649

Fishery and Biology of Tunas in the Indian Seas

N.G.K. Pillai and U. Ganga
Central Marine Fisheries Research Institute
Post Box No. 1603, Ernakulam North P.O., Cochin - 682 018, India
E-mail: gopalji2@rediffmail.com

Tunas and tuna-like fishes belong to 6 genera, *viz.*, *Thunnus, Katsuwonus, Euthynnus, Auxis* (tribe Thunnini) and *Sarda* (bonitos) and *Gymnosarda* (tribe Sardini) of the family Scombridae. Tunas are among the largest, most specialized and commercially important of all fishes (Collette and Nauen, 1983). They are found in temperate and tropical oceans around the world and account for a major proportion of the world fishery products. Tunas are unique among fishes because they possess body temperature several degrees higher than the ambient waters and have high metabolic rates that enable them to exhibit extraordinary growth patterns. They have streamlined bodies and vary extensively in size, color and fin length. They are fast swimmers capable of traveling more than 48 km/h (Collette and Nauen, 1983), migratory and have few predators. They are the second most important item, next only to shrimps, in the world seafood trade and therefore form specifically targeted fisheries globally by nations such as France, Spain, Thailand, Taiwan, Korea, Japan and USA. In the Indian Ocean which contributes 19% of the world tuna catch, tuna fishing and fisheries have emerged as focal points to address issues of sustainable development and management of fishery resources, especially in the context of EEZ regulations, UNCLOS and other international conventions. In India, tuna fishing remains an artisanal activity except for a brief phase of chartered and joint venture tuna fishing by longliners during the 1990s. However, tuna catches have substantially improved during the post-90s period compared to the early eighties, mainly due to motorization of traditional crafts and adoption of progressive and innovative fishing techniques by the mainland fishermen. The tuna exports from India during 2005-06 was estimated to be about 16627 t valued at US$ 15.68 million, largely due to the growing interest in yellowfin tuna fishing by the Indian fishing industry. During 2006-07 it was estimated that about 24,000 t of tunas and tuna products were exported. In view of the rapidly developing fisheries for tuna along the Indian mainland, and recent moves to further extend the EEZ limits of various maritime countries, an appraisal of the tuna fishery of India becomes critical in developing strategies towards sustainable management of the resource.

Field identification characters and fisheries

The various species of tunas represented in the tuna fishery along the Indian coast are given in Table 1.

Table 1: Species represented in Indian tuna landings

Species	Common name	Habitat
Euthynnus affinis	Kawakawa/Little tunny	Coastal
Auxis thazard	Frigate tuna	Coastal
Auxis rochei	Bullet tuna	Coastal
Sarda orientalis	Oriental bonito	Coastal
Thunnus tonggol	Longtail tuna	Neretic
Thunnus albacares	Yellowfin tuna	Oceanic
Thunnus obesus	Bigeye tuna	Oceanic
Katsuwonus pelamis	Skipjack tuna	Oceanic
Gymnosarda unicolor	Dogtooth tuna	Neretic/Oceanic

Euthynnus affinis (kawakawa / little tunny) (Fig. 1): A medium sized coastal species. Upper part of body has numerous blue black broken wavy lines directed backwards and upwards while belly is silvery white. The first and second dorsal fins are contiguous. A few conspicuous black spots are present on sides of body between pectoral and pelvic fins. Exploited throughout the year with peak fishing season from April to November on west coast and from June to August on east coast. Common size in commercial catches is 40-60 cm.

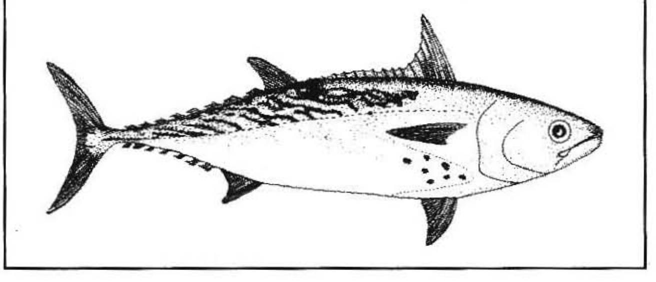

Fig. 1. *Euthynnus affinis*

Auxis thazard (frigate tuna) (Fig. 2): A medium sized, robust bodied coastal species of tuna. It closely resembles the little tunny. Dorsal part of the body contains oblique to nearly horizontal dark wavy lines. The first and second dorsal fins are widely separated unlike the little tunny.

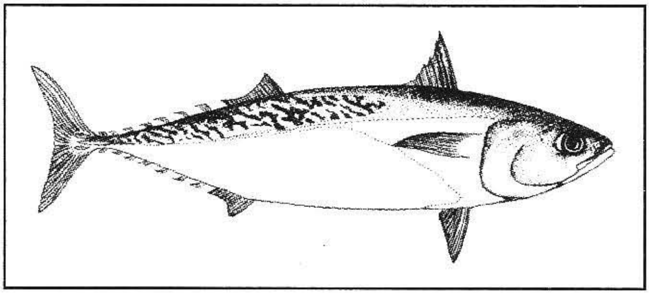

Fig. 2. *Auxis thazard*

Auxis rochei (bullet tuna) (Fig. 3): A small sized coastal species of tuna. Upper part of body bluish with about 15 fairly broad nearly vertical dark wavy lines. The first and second dorsal fins are widely separated. It is distinguished from *Auxis thazard* by its wider corselet which contains 6 or more scales beneath the second dorsal fin. Common size in commercial catches 15-25 cm.

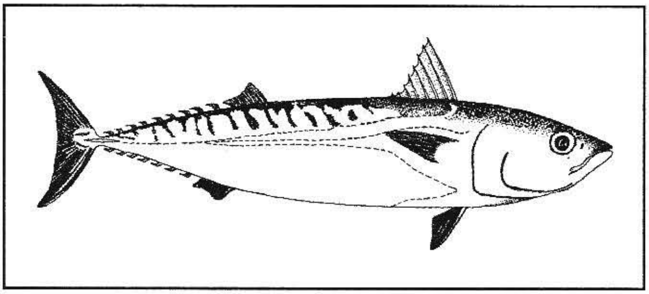

Fig. 3. Auxis rochei

Sarda orientalis (oriental bonito) (Fig. 4): A medium sized coastal species. It has 5 to 11 dark oblique stripes on back and upper sides. Body is entirely covered with scales and a well developed corselet is present. The fishing season on the south-west coast is June to September and common size in the commercial catches is 30 -50 cm.

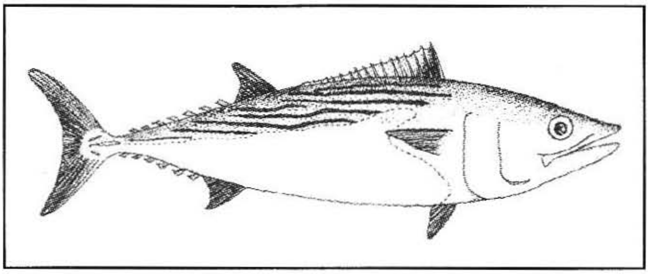

Fig. 4. ***Sarda orientalis***

Thunnus tonggol (longtail tuna) (Fig. 5): Body fusiform and rounded, completely covered with very small scales. A comparatively long caudal region. Upper part of body bluish black and lower part of belly with pale streaks or spots, oriented horizontally. Tips of second dorsal and anal fin faintly tinged with yellow. Common size in commercial catches is 40-70 cm.

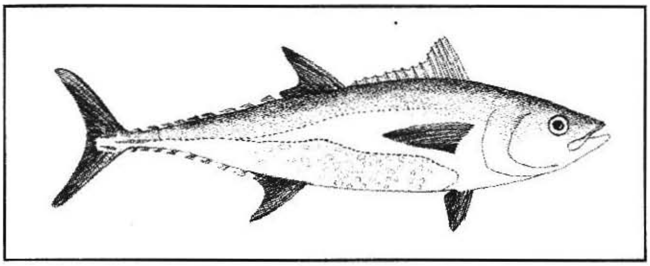

Fig. 5. ***Thunnus tonggol***

Thunnus albacares (yellowfin tuna) (Fig. 6): Body elongate and fusiform, metallic blue or blue black above and belly with about 20 broken nearly vertical pale lines. Entire body covered with very small scales. Dorsal and anal fins very long in large specimens while pectoral fin are moderately long (reaching beyond second dorsal fin origin). Common size in commercial catches 70-150 cm. Large specimens(>100 cm) are

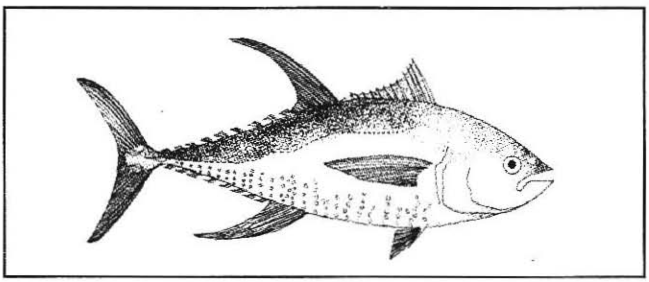

Fig. 6. ***Thunnus albacares***

caught in deep longlines operating in oceanic waters and also by the troll line fishery in Lakshadweep seas. Drift gill nets on the mainland and the pole and line fisheries of Lakshadweep mainly land juveniles (50 -70 cm) which are usually caught from less deep and coastal waters.

Thunnus obesus (bigeye tuna) (Fig. 7): A large oceanic species with a very broad and robust body that is slightly compressed laterally and completely covered with scales. Upper part of the body is black to greenish blue while side and belly are silvery white. Caudal portion is short while eyes and head are fairly large. The first dorsal fin is deep yellow, second dorsal and anal fin slightly yellow while finlets are bright yellowish edged with black. Caudal fin is widely expanded. Caught mainly by longlines with peak catches during October to May. Common size groups represented commercial catches is 60-180 mm.

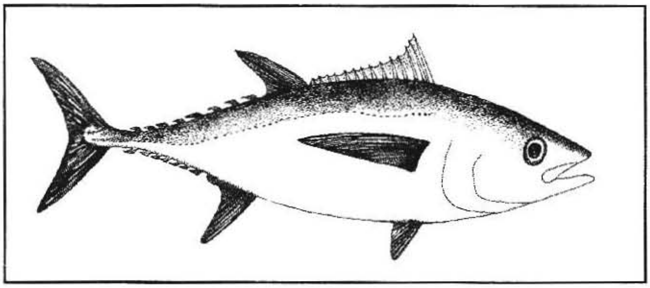

Fig. 7 *Thunnus obesus*

Katsuwomus pelamis (skipjack tuna)(Fig.8): An oceanic species with a robust body. Backside metallic blue tinged with violet and three to five conspicuous longitudinal, dusky to black striped below lateral line on each side of the body. First two dorsal fins separated by a short interspace. Lateral line with downward curve below second dorsal. A major fishery by pole and line in Minicoy Islands with peak fishing during December-April period. Common size in commercial catches is 40-60 cm.

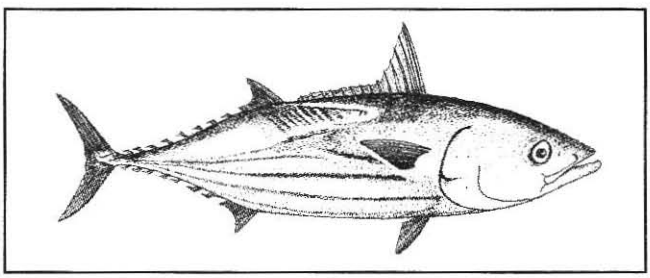

Fig. 8. *Katsuwonus pelamis*

Gymnosarda unicolor (dogtooth tuna) (Fig. 9): A medium sized tuna with a slender and elongate body without any spots or stripes. Dorsal fins close together. Conspicuously large, well-developed and conical teeth present in both jaws. A single large interpelvic process. Strongly undulating lateral line present.

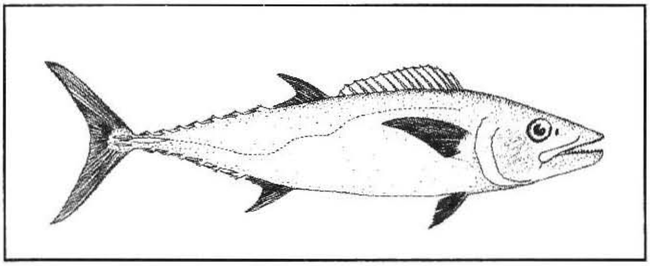

Fig. 9. *Gymnosarda unicolor*

Fishery trends

The tuna landings along the Indian coast have shown a consistently increasing trend. Landings of tunas ranged from 2164 t (1962) to 66742 t (2007) along the mainland coast (Fig. 10). In addition, since the 1990s around 10,000 t of mostly the skipjack tuna is caught annually from the Lakshadweep seas by local fishermen. During the 60s the average tuna landings from the mainland was 3812 t which increased to 11,543 t during the 70s. During the 80s, it further increased to about 24,000 t and 35,402 t in the 1990s. The production during 2002-07 period has ranged from 38,011 t (2004) to 66,742 t (2007) with an average of about 49,000 t (Fig. 11).

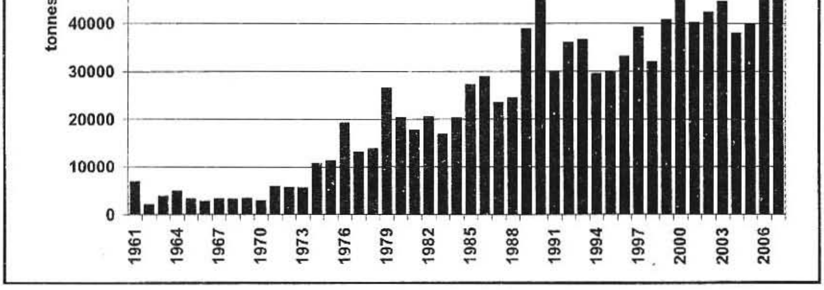

Fig. 10. All India tuna landings (1961 -2007)

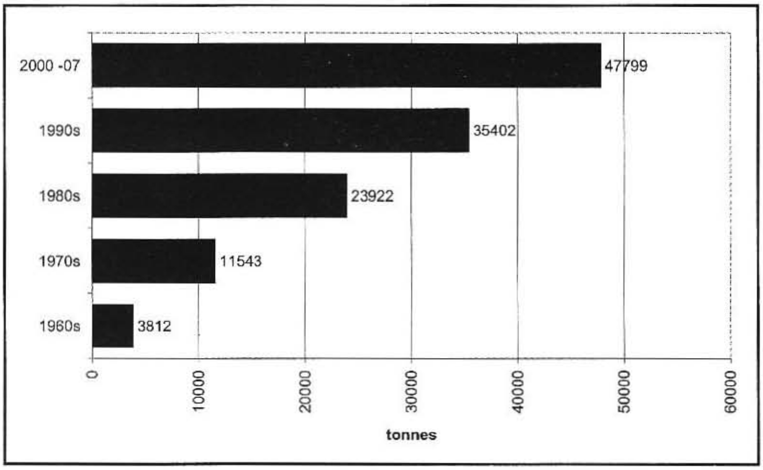

Fig. 11. Decade-wise trend of tuna landings on mainland coast of India

Region-wise and state-wise production trends

The status of exploitation and stock assessment of tunas and billfishes from the Indian EEZ have been reviewed earlier by Silas and Pillai (1985), James and Pillai (1993), James et al. (1993), Somvanshi et al. (2000) Pillai et al. (2002), Pillai and Mallia (2007). Silas and Pillai (1985) reported the average all India tuna catch for the 19-year period during 1965-1983 period as 11,098 t of which Kerala State alone accounted for 48% followed by Tamil Nadu (18%), Maharashtra (7%) and Gujarat (4%). During the 1990-2004 period it was estimated at 40,292 t in which the region-wise contribution was southwest (48%), northwest (27%), southeast (24%) and rest from northeast (Pillai and Mallia, 2007). During the 2002 -2007 period, the average estimated tuna landings further increased to 49,303 t with the west coast contributing 73% (36180 t) and 27% from the east coast.

Sector-wise, the southwest coastal sector comprising states of Kerala, Karnataka and Goa contributed an estimated 25827 t (52%) followed by southeast (Tamil Nadu, Andhra Pradesh) sector (26%) with an estimated 12597 t, northwest (Gujarat, Maharashtra) coast (21%) and north east (West Bengal, Orissa) coast 525 t (1%). State-wise the contribution was mainly by Kerala (42%) followed by Tamil Nadu (17%), Gujarat (11%) and Andhra Pradesh (10%). Along the east coast, the major contributor to the tuna landings was Tamil Nadu (63%) followed by Andhra Pradesh (29%) and the other states contributing 7%. On the west coast, the contribution was highest by Kerala (59%) followed by Gujarat (16%), Maharashtra (12%), Goa (7%) and Karnataka (5%).

During 60s and 70s, the average species composition of landings along the mainland reported was *Euthynnus affinis* (65%), *Auxis* spp. (31%) and other species such as *Sarda orientalis* and *Thunnus tonggol* the rest (4%). James and Pillai (1993) have reported that during the 80s the landings along the mainland were mostly dominated by little tunny (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*), whereas the average landings of longtail tuna (*Thunnus tonggol*) being a mere 663t and skipjack tuna (*Katsuwonus pelamis*), about 5000 t, was landed only from Lakshadweep waters. During 1995–2002 the average tuna landings along the mainland coast was an estimated 36,270 t of which species composition was *Euthynnus affinis* (51%), *Auxis* spp. (21%), *Katsuwonus pelamis* (4%), *Thunnus tonggol* (13%), *Thunnus albacares* (11%) with only occasional landings of other species such as *Sarda orientalis* and *Gymnosarda unicolor*. Since the 1990s, skipjack tuna is regularly landed on the mainland and the average landings of *Thunnus tonggol* show a manifold increase compared to the 80s. Comparison of the species composition of the tuna landings during the 1990-94 and 1995-2002 period showed that *Euthynnus affinis* had declined by 10% but *Auxis* spp. increased while landings of *Thunnus tonggol* doubled. The landings of oceanic species like *Katsuwonus pelamis* and *Thunnus albacares* has also increased since 1995.

In general, coastal and neretic species of tuna dominate in the landings along the mainland (Fig. 12).Of the estimated annual average (2002-07) landing of 49,303 t of tunas, oceanic species contributed 21%

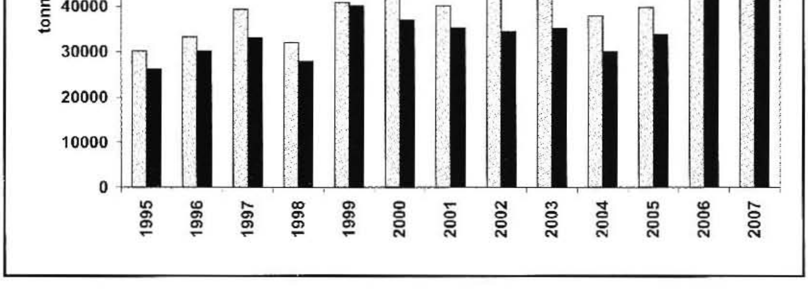

Fig. 12. Contribution of neretic tunas to total tuna landings of India during 1995 -2007

while coastal and neretic tunas comprised 79% (39109 t) (Fig. 13). The average species composition during 2002 –07 period was *Euthynnus affinis* (47%), *Auxis* spp.(21%), *Thunnus tonggol* (11%), skipjack (4%) and yellowfin (17%). Oceanic tunas constituted 35%, 30%, 26% and 15% of the annual tuna landings (average 2002-07) of the north east, southeast, northwest and southwest coasts respectively.

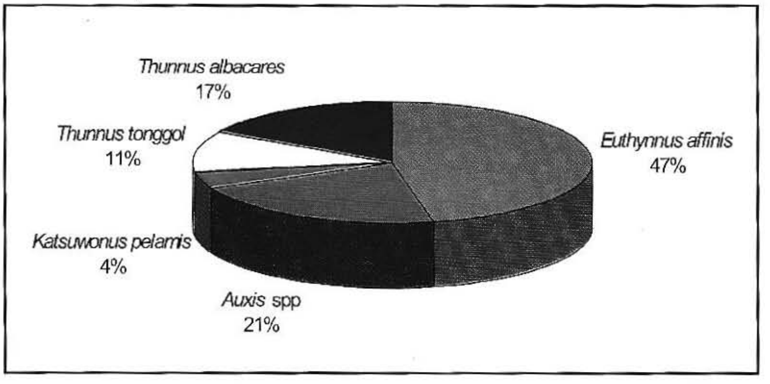

Fig. 13. Average (2002-07) species composition of tuna landings of Indian mainland

Seasonal trends

The average quarterly landings of tunas at an all India level indicate that the two quarters of April to June and October to December are more productive periods. State-wise average quarterly production of tunas during 1970-83 indicate that it is relatively high during the months of April to June along the west coast of India and July to October along the east coast. Productive period for tuna fishery was observed to be during April-June for the Kerala State, July-September for the state of Tamil Nadu and October-December for the northwest coast and north east coasts. The bulk of the tuna landings in the Lakshadweep Islands occur during the period November to May.

Gear-wise trend

The crafts used for tuna fishery in the small-scale sector are motorized, small mechanized and non-mechanized boats. Drift gill nets with mesh size varying from 90-140 mm remain the major gear contributing to the fisheries along the entire coast while purse seines and hooks and line operated off the southwest coast also contribute significantly. Pole and line is the most important gear in Lakshadweep Islands which contributes more than 80% of the tuna landings followed by troll and hand lines. Silas and Pillai (1985) reported on the major gears and crafts employed for tuna fishing (Table 2) and with minor technological upgradations are still in vogue.

Since early 80s, motorization of country crafts along with multiday fishing has been reported all along the coast which has resulted in increased mobility to offshore tuna fishing grounds and significantly contributed to the increased landings of neritic tunas (Gopakumar and Sarma, 1989; Yohannan and Balasubramanian, 1989; Pravin et al., 1998, Pillai et al., 2002). In the mechanized sector, the drift gill net contributes 77% of the total catch followed by hook and line (11%) and purse seine (7%) and other gears (5%) (Fig. 14). Recently, there has been the trend of converting the idling shrimp trawling fleet specifically for tuna long lining along the upper east coast of India which is gradually picking up

Table 2: Craft and gear in operation for tuna fishing along Indian mainland

State	Craft	Gear
Orissa	Plank-built boats; catamarans; mechanized boats (Pablo types)	Hooks and lines; drift gillnets, mesh size 70-130 mm.
Andhra Pradesh	Catamaran; plank-built boats; mechanized boats (Pablo types)	Drift gillnets mesh size 70-130 mm; Hooks and lines
Tamil Nadu	Mechanized boats (Pablo type); catamarans; Dugout canoes; Mechanized boats (Pablo) Tuticorin type boats	Drift gillnets, mesh size 90-140 mm; Hooks and lines; Troll lines
Pondicherry	Mechanized boats (Pablo type); Dugout canoes; Catamarans	Hooks and lines; Drift gillnets, mesh size 90-140 mm
Kerala	Mechanized boats (14.5 mm); Mechanized boats (Pablo types); Dugout canoes; Catamarans	Purse seines (400-600 x 40-60 m); Drift gillnets, mesh size 90-130 mm; Hooks and lines; Shore seines
Karnataka	Mechanized boats (14.5m); Mechanized boats (Pablo type) Dugout canoes	Purse seines (400-600 x 40-60 m); Drift gillnets, mesh size 65-135 mm; Hooks and lines
Goa	Mechanized boats (14.5 m); Mechanized boats (Pablo type); Dugout canoes	Purse seines (600 x 55 m); Drift gillnets
Maharashtra	Mechanized boats (small); country crafts with OBM	Drift gillnets; mesh size 90-130 mm
Gujarat	Mechanized boats (small); Plank-built boats and canoes	Drift gillnets, mesh size 90-130 mm; Hook and line
Lakshadweep	Special type mechanized boats (7.93 & 9.14 m); with bait tank; Non-mechanised boats (12.5 m)	Pole and line (3-4 m long, 35-40 mm dia at the bottom and 20-35 mm at the top, polyethylene line, barb-less hook with lead coating); troll lines

Source: Silas and Pillai (1985)

picking up in certain other parts of the mainland also. Gopakumar and Ajith Kumar (2005) have reported that since 2000 troll line fishing at 300-500 m depth from deep sea shrimp trawlers for large sized oceanic yellowfin tuna is being adopted by the fishermen of Colachel (Kanyakumari district, Tamil Nadu).

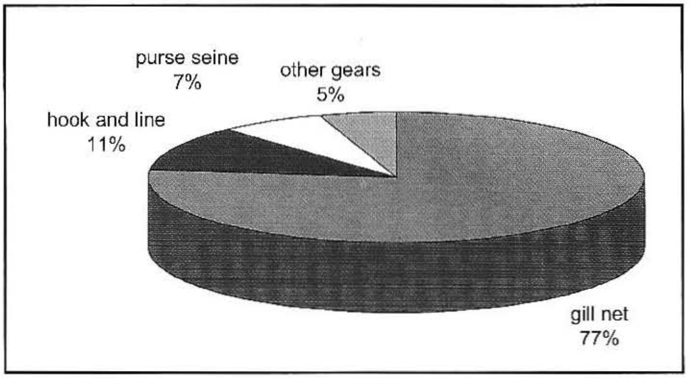

Fig. 14. Average (1994-1997) gear-wise contribution of tuna landings

Sector-wise trends

Northwest region

During 2002-07, the average tuna landings of this sector was 10354 t which comprised 21% of the all India landings. The fishing season is during September to May with peak landings occurring during October to December. Drift gill nets (145-400 mm mesh *Jada jal)* operated either from wooden or FRP canoes with out-board (OB) engines or plank built boats of 9-12 m L_{OA} fitted with inboard engines are the major gear employed for tuna fishing. Operation of gill nets during the monsoon from temporarily modified trawlers by removal of deck fittings like winch and gallows has been reported (Pravin et al., 1998). Longtail tuna, *Thunnus tonggol* a neritic species dominates the landings followed by the coastal tuna *Euthynnus affinis* and juveniles of yellowfin tuna *Thunnus albacares,* an oceanic species.

During 1990 -2002 the species contributing to the landings were *Thunnus tonggol* (42%) followed by *Euthynnus affinis* (37%) and *Thunnus albacares* (11%) and rest by *Katsuwonus pelamis* and *Auxis* spp. (Modayil et al., 2003). Compared to this, during the 2002-07 period, catch composition reflected a major increase in yellowfin tuna while longtail tuna contribution has decreased (Fig.15).

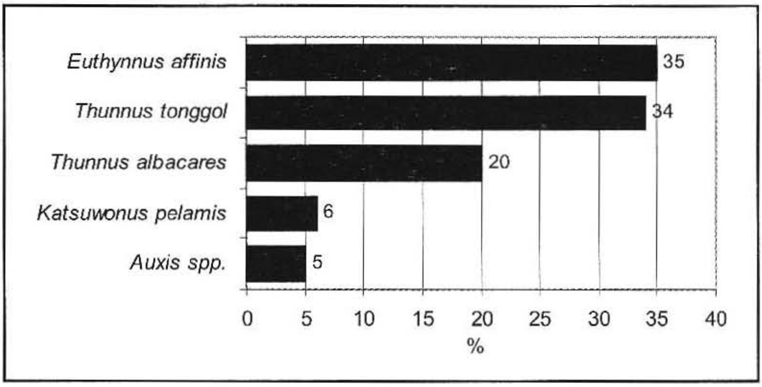

Fig. 15. Average (2002-07) species composition of tuna landings along northwest coast

Southwest region

The total tuna landings, which had peaked during 1990 showed a declining trend until 1995 and thereafter showed a revival. During 2002-07 period, the average tuna landings in this region was 12,597 t which comprised 26% of the total tuna landings of Indian mainland. In this region, tuna fishing is at its peak during the monsoon period of June to September. The major gears employed are the drift gill nets, hooks and line and purse seine. At Cochin, *Pablo* type mechanised boats of 7.6 to 9.4 m L_{OA} were engaged in single day operations at depths up to 50 m during the eighties (Jayaprakash et al., 2002). But presently with most of these boats are having facilities like GPS, mobile phones and enhanced ice storage capacities hence multi day fishing trips of 7-20 days at 100 m depths and beyond are common.

The landings are dominated by *Euthynnus affinis, Auxis* spp., skipjack and yellowfin (juveniles). When compared to the early nineties (1990-95), during the post 1995 period there has been a decline to the tune of 39% with regards to catches of *Euthynnus affinis*, while landings of *Thunnus albacares* and *Katsuwonus pelamis* has increased (Fig. 16). *Auxis rochei* is another important tuna species in this region especially along the Mangalore and Vizhinjam coasts whose contribution has increased in the post motorisation period reflecting the change in fishing grounds. Since 1996 skipjack and yellowfin tuna landings by drift gill netters along the southwest coast has increased. Drift gillnetters here are mainly targeting oceanic species such as skipjack and yellowfin (juveniles) in fishing grounds off Calicut, around Lakshadweep waters and Karwar-Honnavar coast in the north.

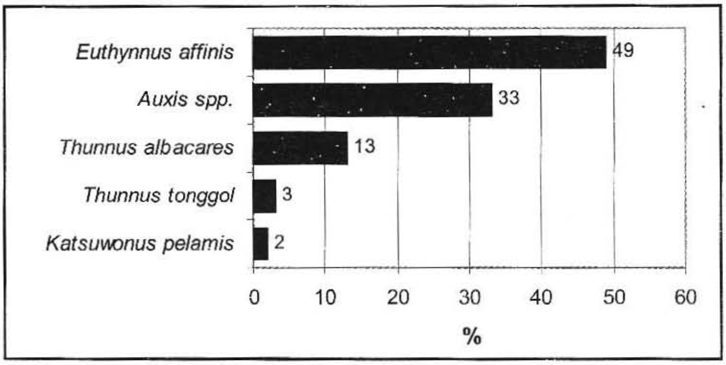

Fig. 16. Average (2002-07) species composition of tuna landings along southwest coast

East coast

The peak fishing for tunas along this coast is June- September and January–March off the southeast (Tamilnadu, Pondicherry) and north east (Visakhapatnam) coasts respectively. Gears employed in the fishery include drift gill nets such as *paruvalai* (mesh 80-160 mm) and *podivalai* (mesh 35-75 mm), long lines, hooks and lines and shore seines and the species-wise abundance is in the order of *Euthynnus affinis, Auxis* spp. and *Katsuwonus pelamis.* On the east coast considerable progress has been achieved in motorization of traditional catamarans with introduction of OB engines and fitting of in-board engines to many artisanal plank built boats in Tamil Nadu since 1990s (Mahadevan Pillai et al., 1994, Thirumilu et al., 1994). Balasubramanian (2000) has reported the conversion of nearly 30 shrimp trawlers for drift gill net fishing at Tharuvaikulam, Gulf of Mannar and its impact on tuna fisheries like availability of tunas round the year compared to a seasonal fishery earlier. Off Visakhapatnam coast recently many non-mechanized crafts (catamarans) operating hooks and lines using troll line/ hand line bring catches comprising mainly of skipjack and yellowfin tunas. Wooden catamarans consisting of two pieces of log is most popular and of late fibre crafts are also being used. Wind power is used for propulsion and rarely outboard engines are used for propulsion. Although fishing activity is carried out throughout the year given that the weather conditions are favorable, peak landings are mostly during October–December period when target fishing for yellowfin tunas is carried out by all traditional crafts based at Lawson's Bay and Pudimadaka at Visakhapatnam. Species composition of the catches indicate yellowfin tuna (80%) followed by skipjack (15%) and little tunny (5%). Fishes landed are graded as first (*Sashimi*), second or third grade for exports and the rest is used for domestic markets. Recently, efforts to tap the rich tuna fishing grounds in the upper north east coast off Visakhapatnam has been initiated by the Association of Indian Fishery Industries (AIFI) with funding support from MPEDA and Ministry of Agriculture. It involves conversion of an idling shrimp trawler fleet (23-27 m L_{OA}) off upper east coast for monofilament tuna longlining and aims at eventual upgradation of around 30 trawlers for tuna fishing which may create a positive impact on tuna production from Indian waters. Thus a rapid progress in the tuna fishing off Andhra coast is visible since 2000.

During 2002-07, the average landings of this region was 12597 t which comprised 26% of the total tuna landings of India. Average species-wise contribution indicated dominance of little tunny and yellowfin (Fig. 17 and 18). Compared to the average species-wise contribution of 64% and 9% respectively by these two species during 1990-2002 period, there is evidently a sharp increase in tuna landings and especially of yellowfin landings.

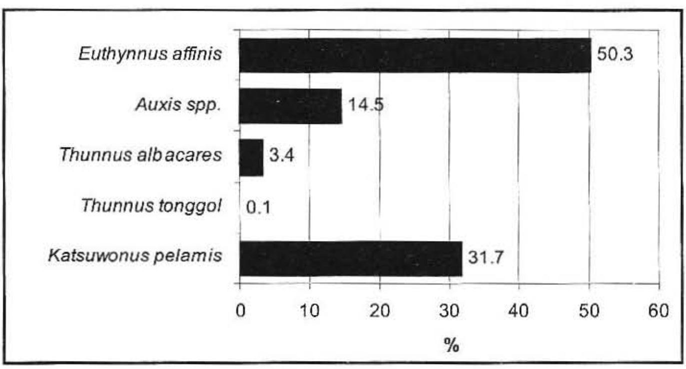

Fig. 17. Average (2002-07) species composition of tuna landings along northeast coast

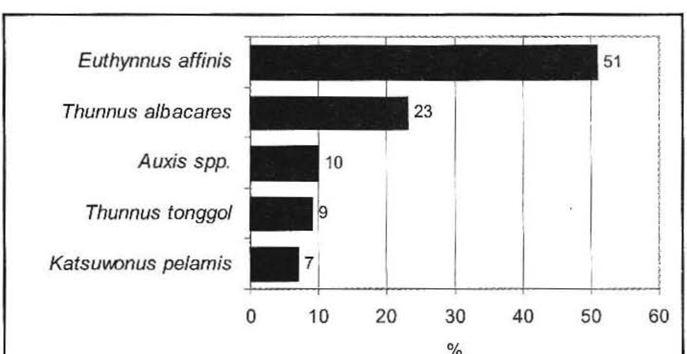

Fig. 18. Average (2002-07) species composition of tuna landings along southeast coast

Lakshadweep Seas

Oceanic species of tunas, namely skipjack tuna and yellowfin are the most important tuna resources of Lakshadweep islands. The fishing method is mainly the pole-and-line method which is believed to have been first adopted in Minicoy islands and which has gradually spread to other islands also since the 1960s. The earliest account of tuna fishing of Minicoy was that by Hornell (1910). This was mainly a traditional fishing method but since the seventies, mechanization of fishing boats was initiated which has seen a complete shift from traditional non-mechanised "*masodis*" to mechanized boats fitted with bait tanks in Minicoy.

During the period 1980 to 2001, annual tuna landings from Lakshadweep has estimated to be between 1,760 t (1980) to a peak of 12,300 t (1998) with an average of 7,000 t during 1990-2000 and about 8,500 t during 2004 (Fig.19). Agatti, Minicoy, Suheli, Androth, Kavratti, Bitra and Kiltan Islands are the major tuna landing centres of Lakshadweep ( ). The major tuna species landed are *Katsuwonus pelamis* (86%) followed by *Thunnus albacares* (12%) and *Euthynnus affinis* (2%).

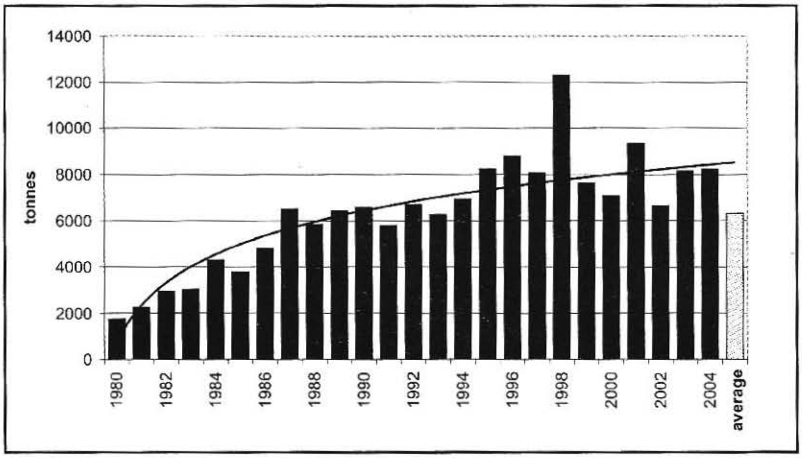

Fig. 19. Tuna landing from Lakshadweep during 1980-2004

Three gears, pole and line, troll line and hand line have been used for tuna fishing in Lakshadweep islands and recently drift gill netting has been adopted in certain islands such as Androth. The pole and line tuna fishery of the Lakshadweep seas has been reported in detail by Jones and Kumaran (1959) and after mechanisation by Silas and Pillai (1982), Madan Mohan et al. (1985), Silas et al. (1986), Yohannan et al., (1993), Sivadas (1998, 2002) and Said Koya et al. (2005). This is the main gear

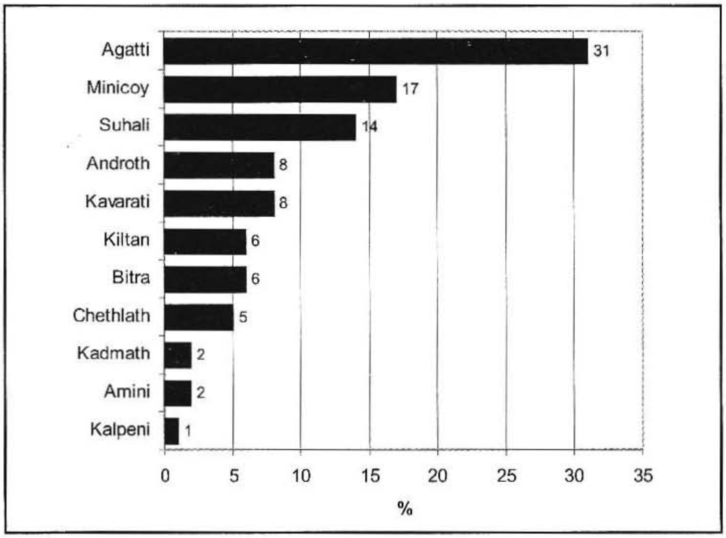

Fig. 20. Average (1980-2001) Island-wise tuna landings in Lakshadweep

used in tuna fishery and is concentrated in four areas: the southern island of Minicoy, the islands of Suheli, Agatti and nearby islands and at Cheriyapani and Valiyapani in the north (Nasser et al., 2002a). Sivadas (2002) has described the recent innovations employed in tuna fishing of Lakshadweep such as mechanical splashers (3.8 hp pump), bait storage tanks, use of GPS etc. During earlier years most of the boats had only compass but are now equipped with GPS and can venture further away from base islands. Multi gear operations like drift gill net cum pole and lining in these islands are suggested as a viable option but fishermen of Minicoy islands prefer only pole and line fishing since they believe that the gillnets operation frighten away tunas from the fishing grounds. However, a major constraint here is that fishes of an average size of about 50-60 cm (5-6 kg) only are amenable to capture by pole and line while large sized fish are abundantly available and can be caught only in gear such as troll lines and gillnet. Difficulty in manoeuvering larger sized pole and line fishing boats within the lagoon is a bottleneck in introducing larger boats with higher fish hold capacity. Baitfish (caesionids and sprats) fishing forms an important component of the pole and line tuna fishing of Lakshadweep and its inadequate availability during the fishing season is a major constraint faced by traditional pole and line fishermen. Availability of required quantities of preferred live baits (sprats, apogonids, caesionids and pomacentrids) in nearby lagoons to attract tunas and capture them by the chumming process is another serious constraint faced by fishermen of Lakshadweep.

Protecting the habitat of baitfish therefore is of prime importance in sustaining the tuna fishery of these islands. In the FAD tuna fishing, the individual sizes of tunas aggregated were found to be smaller than those in natural schools. Assured catches from these grounds are encouraging the fishermen to venture to these fishing grounds with GPS but further monitoring of the fishery is desirable. It is also necessary to overcome constraints such as availability of adequate quantity of ice and fuel which limits the targets set by the fishermen for catching skipjack tuna and to ensure a good export market for tunas so that the fishing fleet is adequately utilized for exploiting the rich tuna fishing grounds in this sea.

Compared to tuna catch of neighbouring island nations such as Maldives and Sri Lanka, exploitation from Lakshadweep waters are very low (Nasser et al., 2002) while stock structure analysis of skipjack indicate that total mortality effected by pole and line fishing on the population is negligible and catches are below the maximum sustainable yield level (Yohannan et al., 1993; Sivadas, 2002). The present annual tuna production from Lakshadweep waters which is only about 20% of the estimated potential of the area can be enhanced by adoption of innovative fishing techniques and judicious deployment of fishing units. Said Koya et al., (2003) suggested the usage of FADs, drift gill net fishing and deep long lining, deployment of more units in specific fishing grounds, mother-ship and dory fishing operations and erection of artificial reefs close to the islands for increasing tuna production from Lakshadweep waters.

Fish Aggregating Devices (FADs) have been considered as a technology with potential to develop the tuna fishery in many tuna fishing countries such as Maldives in the Indian Ocean region. FADs had been introduced in Lakshadweep waters during 2002 in the open sea as well as lagoons in a study conducted by the Central Marine Fisheries Research Institute to understand the tuna aggregation dynamics and behaviour. Data buoys for Arabian Sea Monsoon Experiments- Phase-II deployed by the National Institute of Ocean Technology (NIOT), 16-26 nautical miles off Minicoy, also functioned as FADs aggregating tunas. As mainly juvenile tunas (mainly yellowfin) are reported to aggregate, further monitoring of the fishery is in progress.

Masmin production, followed by canned tuna remains the major commercial product emerging from the skipjack tuna fishery. Besides this, frozen tuna export and tuna pickle preparation has also been picking up under the Lakshadweep Development Corporation. However, there is vast potential to diversify to yellowfin tuna fishing in Lakshadweep waters. Value added products such as *Sashimi* tuna and tuna loins are possible with adequate infrastructure support to the fishermen of Lakshadweep.

Andaman Seas

The Andaman and Nicobar islands are some of the best tuna fishing grounds but their contribution to tuna fishery of India is not significant. In 1999, the production of tuna and tuna-like fishes contributed 5% of the total marine fish landings of 26,673 t (Anon., 1999).The potential yield of tunas in Andaman and Nicobar waters has been estimated at one lakh t (George et al., 1977) and about 90,000 t by FSI. Talwar (1990) has documented the various species available in these waters as *Thunnus albacares, Thunnus obesus, Thunnus alalunga, Katsuwonus pelamis, Thunnus tonggol, Euthynnus affinis, Sarda orientalis* and *Gymnosarda unicolor.* Peak tuna fishery is reported to be during March to August. The fishing fleet mainly comprises plank-built crafts (25 –35 feet OAL) with in-board motors (8-15 HP) and dug-out canoes of 10 – 22 feet size operating with drift gill nets, shore seines and hooks and line. Among the potential fishery resources, coastal and oceanic tunas and tuna – like fishes are the major contributors with yellowfin, skipjack tuna and big eye tuna dominating the tuna landings (Madhu et al.,2002). The species wise average (1997 -2001) catch composition of longline exploratory vessels operated by FSI in the Andaman and Nicobar waters is yellowfin tuna (33%), skipjack tuna (3%) and big eye tuna (0.06%) while other fishes like sharks (41%), sailfish (9%), marlins and seerfish constituted the rest of the catch. The vessel capabilities, infrastructure and expertise available at Andaman & Nicobar Islands are inadequate to effectively tap the rich tuna and tuna - like resources occurring in these waters and hence suitable strategies have to be evolved to expand tuna fishing, preferably involving the idling shrimp trawlers from the mainland coast. The required infrastructure facilities also will have to be developed with support from the local fisheries administration.

Biology of tunas

Reproductive Biology

Tunas are predominantly dioecious and there appears to be no sexual dimorphism in external morphological characters. However a few instances of hermaphroditism have been reported for *Katsuwonus pelamis* in which both testicular and ovarian tissues were observed in the gonads. They are oviparous with asynchronous oocyte development and considered to be multiple or batch spawners, shedding their gametes directly into the sea where eggs are fertilized. Spawning activity for most of the tunas species occurs at temperature of about 24°C or higher only. Spawning activity is observed almost throughout the year in tropical tunas but in the more northern and southern hemispheres it is restricted to the summer months when the sea surface temperature exceeds 24°C. It has been observed that inter annual events such as El Nino-La Nina apparently increase or decrease favourable spawning habitat which causes recruitment fluctuations. An individual tuna must reach a minimum size or age before it is physiologically capable of initiating full gametogenesis in response to the appropriate environmental cues. The size/and or age at which about 50% of the tuna population reaches maturity and is capable of reproducing is called Length at first maturity (L_m) and is an important life history parameter. The optimum size at which it should be exploited L_{opt} is another important parameter and along with L_m parameter taken into consideration while exploiting the tuna stocks will ensure that fishery is sustainable in the long run (Table 3). The fecundity of tunas like other multiple-spawning fish is not fixed at the beginning of their spawning period. Their annual fecundity is indeterminate because tunas spawn numerous times during the season or year and can be roughly estimated from estimates of batch fecundity (number of oocytes released per spawning) and spawning frequency of the species. However batch fecundity is influenced by the body length and weight and inter-annual and geographic variation in batch fecundity is reported in tunas.

Tuna Behaviour

Tunas are described in scientific and popular literature as highly migratory fish and apex predators on the oceanic pelagic realm which is facilitated by a number of anatomical, biological and physiological specializations. Later some studies have come to the conclusion that although tunas are capable of long-distance movements, for some species or populations of tunas at least long distance migrations are more the exception than the rule (Hillborn and Sibert, 1988; Hampton and Gunn, 1998). Uncertainties regarding tuna migrations seriously hamper stock assessment and management of the resources, especially if the resource is shared by many neighbouring countries. These include the timing, extent, direction and seasonality of the movements which is among different management jurisdictions (different EEZs), their residence times and probabilities of return as well as movements along vertical and horizontal habitats fished by different gears and the links with environmental factors. This led to research on tuna movements and migration. The first published account of the acoustic tracking of tuna is that of Yuen (1970) who studied movement and behaviour of skipjack off Hawaii. Later this field of research has benefited immensely from the development of new technologies such as electronic tags, satellite communications and remote sensing. Archival tags have been extensively used and are basically mini-computers, incorporating microprocessor, memory and a suite of environmental and physiological sensors which allow data to be collected over many years regarding movements of the tagged tuna. Since Yuen's work, six species of *Thunnus* have been acoustically tracked which include the Atlantic bluefin (*Thunnus thynnus*), Pacific bluefin (*Thunnus orientalis*), southern bluefin (*Thunnus maccoyii*), yellowfin (*Thunnus albacares*), albacore (*Thunnus alalunga*) and bigeye (*Thunnus obesus*) of which the most extensively studied species is yellowfin.

Tracking data suggest that yellowfin in coastal and open ocean habitats are primarily inhabitants of the mixed layer and although obviously capable of swimming to great depths spend most of their time in the upper 100 m above the thermocline and appear to be unable to cope with temperatures below the thermocline. It has also been observed that yellowfin aggregate around fish aggregating devices and topographic features such as sea mounts and continental shelf edges and these associations even show diurnal variations. Different depth distribution of yellowfin and bigeye has been reported although their geographic ranges overlap significantly and share an association with FADs and floating objects, tracked bigeye differed from yellowfin in that they regularly made extensive and prolonged dives below the thermocline during the day often to depths in excess of 200 m. Small bigeye appear restricted to depths above 15°C isotherm whereas adults are capable of much deeper diving and regularly make prolonged excursions to more than 500 m during the daytime as they follow the deep scattering layers. Thus they are able to take advantage of a much broader foraging space than yellowfin. Diet studies of yellowfin tuna indicate preponderance of squids and finfishes besides cuttlefish, crabs, shrimps and stomatopods.

Length frequency distribution, age and growth

Fishery landings have been routinely monitored at various fishery centres by the CMFRI. The size ranges of the various tuna species landed along the Indian coast are given in Fig. 21. The maximum sizes attained (L_{max}), the length at first maturity (L_m) and optimum size at capture (L_{opt}) based on length based assessment of the resource is given in Table 3 and length weight relationship of coastal tunas is given in Fig. 22. The growth parameters and size at various ages are also given for the various species in the Indian seas in Table 4. For migratory species such as tunas, multiple fisheries which are also seasonal at various centres make stock assessment difficult. However, some

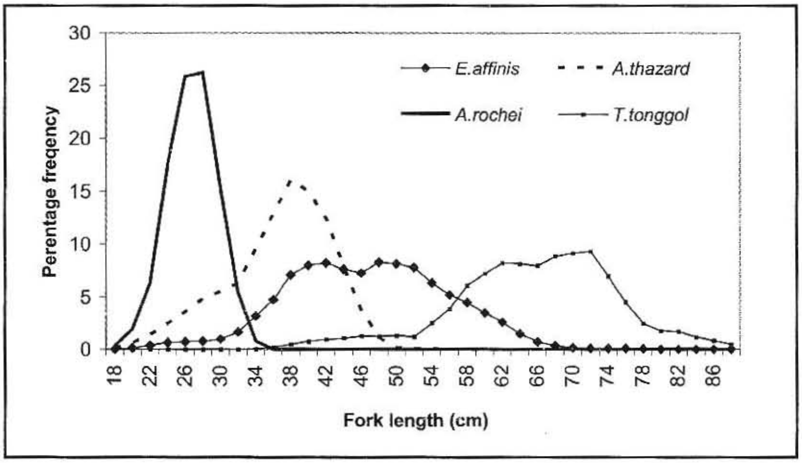

Fig. 21. Length frequency distribution of common coastal and neretic tuna species along the Indian coast

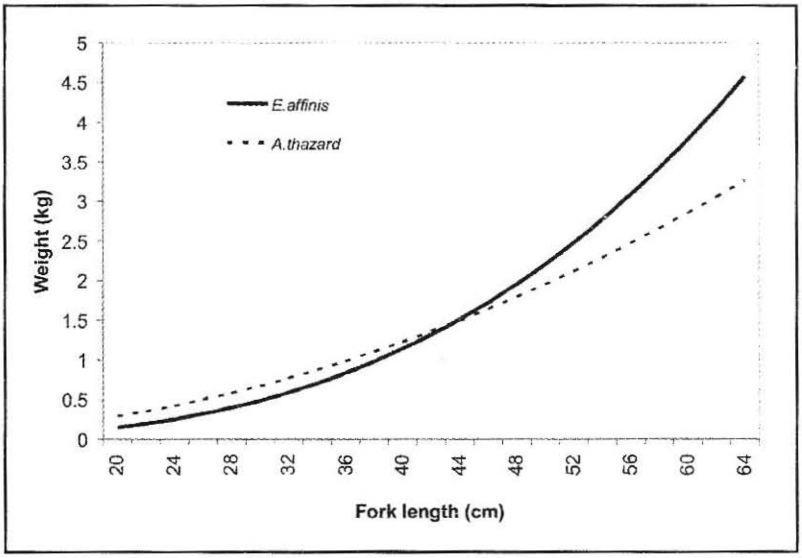

Fig. 22. Length-weight relationship of little tunny and frigate tuna

Table 3: Biological Reference Points for tunas of Indian seas

Species	L_{max} (cm)	L_{opt} (cm)	L_m (cm)	Common size groups supporting fishery (cm)
E. affinis	60	44	42	40-60
A. thazard	68	46	38	25-40
A. rochei	34	24	24	15-31
K. pelamis	78	44	40	50-60
T. tonggol	94	52	50	40-70
T. albacares	190	84	74	70-150

Table 4: Growth parameters and length at age of tunas in Indian waters

Species	L_∞	K (annual)	Length (cm) at age (years)			
			I	II	III	IV
E .affinis	89	0.9	52.8	74.3	83	86.6
A .thazard	54	0.9	31.4	44.5	50	52.3
A. rochei	34	1.1	19.4	22.8	27.5	30.3
K. pelamis	78	0.7	39.2	58.8	68.2	73.2
T. tonggol	93	1.2	64.6	84.1	89.9	91.7
T. albacares	172	0.4	55.5	93.2	118.6	135.9

Table 5: Estimates of growth parameters $L\alpha$, K, t_o. Mortality rates-Natural (M), Fishing (F) and Total (Z), exploitation ratio U for various tuna species at different fishery centres along West and East coast of India

Species	$L\alpha$	K	t_o	M	Z	F	U
Veraval							
E. affinis	82.5	0.825	- 0.0168	1.19	4.56	3.37	0.7
A. thazard	54.5	1.02	-0.0118	1.53	8.83	7.30	0.8
T. tonggol	102.5	1.05	-0.0092	1.31	6.14	4.83	0.7
Mangalore							
E. affinis	80.0	1.05	-0.0099	1.42	7.52	6.10	0.8
A. thazard	58.0	0.725	-0.0235	1.22	4.95	3.73	0.7
A. rochei	42.0	1.0	-0.0133	1.65	6.98	5.33	0.7
T. tonggol	80.0	1.15	-0.0078	1.51	5.20	3.69	0.7
E. affinis	76.0	1.225	-0.0066	1.60	7.44	5.84	0.7
A. thazard	55.0	0.825	-0.0188	1.35	5.24	3.89	0.7
Vizhinjam							
E. affinis	70.0	0.825	-0.0175	1.26	3.70	2.44	0.6
A. rochei	40.0	1.0	-0.0135	1.67	6.78	5.11	0.7
Tuticorin							
E. affinis	82.0	1.05	-0.0098	1.42	5.02	3.60	0.7
A. thazard	53.75	0.975	-0.0132	1.52	5.43	3.91	0.7
Chennai							
E. affinis	82.75	0.925	-0.0132	1.30	4.37	3.07	0.7
A. thazard	56.5	0.95	-0.0138	1.47	1.58	0.11	0.06

estimates have been made based on the catch trends and length frequency of various species which allow the fishery to be assessed as sustainable or unsustainable. The exploitation ratio (U), fishing, natural and total mortality rates are presented in Table 5.

Conclusion

It is evident that tuna fisheries have evolved rapidly since the 1980s and more of the highly valued oceanic species are represented in the catches presently. However, most of these developments have occurred as a result of the initiatives taken by fishermen in the small-scale sector. Although tuna is one of the most important item in world seafood trade, the contribution by India towards global production is negligible. Fishing for tuna is not pursued seriously by the fishermen who perceives the returns as inadequate. Part of this situation emerges due to the fact that the tuna catch is not of *sashimi* grade for which the fishing vessels generally do not have onboard and onshore infrastructure facility and also because tuna is less preferred in the domestic market. Recently, Marine Products Export Development Authority (MPEDA) has announced subsidy schemes for conversion of idling shrimp trawlers (>20 m L_{OA}) for tuna longlining and provisions for equipping small boats (<20m L_{OA}) with insulated refrigerated fishholds and RSW facility for preserving the quality of tunas caught. There are also suggestions for developing a tuna longlining fleet consisting of medium sized 18 m L_{OA} fleet. It will also be worthwhile to develop appropriate market linkages so that it becomes an economically viable proposal for fishermen and entrepreneurs who wish to venture into tuna fishing. This in turn is expected to relieve the fishing pressure on coastal fishery resources and ease the conflicts between the various fishing sectors in Indian waters to a certain extent. Given the rapid developments in tuna fishing, especially for yellowfin tuna, in Indian waters as well as neighbouring countries in the Indian Ocean, it is important to develop a strong shared database on the exploitation of tuna resources including gear-wise fishery trends and other biological data including length composition of the landings. Periodic reassessment of the tuna potential is also required with adequate inputs from exploratory surveys as well as commercial landings and this may prevent any unsustainable trends in the development of tuna fishing industry in India.

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