Journal of Fisheries
Volume 5 Issue 2 Pages: 477–482 August 2017
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

DOI: https://doi.org/10.17017/j.fish.42

Original Article

Estimates of length-based population parameters of the skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) in the Andaman waters

Pradeep Hosahalli Divakar[1] • Swapnil Shivdas Shirke[1] • Annada Bhusan Kar[2]

[1] *Fishery Survey of India, Port Blair Zonal Base, Port Blair 744101, India.*
[2] *Fishery Survey of India, Vishakhapatnam Zonal Base, Vishakhapatnam, India.*

Correspondence
Dr Pradeep Hosahalli Divakar; Fishery Survey of India, Port Blair Zonal Base, Port Blair 744101, India
Email: hdpradeep@gmail.com

Manuscript history
Received: 15 Sep 2016; Received in revised form: 8 Mar 2017; Accepted: 21 Mar 2017; Published online: 05 May 2017

Citation
Pradeep HD, Shirke SS and Kar AB (2017) Estimates of length-based population parameters of the Skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) in the Andaman waters. Journal of Fisheries 5(2): 477–482. DOI: 10.17017/j.fish.42

Abstract

The exploitation level of skipjack tuna, *Katsuwonus pelamis* in Andaman waters is meagre compared to its total landings in India. As the population parameters of this species has not been attempted in these waters, an attempt has been made in this paper to estimate the population parameters of *K. pelamis* based on the length frequency data collected from local fishing boats operating from Junglighat Fishing Harbour, Port Blair, Andaman Islands from January to December 2014. A total of 704 specimens ranging from 16.5 to 71.0 cm fork length were taken for analysis. The parameters L_∞, K and t_0 were 74.55 cm, 0.59/year and –0.21 respectively. The von Bertalanffy growth equation for *K. pelamis* is $L_t = 74.6[1 - e^{-0.59(t+0.214255)}]$. The recruitment pattern was unimodal. The recruitment period was from July – October. The longevity of the species was calculated as 4.9 years. After 1st, 2nd, 3rd and 4th year the length attained by the species is 38.1, 54.4, 63.4 and 68.3 cm respectively. The mortality parameters were Z = 2.07, M = 0.93, F = 1.14 and exploitation ratio was 0.55. The virtual population analysis (VPA) for *K. pelamis* indicated that fishing mortality starts at 41–50 cm class interval and it continues henceforth and was maximum at 61–70 cm and decreased thereafter.

Keywords: Skipjack tuna; age and growth; spawning; recruitment; mortality.

1 | INTRODUCTION

The Exclusive Economic Zone (EEZ) around the Andaman and Nicobar groups of Islands is 30% of the total Indian EEZ (Pradeep *et al*. 2014). The ecosystem of the Andaman and Nicobar islands is considered to be one of the best-preserved ecosystems in the Indian sub-continent. Among the oceanic resources three types of tunas *Thunnus albacores* (yellowfin tuna), *T. obesus* (bigeye tuna) and *Katsuwonus pelamis* (skipjack tuna) are available in the Andaman waters. The *K. pelamis* (Linnaeus, 1758) is mainly caught by gill nets, long lines and by hand lines in the Island groups. The potential of oceanic resources in the Indian EEZ including tuna, billfishes and allied species is estimated at 0.22 million t. This comprises yellowfin tuna (80,000 t), skipjack tuna (99,000 t), bigeye tuna (500 t), billfishes (14,400 t), pelagic sharks (20,800 t) and other species (1,800 t; Anon 2011). The exploitation of these oceanic resources in the Island group is meagre. The exploitation figure of the *K. pelamis* indicates that in comparison to the *K. pelamis* landings of India, it was in between 0.44% and 0.84% only during 2007–2012 (Table 1; Anon 2014a). Total annual marine fish production from the Andaman and Nicobar Islands is about 36980 t during the year 2014–15 and tunas constituted 2,392 t which is only 6.5% of the total landings. Among tunas, *K. pelamis*

landings were 93 t which is around 4% of the total tuna landings from Andaman and Nicobar Islands (Anon 2014b).

TABLE 1 *Katsuwonus pelamis* catch (t) in India

Area	*India*[1]	*A&N islands*[2]
2007	7,682	34
2008	10,176	41
2009	10,363	48
2010	9,563	59
2011	18,934	68
2012	7,212	60
2013	-	59
2014	-	93

1, Anon (2014a); 2, Anon (2014b)

Gopalakrishna Pillai and Palanisamy (2012) studied the biology, fishery, conservation and management of Indian Ocean tuna fisheries. The biological parameters such as length frequency, length – weight relations, sex ratio, food and feeding of the *K. pelamis* has been studied by various researchers (Marcile and Stequert 1976; Appukuttan *et al*. 1997; Madan and Kuhnikoya 1985; Madan *et al*. 1985; Sivasubramanium 1985; James *et al*. 1992; James and Pillai 1993; Yohannan *et al*. 1993; Pandian *et al.* 2007; Sivadas *et al*. 2005; Ganga and Pillai 2006; Said Koya *et al.* 2012). Most of the above studies are from Lakshadweep waters. The population dynamic parameters including temporal distribution of length frequency, age, growth and mortality are necessary for any reliable stock assessments, and to ensure a sustainable exploitation of the fisheries (Chen and Paloheimo 1994). From Andaman and Nicobar waters of the Indian EEZ, population parameters of yellowfin tuna was studied by Ramalingam *et al*. (2012) and its distribution, abundance and biology by Pradeep *et al*. (2014). The information on the population parameters of the *K. pelamis* from the Andaman Sea is meagre. Keeping in view of the proximity of the EEZ of India around Andaman & Nicobar Islands to the neighbouring southeast Asian countries and also the stock nature of *K. pelamis* which is shared by different countries it is utmost important to study the growth and population parameters of this species. Bensam (1999) opined that most fisheries researches in tropical countries are using length frequency data for estimating growth parameters, since it is difficult to determine the periodicity of formation of growth rings in most marine fishes in tropical environment due to the absence of wide variation in environmental condition like in the temperate waters. In this paper an attempt has been made to study the age, growth and mortality parameters of the species based on the length frequency data collected from the Junglighat Fishing Harbour, Port Blair.

2 | METHODOLOGY

A total of 704 specimens of *K. pelamis* of fork length (FL) ranging from 16.5 to 71.0 cm were collected from the Junglighat Fishing Harbour/landing centre situated in Port Blair, Andaman & Nicobar Islands for studies during January to December 2014 (Figure 1). For this study 40–60 specimens were caught by gillnet every month. Length was measured from the tip of the snout to the caudal fork (FL) up to the nearest 5 mm. Length frequency data were grouped into 5 cm interval was used for the estimation of growth and population parameters. The asymptotic length (L_∞) and growth coefficient (K) were estimated using the ELEFAN I (Electronic Length Frequency Analysis) of FiSAT (FAO ICLARM stock assessment tools, Version 1.2.2, 2005) and t_0 was calculated by Pauly's (1979) empirical equation. Longevity was calculated by the formula $t_{max} = 3/K+t_0$ (Pauly 1983a). Natural mortality (M) was calculated from Pauly's (1980) empirical formula. The total mortality (Z) from length converted catch curve by taking the mean annual habitat temperature as 27 °C (Pauly 1983b). The fishing mortality was calculated as $F = Z – M$. The length at first capture (the length at which 50% of the fishes are vulnerable to the gear, L_{50}) was estimated from the length converted catch curve analysis. The exploitation rate (E) was obtained by dividing F by Z. The length structured Virtual Population Analysis (VPA) of FiSAT was carried out to ascertain the loss ascertain the loss due to natural causes, fishing pressure at different length classes and the survivors (Jones 1984).

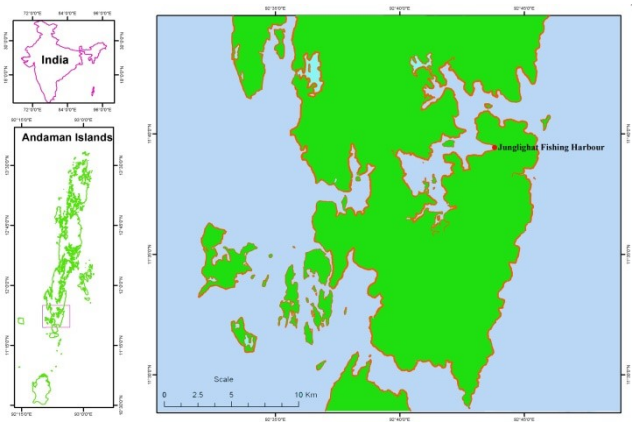

FIGURE 1 Junglighat Fishing Harbour, the sampling station

3 | RESULTS

3.1 | Growth parameters

The growth parameters estimated for the *K. pelamis* were, L_∞= 74.6 cm and K = 0.59/year. t_0 was found to be -0.21. The same length frequency data was analysed by Powell–Wetherall method (Powell 1979; Wetherall 1986; this method was developed by Powell and later improved by Wetherall) of FiSAT programme and the values of L_∞

and *Z*/*K* obtained were 79.7 cm and 4.7 respectively. The growth curve generated by ELEFAN I employing FiSAT programme for the species is shown in the Figure 2. The values of L_∞ and the growth rates obtained by ELEFAN I appear to be the best considering the maximum length observed in the sample (71 cm). Hence, the values obtained in the ELEFAN I were taken as input in further analysis of the growth parameters.

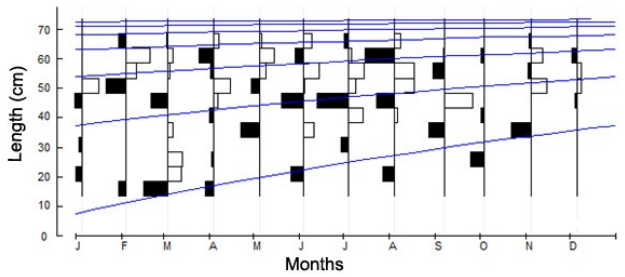

FIGURE 2 ELEFAN I growth curve of *Katsuwonus pelamis* (L_∞ = 74.55 cm, K = 0.59 yr^{-1}). Growth curves are oblique lines and black/white bars are restructured frequencies.

3.2 | Recruitment

The recruitment pattern of the species is unimodal as shown in Figure 3. One peak was observed with maximum during August with a recruitment percentage of 31% followed by July (17%) and September (10%). The recruitment period was from July to October. The length at first recruitment was taken as the smallest length in the length frequency distribution and the length at first capture was obtained by probability of capture analysis (the length at which 50% of the fish are vulnerable to gear). The length at first recruitment was found to be 16.5 cm and the length at first capture was 57.1 cm. The length at which 75% of the fish are retained (L_{75}) in the gear was estimated as 61.4 cm.

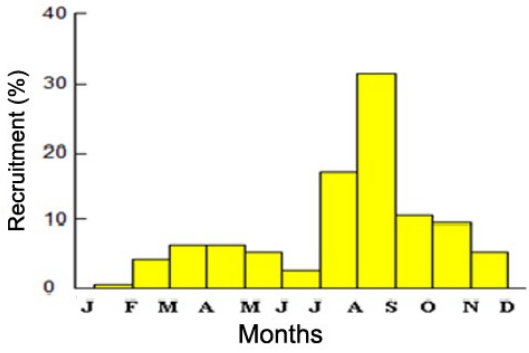

FIGURE 3 Recruitment pattern of *Katsuwonus pelamis*.

3.3 | Age

The longevity of *K. pelamis* was calculated as 4.9 years. After 1st, 2nd, 3rd and 4th year the length attained by the species is 38.1, 54.4, 63.4 and 68.3 cm respectively (Figure 4) registering a growth of 3.2 cm/month and 1.4 cm/month during the first and second year and decreased thereafter. The von Bertalanffy (1938) growth equation for *K. pelamis* can be written as follows:

$$L_t = 74.6\ (1 - e^{(-0.59[t+0.214255])})$$

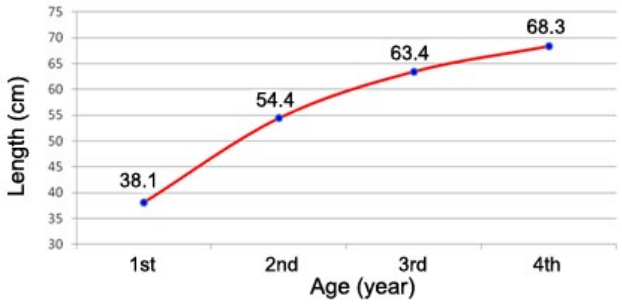

FIGURE 4 von Bertalanffy's growth curve of *Katsuwonus pelamis* from Andaman waters.

3.4 | Mortality

The natural mortality (*M*/year) as per Pauly's empirical formula keeping the habitat temperature as 27 °C was found to be 0.93 for the species. The fishing mortality was found to be 1.14 and the total mortality coefficient (*Z*) was estimated from the length converted catch curve as 2.07 (Figure 5). The exploitation ratio (*E*) was found to be 0.55.

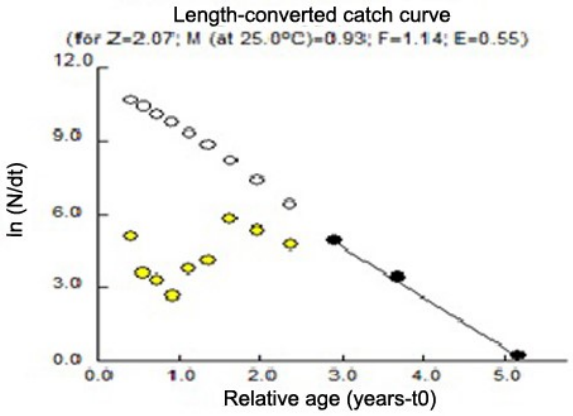

FIGURE 5 Length converted catch curve, estimated annual total mortality rate of *Katsuwonus pelamis* from Andaman waters, *Z* = 2.07.

3.5 | Virtual Population Analysis (VPA)

The virtual population analysis (Figure 6) indicates that the mortality in the population due to natural causes was up to a size of 40 cm. Fishing mortality starts at 41–50 cm class interval and it continues henceforth and was maximum at 61–70 cm class interval and decreased thereafter.

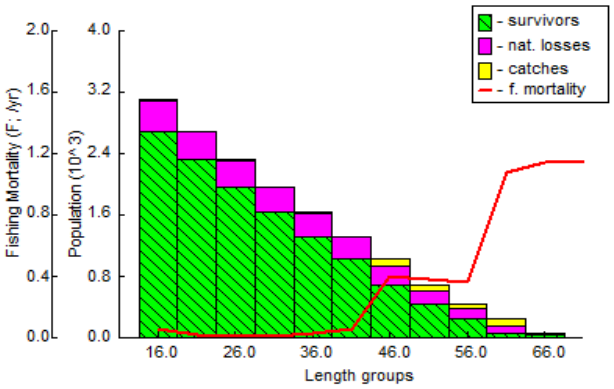

FIGURE 6 Virtual Population Analysis (VPA) of *Katsuwonus pelamis* from Andaman waters.

4 | DISCUSSION

Increasing demand for tunas has led to the pressure on oceanic tuna stocks by distant water fishing nations (Somvanshi and John 2004). As the growth of species can be highly variable according to time and area hence separate studies on growth parameters of the tunas recorded in various parts of Indian coast is of importance to have a clear understanding on the stock structure. As it is migratory in nature and also the proximity of Andaman & Nicobar Islands to the Southeast Asian countries than the mainland India the growth parameters obtained for the *K. pelamis* can be comparable with these countries as well as east coast and west coast of India.

Pandian *et al*. (2007) studied the biology of the species from Andaman waters and recorded the mean length and weight of male as 54.5 cm and 2.8 kg respectively and mean length and weight of female as 54.7 cm and 3.1 kg respectively. The male to female sex ratio was found to be 1:0.7 with dominance of male in all the months. Marcile and Stequert (1976) analysed length frequency data of *K. pelamis* from the Indian Ocean and got the growth parameters as L_∞ = 60.6 cm and K = 0.93 per year. Sivasubramanium (1985) reported the growth parameters as L_∞ = 77 cm and K = 0.52 per year in Sri Lankan waters. Appukuttan *et al.* (1997) estimated the values of K and L_∞ from Minicoy waters to be 0.22 and 84.3 cm FL respectively when the length of the fish ranged between 35.0 and 69.5 cm. The estimated length of the species after 1st, 2nd, 3rd, 4th, 5th and 6th year was 40.7, 49.3, 56.2, 62.0, 66.4 and 69.9 cm FL respectively. Madan *et al*. (1985) also studied the age and growth of *K. pelamis* from Minicoy and reported K, L_∞ and t_0 values as 0.48/year, 90.0 cm and –0.06 respectively. Based on these the age of skipjack was calculated as four years and the growth after the 1st, 2nd, 3rd and 4th year was 36.7, 57.3, 69.0 and 77.7 cm respectively indicating a faster growth during the first year and decreased subsequently. From Indian Ocean, Shabotiniets (1968) calculated the size at age of *K. pelamis* from Madagascar area based on the growth marks in the first spine of the first dorsal fin and estimated the age as 3 years for fishes 40–45 cm long and 4 years for fishes 40–60 cm long. Sivadas *et al*. (2005) estimated L_∞ = 76.65 cm and K = 0.95 per year and found that the species reach a size of 47.0, 65.2, 72.2, 74.9, 76.0 and 76.4 cm during first to sixth year in the Lakshadweep waters. Said Koya *et al*. (2012) studied the growth and population parameters of the *K. pelamis* of fork length varying from 12–88 cm in Indian waters and observed that the length weight relationship is W = 0.0109 L $^{3.147}$. The von Bertalanffy (1938) growth parameters obtained were L_∞ = 92.0 cm, K = 0.50/year and t_0 = –0.0012. All these studies indicate the growth of the species is more during the first year itself and decreases in subsequent years. In the present study the growth parameters L_∞, K and t_0 were 74.6 cm, 0.59/year and –0.21 respectively. The longevity of the species was calculated as 4.9 years. After 1st, 2nd, 3rd and 4th year the length attained by the species was 38.1, 54.4, 63.4 and 68.3 cm FL indicating a growth of 3.2 cm/month during the first year, 1.4 cm/month during the second year, 0.8 cm/month during the third year and 0.4 cm/month during the fourth year respectively. The previous studies also indicated the age of the species in Indian waters as 4 to 6 years. The observations in the present study agree well with the previous studies.

According to James and Pillai (1993) this species spawns during March. Madan and Kuhnikoya (1985) observed mature females during May to August in Minicoy and occurrence of young fishes of 30 cm during January to May and September to December indicating spawning throughout the year. James *et al*. (1992) also reported occurrence of mature fishes almost throughout the year with two spawning peaks during January–April and September–December. Said Koya *et al*. (2012) reported that the species mature and spawn round the year in Indian waters with a peak from December to March and a minor one during June–August. The recruitment pattern showed that young recruits enter the population during most part of the year with peak during May to November. Madan *et al.* (1985) reported maximum recruitment during April from Minicoy waters. In the present study the recruitment was unimodal and the young ones enter the population throughout the year however maximum recruitment was observed during August and the peak recruitment period was from July to October which is in agreement with the earlier observations.

Sivadas *et al*. (2005) studied the mortality parameters from Lakshadweep waters and obtained the values as M = 1.33, F = 2.39 and Z = 3.72. Said Koya *et al*. (2012) studied mortality parameters and they were in the range of M = 0.55, F = 0.85 and Z = 1.41/year with E = 0.61. All these studies indicate fishing pressure on *K. pelamis* is high in

the Lakshadweep waters. In the present study the mortality parameters were *M* (25 °C) = 0.93, *F* = 1.14, *Z* = 2.07 and the exploitation ratio was 0.55. The fishing mortality is slightly higher than the natural mortality suggesting that the fishing pressure on the species is more compared to natural causes. The virtual population analysis for *K. pelamis* indicated that fishing mortality due to natural causes is at 40 cm and the fishing mortality starts at 41–50 cm class interval and it continues henceforth and is maximum at 61–70 cm class interval and decreased thereafter. Though it is indicative that fishing pressure or exploitation is more but these observations alone cannot give a through picture on the status of the *K. pelamis* in Andaman waters as a lot of other factors such as biomass of the species, MSY, total landings needs to be taken into consideration. Also the landing data in India does not include the poaching data, which definitely dilutes the exact landing figures. To have better understanding on the growth of the species it is imperative to study the growth and mortality parameters separately for both the sexes in the Andaman Sea and also the oceanographic conditions affecting the growth for both the sexes. All these things need to be taken care of while forming necessary action plans for the development of the *K. pelamis* fishery in the Andaman Sea. Periodic reassessment of the *K. pelamis* stocks is also required with adequate inputs from exploratory surveys as well as commercial landings to prevent any unsustainable trends in the development of the *K. pelamis* fisheries in these Island groups.

ACKNOWLEDGEMENTS

The authors are grateful to the Director General, Fishery Survey of India, Mumbai for suggesting this research topic and for his encouragement during the study period. They also express their sincere thanks to M/S. Rubin Fisheries, Port Blair for providing the samples for the studies. Further, the authors are thankful to the anonymous reviewers for the betterment of the manuscript.

REFERENCES

Anon (2011) Report of the Working Group for Revalidating the Potential of Fishery Resources in the Indian EEZ. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers welfare, New Delhi. pp. 1–79.

Anon (2014a) Handbook of Fisheries Statistics, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers welfare, New Delhi. pp. 5–16.

Anon (2014b) Fisheries in Andaman and Nicobar Islands. Directorate of Fisheries, Andaman and Nicobar Administration, Port Blair. p. 12.

Appukuttan KK, Radhakrishnan Nair PN and Kunhikoya KK (1997) Studies on the fishery and growth rate of oceanic skipjack, *Katsuwonus pelamis* (Linnaeus), at Minicoy Island from 1966 to 1969. Indian Journal of Fisheries 24 (1&2): 31–47.

Bensam P (1999) Development of marine fisheries science in India. Daya Publishing House, Delhi. 379 pp.

Bertalanffy L. Von (1938) A quantitative theory of organic growth (Inquiries on growth Laws II). Human Biology 10(2): 181–213.

Chen Y and Paloheimo JE (1994) Estimating fish length and age at 50% maturity using a logistic type model. Aquatic Science 56: 206–219. doi: 1007/BF00879965.

Ganga U and Pillai NGK (2006) Tuna resources of India -their potential and exploitation, In: Kurup BM and Ravindran K. (ed.), Proceedings of the International symposium on "Improved sustainability of fish production systems and appropriate technologies for utilization" 16–18 March'2006, pp. 411–420.

Gopalakrishna Pillai N and Palaniswamy S (2012) Biology, Fishery, Conservation and Management of Indian Ocean Tuna Fisheries. Ocean Science Journal 47(4): 411–433. doi: 10/1007/s12601-012-0038-y.

James PSBR, Pillai PP, Jayaprakash AA, Yohannan TM, Siraimeetan P, Muthiah C, Gopakumar G, Pillai NGK, Reuben S, Thiagarajan R, Said Koya KP, Kulkarni GM, Somaraju MV, Kurup KN and Sathianandan TV (1992) Stock assessment of tunas from the Indian seas. Indian Journal of Fisheries 39 (3&4): 260–277.

James PSBR and Pillai PP (1993) Review of national tuna fishery in India. IPTP Collective volume of working documents 8: TWS/93/1/2/2-5.

Jones R (1984) Assessing the effects of changes in exploitation pattern using length composition data (with notes on VPA [Virtual Population Analysis] and cohort analysis).

Madan M, Livingston P and Kunhikoya KK (1985) Fishery and bionomics of tunas, *Katsuwonus pelamis* (Linnaeus) and *Thunnus albacares* (Bonnatere) from Minicoy waters. Tuna fisheries of EEZ of India: Biology and Stock Assessment. Bulletin of Central Marine Fisheries Research Institute 36: 143–148.

Madan Mohan and Kunhikoya KK (1985) Age and Growth of *Katsuwonus pelamis in* Minicoy Islands. Bulletin of Central Marine Fisheries Research Institute 36: 122–237.

Marcille J and Stéquert B (1976) Etude préliminaire de la croissance du listao (*Katsuwonuspelamis*) danslouest de l'océanIndien tropical. Cah ORSTOM Sér Océanogr. 14: 139–151.

Pandian PP, Kar AB, Sinha MK and Pattnayak SK (2007) Observation on the distribution and abundance of tuna resources in the Exclusive Economic Zone (EEZ) of An-

daman & Nicobar Islands. Zoological Survey of India, National Symposium on conservation and valuation of Marine Biodiversity. pp. 287–299.

Pauly D (1979) Theory and management of tropical multi-species stocks: a review with emphasis on the South-east Asian demersal fisheries. ICLARM Studies and Reviews 1. 35 pp.

Pauly D (1980) On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal Du Consiel International Pour L'exploration de la Mer 39(2): 175–192. doi: 10.1093/icesjms/39.2.175.

Pauly D (1983a) Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper No. 243. 52 pp.

Pauly D (1983b) Length converted catch curves. A powerful tool for fisheries research in tropics (Part-1), ICLARM Fishbyte 1: 9–13.

Powell DG (1979) Estimation of mortality and growth parameters from the length frequency in the catch. Rapp. P, -V. Reun. CIEM 175: 167–169.

Pradeep HD, Swapnil SS, Dwivedi SK, Ramachandran S and Premchand (2014) Distribution, abundance and biology of Yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788) in the Andaman and Nicobar waters, Journal of the Andaman Science Association 19(2): 191–200.

Ramalingam L, Kar AB, Govindaraj K and Prasad GVA (2012) Study of the growth and population parameters of yellowfin tuna (*Thunnus albacares*) in the Andaman and Nicobar waters based on the length frequency data. Report of the 14th IOTC proceedings. 24–29 October 2012, Mauritius. 17 pp.

Said Koya KP, Joshi KK, Abdussamad EM, Prathibha Rohit, Sivadas M, Somy Kuriakose, Shubhadeep Ghosh, Mohammed Koya, Dhokia HK, Prakasan D, Kunhi Koya VA and Manju Sebastine (2012) Fishery, biology and stock structure of skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758) exploited from Indian waters. Indian Journal of Fisheries 59(2): 39–47.

Shabotiniets E (1968) Opredelenie vozrasta tuntsov Indiiskogo okeana (Age determination of Indian Ocean tunas). (In Russ., Tr. VNIRO 64, Tr. Azeher NIRO 28 : 374-376. (Engl, transl) by W. L.Klawe. Inter-Am. Tropical Tuna Commission, La Jo Ua. California. p. 5.

Sivadas M, Said Koya KP and Pillai NGK (2005) Stock Assessment of Skipjack Tuna, *Katsuwonus pelamis* from Minicoy, Lakshadweep. Proceedings of Tuna Meet-2003, Fishery Survey of India. pp. 168–180.

Sivasubramaniam K (1985) The tuna fishery in the EEZs of India, Maldives and Sri Lanka. Bay of Bengal Programme/Working Party /31. pp. 19–47.

Somvanshi VS and John ME (2004) Some observations on the highly migratory species and straddling stocks occurring in Indian waters and their fisheries in Indian ocean. In: Somvanshi VS (ed.), Large Marine Ecosystem: Exploration and Exploitation for Sustainable Development and Conservation of Fish Stocks. Fishery Survey of India. pp. 421–432.

Wetherall JA (1986) A new method for estimating growth and mortality parameters from length-frequency data. ICLARM, Fishbyte 4(1): 12–14.

Yohannan TM, Pillai PP and Said Koya KP (1993) Fishery, biology and stock assessment of skipjack tuna in Indian Seas. In: Sudarsan, D. and John, M. E. (Ed.), Tuna Research in India, Fishery Survey of India, Bombay. pp. 77–96.

CONTRIBUTION OF THE AUTHORS

PHD & SSS primary data collection; **PHD** data analysis; **PHD & ABK** manuscript preparation.