off the Indian coast.

The horse mackerel (*Trachurus trachurus* L.) has usually been caught in trawls. It is somewhat larger than the common mackerel, is pelagic and feeds on small animals in the plankton. It probably does not shoal very much and lives rather deeper than the common mackerel or the herring. In the South Atlantic about 100 000 tonnes of maasbanker (*Trachurus trachurus* L.) are caught. Some tens of thousands of tonnes are caught in the open ocean.

## Conclusion

The pelagic fish occupy a central position in the marine ecosystem as they harvest food from lower trophic levels and support the predators in higher ones. The stocks respond to climatic changes and provide near stability to the tuna and fishes like them. Catches are very large, indeed the largest sector in the world harvest.

## See also

**Fish Migration, Horizontal. Fish Reproduction. Marine Fishery Resources, Global State of. Open Ocean Fisheries for Large Pelagic Species. Small Pelagic Species Fisheries.**

## Further Reading

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