Iran. J. Ichthyol. (2024) 11(3): 198-208
P-ISSN: 2383-1561; E-ISSN: 2383-0964

ORIGINAL ARTICLE

Length base spawning potential ratio (LBSPR) and Length Based Indicators (LBI) of Bullet tuna, *Auxis rochei* (Risso, 1810) in the Oman Sea (Iranian southern waters)

Seyed Ahmadreza HASHEMI*[1], Mastoureh DOUSTDAR[2]

[1]Offshore Fisheries Research Center, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization, Chabahar, Iran.
[2]Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization, Tehran, Iran.

Correspondence
seyedahmad91@gmail.com

Article history:
Accepted 25 September 2024

Abstract
The length-Based Spawning Potential Ratio (LB-SPR) model and Length Based Indicators (LBI) were applied to describe the stock status of Bullet tuna, *Auxis rochei* in the Oman Sea. From April 2021 to March 2022, a total of 254 specimens were collected from fish landing sites monthly, and their length (FL) and weight were measured. The maximum length recorded for this species in the area was 43 cm FL with mean length of 32±4cm. The relationship between length and weight was calculated as, $W= 0.0095\times L^{3.12}$ (R^2= 0.92). The t –test showed not significant differences between estimated b and b= 3 at the level of 0.05 (*P*>0.05), which means Isometric growth pattern for Bullet tuna species in the northern waters of the Oman Sea. Length Based Indicators (LBI) of Bullet tuna catches were (Linf= 45cm, Lopt= 28cm, LF=M= 25cm, Lmat= 32cm). Also, length-based reference point was percentage of mature fish in the catch (Lmat= 32cm, Pmat= 0.85), percentage of fish caught at the optimum length for harvest (Lopt= 28 cm, Popt=0.19), and percentage of mega-spawners in the catch (Lmega= 40cm, Pmega= 0.26) and Pobj= 1.79, respectively. Based on ratio of the Pobj value is >1, Pmega>0.1, Lmean/Lopt> and Lmean/LF=M>1 show considered desirable. The range of annual SPR for Bullet tuna stock in the Oman sea (Iranian waters), estimated to be 0.66 (0.56-0.79) which is upper than the threshold value 0.2. Based on time series analysis of SPR, it means that the study indicated that Bullet tuna stock exploitation ratio in Iranian southern waters (Oman Sea) is below sustainable levels (under exploitation/green color), suggesting the need to increase exploitation ratio and fishing effort.

Keywords: Sustainability, Spawning Potential Ratio, *Auxis rochei*

INTRODUCTION

Fisheries management relies on fish stock assessment as a scientific method to recommend strategies for preventing overfishing and maximizing harvests. Traditional models for stock assessment need extensive data sets, including historical records of catch amounts and fishing efforts, which many overfished species lack (Dowling et al. 2019; Halim et al. 2019). Therefore, new assessment techniques have been created to make use of the existing data for advising on stocks that are not amenable to traditional methods, known as data-poor stocks (Lart 2019). Consequently, a set of benchmarks has been established recently, which are derived from data that can be gathered more readily, such as total catch, catch rate, and the size distribution of the caught fish.

The Scombridae family, commonly known as the mackerel, tuna, and bonito family, includes many of the most important and familiar food fishes. The family consists of 54 species in 15 genera and two subfamilies. All species belong to the subfamily Scombrinae, except for the butterfly kingfish, which is the sole member of the subfamily Gasterochismatinae (Froese & Pauly 2024). These fish are generally predators of the open ocean and are found worldwide in tropical and temperate waters. They are capable of considerable speed, thanks to their highly streamlined body and retractable fins. Some members of this family, particularly the tunas, are partially endothermic, which helps them maintain high speed and activity (Froese & Pauly 2024).

The Bullet tuna (*Auxis rochei, species code:* BLT) is a small member of the family Scombridae, found in tropical and subtropical oceans worldwide. It has been observed to inhabit open surface waters up to depths of 50 meters (Agustina et al. 2023; Froese & Pauly

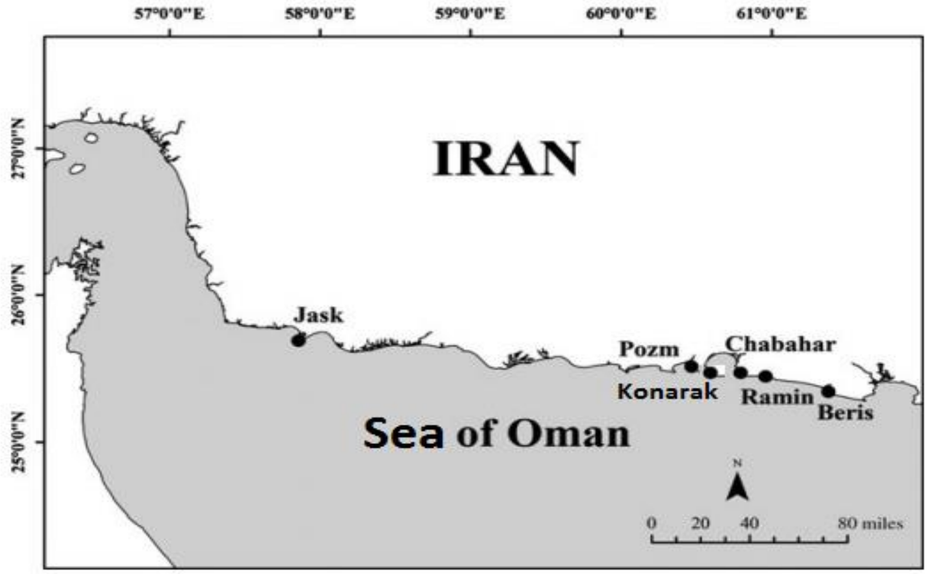

Fig.1. Location of *A. rochei* sampling stations in the northern waters of the Oman Sea, Iran.

2024). This species is recognized by its blue-black back with zig-zag dark markings and a silver underside. It's a relatively small and slender member of the tuna family, with a maximum length of about 50 centimeters and it is known for its rapid growth, short lifespan, and migratory behavior (Ollé-Vilanova et al. 2022). The species plays a crucial role in marine ecosystems and is a target for commercial and recreational fisheries. Bullet tuna are predators, feeding on small fish, squid, planktonic crustaceans, and stomatopod larvae. They are considered a minor commercial species, caught mainly in coastal waters and around islands (Jasmine et al. 2013; IOTC 2017; IOTC 2019). The spawning season varies across different oceans, typically occurring closer to shore than other tuna species, and at sea surface temperatures of 24°C or higher. For conservation, the bullet tuna is currently listed as Least Concern by the IUCN (Froese & Pauly 2024).

The Length-weight relationship (LWR) provides a mathematical explanation of how the length and weight of a fish are related. It's an important tool for transforming measurements of length into estimates of weight, which in turn helps to assess the biomass of fish populations (Froese 1998). In the field of ichthyology, measuring a fish's length is typically quicker and simpler than weighing it, making it advantageous to estimate the weight from the length when only the former is available (Harrison 2001). The LWR relationship as a valuable indicator of a fish's health status and can fluctuate throughout the year due to various external and internal factors, including the availability of food, feeding intensity, overall health, gender, reproductive organ development, breeding cycles (Froese 2006).

The Iranian Fisheries Organization has been taken an effective effort to collect length distribution of the catches of some commercial fish species during the last two decades. This study aims to use the length-frequency data which have been collected for *A. rochei* to describe the stock status of this species by Length-Based Spawning Potential Ratio (LB-SPR) model and Length Based Indicators (LBI), give possible management advice to fishery manager for sustainable exploitation.

MATERIAL AND METHOD

Sampling: Five stations were selected to study the stock status of *A. rochei* in the northern waters of the Oman Sea. There are ports of Beris (61˚10´E, 28˚82´N), Ramin (60˚45´E, 25˚15´N), Pozm (60˚ 28´E, 25˚ 14´N), Konarak (60˚28´E, 25˚60´N) and Jask (57˚77´E, 25˚64´N) (Fig. 1). The catch information was collected from these areas from 2021 to 2022 by Offshore Fisheries Research Center (OFRC).

Biometry: Biometric measurements (fork-length and total weight) were performed. Fork length was measured using a ruler with 1 cm accuracy and wet weight by the close to 10g.

Length-weight relationship (LWR): The Equation (1) was used to calculate relationship between the fork length and weight, with, *Wi* the total weight (g), *Li*, the fork length (mm), a is regression constant (intercept) and b is the regression slope (fish growth rate) (Zar 1996).

$Wi = a \times Li^{b}$ (1)

In order to verify if calculated b was significantly different from 3, the t-test was employed using the statistic: $t_s = (b-3)/Sb$, where Sb is the standard error of the slope (Zar 1996). In order to verify if calculated b was significantly different from 3, the students t-test was employed (Zar 1996).

Growth Studies: The estimation of L∞ or Linf was used by math equation that called the Froese and Binohlan equation, log Linf= 0.044+0.9841×log (Lmax) (Froese & Binohlan 2000).

The size at first sexual maturity (is denoted as 'Lm50' and 'Lm95') was calculated by the equation of: Fork length of all individuals was used to estimate the size at first maturity (Froese & Binohlan 2000). Log(LM)= 0.8979×logl∞-0.0782

Length Based Indicators (LBI): Length Based Indicators (LBI) suggests using three different measurements: percentage of mature fish in the catch (Pmat), percentage of fish caught at the optimum length for harvest (Popt), and percentage of mega-spawners (length between 1.1Lopt and Lmax on the catch length composition) in the catch (Pmega). These three measurements are all combined to give an overall score called the Pobj value, which can help to understand fishing status (Cope & Punt 2009). The *optimal fishing length* (called LF=M) calculated using some calculations *as follows* (2, 3 and 4) (Cousido-Rocha et al. 2022):

$L_{opt} = L_{inf}\,(3/(3+M/K))$ (2)

$L_{F=M} = (0.75L_c + 0.25L_{inf})$ (3)

$P_{mega} = L_{opt} + \%10$ (4)

Spawning Potential Ratio (SPR): The Spawning Potential Ratio (SPR) serves as a biological benchmark for assessing the population status of a species. The established SPR reference points are: SPR 20% as the threshold limit and SPR 40% as the desired target (Hordyk et al. 2015a). To calculate the SPR, one must consider various life history traits. The definition of SPR is provided in the work of Hordyk et al. (2015b).

$SPR = \frac{\sum(1-LX)^{(M/K)[(F/M)+1])}L_x^b}{\sum(1-L_X)^{M/K}L_x^b}$, Where, Lx is fork length; M is natural mortality; k is growth rate; F is fishing mortality, and *b* is exponent usually close to 3. To estimate the Spawning Potential Ratio (SPR) using certain models, it's assumed that fish selectivity follows an asymptotic or logistic pattern without any age-related length variation. The fishing mortality to natural mortality ratio (F/M) can be inferred from the size distribution of the catch (Hordyk et al. 2015b). The connection between F/M and SPR is shaped by the selectivity parameters and follows an asymptotic curve. The Length-Based Spawning Potential Ratio (LB-SPR) model employs maximum likelihood estimation to determine the selectivity curve, presumed to be logistic and defined by the parameters SL50 and SL95, as well as the relative fishing mortality (F/M). These estimates are then utilized to compute the SPR. The LB-SPR analysis was conducted using the LB-SPR package in R (Carruthers & Hordyk 2018).

Statistical analyses: Obtained in different years were compared. The data of population dynamic, lengths and weights value in different years were compared by T-test statistical test. Data analyses were performed using R (4.3.0), R Studio software (2023.06.0) with the LBSPR packages.

RESULTS

During study period, a total of 254 specimens of Bullet tuna species were collected. The weight and length of all specimens were measured. The mean of total length and total weight for this species was 32±7 (25-43cm) and 447±248 (200-1050) g respectively. The length (TL) data was categorized into 2 cm groups which the highest frequency (195 specimens), were belonging to fish with 31 to 33cm length (Fig. 2).

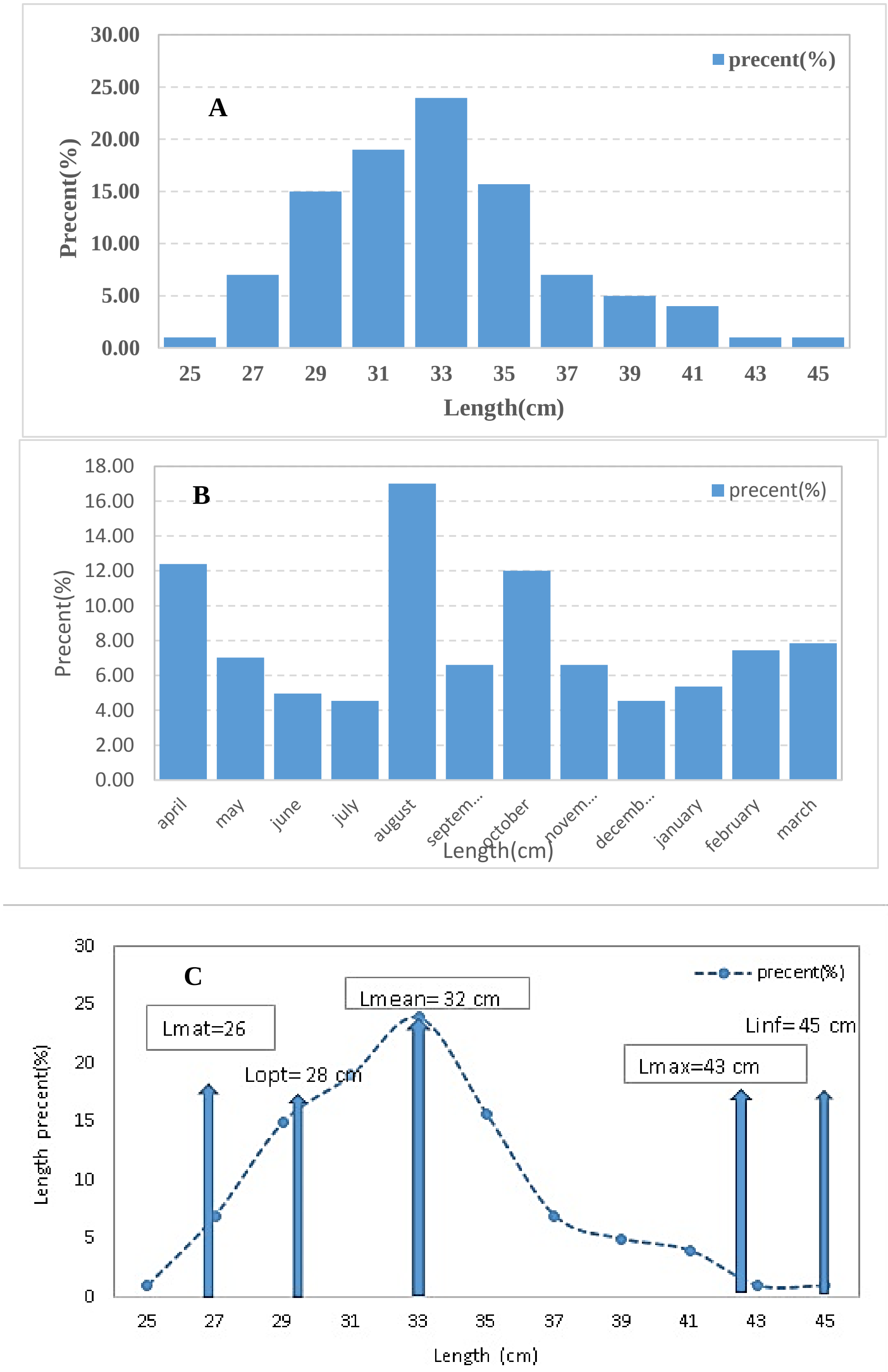

Fig.2. Length frequency percent (%) distributions (A) for *A. rochei*, monthly sampling (B) and LBI index (C) in the northern waters of the Oman Sea, Iran.

The relationship between length and weight was calculated as, W= 0.0095×$L^{3.12}$ (R^2= 0.92). The t –test showed not significant differences between estimated b and b= 3 at the level of 0.05 (P>0.05), which means Isometric growth pattern for Bullet tuna species in the northern waters of the Oman Sea (Fig. 2). Figure 2 illustrates the length based indicators (LBI) for Bullet tuna, indicating the following measurements:

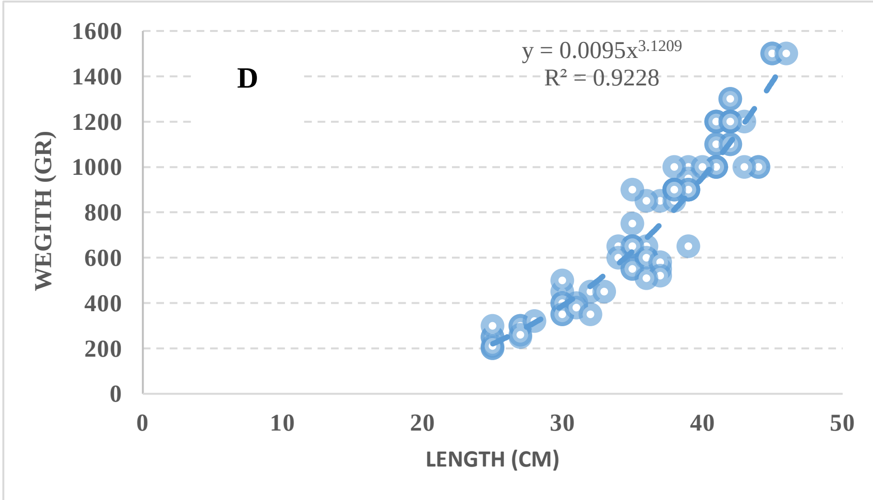

Fig.2. Continued, Length frequency percent (%) distributions (A) for *A. rochei*, LWR (D) in the northern waters of the Oman Sea, Iran.

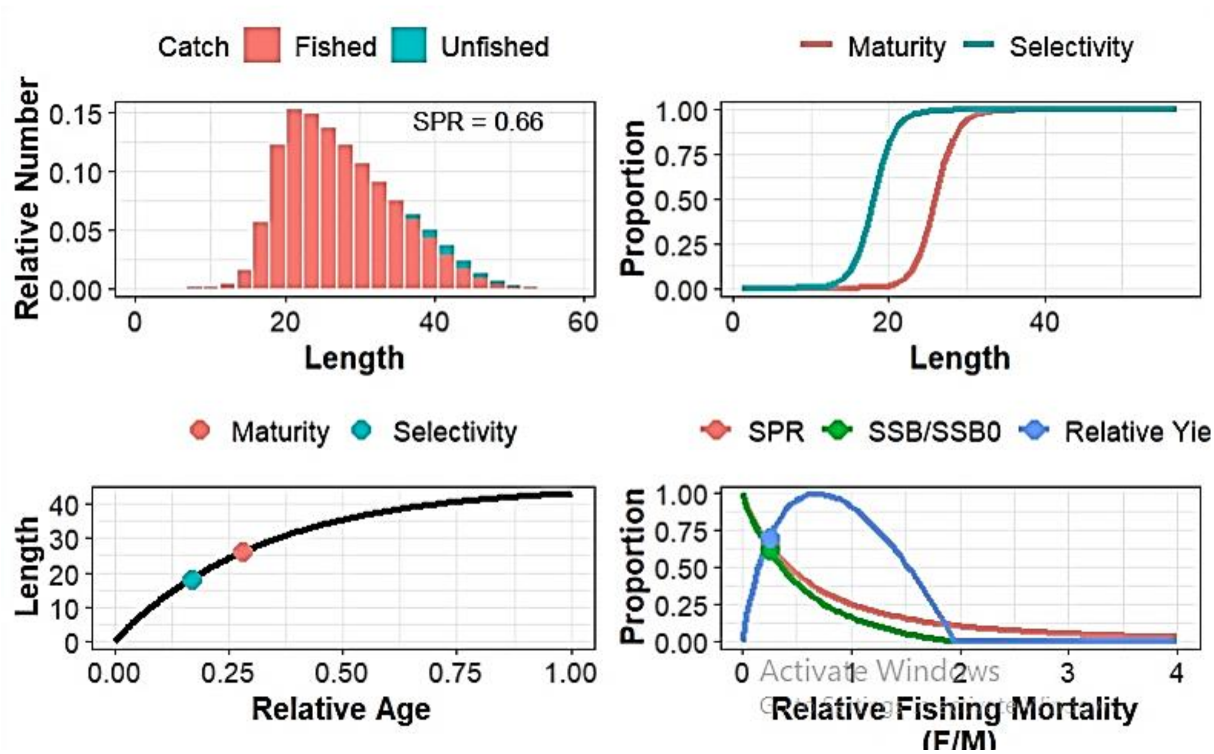

Fig.3. utput from the length-based SPR assessment for *A. rochei* the expected (equilibrium) size structure of the catch and the expected unfished size structure of the vulnerable population.

bmaximum length (Linf) is 45cm, optimal harvest length (Lopt) is 28cm, length at which fishing mortality equals natural mortality (LF=M) is 25cm, and maturity length (Lmat) is 32cm. The length-based benchmarks include the proportion of mature fish in the catch (with Lmat at 32 cm and Pmat at 0.85), the proportion of fish at the optimal length for harvesting (Lopt at 28 cm and Popt at 0.19), and the proportion of major spawners (Lmega at 40cm and Pmega at 0.26), with an objective ratio (Pobj) of 1.79 as shown in Figure 5. The desirable criteria are met when the Pobj ratio is greater than 1, Pmega exceeds 0.1, and the mean length to optimal length ratio (Lmean/Lopt) as well as the mean length to LF=M ratio (Lmean/LF=M) are both greater than 1.

The estimated sizes for 50% and 95% maturity of Bullet tuna are 26 cm and 30 cm, respectively. The life history ratios, natural mortality to growth coefficient

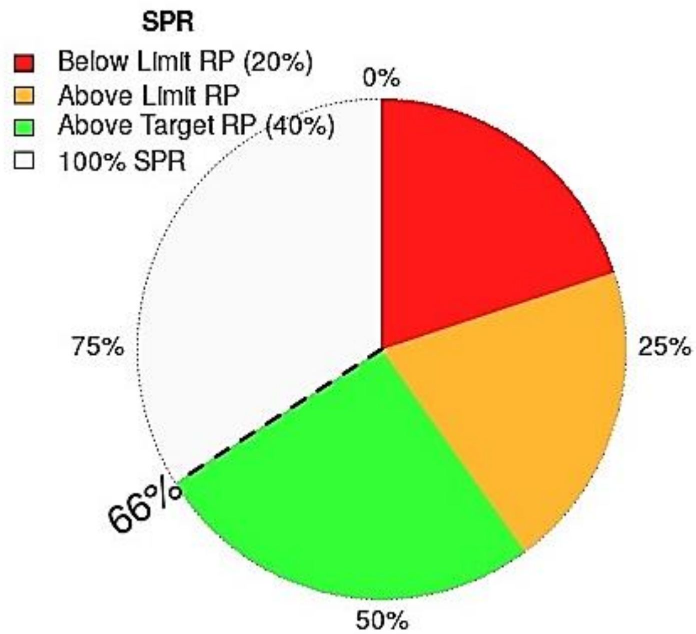

Fig.4. Output from the length-based SPR assessment for *A. rochei* the expected (equilibrium) size structure of the catch and the expected unfished size structure of the vulnerable population, the maturity and selectivity-at-length curves, the growth curve with relative age, and the SPR and relative yield curves as a function of relative fishing mortality**.**

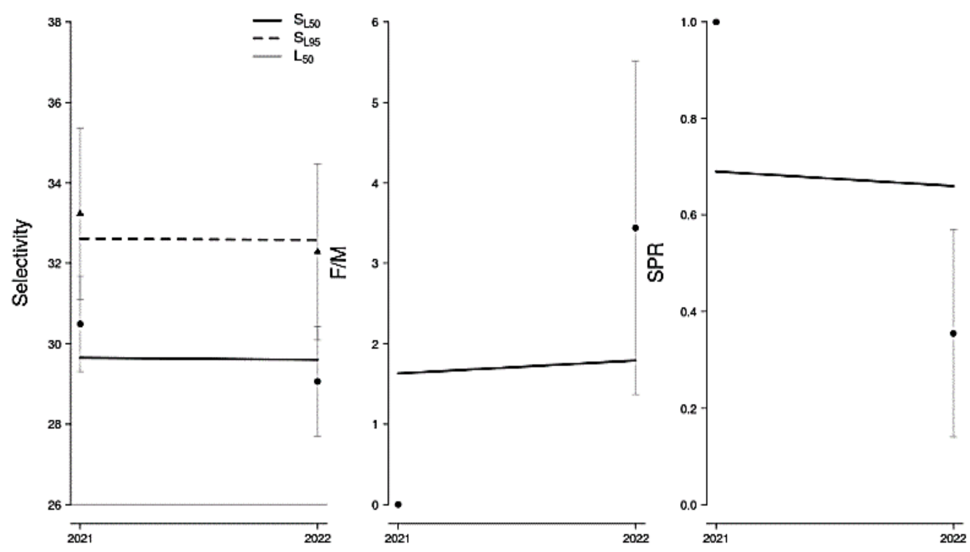

Fig.5. Visual display of estimated quantities (SPR, S50, S95 and F/M). The black line corresponds to the smoother line to the estimated points.

(M/K) and the relative size at first maturity (Lm/L∞), were determined to be 1.47 and 0.57. The size at which 50% of the population reaches maturity (Lm50) is 26cm. The annual spawning potential ratio (SPR) for the Bullet tuna in the Oman Sea (within Iranian jurisdiction) is calculated to range from 0.56 to 0.79, with an average of 0.66, surpassing the minimum threshold of 0.2. This indicates that the *A. rochei* species is not being overfished in these waters.

The ratio of natural mortality to growth coefficient (M/k) for *A. rochei* is greater than 1.4, indicating that the species is fully mature, with individuals of various ages and sizes close to the maximum growth limit. The current fishing pressure, represented by the ratio F/M, is 0.15, which exceeds the optimal range (0.8-1.0) for achieving maximum sustainable yield.

Figure 4, illustrates that a small amount of Bullet tuna fish is captured prior to reaching maturity. This figure showing output from length-based SPR assessment for *A. rochei* and a calculated spawning potential ratio of 66%. The red color shows the desired length-frequency distribution for a population with a spawning potential ratio of 20%.

Maturity and selectivity curve modeled based on length-based data from seventeen years' data for Bullet tuna harvested by fishers and shown in Figure 4. Analysis of length frequency of *A. rochei* for 6 years, indicating that most of this species has been harvested before the size of its first maturity.

The specific estimated parameters SL50, SL95, F/M ratio and SPR by year are presented in Figure 5. The value of SPR based on each year's catch length-frequency is estimated to be 66%. Based on these results it could be concluded that the population of this species, experiencing under fishing during two years.

DISCUSSION

The t –test showed not significant differences between estimated b and b= 3 (P>0.05), which means Isometric growth pattern for Bullet tuna species in the northern waters of the Oman Sea. Some studies refer to the isometric growth of this species similar to the present research (Expósito 2015; Asrial et al. 2021a; Asrial et al. 2021b). The relationship between length and weight of this species has been reported as follows regardless of gender in other studies; in Mediterranean Sea (Türkiye) $W = 0.0076 \times FL^{3.24}$ (Bök & Oray 2001), in Mediterranean Sea (Spain) $W= 0.00559 \times FL^{3.29}$ (Macías et al. 2006), in Mediterranean Sea (Türkiye) $W= 0.054 \times FL^{2.685}$ (Kahraman et al. 2011), in Mediterranean Sea (Spain) $W= 0.0027 \times FL^{3.506}$ (Expósito 2015).

The length-weight relationship (LWR) is a valuable tool in the field of fisheries ecology and management, aiding in the translation of length growth into weight increments, assessing fish condition, and enabling comparisons of life history traits across different geographical areas, as noted by Froese & Pauly in 2024. LWR plays a crucial role in managing fishery resources and offers insights for contrasting the life history and physical characteristics of fish populations from diverse locales. Consequently, the findings of such research provide critical data for the stock assessment models used by fisheries scientists and facilitate spatial and temporal analyses in future studies. Variations in the length-weight parameters from the standard value of 3.0 may indicate influences of reproductive maturity and alterations in body shape due to increased gonad size, leading to a greater body depth. These findings are deemed appropriate for calculating the length-weight relationship, as the observed values fall within the typical range for fish, which Froese (2006) suggests is between 2.5 and 3.5.

Length-based indicators (LBI) and Length-based Spawning Potential Ratio (LBSPR): The L_{mean}/L_{opt} index shows presence of under fishing with values upper than 1, and also $L_{mean}/L_{F=M}$ index shows values upper than 1 and P_{mega} upper than 0.25 is calculated which indicated desirable condition. The desired range for the L_{mean}/L_{opt} and $L_{mean}/L_{F=M}$ indexes is close to 1 and P_{mega} is around 0.3-0.4(Cousido-Rocha et al. 2022). Furthermore, nearly 5% of the individuals of this species had a length below of length at maturity (L_{mat}), which is concerning. The *A. rochei* will reach sexual maturity in a small size, consequently, their adults tend to be vulnerable to fishing in long term. Hordyk et al. (2015a) highlighted that escalating the relative fishing effort where the fishing mortality exceeds the natural mortality (F/M>1) results in a significant decline in the spawning potential ratio (SPR), the relative yield, and the spawning stock biomass (SSB) across all species. Consequently, the adoption of size-based regulations could help avoid the capture of juvenile fish in the Oman Sea.

This species has not shown signs of overfishing; however, research in the Oman Sea indicates that overfishing impacts nearly 50% of all bony fish species, a rate twice the global average (Buchanan *et al.*, 2019). Metrics based on size, such as average length or weight and length distributions, have historically served as markers for population reduction (Beverton & Holt 1959; Cope & Punt 2009). Drift-gill nets are primarily used to capture certain overharvested species near the Oman Sea's seabed.

These nets are criticized for their lack of selectivity, capturing a broad size range of fish, including unintended species (Hicks & McClanahan 2012).

Based on Figure 3 drift gillnet caught fish ranged between 25 and 43cm. The size frequency distributions of different gear show that near 5% of the catch was above length at first maturity for drift gill net. These findings suggest that in general *A. rochei* stocks are removed soon after recruitment to the fishing ground and the proportion of large-sized (>40cm) “mega-spawners” is medium in the catch composition.

The LBSPR rate of this species is 0.66 (% 66), and LBSPR provides estimates of the spawning potential ratio (SPR). If this index value is below 0. 2 *(≈ 0.5 B/*B_{MSY}*)*, it means the stock is depleted. If the value is above 0. 4*(≈ 1.0 B/*B_{MSY}*)*, it means the stock is in good condition. In conclusion, the LBSPR model is a useful tool for measuring the size of fish stocks with limited data (Hordyk et al. 2015). In simple words, scientists have come up with ways to easily and cheaply measure the size and characteristics of an exploited stock. One example is the length-based spawning potential ratio method(Hordyk et al. 2015)

Hommik et al. (2020) emphasize that Spawning Potential Ratio (SPR) estimates should be evaluated in the context of established benchmarks for healthy fishery states and the specialized understanding of each fishery. According to Goodyear (1993), an SPR threshold of SPR=0.20, is deemed the critical limit for sustaining satisfactory stock productivity. Furthermore, an SPR value of SPR=0.40, is generally accepted as a proxy for Maximum Sustainable Yield (MSY) within the framework of national fisheries legislation, as outlined by Mace (1994). The range of annual SPR, for *A. rochei* in the Oman sea (Iranian waters), estimated to be between 0.66 which is even upper than the threshold value noted by Goodyear (1993) such results suggest that the exploitation of *A. rochei* occurred above the maximum sustainable limit of this species in the Oman Sea. The result also indicated harvesting of a low number of juvenile *A. rochei* before they reach sexual maturity which might be related to using multi-gear in these ecosystems.

This study introduces the inaugural application of the LB-SPR method, as proposed by Hordyk et al. (2015b), to evaluate the Spawning Potential Ratio (SPR) in a small-scale, data-limited fishery, focusing on *A. rochei* due to its economic significance in the fisheries of the Oman Sea. The high variety of fishery resources and their critical role in supporting the livelihoods of coastal communities in the Oman Sea region highlight the need for this approach. It sheds light on the susceptibility of species to overfishing and the overall condition of small-scale fisheries. It is noteworthy that approximately 20% of the SPR in fish populations is considered the threshold for maintaining stability under fishing pressures. However, this level does not allow for population growth; it merely maintains the current adult population without increasing it. This threshold is referred to as the ‘replacement level’ because it is just enough to sustain the existing adult fish. When the SPR falls below 20%, it is anticipated that the fish populations will experience long-term declines. This is due to insufficient reproductive capacity to sustain the population, as fish are caught before they can reproduce adequately to maintain their numbers, according to Prince (2017).

Management and exploitation of this species in the Oman Sea: This parameter *helps manage* for fisheries management, *protect the population of Bullet tuna in* the northern waters of the Oman Sea. A scenario of under fishing may arise with the augmentation of average size and LBSPR index, coupled with a reduction in fishing and overall mortality rates. The research indicates that the population of this species has attained a status of being ‘under fished,’ which is a positive development. It is recommended to establish explicit guidelines for the utilization and stewardship of *A. rochei* in this area. The insights garnered from this research are poised to aid in the management and enduring exploitation of the stock of this species.

ACKNOWLEDGMENTS

We're going to like to thank Dr. Bahmani, the head of the Iranian Fisheries Science Research Institute (IFSRI) and the Offshore Fisheries Research Center (Chabahar) experts are also very grateful for helping the project work.

REFERENCES

Agustina, B.; Ariasari, A.; Satriyo, T. & Eko Setyobudi, E. 2023. Food Preference of Bullet Tuna (*Auxis rochei*

Risso, 1810) in Prigi Coast of Trenggalek Regency, East Java. Journal of Tropical Biodiversity and Biotechnology 8(1): 1-11.

Asrial, E.; Arapat, Y.; Hadi, U. K.; Kalih, L. A.; Liliyanti, M. A.; Rosadi, E.; Khasanah, R. I. &

Rathnayake,I.N. 2021a. The Length-Weight Relationship and Condition Factors of Bullet Tuna Landed at the Tanjung Luar Fishing Port, Indonesia. Journal of Ilmiah Perikanan Dan Kelautan 13(1): 1-10.

Asrial, E.; Fathurriadi, Y.; Hadi, U.K.; Kalih, L.A.T.T.W.S.; Rizal, L.S.; Liliyanti, M.A.; Rosadi, E.; Khasanah, R.I.; Setyohadi, D.; Junaidi, M. & Rathnayake, I.N. 2021b. Population Dynamics of Bullet Tuna (*Auxis rochei* Risso1881) from the Indian Ocean, West Nusa Tenggara, Indonesia. Jurnal Ilmiah Perikanan dan Kelautan 13(2): 116-123.

Beverton, R. & Holt, S. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics in: CIBA Foundation colloquia on ageing: Wiley Online Library pp. 142-180.

Bök, T. & Oray, K. 2001. Age and growth of bullet tuna *Auxis rochei* (Risso, 1810) in Turkish waters. Collective Volume of Scientific Papers ICCAT 52(1): 708-718.

Buchanan, J.R.; Ralph, G.M.; Krupp, F.; Harwell, H.; Abdallah, M.; Abdulqader, E. 2019. Regional extinction risks for marine bony fishes occurring in the Persian/Arabian Gulf. Biological Conservation 230(1): 10-19.

Carruthers, T.R. & Hordyk, A.R. 2018. The Data-Limited Methods Toolkit (DLM tool): An R package for informing management of data-limited populations. Methods in Ecology and Evolution 9(12), 2388-2395.

Cope, J.M. & Punt, A.E. 2009. Length-based reference points for data-limited situations: applications and restrictions. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1(1): 169-186.

Dowling, N.A.; Smith, A.D.; Smith, D.C.; Parma, A.M.; Dichmont, C.M. & Sainsbury, K. 2019. Generic solutions for data-limited fishery assessments are not so simple. Fish and Fisheries 20(1): 174-188.

Expósito, P.M. 2015. Assessing the atmospheric oscillations effects on the biology of the bullet tuna (Auxis rochei) and its possible linkage with global warming. Ph.D. thesis.

FAO 1999. The Strategic Framework for FAO, 2000-2015. Food and Agriculture Organization of the United Nations. 5p.

Froese, R. 1998. Length-weight relationships for 18 less-studied Fish Species. Journal Name 14(2): 117-118.

Froese, R. & Pauly, D. 2024. FishBase. World Wide Web electronic publication. www.fishbase.org, (02/2024).

Goodyear, C.P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. Canadian Special Publication of Fisheries and Aquatic Sciences, pp. 67-82.

Halim, A.; Wiryawan, B.; Loneragan, N.R.; Hordyk, A.; Sondita, M.F.A. & White, A.T. 2019. Developing a functional definition of small-scale fisheries in support of marine capture fisheries management in Indonesia. Marine Policy 100(1): 238-248.

Harrison, T.D. 2001. Length-weight relationships of fishes from South African estuaries. Journal Name 17(1): 46-48.

Hicks, C.C. & McClanahan, T.R. 2012. Assessing gear modifications needed to optimize yields in a heavily exploited, multi-species, seagrass and coral reef fishery. PLoS One 7(5): e36022.

Hommik, K.; Fitzgerald, C.J.; Kelly, F. & Shephard, S. 2020. Dome-shaped selectivity in LB-SPR: length-based assessment of data-limited inland fish stocks sampled with gillnets. Fisheries Research 229(2): 105574.

Hordyk, A.; Ono, K.; Sainsbury, K.; Loneragan, N. & Prince, J. 2015a. Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. ICES Journal of Marine Science 72(1): 204-216.

Hordyk, A.; Ono, K.; Valencia, S.; Loneragan, N. & Prince, J. 2015b. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science 72(1): 217-231.

IOTC. 2017. Bullet Tuna: Supporting Information, in Indian Ocean Tuna Commission, viewed 31 Agustus 2020, from https://iotc.org/ node/3379#nt

IOTC. 2019. Report of The 9th Session of The IOTC Working Party on Neritic Tunas. Mahe, Seychelles, 1-5 July 2019. IOTC –2019–WPNT09–R[E], pp.1-80

Jasmine, S.; Rohit, P.; Abdussamad, E.M.; Said Koya, K.P.; Joshi, K.K.; Kemparaju, S.; Prakasan, D.; Elayathu, M.N.K. & Sebastine, M. 2013. Biology and fishery of the bullet tuna, *Auxis rochei* (Risso, 1810) in Indian waters. Indian Journal of Fisheries 60(2): 13-20.

Kahraman, A.E.; Göktürk, D. & Karakulak, F.S. 2011. Age and growth of bullet tuna, *Auxis rochei* (Risso), from the Turkish Mediterranean coasts. African Journal of Biotechnology 15(1): 3009-3013.

Lart, W.B. 2019. Guide to Data-limited stock assessment. Sea Fish Industry Authority, 20 p.

Lelono, T. & Bintoro, G. 2019. Population dynamics and feeding habits of *Euthynnus affinis*, *Auxis thazard*, and *Auxis rochei* in South Coast of East Java waters. The 2nd International Symposium on Marine Science and Fisheries (ISMF2) – 2019. IOP Conf. Series: Earth and Environmental Science 370(2019): 012054.

Mace, P.M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Canadian Journal of Fisheries and Aquatic Sciences 51(1): 110-122.

Macías, D.; Lema, L.; Gómez-Vives M.J. & de la Serna, J.M. 2006. A preliminary approach to the bullet tuna (*Auxis rochei*) fecundity in the Spanish Mediterranean. Collective Volume of Scientific Papers ICCAT 59(2): 571-578.

Ollé-Vilanova, J. 2022. Larval Retention and Homing Behaviour Shape the Genetic Structure of the Bullet Tuna (*Auxis rochei*) in the Mediterranean Sea. Fishes 7(5): 300.

Prince, J. 2017. Length based assessment of the spawning potential of reef fish from iQoliqoli Cokovata in Macuata: A case study in Fiji. WWF-Pacific, Suva, Fiji, 35.

Prince, J.; Hordyk, A.; Valencia, S.R.; Loneragan, N. & Sainsbury, K. 2015a. Revisiting the concept of Beverton–Holt life-history invariants with the aim of informing data-poor fisheries assessment. ICES Journal of Marine Science 72(1): 194-203.

Prince, J.; Victor, S.; Kloulchad, V. & Hordyk, A. 2015b . Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau. Fisheries Research 171(1): 42-58.

Iran. J. Ichthyol. (2024) 11(3): 198-208
P-ISSN: 2383-1561; E-ISSN: 2383-0964
http://www.ijichthyol.org

doi: 10.22034/iji.v11i3.1030

مقاله کامل

نسبت پتانسیل تخم‌ریزی براساس طول (LBSPR) و شاخص‌های مبتنی بر طول (LBI) تون ماهی بولت (گلوله‌ای)، *Auxis rochei* (Risso, 1810) در دریای عمان (آب‌های جنوبی ایران)

سیداحمدرضا هاشمی*[1]، مسطوره دوستدار[2]

[1]مرکز تحقیقات شیلاتی آبهای دور، موسسه تحقیقات علوم شیلاتی کشور، سازمان تحقیقات، آموزش و ترویج کشاورزی، چابهار، ایران.
[2]موسسه تحقیقات علوم شیلاتی کشور، سازمان تحقیقات، آموزش و ترویج کشاورزی، تهران، ایران.

چکیده: مدل نسبت پتانسیل تخم‌ریزی مبتنی بر طول (LB-SPR) و شاخص‌های مبتنی بر طول (LBI) برای توصیف وضعیت ذخیره تون ماهی بولت (گلوله‌ای)، در دریای عمان استفاده شد. از آوریل (فروردین) ۲۰۲۱ تا مارس(اسفند) ۲۰۲۲، در مجموع ۲۵۴ نمونه ماهانه از مراکز تخلیه ماهی جمع‌آوری و طول چنگالی و وزن آنها اندازه‌گیری شد. حداکثر طول چنگالی ثبت‌شده برای این گونه در منطقه ۴۳ سانتی‌متر با میانگین طول ۴±۳۲ سانتی‌متر بود. رابطه طول و وزن به‌صورت (R^2 =۰/۹۲) $W = 0.0095\times L^{3.12}$ محاسبه شد. آزمون t تفاوت معنی‌داری را بین b و b=۳ در سطح ۰/۰۵ (*P*<۰/۰۵) نشان داد که به معنای الگوی رشد ایزومتریک برای گونه تون ماهی بولت (گلوله‌ای) در آب‌های شمالی دریای عمان است. شاخص‌های مبتنی بر طول (LBI) ماهی تون گلوله‌ای بر حسب سانتی متر Linf= ۴۵، Lopt=۲۸، ۲۵ =LF=M، Lmat=۳۲ بود. همچنین، براساس طول نقطه مرجع (Lmat=۳۲ سانتی‌متر)، درصد ماهی بالغ در صید Pmat=۰/۸۵، درصد ماهی صید شده در طول بهینه برداشت (Lopt=۲۸ سانتی‌متر)، Popt= ۰/۱۹ و درصد ماهی صید شده بسیار بزرگ (Lmega= ۴۰ سانتی‌متر)، Pmega=۰/۲۶ بود. براساس نسبت مقادیر به‌دست آمده Pobj>۱ ، Pmega>۰/۱ ، Lmean/Lopt> ۱ و Lmean /LF=M>۱ نمایش مطلوب در نظر گرفته می‌شود. دامنه SPR سالانه، برای ذخایر ماهی تون گلوله‌ای در دریای عمان (آب های ایران)، (۰/۷۹-۰/۵۶) ۰/۶۶ برآورد شده است که بالاتر از مقدار آستانه ۰/۲ است. براساس تجزیه و تحلیل سری‌های زمانیSPR، در سال آخر مطالعه نقطه مرجع SPR بالای ۰/۲ بوده و به این معنی است که نسبت بهره‌برداری از ذخایر تون ماهی بولت (گلوله‌ای) در آب‌های جنوبی ایران (دریای عمان) پایین‌تر از سطح پایدار (پایین‌تر از حد بهینه بهره‌برداری/رنگ سبز)، نشان دهنده نیاز به افزایش نسبت بهره‌برداری و تلاش ماهیگیری است.

کلمات‌کلیدی: پایداری، نسبت پتانسیل تخم‌ریزی، تون ماهی بولت (گلوله ای)