Journal of Fisheries
Volume 8 Issue 3 December 2020 Pages 940–944
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

Short Communication

Fish stock demographics of skipjack tuna (*Katsuwonus pelamis*) from Kavaratti in Lakshadweep, Southern Arabian Sea

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Manuscript history
Received 18 August 2020 | Revised 24 November 2020 | Accepted 4 December 2020 | Published online 13 December 2020

Citation
Muhsin AI, Shahul Hameed PVP, Pookoya P, Harikrishnan M, Ranjeet K (2020) Fish stock demographics of skipjack tuna (*Katsuwonus pelamis*) from Kavaratti in Lakshadweep, Southern Arabian Sea. Journal of Fisheries 8(3): 940–944.

Abstract
Marine fish stocks are depleting at an alarming rate. Skipjack tuna, *Katsuwonus pelamis* has been exploited in Lakshadweep Island area in the Indian Ocean mainly by pole and line fishery which constituted one-third of its production in the country. Age, growth, demographics and stock assessment of this species were investigated from the Lakshadweep waters. The von Bertalanffy growth factors were estimated as asymptotic length 72.5 cm, growth constant 0.480 and the theoretical age at zero-length as –0.1097. This study showed that skipjack grows from 30 to 68.26 cm from first to sixth year. The natural mortality, fishing mortality and total mortality were 0.82, 1.51 and 2.33 respectively. The exploitation ratio was 0.65, while the exploitation which maximises relative yield per recruit (E_{max}) was 1.0. Recruitment pattern showed that young recruits entered the fishing grounds in most months, with peaks during June–July. Length based Virtual Population Analysis indicated that the major loss in its stock up to 22 cm was due to natural causes. At the same time, higher fishing mortality was registered in 40–60 cm length group. The present study provides knowledge on the demographics of *K. pelamis*, pertinent for formulating an effective fisheries management in the region.

Keywords: Growth; *Katsuwonus pelamis*; Kavaratti; Lakshadweep; population dynamics; stock assessment

1 | INTRODUCTION

Skipjack tuna, *Katsuwonus pelamis* inhabits the upper mixed layer of the sea in the temperate and tropical ocean around the world between 45°N and 40°S (Kim *et al.* 2020). This species forms the third largest caught tuna (3.06 million tons) in the world (FAO 2016), contributing about 58% to the total tuna catches (ISSF 2020). The exploitation of this species in the Indian Ocean is mostly with purse seine (40%), gillnets (26%), and pole-and-line (20%) (ISSF 2017). In Indian waters, Lakshadweep Islands is the only region where skipjack is exploited in an organised manner with 'pole-and-line' contributing close to

30% of total tuna landings in India (Koya *et al.* 2012). Being the most dominant commercially exploited tuna species, *K. pelamis* forms the mainstay of the livelihood and fishery associated industry in this island system (Pillai and Satheeshkumar 2012).

Stock assessment provides information on the optimum exploitation, utilisation and conservation of fish wherein the exploitation could be managed sustainably. Growth is an important factor that determines the dynamics of fish populations and directly contributes to an increase in stock biomass (Hilborn and Walters 1992). Age and growth studies of fishes are directed to understand the age composition of the population, age at maturation, life span and pattern of growth of a species in different phases of its life history. These form the basis for calculations leading to the knowledge of growth, mortality, recruitment and other fundamental parameters of the population. Since spatiotemporal variability affects the reproductive strategies in *K. pelamis* (Schaefer and Fuller 2018), an understanding on their region-specific demographics is essential in evolving effective management strategies for the development and judicious exploitation of their resources. Hence, any understanding of the population and stock characteristics of fish stock would help to formulate strategies for its optimal utilisation. Kavaratti is one of the major tuna landing islands in Lakshadweep, contributing to over 1000 tonnes of skipjack tuna annually (Pillai and Satheeshkumar 2012). Although there have been earlier studies on skipjack in the Lakshadweep waters from Minicoy and Agatti Islands (Jones and Kumaran 1959; Appukuttan *et al.* 1977; Sivadas *et al.* 2002), no such information was available from the waters of Kavaratti. The present study is the first focused effort to understand the age, growth and stock structure of skipjack, *K. pelamis* inhabiting the Kavaratti waters.

2 | METHODOLOGY

Random monthly sampling of skipjack tuna, *Katsuwonus pelamis* from Kavaratti (10°33′33.48′′N 72°38′08.88′′E) was carried out for a year (from June 2016 to May 2017). These specimens were collected using diverse types of gears *viz.*, pole and line, hook and line, hand line and drift gillnets (55 – 80 mm mesh size). Fork length (*FL*, from the tip of the snout to the tip of the notch in the tail fin) of all specimens was measured to the nearest 0.1 cm using a measuring board and scale and the individual weight (*W*) was recorded using an electronic balance (0.1 g accuracy). Fork lengths of 4150 specimens were used for the estimation of age, growth and stock structure. The length-weight relationship (LWR) ($M_B = {}_aL_T^{\,b}$) was determined following (Pauly 1984) and the parameters (*a* and *b*) were estimated by least squares regression of log-log plot (Zar 1999). The null hypothesis that $n = 3$ (*i.e.*, individuals show an isometric growth pattern; Froese 2006) was tested using two-tailed *t*-tests. The statistical analysis was performed in PAST (version 3.20).

The length data were grouped into different classes of 4 cm intervals and analysed using FAO-ICLARM Stock Assessment Tools (FiSAT) (Gayanilo *et al.* 2005). Growth parameters, L_∞ and K, were estimated from monthly length-frequency data using Powell-Wetherall plot and ELEFAN-1 programme in FiSAT. Value of t_o was calculated from von Bertalanffy growth plot; similarly, age and growth were estimated from von Bertalanffy growth equation, $L_t = L_\infty(1 - e^{-K*(t-to)})$ and longevity using the equation $t_{max} = t_o + 3/K$ (Pauly 1983a); where t_{max} is the approximate maximum age of fish in a given population. Instantaneous rate of natural mortality (*M*) and total mortality (*Z*) were estimated by the length converted catch curve method (Pauly 1983b) and exploitation rate (*U*) from the relation $U = F/Z\ (1 - e^{-z})$, where, *F* is the fishing mortality.

Probability of capture was estimated from the left ascending arm of length converted catch curve. The method consists of extrapolating the catch curve and comparison of the numbers caught with those that ought to have been caught, being added to the curve. Recruitment patterns were obtained by backward projection, on to the length axis of a set of length-frequency data. Length structured Virtual Population Analysis (Pauly 1984) was used for gathering information on survivors, natural mortality and fishing mortality in each length group. Estimation of yield per recruit and biomass per recruit at different levels of *F* and t_c were made using yield per recruit analysis (Beverton and Holt 1957). The smallest length in the catch over the one-year period was taken as length at recruitment (L_r). Estimation of yield at different values of *F* and length at first capture were also calculated. Total stock (*P*) and biomass (*B*) were estimated from the ratios *Y*/*U* and *Y*/*F*, respectively; where *Y* is the annual average yield in tonnes. The maximum sustainable yield was calculated following Gulland (1979) for exploited fish stocks. The relative yield per recruit (*Y*/*R*) and biomass per recruit (*B*/*R*) at different levels of *F* was estimated using the LFSA package (Sparre 1987).

3 | RESULTS AND DISCUSSION

Annual landings of *K. pelamis* in Kavaratti during the study period were recorded to be 728 MT. The length-frequency included individuals ranging from 22 to 67.2 cm FL and the weight ranged from 200 to 6400 g. The LWR was defined by the equation W = 0.000017 $L^{3.0139}$, and the *b* value 3.0139 was higher than the cube value (t = 1.9631, $p < 0.05$) expected under isometry, indicating that *K. pelamis* shows a positive allometric growth pattern. Growth, mortality and exploitation parameters of skipjack from Kavaratti are depicted in Table 1. The von Bertalanffy growth curve showed an asymptotic length of

72.20 cm and a growth coefficient of 0.48 year^{-1}. The t_0 was calculated as –0.1097 and the longevity (t_{max}) as six years. The von-Bertalanffy growth curve suggested that skipjack grows to 30.0, 46.1, 56.1, 62.4, 66.3 and 68.6 cm during the 1st to 6th years, respectively (Figure 1a). Seasonal recruitment pattern of skipjack tuna inhabiting Kavaratti waters is depicted in Figure 1b, which indicated that young recruits entered the fishing ground in most months with a major peak in June – July and a minor peak in March – April. Natural mortality (*M*) estimated in the present study was found to be 0.82, and total mortality (*Z*) computed by length converted catch curve as 2.33. Fishing mortality (*F*) was estimated at 1.51, and exploitation rate (*U*) was 0.65 (Table 1). The results of virtual population analysis (VPA) showing the number of survivors and portion of the population subjected to natural mortality and fishing are depicted in Figure 1c. It could be inferred that better survival in size groups up to 36 cm due to low *M* and *F*. However, from sizes 36 cm onwards, *F* increased yielding high catches in 40–48 cm size group, which mainly constituted the exploited stock. Relationship between length class and the probability of their capture is depicted in Figure 1d. Length at which 25% of skipjack are vulnerable to gears (L_c 25) was found to be 41.17 cm, while L_c 50 and L_c 75 were estimated at 49.01 and 56.84 cm respectively. Hence, from a fisheries management perspective, it could be inferred that the currently exploited stock constituted optimal size groups. The relative yield per recruitment analysis of skipjack tuna of Kavaratti waters is depicted in Figure 1e. The values of L_c / L_∞ and *M* / *K* used for estimation were 0.670 and 1.708, respectively. The exploitation rate at which the stock would be reduced to 50% of its unexploited biomass (E_{50}) was estimated at 0.42, while the E_{max} was estimated at 1.0. It may be noted that the current exploitation rate is 0.65, which indicated that the current exploitation is well within the maximum exploitation, and the fishery exploitation remains at a sustainable level.

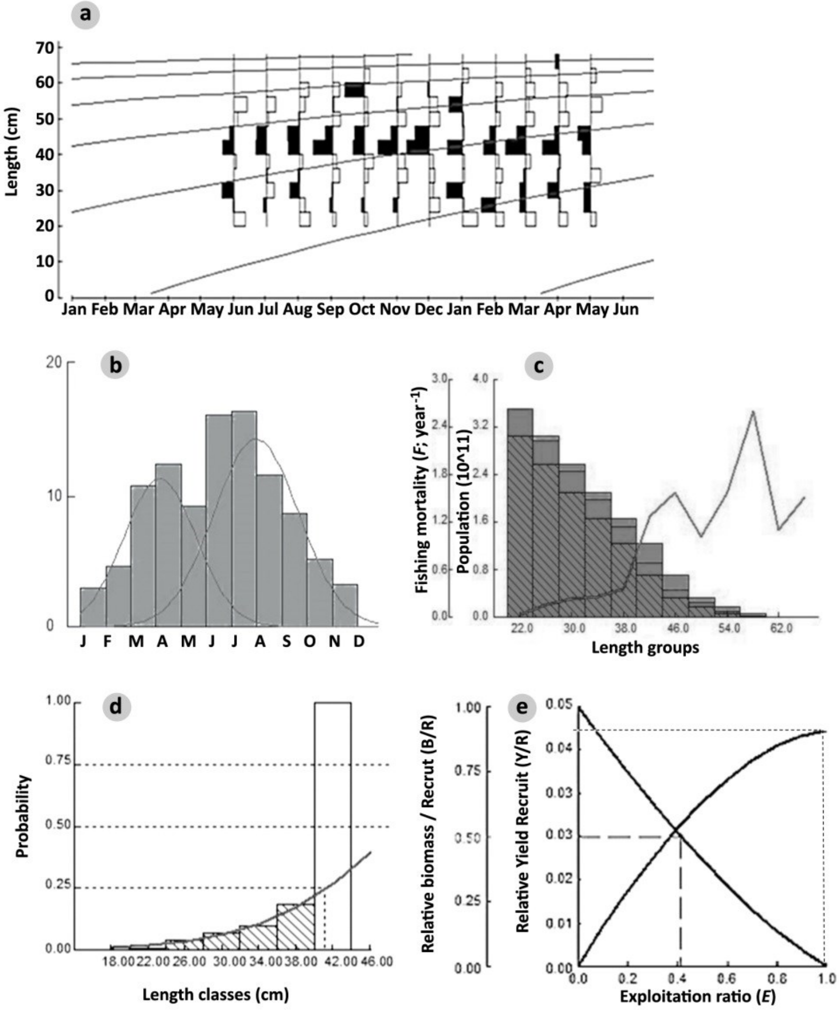

FIGURE 1 Growth and mortality modelling of *Katsuwonus pelamis* from Kavaratti in Lakshadweep, Southern Arabia Sea.

Skipjack is reported to undertake prolonged spawning and recruitment throughout the year in tropical waters (Sivadas *et al.* 2002). The *b* value obtained in the current study is slightly lesser than those observed by Koya *et al.*

(2012). However, their growth remains positively allometric, indicating the population is fast growing. It appeared that the growth is rapid in the juvenile stage than older age groups as observed in previous studies (Appukuttan *et al.* 1977; Sivadas *et al.* 2002; Garbin and Castello 2014). The parameters of growth, L_∞ and K were within the ranges of already recorded in the Indian Ocean, *i.e.*, L_∞ = 66.8 – 95.7 cm and K = 0.40 – 0.63 year^{-1} (Hafiz 1985; Koya *et al.* 2012; Ahmed *et al.* 2016, Kumar et al. 2019). It is evident that the Z, F and U estimated in the present study were very low compared to previous studies in Lakshadweep waters (M = 0.78 – 1.00 year^{-1}, Z = 4.0 – 7.9 year^{-1} and F = 3.2 – 6.9 year^{-1}) (Sivadas *et al.* 2002; Koya *et al.* 2012). Fishing mortality increased towards higher length groups, especially in 40–44 and 44–48 cm groups. The catches were mainly constituted by size groups ranging from 24–56 cm with the size groups 40–44 and 44–48 contributed nearly 48% of total catches, of which the former class alone constituted 28%. The present estimate of L_c is comparable to earlier reports from Indian waters, *i.e.*, 48 cm (Koya *et al.* 2012). It may also be inferred that the current estimate of L_c 50 is well above the size at first maturity (41 cm) of this species (Pillai and Satheeshkumar 2012) indicating that majority of the fish might mature and spawn at least once before being caught. It could also be inferred that the commercial fishery of skipjack in Kavaratti islands was mainly constituted by sexually mature fishes.

TABLE 1 Growth, mortality and exploitation parameters of *Katsuwonus pelamis* from Kavaratti, Lakshadweep.

Demographics and exploitation parameters	Value
Asymptotic length (L_∞; cm)	72.20
Growth coefficient (K; year^{-1})	0.48
Growth performance index (ϕ)	3.40
Longevity (3/K; years)	6.25
Total mortality (Z; year^{-1})	2.33
Natural mortality (M; year^{-1}, at 26°C)	0.82
Fishing mortality (F; year^{-1})	1.51
Current exploitation rate (E)	0.65
Length at first capture (L_c; cm)	49.01
Theoretical age at birth (t_0; year^{-1})	–0.1.907
$E_{0.1}$	0.84
$E_{0.5}$ (Optimum)	0.45
Exploitation rate producing maximum yield (E_{max})	1.00

Skipjack tuna is a fast-growing species, maturing at 2 to 3 years old (40 cm in length); maturity at (50%) age 1–2 years with size 41–43 cm FL in the Indian Ocean (IOTC 2010). Being a migratory stock, its population is also influenced profoundly by the environmental perturbations, especially their seasonal abundance which is dependent on the availability of food, sufficient plankton and accumulation of preferred prey (Kim *et al.* 2020). Since the present exploitation rate was 40% less than the maximum sustainable yield, it could reasonably be concluded that the stock of skipjack in Kavaratti is rather robust.

ACKNOWLEDGEMENTS

The authors are thankful to the Secretary and the Director, Department of Science Technology Lakshadweep for their valuable support for caring out the research work. Authors also thank the project staff working under the "Assessment of marine fishery resources in Lakshadweep waters" project, especially Farsana Beegum P, Shihab B and Abdul Shakir TM, for their support during data collection.

CONFLICT OF INTEREST

The Author(s) hereby declare that there is no conflict of interest. It is further declared that all authors have participated in (a) conception/design/analysis and interpretation of the data and (b) drafting the article/revising it critically for important intellectual content; and (c) approving the final version of the manuscript for forwarding to the Journal of Fisheries.

DATA AVAILABILITY STATEMENT

The data generated from the present study is available with the first author (AIM, muhsinai77@gmail.com) and can be assessed on request.

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