Part II: THE BIOLOGY OF PELAGIC FISHES

by

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THE HERRINGS AND ANCHOVIES.

Both in numbers and in economic value the fishes belonging to the family Clupeidae rank first among the food fishes of the world. They are represented in all temperate and tropical seas and often form large shoals swimming on the surface and performing long migratory journeys. Although most of them are marine, there are a few species which occur in freshwater and, a still larger number that ascend rivers at some phase of their life history. The pelagic species, which are more in the habit of forming shoals than the coastal and estuarine species, are mostly of a small size and, at any rate, never exceed a foot in length. In fact, most species are much smaller and, especially so are the tropical forms averaging from 4 to 8 inches; their economic value would have been negligible but for the enormous numbers in which they appear, providing a source not only of edible fish, but also of fish oil, fish meal and fish manure. This group comprising about sixty species includes the herrings of the North Atlantic, the true sardines of S. Europe, S. America, the Pacific and S. Africa, the menhaden of Atlantic coasts of America, the sprat, the pilchard and the closely related forms shoaling along the coasts of S. Europe, West Africa, India, the Far East, Australia and New Zealand.

Taxonomic Difficulties. The taxonomy of clupeids presents considerable divergence of views. The earlier workers distinguished only one genus *Clupea* for the herring, the sprat, the pilchard, the shad and the many other sardines but in recent years this

has been subdivided into numerous genera. The herring of the Atlantic, *Clupea harengus,* is the best known of all clupeids; in fact, many of the recent ideas relating to fishery science has grown around this species. It is common to both sides of the North Atlantic in the cooler latitudes and extends even to the seas north of Asia. In the North Atlantic, the species has given rise to many types of fisheries in different parts of the year. Thanks to the studies of Hjort, Heincke, Lea, Schnakenbeck, Fulton, Ford and many other fishery naturalists, we have a fair amount of all round information on its habits and movements. Herring is the only known instance of a clupeid whose eggs are demersal and not pelagic; the spawning grounds in the North Atlantic are now well known. The fish spawns both in spring and the autumn.

The growth is slow; the spring herring at the end of the year is hardly 2 inches long while the autumn herring for the same period would show only a much less growth and is rarely over 1½". These differences in growth and the habits attendant have given rise to herrings being recognised broadly as spring spawners and autumn spawners; some authors consider that these are different races. Both males and females attain sexual maturity in about 4-5 years. It is in connection with the herring that the question of races in commercial fishes assumed importance. The pioneer work of Heincke on different samples of herring distributed all over the Atlantic led him to state that he was able to distinguish two main groups of herring, viz., Spring or coastal herring and Autumn or sea herring. He was further able to distinguish many local groups and varieties, whose validity, however, is disputed by other workers, but each particular fishery is often associated with a definite "race" of herring. The great Scottish Fishery is concerned with the sea or Autumn herring as also the great English drift net fishery on the East coast. The Norwegian and Baltic herrings which contribute to great fisheries in Scandinavian countries comprise Spring or coastal herrings. Both drift net and trawl fisheries in a particular area may be based on the same race and stock. According to Ford (1933) the Plymouth winter drift net fishery for herring is subject to seasonal as well as daily fluctuation; this has been indicated as being caused by the variations in the number and character of the boats engaged in the fishery and to the intensity of fishing. These, however, do not fully account for the fluctuations in catches which probably depend upon the behaviour of the fish in the fishing ground itself as they seem to move out off shore during stormy weather. Graham (1931) has described the phenomenon of "swim" in herrings—his explanation being that "herring in a normal state can see the nets and avoid them, so that the sea may be full of herring, yet none caught. When however, they are under the influence of crowd excitement (due to panic, sexual excitement or migratory impulse) herrings are more or less unable to see the net, and are caught".

Race Studies.

Herrings that are landed can usually be classified into three categories:—(1) Full fish in which the roes and milt are fully developed, (2) spawners in which the gonads are actually in the running condition and (3) spent fish.

C. harengus extends to Arctic waters both on the Atlantic and Pacific sides, but the main species of Pacific herring is *C. pallasii* which is also interesting in the fact that it is discontinuously distributed, being found in the White Sea north of Europe and in the sea east of Kamchatka.

The Sprat. Closely related to the herring is the sprat (*Clupea sprattus*) found all round the British Isles, extending in the North Sea as far north as Norway where the fish are extensively canned as "sardine". It is much smaller than the herring and were formerly considered as their young ones. The spawning begins in January and lasts till June or July. The egg is pelagic.

The Pilchard. The South European Pilchard (*Sardina pilchardus*) on the other hand is a warm water species and is rarely found in Northern waters. It is also a small species, occurring in large numbers along the coasts of Southern parts of Ireland and England, France, Spain and Italy, and the coasts of North West Africa. This is the well known European sardine which has been highly developed as an industry in the countries of S. West Europe. The spawning ground is 20-40 miles out at sea but the fishery is concerned not with mature spawning individuals but with juvenile stages. The species is found in the warmer Southern waters of Europe during winter.

The Menhaden & Shad. On the American side of the Atlantic to the south of Cape Hatteras, the clupeids are represented by the Menhaden (*Brevoortia tyrannus*) and the American shad (*Alosa sapidissima*) both of which contribute fisheries of great magnitude. The shad is one of the most important of American food fishes. Originally confined to the Atlantic Coast and the rivers entering the ocean, the shad has

been successfully introduced into the Pacific waters; but this is not a shoaling fish.

Although the American Menhadens include several species, *Brevoortia tyrannus* is the most important one which is found on the Atlantic coast extending from Nova Scotia to Florida and southward up to Brazil. In the South Atlantic regions extensive menhaden fisheries are located in North Carolina and Florida. In volume of production it ranks second among all United State fisheries and is caught in the South Atlantic and Gulf Coasts in greater quantities than all other fishes.

On the Pacific coast of American *Sardina caerulea* or the Pacific sardine ranks first in importance and is the mainstay of the California fisheries. Much work has been done on this species—especially statistical study of the catches and catch per unit effort. There is both an autumn and a winter fishery.

Other Sardines. The true sardines belonging to the genus *Sardina* are confined to the cooler waters of the Northern or Southern hemispheres. To the west of South America in waters washed by the cold Humboldt Current, and in the South African coast washed by the Benguela Current, we come across large shoals of *Sardina sagax,* which is considered by certain authors to extend its range to the Japanese coasts. On the Australian and New Zealand coasts, on the Antarctic side, there are extensive fisheries for *Sardinops (Sardina) neopilchardus, Clupea bassensis* and *Harengula castelnaui.*

In the tropical belt the Clupeids are represented by a large number of species and genera but true sardines of the genus *Sardina* and herrings of the genus *Clupea (sensu stricto)* are conspicuous by their absence. Their place is taken up by species of *Dussumieria* (Rainbow sardine), *Dorosoma, Spratelloides, Amblygaster, Alosa, Sardinella, Harengula, Pellona* and *Ophisthopterus* and a large number of species of Anchovies of the genera *Engraulis* & *Stolephorus.* We shall refer to these subsequently. Among the former category of Clupeid species, the relative importance of the species or groups of species in different areas yet remain to be worked out. From the information we have at our disposal species of *Sardinella* appear to be the most important as shoaling fishes. S. *cameronensis* and S. *aurita* are caught in large numbers on the Gold Coast in July to September, a fishery which according to Howat (1945) seems to coincide with the influx of cold waters from the south, more saline in character and with a higher phosphate content. On the Indian coast, the Oil Sardine, *Sardinella longiceps,* used to appear in enormous shoals on the Malabar coast and gave rise to a most flourishing industry, but these shoals have not been encountered during the past twenty-five years with the exception of small shoals which have appeared within certain years but which were in no way comparable with the shoals which appeared at the time of the old fisheries. Judged from this and the fact that rare instances of shoals of this species have been known to visit the Bay of Bengal, its movements seem to be most uncertain and the solution of this problem is one of considerable value to the Indian fishing industry.

Oil Sardine of Malabar. Investigations on the Oil Sardine have been carried out in India since 1908 when Hornell made his preliminary survey, and a summary of the more important results obtained by Hornell and Nayudu was published in 1924. These studies were made at a time when much of our modern methods in fishery research had not taken definite shape. Nevertheless, their conclusions may be briefly reviewed. They were not able to establish local races among the Oil Sardines of the Malabar and Kanara Coasts. On the other hand they contend that this is a species which is not liable to great variation in its characters.

The species attains sexual maturity and almost full adult size at the age of one year, when individuals are about 15 cms. long, and leave the inshore waters prior to spawning which takes place from June to August. The young again migrate into shallow waters. Their season of abundance as a fishery is from September to December. Growth during the second year is extremely slow, and it is reckoned that the oldest sardines examined were about 2½ years old which probably represent the maximum length of life of the species. Like all pelagic clupeids they are exclusively plankton feeders. Based on examination of scales, Hornell and Nayudu were able to establish a period of arrested growth from December to April coinciding with a season of poor plankton. Devanesan (1943) made further studies on the growth rings in scales but a careful distinction between the annual and so-called false rings does not appear to have been made by this author in his counting of the rings. These distinctions have been clearly set forth by Walford & Mosher (1943) from their study of the Californian Sardine (S. *caerulea*). The use of otoliths in determining the age of the oil sardine has been recently suggested by Nair (1949) who is of the view that the oil sardine attains maturity at about the end of two years and when 15 cm. long. As regards the relative use of scales and otoliths for determining the age it must be admitted that we do not as yet have a reliable method of differentiating between the true and false growth rings on the otoliths.

Sardinella fimbriata often appears in large numbers alone and with *S. longiceps* and, in fact, it has been the dominant sardine of the Malabar Coast ever since the Oil Sardine has diminished in numbers. It is smaller in size than the former, less valuable as a source of oil, and less esteemed as food. On the South-east coast India shoals of *Sardinella gibbosa* have been encountered. Most of these species of *Sardinella* have a wide distribution on the Indo-Pacific areas; both *S. longiceps* and *S. fimbriata* are mentioned by Delsman for the coasts of Java and, are probably of economic importance on the Malayan Coast. The white Sardine *Kowala thoracata* is another shoaling species noteworthy on the west coast of India.

THE ANCHOVIES

The Anchovies belonging to the genera *Thyrsa* and *Stolephorus* are essentially warm water fishes. The European species *Stolephorus encrasicholus* is common in the Mediterranean, the Channel and in Southern North Sea, where it is a migratory fish and apparently the length of life does not exceed three years.

In the Indo-Pacific area there are numerous species of *Thyrsa* and *Stolephorus*. Like other clupeids they are small in size and appear in shoals. From Indian waters alone about forty five species are known of which *Th. mystax, Th. purava, Th. telera, S. commersonii* and *S. tri* are the most important. The last mentioned is known to occur in shoals on the southern tip of India contributing to a summer fishery in the Cape Comorin area and up to the Gulf of Manaar and in many other regions on both the East and West coasts of India.

Delsman and Hardenberg have contributed much to our knowledge of these species in the waters of Java. They have shown that these species are essentially coastal in character and can survive considerable reduction in salinities.

THE MACKEREL

The mackerel is one of world's most important among commercial fishes. Only a few species of the true mackerel exist (unlike the numerous species and races among clupeids), and they are found in all temperate and warm waters of the world except in the Atlantic seaboard of temperate South America. In general the mackerels are gregarious, and essentially warm water species, occurring in large numbers not far away from the coasts and feeding entirely on plankton organisms. Even though widely distributed, they contribute to large scale fisheries only in certain parts of the world, partly because the shoals frequent certain regions which are definite spawning grounds and partly because the fishery has been commercially successful only in certain coasts. The uncertainties in its movements are probably associated with its spawning cycle which has not yet been fully understood.

European & American Mackerel—Scomber scrombrus, the European mackerel, ranges from the south of Norway to the Canary Islands and also in the Mediterranean up to the Adriatic. It is considered that the species found on the Atlantic coast of N. America is the same species extending in range from the coasts of Labrador to Cape Hatteras. Geographical races may exist in the mackerel as in the herring, but they do not seem to have been established. *Scomber colias*, the Spanish mackerel is of economical value in S. Europe, S. Africa and Japan and on the Pacific Coast of America, Gulf of Mexico and Gulf of Maine. The Pacific Mackerel, *Pneumatophorus diego* occurs in large schools from the Gulf of Alaska to the Californian Coast and extending into the Californian Gulf; it is a large species of about 20" length and is caught throughout the year with a main fishing season from September to December.

Species of commercial importance in India and the Far East are now considered to belong to a different genus, *Rastrelliger*, the Indian mackerel being *Rastrelliger kanagurta* (Ruppell) called the striped mackerel by certain authors and enjoying a wide distribution from the coast of Natal in S. Africa to the China Seas. This species is smaller in size than the European mackerel, being of an average length of 7"-10" as against the size of 12"-16" for the cold water species. It is however, the most important single species of fish among warm water marine forms, and accounts for about a fifth of the total production of marine fish in India and Pakistan. It is needless to add that owing to its large numbers and the existence of well developed fisheries in many places in the Indo-Pacific area, we have in this species an object for close study where international collaboration would be most fruitful.

Indian Mackerel Fishery—The mackerel fishery is concentrated along the South West Coast of India from Bombay in the north to Travancore in the south and more especially on the Konkan and Malabar coasts. Karwar, Ratnagiri, Malpe, Tellicherry, Calicut and Cochin are mackerel fishing centres of great activity. To the south of Cochin the fishery dwindles in importance and almost completely disappears near Quilon. It is significant that mackerel are of no importance in fishing centres near Cape Comorin the southern most part of India which otherwise is one of the richest fishing grounds. On

the Eastern seaboard of India, it would appear that mackerel are known to occur in small numbers but there is no fishery devoted to mackerel. The same appears to be the condition in the Persian Gulf where according to Blegvad (1944), this species does not seem to have much commercial importance. The published works of Delsman and others on the fisheries of Netherland East Indies seem to show that even though the mackerel are fished in considerable numbers in the Java Seas, they do not seem to occupy the high place in the commercial fisheries there which they do in the South West Coast of India.

Migration of European Mackerel—It has already been mentioned that much of the irregularities in the movements of the mackerel are probably associated with migrations and spawning about which we at present know so little. The European species has been the subject of numerous investigations and it is now known that in Europe the mackerel fishery exists in both a pelagic and a demersal phase. Much new light on this problem has been thrown by the Plymouth mackerel investigations led by Steven (1949). In the English Channel and the Celtic Sea the very young mackerel remain on the sea floor during the winter months (November to December) in intensely dense patches, distributed over wide areas; these slowly disperse during the succeeding months and begin to spread to new grounds, yet remain near the bottom till about February. Pelagic shoals of juvenile fish begin appearing from January onwards, but it soon becomes an active migration of fish (Jan.-July) to the spawning ground which lies far outward to the west of the Scilly Isles on the edge of the continental shelf or the 100 fathom contour. Having discharged the spawn the shoals break up and disperse around all coasts (June to October) finally to disappear from surface waters and return to the compact demersal phase so characteristic of winter months.

The life history of the mackerel as narrated above postulates a new attitude to the problem of migrations of this fish which has hitherto been considered as purely one of off-shore fish coming inshore to breed, because migration to the spawning centres might involve movements in both directions, depending upon whether the winter packs of fish are situated outside to the sea or inside to the shore of the spawning ground. Steven (1949) and Corbin (1947) have been able to show this convergence to spawning ground from their examination of mackerel from different areas and of the abundance of eggs in the plankton. It is presumed that much of the confusion in interpreting the movements of mackerel has been caused by the thought that migrations can only be either off-shore or shorewards. Further, diurnal vertical migrations are noticed when fish begin to disperse from the compact winter groups to form pelagic shoals, the fish coming to the surface at night and descending to the depths by night. The spawning activity itself is spread considerably both in point of time and space, schools of spawning mackerel seem to arrive in a series of batches from different areas. In conjunction with this should be noted the fact that the ovarian eggs mature and are shed in successive batches over an extended period, there being no stage when the ovary might be called fully ripe or fully spent as observed in many other species of fishes.

Biology of Indian Mackerel—In regard to the Indian species, nothing is known about their movements beyond the fact that large pelagic shoals appear during the October—January period, sometimes extending even as late as March, and it is this phase which contributes to the fishery which is both inshore and pelagic. A full picture of its distribution will depend on the location of spawning grounds and the discovery whether there is any deep-sea mackerel existing in off-shore regions of the coast. From the observations of Deyanesan (1942) it seems probable that spawning ground exists off the Malabar coast and that the occasional mackerel eggs seen at Quilandy and neighbouring places are only from the fringes of the main spawning area.

Other species of the mackerel in the Indo-Pacific are *Scomber neglectus, S. brachysoma,* and *S. janesaba,* probably all of these fall within the genus *Rastrelliger.*

Seer Fishes—The Spanish mackerel of the American coast, *Scomberomorus maculatus* is closely related to the seer fishes found in almost all tropical seas. All these species are now placed in the genus *Scomberomorus,* instead of *Cybium,* to which *genus* they are frequently referred. They often swim in schools but do not form shoals like pelagic fishes. Day recognises five species in eastern waters of which *Cybium guttatum, C. kuhlii* and *C. commersonii* constitute the Indian seer fishes which are highly esteemed as food.

C. guttatum is the commonest species, and according to Delsman it is said to frequent the river mouths in the Java seas, eggs having been found near the lower reaches of the rivers. *Scomberomorus maculatus* enjoys a wide distribution on the American coast ranging from Cape Cod to Brazil on the Atlantic and from San Diego in California to the Galapagos on the Pacific coasts. All species of *Scomberomorus* are believed to be migratory.

Ribbon fishes & Bombay Duck—Along with the scombroids must be mentioned the species of *Trichiurus* popularly called Hair tails or Ribbon-fishes which appear in large shoals on the Coromandel coast of India from September to January. Being ribbon-like, they are particularly suitable for drying. *Trichiurus haumela* and *T. savala* are two common species found throughout the coasts of India and Java; both are voracious feeders and their food often includes a wide variety of organisms probably indicating that they are not necessarily pelagic in habit. The factors governing their movements are not understood but they are probably oceanic. *T. lepturus* is known to enter colder waters from the tropical Atlantic. The Bombay duck *Harpodon nehereus* although belonging to a very different family of fishes may be conveniently mentioned here as it appears in shoals from the Gulf of Cambay to Bombay on the West Coast of India; this also is not a pelagic species, but shoals show a preference for shallow areas with a muddy bottom.

TUNNIES.

The Tunnies, Albacores and Bonitos are large Scombriform fish, of actively predaceous habits, distributed over almost all the oceans. They are active swimmers and often pursue shoals of pelagic fish on which they feed, particularly the Clupeids and mackerel, for long distances. *Thunnus thynnus* L. is the tunny of European waters (or Blue fin Tuna of the Pacific) migrating to the North Atlantic and colder waters in summer. As a fishery, this species has the highest importance in the Mediterranean. Schools of this species have been encountered in different parts of the world and in almost all oceans.

On the American coast the tunnies are usually known by the term "tuna". Several species are present on the Pacific coasts, especially in California where considerable numbers of the Blue fin Tuna (*Thunnus thynnus*) which is believed to be the same as the European tunny, the yellow fin tuna (*Neothunnus macropterus*), the bonito (*Sarda lineolata*) and the skipjack (*Katsuwonus pelamis*) are landed. The skipjacks are not really tunnies, but belong to the same group as the seer fishes.

Tunny fisheries of considerable magnitude exist in the Philippine waters south of Mindanao. These are described in detail by Domanty (1940). The most abundant is *Katsuwonus pelamis (Lin.)* which also occurs in large numbers in Japanese Seas. Next in order of importance are *Neothunnus macropterus Euthynnus yaito, Auxis thazard, Parathunnus sibi, Neothunnus itosibi* and an undetermined species of *Neothunnus*. *Katsuwonus* and *Neothunnus* are said to be the most satisfactory for canning. The peak period for fishing is May, it is interesting to note here the practice of employing live bait composed of clupeid species for the capture of tunas.

Physiologically, the tunny is of the greatest interest because it is unique among cold blooded vertebrates in maintaining a body temperature higher than the surroundings. Information on the biology of the tunny has been summarised by Russel (1934). The eggs are pelagic, and growth is extraordinarily rapid; young tunnies growing to 300—500 gms from June to September. They probably mature at the end of the third year when they have attained nearly a metre in length and weigh about 15 kg.

They are omnivorous feeders mainly on pelagic fish but their stomachs have been found to contain also gadoids and other fish, squid and crustacea. They spawn in summer in the southern European waters. Migrations of the tunny are very difficult to explain. Various theories have been put forward, but it is believed that their movements are governed largely by temperature and salinity. There is also evidence that the catches are poorest in those years when the rainfall has been heavy.

On the Indian coasts our knowledge of the relative abundance of the tunny is extremely scanty, but they are known to appear in shoals near the Laccadive and Maldive Archipelagoes and in the Andaman Seas. Young tunnies are landed in large numbers all over the West Coast of India—more especially between Trivandrum and Cape Comorin during the North East Monsoon period i.e. October to November.

HORSE MACKEREL & SILVER BELLIES.

In the Indo-Pacific areas the Carangid fishes form important pelagic fisheries. The genus *Caranx* includes several species (for India 26 species are listed by Day) and most of them are small in size but the more important species from the commercial point of view, like the horse mackerel, *Caranx crumenophthalmus* attain a length of a foot. On the west coast of India, this fish appears in large shoals during the months, September to October. Numerous species are also known from the Java and Malayan waters. The Jack mackerel of the Californian coasts, *Trachurus symmetricus* is a schooling fish of importance in the tropical Pacific, often obtained along with the Pacific mackerel.

Members of the family *Leiognathidae* often appear in small pelagic shoals in tropical waters. Species of *Leiognathus* and *Gazza*, often not exceeding a size of 4 inches in length, are caught all along

the Indian coasts. They are valuable because they are fished mostly in summer months when the more important pelagic species are not available in coastal waters. *L. splendens*, *L. ruconius* and *L. insidiator* appear in shoals of considerable magnitude on the Malabar coast, at Madras and near Rameswaram Is..

The pomfrets, which are species of *Stromateus* may also be mentioned here. Although they cannot be called pelagic fishes, they are not demersal like sharks and rays and are often caught in seine nets along with many other pelagic species. *Stromateus niger* (the black pomfret), S. *cinereus* (Silver pomfret) and S. *sinensis* (White pomfret) are fishes which grow to about a foot in length and are the most popular among Indian fishes. They do not seem to form shoals but probably move about in schools. At present we know nothing of their habits and bionomics. Other fish in the same category are species of *Lactarius sciaena* and *Polynemus*.

FLYING FISHES.

The Flying fishes (Family *Exocoetidae*) are oceanic fishes found in the warmer waters of the world; they are wholly pelagic and gregarious. As is well known, the chief peculiarity lies in the enormous development of the pectoral fins which help the fish to glide in air. Numerous species have been recorded (7 from Indian waters) but information is lacking whether the species show any definite geographical distribution. Similarly, we have not been able to find the areas where they are exploited as a fishery, with the exception of the Coromandel coast of India between Cuddalore and Point Calimere, where during summer months (May—July) *Cypsilurus poecilopterus* and *Cypsilurus* sp. appear in shoals, advantage being taken by fishermen of the spawning habits of the fish. Bunches of leaves and twigs are laid a few miles away from the coast and around these the fish congregate to deposit the eggs. According to Delsman (1924) a similar method of catching flying-fish exists near Makassar in Celebes, where shoals make their appearance from July to October. Shoals have also been noted near Barbados in the West Indies.

GENERAL OBSERVATIONS ON THE BIOLOGY OF FISH CONTRIBUTING TO PELAGIC FISHERIES.

It may be worth while now to summarize some of the general features concerning pelagic fishes. Among their common characteristics may be mentioned their gregarious habits—swimming either in large shoals like the clupeids or in schools like the Spanish mackerel—but members of a shoal mostly belong to the same stock and brood. The shoaling forms are primary consumers of plankton—both vegetable and animal—and have efficient straining apparatus for the collection of food. They do not seem to exercise any selective faculties in the choice of food except that determined by the stratum of water in which they pursue their food. Variations in food often depend upon variations in plankton, i.e. in organisms according to the season. The larger pelagic fish like the tunny are very selective feeders and their movements are often determined by the movements of species on which they are said to feed. From the nutritional point of view, pelagic fish fall within the early phases of the food cycle of the sea; they are either plankton predators or are forms depending upon such predators for food. This relationship to plankton productivity is a direct one unlike the demersal fishes whose utilization of plankton is an indirect one based on the food cycle of benthic organisms. A direct correlation between plankton and the abundance of pelagic fisheries composed of clupeids and the mackerel should therefore be possible. As plankton productivity is closely dependent upon the nutrients available, the shoaling fishes depending on plankton should show a demonstrable positive correlation between their abundance and suitable available chemical contituents of sea water. Russell has shown a close relationship in the English Channel between the abundance of fish larvae and the amounts of phosphates available in the preceding winter (see Harvey 1945). The experiments of Gross and collaborators (1944) in Scotland have shown increased plankton production followed by higher population of species composing the bottom fauna as a result of artificial addition of phosphates and nitrates into the enclosed arms of the sea, and in a recent paper, Cooper (1948) has been able to establish a correlation on the lines of Russell's data, between the phosphates and the landings of elasmobranch fishes at the Channel Ports. It is possible that reliable hydrographic and plankton data for tropical coasts may help us to understand some of the irregularities in time and place of the appearance of shoaling fishes.

While a rich plankton is usually fruitful in that it is followed by an equally rich succession of organisms that subsist directly or indirectly on the plankton, there are instances when certain species of planktonic organisms multiply and increase in such colossal numbers that they are harmful to the normal productivity of the sea. Such are the instances of "red-water" phenomena noted in many warmer coastal waters of the world which are produced by dense swarms of dinoflagellates. A similar planktonic imbalance may be caused by enormous increase

in numbers of the blue green alga *Trichodesmium* (Oscillatoria). It is known that "red-water" phenomena are inimical to fisheries because shoaling fish do not frequent such patches, and on the Indian coasts the fishermen have learnt to avoid such patches. Hardy (1924, 1926, 1936) in a series of investigations with his plankton indicator showed that there was a regular scarcity of the herring where *Phaeocystis* or diatoms of any kind were present in considerable numbers. There are many comparable instances in the distribution of planktonic species to explain which Hardy developed his theory of "animal exclusion". Lucas (1947) has recently reviewed the evidence relating to these and related phenomena and suggested that these relationships are best understood as the ecological effects of external metabolites produced by planktonic organisms, and that most of these mutual exclusions of organisms are brought about by the agency of these metabolic products liberated into the sea. There is also evidence to show that certain metabolites are beneficial, a view that is widely accepted in micro-biology. Plankton abundance and its influence on fisheries would also be thus regulated by these *"ectocrine"* factors caused by the abundance of individual organisms.

Pelagic shoaling fishes usually have a shorter span of life than demersal species. The tunnies, the sword fish, and the larger species would no doubt live for many years, but clupeids and mackerel which provide the bulk of the catches have only a few years growth as contrasted with demersal species. Even here, the European herring is the longest lived, the full sized individuals are at least five years old, closely followed by the mackerel, which has a minimum age of 3—4 years, but in the tropical shoaling species, it would appear that most species do not live for more than two to three years*. Forms like *Sardinella longiceps* and S. *fimbriata* probably have short spans and the smaller species have probably shorter lengths of life. If we are to go by the size of fish and the rapid growth under tropical conditions, where the rate of metabolic activities increases at least three times what it is in colder latitudes, the maximum size to which most species grow may be attained within the course of 10—12 months. Hardenberg's (1938) observation that most species of fish attain a length of 10—15 cm. during a period of seven months or less is noteworthy in this connection.

This rapid development along with the fact that spawning may take place at different periods of the year makes division of stock into year classes a matter of great difficulty and, as Hardenberg has rightly pointed out, many of the methods in fishery research widely adopted in colder waters have only a limited application in tropical waters.

The eggs of almost all the species of shoaling fishes are pelagic, with the notable exception of the herring where it is demersal. The flying fishes on the other hand which are pelagic and even oceanic in habits have pseudo-benthic (demersal?) eggs which they attach to floating woods. Details of development of the tunnies and sword-fish are unknown. We are largely indebted to Delsman, who has studied the eggs and larvae of fishes from the Java Seas for many years, for our knowledge of the development of many of the Indo-Pacific pelagic species.

It is well known that owing to the constant availability of plankton and other food and fairly uniform conditions of temperature in tropical waters, marine animals have extended spawning periods. Many naturalists, mainly influenced by the observations of Semper, have been inclined to think that sexual periodicity is completely absent in tropics and that species breed, and produce eggs and larvae at all times of the year. While this is true for many invertebrates with a short span of life, recent work has brought evidence to indicate that either definite spawning periods or intensive peak periods in spawning are present even under tropical conditions. There is, however, one significant difference in that mature or nearly mature sexual products are present in most tropical species at most times of the year—a behaviour very much in contrast with cold water species.

Spawing seasons in the warm water species are nevertheless conditioned by external factors like suitable salinities and temperature for the dehiscence of the sexual products and availability of food and favourable environs for the growth of the young. Consequently even though a primary periodicity based on internal rhythms tends to become obliterated, a secondary periodicity based on changes in environment is often noticed.

It is at present difficult to assess how far this general observation will be applicable to pelagic fishes. Promiscuous breeding is seen in certain species. In most cases, periodicities in occurrence are observed but some of these can be correlated with migrations due to rainfall and monsoon conditions and the possible influence these have on reproduction. According to Hardenberg (1938) species of *Decapterus* (*Caranx*) are brought into the Java Sea with the

* *Chirocentrus dorab* among the clupeids which is, strictly speaking, not a shoaling fish, must be a notable exception as it grows to about 100 cms. in length.

Eastern monsoon currents from Flores sea and this stock is driven back with the change in current. A new stock of *Decapterus* enters the Java Seas from the South China Sea in the north and from the Indian Ocean in the south. The changes in direction of winds and currents and in the rainfall which is seasonal often result in sharp changes in coastal salinities. Delays in the onset of monsoons on Indian coasts are often followed by delays in the fishing seasons for sardines, mackerel and many other shoaling fish. In regard to coastal fish inhabiting brackish tracts, there is evidence that the rains act as a stimulus to spawning. It is possible that changes in salinity may likewise act on coastal fishes. In this connection the general observation made by Delsman from his study of fish eggs and larvae in the Java seas is pertinent. He says that the favourite spawning places of those pelagic fish are these where the ocean water of high salinity and the coastal water of low salinity mix and where the salinity begins to decrease and where the places are at a safe distance from the coast so that the waters will not be liable to coastal pollution. Shallow waters are avoided, and for most species it was also found that spawning takes place at night.

CONCLUSION.

In this brief review we have attempted to bring together the salient features controlling the pelagic fisheries of the world together with an account of the biology of these fishery resources. We are aware that it has not been possible to bring together in this account a large part of information that is already available in the publications scattered all over the world, but it is hoped that the more important aspects have been indicated in broad outlines. We are in need of more definite data relating to Indo-Pacific species before we can have a satisfactory picture of our pelagic fisheries and we submit our observations with the hope that these may form a starting point for discussion by many of you assembled here who have a closer knowledge of the fisheries in this area than we have.

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See also Nos. 4, 8, 11 and 17 on page 123.