

RESEARCHES ON SCOMBROID FISHES

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I THE REPRODUCTION OF SCOMBROID FISHES IN THE INDIAN OCEAN

The study of larvae and juveniles of Scombroid fishes, including tuna, scomber, mackerel and bonito, is indispensable for understanding the biology of this group which is of great importance in the World Ocean's fishery. About 17 species of the commercially valuable Scombroid fishes occur in the Indian Ocean. The biology of this group has been studied inadequately, particularly so in the Indian and Atlantic oceans. Of great importance is our knowledge about the duration of ripening of gonads, as well as about time and conditions of spawning and development at the earlier stages of life.

Over the last ten years, due to the increase in tuna fisheries in the open ocean, much attention was paid to the young tuna fishes. The developmental stages of *Thunnus albacores*, *Katsuwonus pelamis*, *Euthynnus alleteratus*, *E. affinis* and *Auxis thazard* have been described better than others. These species are most widely distributed and are comparatively more numerous in occurrence. Most of the investigations were conducted by Japanese scientists in the Pacific Ocean. Larvae and juvenile Scombroid fishes from the Indian Ocean were given comparatively less attention, and only in recent years have the Indian Scientists conducted interesting and much needed studies in this field. Data accumulated so far are

not only sufficient for descriptive papers to be written but may be also used to draw a number of theoretical and applied conclusions. The comparison of the available data on the time and conditions of spawning of Scombroid fishes in the Atlantic, Indian and Pacific oceans reveals definite geographic regularities connected with the distribution of environments.

Spawning seasons of Scombroid fishes vary in different parts of their area of distribution but the spawning conditions are of the same type everywhere and confined to the warmest period of the year. In the tropical waters the spawning lasts almost the whole year round but the most intensive one is observed in the autumn-winter months. In the subtropical region the spawning period is shorter and lasts only 3-4 summer months. The distribution of Scombroid fishes in the Indian Ocean is limited to the tropical waters. Spawning conditions show little change from season to season and the reproductive season of Scombroid fishes is very long, not less than 9-10 months in the year. The duration of the spawning period depends on the non-simultaneous ripening of gonads of adults from different age groups, the intermittent spawning and the conditions necessary for the reproduction and development of Scombroid fishes during the whole year.

The prolonged spawning is typical of all tuna species. It begins in autumn, in September, and lasts until spring with a short decrease in spawning observed in summer (June, July, August). The period of intensive spawning is noted in November, December and January. Other species inhabiting the coastal waters, as, for instance, *Rastrelliger*, *Scomberomorus*, *Scomber* may have other spawning time determined by

somewhat different hydrological regime of the environment.

Thunnus albacores: In the Indian Ocean the larvae of *Th. albacores* were found from January to April and from October to December. The collections made by the research vessel "Kalava" in the Laccadive Sea contain larvae caught in February, March and April. In the open ocean, as the R/V "Vityaz"'s collections show, they were caught from November to March at water temperatures of 27.5–28.5°.

Thunnus obesus: Larvae of big eyed tuna were found in the open parts of the central Indian Ocean in February, March and December ("Vityaz"'s data). In the eastern Indian Ocean, in the vicinity of Indonesia and off the Australian eastern coast, the big-eyed tuna is known to spawn from October to February. This period is confirmed by original data.

Katsuwonus pelamis: Spawning of this species was observed during winter and spring. In the Laccadive Sea larvae were found during winter and spring. In the Bay of Bengal and Andaman Sea larvae were also found in winter. In the central part of the ocean southward from the Equator, larvae of the striped tuna were caught in comparatively large quantities from December to March.

Euthynnus alleteratus: The collections made by the R/V "Vityaz" in the Andaman Sea contained larvae of two species of the genus *Euthynnus*. The first species is little known, while the second one is widely-distributed in the Indian Ocean. Larvae of *Euth. Alleteratus* were caught in October, their length ranging between 3.0 to 16.6 mm.

Euthynnus affinis: Much more information is available on the spawning of *Euthynnus affinis* in the Indian Ocean. Off the eastern coast of Africa it spawns in September-October and in March-April. However, even in

winter adult tunas were found having mature gonads. They were essentially less abundant in summer. One may suppose that spawning in the area under consideration lasts from October to April with a decrease in summer. Similar data are available on the spawning periods in the Gulf of Aden and the Bay of Bengal. Our observations show that *Euthynnus affinis* spawns in more coastal waters than large tunas do.

Auxis thazard: Larvae of this species like those of *Euthynnus* are found in coastal waters. There is evidence of their occurrence from October to April. Larvae of *Auxis thazard* are contained in the surface layer and their abundance in some cases is very large—about 500-700 specimens in one sample. Similar results were obtained during sampling made in the Gulf of Aden and off the south-western coasts of Ceylon in October. In the Indian ocean two larval types different in the structure of body are found.

Little is known about spawning of *Scomber* in the Indian Ocean. One may suppose that the reproduction takes place in the coastal zone. The spawning conditions of *Scomber* in the Indian Ocean are of interest since all the species of this genus prefer cold waters and are abundant in the waters of the sub-tropical and temperate zones.

Much more widely-distributed in the Indian Ocean are the species of *Rastrelliger* which represent an important object for the Indian commercial fisheries. The study undertaken by the Indian scientists (Sekharan, Vijayaraghavan, Radhakrishnan) resulted in establishing the fact that spawning in the coastal regions begins in April and lasts the whole summer. Spawning conditions of these representatives of Scombroid fishes are somewhat different, they spawn in summer but not in winter.

In addition to *Rastrelliger* 2-3 species of

Scomberomorus are known to occur in the Indian Ocean coastal waters: *Scomberomorus guttatus* and *Scomberomorus comersoni* which spawn also in the coastal areas. The spawning period, according to Vijayaraghavan's data, is rather long and is observed from July to January. In the vicinity of the Island of Rameswaram the spawning of *Scomberomorus* lasts from April to July (Krishnamoorthi's data). Catches of these fishes show a considerable increase in the above-mentioned period, whereas in winter they fall.

The biology of the reproduction of *Sarda* has been studied still inadequately. Only separate collections of larvae made in December, January and April are available. Like *Scomber*, *Sarda* inhabits colder subtropical waters but we do not know, yet, when the reproduction of this species occurs in the warm Indian waters.

Grammatorcynus bicarinatus: This species also inhabits the coastal waters, the biology of its reproduction has been studied not enough. As observations of the adults show, spawning of this species takes place in the Andaman Sea from January to March, but in the Sulu and Celebes seas, larvae 8.5-17.5 mm long were caught in summer.

Summarizing all the data on the larvae of Scombroid fishes in the Indian Ocean, we should note not only the regions of their occurrence but also certain regularities in the larval distribution of some species. Larvae of *Thunnus albacores*, *Thunnus obesus*, *Thunnus alalunga*, *Katsuwonus pelamis* are found mainly in the open ocean, whereas those of *Auxis thazard*, *Euthynnus affinis*, *Rastrelliger*, and *Scomberomorus* prevail in the coastal regions. Spawning of Scombroid fishes is uneven over the ocean area, and the areas of the most intensive spawning are distinguishable. They include, first of

all, the eastern part of the Indian Ocean with the Bay of Bengal where, according to the available data, not less than 10 species of this important group of fish spawn. Many larvae of Scombroid fishes are found in the Gulf of Aden for which both the great frequency of occurrence and large catches are typical. For example, a single sample was found to contain 767 larvae of 3 species of *Thunnus*. A great number of tuna larvae is also found in the coastal waters of Ceylon. Ichthyoplankton samples taken from the open ocean contain usually not more than 3-4 larvae. Of great interest is the absence of larvae in the Arabian Sea which is, apparently, due to the peculiarities of its hydrochemical regime. A thorough analysis of all the data would allow the elucidation of this important practical question.

Larval morphology of the most widely distributed species of Scombroid fishes has so far been described rather well, although considerable difficulties turn up in determinations. One of the essential points in the determinations is not only morphological features but also differences in the developmental stages of various species. Despite some difficulties that arise, we may consider that the period of describing larvae is over, and now we should turn to elucidating the conditions of reproduction and regularities in the life cycle.

II ECOLOGICAL AND GEOGRAPHICAL PECULIARITIES IN REPRODUCTION OF SCOMBROID FISHES OF THE WORLD OCEANS

As is well known breeding periods and character of spawning in fishes (as in other animals, too) depend on their hereditary nature and are affected by environmental factors. Closely related taxa, pertaining to the same genus or family usually require similar environmental factors for their reproduction. These factors and especially those

playing the most important limiting role, are, as a rule, liable to great diurnal or seasonal changes affected by the situation of the area concerned and on its hydrological regime. Among such factors temperature, light, oxygen content, salinity and current system pattern should be mentioned as most important.

All Scombroid fishes numbering about thirty species spawn in warm waters. The narrow range of appropriate temperatures required for their breeding and their larval development is largely responsible for different terms and duration of spawning in distinct areas. Analysis of the data on the breeding time and spawning conditions of Scombroid fishes in the Atlantic, Indian and Pacific ocean enables us to disclose and outline certain ecological and geographical regularities affected by the change of environmental factors, and especially the temperature, in different climatic zones. The majority of species of this group breed in tropical waters, where annual temperature within the upper fifty meters layer does not decrease below 25°C. Here spawning period lasts from nine to ten months and even more. Breeding season of Scombroid fishes in tropical waters being prolonged to its utmost, nonetheless, the most intensive spawning is observed here from November to April when the occurrence of the larvae is the greatest.

In subtropical and warm temperate zones of both hemispheres (approximately between 25° and 15° northern as southern latitudes) breeding occurs during the warmest spring-summer season, when the limits of the breeding areas gradually expand while the twenty-five degrees isotherm is moving on. No more than five Scombroid species are found to spawn at approximately twenty degrees. Under these conditions breed such species as *Sarda sarda*, *Scomber scomber* and blue-

fin tuna (*Thunnus thynnus*) which require the lower temperatures for their reproduction. Among the species just referred to, the blue tuna deserves the greatest attention. Its breeding areas were found in the off-shore waters and in semi-enclosed basins in the Atlantic (Cuban waters, the Gulf of Mexico, and off Florida) and Pacific (off Southern Japanese islands and in Tonking bay in the Northern Hemisphere and in the Great Australian Bight in the Southern Hemisphere). Breeding areas of this species are not known in the Indian Ocean as yet. So far as we know it does not breed in tropical waters at all.

In the regions influenced by cold-water currents breeding of Scombroid fishes is more restricted in time as compared with other areas at the same latitudes. For example, *Thunnus obesus* in the south-eastern Pacific spawns at zero-ten degrees southern latitudes but from January to the middle of March. The variability in duration of the breeding season in different climatic zones (from well-nigh perennial in tropical waters up to 2-3 months in warm-temperate waters) shows a great adaptive "plasticity" in reproductive biology of Scombroid fishes while temperature requirements stay rather rigid. It is evident that more detailed comparative investigations of distinct populations within each species are badly needed. These should include experimental studies on defining thermal parameters required for their development and observations on the differences in intermittant ripening of gonads in the members of distinct populations.

The analysis of other environmental factors, such as salinity, hydrochemical regime and so on, does not reveal such a clear-cut and direct influence on reproduction of Scombroid fishes, as temperature does. However, some irregularities, often inexplicable as yet, may

be mentioned. For example. In the Arabian Sea the oxygen content in the upper water layers is adequate and, as it seems, all other environmental factors are favourable for reproduction of Scombroid fishes, and although this region was covered with a dense net of stations, nonetheless no tuna larvae were found here.

Study of reproductive biology of Scombroid fishes is greatly hampered owing to a well-nigh total lack of knowledge concerning the larval developmental stages. Furthermore, diagnostic characters of tuna eggs are not worked out. It is to be hoped that in the near future this problem will be solved.