https://doi.org/10.48047/AFJBS.6.16.2024.2986-2998

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Stock assessment of the horse mackerel for management on the Algerian coast (Southern Mediterranean)

Amina Tania Dahel [1, 2,*] and Abdallah Borhan Djebar [2]

[1] Laboratory of Biodiversity and Pollution of Ecosystems, Department of Marine Sciences, Faculty of Natural and Life Sciences, Chadli Bendjedid University, B.P. 73, 36000, El-Tarf, Algeria.
[2] Laboratory of Ecobiology of Marine and Littoral Environments, Department of Marine Sciences, Faculty of science, Badji Mokhtar University, B.P.12, 23000, Annaba, Algeria.

***Corresponding author**: dahel-amina@univ-eltarf.dz / dahelzanat@yahoo.fr

Volume 6, Issue 16, Dec 2024

Received: 15 Oct 2024

Accepted: 25 Nov 2024

Published: 09 Dec 2024

doi:10.48047/AFJBS.6.16.2024.2986-2998

Abstract

This study analyzes the population of horse mackerel (*Trachurus trachurus*) in Algeria's northeastern coastal region. Between February 2023 and January 2024, 799 fish specimens were collected monthly from commercial landings, exhibiting a total length (TL) ranging from 6.4 to 30.5 cm and a total weight (TW) between 2.65 and 232.03 g. The findings, using FiSAT II software, indicate that *T. trachurus* can survive for up to 5 years in the Gulf of Annaba. The growth parameters are $L\infty$ = 32.60 cm, K = 0.37 yr^{-1}, t_0 = -0.152 yr, and ϕ' = 2.59. The "b" value (3.045) in the length-weight relationship indicates isometric growth. On the first capture, the length (Lc_{50}) was 7.63 cm. The total (Z), natural (M), and fishing (F) mortalities were assessed at 1.61, 0.37, and 1.24 yr^{-1}, respectively. The exploitation rate (E), calculated at 0.77, surpasses the optimal rate (0.5), indicating overexploitation. Analysis of relative yield per recruit (Y'/R) indicates that the exploitation rate exceeds E_{max} (0.41) and $E_{0.5}$ (0.30), thereby confirming overfishing. To ensure sustainable and rational management of this species, it is advised to decrease the exploitation rate from 0.77 to 0.30, representing a 61% reduction.

Keywords: Eastern Algerian coast, exploitation, *Trachurus trachurus*, yield per recruit

Introduction

Marine resources are essential for global food security and constitute a fundamental element of diets in numerous nations. Worldwide capture fisheries production, excluding seaweed, amounted to 90.3 million tons in 2020, of which 80% was fish. Small pelagic fish constitute a substantial segment of this output, comprising more than one-third of total catches, rendering them the most intensively fished species group globally (FAO, 2022). Currently, global fisheries are experiencing a decline due to the overexploitation of significant economically vital stocks. Increased fishing activities have worsened the status of the globe's most productive fish stocks, with FAO estimates from 2022 suggesting that around 35.5% of fish stocks are overexploited. The Mediterranean situation

is particularly alarming, with 91% of fish stocks classified as overfished, as reported by the European Commission in 2023. This overexploitation impacts 96% of demersal stocks and 59% of pelagic species stocks.

Algeria's geographical location provides access to substantial fish stocks influenced by Atlantic Ocean currents, yet it also renders the region susceptible to overexploitation. The Ministry of Fishing and Fishery Products had valued fisheries production for 2023 at around 120.000 tons (MPPH, 2023). Small pelagic fish constitute approximately 80% of this fishery's potential. A diverse array of species is represented, with sardines comprising 26%, sardinellas 25%, horse mackerels 17%, bogues 5%, anchovies 3%, mackerels 1%, and others (MPPH, 2023). The *Trachurus trachurus*, a prevalent species of horse mackerel along the Algerian coast, constitutes a substantial segment of this production. It is widely consumed due to its affordability and year-round availability. It is harvested in large quantities using seine and trawl fishing methods.

Numerous studies have been undertaken on this species across various regions of the Mediterranean and Atlantic, focusing on aspects such as morphology, reproductive biology, physiology, age, growth, recruitment, and genetics. Significant studies encompass those by Carrillo (1978) in the Catalan Mediterranean, Nazarov (1978) in the Bay of Biscay, Kerstan (1985) off the British coast, Junquera et al. (1988) along the Galician coast, Karlou-Riga and Sinis (1997) in the Gulf of Saronikos, Šantić et al. (2002 and 2011) in the Adriatic Sea, Karakulak et al. (2006) in the Aegean Sea, and Kalayci et al. (2007) in the Black Sea, alongside investigations by Gherram et al. (2018), Azzouz et al. (2019), and Rahmani et al. (2021) on the Algerian coast. This literature review underscores a deficiency in research specifically addressing the stock dynamics of this species in Algerian coastal waters. This study is likely the inaugural comprehensive analysis of *T. trachurus* stock dynamics in this region. The data obtained can provide a solid basis for future studies on this valuable commercial species.

Materials and Methods

From February 2023 to January 2024, a cumulative total of 799 specimens of *T. trachurus* were seized monthly during the commercial landings of bottom trawlers in the Gulf of Annaba, located on the Algerian East Coast (Figure 1). The specimens were brought to the laboratory on ice, thereafter measured for total length (TL, mm), weighed for total weight (TW, with an accuracy of 0.1 g), and segregated by sex.

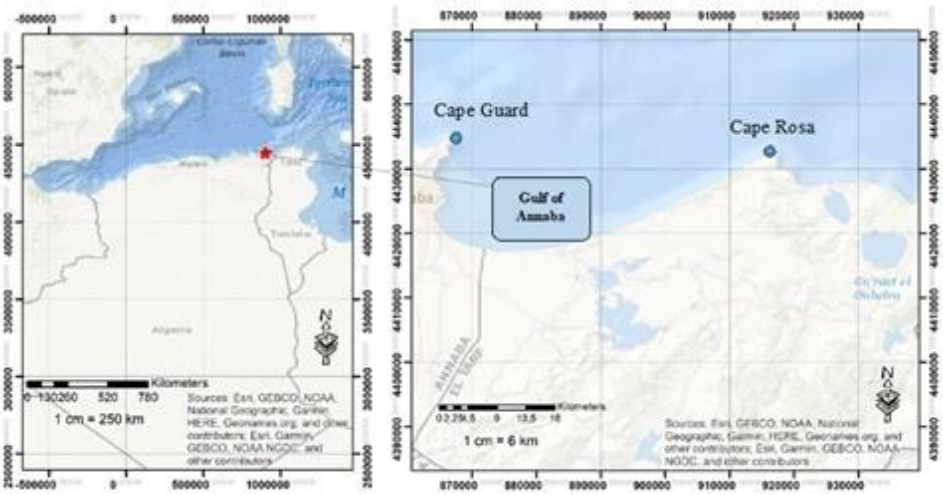

Figure 1. *Location of the Gulf of Annaba (Cape Guard, 36°58'10.52"N -7°47'34.18"E and Cape Rosa, 36°57'6.81"N - 8°13'36.42"E).*

The sex ratio denotes the percentage distribution of male (M) and female (F) individuals within a specific population. The relationship is articulated as follows: $SR = M / F$. The divergence of the observed sex-ratio values from the theoretical percentage of 50% is assessed using a chi-square test (χ^2) (Dagnelie, 1975).

The Bhattacharya approach (1967), incorporated into FiSAT II software version 1.2.0 (Gayanilo et al., 2005), was utilized to ascertain the age-length key. This method involves studying the size distributions of captures to identify various age groups. We utilized the von Bertalanffy growth function (VBGF) from the FiSAT II program and the VONBIT package (Stamatopoulos, 2005) for Excel to model population expansion and determine growth parameters (asymptotic length $L\infty$; growth co-efficient K and theoretical age at length zero t_0) represented by the following equation: $Lt = L\infty[1 - e^{-K(t-t0)}]$ (Lt: total length at time t).

The length-weight relationship expressed by Ricker's (1973) formula was used: $TW = a\ TL^b$ (a: constant and b: allometric coefficient that gives the type of fish growth).

The growth performance index for evaluating the growth rate against other published values was derived using the equation: $(\phi') = 2\ log_{10} L\infty + log_{10} K$ (Pauly and Munro, 1983).

The total instantaneous mortality coefficient (Z) was determined using the length-converted catch curve incorporated in the FiSAT II tool, as outlined by Pauly (1984). The natural mortality coefficient (M) was calculated using an empirical equation formulated by Djabali *et al.* (1994) for Mediterranean fish stocks, which incorporates growth and mortality parameters: $Log_{10} M = 0.0278 - 0.1172\ Log_{10} L\infty + 0.5092\ Log_{10} K$. Fishing mortality (F) was determined using the equation $F = Z - M$ (Pauly, 1980). The exploitation rate (E) was determined using the formula $E = F/Z$. According to Gulland (1971), the stock is in equilibrium when E = 0.5, underexploited when E < 0.5, and overexploited when E > 0.5.

The probability of the capture or the length at first capture (Lc_{50}), calculated using the length-converted catch curve produced by FiSAT II, was plotted against the mean length, resulting in a curve from which Lc_{50} was

determined where the cumulative probability reached 50%. In addition, the lengths associated with the 25th and 75th percentiles of catches were established at cumulative probabilities of 25% and 75%, respectively.

The length-structured Virtual Population Analysis (VPA) was estimated using the FiSAT II routine. The previously estimated parameters ($L\infty$, K, t_0, M, F, a, and b) were utilized as inputs.

The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were computed using a "knife-edge" approach developed by Beverton and Holt (1966) and refined by Pauly and Soriano (1986), as implemented in the FiSAT software. The analysis determined the maximum allowable exploitation rate (E_{max}) that produces the highest relative yield-per-recruit (MSY = Maximum Sustainable Yield). Additionally, $E_{0.1,}$ the exploitation rate at which the marginal increase in relative yield-per-recruit attains 10% of its virgin stock, and $E_{0.5}$, the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B/R) (TRP = target reference point), were calculated. Yield contours were created to illustrate the yield isopleths, enabling an assessment of the impacts of changes in exploitation rate (E_{max}) and the critical length ratio ($L_c=Lc_{50}/L\infty$) on yield.

Results

A total of 799 individuals of *T. trachurus* were seized throughout the investigation. Figure 2 shows that the size frequency distribution of the fish varied from 6.4 to 30.5 cm. The highest frequencies for the entire population were recorded between 14 and 19 cm, with the most significant size class occurring between 16 and 17 cm. The frequencies below 10 cm and above 26 cm were insignificant. The sample comprised 339 females (42.43%), 393 males (49.19%), and 67 immatures (8.39%), resulting in an overall sex ratio of SR = 1.16:1. The chi-square test indicated a significant deviation from the 1:1 ratio (observed χ^2 (3.98) > theoretical χ^2 (3.84); $P < 0.05$) favoring males.

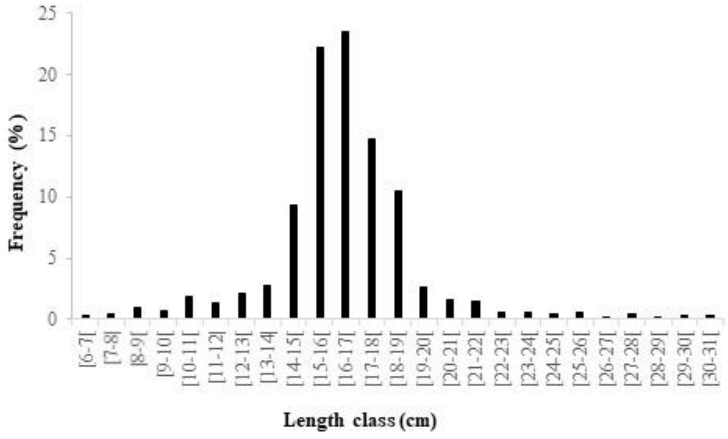

Figure 2. *Length frequencies of T. trachurus sampled in the Gulf of Annaba.*

The method of Bhattacharya (1967) was applied through the FiSAT II software version 1.2.0 (2005), with a 1 cm interval, to analyze the size-frequency distribution of the total population and decompose the samples into 5 cohorts (Table 1). The 2-year-old horse mackerel accounted for the majority of the catches (72%). A separation

index (SI) greater than 2 confirms the validity of the results (Gayanilo et al., 2005). The age-length key, calculated using the New VONBIT software (Stamatopoulos, 2005), yielded the following growth parameters for the *T. trachurus* population: $L\infty$ = 32.60 cm, K = 0.37 yr^{-1}, and t_0 = -0.152 yr (Figure 3). The findings led to the following growth equation: $Lt = 32.60\ [1- e^{-0.37(t+0.152)}]$, with a growth performance index (ϕ') of 2.59.

Table 1. Age-length Key of *T. trachurus* obtained by Bhattacharya's method.

Age group (yr)	Mean length ± S.D. (cm)	Number	%	S.I.
1	8.77 ± 0.99	17	2.65	n.a.
2	16.22 ± 1.31	579	90.32	6.77
3	20.99 ± 1.08	30	4.68	3.99
4	25.13 ± 0.74	10	1.59	4.55
5	27.00 ± 0.96	5	0.78	2.20

S.D.: standard deviation, S.I.: separation index, n.a.: not affiched.

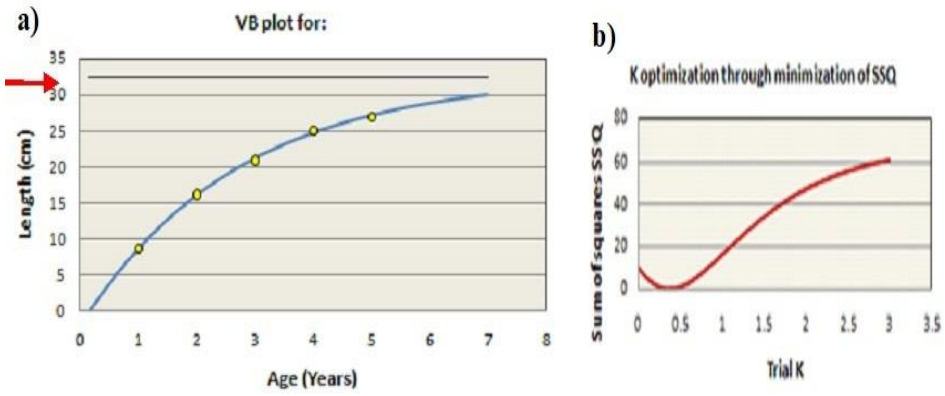

Figure 3. *(a) Linear growth curves and (b) growth rate of T. trachurus caught in the waters of the Gulf of Annaba (New VONBIT software).* → *L∞, asymptotic length (cm).*

The length-weight relationship was calculated as follows: $TW = 0.007\ TL^{3.045}$ (Figure 4), with a correlation coefficient (r) close to 1, indicating a strong correlation between weight and length. The comparison of the slope (*b*) using the t-test shows values less than 1.96 for α = 5%. This suggests that *T. trachurus*, from the eastern Algerian coast waters, exhibits isometric growth allometry between total weight (WT) and length (LT). Thus, the horse mackerel has a weight growth proportional to its size.

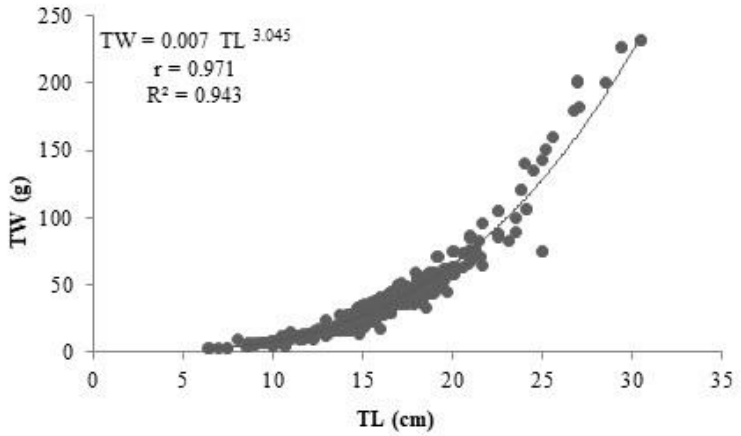

Figure 4. *Length-weight relationship of T. trachurus in the Gulf of Annaba (r: correlation coefficients; R^2: determination coefficient).*

The total (Z), natural (M), and fishing(F) mortalities were calculated to be at 1.61, 0.37, and 1.24 yr^{-1}, respectively, and the exploitation rate (E) was evaluated at 0.77 (Figure 5).

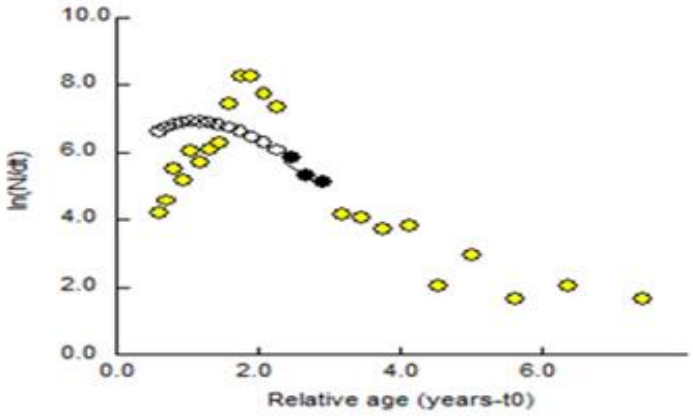

Figure 5. *Catch curve converted to the length of T. trachurus.*

The capture probability enabled us to estimate L50% at 7.63 cm. The estimates for L25% and L75% were 6.65 cm and 8.61 cm, respectively. As a result, the length at first capture (Lc_{50}) of *T. trachurus* was determined at 7.63 cm (Figure 6).

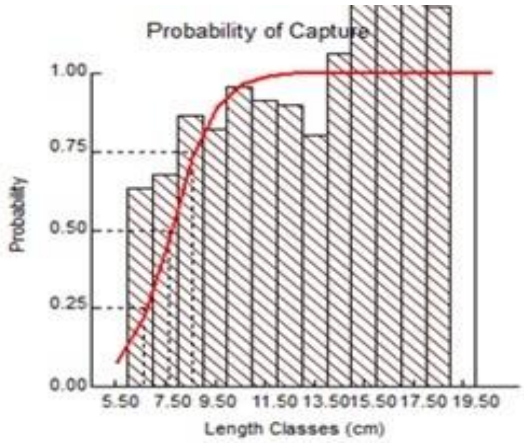

Figure 6. *Probability of capture of T. trachurus in the Gulf of Annaba.*

The virtual population analysis (VPA) for *T. trachurus* indicated that fishing mortality (F) was exerted on small fish and peaked for individuals measuring 15 to 18 cm (Figure 7). F attained a peak of 2.50 yr^{-1} at a mid-length of 16.5 cm and a minimum of 0.013 yr^{-1} at 6.5 cm.

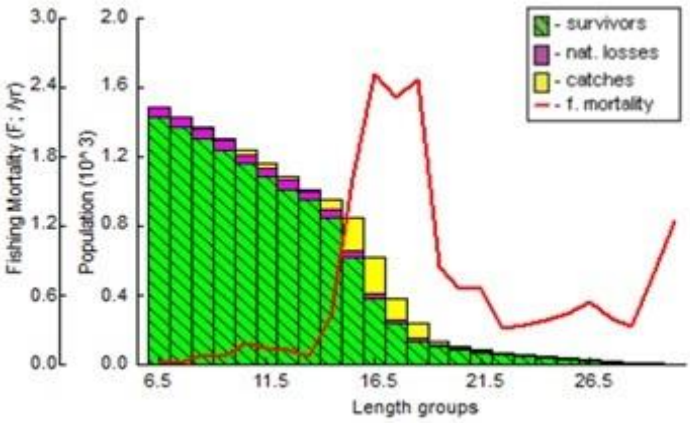

Figure 7. *Virtual population analysis of T. trachurus in the Gulf of Annaba.*

The Y'/R and B'/R values were evaluated according to $Lc_{50}/L\infty$ and M/K, yielding respective values of 0.23 and 1. The peak relative yield per recruit (Y'/R) occurred at E_{max} = 0.48, signifying the maximum sustainable yield (MSY). The $E_{0.1}$ and $E_{0.5}$ obtained rates were 0.41 and 0.30, respectively. The findings demonstrate that the exploitation rate (E = 0.77) surpasses the threshold that would yield the maximum relative yield per recruit (E_{max} or MSY) (Figure 8 a). The yield isopleths categorize the *T. trachurus* fishery in quadrant D (Pauly and Soriano 1986), signifying the inclusion of juvenile fish in the landings throughout the study period (Figure 8 b).

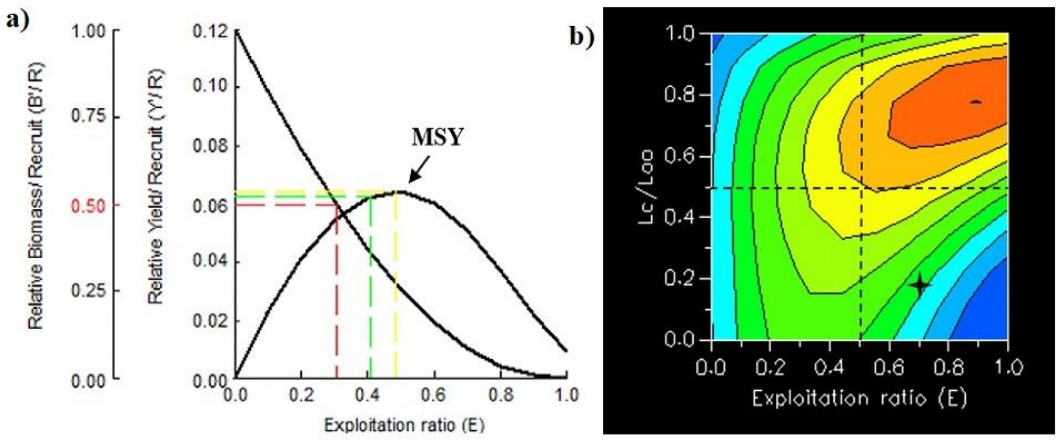

Figure 8. *(a) Relative yield/recruit and biomass/recruit ($E_{0.5}$ = red; $E_{0.1}$ = green and E_{max}= yellow), (b) Yield Isopleth diagram of T. trachurus.*

Discussion

Trachurus trachurus (Linné, 1758), commonly referred to as Horse mackerel, is a pelagic species abundant along the Algerian coastline. It is harvested year-round and holds considerable financial significance in Algerian markets. We have examined the fundamental elements necessary to formulate a rational and sustainable management strategy for this species stock. Among 799 sampled individuals, with size frequency distribution from 6.4 to 30.5 cm, the overall sex ratio (SR = 1.16) indicated a significant disparity, favoring males. Kartas and Quignard (1984) suggest that the physiological condition of fish and fluctuations in the quantity and quality of sex-specific food may account for variations in the sex ratio and the differential susceptibility of each sex to the employed fishing gear.

To estimate age, we acquired an age-length key comprising five age categories (Table 2). This finding differs from those documented by Nasri et al. (2024), Zeid et al. (2023), Aydin and Karadurmuş (2012), and Karlou-Riga and Sinis (1997). The discrepancies may be attributed to the varied methodologies employed by each author, in addition to the sample size. The asymptotic length (L∞) was estimated to be 32.60 mm, with a growth coefficient (K) of 0.37 yr^{-1}. Comparisons with population parameters from alternative studies indicate substantial discrepancies (Table 2). These disparities are thought to stem from the methodologies employed in sampling and statistical analysis of the data (Wootton 1998), as well as the environmental conditions in which these fish inhabit (Pauly, 1981). The findings show that the growth performance index (ϕ') was 2.59 (Table 2). Aydin and Karadurmuş (2012) documented a value of 4.58 in Ordu (Black Sea). Fluctuations in this index may be ascribed to environmental factors (temperature, geographical location), the quantity of sampled individuals, or the dimensions of the largest individual.

Table 2. Growth parameters of *T. trachurus* according to various authors in different Mediterranean regions.

Location	**Source**	**N**	**Method**	**Age (yr)**	**Sex**	**L∞ (cm)**	**K (yr^{-1})**	**t_0 (yr)**	**ϕ'**
Gulf of Saronikos (Greek coast)	Karlou-Riga and Sinis (1997)	6791	Otolith	10	♂♀	30.27	0.36	-0.943	-
Adriatic Sea	Šantić et al. (2002)	2304	Otolith	8	♂♀	37.68	0.23	-0.30	-
Ordu (Black Sea)	Aydin and Karadurmuş (2012)	1307	Otolith	7	♂♀	20.50	0.23	-2.99	4.58
Alexandria (Western Egyptian Mediterranean)	Zeid et al. (2023)	1054	Frequency analysis	4	♂♀	29.58	0.27	-1.49	-
Bay of M'diq (Mediterranean of Morocco)	Kerkich et al. (2013)	1143	Otolith	6	♂♀	43.90	0.10	-0.32	-
Mediterranean of Morocco	Nasri et al. (2024)	390	Otolith	6	♂	38.39	0.22	-0.95	-
					♀	38.56	0.23	-0.90	-
Gulf of Annaba (Eastern Algerian coast)	**Present study**	**799**	**Frequency analysis**	**5**	♂♀	**32.60**	**0.37**	**-0.152**	**2.59**

N: Number of fish; L∞: Asymptotic length (cm); K: Growth co-efficient (1/ year); t_0: theoretical age at length zero (year); ϕ': growth performance index.

The length-weight relationship of *T. trachurus* on the eastern Algerian coast is isometric (b = 3.045) for the entire population, showing that the horse mackerel's weight increases proportionally with its length. Our findings closely align with those documented by Karakulak et al. (2006) in the Aegean Sea, Šantić et al. (2002 and 2011) in the Adriatic Sea, and Kerkich et al. (2013) in the Mediterranean Sea near Morocco. The parameters *a* and *b* of the length-weight relationship are significantly influenced by the monthly fish sampling frequency, as indicated by Fréon (1988), and by environmental and biological factors, including seasons, feeding behavior, competition, maturity, sex, and age, as proposed by Sparre et al. (1989) and Mommsen (1998).

The total (Z), natural (M), and fishing(F) mortalities for *T. trachurus* along the eastern Algerian coastal waters were estimated at 1.61, 0.37, and 1.24 yr^{-1}, respectively. The fishing mortality (1.24 yr^{-1}) is very high, indicating overexploitation. The exploitation rate (E) observed in this study is 0.77, exceeding the optimal exploitation level of 0.5, as estimated by Gulland (1971), reflecting the intense fishing pressure on this species. A similar phenomenon was also reported by Zeid et al. (2023) in the Egyptian Mediterranean waters (E=0.69).

The probability of capture was assessed at 7.63 cm, which is below the length at first sexual maturity recorded in Algeria by Azzouz et al. (2019) on the eastern Algerian coast (Lm_{50} =13.65 cm for females and 14 cm for males). This size falls beneath the minimum commercial size of 14 cm established by the Algerian Ministry of Fisheries and Marine Resources. As a result, the horse mackerel caught along the eastern Algerian coast does not reach sexual maturity before being harvested. Under these conditions, the individuals are unable to contribute to the stock's renewal. This situation is supported by the virtual population analysis (VPA), which revealed fishing pressure on smaller fish. As a result, there is a risk that the stock will not benefit from good renewal through recruitment, which could lead to very significant declines in biomass by altering demographic structures (Gascuel, 2008).

The examination of Y'/R and B'/R indicates that the current exploitation level (E=0.77) substantially exceeds both E_{max} and $E_{0.5}$ (0.48 and 0.30, respectively). To ensure effective management, the exploitation rate of *T. trachurus* must be decreased from 0.77 to 0.30, representing a 61% drop, to sustain the spawning stock biomass. The yield isopleths have placed the *T. trachurus* fishery in quadrant D, indicating that in terms of relative yield per recruit, the capture of horse mackerel in the waters of the Gulf of Annaba (Eastern Algerian coast) involves juvenile fish at a high level of fishing effort (Pauly and Soriano, 1986). This finding is consistent with the results obtained from the virtual population analysis (VPA). Therefore, we can note that the stock of *T. trachurus* caught off the Gulf of Annaba on the east coast of Algeria is overexploited and cannot achieve a sustainable fishing rate. This reflects a tendency to catch immature or maturing fish. Raising awareness among fishers about the negative impact of this practice could gradually change their behavior and motivations.

Conclusion

In conclusion, our research on *Trachurus trachurus* (Horse mackerel) along the eastern Algerian coast highlights several pivotal findings crucial for sustainable fisheries management. A notable imbalance in the sex ratio favoring males was observed, potentially attributable to physiological and dietary factors. Age estimation identified specific parameters differing from prior studies, emphasizing methodological discrepancies and environmental factors. The length-weight relationship demonstrated isometric growth, aligning with other Mediterranean studies, whereas mortality rates reflected significant fishing pressure and overexploitation, jeopardizing stock sustainability. Our analysis recommends a 61% reduction in exploitation rates to restore spawning biomass and promote stock recovery, highlighting the necessity for adaptive management strategies to protect this vital marine resource.

Acknowledgements

We express our gratitude to Dr. Mohamed Faouzi Samar for creating the map of the study site.

References

1. Aydin, M. and Karadurmuş, U. (2012). Age, growth, length-weight relationship and reproduction of the Atlantic horse mackerel (*Trachurus trachurus*, Linnaeus, 1758) in Ordu (Black sea). *Ordu. Univ. J. Sci. Tech*. 2 (2), 68-77.
2. Azzouz, S., Mezedjri, L. and Tahar, A. (2019). Reproductive cycle of the pelagic fish Saurel *Trachurus trachurus* (Linnaeus, 1758) (Perciformes Carangidae) Caught in the Gulf of Skikda (Algerian East Coast). *Biodivers. J.* 10 (1), 13-20. https://doi.org/10.31396/Biodiv.Jour.2019.10.1.13.20
3. Bhattacharya, C.G. (1967). A simple method of resolution of a distribution into Gaussian components. *Biometrics,* 23 (1), 115-135.
4. Beverton, R.J.H. and Holt, S.J. (1966). Manual of methods for fish stock assessment. Part 2. Tables of yield functions. Rome: FAO. *Fish. Tech. Pap.* 38 (1), 1-67.
5. Carrillo, J. (1978). Biologia y crecimiento del jurel *Trachurus trachurus* (L) y *Trachurus mediterraneus* (L) del mar mediterraneo catalan. Tesina de Licenciatura, Dpto.de Zoologia y ciencias marina, Universidad de la Laguna (Tenerife, Espana), p.103.
6. Dagnelie, P. (1975). Théorie et méthodes statistiques. Applications agronomiques. Vol.2. Les méthodes de l'interférence statistique. (2nd ed.). Presses agronomiques de Gembloux.
7. Djabali, F., Mechailia, A., Koudil, M. and Brahmi, B. (1994). A reassessment of equations for predicting natural mortality in Mediterranean teleosts. Naga, *the ICLARM Quarterly,* 17(1), 33-34.
8. FAO. (2022). The State of World Fisheries and Aquaculture 2022. Towards a blue transformation, Rome, FAO. https://doi.org/10.4060/cc0461fr
9. Fréon, P. (1988). Réponses et adaptation des stocks de clupéidés d'Afrique de l'Ouest à la variabilité du milieu et de l'exploitation. Analyse et réflexion à partir de l'exemple du Sénégal. ORSTOM Etudes et thèses, Paris, p. 287.

10. Gascuel, D. (2008). Dynamique des populations et gestion des stocks halieutiques. Support de cours en ligne, Agrocampus Ouest/Campus numérique ENVA Méd., Rennes, France,125 p.
11. Gayanilo, Jr.F.C., Sparre, P. and Pauly, D. (2005). FAO-ICLARM stock assessment tools II (FiSAT II): user's guide. FAO Computer Information Service 8, 168 p.
12. Gherram, M., BensahlaTalet, A., Dalouche, F. and Abi Ayad, S.M.E.A. (2018). Study of reproductive aspects of *Trachurus trachurus* (Linnaeus, 1758) from western coast of Algeria. *Indian J. Geo-Mar. Sci.* 47 (12), 2469-2476.
13. Gulland, J.A. (1971). The fish resources of the Oceans. West Byfleet, Survey, England: Fishing News (Books) Ltd. FAO, 255 p.
14. Junquara, S.C., Porteiro, C. and Moguedet, Ph. (1988). Contribution to the interpretation of the ring distribution pattern of Horse mackerel *Trachurus trachurus* (L) otoliths. ICES C. M. H:25, 13p. Retrieved from http://hdl.handle.net/10261/329322
15. Kalayci, F., Samsun, N., Bilgin, S. and Samsun, O. (2007). Length-weight relationships for 10 fish species caught by botton trawl and midwater trawl from the middle Black Sea, Turkey. *Turk. J. Fish. & Aquat. Sci*. 7, 33-36.
16. Karakulak, F.S., Erk, H. and Bilgin, B. (2006). Length-weight relationships for 47 coastal fish species from the northern Aegean Sea, Turkey. *J. Appl. Ichthyol.* 22, 274-278. https://doi.org/10.1111/j.1439-0426.2006.00736.x
17. Karlou-Riga, C. and Sinis, A. (1997). Age and growth of horse mackerel, *Trachurus trachurus* CL.), in the Gulf of Saronikos (Greece). *Fisheries Research* 32, 157-171.
18. Kartas, F. and Quignard, J.P. (1984). La Fécondité des Poissons Téléostéens. Collection de Biologie des Milieux Marins, Masson.
19. Kerkich, M., Aksissou, M. and Hernando Casal, J.A. (2013). Age and growth of the horse mackerel *Trachurus trachurus* (Linnaeus,1758) catches in the bay of M'diq (Mediterraneen coast of Morocco). IRACST – *JESTECH*, 3 (4), 708-714.
20. Kerstan, M. (1985). Age, growth, maturity, and mortality estimation horse mackerel (*Trachurus trachurus*) from the waters west of Great Britain and Ireland in 1984. *Arch. FischWiss*. 36, 115-154.
21. Mommsen, T.P. (1998). Growth and metabolism. In Evans, D.H. (Eds.). The Physiology of Fishes (pp. 65-98). CRC Press, New York.
22. MPPH. (2023). Ministère de la pêche et des productions halieutiques. Rapport statatistique annuel de 2022.
23. Nasri, H., Kasmi, K., Abdellaoui, S., Omari, A., Slimani, D., Melhaoui, R., Chafi, A. and Chaabane, K. (2024). Study of the growth of *Trachurus trachurus* (Linnaeus, 1758) fished on the eastern coast of the Moroccan Mediterranean. *E3S Web Conf.* 527. 01018. https://doi.org/10.1051/e3sconf/202452701018

24. Nazarov, N.A. (1978). Age and growth rate of the northeast Atlantic horse mackerel. International Council for the Exploration on the Sea. ICES C M H:22, 23p. Retrieved from https://www.ices.dk/sites/pub/CM%20Doccuments/1978/H/1978_H22.pdf
25. Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *ICES J. Mar. Sci.* 39 (2), 175-192. https://doi.org/10.1093/icesjms/39.2.175
26. Pauly, D. (1981). The relationship between gill surface area and growth performance in Fish: a generalization of Von Bertalanffy's theory of growth. *Meeresforschung*, 28, 251-282.
27. Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM, *Studies and Reviews*, 8, 1-325.
28. Pauly, D. and Munro, J.L. (1984). Once more on the comparison of growth in fish and invertebrates. *ICLARM, Fishbyte,* 2 (1), 21-32.
29. Pauly, D. and Soriano, M.L. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In Maclean, J.L., Dizon, L.B. and Hosillos, L.V. (eds), First Asian Fisheries Forum (pp. 491- 496). Manila, Philippines.
30. Rahmani, K., Koudache, F., Bouziani, A.L. and Belmahi, A.E. (2021). Length-weight relationships and metric characters of the atlantic horse mackerel, *Trachurus trachurus* (Perciformes: Carangidae), caught in Béni-Saf Bay, Western Mediterranean (Algeria). *Ann. Ser. Hist. Nat.* 31 (1),107-118. https://doi.org/10.19233/ASHN.2021.13
31. Ricker, W.E. (1973). Linear regression in fishery research. *J. Fish. Res. Board. Can.* 30 (3), 409-434. https://doi.org/10.1139/f73-072
32. Šantić, M., Jardas, I. and Pallaoro, A. (2002). Age, growth and mortality rate horse mackerel *Trachurus trachurus* (L), living in the eastern central Adriatic. *Period. Biol.* 104 (2), 165-173.
33. Šantić, M, Biljana, R. and Antonila, P. (2011). Condition and lengh-weight relationship of the horse mackerel *Trachurus trachurus* (L) and the Mediteranean horse mackerel *Trachurus mediterraneus* (L) from the eastern Adriatic Sea. *Arch. Biol. Sci.* 63 (2), 421-428. https://doi.org/10.2298/ABS1102421S
34. Sparre, P., Ersin, E. and Venema, S.C. (1989). Introduction to tropical fish stock assessment. Part 1. *Manual, FAO Fish. Tech.* 301 (1), 1-337.
35. Stamatopoulos, C. (2005). VONB Iterative Method for estimating growth parameters. Including non-asymptotic approaches, Version B/2005. Fisheries Department, FAO.
36. Von Bertalanffy, L. (1938). A quantitative theory of organic growth. *Hum. Biol.* 10 (2), 181-213.
37. Wootton, R.J. (1998). Ecology of Teleost Fishes. (2nd ed.). Fish and Fisheries Series 24. Dordrecht: Kluwer Academic Plubishers.
38. Zeid, S.M., Mahmoud, H.H., Tserpes, G., Fahim, R., Moustafa, K.M. and El-Sayed A.F.M. (2023). Population Dynamics and Stock Asssessment of Atlantic Horse Mackerel (*Trachurus trachurus*) Stocks

in the Western Egyptian Mediterranean Waters. *Egypt. J. Aquat. Biol. Fish.* 27 (6), 511-523. https://doi.org/10.21608/ejabf.2023.329301