

Length based population characteristics and fishery of skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) from Tuticorin waters, Tamil Nadu, India.

Ramesh Kumar^{1*}, B. Sundaramoorthy¹, N. Neethiselvan¹, S. Athithan¹, Rajan Kumar², Shikha Rahangdale² & M. Sakthivel¹

¹Fisheries College and Research Institute, Tamil Nadu Fisheries University, Tuticorin – 628 008, Tamil Nadu, India

²Indian Council of Agricultural Research-Central Marine Fisheries Research Institute, Kochi-682018, Kerala, India

*[E-mail: kumarramesh.vns@gmail.com]

Received 04 September 2017; revised 09 January 2018

Fishery and population characteristics of skipjack tuna (*Katsuwonus pelamis*) along Tuticorin coast were studied for the period of one year from June 2016 to May 2017. Population parameters of *Katsuwonus pelamis* based on the length frequency data collected from fish landing centers of Tuticorin. Lengths ranging from 25 to 80 cm total length were observed and analyzed in current study. The population parameters L_{∞} , K, M, Z and F were estimated as 95.70 cm, 0.40 year⁻¹, 0.73, 1.63 and 0.90 respectively. Virtual Population Analysis (VPA) indicated that noticeable fishing mortality starts from 35-39 cm class interval and continued increasing till 50-54 length class. Afterwards a general decline in fishing mortality was observed with a relatively heavy fishing pressure on penultimate length class. The exploitation ratio (E) of 0.55 was derived from present study which is less than the maximum exploitation ratio ($E_{max} = 0.805$) indicating a scope for potential increase in production.

[**Keywords:** Skipjack tuna, fishery, growth, mortality, recruitment]

Introduction

Skipjack tuna (*Katsuwonus pelamis*) is a pelagic-oceanic, oceanodromous, highly migratory and cosmopolitan species found in the tropical and subtropical waters of the Indian, Pacific and Atlantic Oceans in depth ranging from surface to 260 m depth¹. It generally forms large schools, often in association with other tunas of similar size such as juveniles of yellowfin tuna and bigeye tuna. The average distance between skipjack tagging and recovery positions was estimated around 640 nautical miles. Skipjack tuna in the Indian Ocean are considered a single stock for assessment purposes. The male and female of Skipjack tuna mature (T_m 50%) at age of less than two years and size of 40 to 45 cm. It spawns opportunistically throughout the year in the whole inter-equatorial Indian Ocean with sea surface temperature greater than 24°C when conditions are favorable. Maximum length and weight of skipjack tuna reported from Indian Ocean were 80 cm fork length and 10 kg weight²⁻³.

Most of the catches of tuna were reported from the fishing areas 71, 51, 61 and 34. As per FAO estimates, *Katsuwonus pelamis* during 2015 forms the largest tuna fishery with a landing of 2.82 mmt followed by *Thunnus albacares* with 1.35 mmt in the world⁴⁻⁵. Globally, skipjack tuna is caught at the surface, mostly

with purse seines and pole and lines and to a small extent by gillnets, troll lines and longlines. Recently, Indian Ocean Tuna Commission (IOTC) undertook a tagging based study on skipjack tuna revealing the migratory pattern of the species. Exploitation of tuna resources from the oceanic waters was initiated by the chartered longliners in the late 1980s but, actual commercial exploitation of large pelagic fishes from the oceanic waters by Indian fishermen commenced only by the late nineties. Longlines, pole and lines, purse seines and drift gillnets are the main gears employed to capture tuna in Indian waters⁶. The skipjack tuna is mainly exploited by gillnets, longlines and the larger meshed purse seines along the Indian coast. The total tuna landings of India and Tamil Nadu were around 78,470 t and 15,885 t respectively, whereas the figures for skipjack tuna were 8,302 t and 1,756 t respectively during 2015⁷.

Tuna being an important and migratory species, the need to study the biological and fishery related parameters from the entire migratory trajectory is a prerequisite for devising a comprehensive management regime for sustainable exploitation of the species. The current study is an attempt to study the fishery and fishery dependent population parameters from commercial landings for the species from the Tuticorin

coast of Tamil Nadu where tunas are emerging as a major target species.

Materials and Methods

The present study was conducted for one year from June 2016 to May 2017 along the Tuticorin coast in western coastal belt of Gulf of Mannar in the Bay of Bengal and it has a coastal length of 163.5 km. Tuna fishing crafts and gears details were collected through direct interview of fishers and visual observations. Details regarding fishing ground, catch, effort and length frequency of skipjack tuna were collected from fish landing centers of Tuticorin coast namely Tharuvaikulam (78.89°E and 8.17°N), Therespuram (78.16°E and 8.81°N), Kombudurai (78.14°E and 8.58°N) and Tuticorin Fishing Harbour (78.16°E and 8.79°N) weekly. Catch data were expressed in terms of numbers and weight during each sampling days. Each sampling day was multiplied by the number of boats engaged in fishing on the day of sampling to obtain the average daily catch. Average daily catch was multiplied by the number of fishing days in the particular month to obtain the monthly catch. The effort was expressed as number of boat days per month.

Length weight relationship was established as per LeCren⁸. Growth parameters, mortality rates and recruitment pattern were estimated from length frequency data. Asymptotic length (L_{∞}) and growth constant (K) were estimated by ELEFAN, natural mortality (M) was calculated by Pauly's Empirical Equation and total Mortality (Z) from length converted catch curve I module of FiSAT software package⁹. Exploitation ratio was estimated from the equation, $E = F/Z$; where F is the fishing mortality rate. Yield per recruit (Y/R) was assessed using the Beverton and Holt model¹⁰.

Results

Length weight Skipjack tuna resources along Tuticorin waters are mainly exploited by large meshed drift gillnet amounting to 99.90 % (mesh size 120 to 145 mm) of the total catch. Minor landings are also reported from longlines (hooks size 4 to 7). Large meshed drift gillnets are operated by the mechanized gillnetters, converted trawlers and motorized plank built boats "Vallam" with engine power ranging from 48 to 108 hp. Longlines are operated by motorized plank built boats seasonally and FRP boats with engine power of 9.9 to 15 hp. Gillnet fishing are multiday fishing having 4 to 11 days fishing trips whereas

longliners trips is of 1-3 days. Based on the GPS based exploration, the gill net fishing grounds were extended from 100 nm off Kanyakumari in south to 110 nm off Nagapattinam in north. Drift gillnets were operated at depth of 20 to 500 m whereas longlines were operated in shallower water of depth 20-60 m.

Fishing by mechanized and motorized crafts was exclusively of multiday nature (4 to 11 days per fishing trip) unlike longline operating FRP boats which operates for 1-3 days per fishing trips. The crew size was five to eight for drift gillnetters and two to three for longline fishing. At Tharuvaikulam, the observed CPUE of skipjack tuna for large meshed drift gillnets were found maximum during April (232.57 kg/day) and minimum during October (49.13 kg/day) and the annual mean CPUE was estimated as 80.39 kg/day. At Therespuram, large meshed drift gillnets were operated seasonally from June to November and maximum CPUE was observed during the month of August (50.74 kg/day) while minimum was recorded during October (12.10 kg/day). The mean CPUE was estimated as 34.41 kg/day. Longline skipjack tuna fishery existed only during a short period of April and May with a mean CPUE of 6.62 kg/day (Table 1).

Katsuwonus pelamis was second major commercial species of tuna landed along Tuticorin coast with a contribution of 19.46 % of total tuna landings of the region. *Katsuwonus pelamis* was landed throughout the year with two peak fishing seasons June to September and March to April. The maximum landing was reported in the month of April while the minimum was during December (Fig. 1).

Skipjack tuna along the Tuticorin coast are mostly caught in large meshed drift gillnets and minor catches comes from longliners. The specimens landed were found to be in the size range of 25 to 80 cm (total length) but from the length class 45-49 cm contributed maximum to the catch. A monthly analysis of length frequency distribution showed a marginal drift of mean length of capture towards higher length class from June till November. A reversal of the trend was obvious from December to February.

A more uniformly distributed length composition was observed during March and April (Fig. 2).

The length weight relationship for the species is established as $W = 0.0000043L^{3.33}$. The relationship indicated a positive allometric growth (Fig. 3). The growth parameters estimates for the species were asymptotic length (L_{∞}) = 95.70 and growth coefficient (K) = 0.40. The Von Bertalanffy growth curve obtained

by ELEFAN I programme for skipjack tuna is presented in Figure 4.

The natural mortality (M) was estimated as 0.73 yr^{-1} by using Pauly's empirical equation taking mean habitat temperature as 29.5°C . Total mortality (Z) was estimated from the length converted catch curve as 1.63 yr^{-1} (Fig. 5). The fishing mortality (F) and exploitation ratio (E) were found to be 0.90 yr^{-1} and 0.55 respectively.

The monthly recruitment pattern of skipjack tuna is shown in Figure 6. The maximum recruitment was observed between August and October (49.08%). The length at first recruitment was taken as smallest length specimen recorded in the catch which happened to be 25 cm.

A virtual population analysis indicated that the main loss in the stock up to 35-39 cm length class was due to

Table 1 — Monthly Catch (kg), Effort (unit) and Catch per unit effort (CPUE) of *Katsuwonus pelamis* from different gears along Tuticorin coast during June 2016 to May 2017

Month	Large meshed drift gillnets of Tharuvaikulam			Large meshed drift gillnets of Therespuram			Longlines of Therespuram			Total Catch (kg)
	Effort	Catch	CPUE (kg/day)	Effort	Catch	CPUE (kg/day)	Effort	Catch	CPUE (kg/day)	
Jun'16	920	48105	52.29	770	33187	43.10	-	-	-	81292
Jul	1150	71088	61.82	990	39459	39.86	-	-	-	110547
Aug	990	62489	63.12	800	40589	50.74	-	-	-	103078
Sep	800	46030	57.54	595	28104	47.23	-	-	-	74134
Oct	855	42003	49.13	500	6049	12.10	-	-	-	48052
Nov	540	50622	93.74	270	3622	13.41	-	-	-	54244
Dec	700	26167	37.38	-	-	-	-	-	-	26167
Jan'17	720	44228	61.43	-	-	-	-	-	-	44228
Feb	630	59459	94.38	-	-	-	-	-	-	59459
Mar	880	71234	80.95	-	-	-	-	-	-	71234
Apr	495	115123	232.57	-	-	-	55	271	4.93	115394
May	-	-	-	-	-	-	57.5	478	8.31	478
Average	789	57868	80.39	654	25168	34.41	56	374.5	6.62	65692

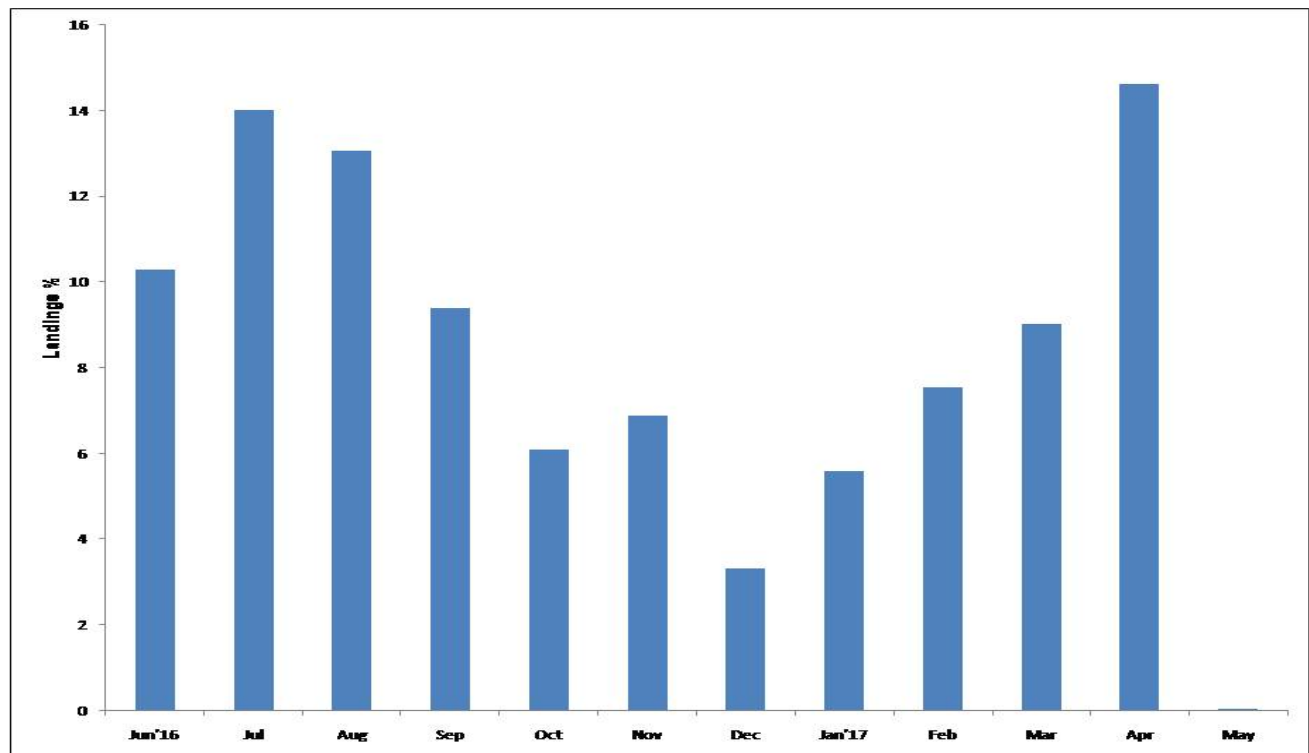


Fig. 1 — Month-wise landings of *Katsuwonus pelamis* along Tuticorin coast of Tamil Nadu (June 2016 to May 2017).

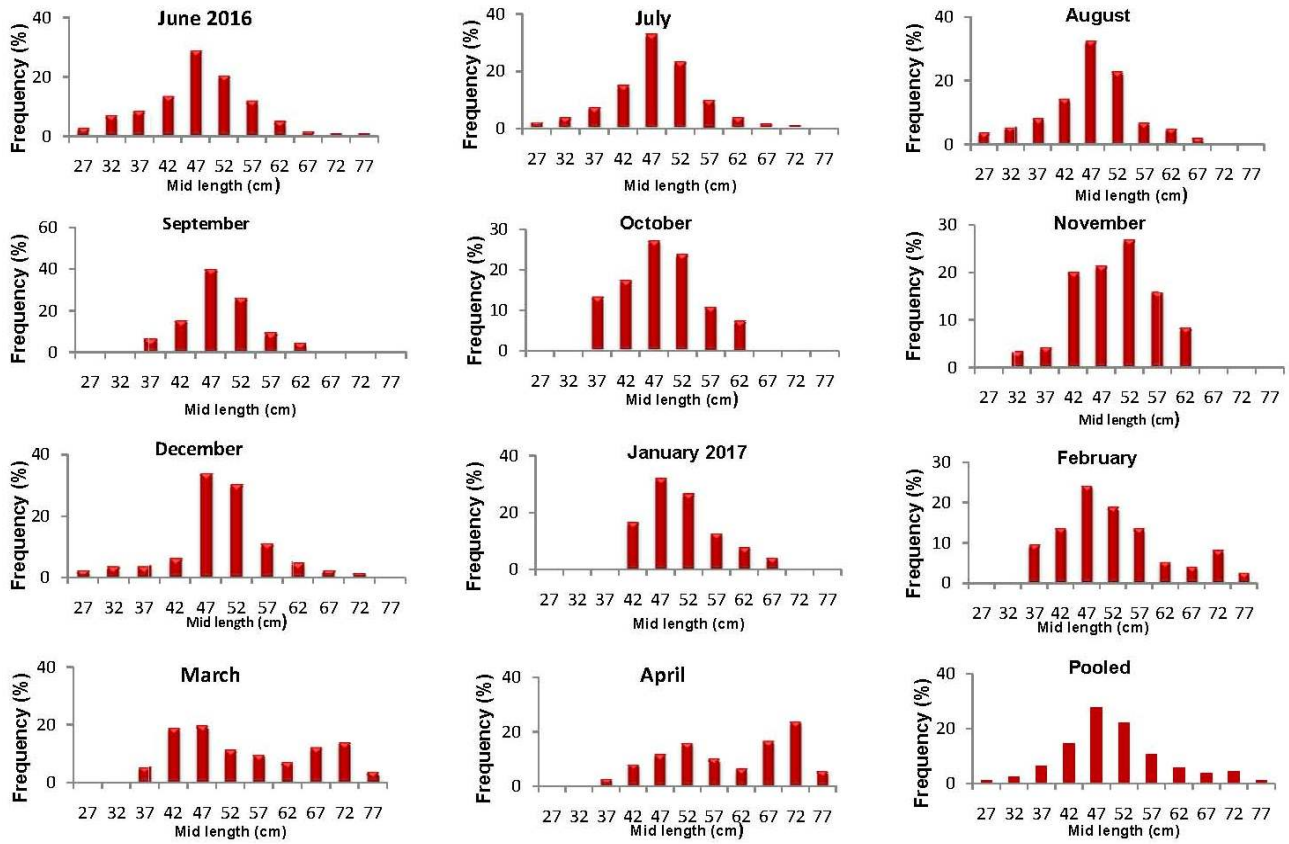


Fig. 2 — Length frequency distribution of *Katsuwonus pelamis* from June 2016 to May 2017

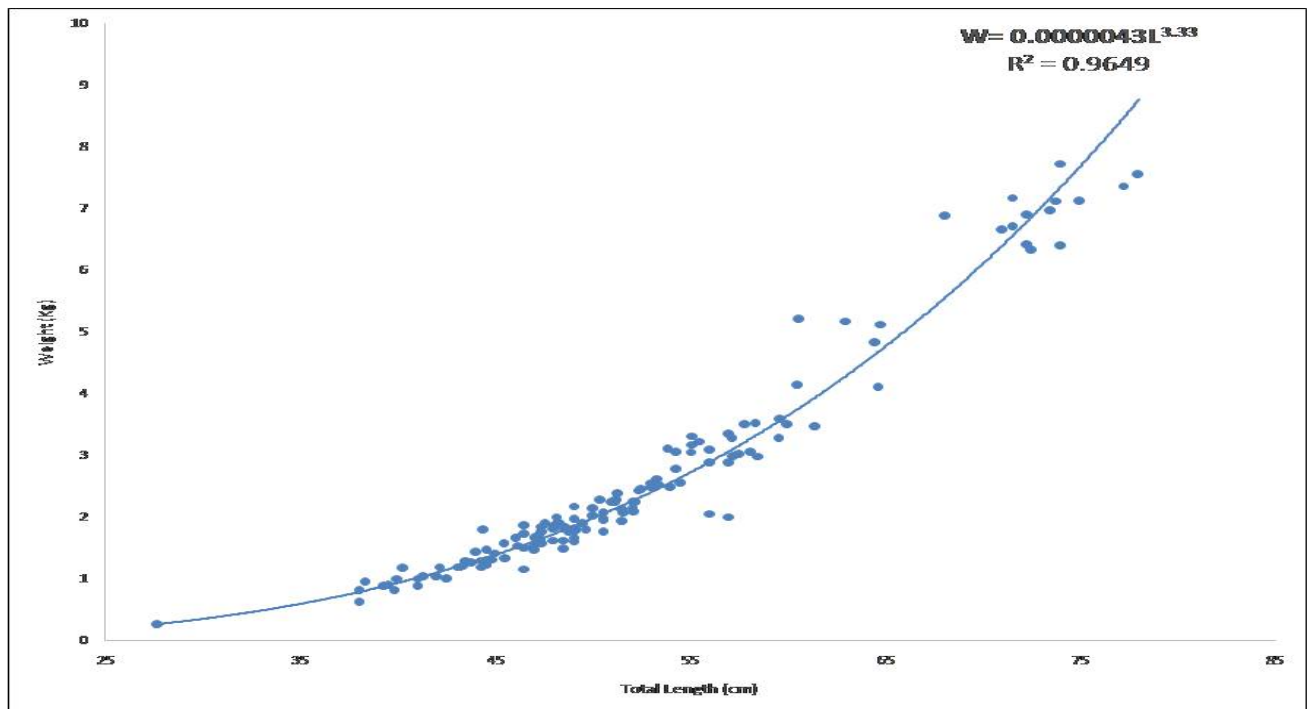


Fig. 3 — Length-weight relationship of *Katsuwonus pelamis* from Tuticorin waters

natural causes (Fig. 7). A significant fishing mortality was observed for a length class 40-44 cm onwards. A general drop in fishing pressure was observed post 50-54 cm length class. A relatively high fishing pressure was observed for penultimate length class (70-74 cm).

The relative yield per recruit was found to be highest at an exploitation ratio (E_{max}) 0.805 while the present exploitation ratio (E) was 0.55 (Fig. 8). The yield per recruit as a function of fishing mortality rate

shows that the present fishing mortality rate is below the level at which maximum yield per recruit is obtained.

Discussion

In the recent past fishing effort registered gradual increase and the area of fishing also extended to distant waters. As a result, fishery and catch rate of tuna increased gradually. Contribution of oceanic species also increased considerably during the period. Increase

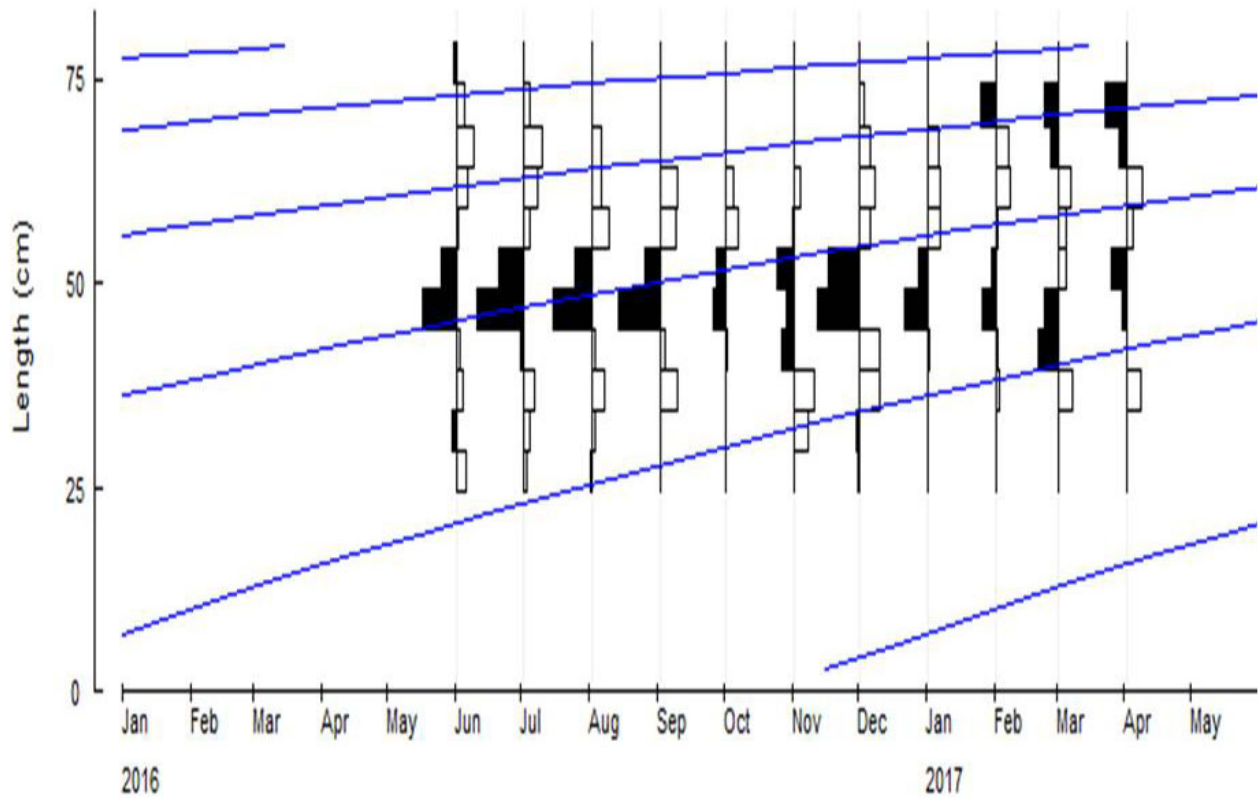


Fig. 4 — von Bertalanffy growth curve for *Katsuwonus pelamis* from Tuticorin waters.

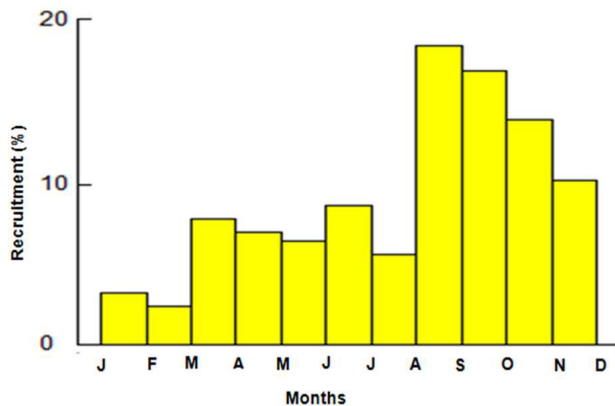


Fig. 5 — Recruitment pattern of *Katsuwonus pelamis* along Tuticorin coast

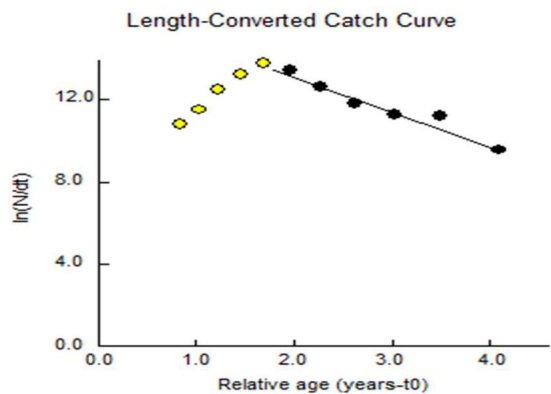


Fig. 6 — Length-converted catch curve of *Katsuwonus pelamis* from Tuticorin waters.

in catch and catch rate indicated the resources abundance in deeper waters which affirms the opinion of Abdussamad *et al.*¹¹ According to Harsha *et al.*¹², the fishermen of Tharuvaikulam went for fishing beyond the coastal water up to 25 to 80 nm by their motorized and mechanized crafts. The movement towards deeper water is mostly to explore the tuna fishing grounds of deeper waters to enhance the fish production. The dominance of drift gillnetters in exploitation of tuna along Tuticorin coast is not a new phenomenon. A similar dominance in terms of percentage was also prevalent two decades earlier¹³. The general exploitation pattern of tuna is also applicable for skipjack tuna. The things that have changed over the years is the absolute quantum of effort and catch. Other observation which is in contrast with the earlier worker⁶ is the narrow range of mesh size operated currently (120-145 mm) compared to 90-170 mm. The reason could be optimization by

fishermen with their increasing experience in tuna exploitation. The mean size of landings showed a general increasing trend from till November. Afterwards it decreases up to February. The month of March and April tend to have higher proportion of larger fishes in catch. This pattern could be attributed to the shift in fishing grounds. A relatively larger specimens were landed when gear were operated off Nagapattinam during March and April.

The length-weight relationship for the species revealed a distinct positive allometric growth, a common phenomenon in several fishes where the fish body tends to become deep as it grows mostly to accommodate gonads as the fish matures. The current estimates are found to be in agreement with earlier estimates¹⁴⁻¹⁹. The growth parameters of skipjack tuna were estimated by several workers from different waters. Asymptotic length (L_{∞}) estimates ranged between 61.3 to 142.5 cm and growth coefficient (K) values ranged from 0.25 to 1.65 per year^{18, 20-27}. The current estimates of L_{∞} (95.70 cm) and K (0.40 year⁻¹) were found to be in proximity of other recent estimates. The large deviation from the present estimates in some of the older works was possibly due to inappropriate length coverage in their data. The bigger sized specimens from deeper waters forming a regular component of commercial catches are only a recent phenomenon.

Sivadas *et al.*²⁵ studied the mortality parameters from Lakshadweep waters and obtained the values as $M = 1.33$, $F = 2.39$, $Z = 3.72$ and exploitation ratio (E) = 0.64. Kasim and Mohan (2009) studied the mortality parameters in Chennai coast and obtained values as $M = 1.92$, $F = 2.78$, $Z = 4.70$ and $E = 0.59$. Koya *et al.*¹⁸ studied the mortality parameters in Indian waters and obtained the values as $M = 0.56$, $F = 0.85$, $Z = 1.41$ and $E = 0.60$. Pradeep *et al.*²⁷ studied the mortality parameters in Andaman waters and obtained values as $M = 0.93$, $F = 1.14$, $Z = 2.07$ and $E = 0.55$. In present study mortality parameters from Tuticorin waters estimated as $M = 0.73$, $F = 0.90$, $Z = 1.63$ and $E = 0.55$ (Table 3). The profound difference of the current estimates from some of the earlier works^{18, 25} is mostly due the difference in estimates of K which in above mentioned case is possibly an over estimate.

In present study, a significant fishing mortality starts from the length class 35-39 cm and increased till the length class 50-54, after which it shows a general declining trend. The above pattern of fishing mortality distribution across length class is typical of a gill net

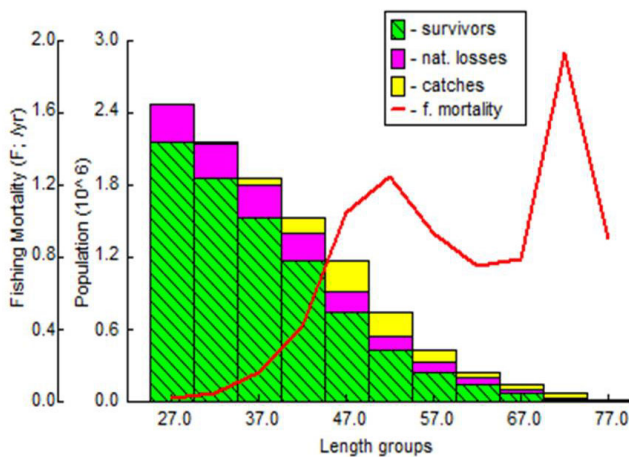


Fig. 7 — Virtual Population Analysis of *Katsuwonus pelamis* from Tuticorin coast.

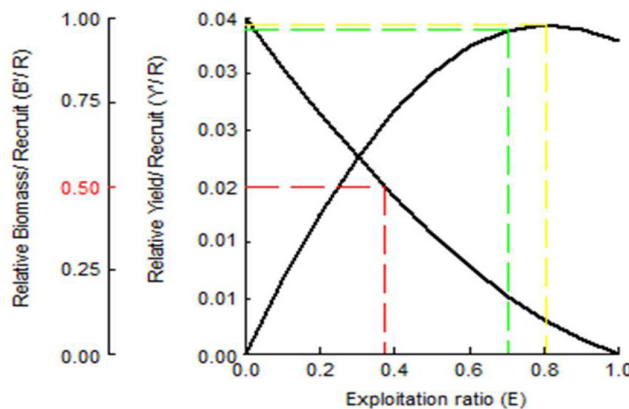


Fig. 8 — Relative yield per recruit for *Katsuwonus pelamis* from Tuticorin waters.

fishery which often exerts a heavy fishing pressure on middle length class. The higher proportionate fishing mortality for terminal length class is obvious as the natural mortality fraction will reduce to minimum. A similar trend in pattern of F distribution was observed by Pradeep *et al.*²⁷ for the species from Andaman waters where the species is also targeted using gill netters but the mean length of the capture in the case was higher than that of ours. The relative yield per recruit was found to be highest at an exploitation ratio (E_{\max}) 0.805 while the present exploitation ratio (E) was 0.55. The current exploitation ratio is less than the estimated maximum exploitation ratio which indicated the scope for increasing the production in future from the present fishing areas unlike the estimates of Koya *et al.*¹⁸ where E_{\max} was found to be lower than calculated exploitation ratio.

Conclusion

Tuna fisheries along the Tamil Nadu coast is expanding as the fisheries is shifting towards deeper waters. The shift has brought the earlier inaccessible length class to the commercial landings. Shift in length composition in catch gives an opportunity to reassess the length based population parameters for the species to arrive at a more robust measure as broader size range is now available for an assessment. Divergence from the older estimates in current study is affirming the changing catch composition. In addition the changing harvest pattern in terms of craft, gear and effort employed need to be documented and monitored to direct the developing fisheries towards sustainability.

Acknowledgements

The authors are grateful to the Dean, Fisheries College and Research Institute, Tuticorin, Tamil Nadu Fisheries University for facilitating research work and providing constant encouragement during the study period.

References

- Collette, B. B. and Nauen, C. E., FAO species catalogue Vol Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date, (FAO, Rome) 1983, pp. 137.
- Grande, M., Murua, H., Zudaire, I. and Korta, M., Spawning activity and batch fecundity of skipjack, *Katsuwonus pelamis*, in the Western Indian Ocean, In: IOTC Working Party on Tropical Tunas, (IOTC-2010-WPTT) 2010, pp. 12-47.
- Eveson, P., Million, J., Sardenne, F. and Le Croizier, G., Updated growth estimates for skipjack, yellowfin and bigeye tuna in the Indian Ocean using the most recent tag-recapture and otolith data, In: IOTC Working Party on Tropical Tunas, (IOTC-2012-WPTT) 2012, pp. 14-23.
- FAO, Fishery and Aquaculture statistics, FAO year book, 2009, (FAO, Rome) 2011, pp. 159.
- FAO, FAO Global Capture Production database updated to 2015 – Summary Information, (FAO, Rome), 2017.
- Kasim, H. M., Fishery, growth, mortality rates and stock assessment of *Auxis thazard* (Lacepede) along Tuticorin coast, Gulf of Mannar, In: The Fifth Indian Fisheries Forum Proceedings, (Eds. Ayyappan, S., Jena, J. K. and Joseph, M.), 2000, pp. 351-355.
- CMFRI, Annual Report 2015-16, (CMFRI, Cochin) 2016, pp. 294.
- Le Cren, E. D., The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*), *J. Ani. Ecol.*, 20 (2) (1951) 201-219.
- Gayanilo, F. C. Jr. and Pauly, D., The FAO-ICLARM Stock Assessment Tools (FISAT) Reference manual, (FAO, Rome) 1997, pp. 196.
- Beverton, R. J. H. and Holt, S. J., On the dynamics of exploited fish populations, (Fishery Investigations Series, London), 1957, pp. 533.
- Abdussamad, E. M., Pillai, N. G. K. and Balasubramanian, T. S., Population characteristics and fishery of Yellowfin tuna, *Thunnus albacores* landed along the Gulf of Mannar Coast, Tamil Nadu, India, Egypt. *J. Aquat. Res.*, 34(2) (2008) 330-335.
- Harsha, K., Sundaramoorthy, B., Neethiselvan, N., Athithan, A., Sugumar, G. and Ravikumar, T., A rising model of self-disciplinary fishing village in southeast coast of Tamil Nadu, *J. Exp. Zool. India*, 19(2) (2016) 763-766.
- Kasim, H. M., 2000: Status of the World Tuna Fishery with Special Reference on the Strategies for the Development and Management of Tuna Fishery in Indian Waters. In: The Fifth Indian Fisheries Forum Proceedings, (Eds. Ayyappan, S., Jena, J. K. and Joseph, M.), (AFSIB, Mangalore and AoA, Bhubaneswar) 2000, pp. 297-307.
- Mohan, M. and Kunhikoya, K. K., Age and growth of skipjack, *Katsuwonus pelamis* (Linnaeus) and *Thunnus albacares* (Bonnaterre) from Minicoy waters, *Bull. Cent. Mar. Fish. Res. Inst.*, 36 (1985) 143 – 148.
- Silas, E. G. and Pillai, P. P., Exploratory fishing by oceanic drift gill netting and purse seining in the Lakshadweep, *Bull. Cent. Mar. Fish. Res. Inst.*, 36 (1985) 165-208.
- Andrade, H. A. and Campos, R. O., Allometry coefficient variations of the length-weight relationship of skipjack tuna (*Katsuwonus pelamis*) caught in the southwest South Atlantic, *Fish. Res.*, 55 (2002) 307-312.
- Ahmed, Q., Yousuf, F., Siddidui, S. and Türkmen, M., Seasonal Variations in Length, Weight and Condition Factor in *Katsuwonus pelamis* from the Coast of Karachi, Pakistan, *Karadeniz Fen Bilimleri Dergisi*, 2(7) 2012 82-89.
- Koya, K. P. S., Joshi, K. K., Abdussamad, E. M., Prathibha, R., Sivadas, M., Kuriakose, S., Ghosh, S., Koya, M., Dhokia, H. K., Prakasan, D., Kunhikoya, V. A. and Sebastine, M., Fishery, biology and stock structure of skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) exploited from Indian waters, *Indian J. Fish.*, 59(2) (2012) 39-47.
- Jin, S., Yan, X., Zhang, H. and Fan, W., Weight-length relationships and Fulton's condition factors of skipjack tuna (*Katsuwonus pelamis*) in the western and central Pacific Ocean, *PeerJ*, (2015) Doi: 10.7717/peerj.758.

- 20 Appukuttan, K. K., Radhakrishnan P. N. and Kunhikoya, K. K., Studies on the fishery and growth rate of oceanic skipjack *Katsuwonus pelamis* (Linnaeus) at Minicoy Island from 1966-69, *Indian J. Fish.*, 24(1 & 2) (1977) 31-47.
- 21 Tandog, D. D., Cortez, E. C., Dalzell, P. and Pauly, D., Some aspects of the biology and population dynamics of skipjack (*Katsuwonus pelamis*) in Phillipine waters, In: Proceedings of FAO/IPTP meeting of Tuna Research Groups in the Southeast Asian Region, (Manila, 25-28 August, 1987.) 1987.
- 22 James, P. S. B. R., Pillai, P. P., Jayaprakash, A. A., Yohannan, T. M., Siraimetan, P., Muthiah, C., Gopakumar, G.; Pillai, N. G. K.; Reuben, S.; Thiagarajan, R.; Koya, K. P. S.; Kulkarni, G. M.; Somaraju, M. V.; Kurup, K. N., Sathianandan, T. V., Stock assessment of tunas from the Indian seas, *Indian J. Fish.*, 39 (3&4) (1992) 260-277.
- 23 Yohannan, T. M., Pillai, P. P. and Said Koya, K. P., Fishery, biology and stock assessment of skipjack tuna in Indian Seas. In: Tuna Research in India (Eds: Sudarsan, D., John, M. E.), (Fishery Survey of India, Bombay) 1993, pp. 77-96.
- 24 Chu Tien Vinh., Study on biology of tuna in the South China Sea, Area IV: Vietnamese Waters, In: Proc. of the SEAFDEC seminar on fishery resources in the South China Sea, Area IV: Vietnamese waters, 2000, pp. 146-168.
- 25 Sivadas, M., Pillai, P. P. and Ganga, U., Stock assessment of the oceanic skipjack, *Katsuwonus pelamis* in Minicoy, Lakshadweep, In: Management of scombroid fisheries, (Eds. Pillai, N. G. K.; Menon, N. G.; Pillai, P. P.; Ganga, U.), (CMFRI, Kochi) 2002, pp. 131-138.
- 26 Kasim, H. M. and Mohan, S., Tuna fishery and stock assessment of component species off Chennai coast, *Asian Fish. Sci.*, 22(1) (2009) 245-256.
- 27 Pradeep, H. D., Shirke, S. S. and Kar, A. B., Estimates of length-based population parameters of the Skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) in the Andaman waters, *J. Fish.*, 5 (2) (2017) 1-6.