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Synopsis of the Distribution, Biology and Fisheries of the Bigeye Tuna (*Thunnus obesus*, Lowe) with a Bibliography

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Synopsis on the Distribution, Biology and Fisheries of the Bigeye Tuna (*Thunnus obesus*, Lowe) with a Bibliography

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Abstract

This bibliography lists over 370 scientific papers, technical reports and articles published before 1993 that contain information on the distribution, biology and fisheries of bigeye tuna (*Thunnus obesus* (Lowe)). Each entry is indexed by author and subject. Only articles in English or with an English abstract are included; newspaper articles are not included. Aspects of the biology and fishery of this species are also discussed.

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Disclaimer and Acknowledgements

While every effort has been made to record faithfully other authors' observations, readers are advised to refer to the original papers for confirmation and to ensure that observations have not been unintentionally taken out of context.

We thank Dennis Abbott, Glen Forbes, Janet Virag and Angela Webb from the CSIRO Marine Laboratories Library for their assistance in tracking down obscure and ill-referenced articles; Toni Cracknell for some typing and editorial changes; Vivienne Mawson, John Gunn, Geoff McPherson and Clive Stanley for dotting the i's and crossing the t's; and David Taylor *for formatting the text and bibliography.*

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Introduction and explanation

Introduction and Explanation

This report has been compiled to help amalgamate and elucidate the published literature on bigeye tuna. Globally, bigeye tuna is a large component of the pelagic fisheries. However, despite its commercial importance, it is one of the least known and least researched of the tuna species. This report attempts to bring together the research findings for this tuna species, to help managers, fishers and researchers and to highlight gaps in our information.

1 Classification and Affinities

1.1 Species name: *Thunnus obesus* (Lowe, 1839)

Phylum	Chordata
Class	Osteichthyes
Subclass	Actinopterygii
Order	Perciformes
Suborder	Scombroidei
Family	Scombridae

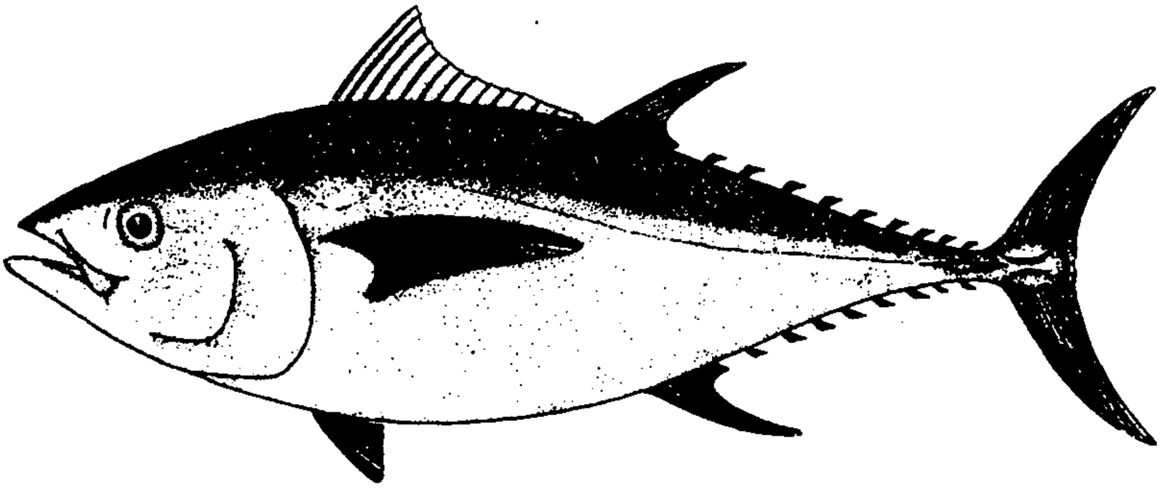


Figure 1. *Thunnus obesus* (Lowe, 1839). (from FAO 1983)

1.2 Synonyms

Thynnus obesus	*Lowe, 1839* *Gunther, 1840*
Thynnus sibi	*Gunther, 1840* *Temminck and Schlegel, 1842* *Richardson, 1846*
Orcynus sibi	*Kitahara,, 1897*
Germo sibi	*Jordan and Snyder, 1901*
Thunnus sibi	*Jordan and Snyder, 1901*
Thunnus mebachi	*Kishinouye, 1915*
Parathunnus obesus	*Jordan and Evermann, 1926* *Frade, 1960*
Parathunnus mebachi	*Kishinouye, 1923* *Mimura, 1963*
Parathunnus sibi	*Jordan and Hubbs, 1925* *Jordan and Evermann, 1926* *Tinker, 1944* *Brock, 1949* *Rivas, 1961* *Roedel and Fitch, 1962* *Alverson and Peterson, 1963*
Germo obesus	*Fowler, 1936*
Parathunnus obesus mebachi	*Jones and Silas, 1960*
Thunnus obesus sibi	*Jones and Silas, 1963*
Thunnus obesus mebachi	*Jones and Silas, 1964*
Thunnus obesus	*Frazer-Brunner, 1950* *Talbot and Penrith, 1960* *Collette, 1962* *Bruce and Gibbs, 1963* *Watson, 1963* *Iwai, Nakamura and Matsubara, 1965* *Collette and Naeun, 1983* *Itano, 1992*

1.3 Vernacular names

Bigeye tuna, bigeye tunny (English)
Thon obese (French)
Thono obeso (Italian)
Mebachi maguro (Japanese)
Grootoog tuna (Afrikaans)
Patudo (Spanish)
Grossaugen-thunfisch (Dutch)
Storoyd mackrellsorje (Norwegian)

1.4 Geographical distribution

World-wide in tropical and subtropical waters of the Atlantic, Indian and Pacific oceans, but absent from the Mediterranean (Collette and Nauen 1983).

1.5 Diagnostic features

There is considerable variation in the description of this species in relation to its diagnostic characters and taxonomic affinities, depending on the site-of collection and the approach of each worker. The following description is compiled from Mimura (1963), Talbot and Penrith (1963), Collete and Nauen (1983) and Itano (1992).

A fish in the genus *Thunnus*, having a liver striated with peripheral blood vessels (but striations few in number), comprising three rounded lobes of equal length and the central lobe slightly enlarged. Cutaneous blood vessels are found from the myotomes of the seventh vertebra and backwards. Swim bladder, wide, running the full length of the body cavity dividing anteriorly into two pits in the dorsal side of the body cavity. 23–31 gill rakers on the first gill arch.

The dorsal outline of the body is curved; the ventral outline is more curved. The body is very broad, the greatest body depth being about the middle of the body near the middle of the first dorsal, the caudal portion short, having a distance from the snout to soft dorsal over 50% of the fork length. Length of head is nearly equal to the height of the body in the young, but becoming shorter in older fish. Live or fresh specimens have dark blue/black back shading into a characteristic iridescent metallic blue with silvery grey below and a white belly. The boundary between the dark blue above and the silvery grey below is sharply defined with a distinct golden bar. After death, the boundary is less clearly defined.

The pectoral fins are moderately long, reaching 22–31% of the fork length; often reaching beyond the base of the second dorsal in young fish. Soft dorsal and anal fins are relatively short in adults, being less than 17% of fork length. The spinuous dorsal is dusky, fringed with bright yellow distally, edged with a thin black rim. The caudal fin can be purplish black in live specimens, fading to dusky after death. Finlets are bright lime yellow with a black rim. The central position of the trailing edge of the caudal forms a semicircular notch with low lateral keels (contrast to the "v" notch and high lateral keels of the yellowfin tuna).

Differentiating between small bigeye and yellowfin can be difficult. Itano (1992) notes some distinguishing features: the bigeye have a few vertical bars in the mid to tail region, whereas the yellowfin have more and narrower bars. Bigeye also have a bigger eye, but this characteristic is of little use if you have only a single specimen available. Yellowfin tuna tend to have a distinct notch in the caudal fin (in the "v") as well as a larger, more pronounced pair of keels, while in bigeye the margin tends to be straight.

FAO (1992) provides a good description of the Scombridae family and the *Thunnus* genus in particular.

2 Distribution of Bigeye Tuna

The bigeye inhabits the warm waters of the Indian, Pacific and Atlantic oceans. It is found across the entire east–west extent of the Pacific between northern Japan and the north island of New Zealand in the western Pacific, and from about 40°N to 30°S in the eastern Pacific (Bayliff 1980).

2.1 Areas of abundance

Analyses of long-term data from longline fisheries by several authors suggests that the bigeye tuna *Thunnus obesus* is distributed in the temperate and tropical waters of the Indo–Pacific region between about 45°N and 40°S. Nakamura and Yamanaka (1959) reported that the distribution had a concentration in the northern (around 7°N) and southern edges of the north equatorial counter-current in the central and western tropical Pacific Ocean. Kawai (1969) observed that the main fishing ground was in the current boundary along the axis of the subtropical gyre (between 30°N and 40°N) as well as near the current boundary along the northern edge of the north equatorial current (between 5°N and 10°N) and along the thermal ridge along the equator.

IATTC (1992) reported that fishing effort was high in most of the eastern Pacific except the area north of 5°N and east of 125°W. The areas with the greatest catch rates were between the equator and the Galapagos Islands throughout the year; north-east of Hawaii in the area between 18° and 33°N and 120° and 145°W during the first and fourth quarters of the year; south of Peru and northern Chile in the area between 18° and 25°S and 80° and 90°W during the third and fourth quarters. The distribution of fishing effort did not coincide with the greatest catch rate of bigeye in the areas discussed. Effort was heavy in the equatorial waters (10°N to 15°S and west of 110°W), but the catch rate in this area was not particularly high. Furthermore, although the catch rates were high to the north-east of Hawaii and off southern Peru and northern Chile, not much effort was exerted in those areas. IATTC suggests that bigeye can be caught throughout the year in the equatorial region (the fish tend to be large), whereas in the higher latitudes, bigeye were more seasonal and tended to be smaller. Bigeye tuna are often caught in conjunction with other tuna species such as yellowfin and may not be the target species.

Suzuki *et al.* (1977) and Suzuki and Kume (1981) identified extensions of fishing grounds in the peripheral areas of existing fishing grounds such as the areas between 15°N and 20°N and between 0° and 5°S along the 180° meridian. The catch rate in the longline fishery indicates at least two east–west zonal bands of high abundance: one in the north Pacific centred around 30°N in the winter; the other in the equatorial area, with the east–west zone being almost continuous. However east of 150°W is another zone of high abundance further south along 10°S (Anon. 1980). Hanamoto (1986) suggests that the areas now poor in bigeye catches (around 20°N and also in the high latitudes of the south Pacific between 30°S and 40°S) could also be good fishing grounds if fished deeper, since the optimum temperature layers for bigeye have been found at the greater depths of 250–500 m and 100–500 m respectively in these areas.

In the Indian Ocean, the bigeye tuna are distributed mostly between 20°N and 40°S and are concentrated in the equatorial area, including the Banda Sea, throughout the year and along 30°S during the summer (Anon. 1980). Stequert and Marsac (1989) reported that bigeye tuna fishing in the Indian Ocean was distributed throughout the intertropical zone, and also bordering the areas where the yellowfin were scarce, such as the Arabian Sea, with its low oxygen level, and in subtropical areas when the water temperatures were low. Mohri *et al.* (1991) describe bigeye's distribution in the Indian Ocean as a wide area between 25°N and 40°S. Catch rates were higher in the western and central tropical regions of the southern higher latitudes. Areas with low catches were in the middle latitude areas between the tropical region and the northern high-latitude regions, the Arabian Sea, north of the Bay of Bengal and between 35°S and 50°S.

The geographical distribution of bigeye tuna in the Pacific by quarter years is shown in Figure 2. Figures 3 and 4 show the geographic distribution of long-term mean number of bigeye tuna caught by longline by 5° squares for both the Pacific and Indian Oceans. FAO (1981) describes the distribution of bigeye tuna in the Atlantic Ocean.

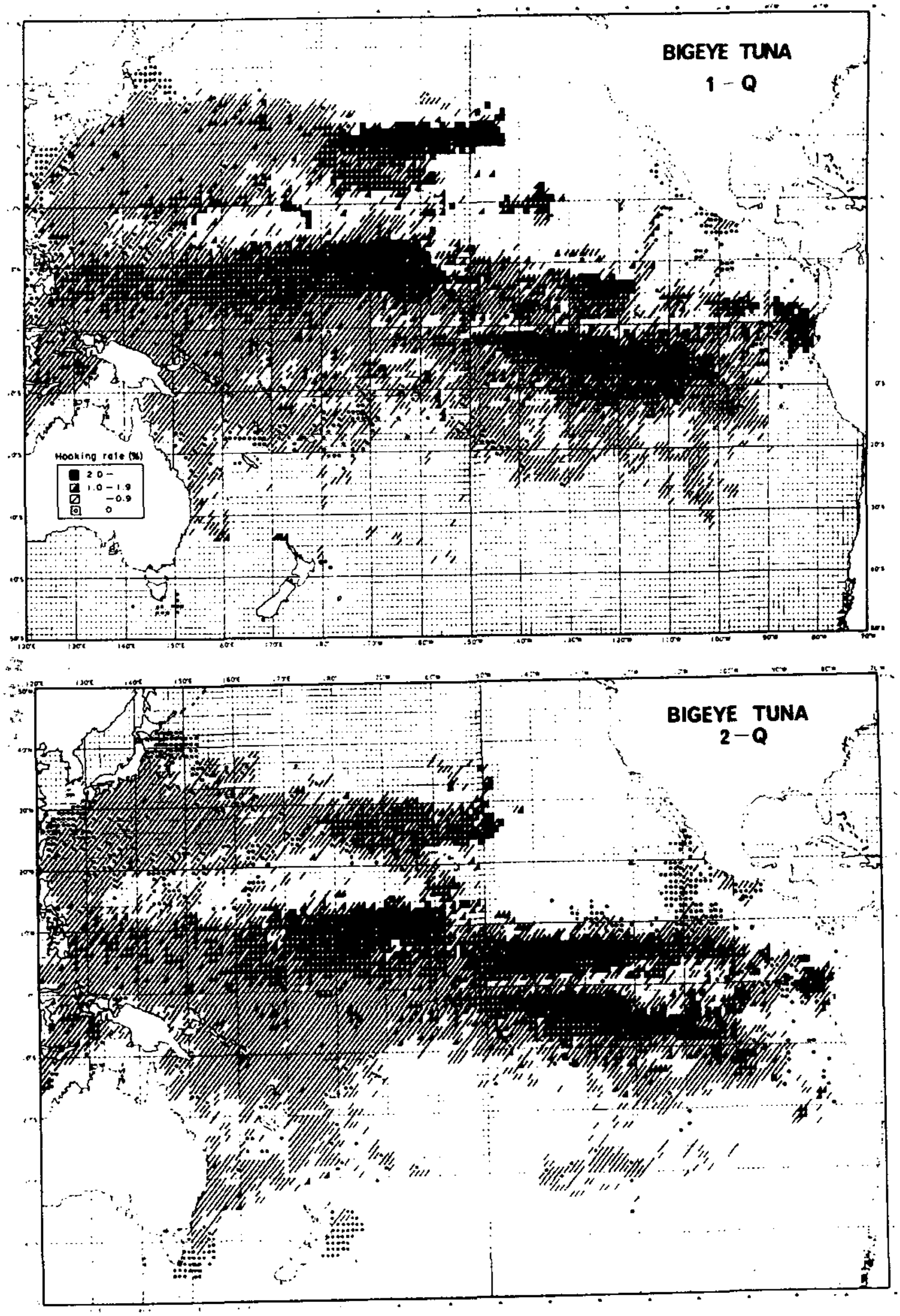
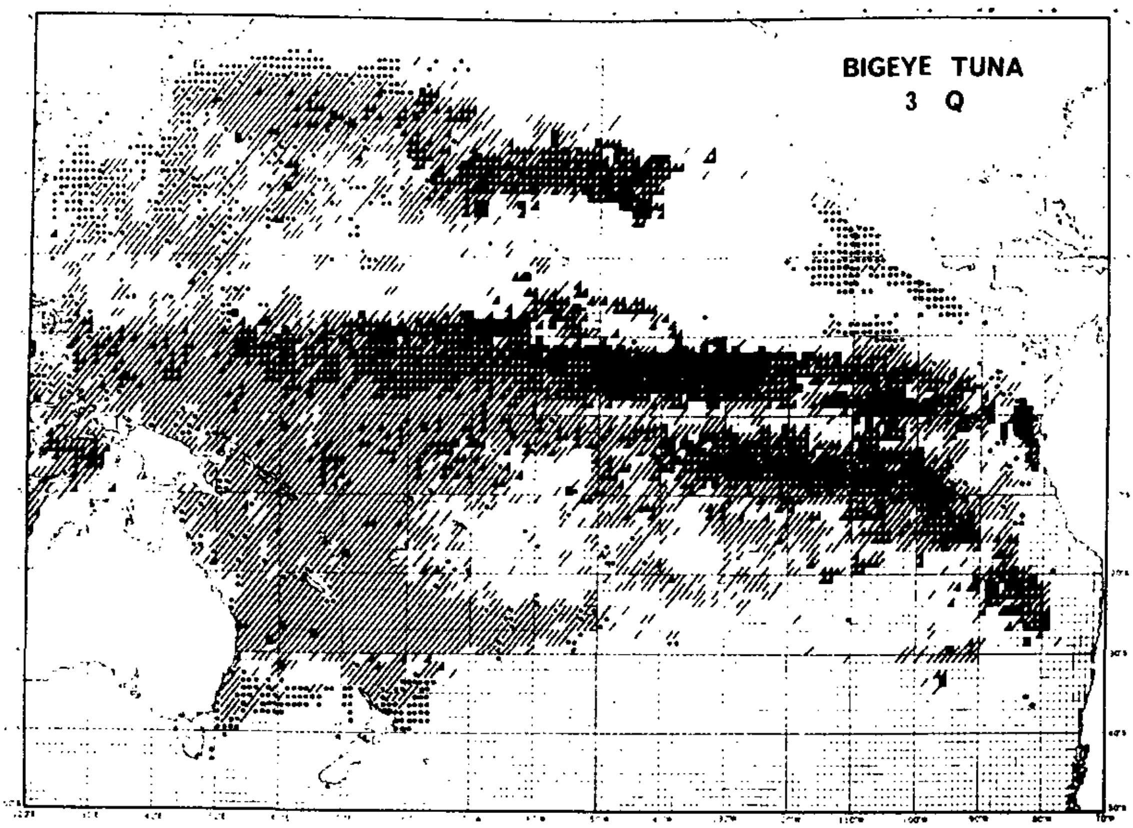


Figure 2. Ist and 2nd quarters

Quarterly distribution of bigeye tuna in the Pacific Ocean, expressed by average catch rates in the Japanese longline fishery (from FAO 1980)



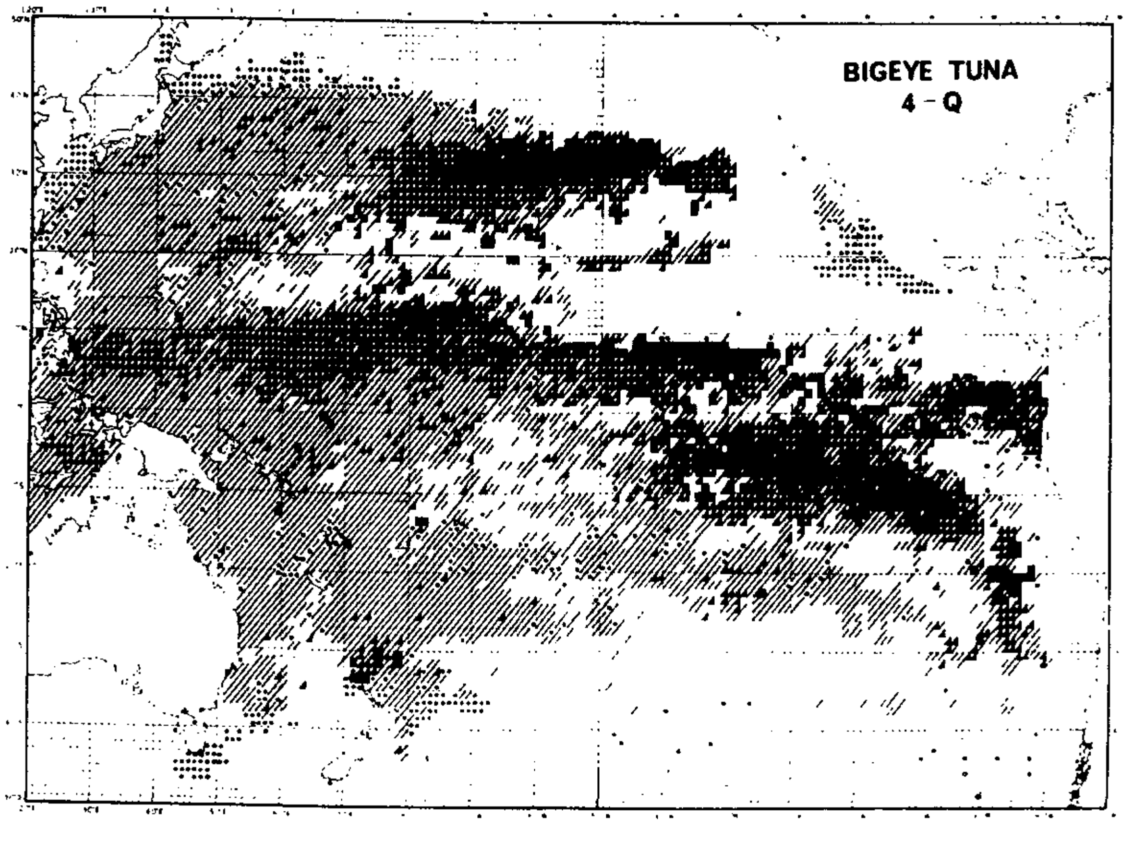


Figure 2 (cont.). 3rd and 4th quarters Quarterly distribution of bigeye tuna in the Pacific Ocean, expressed by average catch rates in the Japanese longline fishery (from FAO 1980)

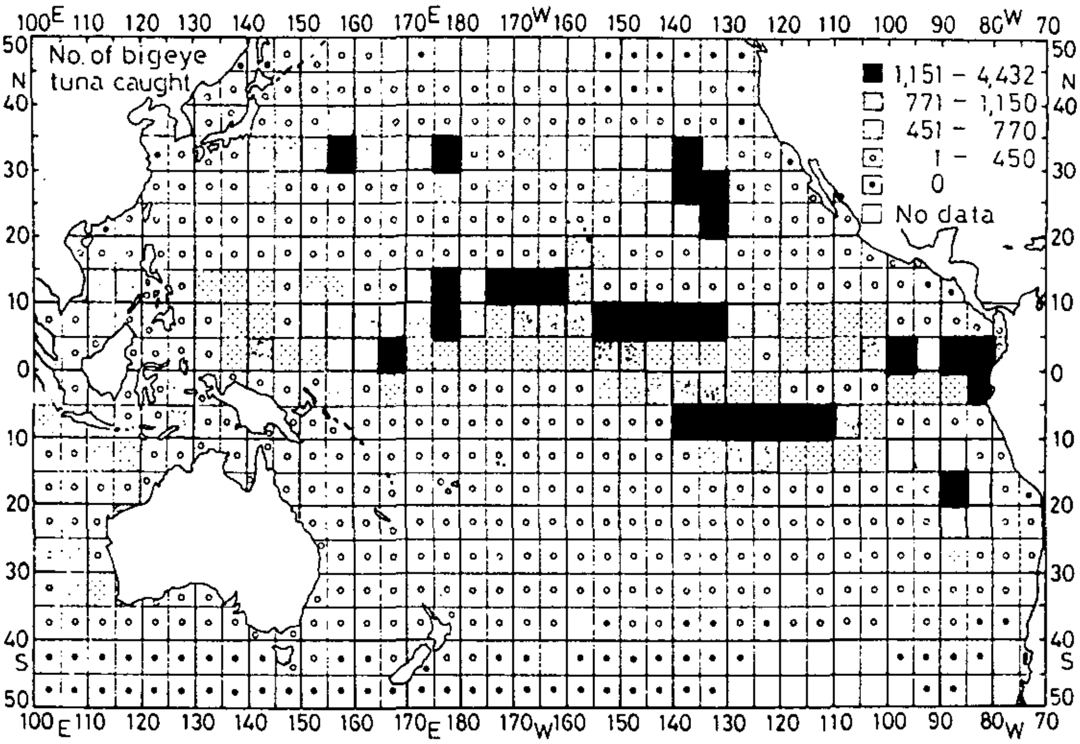


Figure 3. Geographical distribution of the long-term mean number of bigeye tuna caught by tuna longline, by 5° squares (catch per month, 1964–1978). Figures in the upper right of the figure show the number of blueye tuna that each symbol represents.

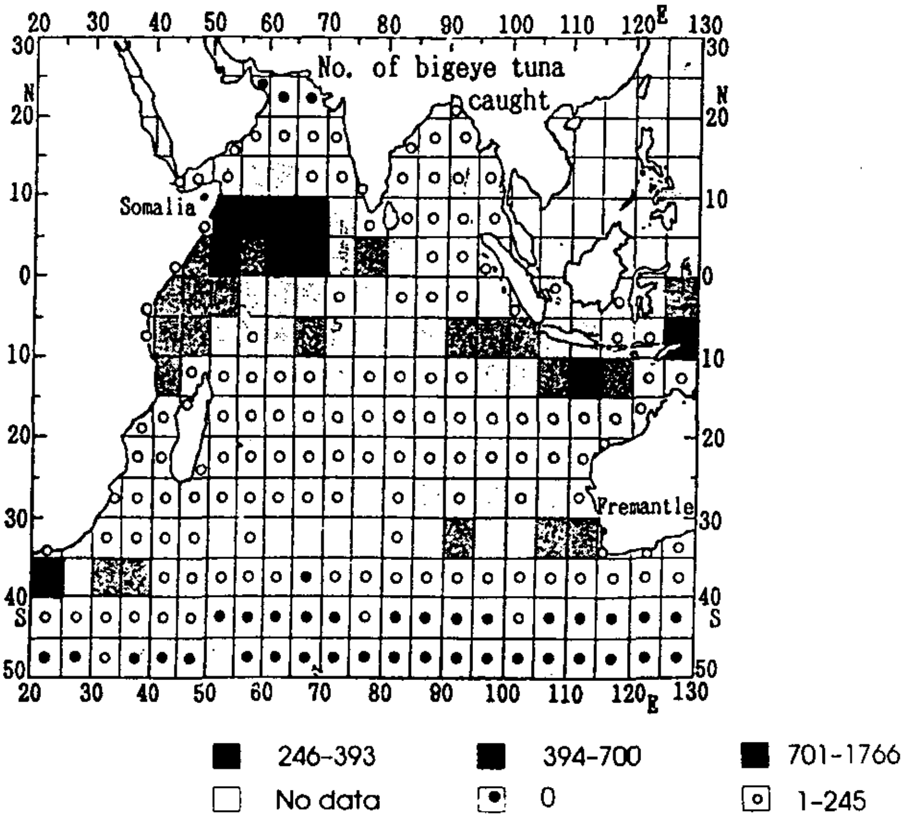


Figure 4. Geographical distribution in the Japanese longline fishery of long-term (1967–85) mean monthly catches (in numbers) of bigeye tuna in the Indian Ocean, shown in 5° squares. (from Mohri *et al.* 1991

2.2 Factors influencing bigeye distribution

Researchers are in general agreement that the distribution of the bigeye tuna is largely controlled by two major factors: optimum temperature and dissolved oxygen levels in the oceanic waters. From physiological experiments, Sharp (1979) estimated the optimum temperature for the bigeye tuna is in the range of 11–23°C, with dissolved oxygen requirements of 1 mL/L (based on the tolerance by fish of 50–75 cm for 10 minutes at 0.5 to 1.0 mL/L). Collette & Nauen (1983) report that the water temperatures that bigeye tuna have been found in range from 13°C to 29°C, with the optimum lying between 17°C and 22°C.

Earlier authors such as Suzuki *et al.* (1977) give a comparative account of the catches by regular and deep-set tuna longline gears in the western and central equatorial Pacific (10°S–20°N, 120°E–160°W). Although the area along 10°N to the east of 180° is generally considered to be a principal fishing ground for tuna by regular longlining, deeper longlines found better fishing grounds further to the south, in waters between 5°N and 10°S as well as in the Banda Sea. The catch rate tended to be lower along the equator. Also, along 10°N, the deep longline method appeared to have relatively lower catch rates than either side of this latitude, which is not the case with regular longline gear. Suzuki *et al.* (1977) postulate that the thermocline is narrower around 8°–10°N (100–180 m), and thus the range of hook depth of the deeper longline is just outside the thermocline area, whereas the hooks of regular longline gear adequately cover the thermocline at this location. This explains why the latter gear caught more bigeye around 10°N. South of 5°N, the thermocline is deeper and the deeper-set longlines are sufficiently deep (50–250 m) to fish the thermocline and so increase tuna landings. Kawai (1969), Suda *et al.* (1969) and Saito (1975) also correlated the distribution pattern of the bigeye with the thermocline pattern. de Jaeger (1963) noticed that at 7°–35°E and 12°–40°S, the bigeye was distributed within the temperature range of 16°–21°C, with the highest catch at 18–19°C. Hisada (1988) found that the catch from Coral Sea surface waters by handline is 26 times more efficient than by longline, but only for a short period at the beginning of the season. The tuna appeared to be concentrated at the 26°C isotherm as it moved south through the fishery.

Martinez and Bohm (1983) observed *T. obesus* distributed between the surface and up to 380 m depth in the Pacific Ocean. Blackburn (1965) and Grudinin (1989b) are of the view that the 10°C isocline is the lower tolerance limit for the bigeye and that this is a chief factor affecting its distribution. In some regions of the eastern part of the Pacific Ocean, close to the southern coast of Mexico and Peru, the oxygen content drops below 1 mL/L at a depth of 100 m, and *T. obesus* does not occur in any numbers despite favourable temperature conditions.

Light is another possible factor in controlling the distribution of tunas, since they are sight feeders (Magnuson 1963). They are not found in the greenish waters of coastal upwellings, but occur on their boundaries in clearer oceanic waters. Tuna also do not occur in turbid waters, since poor visibility inhibits their feeding (Hunter *et al.* 1986). In the studies by Grudinin (1989b), 78% of the bigeye catch was from the 9–13°C zone, 0.49% from below the 10°C zone, and 12.5% from the zone above 14–15°C. Hanamoto (1986) suggests the vertical distribution of the bigeye tuna ranges from the surface to 600 m depth, and that the commonly accepted estimates of its distribution and abundance, which are based on the longline fishery, are not accurate.

Based on Hanamoto's (1986) conclusions, it appears that bigeye tuna is restricted to water temperatures between 9°C and 28°C, with 50% of all the catches coming from within the 10°–15°C range. Catches decreased rapidly on the lower side of this range but more slowly on the higher side. The salinity corresponding to the optimum temperature (10°–15°C) range was 34.5–35.5 ppt in the north Pacific. This author postulates that this species is distributed within the optimum temperature levels where the dissolved oxygen level is greater than 1 mL/L. This area lies horizontally between 40°N and 40°S and vertically between the surface and 600 m depth. The depth distribution varies with area, depending on the depth of the optimum temperature zone. Hanamoto (1986) surmised that "it is clear that the tuna longline fishes only a very narrow segment (within the limits of the hook depths) of the vertical distribution of the bigeye tuna; the so-called productive bigeye tuna longline fishing grounds are nothing more than the areas where the hook depths happen to coincide with the optimum temperature layer of bigeye tuna, and where the dissolved oxygen content happens to be greater than the minimum requirement for the bigeye tuna (1 mL/L), and therefore not necessarily representative of areas of higher fish concentrations". He argues for further experimental fishing and fish-finding surveys in waters where the optimum temperature layer lies deeper or shallower than the hook depths of longline gear.

2.3 Distribution related to maturity

Suda *et al.* (1969) studied the distribution in relation to maturity and suggested that immature fish were largely distributed in the north Pacific current area (between 140°E and 180°) with a tendency to be concentrated in the more eastern part of the current system, while mature fish were distributed in a wider area south of the subtropical convergence, with their spawning ground in the equatorial counter-current area.

Hisada (1979) found that the stage of maturity and water temperature influenced the vertical distribution of bigeye in the area studied (80°–160°W, 10°N–10°S). He suggested that, in the case of bigeye tuna in the central and eastern tropical Pacific, segregation by vertical habitat may be one component of their spawning migration.

2.4 Distribution of larvae and young fish

The distribution of larvae has been little studied. Nishikawa *et al.* (1978) prepared an atlas of larval distribution in the Indo–Pacific region based on the surveys conducted by the Fishery Agency of Japan (Fig. 5). Larvae have been collected from both surface and subsurface waters, mostly from the equatorial areas during January to March.

Schools of young bigeye are frequently found in association with drifting logs, wreckage and fish aggregation devices in 50–100 m of water (Suzuki *et al.* 1977; FAO 1981; Stequert and Marsac 1989; Itano 1992). Talbot and Penrith (1963) noted there were no large schools of bigeye tuna; rather, they moved in compact groups of 10–20 individuals. FAO (1981) reports that juveniles and small adults school at the surface in mono-species groups or together with yellowfin tuna and/or skipjack. This also occurs in the Coral Sea off Australia, sometimes associated with whale sharks (pers. obs.).

The surface bigeye tuna catch in the Pacific Ocean was recently analysed by the IATTC and the National Research Institute of Far Seas Fisheries, Japan (IATTC 1992). About 64% of the surface catch of small bigeye was associated with free schools, 29% was from schools associated with floating objects, and the rest was in schools associated with whales, sharks and dolphins. The highest surface catches were made off northern South America and offshore west of South and Central America.

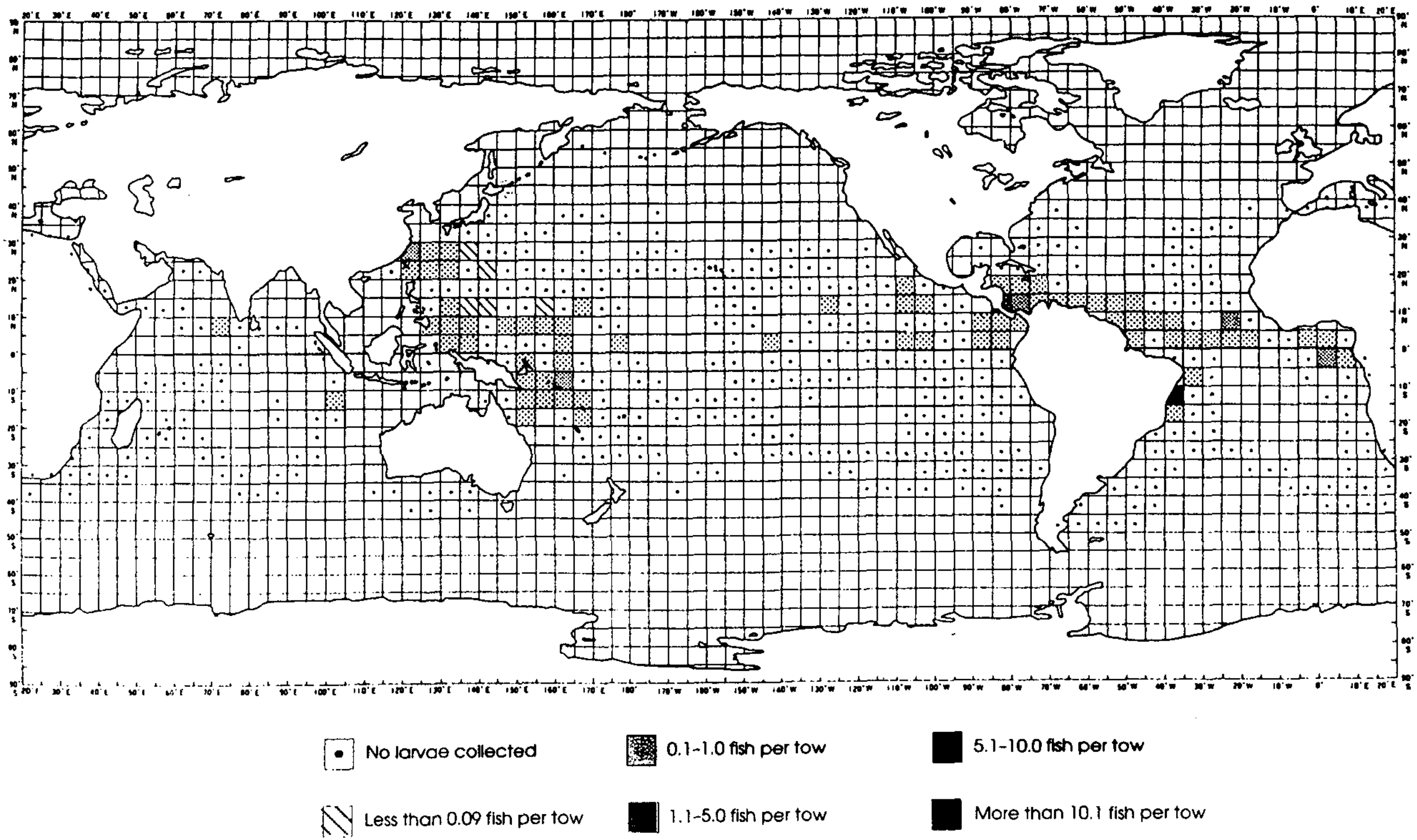


Figure 5 Distribution atlas of larvae of bigeye tuna in the oceans. The atlas presents the larval distribution based on larval net collections made during research surveys of RV *Shoya maru* and RV *Shunyo maru* during 1956–1975 (by Far Seas Research Laboratory, Shimizu, Japan). Larval occurrence is expressed by the number of larvae per tow by 5° areas. (from Y. Nishikawa et al. 1978)

2.5 Prediction of fishing ground/seasons

Pereira (1991) investigated the detection indices of tuna populations, and remarked that the presence of birds was the most important detection index of tuna schools. He also observed that schools associated with fish aggregation devices were normally smaller than free-swimming schools.

Yamanaka (1976) evaluated the prediction of fisheries conditions as carried out by several research institutions. He used oceanographic and climatological data to look at predicting; fishing seasons, fishing grounds and whether the fishing should be good or bad. His overall prediction results showed that 59.1% of total predicted cases were successful. This increased to an 81.1% success rate for climatologically positive cases. Yamanaka (1976) adds that climatological prediction is mainly by common sense and tends to have a high rate of success.

3 Food and Feeding Rhythm

3.1 Food composition

Investigators are in agreement on the general composition of the diet of the bigeye tuna, which they recognise as an opportunistic feeder. Opinions differ, however, on the extent they share the same niche with other tunas and marlins, especially the yellowfin tuna. Feeding intensity has also been investigated in relation to geographical area, availability of food items in the ecosystem, and fish size and maturity (McPherson 1991).

Studies by Yabe *et al.* (1958) indicated that the bigeye preyed mainly on cuttlefish and the young of other fish, which were invariably found in the gut contents examined. de Jaeger (1963), who examined the gut contents of bigeye tuna from South African waters, observed the composition to be 27% fish, 18% crustaceans and 53% cephalopods by number (26%, 18% and 56%, respectively, by volume). Talbot and Penrith (1963) concluded that bigeye fed exclusively on fish, squid and prawn (50.7, 38.8 and 10.1% respectively by volume). In the Atlantic Pelczarski (1990) found that fish constituted 70–80% of the food by weight, cephalopods constituted 9–27% and crustaceans 0.5–1.0%. He suggested that the large quantities of fish (Gonostromatidae, *Alepisaurus* sp., *Brama dussumieri*, *Paralepis* sp.) and squid *(Ornithoteuthis antillarum)* in the stomach samples was an indicator of the concentration of these species in the water column.

Koga (1958) reports that the food in the stomachs of western Indian Ocean bigeye included alepisaurids, sphyraenids, sternoptychids and young skipjack (the main food types) as well as decapods. Watanabe (1960) reported that in the eastern waters around 10°S, the main food items were squids and such fishes as alepisaurids, sternoptychids, palalepeds, lepidotids and chiasmodontids, but south of 10°S, amphipods, chiasmodontids and sternoptychids were much less common, while pterachlid fish (which were abundant in northern waters) amounted to 30% of the food items. The bigeye were also eating ocean sunfish larvae.

McPherson (1991) reports that aggregating bigeye tuna in the Coral Sea fed almost exclusively on myctophids (single species of *Diaphus* sp.).

Watanabe (1960) noted that the food items identified in the waters of high latitudes (north of 30°N and south of 30°S) were simpler than those in waters of lower latitudes, where more varied forms are found. The food of bigeye near islands differed from that of the oceanic fish sampled, probably influenced by the local fauna. The author concluded that a close relationship existed between the food of the tuna and the fauna of the region.

3.2 Diurnal rhythm in feeding

Mimura *et al.* (1963) and Grudinin (1989b) studied the feeding rhythm of the bigeye tuna and observed that feeding was more active at night. The fish started feeding one hour after dawn and continued until around 10 PM. An index of fullness of 2.4–2.5 corresponded to the complete satiation of the tunas. Bayliff (1980) reports that bigeye feed during both the day and night, as they are caught at the surface during the day by pole and line and purse seine, and during the day and night by longline. Kume and Morita (1966) state that about 15% of the bigeye caught in the northwestern Pacific are taken by night-time longlining.

Theories of chemoreception, mechanoreception and electrodetection of prey have been put forward by Sund *et al.* (1981). McPherson (1991) reports that bigeye in the Coral sea fed on aggregations of *Diaphus* sp. as they moved into shallow surface layers with the onset of darkness. His observations indicate that feeding activity peaks during the night, as *Diaphus* sp. has decomposed in their stomachs by dawn.

3.3 Niche-sharing

King and Ikehara (1956), Juhl (1955) and Koga (1958) found no significant preferences in the food spectra of bigeye, yellowfin, albacore and the marlins. Grudinin (1989a) thought that the ecological niches of the bigeye and yellowfin tunas overlapped significantly.

However, Watanabe (1958) and Talbot and Penrith (1963) held the view that the composition of the bigeye's diet differed markedly from that of the yellowfin. Kornilova (1980) recorded the diets of the bigeye and the yellowfin tunas in different parts of the equatorial waters of the Indian Ocean. According to him, the index of food similarity of the two tunas is

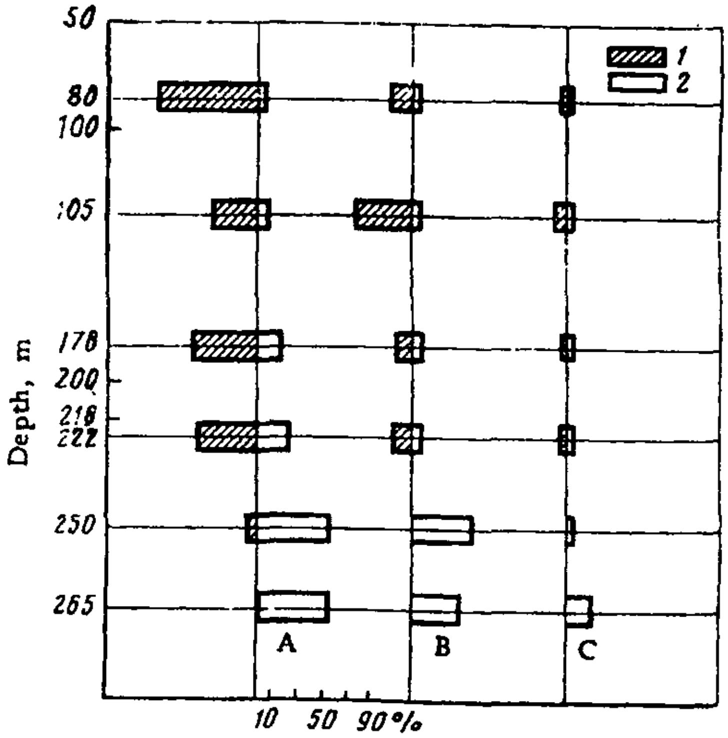


Figure 6. Consumption of food organisms at different depths by yellowfin and bigeye tunas in the Indian Ocean.

(1) yellowfin tuna
(2) bigeye tuna

A: fishes
B: cephalopods
C: crustaceans

(from Korniliva 1980)

small because they consume different species and different sizes of organisms. The feeding interrelationships of the two species are complementary due to their feeding at different depths (Fig. 6). Some other authors also give information on the separation of ecological niches of the yellowfin and bigeye tunas (Solov'yev 1970; Ivshin *et al.* 1971; Borodulina 1974 and Osipov 1977). Solov'yev (1970) suggests that the most favoured depth range for feeding bigeye tuna is 218–265 m, from where the largest bigeye catches are recorded.

3.4 Predation

Hooked tunas are commonly attacked by sharks, false killer whales and marlin. Although killer whale attacks are not as prevalent as shark attacks, they can affect the catch. Tuna are said to aggregate when chased by killer whales, and fishermen often experience a good catch before a killer whale is sighted (author's note). Talbot and Penrith (1963) noted that in South African waters, potential predators were the Mako shark (*Isurus glaucus*) and black marlin (*Makaira indica*). Collette and Nauen (1983) report that generally the main predators of bigeye tuna are large billfish and toothed whales.

4 Sex Ratio

In almost all relevant studies, there were proportionally more males than females. Mimura *et al.* (1963) stated that in the Indian Ocean as a whole, this was the case, not only in all the size groups observed, but most markedly in the larger individuals. Over 75% of the fish over 170 cm long were males, as observed in the Pacific Ocean by Kume and Joseph (1966). Kataoka (1957) and Stequert and Marsac (1989) also found a higher proportion of males in their studies.

5 Maturity and Spawning

5.1 Distribution and seasonal availability of mature fish

The maturity and spawning of bigeye were investigated by Kikawa (1961, 1962, 1966), Kume and Joseph (1966 and 1969), Kume (1969a, 1969b, 1979), Sakamoto (1969), Shingu *et al.* (1974), Hisada (1979 and 1988), Miyabe and Bayliff (1987), Nikaido *et al.* (1991), McPherson (1992b) and Nakano and Bayliff (1992). Most of these workers identified the geographical regions where the majority of mature fish are caught. In general, mature fish are more common in the equatorial region between 10°N and 10°S.

Kikawa (1961) studied the seasonality of maturation in bigeye from 1951 through to 1960 at 130°E to 110°W, 12°N to 10°S. The main spawning season was from April to September throughout the entire equatorial Pacific except for the eastern area south of the equator (150°–110° W, 0°–10° S) where spawning took place most intensively from January to March. In each size class, there was a marked increase from west to east in the percentage of the population that was spawning. This indicated a higher spawning activity in the eastern Pacific than in the western or central Pacific. Collette and Nauen (1983) report, that in the eastern Pacific, some spawning is recorded between 10°N and 10°S throughout the year, with a peak from April through September in the northern hemisphere and from January through March in the Southern hemisphere.

Nakamura and Yamanaka (1959), Suda (1959, 1962) and Kikawa (unpublished; quoted by Mimura 1963) believed that the bigeye breeds in the equatorial counter-current area. Kume (1979b) noted that in the eastern Pacific Ocean, sexually immature fish occur in cooler waters. Shingu *et al.* (1974) noticed that all areas with a high incidence of mature fish had a sea temperature greater than 24° C. Yabe *et al.* (1958), based on the discovery of bigeye larvae and young in the stomach of tuna and marlins caught in the Pacific and Indian Oceans, concluded that the spawning of bigeye extended from 10°N to 10°S. Hisada (1979) noticed mature fish over a fairly wide range, but predominately at 4°–8°N, 110°–160°W and 4°–10°S, 110°–160°W. There seems to be a close relationship between the maturity of bigeye tuna and the water temperature of their habitat, with the mature fish apparently increasing in proportion to the degree of vertical coverage by warmer water (at least over 24°C).

Martinez and Bohm (1983) report from the eastern Pacific Ocean that the bigeye spawn from January to March near the oceanic islands. Nakano and Bayliff (1992), after studying over six thousand fishes from the eastern Pacific Ocean, found that the incidence of mature fish was high in the region between 20°N and 10°S throughout the year. They found no mature fish to the east of 100°W.

Hisada (1979) observed mature fish from a fairly wide area, but predominantly the area enclosed by 4°–8°N, 110°–160°W and 4°–8°S, 110°–160°W. The fish east of 160°W and west of 110°W were mainly immature.

Observations by several authors indicate that the Indian Ocean bigeye spawns in a wide area 6°N to 10°S from east to west, at least from January to March. Hisada (1988) analysed the size-at-first-maturity of the fish caught in the Coral Sea between October and December. He found that, of the fish less than 100 cm in length caught by handline, 81% were in the maturing stage, but only 3% were mature. Of the fish less than 100 cm caught by longline in this area, about 88% were immature, with a gonad index less than 1.0. Of the total handline catch, only 12% were mature; of the total longline catch around 5% were mature.

5.2 Size at maturity

Kikawa (1957 and 1961) studied the percentage of mature fish in the population of bigeye tuna. The minimum size for the ripe stage was estimated at 101–105 cm for the males and 91–95 cm for the females. Based on this, he arrived at 100 cm as the length with potential to be sexually mature. Yuen (1955) recorded the range of 14 to 20 kg weight as being able to attain sexual maturity. Kume (1962) recorded the minimum size for spawning as 92 cm in fork length, while Kume and Joseph (1966) estimated that bigeye in the eastern Pacific reached maturity at 100 to 130 cm. Solov'yev (1970) suggested that the bigeye matured at three years old, which, he calculated, corresponded to an average length of 67 cm. McPherson (1988b), in the Coral Sea, noted mature fish as small as 100 cm long.

5.3 Spawning periodicity

Yuen (1955) found the residual eggs of Pacific bigeye in the early resorption stage mixed with developing eggs in the mature and late mature stages. This was an indication of at least two spawning spurts in quick succession. It was not clear whether the fish discharged the eggs at the surface or in the midlayer.

From December to February in tropical areas, Goldberg and Herring-Dyal (1981) saw no typical increase in oocyte size with a concomitant appearance of vacuoles (which usually appear 8–10 weeks before spawning). This suggests spawning does not begin before April.

McPherson (1998a,b) indicates that, in the Coral Sea, spawning occurs between 02:00 and 05:00h.

Nikaido *et al.* (1991) studied the time of spawning in bigeye from two locations: 12°–14°S, 109°–115°E from January to March, and 11°–13°N, 163°–176°W (offshore to the south-west of Hawaii) from May to June. The gonad indices, mean diameter of the most advanced egg group as well as post-ovulatory follicles and maturation stages of ovaries determined by histological examination, indicated that spawning took place from around 14:00 to midnight in both areas and that the degeneration of post-ovulatory follicles took about a day. Females with post-ovulatory follicles accounted for more than 90% of the mature females. He concluded that the same fish spawned nearly every day, although the duration of the spawning period could not be ascertained because the same fish could not be sampled twice.

5.4 Maturity stages

Kume (1962) describes the stages of ovarian maturity of the bigeye tuna as follows:

I	Immature	eggs not visible to the naked eye
II	Maturing	ovary rather enlarged and eggs visible to the naked eye
III	Maturing	ovary enlarged and filled with eggs, but (ripening) transparent eggs not present
IV	Ripe	transparent eggs, each of which has an oil globule
V	Spent	ovary becomes shrunken and lumen of the ovary empty; outer membrane of ovary thin; occasionally remnant eggs in lumen.

Descriptions of Indian Ocean bigeye tuna eggs are given by Kikawa (1953) and Yeun (1955) and of Pacific bigeye by Kume (1962). The mean egg diameter of the most advanced eggs ranged from 0.81 to 1.08 mm. McPherson (1992b) also provides a table of maturity stages with the egg diameter of the final hydration stage ranging from 0.8–1.3 with a mean of 1.125 mm.

5.5 GSI and fecundity

Following Kikawa (1961 and 1966), generally fish with gonad indices of 3.1 and above (GI= Wo/L3 X 103: Wo = weight of ovary, L = fork length in cm) are considered to be mature. Sakamoto (1969) classified the bigeye with a gonad index less than 1.0 as non-mature fish and the ones with a gonad index of 1.1–3.0 as maturing fish. The smallest fish with gonad indices of 3.1 and above were in the 71–80 cm size class in Nakano and Bayliff's (1992) study. The highest gonad index they recorded was 19.27 for a 164 cm fish with gonads weighing 8500 g. The GSI of the mature ovaries ranged from 2.5 to 10.5 for fish between 111 and 163 cm fork length.

The relationship between fork length (X cm) and the number of eggs spawned per day (Y) was estimated by Nikaido *et al.* (1991):

$Y = 0.0058\ X^{3.994}$: (fishes from waters off Java) and
$Y = 0.0018\ X^{4.175}$: (fishes from south-west offshore of Hawaii)

The number of eggs spawned per day varied from 0.4×10^6 (100 cm fork length) to 5.9×10^6 (180 cm fork length). Yuen (1955) observed that the number of eggs per spawning ranged from 2.9 to 6.3 million for fish weighing between 39 and 109 kg, with wide variations between fish of the same size. He also described that there was evidence of more than one spawning per year. Martinez and Bohm (1983) also observed that the species spawns more than once a year.

5.6 Artificial spawning and embryonic development

Kume (1962) conducted source spawning of longline caught bigeye tuna in the Indian Ocean. Eggs and sperm were stripped from mature fish and fertilised in glass bottles. The eggs were buoyant, transparent spheres with a single oil globule. The diameter of the eggs ranged from 1.03 to 1.08mm and those with oil globules from 0.23 to 0.24 mm. After fertilisation a blastodermal cap formed, and the first cleavage took place within 40 minutes of fertilisation. At intervals of 15 minutes, first, second, third, fourth and fifth cleavages occurred and attained morula stage within 150 minutes. In six hours, an embryonic shield was formed and within eight hours of fertilisation, the embryo was well differentiated. By that time most of the eggs ceased to develop, turned white and sank to the bottom. Hatching began 21 h after fertilisation and was completed in 30 minutes (Fig. 7a). The larvae were 1.5 mm long. Only two larvae hatched out of three experiments. The larvae floated at the surface with the yolksac upwards. Water temperature during the development ranged from 28.1 to 29.4°C.

Matsumoto (1961, Fig. 7b) and Nishikawa and Rimmer (1987) provide a description of bigeye tuna larvae and list features to discriminate between *Thunnus* species.

6 Length-Weight Relationship

Kume and Shiohama (1964) collected the data on length–weight relationships from three areas of the Pacific. The equations they arrived at were:

Area	
128–170° E, 28°–45° N:	$\log W = -4.9340 + 3.1056 * \log L$
170°E–150°W, 0°–45° N:	$\log W = -4.8273 + 3.0475 * \log L$
120°–170°E, 0°–28° N:	$\log W = -4.5425 + 2.9180 * \log L$

W = weight of fish with gills and viscera removed, L = length in cm

Iverson (1955) estimated the relationship for western pacific bigeye as:
$\log W = -7.1167 + 2.9304 * \log L$: W = weight in lbs; L= total length (mm).

After investigating the bigeye from South African waters, de Jaeger (1963) suggested the following formula for the species:

$W = 1.8172 * 10^{-4} * L^{2.72}$ (males) and $W = 1.2812 * 10^{-4} * L^{2.79}$ (females)
L = length in cm; W = weight in lb

Tankevich (1982) is of the view that the sex does not substantially influence the correlation factor of length and weight. The weight of the females and males of the same length was practically the same. McPherson (1988b) also provides length–weight parameters of Japanese handline-caught fish.

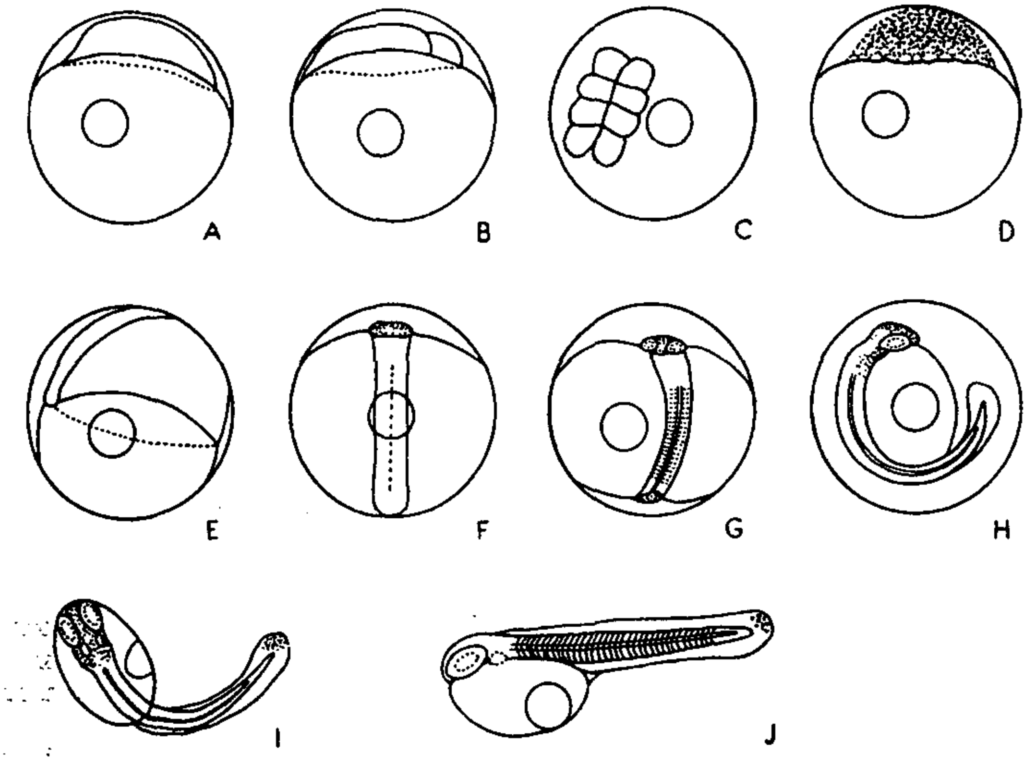


Figure 7a
(from Kume 1962)

Various stages of development of bigeye eggs.
A: 30 minutes after fertilisation. B : 40 minutes after. C. 70 minutes after.
D: 2.5 hours after. E: 6 hours after. F: 6 hours after. G: 14 hours after.
I, J: Newly hatched larva, 1.5 mm in total length.

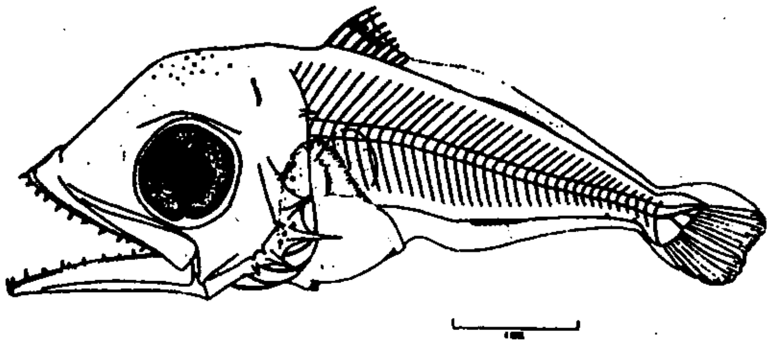


Figure 7b
(from Matsumoto 1961)

Larva of the bigeye

7 Length-frequency Distribution

Data on the length frequencies of bigeye tuna caught by longline in the eastern Pacific Ocean have been collected by Yukinawa (1958), Kikawa (1962), Kume and Joseph (1966, 1969), Miyabe and Bayliff (1987) and Nakano and Bayliff (1992). The length-frequency distribution is also analysed and presented in the IATTC annual reports. The IATTC report (1992) shows that the length-frequency data for the years 1981–87 indicated most of the catch was in the range of 90–170 cm. The length composition varied considerably from year to year. The proportions of smaller fish were greatest during 1982 and 1986, those of larger fish were greatest during 1983 and 1984.

Kume and Shiohama (1965) studied the length-frequency distribution in the equatorial Pacific. The distribution suggested a longitudinal gradient, with small fish in the western Pacific and an increase in size to the eastward. The observations of Kume and Joseph (1966) showed an opposite trend. Hisada (1988) observed some difference between the length-frequency distributions in the Coral Sea bigeye caught by handline and longline. Most of the handline-caught fish were between 80 and 120 cm, with a single mode around 90–100 cm. The longline catch consisted of larger fish: over 120 cm, with modes at 100 and 130 cm. In a study in the Pacific region (IATTC 1992), about half of the surface catch were fish smaller than 100 cm in size, and there was considerable overlap in the lengths of bigeye caught by surface and longline fisheries. Studies by the South Pacific Commission, Itano and Bailey (1991) and Gunn et. al. (1992) provide some length–frequency results for the Coral Sea area where a tagging program was being carried out.

Recent analysis by Nakano and Bayliff (1992) covering 311,064 fish (60–180 cm) gives the length-frequency trend separately for the different FAO areas in the eastern Pacific Ocean. Most of the fish measured were between 80 and 150 cm. The modal progression indicated that the appearance of a mode and its subsequent disappearance were caused by either recruitment or mortality, movement to other places or changes in the fishing mortality. The appearance of modes of fish less than 100 cm in length could be due to recruitment, and a decrease in the number of fish above 140 cm could be due to fishing mortality. Since the fish of the first modal group were prominent in FAO areas 1 and 9, the authors inferred that recruitment to the longline fishery in the eastern Pacific Ocean occurred primarily in those areas. The average weight of the fish in the catch decreased in the area from 1973 to 1979 and thereafter fluctuated between 45 and 60 kg.

Some of the main studies on the length-frequency distribution of bigeye tuna in the Indian Ocean are Kamimura and Honma (1953), Nakamura *et al.* (1953), Iverson (1955), Yukinawa (1958), Yabuta and Yukinawa (1959) and Murphy and Shomura (1972). Mimura and Nakamura (1959) investigated the length-frequency distribution of the species in Javanese waters (Indian Ocean) and found that, in general, there are proportionally fewer of the larger bigeye in the Indian Ocean than the Pacific.

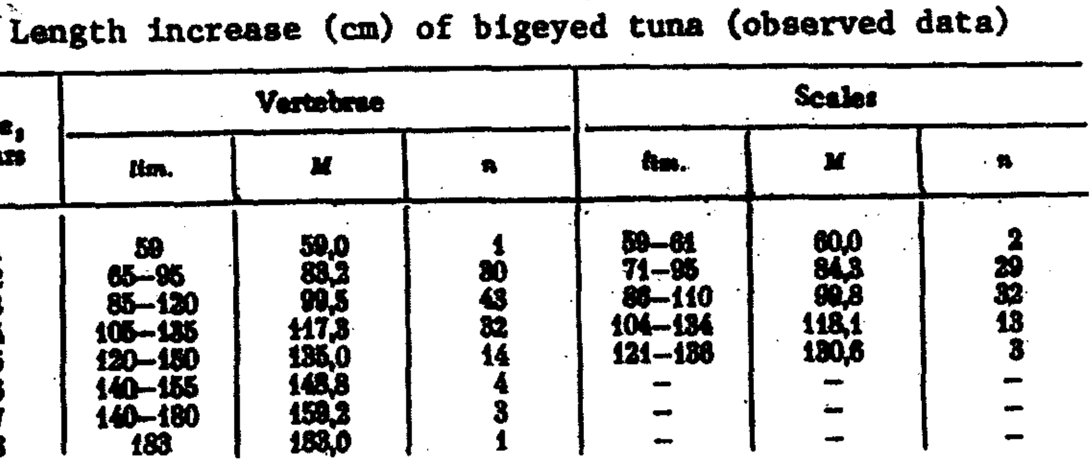
8 Age and Growth

8.1 Growth rate

Pacific Ocean Iverson (1955) used the weight frequency to estimate the annual growth rate. He found the Hawaiian bigeye gains as much as 50 lbs in a year. Kume and Joseph (1966) determined the length of bigeye tuna from the eastern Pacific Ocean as 113 cm at the end of the fish's 12th quarter, 136 cm at the 16th quarter, and 148 cm at the 19th quarter. According to them, males and females grew at the same rate up to 150 cm in length. Nakano and Bayliff (1992) reported the prominent groups in their quarterly length-frequency modal analysis of bigeye in the Pacific Ocean as being between 80 and 100 cm, 100 and 130 cm and 130 and 150 cm. The second and third groups indicated growth rates of about 25 and 20 cm respectively per year, these values are in agreement with those suggested by Kume and Joseph (1966).

Indian Ocean Talbot and Penrith (1960) estimated the growth of bigeye tuna from the Cape of Good Hope region in the Indian Ocean to be 30–35 cm per year, depending on modal values in the size frequency. Marcille and Stequert (1976) reported that the growth rates of young bigeye northwest of Madagascar were approximately 18 cm/year, as the bigeye measured at 51 cm in February reached 60 cm by September. Tankevich (1982) estimated the growth rate by age from scale readings and analysis of bone structure. The results are shown in Table 1.

Table 1 Length (total, cm) at age of bigeye tuna (from Tankevich 1982)



Length increase (cm) of bigeyed tuna (observed data)

Age, years	Vertebrae			Scales		
	lim.	M	n	lim.	M	n
1	59	59,0	1	59–61	60,0	2
2	65–95	83,2	30	71–95	84,3	29
3	85–120	99,5	43	86–110	99,8	32
4	105–135	117,3	32	104–134	118,1	13
5	120–150	135,0	14	121–136	130,6	3
6	140–155	148,8	4	–	–	–
7	140–180	159,2	3	–	–	–
8	183	183,0	1	–	–	–

(*lim*= total length (cm), *M* = mean value, *n* = number of samples)

Tankevich (1982) gives the following growth equation for bigeye tuna from the Indian Ocean based on the von Bertalanfffy growth equation:

$$Lt = 296.53\ [1-e^{-0.094(t-(-1.34))}]$$

$$Wt = 309.85\ [1-e^{-0.117(t-(-1.12))}]\ 3$$

where Lt and Wt are, respectively, length and weight of fish at age t.

Sex-differentiated growth equations for bigeye tuna in three regions of the Indian Ocean are given in table 2. The author concluded that the bigeye originating in the north-east Indian Ocean grew faster than those from the other regions.

Suda (1962) reports the growth increment of two recaptured tagged specimens as 37 cm (81 to 119) in 20 months, and 33 cm (82 to 115) in 18 months.

Yukinawa and Yabuta (1963) examined fish growth in the Pacific Ocean from modal progression and scale rings. They theorised that two rings were formed in a year, one from March to April and the other from September to October. The results are tabulated below:

	Age (years)				
	1	2	3	4	5
Scale readings	44*	77	102		
von Bertalanffy growth equation	40	73	100	122	139
Length-frequency modal progrssion	72	100	121	142	

* lengths are fork length and measured in cm.

Table 2 Length (cm) and weight (kg) at age in bigeye tuna from three regions of the Indian Ocean (calculated by Bertalanffy's equations; from Tankovich 1982).

Region	Sex	Age, years								Maximum value	K*
		1	2	3	4	5	6	7	8		
					Length						
North-eastern	♀♀ ♂♂	– 60,3	81,2 82,4	101,4 101,6	118,5 119,8	132,8 136,9	144,9 153,1	155,0 168,3	– 182,0	209,8 423,0	0,171 0,058
South-eastern	♀♀ ♂♂	– –	79,5 79,3	98,8 98,0	116,3 115,8	132,3 132,8	147,1 148,9	160,7 164,2	– 178,0	317,3 455,9	0,083 0,051
South-western	♀♀ ♂♂	– –	77,0 78,5	99,2 98,8	117,5 117,0	132,8 133,4	144,8 148,0	– 161,1	– –	202,2 274,3	0,195 0,110
					Weight						
North-eastern	♀♀ ♂♂	– 4,1	11,2 11,0	21,9 21,9	34,9 36,8	48,1 54,7	63,5 75,8	84,0 99,0	– 123,0	182,9 605,9	0,178 0,099
South-eastern	♀♀ ♂♂	–	10,1 10,0	19,0 18,8	30,7 30,1	44,3 43,4	58,8 58,4	73,9 74,5	– 91,4	255,7 414,3	0,131 0,093
South-western	♀♀ ♂♂	– –	9,1 9,9	19,0 19,5	31,0 31,6	43,8 45,7	56,5 60,9	– 76,8	– –	142,7 281,2	0,202 0,127

8.2 Asymptotic length

Mimura (1963) reports that the largest bigeye recorded was 183 cm; it was caught in the Indian Ocean by researchers from the Nankai Regional Fish Research Laboratory. However, some laboratories have recorded fish up to 197 cm. The record for the species is 239 cm. The Australian Fishing Zone

Observer Program reported a bigeye tuna of 187 cm in the south–east Indian Ocean during 1993 (author's note). Talbot and Penrith (1960) report fish up to 188.5 cm in fork length from waters off South Africa. Yukinawa and Yabuta (1963) estimated the asymptotic length from Walford plots as 214.9 cm.

8.3 Longevity

On the longevity of the bigeye tuna, Iverson (1955) wrote: "Judging from the slope of growth curves and the maximum size attained by Hawaiian bigeye, about six or seven years would seem to be a fair estimate of the life span of the species in Hawaii". Also refer to section 8.1.

9 Trends in Fisheries

Nakano and Bayliff (1992) and the IATTC (1992) give the most recent accounts of the bigeye tuna fishery in the Pacific Ocean. The bigeye fishery became significant when the Japanese longline fishery became involved in the mid- 1950s. Thereafter, the fishing effort continued to rise to reach about 190 million hooks by 1987 (Fig. 8). In spite of the substantial augmentation of the fishing effort, the CPUE did not change significantly from one fish per 100 hooks. Possibly the introduction of deep-set longlines in the late 1970s kept the CPUE at the same level while the population decreased (Nakano and Bayliff 1992).

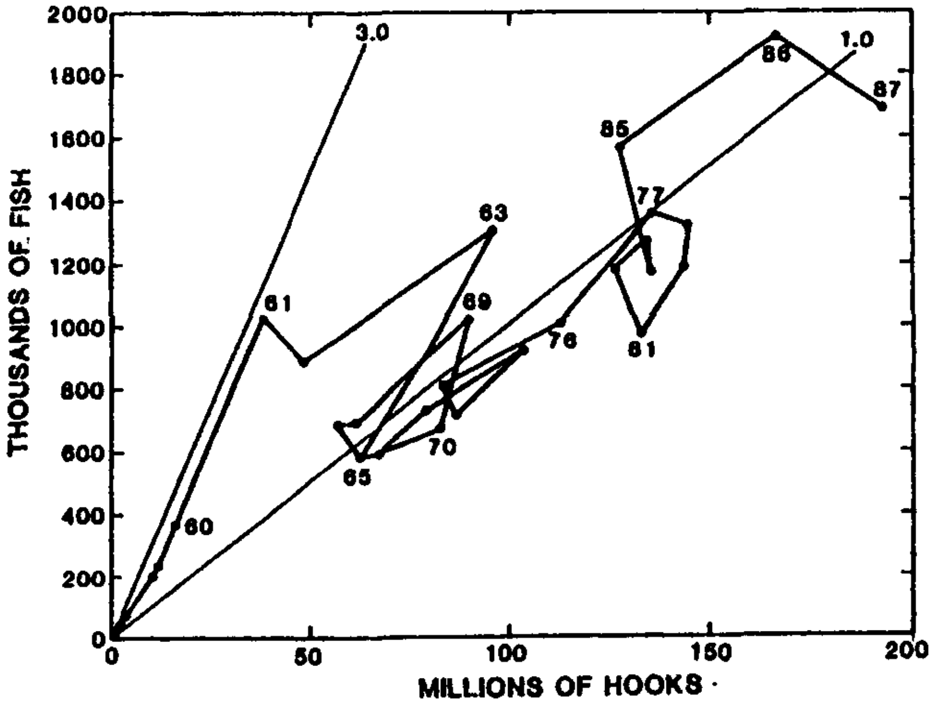


Figure 8 Relationship between estimated longline catch-and-effort for bigeye tuna in FAO areas 2–5 and 8–9 of the Pacific Ocean for 1985–1987 (From Nakano 1992)

Punsly and Nakano (1992) used generalised linear models to eliminate the effects of area, season and depths of fishing on the hook rates of bigeye so the annual effects could be better evaluated. The surface fishery in the eastern Pacific Ocean showed an upward trend during the 1950s and 60s but declined after 1981. The data are reported to be limited in accuracy, as fishermen often report surface bigeye catches as yellowfin for want of proper identification. Moreover, the surface-caught yellowfin and bigeye tunas received the same price at the canneries (marked as "soft tuna meat") so the fishermen were not encouraged to distinguish between them. The data have become more reliable since the introduction of catch regulations for the yellowfin (IATTC 1992; Itano 1992). Suda and Schaefer (1965), Kume and Schaefer (1966), Kume and Joseph (1966 and 1969), Shingu *et al.* (1974) and Miyabe and Bayliff (1987) have also studied the trend in bigeye fisheries of the region.

IATTC (1992) reports that it was difficult to estimate the coefficient of natural mortality with any degree of confidence, so trial values of 0.4, 0.6, 0.8 and 1.0 were used on an annual basis. The results with lengths–at–entry of 40 cm (2 kg), 60 cm (5 kg), 90 cm (17 kg), 120 cm (40 kg) and 150 cm (76 kg) for annual F values of 0.0 to 1.6 were estimated. In every case, the yield-per-recruit value was least for 150 cm. It appeared that most of the bigeye caught by purse seine and longline had a fishery recruitment size of 60–90 cm and 90–120 cm respectively. The yield-per-recruit at different F and M values for the sizes 40, 60, 90 and 120 cm were determined. In general, at high values of M, the greatest yield-per-recruit was realised at low to intermediate lengths at entry (40, 60 and 90 cm) and at high values of M, the greatest yield-per-recruit was suggested at intermediate lengths (90–120 cm). An M value of 0.4–0.8 for the surface fishery is suggested, though not conclusively proved. The study implied that the average length at entry to the surface fishery is less than the optimum size for highest yield, while for the longline fishery, the average size at entry was greater than the optimum length. Further studies are suggested for confirmation of these results.

The preliminary results of tagging studies do not prove conclusively that the bigeye in the eastern Pacific Ocean is a discrete population. From the recovery of tagged specimens, it appears that the bigeye does not travel as far as other principal market species of tuna. The validity of these observation is not totally reliable in view of the small number of returns. The uncertainty about the amount of interchange of fish between the area in question and the neighbouring area also might affect the interpretation of the results (Nakano and Bayliff 1992). Nevertheless, from the effort and catch data, it has not been demonstrated that there is a need at present for strict conservation measures for the bigeye in the eastern Pacific Ocean (IATTC 1992).

Investigations by Japanese researchers suggest that, for the longline fishery alone, the MSY is around 127 000 tonnes in the Pacific Ocean (IPTP 1984). After a substantial increase in catch after longlines were introduced in the late 1970s and '80s, the present level of exploitation is around this rate.

Virtual population analysis on the Indian Ocean bigeye population was conducted by Miyabe (1988) based on Japanese (1952–85), Taiwanese (1967–1985) and Korean (1975–1982) longline fisheries. He demonstrated that the Indian bigeye stock was still in good condition, though close monitoring was required because of the high level of exploitation.

BIBLIOGRAPHY

1. Alverson, F. G. and Peterson, C. L. (1963). Synopsis of the biological data on bigeye tuna *Parathunnus sibi* (Temminck and Schlegel) 1844. *FAO Fish. Rep.* **6** (2): 482–514.

2. Anderson, R. C. and Hafiz, A. (1988). A summary of information on the fisheries for billfishes, seerfishes and tunas other than skipjack and yellowfin, in the Maldives: *Studies of the tuna resource in the EEZs of Sri Lanka and Maldives*: 68–78.

3. Anon. (1964). Proceedings of the symposium on Scombroid fishes, held at Mandapam camp from January 12 to 15, 1962. Mar. Biol. Assoc. India, 3 vols, 1236 pp.

4. Anon. (1980). State of selected stocks of tuna and billfish in the Pacific and Indian oceans. Summary report of the Workshop on Assessment of Selected Tunas and Billfish Stocks in the Pacific and Indian Oceans, Shimizu, Japan, 13–22 June, 1979, National Marine Service, South-west Fisheries Center, Honolulu Laboratory, and Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan. *FAO Fish. Tech. Pap.* (200); 89 pp.

5. Anon. (1982). Trials show Coral Sea tuna fishery has potential. *Aust. Fish*, **41** (2): 7.

6. Anon. (1987). Bigeye data catalog. *Collect. Vol. Sci. Pap. ICCAT/RECL Doc. Sci. CICTA/Collect. Doc. CIENT. CICAA* **26** (1): 68–82.

7. Anon. (1989). Conference for the adoption of a draft agreement for the establishment of an Indian Ocean Tuna Commission and existing arrangements for tuna management, 3–7 April 1989. Doc. No. IOTC/89/Inf. 5.

8. Anon. (1991) A proposal for a large-scale tuna tagging programme in the Indian Ocean (1st draft). (SEAC/90/23). Collective volume of working documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November, 1990: 173–177.

9. Ariz, J., Delgado de Molina, A. and Santana, J. C. (1987). Spanish fisheries of bigeye (*Thunnus obesus* Lowe, 1839). *Collect. Vol. Sci. Pap. ICCAT* **26** (1): 116–126.

10. Au, D. W. K. (1985). Species composition in the Japanese longline fishery off the southern and eastern United States. *Collect. Vol. Sci. Pap. ICCAT* **23** (2): 376–385.

11. Bahar, S. (1985). Study on deep tuna long line for bigeye tuna (*Thunnus obesus*) fishing. A study on the use of deep tuna longline by employing various number of branchlines per basket to catch bigeye tuna (*Thunnus obesus*) in Banda Sea. *Mar. Fish. Res. Rep.* **32**: 39–51.

12. Bahar, S. (1987). A study on the deep longlining for bigeye tuna (*Thunnus obesus*) in the waters west off Sumatra. *J. Mar. Fish. Res*, **40**: 51–63.

13. Bahar, S. (1991). Potential area for fishing ground of bigeye tuna (*Thunnus obesus*) in the southern Java and Nusatenggara waters (SEAC/90/13). Collective volume of working documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November, 1990: 87–93.

14. Bahar, S and Gafa, B. (1988). Study on the operation of tuna long line for catching fresh tuna in Indonesia. Collective volume of working documents. Vol. 3. Consultation on the stock assessment of tunas in the Indian Ocean held in Mauritius, 22–27 June, 1988: 324–333.

15. Bard, F. X. and Kothias, J. B. A. (1986). Results of tagging studies of tropical tuna migrations in the Ivory Coast (1983–1984). *Collect. Vol. Sci. Pap. ICCAT* **25**: 30–36.

16. Bard, F. X. and Pezennec, O. (1991). Analysis of the stomach contents of the yellowfin (*Thunnus albacares*) fished by purse seines in the Gulf of Guinea. *Collect. Vol. Sci. Pap. ICCAT* **35** (1): 1–7.

17. Barret, I. and Kume, S. (1965). Observations on the bigeye caught in the surface tuna fishery in the eastern Pacific Ocean 1951–1964. *Calif. Fish Game* **51** (4): 252–258.

18. Bartlett, S. E. and Davidson, W. S. (1991). Identification of *Thunnus* tuna species by the polymerase chain reaction and direct sequence analysis of their mitochondrial cytochrome b genes. *Can. J. Fish. Aquat. Sci.* **48** (2): 309–317.

19. Barut, N. C. and Arce, F. M. (1990). Skipjack and tuna tagging in the Philippines (Progress Report). (SEAC/90/25). Collective volume of working documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November, 1990: 193–197.

20. Bayliff, W. H. (1973). Materials and methods for tagging purse seine and bait boat caught tunas. *Bull. IATTC/Bol. CIAT* **15**(36): 463–503.

21. Bayliff, W. H. (1980). Synopses of biological data on eight species of scombrids. *IATTC Special Report* **2**: 259 pp.

22. Bayliff, W. H. (1981). Memorandum to the members of the FAO Working Party on the tuna and the billfish tagging in the Pacific and Indian oceans, July 1, 1981 (mimeo).

23. Bayliff, W. H. and Holland, K. N. (1986). Materials and methods for tagging tuna and billfishes, recovering tags and handling recapture data. *FAO Fish. Tech. Pap.* 279: 36p.

24. Beeb, W. and Tee-Van, J. (1936). Systematic notes on Bermudan and West Indian tunas of the genera *Parathunnus* and *Neothunnus*. *Zoologica, N.Y.* **21** (3): 177–194.

25. Belevich, R. R. (1970). The circulation and zones of possible commercial concentrations of tunas. *Rybn. Kh-vo* **1**.

26. Bertolino, A. R. and Hoey, J. J. (1987). Descriptive review of the U. S. pelagic longline fishery data system, 1986 to 1987. *Collect. Vol. Sci. Pap. ICCAT* **30** (1): 68–76.

27. Blackburn, M. (1965). Oceanography and ecology of tunas. *Oceanogr. Mar. Biol. Ann. Rev.* **3**: 299–322.

28. Blackburn, M. (1969). Conditions related to upwelling which determine the distribution of tropical tunas off western Baja California. *Fish. Bull. U. S.* **68**: 147–176.

29. Blunt, Jr. C. E. (1960). Observations on the food habit of longline caught bigeye and yellowfin tuna from the tropical eastern Pacific 1956–63. *Calif. Fish Game* **46** (1): 69–80.

30. Borodulina, O. D. (1974). The bigeye and yellowfin tunas (*Thunnus obesus, Th. albacares*) in the tropic system of oceanic pelagic zone. Thesis, Moscow Univ.

31. Brock, U. E. (1949). A preliminary report on the *Parathunnus sibi* in Hawaiian waters and key to the tunas and tuna-like fishes of Hawaii. *Pacific Sci.* **3** (3): 271–277.

32. Bruce, B. C. and Gibbs, R. H. jr. (1963). A preliminary review of the fishes of Scombridae. *FAO Fish. Rep.*, **6** (1): 23–32.

33. Burke, W. T. and Christy, F.T. (1990). Options for the management of tuna fisheries in the Indian Ocean. *FAO Fish. Tech. Pap.* **315**; 73 pp.

34. Bush, G. M. and Thieleke, J. R. (1983). Total mercury content in yellowfin and bigeye tuna. *Bull. Environ. Contam. Toxicol.* **30** (3): 291–297.

35. Bushnell, P. G., Brill, R. W. and Bourke, R. E. (1990). Cardiorespiratory responses of skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), and bigeye tuna (*Thunnus obesus*) to acute reductions of ambient oxygen. *Can. J. Zool.* **68** (9): 1857–1865.

36. Calkins, T. P. (1980). Synopsis of biological data on the bigeye tuna, *Thunnus obesus* (Lowe, 1839), in the Pacific Ocean. In: Bayliff, W. H. (ed.). Synopsis of the biological data on eight species of scombrids: *Spec. Rep. IATTC* **2**: 2213–259.

37. Cayre, P. and Diouf, T. (1987). Exploitation of the bigeye (*Thunnus obesus*) in the northeastern tropical Atlantic from 1969 to 1985 in relation to the fishing surface temperature. *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 127–140.

38. Cayre, P. and Marsac, F. (1991). Report and preliminary results of the tagging programme of natural drift logs in the tuna purse seine fishery area of the western Indian Ocean. (SEAC/90/18). Collective volume of working documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November 1990: 125–133.

39. Cayre, P., Norungee, D. and Begue, C. (1991). Catches and landings of tuna in Mauritius from 1987 to 1989 and description of the 1989 Mauritian purse seine fishery (distribution and size composition of the catches). (TWS/90/60). Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 283–292.

40. Cayre, P. and Ramcharrun, B. (1991). Results of the tagging operations conducted within the Regional Tuna Project (Indian Ocean Commission) in 1988 and 1989 (TWS/90/61). Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 261–265.

41. Chabanne, J. (1980). Tuna fishery in the exclusive economic zone of French Polynesia during 1979. *Notes Doc. Oceanogr. Cent. Noumea Orstom* (80/22); 21 pp.

42. Chabanne, J. and James, P. (1980). Japanese longlining in the exclusive economic zone of the French Polynesia (October 1979 to April 1980). *Notes Doc. Oceanogr. Cent. Noumea Orstom,* (80/21); 23 pp.

43. Chiche, J. L. (1989). Contribution to the study of tunas: Albacore (*Thunnus albacares*, Bonnaterre, 1788), germon (*Thunnus alalunga*, Jordan, 1913), patudo (*Thunnus obesus*, Lowe, 1839). Ecole Nationale Veterinaire, Toulouse, France; 90 pp.

44. Cho, K. D., Kim, Y. A., Prak, S. W., Kim, J. C. and Park, M. S. (1987). Relationship between the catches of tuna and oceanographic conditions in the south-east Pacific. *Bull. Korean Fish Soc.* **20** (4): 360–369.

45. Chow Chau-Jen, Ochiai, Y., Watabe, S. and Hashimoto, K. (1988). Effect of freezing and thawing on the discoloration of tuna meat. *Nippon Suisan Gakkaishi/ Bull. Jpn. Soc. Sci. Fish.* **54** (4): 639–648.

46. Collette, B. B. (1962). A preliminary review of the tunas of the genus *Thunnus*. In: Pacific tuna biology conference, August 14–17, 1961, Honolulu. *U. S. Fish. Wildlife Serv., Spec. Sci. Rep.* **415**; 24 pp.

47. Collette, B. B. and Nauen, C. E. (1983). FAO species catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. *FAO Fish. Synop.* (125), Vol. 2. 137p.

48. Compean, G. (1988). Tuna reproduction zones in Mexican waters. *Panorama Atunero* **3**: 10–12.

49. Cort, J. L. (1987). Tagging of tuna in the Cantabrican sea (North Spain). *Collect. Vol. Sci. Pap. ICCAT* **26** (2): 254–256.

50. Cort, J. L., Rey, J. C. and Lavin, A. (1981). Tuna tagging in the Bay of Biscay during the summer of 1980. *Collect. Vol. Sci. Pap. ICCAT* **15**(2): 302–304.

51. Cramer, J. L., Nakamura, R. M., Dizon, A. E. and Idehara, W. N. (1981). Burnt tuna: conditions leading to rapid deterioration in the quality of raw tuna. *Mar. Fish. Rev.* **43** (6): 12–16.

52 de Jaeger, B. (1963). Synopsis of biological data on bluefin tuna *Thunnus thynnus orientalis* (Temminck and Schlegel) 1842, longfin tuna *Thunnus alalunga* (Bonnaterre) 1788, yellowfin tuna *Thunnus albacares* (Bonnaterre) 1788 and bigeye tuna *Thunnus obesus* (Lowe) 1839 (South Africa). *FAO, Fish. Rep.* **6** (2): 588–607

53. Delgado de Molina, A and Santana, J. C. (1986). Age and growth determination of bigeye tuna (*Thunnus obesus*, Lowe 1839) caught in the Canary Islands. *Collect. Vol. Sci. Pap. ICCAT* **25**: 130–137.

54. Diouf, T. (1985). Method used in Senegal for the estimation of statistics of Task I and II concerning major tuna species (albacore, skipjack and bigeye) in the eastern Atlantic. *Collect. Vol. Sci. Pap. ICCAT* **23** (2): 426–432.

55. Diouf, T. (1991). The fishery and research concerning the deep-sea stocks in Senegal during 1989. *Collect. Vol. Sci. Pap. ICCAT* **35** (1): 199–201.

56. Dizon, A. E. (1977). Effect of dissolved oxygen concentration and salinity on swimming speed of two species of tunas. *Fish. Bull. NOAA* **75**: 458–466.

57. Dotson, R. C and Graves, J. E. (1984). Biochemical identification of a bluefin tuna establishes a new California size record. *Calf. Fish Game* **70** (1): 62–64.

58. Dubad, O. (1991). The status of tuna in Somalia. (TWS/90/40). Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 465–471.

59. Eslava de Gonzalez, N. and Gaertner, D. (1991). The vertical distribution of tunas and billfish and the abundance in the Caribbean Sea. *Collect. Vol. Sci. Pap. ICCAT* **32** (1): 39–47.

60. Eslava de Gonzalez, N. and Salazar, H. (1990). Comparison of catch data from official statistics with those obtained from sampling by the tuna longline fishing fleet during 1988. *Collect. Vol. Sci. Pap. ICCAT.* **32** (1): 48–55.

61. FAO (1963). Proceedings of the world scientific meeting on the biology of tunas and related species. *FAO Fish. Rep.* **6**.

62. FAO (1975). Report on the third joint meeting of the IPFC, Special Committee on the Management of Indo–Pacific Tuna, third Session, and the Indian Ocean Fisheries Commission, Committee on Management of Indian Ocean Tuna, Fourth Session, Mombasa, Kenya, 18–19 July 1975. *FAO Fish. Rep.* 175; 47 pp.

63. FAO (1980). State of selected stocks of tuna and billfishes in the Indian and Pacific oceans. *FAO Fish. Tech. Pap.* **200**; 89 pp.

64. FAO (1981). Atlas of the living resources of the seas. *FAO Fish. Ser.* **15**; 93 pp.

65. FAO (1990a). Report of the 11th session of the Indian Ocean Fishery Commission Committee for the Management of Indian Ocean Tuna, Bangkok, 9–12 July 1990. *FAO Fish. Rep.* 439.

66. FAO (1990b). Report of the Expert Consultation on Stock Assessment of Tuna in the Indian Ocean, Bangkok, 2–6 July 1990. *IPTP Series,* IPTP/90/Gen/18.

67. Fishery Agency of Japan (1980). Vertical distribution of tunas and billfishes in the western equatorial Pacific Ocean, October–December 1979. Report on 1979 research cruise of the R/V *Shoyo Maru*. Fishery Agency of Japan, Research Division; 57 pp.

68. Fishery Agency of Japan (1981). Vertical distribution of tunas and billfishes in the western equatorial Pacific Ocean, December 1980–February 1981. Report on the 1980–81 research cruise of the R/V *Shoyo Maru.* Fishery Agency of Japan, Research Division; 58 pp.

69. Fishery Agency of Japan (1985). Report on 1984 research cruise of the R/V *Shoya Maru.* Distribution of tunas and billfishes and their larvae in the eastern Indian Ocean, January–March 1985; 105 pp

70. Fishery Agency of Japan (1987). Report on 1986 research cruise of the R/V Shoya Maru. Distribution of tunas and bill fishes larvae and oceanographic observation in the eastern Indian Ocean, January–March 1987; 100 pp.

71. Fernandez, A. M. (1985). Methods used by Spain to prepare ICCAT Task I and II statistics on tropical tuna fishery. *Collect. Vol. Sci. Pap. ICCAT* **23** (2): 414–418.

72. Fonteneau, A. (1987). Specific catch composition of small size tunas (yellowfin, bigeye and skipjack) by purse seiners and baitboats in the area of Three Points Cape. *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 210–215.

73. Fowler, H. W. (1936). The marine fishes of West Africa. *Bull. Am. Mus. Nat. Hist.* **70** (2): 607–1493.

74. Frade, F. (1960). Le lethon patudo *Parathunnus obesus* (Lowe) et sa peche. *Estud. Yta. Invest. Ultramar* **69**: 74 pp.

75. Frazer-Brunner, A. (1950). On the fishes of the family Scombridae. *Ann. Mag. Nat. Hist.* **12** (3): 131–163.

76. Fujii, I. and Okamoto, H. (1971). On the shape of tuna longline gear under water and catches of tuna and billfishes. *Showa 44 nendo Mie-ken Hamajima Sushi Jigyo Hokuko:* 45–103.

77. Fujii, Y. (1963a). Biochemical studies on the races of tuna. XII. The antigen–antibody reaction between tuna testis DNA and antiserum. *Rep. Nankai Reg. Fish. Res. Lab.* **17**: 53–67.

78. Fujii, Y. (1963b). Biochemical studies on the races of tuna. XIII. Immunological studies of DNA of tuna testis by technique of complement fixation. *Rep. Nankai Reg. Fish. Res. Lab.* **17**: 69–78.

79. Fujii, Y. and Higasa, S. (1959). Biochemical studies on the races of tuna. III. Antigen properties of DNA of tuna. *Rep. Nankai Reg. Fish. Res. Lab.* **11**: 7–16.

80. Fujii, Y., Mimoto, K. and Higasa, S. (1959). Biochemical studies on the races of tuna. II. The base composition of DNA of yellowfin and bigeye tuna. *Rep. Nankai Reg. Fish. Res. Lab.* **11**: 1–6.

81. Fujii, Y., Mimoto, K. and Higasa, S. (1960a). Biochemical studies on the races of tuna. IV. Several investigations on the treatment of samples in the determination of the base composition of testes DNA. Part 1. *Rep. Nankai Reg. Fish. Res. Lab.*, **12**: 14–22.

82. Fujii, Y., Mimoto, K. and Higasa, S. (1960b). Biochemical studies on the races of tuna. V. The base composition of DNA of tuna. Part 1. *Rep. Nankai Reg. Fish. Res. Lab.* **12**: 23–32.

83. Gaertner, D., Gaertner-Medina, M., Castillo, C. and Martinez, L. (1988). Installation of a logbook system for the Venezuelan tuna fishery and analysis of preliminary results. *Collect. Vol. Sci. Pap. ICCAT.* **28**: 130–140.

84. Gaikov, V. Z. and Fedoseev, YuP (1986a). The influence of temperature and biotic factors on vertical distribution of bigeye tuna (*Thunnus obesus*) in the Atlantic Ocean. *Collect. Vol. Sci. Pap. ICCAT* **25**: 113–118.

85. Gaikov, V. Z. and Fedoseev, YuP (1986b). Comparison between the indices of stomach fullness of living and distressed specimens of bigeye tuna. *Collect. Vol. Sci. Pap. ICCAT* **25**:110–112.

86. Goldberg, S. R. and Herring-Dyal, H. (1981). Histological gonad analyses of late summer–early winter collections of bigeye tuna, *Thunnus obesus*, and yellowfin tuna, *Thunnus albacares*, from the northwest Atlantic and the Gulf of Mexico. *NOAA Tech. Memo.*: 11 pp.

87. Gong, Y. and Lee, J. U. (1983). Report on the Korean dart tagging experiments for ISYP during 1981–82. *Coll. Vol. Sci. Pap.ICCAT* **18** (1): 183–186.

88. Gong, Y., Lee, J. U. and Kim, Y. S. (1987). Fishing efficiency of Korean deep longline gear and vertical distribution of tunas in the Indian Ocean. Collective volume of working documents presented at the Expert Consultation on Stock Assessment of Tunas in the Indian Ocean held at Colombo, 4–8 December, 1986: 367–372.

89. Gong Y., Lee J. U., Kim, Y. S. and Yang, W. S. (1989). Fishing efficiency of Korean regular and deep longline gears and vertical distribution of tunas in the Indian Ocean. *Bull. Korean Fish. Soc.* **22** (2): 86–94.

90. Gong, Y., Lee, J. U. and Yang, W. S. (1981). Review of the catch composition by species caught by Korean baitboat fishery based in Tema for 1977–1979. *Collect. Vol. Sci. Pap. ICCAT* **15**(1): 20–25.

91. Gonzalez Ania, L. V. and Zarate Villafranco, A. (1988). Tuna fishing in the Gulf of Mexico. *Panorama Atunero* **2**: 26–29.

92. Gouveia, L. (1986). Length composition of bigeye tuna caught by Madeiran baitboat fishery, 1979–1984. *Collect. Vol. Sci. Pap. ICCAT* **25**: 119–129.

93. Gouveia, L. (1989). Comments on bigeye tuna fishery in Madeira, 1979–1987. *Collect. Vol. Sci. Pap. ICCAT* **30** (1): 118–130.

94. Green, R. (1988). An annotated bibliography of Japanese literature on the tuna (excluding southern bluefin tuna) and billfishes of the Coral and Tasman seas. *CSIRO Mar. Lab. Rep.* 199: 24 pp.

95. Grudinin, V. B. (1989a). Some aspects of ecology of yellowfin and bigeye tunas. *Vopr. Ikhtiol* **29** (4): 555–563.

96. Grudunin, V. B. (1989b). On the ecology of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*). *J. Icthyol.* **29** (6): 22–29.

97. Gunn, J., Bailey K., Itano, D., Whitelaw, W. and Davis, T. (1992). Yellowfin, Bigeye and Skipjack tuna tagging in the Coral Sea. Australian Fisheries - June: 22-24.

98. Gunther, A. (1840). Catalogue of the Acanthopterygian fishes in the British museum. 2 Vols. Taylor and Francis, London, 548 pp.

99. Hafiz, A. (1991). The Maldivian tuna fishery: an update. (TWS/90/12). Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 343–350.

100. Hallier, J. P., Mou-Tham, G. and Rivaton, J. (1985). Longlining in the southwest Pacific: Japanese from 1969 to 1980, Taiwanese from 1972 to 1982 and Korean in 1979. *Rapp. Sci. Tech. Cent. Noumea Orstom*, 135.

101. Hampton, J. (1988). Status of tuna fisheries in the western and central Pacific Ocean. Report of the 2nd Southeast Asian Tuna Conference and Meeting of Tuna Research Groups in the Southeast Asian Region, Malaysia, 22–25 August 1988: 187–200.

102. Hanamoto, E. (1974). Fishery oceanography of bigeye tuna. I. Depth of capture by tuna longline gear in the eastern tropical Pacific Ocean. *La mer,* **12** (3): 10–18.

103. Hanamoto, E. (1975). Fishery oceanography of bigeye tuna. II. Thermocline and dissolved oxygen content in relation to tuna longline fishing grounds in the eastern tropical Pacific Ocean. *La mer* **13** (2): 58–79.

104. Hanamoto, E. (1976). Swimming depth of bigeye tuna. *Bull. Jpn. Soc. Fish. Oceanogr.* **29**: 41–44.

105. Hanamoto, E. (1983). Vertical distribution of bigeye tuna. *Bull. Jpn. Soc. Sci. Fish. Oceanogr.* **44**: 126–127.

106. Hanamoto, E. (1986). Distribution of bigeye tuna catch in the Pacific Ocean. *Bull. Jpn. Soc. Fish. Oceanogr.* **51**: 9–15.

107. Hanamoto, E. (1987). Effect of oceanographic environment on bigeye tuna distribution. *Bull. Jpn. Soc. Fish. Oceanogr.* **51** (3): 203–216.

108. Hanamoto, E., Shibata, T and Okui, H. (1982). Some considerations on the vertical distribution particularly of the striped marlin in the Indian Ocean and on the fishing characteristics of the tuna longline gear. *Bull. Kanagawa Prefect. Fish Exp. Stn.* **4**: 17–21.

109. Hashimoto, K. and Watabe, S. (1983). Changes in color and water holding capacity of tuna meat during frozen storage. *Bull. Jpn. Soc. Fish.* **49** (2): 203–206.

110. Hirano, T., Suzuki, T. H. and Suyama, M. (1987). Changes in extractive components of bigeye tuna and Pacific halibut meats by thermal processing at high temperature of F sub(0) values of 8 to 21. *Nippon Suisan Gakkaishi/ Bull. Jpn. Soc. Sci. Fish.* **53** (8): 1457–1461.

111. Hisada, K. (1973). Investigations on tuna hand-line fishing ground and some biological observations on yellowfin and bigeye tunas caught in the north-western Coral Sea. *Far Seas Fish. Res. Lab. Bull.* **8**: 35–69.

112. Hisada, K. (1979). Relationship between water temperature and maturity status of bigeye tuna caught by longline in the central and eastern Pacific Ocean. *Far Seas Fish. Res. Lab. Bull.* **17**: 159–175.

113. Hisada, K. (1988). Investigations of the tuna hand-line fishing grounds and some biological observations on the yellowfin and bigeye tunas caught in the north-western Coral Sea. *CSIRO Mar. Lab. Rep.* **194**: 39 pp. (Translation from Japanese).

114. Holland, K. N., Brill, R. W. and Chang, R. K. C. (1990). Horizontal and vertical movements of yellowfin and bigeye tuna associated with fish aggregating devices. *Fish. Bull.* **88** (3): 493–507.

115. Holland, K. N., Brill, R. W., Chang, K. C., Sibert, J. R. and Fournier, D. A. (1992). Physiological and behavioural thermoregulation in bigeye tuna *(Thynnus obesus)*. *Nature* **358**: 410–411.

116. Holland, K., Brill, R., Ferguson, S., Chang, R. and Yost, R. A. (1985). Small vessel technique for tracking pelagic fish. *Mar. Fish. Rev.* **47** (4): 26–32.

117. Holland, K., Chang, R. and Ferguson, S. (1985). Progress report on tuna tracking. *SPC Fish. Newsl.* **32**: 19–23.

118. Honma, M., Warashina, Y. and Suzuki, Z. (1973). Identification of young yellowfin and bigeye tunas in the western Pacific Ocean. Examination of practical standards based on external characteristics and their reliability in field survey. *Bull. Far Seas Fish. Lab.* **8**: 1–23.

119. Hoogesteger, J. (1988). The potential for offshore fisheries in the St. Helena Exclusive Fishing Zone. Final report on an ODA Resource Assessment Survey 1985–88. ODA; London 185 pp.

120. Honma, M., Hisada, K. and Kanno, S. (1969). Tuna fisheries with the use of pole-and-line and purse seine, and their yellowfin stocks along the west coast of equatorial Africa. *Bull. Far Seas Fish. Res. Lab.* **2**: 85–114.

121. Honma, M. and Yonemori, T. (1985). Manual for storing tuna tagging programme in computer readable form. IPTP/85/WP/13: 19 pp.

122. Hunter, J. R., Arque, W. A., Bayliff, W. H. *et al.* (1986). The dynamics of tuna movement. Evaluation of past and future research. *FAO Fish. Tech. Pap.* **277**: 23–33.

123. IATTC (1938). Annual report of the Inter-American Tropical Tuna Commission 1987. La Jolla, CA (USA); 222 pp.

124. IATTC (1992). Annual report of the Inter-American Tropical Tuna Commission 1990. La Jolla, CA (USA).

125. ICCAT (1988). International Commission for Conservation of Atlantic Tunas. Report for the biennial period 1987–88. Part 2: 1987.

126. ICCAT (1989). International Commission for Conservation of Atlantic Tunas. Report for the biennial period 1988–89. Part 1: 1990.

127. ICCAT (1991). International Commission for Conservation of Atlantic Tunas. Report for the biennial period 1990–91. Part 1: 1990.

128. ICCAT (1992). International Commission for Conservation of Atlantic Tunas. Report for the biennial period 1990–91. Part 2: 1991.

129. Ikuno, Y. and Matsuno, T. (1987). Carotenoids and their metabolism in bigeye tuna *Thunnus obesus*. *Suisan Gakkaishi/ Bull. Jpn. Soc. Sci. Fish.* **53** (10): 1893–1896.

130. IPTP (1983). Manual for collection of historical statistical data on tuna and tuna-like species in the Indo–Pacific region. *IPTP Manual* **1**:

131. IPTP (1984). "Current status of the tuna stock fiscal year 1983. Japan Tuna Research Conference held in Shimizu". Report submitted to the adhoc Workshop on Stock Assessment of Tuna in Indo–Pacific Region, 20–22 August 1984, Jakarta, Indonesia. (TWS/3C).

132–137.
IPTP (1985a–1990a). IPTP data catalogues, 1985–1990. Indo–Pacific Tuna Management Programme, Colombo, Sri Lanka.

138. IPTP (1985b). Report on the preparatory Expert Meeting on Tuna Longline Data for Stock Assessment in the Indian Ocean, Pusan, Republic of Korea, 8–12 April 1985. IPTP/85/GEN/7; 14 pp.

139. IPTP (1985c). Report on the Expert Consultation on the Stock Assessment of Tunas in the Indian Ocean. Colombo, Sri Lanka, 28 November–2 December 1985. IPTP, Colombo; 78 pp.

140. IPTP (1985d). Collective volume of working documents presented at the Expert Consultation of Stock,Assessment of Tunas in the Indian Ocean, held in Colombo, 28 November–2 December 1985. Vol. 1; 364 pp.

141. IPTP (1987b). Collective volume of working documents presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean, held in Colombo, Sri Lanka, 4–8 December 1986. Vol. 2; 374 pp.

142. IPTP (1987c). Report on the Expert Consultation on the Stock Assessment of Tunas in the Indian Ocean, Colombo, Sri Lanka, 4–8 December 1986. IPTP Colombo; 74 pp.

143. IPTP (1987d). Manual for collecting statistics and sampling on tuna and tuna-like species in the Indian Ocean and southeast Asian region. *IPTP Manual* **2**, 157 pp.

144. IPTP (1988b). Interim report on 1987 tuna catch statistics in the Indian Ocean and southeast Asian regions, December 1988; 61 pp.

145. IPTP (1988c). Collective volume of working documents presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean, held in Mauritius, 22–27 June, 1988. Vol. 3. IPTP Colombo; 418 pp.

146. IPTP (1989b). Manual for computer operation of tuna database management. *IPTP Manual* **3**; 99 pp.

147. IPTP (1991). Collective volume of working documents presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean, held in Bangkok, 2–6 July 1990. Vol. 4. IPTP Colombo; 418 pp.

148. IPTP, 1992. Indian Ocean and southeast Asian tuna fisheries data summary for 1990. *IPTP Data Summary* **12**; 94 pp.

149. Itano, D. (1992). Are you sure that fish was a yellowfin? *SPC Fish. Newsletter,* **62** (July/September 1992): 29–32.

150. Itano, D.G. and Bailey, K. (1991). Regional tuna tagging project activity report Australia 1. Tuna and Billfish assessment program, RTTP Activity Report **16**: 31 pp.

151. Iverson, E. S. (1955). Size frequencies and growth of central and western Pacific bigeye tuna. *U. S. Fish. Wildl. Serv. Spec. Sci. Rep. Fish.* **162**.

152. Ivshin, A. Ye. P., Gubanov, Ye.P. and Bozhkov, 1971. Formation conditions of tuna aggregations. *Rybn. Kh-vo* **7**.

153. Iwai, T., Nakamura, I. and Matsubara, K. (1965). Taxonomic study of the tunas. *Spec. Rep., Misakai Mar. Biol. Inst., Kyoto Univ.* **2**; 51 pp.

154. James, P. S. B. R. and Pillai, P. P. (1988). Strategies for tuna fisheries development and management in the Indian Exclusive Economic Zone. *CMFRI Spec. Publ.* **40**; 95p, CMFRI, Kochi, India.

155. Jones, S. and Silas, E. G. (1961). Indian tunas: A preliminary review with a key for their identification. *Indian J. Fish.* **7** (2): 369–393.

156. Jones, S. and Silas, E. G. (1963). Tuna and tuna–like fishes from the Indian seas. *FAO Fish. Rep.* 6 (3). 1775–96.

157. Jones, S. and Silas, E. G. (1964). A systematic review of the Scombroid fishes of India. In: Symposium on Scombroid fishes Part I., *Symp. Ser. Mar. Biol. Assoc. Ind.* **1**(1): 255–82.

158. Jordan, D. S. and Evermann, B. W. (1926). *Occas. Pap., Calif. Acad. Sci.* **12**; 1–113.

159. Jordan, D. S. and Jordan, E. K. (1922). A list of fishes of Hawaii, with notes and descriptions of a new species. *Mem. Carnegie Mus.* **5** (2): 93–332.

160. Jordan, D. S. and Snyder, J. O. (1901). A preliminary checklist of the fishes of Japan. *Annot. Zool. Jpn.* 3 (2–3): 31–159.

161. Joseph, J. (1972). An overview of the tuna fisheries of the World. *Organ. Econ. Coop. Develop. Inter. Symp. Fish. Econ.* FI/T(71)1/40(i); 20 pp..

162. Joseph, J. (1973). The scientific management of world stocks of tunas, billfishes and related species. FAO Technical Conference on Fishery Management and Development, Vancouver, Canada, 13–23 February 1973; 23 pp.

163. Joseph, J. (1990). The world fishery of tuna and the need for international management. (Ms).

164. Joseph, J., Klawe, W. and Murphy, P. (1980). Tuna and billfish: fish without a country: Inter-American Tropical Tuna Commission, La Jolla, Calif. 46 pp.

165. Juhl, R. (1955). Notes on the feeding habits of subsurface yellowfin and bigeye tunas of the eastern tropical Pacific Ocean. *Calif. Fish. Game* **41** (1): 99–101.

166. Kai, N., Ueda, T., Takeda, Y. and Kataoka, A. (1988). The levels of mercury and selenium in blood of tunas. *Nippon Susan Gakkaishi/Bull Jpn. Soc. Sci. Fish.* **54** (11): 1981–85.

167. Kamimurai, T. and Honma, M. (1953). Biology of the bigeye tuna *Parathunnus mebachi*. I. Length frequency of the bigeye tuna caught in the north Pacific, with special reference to biennial frequency. *Nankai Reg. Fish. Res. Lab. Rep. Con.***1**.

168. Kanda, K., Ozawa, K., Suzuki, H. and Saotome, Y. (1958). Tuna longline fishing in the Indian Ocean and biological research of the catches. I. Tuna longline fishing in the central Indian Ocean. *J. Tokyo Univ. Fish. Spec. Edit.* **1** (1): 39–50.

169. Kataoka, A. (1957). Fishing condition of tunas and sea conditions in the mid-Indian Ocean. *J. Shimonoseki College Fish.* **6** (2): 241–248

170. Kawai, H. (1969). On the relationship between thermal structure and distribution of longline fishing grounds of tunas in the inter-tropical Atlantic. I. Analysis based on isotherms of thermocline, etc. *Bull. Far Seas Fish Res. Lab.* **2**: 275–303.

171. Kihara, K and Itosu, C. (1989). Structure of demersal fish community in the South China Sea. *Nippon Susan Gakkaishi/Bull Jpn. Soc. Sci. Fish.* **55** (4): 639–642.

172. Kikawa, S. (1953). Observations on the spawning of bigeye tuna (*Parathunnus mebachi*, Kishinouye) near South Marshall islands. *Con. Nankai Reg. Fish Res. Lab.***1**.

173. Kikawa, S. (1957). The concentrated spawning areas of bigeye tuna in the western Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **5**: 145–157.

174. Kikawa, S. (1961).The group maturity of bigeye tuna *Parathunnus mebachi* in the spawning area of Pacific. *Rep. Nankai Reg. Fish. Res. Lab.*,**13**: 35–46.

175. Kikawa, S. (1962). Studies on the spawning activity of Pacific tunas, *Parathunnus mebachi* and *Neothunnus macropterus* by gonad index examination. *Nankai Reg. Fish. Res. Lab. Occas. Rep.* **1**: 43–56.

176. Kikawa, S. (1966). The distribution of maturing bigeye and yellowfin and an evaluation of their spawning potential in different areas in the tuna longline grounds in the Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **23**: 131–208.

177. King, J. E. and Ikehara, I. I. (1956). Notes on feeding habits of subsurface yellowfin and bigeye tunas of eastern Pacific Ocean. *Fish. Bull. U. S. Fish. Wildlife Serv.* **57**: 108.

178. Kishinouye, K. (1923). Contribution to the so-called scombrid fishes. *Coll. Agr. Imp. Univ. Tokyo* **8** (3): 298–475.

179. Kitahara, T. (1897). Scombridae of Japan. *J. Imp. Fish. Bur. Tokyo* **6**: 15 pp.

180. Kitahara, Y., Matsuoka, A., Kobayashi, N. and Shikama, K. (1990). Auto-oxidation of myoglobin from bigeye tuna fish (*Thunnus obesus*). *Biochem. Biophys. Acta* **1038**: 23–28.

181. Klawe, W. L. (1978). Estimates of catches of tunas and billfishes by the Japanese, Korean and Taiwanese longliners from within 200 mile economic zone of member countries of South Pacific Commission. *South Pacific Comm. Occas. Pap.* **10**; 41 pp.

182. Klawe, W. L. (1980). Longline catches of tunas within the 20 mile economic zones of the Indian and western Pacific oceans. *FAO Indian Ocean Programme, Develop. Rep.* **48** (6); 86 pp.

183. Koga, S. (1958). On the difference of the stomach contents of tunas and black marlin in south equatorial Pacific Ocean. *Bull. Fac. Fish., Nagasaki Univ.* 7: 21–30.

184. Koga, S. (1967). Studies on the fishery biology of the tuna and marlin in the Indian Ocean and south Pacific Ocean. *J. Shimonoseki Univ. of Fish.* **15** (2): 1–208.

185. Koga, S. (1968). A study of the fishing conditions of the tuna and marlin in the Tasman Sea. *J. Shimonoseki Univ. of Fish.* **16** (2,3): 51–70

186. Koido, T. and Miyabe, N. (1987). Trend of Japanese longline CPUE for yellowfin and bigeye tunas. Collective volume of working documents presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held at Colombo, 4–8 December, 1986: 40–43.

187. Koizumi, C., Ohsima, T. and Wada, S. (1984). Inhibitory effect of bigeye tuna meat extract on sodium chloride-catalyzed oxidation of linoleate. *Bull. Jpn. Soc. Sci. Fish.* **50**: 275–280.

188. Kornilova, G. N. (1980). Feeding of yellowfin tuna *Thunnus albacares*, and bigeye tuna *Thunnus obesus* in the equatorial zone of Indian Ocean. *J. Icthyol.* **20** (6): 111–119.

189. Kothias, J. B. A. and Bard, F. X. (1986). Rates of mixing of skipjack and yellowfin and bigeye tuna juveniles in catches of the French, Ivory Coast and Moroccan fleets. In: Symons, P. E. K., Miyake, P. M. and Sakagawa, G. T. (eds). Proceedings of the ICCAT Conference on the International Skipjack Year; 160 pp.

190. Kubo, Y. and Asano, H. (1990). Relative growth pattern and hard tissue of vertebral centra by microradiography of bluefin tuna, bigeye tuna and skipjack. *Nippon Suisan Gakkaishi / Bull. Jpn. Soc. Fish.* **56** (7): 1021–1027.

191. Kume, S. (1962). A note on the artificial fertilisation of bigeye tuna, *Parathunnus mebachi* (Kishinouye). *Rep. Nankai Reg. Fish. Res. Lab.* **15**: 79–84.

192. Kume, S. (1963). Ecological studies of bigeye. I. On the distribution of the bigeye tuna in the Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **17**: 121–131.

193. Kume, S. (1967). Distribution and migration of bigeye tuna in the Pacific Ocean. *Rep. Nankai Reg. Fish. Res. Lab.* **25**: 75–80.

194. Kume, S. (1969a). Ecological studies of bigeye tuna. V. A critical review of its distribution, size composition and stock structure of bigeye tuna in the north Pacific Ocean (north of 16°N). *Far Seas Fish Res. Lab. Bull.* **1**: 57–75.

195. Kume, S. (1969b). Ecological studies of bigeye tuna. VI. A review of distribution and size composition in the equatorial and south Pacific Ocean. *Far Seas Fish Res. Lab. Bull.* **1**: 77–98.

196. Kume, S. (1979a). Bigeye tuna resource in the Pacific Ocean: Its fishery biology and status of the stock. Background Paper, Workshop on the assessment of selected tunas and billfish stocks in the Pacific and Indian oceans, Shimizu, Japan, 13–22 June, 1979. FAO, SAWS/BP/6.

197. Kume, S. (1979b). Fishery biology of bigeye tuna resource in the Pacific Ocean. *Suisan Kenkyu Sousho (Japan Fisheries Resources Conservation Association)* **32**: 54 pp.

198. Kume, S. (1986). Species composition of tuna schools caught by a baitboat fishery in the Gulf of Guinea. *In:* Symons, P. E. K., Miyake, P. M. and Sakagawa, G. T. (eds.). Proceedings of the ICCAT Conference on the International Skipjack Year: 122–126.

199. Kume, S. and Joseph, J. (1966). Size composition, growth and sexual maturity of bigeye tuna, *Thunnus obesus* (Lowe), from Japanese longline fishery in eastern Pacific Ocean. *Inter-Amer. Trop. Tuna Comm. Bull.* **11** (2): 45–99.

200. Kume, S. and Joseph, J. (1969). The Japanese longline fishery for tunas and billfish in the eastern Pacific Ocean, east of 130°W, 1964–1966. *Inter-Amer. Trop. Tuna Comm. Bull.* **13** (2): 275–418.

201. Kume, S and Morita, Y. (1966). Ecological studies on bigeye tuna. III. On bigeye tuna caught by "night-time longline" in the north Pacific Ocean. *Rep. Nankai Reg. Fish. Res. Lab.* **24**: 21–30.

202. Kume, S. and Morita, Y. (1967). Ecological studies on bigeye tuna. IV. Size composition of bigeye tuna *T. obesus* (Lowe) caught by pole and line fishing in the northwest Pacific Ocean. *Rep. Nankai Reg. Fish. Res. Lab.* **25**: 85–89.

203. Kume, S and Morita, Y. (1979). Brief review of the fishery biology of the bigeye tuna in the Indian Ocean and its stock assessment. Background paper, Workshop on the Assessment of Selected Tunas and Billfish Stocks in the Pacific and Indian oceans, Shimizu, Japan, 13–22 June, 1979. SAWS/BP/18.

204. Kume, S. and Schaefer, M. B. (1966). Studies on the Japanese long-line fishery for tuna and marlin in the eastern tropical Pacific Ocean during 1963. *Inter. Amer. Trop. Tuna Comm. Bull.* **11** (3): 101–170.

205. Kume, S. and Shiohama, T. (1964). On the conversion between length and weight of bigeye tuna landings in the Pacific Ocean (preliminary report). *Rep. Nankai Reg. Fish. Res. Lab.* **20**: 59–67.

206. Kume, S. and Shiohama, T. (1965). Ecological studies on bigeye tuna. II. Distribution and size composition of bigeye tuna in the equatorial Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **22**: 71–83.

207. Laevastu, T. and Rosa, H. (1963). Distribution and relative abundance of tunas in relation to their environment. *FAO Fish. Rep.* **6**: 1835–1851.

208. Lee, J. U. (1986). Aspects of fishing effort of Korean tuna longline fishery exerted to the Atlantic yellowfin and bigeye tuna. *Collect. Vol. Sci. Pap. ICCAT* **25**: 99–103.

209. Lee, J. U. and Yang, W. S. (1983). A study on the population analysis of yellowfin tuna, *Thunnus albacares*, Bonnaterre and bigeye tuna, *Thunnus obesus*, Lowe, exploited by longline fishery for 1971–1979. *Bull. Fish. Res. Div. Agency, Busan* **31**: 21–32.

210. Lee, J. U., Kim, B. Y. and Yang, W. S. (1980). A study on the relative growth of yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *Thunnus obesus*, taken by Korean tuna longliners in the Indian Ocean. *Bull. Fish. Res. Div. Agency, Busan* **23**: 187–195.

211. Lewis, A. D. (1991). South Pacific Commission tagging programmes. A progress report to November 1990. (SEAC/90/26). Collective volume of working documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November, 1990: 198–204.

212. Lowe, R. T. (1839). A supplement to the synopsis of the fishes of Madeira. *Proc. Zool. Soc. London* **7**: 76–92.

213. McPherson, G. R. (1988a). Verification of the postovulatory follicle method for establishing the spawning frequency of yellowfin, bigeye and skipjack tuna in the Coral Sea. *Qld. Dept. Prim. Ind. Res. Branch Tech. Rep. FRB 88/9*, 42 pp.

214. McPherson, G. R. (1988b). Reproductive biology of yellowfin and bigeye tuna in the eastern Australian Fishing Zone with special reference to the north-western Coral Sea. *Qld. Dept. Prim. Ind. Res. Branch Tech. Rep. FRB 88/10*, 80 pp.

215. McPherson, G. R. (1991). A possible mechanism for the aggregation of yellowfin and bigeye tuna in the north-western Coral Sea. *Qld Dept. Prim. Ind. Information series Q191013*. 11 pp.

216. McPherson, G. R. (1992a). Coral Sea tuna; background information on the resource, research status and fishery potential to 1985. *Qld Dept. Prim. Ind. Information series Q192020*. 33 pp.

217. McPherson, G. R. (1992b). Assessing macroscopic and histological staging of yellowfin and bigeye tuna ovaries in the north-western Coral Sea. *Qld Dept. Prim. Ind. Information series Q192021*. 19 pp.

218 Maeda, H., Minami, S. and Nishino, M. (1968). A preliminary report of hauling speed of tuna longline. *Bull. Jpn. Soc. Sci. Fish.* **34** 1009–1014.

219 Magnuson, J. J. (1963). Tuna behaviour and physiology: A review. *FAO Fish. Rep.* **6**: 1057–1066.

220. Maldeniya, R., Dayaratne, P. and Boniface, B. (1991). Incidence of juvenile bigeye tuna (*Thunnus obesus)* among the tuna catches in southwest coast of Sri Lanka (TWS/90/72). *In*: Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 108–110.

221. Marcille, J. and Bour, W. (1981). Tuna fishery by seine and by rod in the tropical Pacific Ocean: Present situation and developmental perspectives. *Trav. Doc. ORSTOM* **134**: 259 pp.

222. Marcille, J. and Stequert, B. (1976). Croises des jeunes albacores *Thunnes albacares* et patudo *Thunnus obesus* de la cote nord-ouest de Madagascar. *Cah. Orstom (Oceanogr.)* **14** (2): 152–162.

223. Marsac, F. (1989). Le Gall J. Y. (ed.). Species and their fisheries in the inter tropical zone. 2.2. Species and tuna fisheries in the tropical waters of the western Indian Ocean. Satellite Geosensing and Oceanic Fisheries: Teledetection. *FAO Doc. Tech. Peches* **302**.

224. Marsac, F. and Hallier, J. P. (1985). Environmental conditions and tuna fishing in the western Indian Ocean (1983–1984). *Rapp. Sci. Antene ORSTOM* (Seychelles) **5**.

225. Martinez, F. Z. and Bohm, S. G. (1983). Biological synopsis of *Thunnus obesus* (Lowe) with special reference to the eastern Pacific Ocean. Regional seminar on fish resources and their fisheries in the southeast Pacific. *Rev. Com. Perm. Pac. Sur.* **13**: 103–123.

226. Mather, F. J. and Gibbs, R. H. (1958). Distribution of the Atlantic bigeye tuna *Thunnus obesus* in the western north Atlantic and the Caribbean sea. *Copeia* **1958** (3): 237–239.

227. Matsumoto, W. A., Alhstrom, E. H., Jones, S., Klawe, W. J., Richards, W. J. and Ueyanagi, S. (1972). On the clarification of larval tuna identification, particularly in the genus *Thunnus*. *U. S. Fish. Bull.* **70** (1): 1–12, figs. 1–6.

228. Matsumoto, W. M. (1961). Identification of larvae of four species of tuna from the Indo–Pacific region. I. The Carlsberg Foundation's oceanic expedition round the world 1928–30 and previous Dana expeditions. *Dana Rep.* **5**; 16 pp.

229. Mimura, K. (1963). Synopsis of the biology of the bigeye tuna *Parathunnus mebachi* Kishinouye 1923 (Indian Ocean). *FAO Fish Rep.* **6**; Vol. 2: 350–379.

230. Mimura, K. and Nakamura, H. (1959). Fishing grounds in the Indian Ocean and vicinity. In: Average year's fishing condition of tuna longline fisheries (ed. Nankai Regional Fisheries Research Lab). 1958 edn. Federation of Japan Tuna Fisherman's Co-operative Associations, Tokyo, pp. 353–414. [In Japanese]

231. Miyabe, N. (1987). A note on the movement of bigeye tuna based on tagging experiments. *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 105–110.

232. Miyabe, N. (1988). Production model analysis and preliminary application of virtual population analysis on the Indian bigeye tuna. Collective volume of the working documents. Vol. 3. Consultation on the Stock Assessment of Tunas in the Indian Ocean held in Mauritius, 22–27 June 1988: 74–81.

233. Miyabe, N. (1991). General review paper of Pacific bigeye tuna *Thunnus obesus.* FAO expert consultation on interactions of Pacific Tuna fisheries.

234. Miyabe, N. and Bayliff, W. H. (1987). A review of the Japanese longline fishery for the tunas and billfishes in the eastern Pacific Ocean, 1971–80. *Inter-Amer. Trop. Tuna. Comm., Bull.* **19** (1): 1–163.

235. Miyabe, N. and Suzuki, Z. (1991). Stock analysis of bigeye and yellowfin tunas based on longline fishery data. (TWS/90/59). Collective volume of working documents, Vol. 4. Presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held in Bangkok, 2–6 July 1990: 84–90.

236. Miyake, P. M. (1985). Populations of tunas and tuna-like fish of West African waters. In: Bas, C., Margalef, R. and Rubies, P. (eds). International symposium on the most important upwelling areas off western Africa (Cape Blanco and Benguela). Vol. 2: 735–748.

237. Miyake, P. M., Kume, S. and Yang, R. T. (1982). Review of Task II catch and effort data for Taiwanese longline fleet, 1976–78. *Collect. Vol. Sci. Pap. ICCAT* **17** (2): 249–257.

238. Mohri, M., Hanamoto, E. and Takeuchi, S. (1991). Distribution of bigeye tuna in the Indian Ocean as seen from tuna longline catches. *Nippon Suisan Gakkaishi* **57** (9): 1683–1687.

239. Montaudouin, X de, Hallier, J. P. and Hassani, S. (1990). Analysis of data collected by observers on board seiners based at the Seychelles (1986–89). *Tech. Rep. Seychelles Fish. Auth.* **014** SFA; Victoria (Seychelles); 34 pp.

240. Mori, K. (1970). A consideration of spawning of tunas, especially of the yellowfin tuna (*Thunnus albacares*) in adjacent seas of Japan. *Bull. Far Seas Fish Res. Lab.* **3**: 215–228.

241. Morita, Y. (1973). Conversion factors for estimating live weight from gilled-and-gutted weight of bigeye and yellowfin tunas. *Bull. Far Seas Fish Res. Lab.* **9**: 109–121. (in Japanese with English abstract)

242. Murphy, G. I. and Shomura, R. S. (1972). Pre-exploitation abundance of tunas in the equatorial central Pacific. *U. S. Nat. Mar. Fish. Serv., Fish. Bull.* **70** (3): 875–913.

243. Munro, I. S. R. (1957). Occurrence of the bigeye tuna *Parathunnus mebachi* (Kishinouye) in Queensland. *Icthol. Notes, Dept. Harb. Mar. Qld* **3**: 145–148.

244. Nakamura, H. (1949). Tunas and their fisheries. Takeuchi Shobo Tokyo, 118 pp [In Japanese. Translation by W.G. Van Campan. Published in *[U.S.] Fish Wildl. Serv., Spec. Sci. Rep. Fish.* **82**, 115 pp., 1952]

245. Nakamura, H. (1954). Ocean current and tuna fishing ground. *Suisan Kagaku* **14**: 9–17.

246. Nakamura, H. (1962). An outline of the tuna longline grounds in the Pacific Ocean. *Rep. Nankai Reg. Fish. Lab.* **1**: 1–8.

247. Nakamura, H. (1969). Tuna distribution and migration. Whitefriars Press. London. 76 pp.

248. Nakamura, H., Kamimurai, T. and Yabuta, Y. (1953). Size composition of the albacore and bigeye tuna caught in the north Pacific area. *Nankai Reg. Fish. Res. Lab. Rep. Con.***1**.

249. Nakamura, H. and Yamanaka, H. (1959). Relation between the distribution of tunas and the Ocean structure. *Oceanog. Soc. Jpn. J.* **15**: 143–149.

250. Nakamura, I and Kikawa, S. (1966). Infracentral grooves of tunas with special reference to the identification of the young tunas found in the stomachs of large predators. *Rep. Nankai Reg. Fish. Res. Lab.* **23**: 55–66.

251. Nakano, H. and Bayliff, W. H. (1992). A review of Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1981–87. *Bull. IATTC* **20** (5); 355 pp.

252. National Taiwan University (1985). Annual catch statistics of Taiwan's tuna longline fishery, 1980. Tuna Research Centre, Institute of Oceanography, National Taiwan University, Taipei.

253. Navarro, I., Gutierrez, J., Caixach, J., Rivera, J. and Planas, J. (1991). Isolation and primary structure of glucagon from the endocrine pancreas of *Thunnus obesus*. *Gen. Comp. Endocrinol.* **83** (2): 227–232.

254. Nikaido, H. Miyabe, N and Ueyanagi, S. (1991). Spawning time and frequency of bigeye tuna, *Thunnus obesus*. *Bull. Natl. Res. Inst. Far Seas Fish.* **28**: 47–73.

255. Nishi, T. (1990). The hourly variations of the depth of hooks and the hooking depth of yellowfin tuna (*Thunnus albacares*), and bigeye tuna (*Thunnus obesus*), of tuna longline in the eastern region of the Indian Ocean. *Mem. Fac. Fish. Kagoshima Univ.* (*Kagoshimadai Suisangakabu Kiyo*) **39**: 81–98.

256. Nishikawa, Y. (1985). Identification for larvae of three species of genus *Thunnus* by melanophore patterns. *Bull. Far Seas Fish. Res. Lab.* **22**:119–129.

257. Nishikawa, Y., Homna, M., Ueyanagi, S. and Kikawa, S. (1975). Average distribution of larvae of oceanic species of scombrid fishes, 1956–1981. *Bull. Far Seas Fish. Res. Lab., S series* **12**; 99 pp.

258. Nishikawa, Y., Kikawa, S. Honma, M. and Ueyanagi, S. (1978). Distribution atlas of larval tunas, billfishes, and related species. Results of larval surveys by R/V *Shunyo Maru* and R/V *Shoyo Maru*, 1956–75. *Far Seas Fish. Res. Lab., S Series* **9**; 99 pp..

259. Nishikawa, Y and Rimmer, D.W. (1987). Identification of larval tunas, billfishes and other Scombroid fishes (Suborder Scombroidei): an illustrated guide. CSIRO Marine Laboratories Report. **186**; 20pp.

260. Nishiwaki, S., Kato, M., Okuno, M., Kanai, M. and Muto, Y. (1990). Purification and partial characterization of a novel cellular retinol-binding protein, type three, from the piscine eyes. *Biochiem. Biophys. Acta* **1037** (2): 192–199.

261. Nose, Y., Kawatsu, H. and Hiyama, Y. (1957). Age and growth of Pacific tuna by scale reading. *In collection of works on fisheries science, Jubilee publication of Professor I. Amemiya*. Uni. Tokyo Press: 701–716.

262. Ochiai, Y., Chow Chau-Jen, Watabe, S. and Hashimoto, K. (1988). Evaluation of tuna meat discoloration by Hunter color difference scale. *Nippon Suisan Gakkaishi/ Bull. Jpn. Soc. Sci. Fish.* **54** (4): 649–653.

263. Olvera Limas, R. M., Cerecedo, E. J. L. and Compean, G. A. (1988). Tuna larvae distribution in the Gulf of Mexico and Caribbean Sea: Abundance and biomass of three species in the Exclusive Economic Zone. *Cienc. Pesq.* **6**: 119–140.

264. Osipov, V. G. (1977). Some vertical distribution features of the pelagic fisheries of the oceanic pelagic zone. In: I. All Union Conference on Marine Biology, Abstracts of Proceedings, Vladivostock.

265. Otsu, T. and Uchida, N. (1956). Tagged bigeye tuna recovered. *Pacif. Sci.* **10** (2): 236.

266. Ozawa, K. and Inoue, K., 1964. Experimental tuna longline in the eastern Indian Ocean, November 1963 and January 1964. *J. Tokyo Univ. Fish. Spec. Edit.* **8** (2): 237–241.

267. Pallares, P., Garcia Mamolar, J. M. and Fernandez, A. M. (1983). Estimates of bigeye–yellowfin proportions in the catches of the Spanish tropical fleet, 1979–1981. *Collect. Vol. Sci. Pap. ICCAT* **18** (2): 343–346.

268. Pelczarski, W. (1990). Food of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*T. obesus*) from the open waters of the central Atlantic. *Pr. Morsk. Inst. Rybak. Gdynia/Rep. Sea Fish. Inst. Gdynia* **22**: 85–106.

269. Pereira, J. (1985). Observations on the sex ratio of bigeye (*Thunnus obesus*) in the Azores. *Collect. Vol. Sci. Pap. ICCAT* **23** (2): 237–241.

270. Pereira, J. (1986). Species composition of tuna catches of purse seines in the Azores. *Collect. Vol. Sci. Pap. ICCAT* **25**: 395–400.

271. Pereira, J., (1987a). Present situation of the bigeye tuna fishery in the Azores. *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 174–183.

272. Pereira, J., (1987b). Sexual maturity and sex ratio of bigeye tuna caught in the Azores. *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 168–173.

273. Pereira, J. (1991). Detection indices and size of tunas in schools associated with floating objects. *Collect. Vol. Sci. Pap. ICCAT* **35** (1): 192–195.

274. Peterson, C. L. and Bayliff, W. H. (1985). Size composition, growth and sexual maturity of bigeye tuna *Thunnus obesus* (Lowe), from the Japanese longline fishery in the eastern Pacific Ocean. *Bull. IATTC* **11**: 45–100.

275. Polovina, J. J., Moffitt, R. B., Ralston, S., Shiota, P. M. and Williams, H. A. (1985). Fisheries resource assessment of the Mariana Archipelago, 1982–85. *J. Mar. Fish. Rev.* **47** (4): 19–25.

276. Postel, E. (1973). Tunnidae. In: Hureau, J. C. and Monod, T. (eds.). Checklist of fishes of the north eastern Atlantic and of Mediterranean. Unesco; pp. 467–472.

277. Punsly, R. and Nakano, H. (1992). Analysis of variance and standardization of longline hook rates of bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) tunas in the eastern Pacific Ocean during 1975–1987. *Bull. IATTC/BOL. CIAT.* **20** (4); 18 pp.

278. Rahardjo, P. (1985). Preliminary study on tuna longline fishery in the Banda and Flores sea. *J. Mar. Fish. Rev.* **33**: 83–93.

279. Regan, C. T. (1909). On the anatomy and classification of scombroid fishes. *Ann. Mag. Nat. Hist.* **8** (3): 66–75.

280. Rey, J. C. and Cort, J. L. (1985). Results of tuna tagging programs from the Bay of Biscay and the Mediterranean from 1982 to 1984. *Collect. Vol. Sci. Pap. ICCAT* **23** (2): 373–375.

281. Richards, W. J. and Klawe, W. L. (1972). Indexed bibliography of the eggs and young of tunas and other scombrids (Pisces, Scombridae), 1880–1970. *NOAA Tech. Rep. NMFS SSRF* (652): 107 pp.

282. Richards, W. J., Potthoff and Kim, J. M. (): Problems of identifying tuna larvae species (Pisces: Scombridae: *Thunnus*) from the Gulf of Mexico. *U. S. Fish Bull.* **88** (3).

283. Richardson, J. (1846). Report on the ichthyology of the seas of China and Japan. *Rep. Brit. Assoc. Advan. Sci. for 1845:* 187–320.

284. Riggs, F. V. (1981). Status report: Tunas in the Indian Ocean. Status reports on world tuna and billfish stocks. Proceedings of the Second Research Workshop held in California, December 15–17 1990: *NOAA Tech. Memo*: 99–117.

285. Rivas, L. (1951). A preliminary review of the western north Atlantic fishes of the family Scombridae. *Bull. Mar. Sci. Gulf. Caribb.* **1** (3): 209–230.

286. Rivas, L. (1961). A review of the tuna fishes of the subgenera *Parathunnus* and *Neothunnus* (genus *Thunnus*). *Ann. Mus. Stor. Nat. Genoa* **72**: 126–148.

287. Rodriguez, R. A., Nieto Misas, S. F. and Munoz Uribarre, L. (1988). Analysis of the abundance (1973–85) of large pelagic fish in oceanic water of the eastern tropical Atlantic. *Collect. Vol. Sci. Pap. ICCAT.* **28**: 339–349.

288. Roedel, P. M. and Fitch, J. E. (1962). Taxonomy and nomenclature of Pacific tunas. In: Pacific Tuna Biology Conference, April 14–17, 1961, Honolulu. *U. S. Fish. Wildl. Serv., Spec. Rep. Fish.* **415**: 33–34.

289. Rosa, H. (1950). Scientific and common names applied to tunas, mackerels and spearfishes of the world with notes on their geographic distribution. FAO, Washington D. C., 235 pp.

290. Ross, A. and Bailey, K. (1986). The foreign longline catch of southern bluefin and bigeye tuna in the New Zealand EEZ for 1984. *Catch* '86 **13** (1): 8–10.

291. Rudomiotkina, G. P. (1983). Areas, periods and conditions of bigeye tuna, *Thunnus obesus* (Lowe), spawning in the tropical part of the Atlantic Ocean. *Collect. Vol. Sci. Pap. ICCAT* **18** (2): 355–362.

292. Saito, S. (1975). On the depth of capture of bigeye tuna by further improved vertical longline in the tropical Pacific. *Bull. Jpn. Soc. Sci. Fish.* **41** (8): 831–841.

293. Sakagawa, G. T. and Coan, A. L. (1988). Species composition of U.S. tuna imports from the TEMA-based pole-and-line fleet 1976–1985. *Collect. Vol. Sci. Pap. ICCAT* **28**: 40–46.

294. Sakagawa, G.T., Coan, A. L. and Bartoo, N.W. (1987). Patterns in longline fishery data and catches of bigeye tuna, *Thunnus obesus*. *Mar. Fish. Rev.* **49** (4): 57–66.

295. Sakamoto, H. (1966). Annual changes in the abundance and age composition of bigeye tuna in the Indian Ocean for the years 1965 through 1963. *Rep. Nankai Reg. Res. Lab.* **26**: 31–40.

296. Sakamoto, H. (1969). Preliminary review on the regional change in size composition, sex ratio and gonad index of the Atlantic bigeye caught by the tuna longline fishery. *Bull. Far Seas Fish. Res. Lab.* **1**: 49–56.

297. Sakurai, T. (1984). Major findings from the Indo–Pacific historical tuna fisheries summary. IPTP/84/WP/11: 11 pp. Indo–Pacific Tuna Management Programme, Colombo.

298 Seno, J. (1958a). Biological research on the catches by primary tuna longline fishing in the Indian Ocean. *J. Tokyo Univ. Fish. Spec. Edit.* **1** (1): 51–62.

299. Seno, J. (1958b). Biological research on the catches by secondary tuna longline fishing in the Indian Ocean. *J. Tokyo Univ. Fish. Spec. Edit.* **1** (1): 63–72.

300. Seno, J. and Masuda, T. (1964). Fish specimens collected by tuna longline. *J. Tokyo Univ. Fish. Spec. Edit.* **8** (2): 243–250.

301. Sharp, G. D. (1979). Areas of potentially successful exploitation of tunas in the Indian Ocean with emphasis on surface methods. FAO, IOFC/DEV/79/47; 55 pp.

302. Sharp, G. D. and Dizon, A. E. (1978). Physiological ecology of tunas. Academic Press, 485 pp.

303. Shimada, B. M. (1951). An annotated bibliography on the biology of Pacific tunas. *Fish. Bull.* **52** (58); 58 pp.

304. Shimamura, T and Soeda, H. (1981). On the catch by deep-layer tuna fishing. *Bull. Jpn. Soc. Sci. Fish.* **47** (12): 559–1565.

305. Shimudu, Y. and Morio, T. (1963). Biochemical study on the growth and maturation of fish. 20. Contents of moisture, protein, phosphorous, calcium, cholesterol and alkaline phosphatase in the serum of bigeye tuna in the Pacific Ocean, mainly nearby the equator. (Part-II). *Rep. Nankai Reg. Fish. Res. Lab.*,**17**: 79–86.

306. Shimudu, Y., Morio, T., Mimoto, K. and Higasa, S. (1963). Biochemical study on the growth and maturation of fish. XX. Contents of moisture, protein, phosphorous, calcium, cholesterol and alkaline phosphatase in the serum of bigeye tuna in the Pacific Ocean, mainly nearby the equator. (Part I). *Rep. Nankai Reg. Fish. Res. Lab.* **17**: 25–30.

307. Shingu, C., Thomlinson, P.K. and Peterson, C.L. (1974). A review of Japanese longline fishery for tuna and billfishes in the eastern Pacific Ocean. *Inter-Amer. Trop. Tuna Comm., Bull.* **16** (2): 65–230.

308. Shomura, R. S. and Keala, B. S. (1973). Growth and sexual dimorphism in the bigeye tuna *Thunnus obesus*: a preliminary report. *FAO Fish Rep.* **6** (3): 1409–1417.

309. Sibert, J. (1987). Tuna stocks of the southwest Pacific. Proceedings of the INFOFISH tuna trade conference, Bangkok, 25–27 February, 1986: 18–37.

310. Sivasubramaniam, K. (1987). Some observations on the tuna fisheries in the Indian Ocean, particularly in the central equatorial sub-region. Collective volume of working documents presented at the Expert Consultation of Stock Assessment of Tunas in the Indian Ocean held at Colombo, 4–8 December 1986: 294–298.

311. Skillman, R. A. (1982). Tuna fishery statistics for the Indian Ocean and the Indo–Pacific (Regional). IPTP/85/WP/13: 19 pp. IPTP, Colombo.

312. Solov'yev, B. S. (1970). Distribution and biology of bigeye tuna in the Indian Ocean. *Rybn. Khos* **3**.

313. Stequert, B. and Marsac, F. (1989). Tropical tuna 1989: Surface fisheries in the Indian Ocean. *FAO Fish. Tech. Pap.* **282**: 238 pp.

314. Stretta, J. M. (1987). Diets and feeding behaviour of the yellowfin, skipjack and bigeye in the eastern tropical Atlantic (Bibliographic review). *Collect. Vol. Sci. Pap. ICCAT.* **26** (1): 95–104.

315. Stretta, J. M. and Petit, M. (1989a). *In:* Le Gall, J. Y. (ed.). Species and their fisheries in the inter tropical zone. 2.1. Panorama of the tuna fisheries in the Inter tropical Atlantic. Satellite Geosensing and Oceanic Fisheries: Teledetection. *FAO Doc. Tech. Peches* **302**: 9–19.

316. Stretta, J. M. and Petit, M. (1989b). *In:* Le Gall, J. Y. (ed.). Physiological aspects of thermoecology in tunas. 3.2. Catchability/surface temperature relationship. Satellite Geosensing and Oceanic Fisheries: Teledetection. *FAO Doc. Tech. Peches* **302**: 49–50.

317. Stretta, J. M. and Slepoukha, M. (1986). Analysis of biotic and abiotic factors associated with tuna schools. In: Symons, P. E. K., Miyake, P. M. and Sakagawa, G. T. (eds). Proceedings of the ICCAT Conference on the International Skipjack Year: 161–169.

318. Suda, A. (1959). Catch variation in the north Pacific Albacore. II. Variation in the amount of recruitment. *Rep. Nankai Reg. Fish. Res. Lab.* **10**: 72–87. [In Japanese, Translation by Grace Y. Beard, Bureau of Commercial Fisheries, Honolulu, Hawaii]

319. Suda, A. (1962). Catch variations in the north Pacific albacore. III. Comparison of abundance between albacore and bigeye in the northwest Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **15**: 69–77.

320. Suda, A. (1971). Tuna fisheries and their resources in the IPFC area. *Far Seas Fish. Res. Lab., S Series* **5**, 1–58

321. Suda, A. *et al.* (1959). In: Average year's fishing condition of tuna longline fisheries. 1958 edn. Federation of Japan Tuna Fisherman's Co-operative Associations, Tokyo, pp. 28–135.

322. Suda, A. and Kume, S. (1967). Survival and recruit of bigeye tuna in the Pacific Ocean, estimated by the tuna longline catch. *Rep. Nankai Reg. Fish. Res. Lab.* **25**: 91–103.

323. Suda, A. and Schaefer, M. B. (1965). General review of the Japanese tuna longline in the eastern tropical Pacific Ocean 1956–1962. *Inter-Amer. Trop. Tuna Comm. Bull.* **9** (6): 305–462.

324. Suda, A., Kume, S. and Shiohama, T. (1969). An indicative note on a role of permanent thermocline as a factor controlling the longline fishing ground for bigeye tuna. *Bull. Far Seas Fish Res. Lab.* **1**: 99–114.

325. Suhendrata, T. and Bahar, S. (1986). The tuna longline fishing grounds in Indonesian waters and the possibility of its industrial development. *J. Mar. Fish. Res.* **37**: 79–93.

326. Sund, P. N., Blackburn, M and Williams, F. (1981). Tunas and their environment in the Pacific Ocean: A review. *Oceanogr. Mar. Biol. Ann. Rev.* **19**: 443–512.

327. Suyama, M., Hirano, T. and Suzuki, T. (1985). Decomposition of carnosine and its methyl derivatives in aquatic animal meats during storage. *Bull. Jpn. Soc. Sci. Fish.* **51** (12): 2037–2041.

328. Suzuki, S., Warashina, Y. and Kishida, M. (1977). The comparison of catches by regular and deep tuna longline gears in the western and central Pacific. *Bull. Far Seas Fish. Res. Lab.* **15**: 51–89.

329. Suzuki, T., Hirano, T. and Suyama, M. (1986). Changes in extractive components of white and dark meats of bigeye tuna by thermal processing at high temperature of F sub(0) value of 4. *Nippon Suisan Gakkaishi/ Bull. Jpn. Soc. Sci. Fish.* **53** (4): 1633–1636.

330. Suzuki, Z. (1981). A preliminary analysis on mixing of species within schools fished by Tema-based Japanese baitboat fleet during 1979 and 1980. *Collect. Vol. Sci. Pap. ICCAT* **15** (1).

331. Suzuki, Z. (1988). Recent Japanese research activities on tunas and billfishes resources in the western equatorial Pacific. Report of the second Southeast Asian Tuna Conference and Meeting of Tuna Research Groups in the Southeast Asian Region, Malaysia, 22–25 August 1988: 201–207.

332. Suzuki, Z. and Kume, S. (1981). Fishing efficiency of deep longline for bigeye tuna in the Atlantic as inferred from the operations in the Pacific and Indian oceans. Document prepared for the SCRS Symposium of the ICCT, November 1981: 30 pp.

333. Suzuki, Z. and Kume, S. (1982). Fishing efficiency of deep longline for bigeye tuna in the Atlantic as inferred from the operation in the Indian and Pacific oceans. *Inter. Comm. Cons Atlan. Tunas, Coll. Vol. Sci. Pap.* **17**(2): 471–486.

334. Suzuki, Z., Warashina, Y. and Kaneko, K. (1979). The comparison of length of catches by regular and deep longline gears for bigeye, yellowfin and blue marlin in the western and central equatorial Pacific. Background Paper, Workshop on the assessment of selected tunas and billfish stocks in the Pacific and Indian oceans, Shimizu, Japan, 13–22 June, 1979. FAO, SAWS/BP/16.

335. Talbot, F. H. and Penrith, M. J. (1960). *Thunnus (Neothunnus) albacares* Bonnaterre, the yellowfin tunny and *Thunnus (Parathunnus) obesus* Lowe, the bigeye tunny, on the south and east coasts of Africa. Paper presented at the CCTA/CSA Symposium on Thunnidae, Dàker, 12–17 December 1960, Tunny **60** (11): 12 pp. (mimeo).

336. Talbot, F. H. and Penrith, M. J. (1963). Synopsis on the biological data on species of the genus *Thunnus* of South Africa. *FAO Fish. Rep.* **6** (2): 609–646.

337. Tanaka, M. and Kimura, S. (1988). Effect of heating condition on protein quality of retort pouched fish meat. *Nippon Susan Gakkaishi/Bull Jpn. Soc. Sci. Fish.* **54** (2): 265–270

338. Tanaka, T. (1989). Shift of the fishing ground and features of shoals caught by purse seine fishery in the tropical seas of the western Pacific Ocean. *Bull. Tohoku Reg. Fish. Res. Lab/Tohoku Suikenho* **51**: 75–88.

339. Tankevich, P. B. (1982). Age and growth of bigeye tuna *Thunnus obesus* (Scombridae) in the Indian Ocean. *J. Icthyol.* **22** (4): 26–31.

340. Tatsuki, K., Uto, M., Okuda, T. and Kitamura, K. (1960a). Ecological studies on tunas in the Kinan area. I. Length frequency distribution and hooked rates of bigeye tuna. *Rep. Nankai Reg. Fish. Res. Lab.* **12**: 52–57.

341. Tatsuki, K., Uto, M., Okuda, T. and Kitamura, K. (1960b). Ecological studies on tunas in the Kinan area. II. Annual changes of hook rate and size composition of bigeye tuna. *Rep. Nankai Reg. Fish. Res. Lab.* **12**: 58–62.

342. Temminck, C. J. and Schlegel, H. (1842). Fauna Japonica, sive descriptio animalium quae in itinere per japonium suscepto, annis 1822–30 collegit, notis, observationbus et adumbrationbus illustravit *P. E. SEIBOLD* Pt. 2. Pisces, 1–323.

343. Tinker, S.W. (1944). Hawaiian fishes; a handbook of the fishes found among the islands of the central Pacific. Tongg Publishing, Honolulu, Hawaii. 404 pp.

344. Udo, M. (1957). A consideration of the long years trend of fisheries fluctuation in relation to sea condition. *Bull. Jpn. Soc. Sci. Fish.* **23**: 368–372.

345. Ueyanagi, S., 1969. Observations on the distribution of tuna larvae in the Indo–Pacific Ocean with emphasis on the delineation of spawning areas of albacore, *Thunnus alalunga*. *Bull. Far Seas Fish. Res. Lab.* **2**: 177–256.

346. Uno, M. (1965). On the periodicity of tuna migration in the south Pacific. *J. Fish. Prefect. Univ. Mie.* **6** (3): 341–349.

347. Uotani, I., Matsuzaki, K., Makino, Y., Noka, K., Inamura, O. and Horikawa, M. (1981). Food habits of larvae of tunas and their related species in the area. *Bull. Jpn. Soc. Sci. Fish.* **47** (9): 1165–1172.

348. van Campen, W. G. (1956). Tunas and tuna fisheries of the world. An annotated bibliography. *U. S. Fish. Wildl. Ser. Fish. Bull.* **111**: 349 pp.

349. Watanabe, H. (1958). On the difference of stomach contents of the yellowfin and bigeye tunas from the western equatorial Pacific. *Rep. Nankai Reg. Fish. Res. Lab.* **12**: 63–74.

350. Watanabe, H. (1960). Regional differences in the food composition of the tunas and marlins from several oceanic areas. *Rep. Nankai Reg. Fish. Res. Lab.* **12**: 75–84.

351. Watanabe, Y. (1979). Interim report of tuna resources survey in the northern area of the Coral Sea by R.V. Nippon Maru.. *Jap. Mar. Fish. Res. Centre, Nov.*: 19 pp..

352. Watson, C., Bourke, R. E. and Brill, R. W. A. (1988). Comprehensive theory on the etiology of burnt tuna. *Fish. Bull.* **86** (2): 367–372.

353. Watson, M. E. (1963). Tunas (genus *Thunnus*) of western north Atlantic. Part 1. Key to the species of *Thunnus* based on skeletal and visceral anatomy. In: Symposium on Scombrid Fishes, Part I: 1–6. Mar. Biol. Assn. Kochi, India.

354. White, T. (1982). The Philippine tuna fishery and aspects of population dynamics of tunas in Philippine waters. IPTP/82/WP/5,SCS/82/WP/114 FAO: 64 pp.

355. Wise, J. P. (1986). Analysis of levels of sampling for catch and effort by species and country in the ICCAT Task II Data Base, 1976–83. *Collect. Vol. Sci. Pap. ICCAT* **25**: 333–348.

356. Yabe, H., Ueyanagi, S., Kikawa,S. and Watanabe, H. (1958). Young tunas found in the stomach contents. *Rep. Nankai Reg. Res. Lab.* **8**: 31–48.

357. Yabuta, Y. 1953. On the stomach contents of tuna and marlin from the adjacent seas of the Bonin islands. *Contrib. Nankai Reg. Res. Lab.* **1**: 1–6.

358. Yabuta, Y. and Yukinawa, M. (1959). Fishing grounds in the equatorial Pacific. In: Average years fishing conditions of tuna long-line fisheries. (ed. Nankai Regional Fisheries Research Laboratory). Japan Fishermens' Co-operative Associations, Tokyo, pp. 263–307. [In Japanese].

359. Yamanaka, H., Morita, J. and Anraku, N. (1969). relation between the distribution of tunas and water types of the north and south Pacific Ocean. *Bull. Far Seas Fish. Res. Lab.* **2**: 257–273

360. Yamanaka, I. (1976). Discussion on "Oceanographic conditions in relation with fishing conditions" by applying the information theory. II. On the prediction of tuna fishing conditions. *Bull. Far Seas Fish. Res. Lab.* **14**: 105–122.

361. Yang, W. S. and Gong, Y. (1987). The vertical distribution of tunas and billfishes, and fishing efficiency between Korean regular and deep longlines in the Atlantic Ocean. *Collect. Vol. Sci. Pap. ICCAT/RECL Doc. Sci. CICTA/collect. Doc. CIENT. CICAA* **26** (1): 184–187

362. Yang, W. S. and Gong, Y. (1988). The vertical distribution of tunas and billfishes, and fishing efficiency between Korean regular and deep longlines in the Atlantic Ocean. *Bull. Natl. Fish. Dev. Agency* [Pusan, Korea] **42**: 39–42

363. Yang, W. S. and Park, Y. C. (1988). Distribution of yellowfin and bigeye tunas by the Korean longline fishery in the Indian Ocean. Collective Volume of the Working Documents. Vol. 3. Consultation on the stock assessment of tunas in the Indian Ocean held in Mauritius, 22–27 June, 1988: 89–93.

364. Yano, K. (1991). An interim analysis of the data on tuna tagging collected by R/V *Nippon Maru* in the Indian Ocean, 1980–1990. (SEAC/90/17). Collective Volume of Working Documents presented at the Fourth Southeast Asian Tuna Conference held in Bangkok, 27–30 November 1990: 107–124.

365. Yasin, A. H. (1987). Tuna fisheries in Sarawak and Sabah, Malaysia. Report of the Second Meeting of Tuna Research Groups in the southeast Asian region, Manila, 25–27 August 1987: 28–32.

366. Yoshida, H. O. (1979). Compilation of published estimates of tuna life history and population parameters. Background paper, Workshop on the assessment of selected tunas and billfish stocks in the Pacific and Indian oceans, Shimizu, Japan, 13–22 June 1979. FAO, SAWS/BP/1; 30 pp.

367. Yoshihara, T. (1951). Distribution of fishes caught by the longline. II. Vertical distribution. *Bull. Jpn. Soc. Sci. Fish.* **16** (8): 370–374. (in Japanese).

368. Yoshihara, T. (1954a). On the distribution and catches by tuna longline. *J. Tokyo Univ. Fish.* **41** (1): 1–26.

369. Yoshihara, T. (1954b). Distribution of fishes caught by the longline. IV. On relation between k and y with a table and diagram. *Bull. Jpn. Soc. Sci. Fish.* **19** (10): 1012–1014.

370. Yuen, H. S. H. (1955). Maturity and fecundity of bigeye tuna in the Pacific. *U. S. Fish. Wildl. Serv. Spec. Sci. Rep.* **150**: 1–30.

371. Yukinawa, M. (1958). Size frequency of the bigeye caught in the equatorial Pacific. *Nankai Reg. Fish. Res. Lab. Rep.* **8**: 22–30.

372. Yukinawa, M. and Yabuta, Y. (1963). Age and growth of bigeye tuna *Parathunnus mebachi* (Kishinouye). *Rep. Nankai Reg. Fish. Res. Lab.* **19**: 103–108.

373. Zabala, P.T. (1982). A selected bibliography on tuna fisheries in the South China Sea region. IPTP/82/GEN/2, 24 pp.

SUBJECT INDEX

Reference No.	Systematics/ Racial studies	Distribution	Food/feeding habits	Age and growth	Size composition	Length-weight relationship	Maturity/ fecundity	Spawning/ Breeding	Sex ratio	Larval studies	Tagging	Fishery/ Gear	Resource assessment	Physiology/ Biochemical studies	Processing/ Preservation	Reviews/Synopses/ Bibliography
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Reference No.	Systematics/ Racial studies	Distribution	Food/feeding habits	Age and growth	Size composition	Length-weight relationship	Maturity/ fecundity	Spawning/ Breeding	Sex ratio	Larval studies	Tagging	Fishery/ Gear	Resource assessment	Physiology/ Biochemical studies	Processing/ Preservation	Reviews/Synopses/ Bibliography
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