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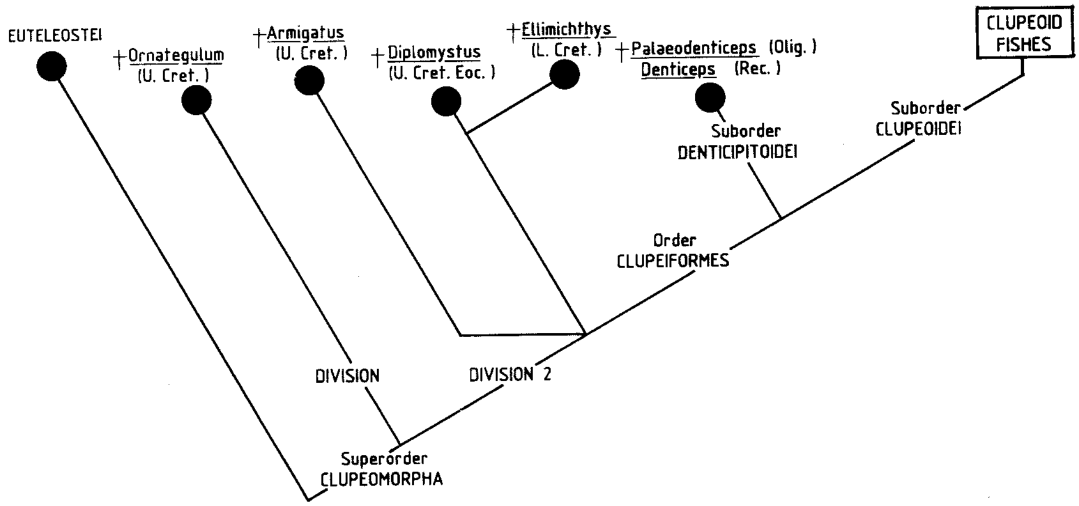

Fig. 2 Relationships of clupeoid-like fishes (fossil forms, from Lower and Upper Cretaceous, Eocene and Oligocene, shown with +)

1.1 Clupeoids in World Fisheries

1.1.1 Clupeoid catches

More clupeoid fishes are caught (by weight, but presumably also by number) than members of any other single systematic group of fishes. The following figures, from the FAO Yearbook of fishery statistics (1982) bear this out.

All marine and freshwater fishes	67 769 371 tons	
Clupeoid fishes	18 897 731 tons	= 17.9%
Cod-like fishes	10 969 042 tons	= 16.2%
Tunas	2 593 212 tons	= 3.8%
Flatfishes	1 126 879 tons	= 1.7%

This huge contribution made by clupeoid fishes to world fisheries can be expressed in other ways. For example, the top 56 fish species (i.e. those harvested at over 100 000 tons in 1982) accounted for 40 004 027 tons or about 60% of the world fish catch. Of these 56 top species, no less than 18 were clupeoids, which contributed 16 693 748 tons or about 24% of the world fish catch. Again, in 1982 there were 24 fish species harvested at over half a million tons. Of these 24 species, 10 were clupeoids, which contributed just over 20% to the total world fish catch. In that year, the second most exploited fish in the world was a clupeoid (Sardinops melanostictus of Japan), as also the third (S. sagax of Peru and Chile) and the seventh, ninth and tenth (Engraulis ringens of Peru and Chile, formerly the most exploited fish in the world; Clupea harengus of the North Atlantic; Sardina pilchardus of the northeast Atlantic and Mediterranean). In fact, the most heavily exploited fish in the whole history of world fishing was the Peruvian anchoveta E. fingens of which over 13 million tons was landed in 1970.

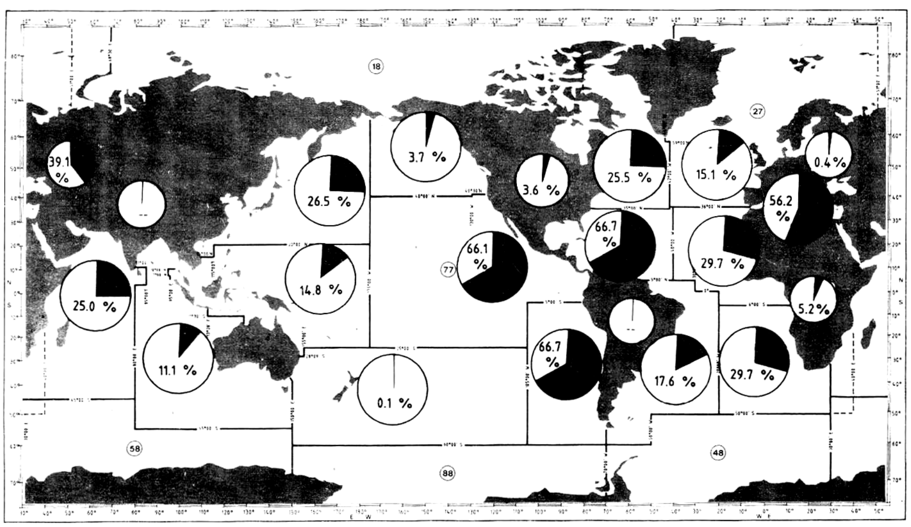

Fig.3 Clupeoids as a percentage of the total fish catch in each fishing area (1982 figures)

In four of the FAO fishing areas (see Fig. 3), clupeoids account for over haif the fish catch and in another six fishing areas they account for over a quarter of the fish catch.

The size of the clupeoid fisheries is the result of two main factors. First, the majority of clupeoids feed close to the base of the food chain and can thus benefit more directly from nutrient-rich areas where there is a seasonal or more continuous bloom of plankton. Second, clupeoids are almost always schooling fishes and thus extremely vulnerable to nets (especially purse seines), which can catch a large volume of fish in a short time. Since it is the cooler high latitude seas and the areas of upwelling that are richest in plankton, it is here that the major clupeoid fisheries exist, as the following figures show (divisions not based on FAO fishing areas; 1982 totals).

All clupeoid species	18 897 731 tons	
Cool or upwelling areas	15 603 531 tons	= 82.6%
Subtropical areas	1 777 278 tons	= 9.4%
Tropical areas	1 516 922 tons	= 8.0%

Not only do the cooler-water clupeoids dominate the total clupeoid catch, but they represent nearly a quarter of the world fish production. The 1982 catch of the Japanese pilchard (Sardinops melanostictus) was alone more than the combined catch of all tropical and subtropical clupeoids, while the catch of the South American pilchard (S. sagax) was almost that amount. In tropical waters, clupeoids are represented by more species, none of which can rival in abundance the cool-water species. The only warm-water clupeoids whose stocks approach those of the cooler waters are members of the Sardinella aurita complex (S. aurita in the eastern and western Central Atlantic, plus S. brasiliensis; S. longiceps in the Indian Ocean; S. lemuru in Indonesia, western Australia and Japan), also the unrelated S. maderensis off West Africa. However, in each area these fishes are associated with at least some upwelling during the year and in at least some part of their natural range.

The predominance of the cool-water clupeoids does not mean that the tropical and subtropical clupeoid fisheries are unimportant. First, they may in some cases be capable of further development by more mechanized exploitation and better processing facilities, whereas the cool-water clupeoid fisheries are usually fully or even over-exploited and are often prone to collapse. Second, the warm-water clupeoid fisheries are frequently a subsistence rather than a cash resource in exactly those areas where other sources of animal protein are inadequate or unused. Certainly, their cash value is low, but so also is their local purchase price, so that their contribution to nutrition in such areas is not to be judged merely by contrasting warm-water with cool-water catches.

The largest clupeoid catches (see Fig. 4) come from the southeast Pacific (Fishing Area 87; 27.4% of all clupeoid catches), based primarily on the Peruvian pilchard and the Peruvian anchoveta, and also from the northwest Pacific (Fishing Area 61; 24.5% of all clupeoid catches), based primarily on the Japanese pilchard. Next in importance are the northeast Atlantic (Fishing Area 27), the eastern Central Pacific (Fishing Area 77), the Mediterranean and Black Sea (Fishing Area 37) and the western Central Atlantic (Fishing Area 31), each of which catches over a million tons of clupeoids annually. The remaining areas, not all of them tropical, each catches three quarters of a million tons or less. In general terms, the entire Pacific yields ahout 60% of all clupeoids, the Atlantic ahout 30% and the Indian Ocean only about 3%.

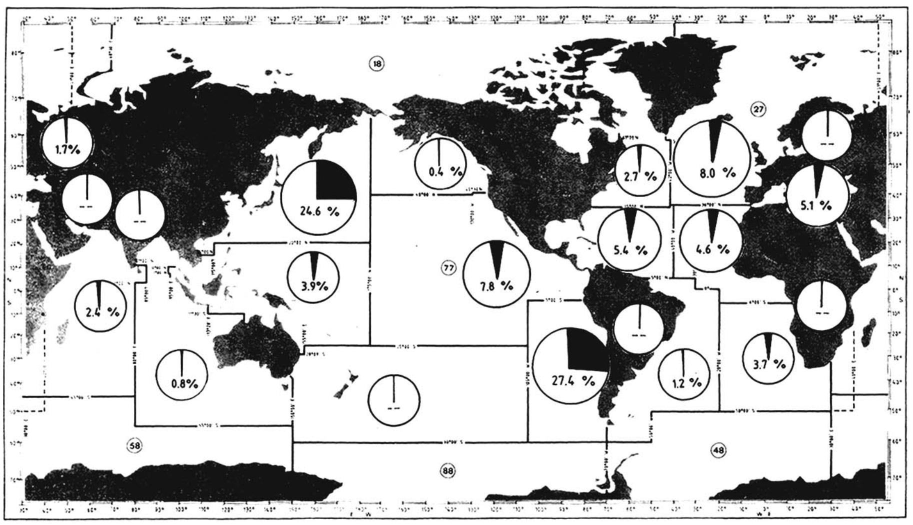

Fig. 4 Clupeoid catches by fishing area as a percentage of the total world catch of clupeoids (1982 figures)

As in other groups of fishes, the cool-water and upwelling areas support few clupeoid species and the main component of the catch may come from a single species, or perhaps two. Often these are a pilchard (Sardinops) and an anchovy (Engraulis), whose relative abundance may oscillate as a result of a complex ecological relationship between the two (further modified by bird or fish predation and human exploitation). The subtropical and especially the tropical areas, on the other hand, support a great diversity of clupeoids and the fisheries are multispecies. A purse seine or a heach seine may bring in ten or more clupeoid species which have schooled more or less together, but little is known yet of the factors that determine the relative abundance of each species and the effect than one species may have on another. In terms of diversity, the richest area is the Indo-West Pacific (Fishing Areas 51, 57, 71), with about 160 clupeoid species or half the total clupeoid species known, yet it produces only 7% of the world clupeoid catch.

Catches of clupeoids have increased,especially since the second world war, sometimes very much in advance of the general rate of increase in fish production (especially during the boom years of the Peruvian anchoveta fishery in the late sixties and early seventies) (Fig. 5). Dominating the clupeoid increase have been the pilchard (Sardinops) and anchovy (Engraulis) fisheries and not the traditional northern fisheries for herrings (Clupea), nor the tropical clupeoid fisheries. Characteristic, however, of those clupeoid species which dominate the fisheries of particular areas is a tendency to oscillate rather drastically in their abundance (Fig. 6). Although the production of good or bad year-classes (which may vary by a factor of ten or more) can be related to ecological factors, the precise role played by fisheries is still not clear. The considerable fluctuations in catches of Atlanto-Scandian herrings (Clupea harengus), both before the second world war (27 to 108 thousand tons) and after (33 to 78 thousand tons) may merely have reflected fishing effort itself, not interrnittent over-exploitation. Nevertheless, with the collapse of this fishery in 1970 following heavy exploitation of the outstanding 1959 and 1960 year-classes, a period of strict regulation has seen an apparent recovery. Whether low stocks can produce good recruitment even when ecological factors are favourable is not yet certain. The dramatic collapse of the Peruvian anchoveta fishery after the mid-seventies poses the same problem, as also that of the Californian pilchard collapse in the early fifties.

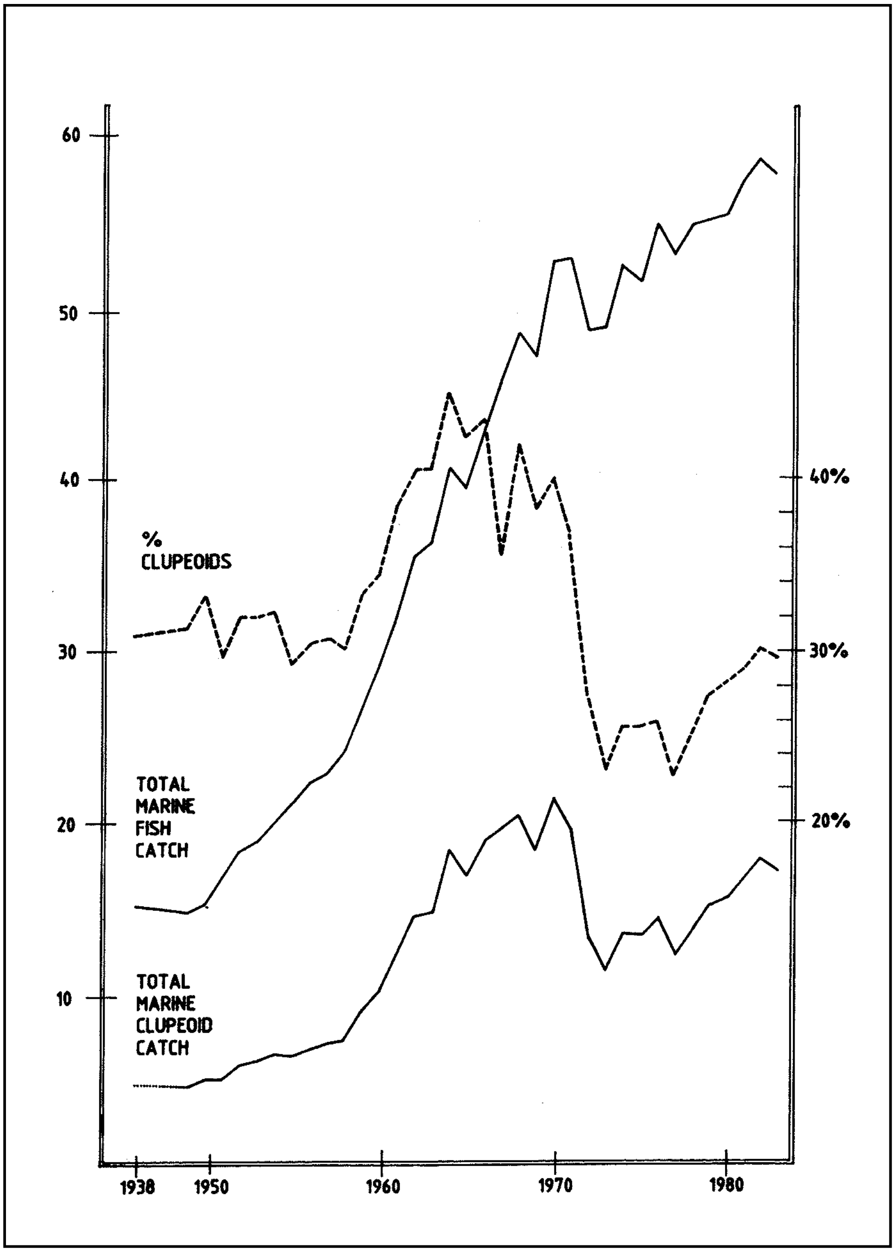

Fig.5 World catches of marine fishes and of clupeoid fishes, 1938 and 1949-1983 (in millions of tons, on left). Also, the clupeoid catch as a percentage of world catch (% on right).

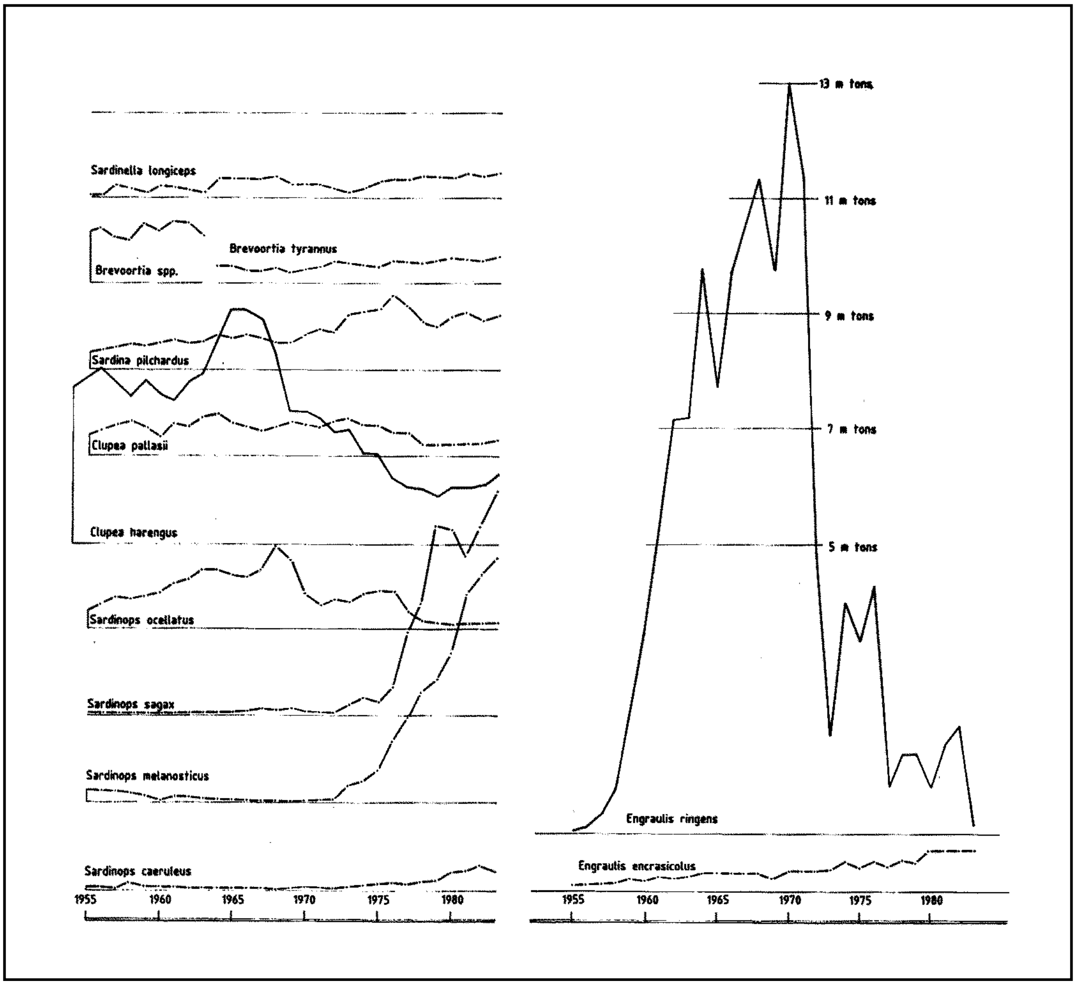

Fig. 6 Trends in catches of major clupeoid species, 1955-1983
(divisions on left are 500 000 tons)

Since members of the same clupeoid genus often have a fairly similar biology, and since sympatric members of a genus may not always have been separated in the catch statistics, it is of interest to know which genera play a major role in fisheries. In fact, 10 clupeoid genera, comprising about 36 species, contribute over 90% of the total world clupeoid catch (Fig. 7). The following figures show the catches for 1982:

Species	Catch in tons	% of total clupeoid catch
Sardinops (4 species)	7 820 021	41.4
Engraulis (6 species)	3 570 522	18.9
Brevoortia (3 species)	1 257 906	6.6
Clupea (2 species)	1 207 478	6.4
Sardinella (6 species) 1/	1 056 324	5.6
Sardina (1 species)	896 975	4.7
Opisthonema (2 species)	576 555	3.1
Sprattus (1 species)	525 135	2.8
Clupeonella (1 species)	434 655	2.3
Stolephorus (about 10 species)	231 344	1.2
		93.0

1/ Only S. aurita, S. brasiliensis, S. lemuru, S. longiceps, S. maderensis, S. neglecta

The order of these genera varies a little from year to year, depending on the state of the stocks. Other genera which have been of importance in previous years (i.e. a catch of over 100 000 tons) are the round herring Etrumeus (1 species), the wolf herrings (Chirocentrus, 2 species) and the African freshwater Stolothrissa and Limnothrissa (1 species each). Clearly these are the genera that merit further fishery, biological and taxonomic study.

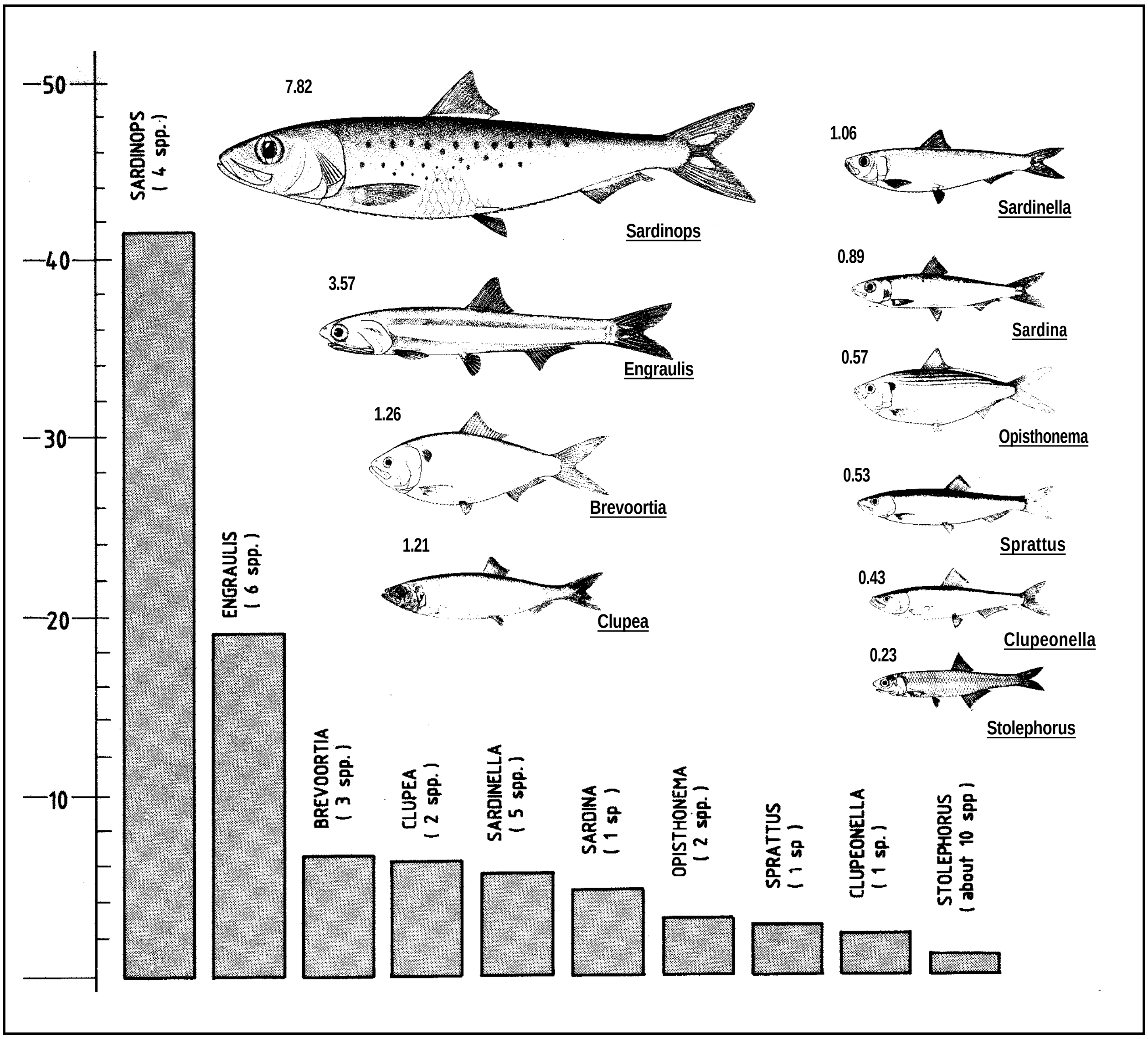

Fig. 7 Relative importance of the ten major clupeoid genera (as % of total clupeoid catch; fishes tagged with their catch in millions of tons; 1982 figures)

1.1.2 Fishing gear

Since clupeoids are mainly schooling fishes and thus most easily caught by nets, quite a wide variety of nets and netting techniques has been developed to suit particular environmental and economic restraints. Although the major clupeoid catches come from fully mechanized large-scale netting operations, it is worth recording also the small-scale artisanal gear which in human and nutritional terms is nevertheless important in many tropical and subtropical areas. Even when clupeoids are merely a bycatch in such artisanal gear, carful sorting can result in large baskets containing one or two species of small Stolephorus which are as much appreciated as the large 'table' fishes.

Surrounding nets : Used to encircle schools at or near the surface. There are two kinds, both usually set with a single boat (or with an auxillary craft).

Purse seine - a running line at the bottom of the wall of netting that has been set around the school closes the net like a purse. Used with or without a light to attract the fishes. Employed for the Sardinella fisheries off West Africa and the Sardinops and Engraulis fisheries off Peru, Chile and elsewhere.

Lampara net - no purse lines, but with a spoon-shaped small-meshed central bunt and slender wide-meshed lateral wings. Used with or without a light. Employed generally for the same clupeoids as the purse seine.

Seine nets : Used between surface and bottom, or at the bottom, to encircle schools, with or without a bag at the centre and usually hauled by a rope at each end.There are two methods of operation.

Beach seine - set from the land, either by wading or from a small boat, then hauled to the beach. Very commonly used in most tropical or subtropical areas for small inshore clupeoids (Sardinella, Herklotsichthys, Thryssa, Stolephorus, etc.).

Boat seine - operated from a boat, with long ropes to herd the fishes, usually hauled along the bottom; the most representative is the Danish seine (used for flatfishes, but less frequently for clupeoid fishes).

Trawlnets : Both bottom trawls and midwater trawls will catch clupeoid fishes, but apart from a few species subject to aimed fisheries they generally form a bycatch and are not economically exploited in this way.

Liftnets : Horizontal nets that are raised when fish are suspected to be over the net or have been attracted there by light. There four two main kinds.

Portable - small hand nets used from river banks, jetties, etc.

Boat-operated - bag nets and blanket nets worked from one or more boats. Extremely effective for small clupeoid fishes, especially if used with a light.

Shore-operated - portable or fixed; a horizontal net is lifted by an often ingenious counter-weight or is winched by hand or machine. Effective for small clupeoids, especially if used with a light. Employed in Southeast Asia.

Rig-operated - a large bamboo rig or tower in water of 5 to 15 m encloses a square net which can be winched up; from the platform on top a light is lowered to attract the fish. Common along the Java Sea coast of Indonesia, where they are called bagan. Effective for small clupeoids (especially Sardinella, Thryssa and Stolephorus).

Falling gear : Cast nets produce rather few clupeoids.

Gillnets : Vertically-hung nets, at the surface, midwater or bottom, with a mesh size that usually ‘gills’ a restricted size range of fishes; often set in long lines or ‘fleets’ of nets. Drifting gillnets (driftnets) were the traditional gear for the northern herring fisheries (Clupea). Short gillnets are also used in rivers, being drifted downstream to catch runs of anadromous fishes. They are used in this way for shads (Tenualosa species) in India.

Traps : Either with a non-return funnel or relying on the inability of the fish to turn and escape (aided by the pressure of the water current). Three main types catch clupeoids.

Fyke nets - conical non-return bag with wing(s) held apart by stakes; used in shallow water. Shads are sometimes caught in fyke nets.

Stow nets - conical or wedge-shaped nets frequently used in estuaries or lower parts of rivers where the current is strong, the net being held by stakes or anchors. Catches anadromous, euryhaline or riverine clupeoids. In some cases a basket is used rather than a net.

Barriers - estuarine barriers of stakes, reeds, etc., with wings to direct the fishes; they often catch inshore and mainly euryhaline clupeoids, particularly in tropical areas. River barriers or weirs with non-return or funnel-shaped baskets are used for anadromous clupeoids such as shads (e.g. Tenualosa ascending Indian rivers).

Hook-and-line : Although not important economically, it is of interest that some clupeoids will take a hook, as for example large pilchards in the northeast Pacific (Sardinops caerulea) or shads in Europe (Alosa species).

Pumps : Usually operated in conjunction with a light to attract schools. Employed on the Caspian Sea for chilka (Clupeonella species).

Explosives : Although illegal, explosives have been used instead of the liftnets from the Java Sea bagan towers.

Poisons : Some freshwater clupeoids occur in the more general catches made by poisons in tropical rivers.

1.1.3 Utilization of clupeoids

Clupeoid fishes contribute to world food resources in two ways: directly, through actual consumption (fresh, frozen or processed) and indirectly, by providing products used for animal feeds and fertilizers or by serving as bait to catch other fishes further up the food chain. Very small clupeoids may be consumed whole (e.g. whitebait Sprattus sprattus in Europe, small Stolephorus in southeast Asia); slightly larger clupeoids (e.g. pilchards, sardines, Sardina, Sardinops) may be processed so that all but the head is palatable; most medium and large species, however, are valued almost entirely for their epaxial and hypaxial body muscles, the head, guts, fins and axial skeleton being removed and the intermuscular bones largely ignored. Parts that are consumed or marketed separately are the gonads (e.g. the eggs of the Pacific herring Clupea pallasii from the Pacific coast of Canada) and oils or body fluids extracted from the liver and other tissues (e.g. from the menhaden Brevoortia tyrannus).

From earliest times the need to store clupeoid catches for later consumption necessitated some form of preservation. Nowadays a large part of the world clupeoid catch is processed in one way or another, most particularly in the case of the enormous single species fisheries of temperate waters (for Sardinops, Engraulis, Clupea, etc.). The tropical clupeoids, on the other hand, are more frequently eaten fresh (or after short storage in ice), not only because industrialization is generally less advanced in such areas, but also because catches are relatively smaller and the species composition is much more diverse; nevertheless a substantial proportion of the catch may be cured (often sun-dried or smoked), especially the smaller species. As clupeoid fisheries have developed (e.g. the Sardinella fisheries of West Africa), the investment in mechanized exploitation has had to be matched by that for storage and processing. The concommitant rise in price of the product has usually meant marketing in the developed countries.

Clupeoid fishes are utilized in ten main ways. For the main categories an approximate percentage is given below, although this can vary from year to year, depending on availability and market factors (especially prices). The collapse of the Peruvian anchoveta fishery led to a drop in fishmeal and fish oil production (Peru became a major fish oil importer in 1983), but price rises (e.g. by 51% for fish oil in 1983) probably stimulated meal and oil production from other species. New processing techniques, as also alternative sources (e.g. jojoba for vegetable oil), also vary patterns of utilization.

(Direct)

Fresh (17%): all species, although fresh consumption is minimal in some (e.g. menhaden).

Frozen (12%): most species, depending on the need to store or transport.

Cured (12%): numerous species, especially Clupea in northern waters and small clupeoids in the tropics; salted (dry or brine solution), smoked, sun- and/or wind-dried; also allowed to ferment to produce a condiment (Roman garum, Greek halec; southeast Asia nowadays) or a fish silage as an animal feed additive.

Canned (14%): industry dominated by scombrids and clupeoids, the latter including species of Clupea, Sprattus, Sardinella (chiefly the S. aurita complex), Sardina, Sardinops, Brevoortia and Engraulis (E. encrasicolus, also the Argentine E. anchoita); sardines and pilchards form almost half the canned small pelagics; packed mainly in vegetable oils, but also in tomato sauce, brine or water.

Minced: chiefly applied to gadoid fishes, but trials have been made with Clupea, Sprattus, Sardinella, Sardinops, Brevoortia, Engraulis and Thryssa; the flesh is separated in a cominuted form from skin, bones, scales and fins; various clupeoids used for fish paste (especially anchovies).

Fish flour: refinement of techniques used to produce animal feeds from whole degutted fishes, resulting in a useful protein additive for human consumption.

Oil: over 80% of the USA fish oil production has in some years come from the menhaden Brevoortia tyrannus (yielding 8 to 20 gallons of oil per 1000 fishes, depending on how far north the fishes are caught); body oils (used in paints, soap, shortenings and margarine) are also extracted from Sardinops and Engraulis; vitamin rich condensed fish solubles, serving as an animal feed additive, result from wet reduction of fishes such as menhaden.

(Indirect)

Animal feeds (44%): chiefly Clupea, Sardinops, Brevoortia and Engraulis; the principal product from reduction plants, using either whole fish (with or without extraction of oil) or offal; used for supplementing feeds for cultured fishes (trout), poultry, cattle, sheep and pigs.

Fertilizers: herring in Scandinavia and menhaden on the eastern coast of North America have been used since earliest times, but the practice is relatively unimportant nowadays.

Bait: Sardinops and Engraulis used for ‘chumming’ tuna; species of Stolephorus used as live-bait, especially in southeast Asia.

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