Compilation of information on neritic tuna species in the Indian Ocean

A working paper

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This document presents some biological characteristics of the following seven neritic tuna species under the management mandate of IOTC: the narrow-barred Spanish mackerel (*Scomberomorus commerson*), the kawakawa (*Euthynnus affinis),* the wahoo *(Acanthocybium solandri),* the longtail tuna *(Thunnus tonggol),* the indo-Pacific king mackerel (*Scomberomorus guttatus*), bullet tuna *(Auxis Rochei),* frigate tuna *(Auxis thazard).*

This document is based primarily on information from literature and studies carried out in Indian Ocean, but when the literature available is scarce we will mention studies available from other oceans. The information pertaining to each species is arranged by paragraphs. Nevertheless, accurate information is sometimes difficult to find. General descriptive characters, illustrations of diagnostic features for each species are given in appendix.

1 Distribution

Scomberomorus commerson

The narrow-barred Spanish mackerel is found throughout tropical marine waters of the Indo-West Pacific. In Indian Ocean, the distribution extends from the Red Sea and the east coast of Africa, and through Mauritius, the Arabian Sea, and the Gulf (Persian Gulf/Arabian Gulf), the coasts of India, Sri Lanka, Myanmar, Thailand, Malaysia, Indonesia and in Australia.

Euthynnus affinis

Kawakawa lives throughout the Indo-West Pacific in open waters close to the shoreline and prefers waters temperatures ranging from 18° to 29°C. This species is generally abundant in coastal areas over continental shelves.

Acanthocybium solandri

Wahoo is an epipelagic (surface to 200m) species occurring widely in the tropical and sub-tropical Pacific ocean between 40°N and 40°S.

Thunnus tonggol

The longtail tuna lives throughout the Indo-West Pacific, it is most abundant over areas of broad continental shelf.

Scomberomorus guttatus

The Indo-Pacific king mackerel is epipelagic and is encountered in turbid waters with reduced salinity along the shores of continental Indo-West Pacific from Wakasa Bay, Sea of Japan and Hong Kong south to the Gulf of Thailand and west to the Gulf lying between the Arabian peninsula and Iran (Collette & Russo, 1979).

Auxis Rochei

Bullet tuna is an epipelagic, neritic as well as oceanic species with strong schooling behaviour. Adults are principally caught in coastal waters and around islands.

Auxis thazard
Frigate tuna is probably cosmopolitan in warm waters. It is an epipelagic, neritic as well as oceanic species.

2 Schooling behaviour and food

Scomberomorus commerson
Juveniles inhabit shallow inshore areas whereas adults are found in coastal waters out to the continental shelf. Adults are usually found in small schools but often aggregate at particular locations on reefs and shoals to feed and spawn.
Spanish mackerel feed primarily on small fishes such as anchovies, clupeids, carangids, also squids and shrimps.

Euthynnus affinis
Kawakawa form schools by size with other species sometimes containing over 5,000 individuals. Kawakawa are often found with small yellowfin, skipjack and frigate tunas. Kawakawa are typically found in surface waters, however, they may range to depths of over 400 m (they have been reported under a fish-aggregating device employed in 400 m), possibly to feed (Lee, 1982).
This species is a highly opportunistic predator feeding on small fishes, especially on clupeoids and atherinids; also squids, crustaceans and zooplankton.

Acanthocybium solandri
Larger individuals are frequently solitary, but may also be found in small, loose aggregations. In sub-tropical areas, peak abundance seems to mostly occur during the winter months. As with other oceanic scombrids, wahoo are often found in association with current lines, near seamounts and around floating objects and debris.
As a top-level predator, wahoo, which lack gillrakers associated with the ingestion of smaller prey, take a range of open-water prey including other scombrids (skipjack, frigate tuna), scads, flying fish, squid and occasionally, fishes of the mixed scattering
layer (e.g. lantern fish).
Wahoo are adapted for swimming in high-speed bursts and are amongst the fastest fishes known. A burst speed of 77 km/hr has been recorded for an 8kg fish.

Thunnus tonggol
Longtail tuna forms schools of varying sizes and feeds on a variety of fish, cephalopods, and crustaceans, particularly stomatopod larvae and prawns.

Scomberomorus guttatus
The Indo-Pacific king mackerel forms small schools has not been studied. As with other species of Somberomorus, the food of Indo-Pacific king mackerel consists primarily of fishes.

Auxis Rochei
Bullet tuna has a strong schooling behaviour. It feeds on small fishes, particularly anchovies, crustaceans (commonly crab and stomatopod larvae) and squid. Cannibalism is common. Because of their high abundance, bullet tuna are considered to be an important prey for a range of species, especially the commercial tunas.

Auxis thazard
Frigate Tuna is usually shoaling with other Scombridae. feeds on small fish, squids, planktonic crustaceans (megalops), and stomatopod larvae. Canibalism is widespread.

3 Migration

Scomberomorus commerson

Known to undertake lengthy long-shore migrations (Collette and Nauen 1983), but permanent resident populations also seem to exist.

Based on fishermen's experiences and seasonal size composition of catches in Oman, the migration pattern of *S. commerson* in the eastern Arabian Sea, the Gulf of Oman, and the Gulf was constructed (Al-Mamry, 1989). In the early spring, fish appear to move into the Gulf from the eastern Arabian Sea and Indian Ocean for spawning. This season lasts for a period of one to four months. The return migration of spent fish from the Gulf to the Arabian Sea occurs by the end of summer. On their return journey, fish spend approximately three months near the shore of Sur in the Gulf of Oman. They may stay longer if there is a high abundance of sardine and cool water temperatures. Thus, fishermen's stories implicitly associate fish abundance with the strength of monsoon upwelling. There is also a third migration, in which very large fish from offshore move to nearshore water. This occurs just before the spawning migration period. Following the peak summer spawning, newly recruited cohort of *S. commerson* starts to move south from the Gulf along the coast into the Arabian Sea (Siddeek, 1995).

Tagging experiments undertaken on *S. commerson* off Queensland (Australia) indicated seasonal north-south migration as well as onshore-offshore spawning migration (McPherson, 1981).

Acanthocybium solandri

Little information is available on wahoo movement, although their seasonal changes in availability and the latitudinal variation in average size suggest that at least seasonal movements may be routinely undertaken. These are likely to be related to current movements, temperature shifts, or even water masses.

Scomberomorus guttatus

Species believed to be less migratory than *S. commerson.* Movements in the Gulf of Thailand might be deduced from seasonal changes in peak fishing months along the coast of Thailand. These peaks are November/December in eastern Thailand, late December/January in the northern part of the Gulf and January-March in its western part.

Auxis Rochei, Auxis thazard

Bullet tuna and frigate tuna are highly migratory. No information is available about their movement

4 Unit stock

Scomberomorus commerson

Shaklee and Shaklee (1990) carried out genetic studies on *S. commerson* from Djibouti, Oman and U.A.E., and found small genetic differences among stocks in these three places. Although Siddeek (1995) assume that *S. commerson* stocks in Oman and U.A.E. are reported to be genetically different, it is very likely that both stocks are shared by the two countries or many more because of along-shore long-distance migration. It is unlikely that the stock parameters among the sub-stocks within the larger unit will differ significantly. Therefore, for stock assessment purposes, the sub-stocks in the north- eastern Arabian Sea, the Gulf of Oman, and the Gulf may be grouped under one unit stock. Similarly, the stocks in the northwestern Arabian Sea and the Red Sea may be grouped under another unit stock.

No information is available on stock structure in Indian Ocean for the other species studied here.

5 Reproduction

5.1 Spawning season and areas

Scomberomorus commerson

Females spawn several times over the season, about 2 to 6 days apart (In Australian waters). Depending on temperature regime, the spawning season may be more or less extended. Spanish mackerel spawn off the reef slopes and edges, and they form spawning aggregations in specific areas.

Spawning season most probably occurred during August-September (Eastern Peninsular Malaysia), February-March and June-September (Gulf of Thailand).

Based on gonad index and ova diameter analyses, Devaraj (1983) determined an extended spawning period of January-September, with a peak in April-May in the south coast of India and the southeast Arabian Sea.

The spawning period in Iranian waters was reported to be August-October.

Based on otolith-derived ages, Dudley *et al.* (1992) determined the fertilisation period to be 15 April-15 July, with a mean of 1 July in Omani waters.

Based on the gonad index, Kedidi and Abushusha (1987) and Kedidi et al. (1993) reported a peak spawning period of April-June in the Red Sea and the Gulf.

Bouhlel (1985) recorded a peak spawning period of April-July for the stock off the coast of Djibouti.

Nzioka (1991) observed year-round spawning activity with peaks in May and October in Kenyan coastal waters. He associated these peaks with monsoon rainfall.

Williams (1964) observed year-round spawning in east African waters.

It appears that in Area 51 the prime species, *S. commerson*, spawns year-round, with two peaks, a major one during late spring to summer (April-July) and a minor one in autumn (September - November). The two spawning peaks appear to be synchronised with the two seasonal monsoons to exploit the post-monsoon plankton and small pelagic fish production in coastal waters (Siddeek, 1995). McPherson (1993) reported that the Queensland stock of *S. commerson* spawned in the late afternoon.

Euthynnus affinis

Although sexually mature fish may be encountered throughout the year, there are seasonal spawning peaks varying according to regions: i.e. March to May in Philippine waters; during the period of the NW monsoon (October-November to April-May) around the Seychelles; from the middle of the NW monsoon period to the beginning of the SE monsoon (January to July) off East Africa; and probably from August to October off Indonesia (Collette, B.B. and Nauen. C.E., 1983).

Acanthocybium solandri

Wahoo are probably multiple spawners, with spawning occurring over a protracted period when favourable conditions (temperature, food) are encountered. Spawning occurs year-round in the tropics and during the summer months in higher (subtropical) latitudes.

Thunnus tonggol

The spawning season varies according to location. Off the west coast of Thailand there are two distinct spawning seasons: January-April and August-September.

Scomberomorus guttatus

Based on occurrence of ripe females and size of maturing eggs, spawning probably occurs from April to July around Rameswaram Island between India and Sri Lanka. Ripe females (32.5 to 46.5 cm fork length) are taken in May in Thai waters. Devaraj (1987) observed that the Gulf of Mannar stock of *S. guttatus* spawned around the full moon period during the spawning period.

Auxis Rochei

The species is a multiple spawner with asynchronous oocyte development that carried out several spawning step by reproductive season (Niiya, 2001). The spawning season may vary from region to region depending on the hydrographical regime. but in some places it may even extend throughout the year. From larval records, it is deduced that Auxis spawns throughout its distribution range.

Auxis thazard

In the southern Indian Ocean, the spawning season extends from August to April; north of the equator it is reported from January to April.

5.2 Size and age at first maturity

Scomberomorus commerson

The Length at first maturity (Lm) and Length with optimum yield (Lopt) were estimated to be 93.9 cm and 72.1 cm respectively for west coast and 130.5 cm and 78.4 cm for east coast. Analysis of pooled length frequency data collected from different centers from west coast gave growth parameters as $L\infty$ = 142 cm, K = 0.5/year and t0 = -0.0314 year. Using the length-frequency weighted to the west coast landings, the mortality parameters were estimated to be M = 0.73, Z = 2.43, F = 1.69 and E = 0.70. Length-cohort analysis indicated higher fishing mortalities of young king seer (23- 30 cm) by trawl and higher length groups (74-78 and 90-94 cm) by gill net (Somvanshi *et al.*, 2003).

Numerous studies have been completed to determine the size at first maturity and the corresponding age for *Scomberomorus commerson* and to determine the growth parameters.

Euthynnus affinis

On the Natal coast in South Africa, sexual maturity is attained at 45-50 cm and spawning occurs mostly during summer.

Acanthocybium solandri

Fish in different maturity stages are frequently caught at the same time. Specimens of 90 cm are sexually mature. They possibly commence spawning at the end of the first year of life

Scomberomorus guttatus

The minimum mature length ranges from 40 to 52 cm total length (TL) (approximately 1-2 years) for female *S. guttatus.* Two studies have been completed to determine the size at first maturity and the corresponding age for *Scomberomorus guttatus* (Table 1) and to determine the growth parameters (Table 2).

Auxis Rochei

The first maturity size has been stated in 35 cm (FL) when the fish is two years old (Rodriguez-Roda 1983). The species is a multiple spawner with asynchronous oocyte development that carried out several spawning step by reproductive season (Niiya, 2001).

Auxis thazard

Size at first maturity is reported at about 29 cm fork length in Japanese but 35 cm around Hawaii.

6 Fecundity

Scomberomorus commerson

Fecundity (Fc) increased with age in the Indian waters. Devaraj (1983) established the following linear equation relating absolute fecundity (i.e., total number of ova spawned by a fish in a season) to the total length (TL in mm) of mature narrow-barred Spanish mackerel: Fc = -2273 + 3.5793 * TL .

Euthynnus affinis

The only available information on fecundity applies to Indian Ocean material: a 1.4 kg female (48 cm fork length) spawns approximately 0.21 million eggs per batch (corresponding to about 0.79 million per season), whereas a female weighing 4.6 kg (65 cm fork length) may spawn some 0.68 million eggs per batch (2.5 million per season) (Collette, B.B. and Nauen C.E., 1983).

Acanthocybium solandri

Fecundity is believed to be quite high: some 6 million eggs per spawning were estimated for a 131 cm long female.

Scomberomorus guttatus

Fecundity (Fc: total number of ova spawned by a fish in a season) increased with age in the Indian waters. Thus, Fc increased from 385,000 eggs at age 2 years to 1,100,000 eggs at age 4 years.

Auxis Rochei

Estimated fecundity can range between 31,000 and 103,000 eggs per spawning according to the size of the fish.

Auxis thazard

Fecundity was estimated at about 1.37 million eggs per year in a 44.2 cm long female. Fecundity of fish in Indian waters ranged between approximately 200 000 to 1.06 million eggs per spawning in correlation with size of females.

7 Sex-ratio

Scomberomorus commerson

The sex ratio of the S. *commerson* population in eastern Arabian Sea and in Oman waters is approximately 1:1. However, among the spawners and larger fish of *S. commerson* the sex ratio is in favour of females (Bal and Rao, 1990).

Euthynnus affinis

The sex ratio in immature fish is about l:l, while males predominate in the adult stages.

Acanthocybium solandri

Latitude appears to influence size, with average weight increasing with distance from the equator, apparently correlated to cooler temperatures. Males appear to predominate at sizes greater than 140 cm. It is believed that wahoo live up to or more than 5-6 years of age.

8 Early stage

Acanthocybium solandri

Little is known of their early life history, however wahoo larvae are pelagic and prefer shallow water less than 100 m in depth. Distribution of juveniles is unknown.

Auxis Rochei* and *Auxis thazard
Though larvae have a high temperature tolerance (at least between 21.6° and 30.5°C), the widest among tuna species studied, their optimum temperature is between 27.0° and 27.9°C, and the species is usually confined to oceanic salinities.

9 Growth and Age

Tables 2 and 3 (Appendix 8) present summaries of the estimated parameters of Von Bertalanffy growth equation from studies carried out on the following species.

Scomberomorus commerson
Differential growth in length, weight and longevity exist between the sexes of the narrow-barred Spanish mackerel. In North-eastern Queensland waters, McPherson G.R. (2001) found that the oldest male was 10 years old (127 cm FL, 19.0 kg) and the oldest female was 14 years old (155 cm FL, 35 kg). The von Bertalanffy growth parameters L∞ and K are 127.5 cm and 0.25 for males and 155.0 cm and 0.17 for females. The narrow-barred Spanish mackerel can reach 240 cm fork length, 70 kg and over 15 years of age.

Euthynnus affinis
Numerous studies have been completed to determine the age and growth of kawakawa. These include studies based on length-frequency distributions and one study each on vertebrae, dorsal spines, and otoliths (Table 1).
Available evidence suggests rapid growth during the juvenile stage of kawakawa. Yabe et al. (1953) sampled juvenile kawakawa landed at Aburatsu, Japan, during August-October 1950. The mean size of the juveniles increased from 20.0 to 27.2 cm in 53 days. In Indian Ocean it is reached between 50 and 65 cm in the third year of age. The von Bertalanffy growth parameters L∞ and K are 90 cm (FL) and 0.44 (Seychelles, FAO).
Kawakawa can reach a length of 100.0 cm FL for a weight of 13.6 kg but common size is around 60 cm.

Acanthocybium solandri
Two studies have been completed to determine for *Acanthocybium solandri* the growth parameters (Table 1). Wahoo exhibit rapid growth, it is believed that wahoo live up to or more than 5-6 years of age. it can attain at least 210 cm fork length (83 kg).

Thunnus tonggol
Longtail grow rapidly to reach 40 to 46 cm in FL in one year. It can reach around 145 cm FL or 35.9 kg but the most common size in Indian Ocean ranges from 40 to 70 cm.

Scomberomorus guttatus
Two studies have been completed to determine the size at first maturity and the corresponding age for *Scomberomorus guttatus* and to determine the growth parameters.

Auxis Rochei
In India, the growth parameters estimated were L∞ = 34 cm and K = 1.1 (annual). The estimated fork lengths for 0.5, 1, 1.5 and 2-year classes were 19.4, 22.8, 27.5 and 30.3 cm respectively. The Z was 4.81, M = 1.85, F = 2.96 (Somvanshi *et al.*, 2003).

Auxis thazard

The species grows larger than *A. rochei*. Adults can reach a maximum length of 65 cm fork length but maximum fork length record in the Indian Ocean is 58 cm (off Sri Lanka);

10 Size at capture

Scomberomorus commerson

Usually size caught between 32-119 cm (Eastern Peninsular Malaysia), 17-139 cm (East Malaysia) and 50-90 cm (Gulf of Thailand).
In India, the size range of king seer in large mesh gillnet was 30-140 cm along west coast and 14-154cm along east coast with mean length at 67 cm and 71 cm respectively.

Euthynnus affinis
A high percentage of the kawakawa captured by Thai purse seiners in the Adaman sea is comprised of fish in the 8- to 42-cm interval (OFCF program). The frequent capture of kawakawa juveniles is attributed to the neritic habit of the species.

Thunnus tonggol
The most common size of Longtail tuna in Indian Ocean ranges from 40 to 70 cm.

Auxis Rochei
fork lengths in the Indian Ocean range between 15 and 25 cm (Silas & Pillai, 1982).

Auxis thazard
the common size in catches ranges between 25 and 40 cm, but depends on the type of gear used, and may also vary seasonally and by region.

11 Length- weight conversion

Table 1 presents the coefficients of the general equation for predicting fish round weight from standard length for seven species of neritic tunas.

Table 1: Coefficients of the general equation used: *W*=(a)FL ^{b}. for predicting fish round weight (kg) from standard length (cm) for tuna and tuna like species.

Species	*Type of Measurement*	*a*	*b*	*Remarks*
S.Commerson	TL	$9.61*10^{-3}$	2.857	India (Devaraj,1981)
	TL	$1.54*10^{-2}$	2.814	India (Pilial et al, 1993)
	FL	$1.72*10^{-6}$	3.31	Oman (Dudley et al, 1992)
	TL	$5.6*10^{-3}$	2.979	Saudi Arabian Gulf (Kedidi et al, 1993)
	TL	$1.2*10^{-3}$	2.812	Red Sea (Kedidi and Abushusha.1987)
	FL	$1.1*10^{-2}$	2.85	Gulf of Aden, Yemen(Edwards et, 1985)
	FL	$1.06*10^{-5}$	2.94	South Africa (Torres,1991)
	FL	$7.3*10^{-3}$	3.01	Western Australia (fishbase)
	FL	$1.32*10^{-2}$	2.89	Queensland Australia (fishbase)
	FL	$5.7*10^{-3}$	3.125	Indonesia (fishbase)
	FL	$1.72*10^{-6}$	3.31	Oman (Bertignac M, Yesaki M., 1993)
S. guttatus	TL	$1.01*10^{-2}$	2.86	India (Devaraj,1981)
A. solandri	*FL*	$2.51*10^{-4}$	*3.19*	*South Africa (Torres,1991)*
T. tonggol	FL	$1.5*10^{-4}$	2.437	Hormuzgan waters (Khorshidian, carrara (1993)
S.guttatus	FL	$9.6*10^{-3}$	3.002	Indonesia Indian Ocean (fishbase)
A. rochei	FL	$1.7*10^{-5}$	3	Indian Ocean (IPTP,1993)
A. thazard	FL	$1.7*10^{-5}$	3	Indian Ocean (IPTP,1993)

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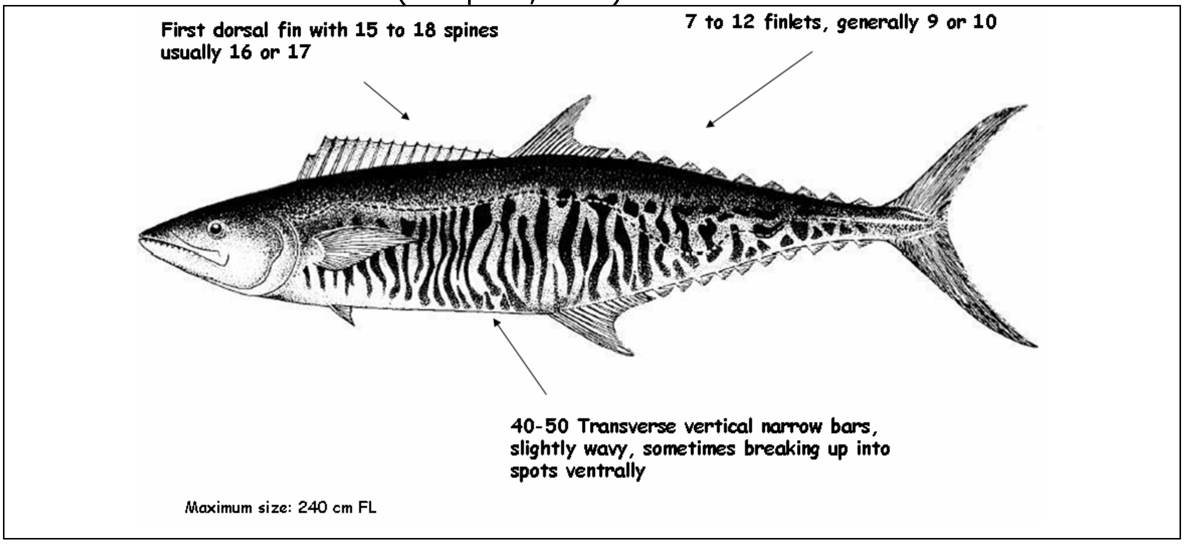
13 Appendices

APPENDICE 1

Scomberomorus commerson (Lacepède, 1800)



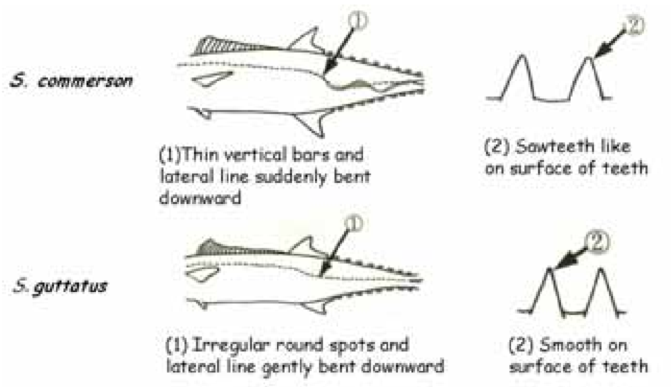
Class - Actinopterygii (ray-finned fishes)
Order-Perciformes
Family – Scombridae
FAO Names : En - Narrow-barred Spanish mackerel; Fr - Thazard rayé
Alpha code : COM, **Large Group** : SEERFISH,

Diagnostic Features:

D XV-XVI +19-21 +8-10 finlets; A 19-22+8-10 finlets; P 22-25; GR(2-3)+(9-13) = 12-15 ; vertebrae (19-22)+(25-29).
This large elongate fish has a moderately compressed body with a pointed snout. The mouth is large and armed with razor-sharp, triangular teeth. The first gill arch carries 3-6 short rackers. The scales are minute and almost invisible, giving the fish its characteristically smooth body surface. Fins are well developed with a dorsal comprising two parts. Interpelvic process is small and bifid. The Lateral line abruptly bent downward below end of second dorsal fin. Its colours are blue-grey above with silvery sides. Vertical bars on trunk sometimes break up into spots ventrally which number 40-50 in adults. The belly is white.

Dissection reveals an intestine with 2 folds and 3 limbs and no Swim bladder.
Juveniles with large oval dark spots on body (less than 20); middle third of first dorsal fin white, rest of fin black

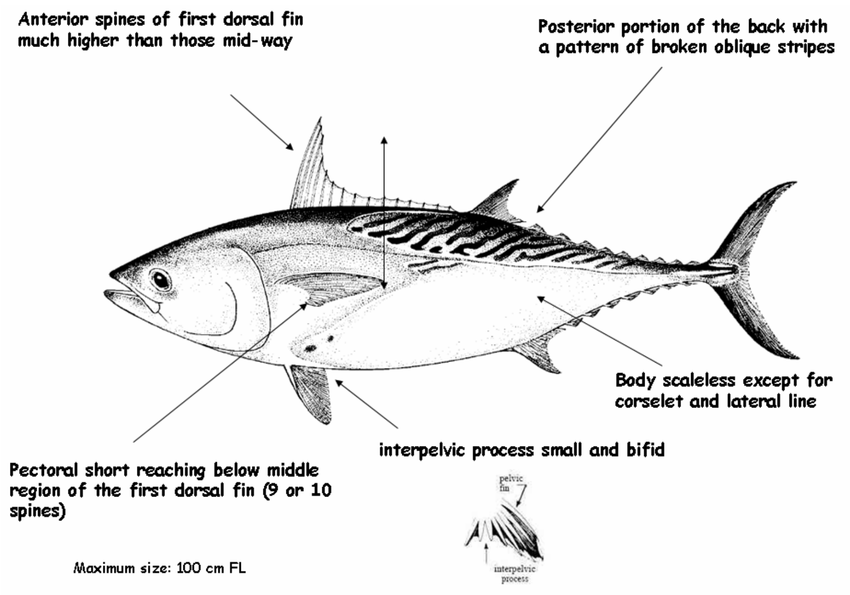
Remarks: the narrow-barred Spanish mackerel, also called King seer, is the largest of the mackerel-like fishes. *Scomberomorus* is an ancient name for mackerel fish. It can be confused with other mackerels and wahoo. Vertical bars, gill rackers, lateral line and teeth shape serve to confirm identity.



Source: Anonyme , 2000. Fishes of Japan with pictorial key to the species , Tokai University Press.

APPENDICE 2

Euthynnus affinis (Cantor, 1849)



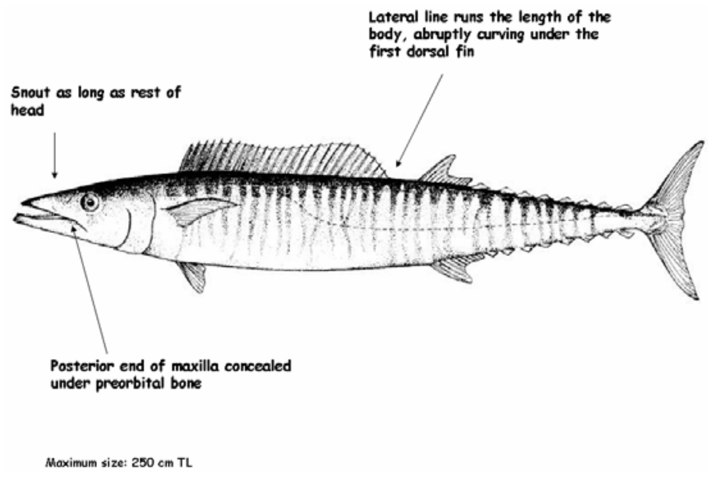
Class:-Actinopterygii (ray-finned fishes)
Order – Perciformes
Family – Scombridae

FAO Names : En - Kawakawa; Fr - Thonine orientale;
Alpha Code : KAW, Large Group : TUNAS,

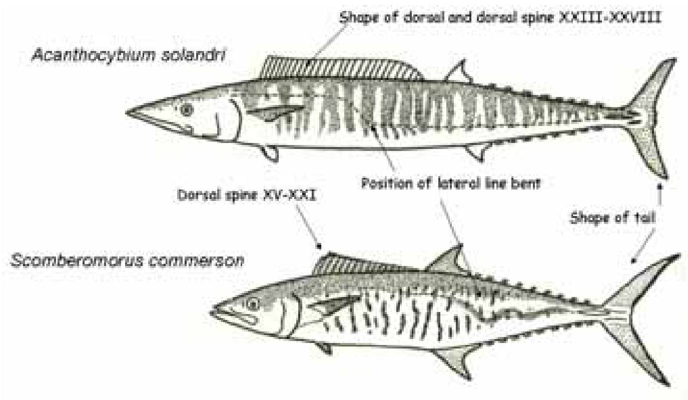
Diagnostic Features :
D XV-XVII + 12-13+ 8 finlets; A 13-14 +7 finlets; P 26-29; GR (6-9) + (23-26)= 29-35 ; vertebrae 20+19=39.
Anterior spines of first dorsal fin much higher than those mid-way. Interpelvic process small and bifid. Upper body green-blue with wavy dark stripes that does not extend forward of the pectoral fins. Body naked except for corselet and lateral line. Several dark spots near pectoral fins may occur especially when the fish is excited or stressed. Dark caudal keel and finlets.

APPENDICE 3

Acanthocybium solandri (Cuvier, 1832)



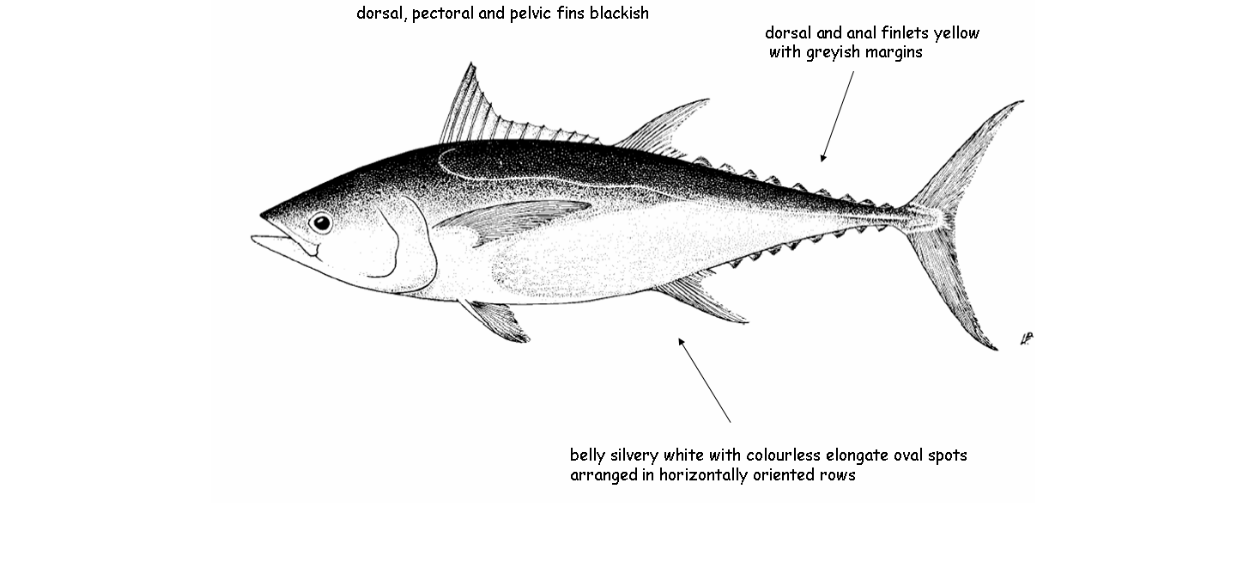
Class - Actinopterygii (ray-finned fishes)
Order - Perciformes
Family – Scombridae
FAO Names : En - Wahoo; Fr - Thazard-bâtard;
Alpha Code :WAH, **Large Group** : SEERFISH
Diagnostic Features :
D XXIII-XXVII + 12-16+7-10 finlets; A 12-14 +7-9 finlets; P 22-24 ; GR 0 + (23-26)= 29-35 ; vertebrae (30-32)+(31-33)=62-64.
Body very elongate, fusiform and only slightly compressed. Mouth large with strong, triangular, compressed, and finely serrate teeth closely set in a single series; snout about as long as the rest of head; gillrakers absent.
Body covered with small and narrow scales; the body appears almost naked, no anterior corselet developed; caudal peduncle slender, with a well defined lateral keel between the two small ones on each side. The lateral line is distinct and noticeably wavy. Swimbladder present.
Remarks: Once stripes have disappeared, the wahoo can look like a King mackerel, though the wahoo has longer, pointed snout that is half the total head length, and also lacks any gillrakers. The shape of the dorsal and of the tail and the position of the lateral line bent are good indicators to identify these species.



Source: Anonyme , 2000. Fishes of Japan with pictorial key to the species , Tokai University Press.

APPENDICE 4

Thunnus tonggol (Bleeker, 1851)



Class - Actinopterygii (ray-finned fishes)
Order - Perciformes
Family – Scombridae

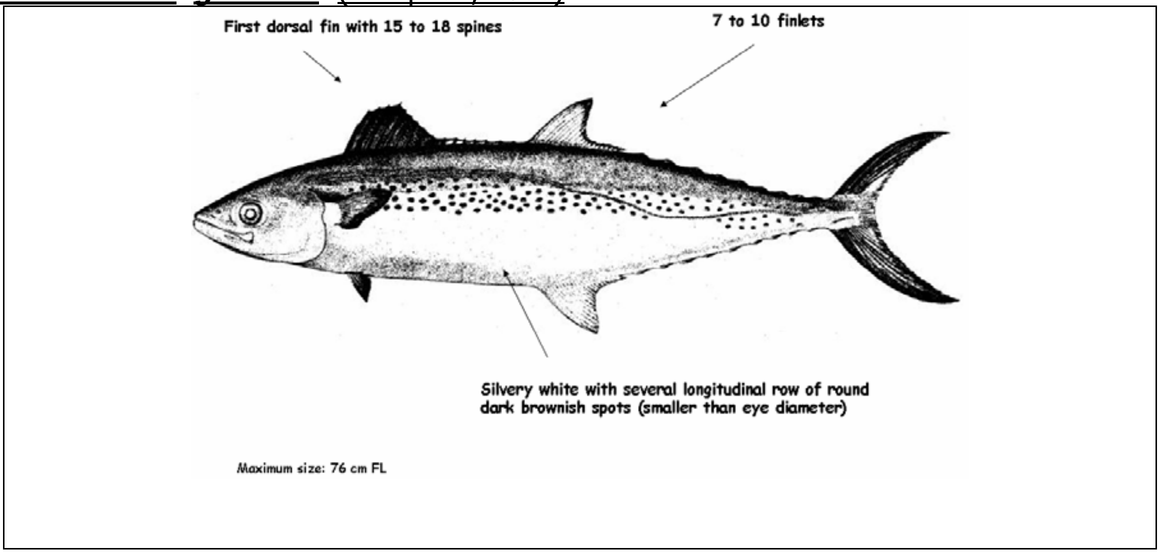
FAO Names : En - Longtail tuna; Fr - Thon mignon
Alpha Code : LOT, **Large Group** : TUNAS

Diagnostic Features :
Vertebrae: 39. A small species, deepest near the middle of the first dorsal fin base. The second dorsal fin is higher than the first dorsal fin; the pectoral fins are short to moderately long. The dorsal, pectoral and pelvic fins are blackish; the tip of the second dorsal and anal fins are washed with yellow; the anal fin is silvery; the dorsal and anal finlets are yellow with grayish margins; the caudal fin is blackish, with streaks of yellow green. Lower sides and belly silvery white with colorless elongate oval spots arranged in horizontally oriented rows. Swimbladder is absent or rudimentary.

Remarks: Juveniles of this species, bluefin tuna, yellowfin tuna and bigeye tuna are very similar.

APPENDICE 5

Scomberomorus guttatus (Lacepède, 1800)



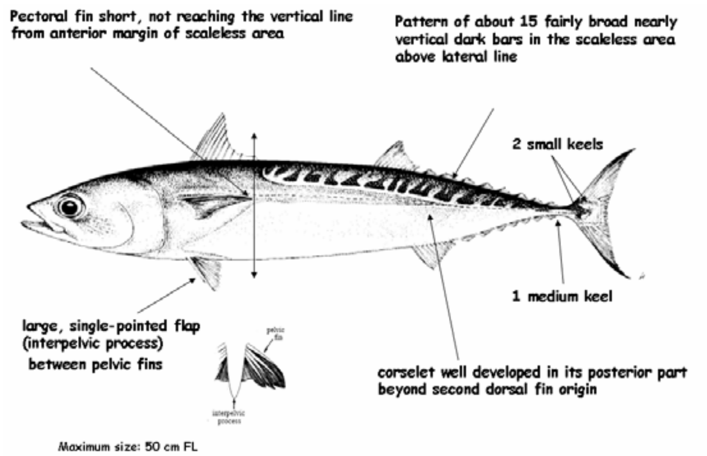
Class - Actinopterygii (ray-finned fishes)
Order-Perciformes
Family – Scombridae
FAO Names : En - Indo-Pacific king mackerel; Fr - Thazard ponctué
Alpha code : GUT, **Large Group** : SEERFISH
Max. size: 76.0 cm FL.

Diagnostic Features:
D XV-XVIII +18-24 +7-10 finlets; A 19-23+7-10 finlets; P 22-25; GR(1-2)+(15-18) = 16-20 ; vertebrae (19-22)+(28-31).
Body entirely covered with small scales. First dorsal fin membrane black (up to the 8th spine) white posteriorly, with the distal margin black; pectoral, second dorsal and caudal fins dark brown; Interpelvic process is small and bifid. Lateral line with many auxiliary branches extending dorsally and ventrally in anterior third, curving down toward caudal peduncle.
Its colours are sides silvery white with several longitudinal rows of round dark brownish spots (smaller than eye diameter) scattered in about 3 irregular rows along lateral line.
Dissection reveals an intestine with 2 folds and 3 limbs and no Swim bladder.

Similar species: it can be confused with other mackerels and wahoo. Vertical bars , gill rackers, lateral line and teeth shape serve to confirm identity.

APPENDICE 6

Auxis rochei (Risso, 1810)

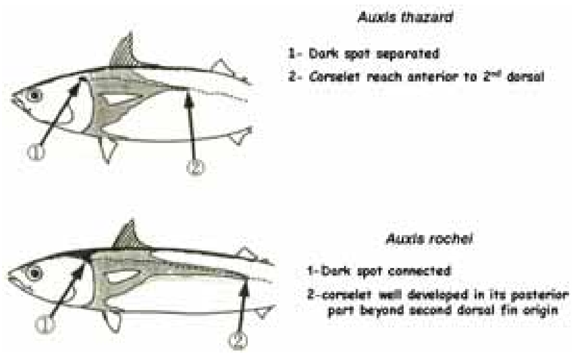


Class-Actinopterygii-(ray-finned-fishes)
Order-Perciformes
Family – Scombridae

FAO Names : En - Bullet tuna; Fr - Bonitou
Alpha Code : BLT, **Large Group** : TUNAS
Max. size: 50.0 cm FL. Common to 35 cm. Common fork lengths in the Indian Ocean range between 15 and 25 cm
Environment: Cosmopolitan in warms waters, pelagic; oceanodromous; brackish; marine; depth range - 10 m

Diagnostic Features :
D X-XI +10-11+ 8 finlets; A 13-15 +6-7 finlets; GR (9-10) +(33-37)= 42-46
Back bluish, turning to deep purple or almost black on head. Scaleless area with pattern of 15 or more fairly broad, nearly vertical dark bars. Belly white. Pectoral and pelvic fins purple, their inner sides black. Body robust, elongate and rounded. Teeth small and conical, in a single series. Pectoral fin short, not reaching the vertical line from anterior margin of scaleless area. A large, single-pointed flap (interpelvic process) between pelvic fins. Body naked except for corselet, which is well developed in its posterior part (more than 6 scales wide under second dorsal-fin origin). A strong central keel on each side of caudal-fin base between 2 smaller keels. Swim bladder is absent.

Similar species: it can be also be confused with *Euthynnus affinis*, *A. thazard.*

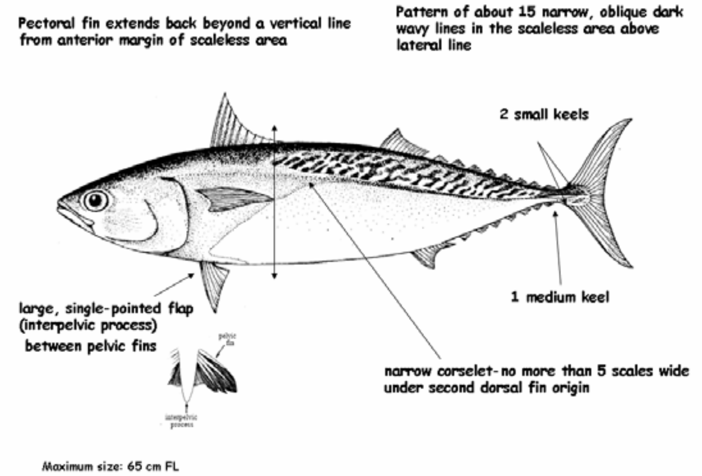


Source: Anonyme , 2000. Fishes of Japan with pictorial key to the species , Tokai University Press.

Auxis thazard is identified by its narrow corselet (no more than five scales wide under second dorsal fin origin) compared to *Auxis rochei* which has wider corselet (6-20 scales).
Pectoral fin of *Auxis thazard* extends posteriorly to the beginning of scaleless area above corselet while in *Auxis rochei* pectoral fin does not reach the beginning of the scaleless area.
Dark wavy line in the dorsal scaleless area usually oblique to nearly horizontal in *Auxis thazard* while in *Auxis rochei* nearly vertical.
Gill rackers on lower limb of 1st arch count 31 to 36 in *Auxis rochei* compared to 29 to 32 in *Auxis thazard.*

APPENDICE 7

Auxis thazard (Lacepède, 1800)



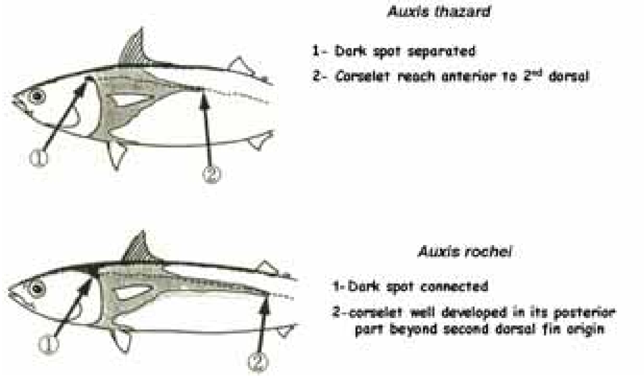
Class - Actinopterygii (ray-finned fishes)
Order-Perciformes
Family – Scombridae

FAO Names : En - Frigate tuna; -Fr - Auxide;

Alpha Code : FRI, **Large Group** : TUNAS,

Diagnostic Features :
Dorsal spines (total): 10-12; Dorsal soft rays (total): 10-13; Anal spines: 0; Anal soft rays: 10-14. Body robust, elongate and rounded. Pectoral and pelvic fins purple, their inner sides black. Teeth small and conical, in a single series. Pectoral fin extends back beyond a vertical line from anterior margin of scaleless area. A large single-pointed flap (interpelvic process) between pelvic fins. Body naked except for the corselet, which is well developed and narrow in its posterior part (no more than 5 scales wide under second dorsal-fin origin). A strong central keel on each side of caudal-fin base between 2 smaller keels. Back bluish, turning to deep purple or almost black on the head. Pattern of about 15 narrow, oblique dark wavy lines in the scaleless area above lateral line. Belly white. Swim bladder is absent.

Name derivation: a reference to its association with feeding frigate birds
Similar species: it can be also be confused with *Euthynnus affinis*. In the closely related *A. rochei*, the pectoral fin does not reach the scaleless area above the corselet.



Source: Anonyme , 2000. Fishes of Japan with pictorial key to the species , Tokai University Press.

Auxis thazard is identified by its narrow corselet (no more than five scales wide under second dorsal fin origin) compared to *Auxis rochei* which has wider corselet (6-20 scales).
Pectoral fin of *Auxis thazard* extends posteriorly to the beginning of scaleless area above corselet while in *Auxis rochei* pectoral fin does not reach the beginning of the scaleless area.
Dark wavy line in the dorsal scaleless area usually oblique to nearly horizontal in *Auxis thazard* while in *Auxis rochei* nearly vertical.
Gill rackers on lower limb of 1st arch count 31 to 36 in *Auxis rochei* compared to 29 to 32 in *Auxis thazard.*

APPENDICE 8

Table 2: Growth (L∞, K, to) parameters and the largest size of fish (length / weight) for for *S.Commerson, S. guttatus, A. Solandri, T.tonggol)*

Species	L∞(cm)	k(yr)	$T_{O(YR)}$	Larger size	Remarks
S.Commerson	146 Fl	0.37			Sri Lanka, 1986-1987 data. ELEFAN (Dayaratne, 1989b)
	208.1 TL	0.18	-0.16	193.6cm TL 33kg	South and South west India, 1967-1969 data, Rafai'l iterative method of fitting on length modes determined by Petersen's Method and length at cotolith age (dearaj, 1981)
	146 TL	0.78			Southwest Indian, 1989-91 data modal progression analysis (Pillai et al.., 1993)
	177.5F	0.38	-0.23		South east India, Ford-walford plot (thiagarajan, 1989)
	226 FL	0.21	-0.85	200cm Fl	Oman, ELEFAN and graphical method (Dudley et al, 1992)
	193.6 FL	0.29	-0.678		Oman, least square fitting on modal lengths from Bhattacharya Method (Dudley et al., 1992)
	138.3 FL	0.36	-1.16		Oman, Least square fitting on length at otolith age (Dudley et al, 1992)
	131.2 FL	0.61	-0.438		Oman, least square fitting on the combined set of otolith and length frequency modal lengths (Dudley et al, 1992)
	164 FL	0.34			Oman, 1987-89-data ELEFAN (Dudley and AghanashiIkar 1989)
	182 FL	0.3	-0.7		Oman, least square fitting on modal lengths of the catch from Bhattacharya method (Bertignac and Yesaki, 1993)
	183.6 TL	0.26			Saudi Arabian Gulf, 186-1992 data, modal length of the catch from Bhattachary method used in VONBER programme (Sparre et al 1989) and average growth parameters estimated by ELEFAN (kedid et al, 1993)
	153.3 TL	0.38	-0.26		Saudi Arabian Red Sea, 1985-1986 data, Gulland and Hoolt plot on modal on modal lengths of the catch from Bhattacharya method (kedidi and Abushusha, 1987)
	151 TL	0.21			Djibouti, Ford Watford plot (Bouhlel, 1985)
	230.3 FL	0.12	0.01		Gulf of Aden, Yemen (Edwards et al, 1985)
				230 cm FL	Gulf of Eden, Yen (Edwards and Shaher, 1991)
				200 cm FL	South Africa (Torres, 1991)
S. guttatus	127.8 TL	0.18	-0.47	70.5 cm TL	south and southwest India, 1967 length and otolith annuli data, Rafia's iterative method fitting (Devaraj, 1981)
				76 cm FL	Female, unspecified area (collette and Nauen, 1983)
A. Solandri	158.5 FL	0.35			St. Lucia, West Indies, 1982-83 data, mean values from 1982 and 1983 growth parameter estimates by ELEFAN (Murray and sarvay, 1987)
				200 cm FL	Female, South Africa (Torres, 1991)
T.tonggol	122.9	0.41	-0.032		Wilson (1981)- Modal progress
	131.8	0.395	-0.035		Wilson (1981)- otolith increments
	93	0.49	-0.24		Silas *et al* (1981)- ELEFAN
	58.2	1.44	-0.027		Supongpan and Saikliang (1987)- Modal progress
	133.2	0.228			Prabhakar and Dudley (1989) - ELEFAN
	108	0.55			Yesaki (1989)- Modal progress
	149.5	0.3	-0.06		Khorshidian and carrara (1993)- Modal progress
	55.0	1.70	-0.08934		Itoh *et al*. (1989) otolith increments

Table 3: Summary of age and growth studies on kawakawa by length-frequency distributions and hard parts (from Yesaki, 1989).

Author	Area	Method	Growth parameters			Length at relative age				
			K	L_{oo}(cm)	to	1	2	3	4	5
(a) Length-frequency distributions										
Ommanney (from Yoshida, 1979)	Seychelles	Modal lengths	-	-	-	25	45	65	65	-
Williamson, 1970	Hong Kong	Modal lengths	-	-	-	44	62	-	-	-
Chiampreecha, 1978	Gulf of Thailand	Modal lengths	-	-	-	21	30	41	-	-
	east coast Malaysia	Modal lengths	-	-	-	19	29	35	50	-
Klinmuang, 1978	Gulf of Thailand	Modal progres.	-	-	-	27	41	53	-	-
Yesaki, 1982	west coast Thailand	Modal progres.	0.46	76.0	-	29	45	57	65	-
Silas et al., 1985b	India	ELEFAN	0.37	81.0	-.344	31	47	57	64	70
Joseph et al., 1987	Sri lanka	ELEFAN	0.63	59.6	-	28	43	51	55	57
	Sri Lanka	ELEFAN	0.61	63.0	-	29	44	53	58	60
	Sri Lanka	Bhattacharya	0.69	59.5	-	30	45	52	56	58
Supongpan and Saikliang, 1987	Gulf of Thailand	Modal progres.	2.23	55.1	-.015	49	55	55	55	-
Yesaki, 1989b, 10-day intervals	Gulf of Thailand	Modal progres.	0.96	76.0	-	47	65	72	-	-
Yesaki, 1989b, monthly intervals	Gulf of Thailand	Modal progres.	0.56	76.0	-	33	51	62	68	71
(b) Hard parts										
Landau, 1965	Red Sea	vertebrae	-	-	-	35	46	51	54	55
Shabotinets, 1968	Gulf of Aden	dorsal spines	-	-	-	-	-	58[1]	65[1]	73[1]
Uchiyama, 1980	Hawaii	otoliths	0.42	117.8	-.030	41	68	85	96	104

[1] - median