Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(1): 411 – 422 (2024)
www.ejabf.journals.ekb.eg

Some biological aspects and life history parameters of common bluestripe snapper Lutjanus kasmira (Family: Lutjanidae) from Shalatein, Red Sea, Egypt

Taha Saleh Salem Baker[1] and Sahar Fahmy Mehanna[2]
[1]Department of Biology, Faculty of Education, Shabwah University, Yemen
[2]National Institute of Oceanography and Fisheries NIOF, Fisheries Division, Egypt
[*]**Corresponding Author: sahar_mehanna@yahoo.com**

ARTICLE INFO
Article History:
Received: Jan. 3, 2024
Accepted: Jan. 14, 2024
Online: Jan. 27, 2024

Keywords:
Red Sea,
Lutjanus kasmira,
age and growth,
exploitation level,
population parameters,
management.

ABSTRACT

Life history parameters and biology of fish like aging, growth, mortality and exploitation levels are essential to evaluate the fishery status of fish stocks. The common bluestripe snapper *Lutjanus kasmira* in the Shalatein fishing area, Red Sea, Egypt was assessed in this study for the first time. Age was determined based on otolith readings and the maximum life span was five years for males and females. The confidence interval for slope b of the length-weight relationship indicates positive allometric growth (b= 3.128; CI: 3.071-3.185). The von Bertalanffy equation for the growth in length was $L_t = 33.76\ [1 - e^{-0.35(t + 1.15)}]$. The total mortality coefficient Z, natural mortality coefficient M, and fishing mortality coefficient F were estimated at 1.58, 0.59, and 0.99 $year^{-1}$, respectively. The current exploitation rate E was 0.62 $year^{-1}$. The critical lengths of the species were 13, 17.97 and 19.70 cm TL for length at recruitment, length at first capture and length at first sexual maturity respectively. The results indicated that the stock of *L. kasmira* in the Shalatein fishing area is currently overexploited where the current F and E were greatly higher than the optimum ones which produces the maximum sustainable yield. It is recommended that the current fishing pressure should be reduced, in addition to protecting the spawning stock biomass during the spawning season and reducing the natural mortality rates. Also, urgent improvement for the fishhing techniques to protect the young individuals should be applied.

INTRODUCTION

Family Lutjanidae, which known as snappers, is composed of 17 genera and 113 species (**Fishbase, 2023**), all are marine and most of them inhabiting the coral reef ecosystems (**Allen, 1985**). Snappers are essentially predators, feeding on fishes, crustaceans, small echinoids and mollusks. Snappers constitute an important component of the local artisanal catch throughout their geographic range (**Allen, 1985**) especially in Red Sea. Up to 15 species were recorded in the Red Sea (**Randall, 1995**) from which 8 species were confirmed in the Egyptian Red Sea. *Lutjanus bohar, L. gibbus, L. argentimaclatus, L. monostigmus, L. fulviamma, L. lutjanus, Lutjanus ehrenbergii* and *L. quinquelineatus* (**Mehanna *et al.*, 2017a&b**). The common bluesripe snapper, *L. kasmira* which is member of family Lutjanidae, is a valuable species for fisheries and has a wide distribution inhabiting Red Sea and East Africa to the Marquesas and Line islands, north to southern Japan, south to Australia. Southeast Atlantic: East London, South Africa (**Anderson, 1986**). It is marine, reef-associated species found on depth range of 3 - 265 m (**Randall, 1995**), usually 30 - 150 m (**Myers, 1999**). In the Egyptian Red Sea, the common bluestripe snapper *L. kasmira* along with the other lutjanid species are of very high commercial importance and are captured by different kind of fishing methods like trawl, lines, gill and trammel nets.

Most snapper species are appreciated as sea food with high commercial value. Despite the growing interest in these fish species, few studies on some aspects of their biology and dynamics are available (**AL- Zahaby *et al.*, 1987; El-Serafy *et al.*, 1987&1988; Mehanna, 2003; Basmidi, 2004; Mehanna *et al.*, 2017a&b**). Effective fisheries management needs an understanding of the population dynamics and stock status of the targeted fish species, where the growth parameters ($L\infty$ and K) are among the crucial inputs (**Katsanevakis and Maravelias, 2008**). So, the current study was conducted to investigate some biological aspects and population dynamics of *L. kasmira* from the Egyptian Red Sea, Shalatein fishing area for the first time.

MATERIALS AND METHODS

Study area and sampling

Foul Bay (Fig. 1) lies in the west side of the Red Sea near the Egyptian boundaries with Sudan and enclosed between Ras Banas (23° 54' 10" N, 35° 47' 12" E) in the north and Abu Dara in the South (220 41' 00" N, 360 05' 00" E). Its length is about 150 Km and its width varied between 20 and 65 Km with depth of about 200 m (**El-Sharkawy, 1984**). There are five landing sites along the Bay: Ras Banas, Berenice, Mersa Hemaira, Shalatein and Abo Ramad from which Shalatein the most productive one. The main fishing methods that operated in Shalatein fishing area are artisanal fisheries especially long and hand lines, Gill and trammel nets.

Fig. 1. Egyptian Red Sea showing the main fishing grounds and study area

Lutjanus kasmira samples were collected monthly from the commercial landing at Shalatein fishing area during the period from September 2021 to August 2022. A total of 714 (375 male and 339 female) specimens of *L. kasmira* were collected, and their total lengths were measured to the nearest mm and the total body weights were recorded to the nearest 0.1 g. The sex was determined and otoliths were extracted for age determination.

Methods

Length-weight relationship LWR

The length–weight relationship of the striped red mullet was described by the power equation: $W = a\,TL^b$ **(Ricker, 1975**), where **a** and **b** are constants whose values were estimated by the least square method. Confidence intervals CI of 95% were calculated for the slope (b) to see if it was statistically different from 3. The Student's t-test determines the growth as isometric (b = 3) or allometric (b > or <3).

Age determination

Otoliths of *L. kasmira* were stored dry in paper envelopes with all data of specimens. The whole sagittal otoliths immersed in glycerol, were read against a black background using a compound microscope. Each otolith was read three times and the consistency of the otolith interpretation was determined by the average percentage error (APE) index (**Beamish and Fournier, 1981**).

Growth parameters

The growth parameters ($L\infty$, k and t_0) were estimated following the von Bertalanffy growth curve (1938). Von Bertalanffy growth in length equation can be expressed as:

$$L_t = L_\infty\,[1 - e^{-k\,(t - to)}]$$

Where: L_t = mean length at age t, L_∞ = asymptotic length, K = growth coefficient that determines the rate at which L_∞ is attained, t_0 = age at which the length is theoretically equals zero. The growth parameters were determined using the formula of Chapman (1961) as: $L_{t+1} - L_t = L_\infty (1 - e^{-k}) - (1 - e^{-k}) L_t$

By plotting ($L_{t+1} - L_t$) against (L_t), it gives a straight line has a slope (b) equals to ($1- e^{-k}$) and an intercept (a) equals to ($L_\infty (1-e^{-k})$). Thus, the value of K and L_∞ can be estimated. The $\mathbf{t_0}$ was estimated from the following rearranged formula of the von Bertalanffy equation: $- \ln [1 - (L_t/L_\infty)] = - kt_0 + kt$

This is a straight line equation relating the age (t) and -ln ($1-(L_t/L_\infty)$), having a slope (b) equals to (k) and an intercept (a) equals to ($-k*t_0$) then: $t_0 = - a/b$

Growth Performance Index (Ø)

The growth performance index (φ') was computed according to the formula of **Pauly and Munro (1984)** as $\varphi' = \text{Log}_{10} K + 2 \text{Log}_{10} L\infty$.

Critical lengths

The length at recruitment (L_r) was determined as the smallest fish in the catch, The length at first capture (L_c) was estimated by the analysis of catch curve using the method of **Pauly (1984),** while the length at first sexual maturity (L_m) was estimated by fitting the maturation curve between the observed points of mid-class interval and the percentage maturity of fish corresponding to each length interval.

Mortality and Exploitation rates

Two different methods were applied to estimate the total mortality of *L. kasmira*; **Jones and Van Zalinge, 1981** (Analysis of the cumulative catch curve) and **Pauly, 1983** (Analysis of the length converted catch curve). While the natural mortality coefficient was estimated as the geometric mean of three different methods; **Taylor's** method (1960) as $M = 3/t_{max}$ where t_{max} = maximum age attained, **Rikhter and Efanov (1976)** as $M = (1.52/t_{mass})^{0.72} – 0.16$ where t_{mass} is the age at massive maturation. **Pauly's (1980)** empirical formula as $\log M= -0.0066 – 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T$ where T is the mean water temperature also used. **The Alagaraja (1984)** criterion was used in this study in order to choose the best estimate of natural mortality. The Alagaraja (1984) equation is expressed as: longevity (Te) = 4.605/M (year). Also, the validity of estimates of M can be judged by the M/K ratio as this ratio has been demonstrated to be within the range of 1.12–2.50 for most species around the world (**Beverton and Holt, 1957**). The fishing mortality coefficient F was estimated as F= Z – M and the exploitation rate E was calculated as E = F / Z (**Gulland, 1971**).

RESULTS AND DISCUSSION

1. Age and growth

Accurate estimates of growth parameters are important for monitoring the stock status as well as for assessing management actions that have been applied to maintain the integrity of the fish stock (**Zhang *et al.*, 2020**). To estimate growth, precise and accurate age data are required. Age can be estimated by several methods but counting natural growth rings of hard body parts is the most common and is generally reliable (**Vitale *et***

***al.*, 2019**). The whole otolith readings indicated good agreement between the different estimates (agreement = 90.75%, CV = 4.79% and APE = 3.21%). Campana (2001) suggested that acceptable levels for APE and CV were 5.5% and 7.6%, respectively. Therefore, the present results are close to the acceptable values for both APE and CV. The maximum observed age was 5 years for male and female. The results revealed that there is no significant difference in back-calculated lengths between the two sexes (P > 0.05). Age group one was dominant in the catch (49%) followed by age group two (28%) (Fig. 2). The ageing of *L. kasmira* was used to construct the growth curve (Fig. 3).

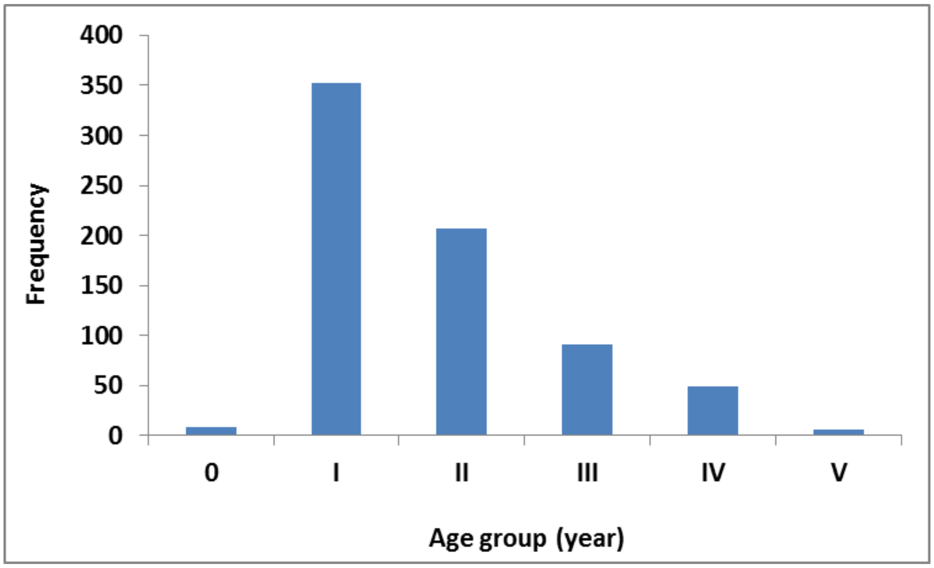

Fig. 2. Age composition of *Lutjanus kasmira* from Shalatein, Red Sea

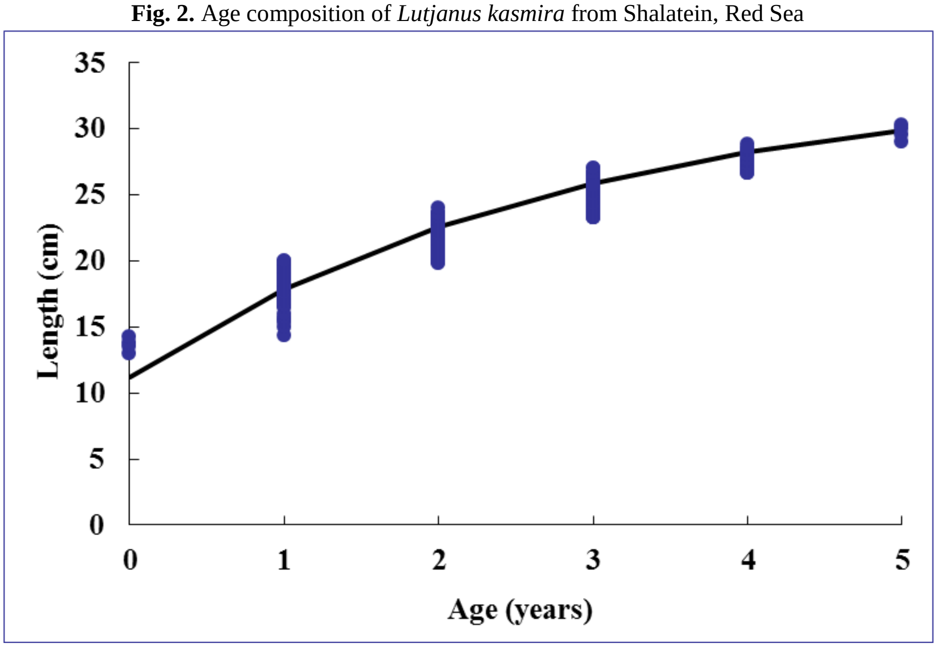

Fig. 3. Growth curve of *Lutjanus kasmira* from Shalatein, Red Sea

2. *Length-Weight relationship LWR*

The length-weight relationship is helpful in the estimation of metamorphosis, gonad maturity and the fish feeding rate (**Le Cren, 1951**), and it is the basic parameter in fishery biology and stock assessment of fish (**Mehanna and Farouk, 2021**).

The total length of *L. kasmira* ranged between 13 and 30.3 cm, while the total weight varied from 29 to 425 g. Size frequency distribution between sexes was not significantly different (Kolmogorov–Smirnov two sample test, $P > 0.05$) and there is no significant difference in length-weight relationship between sexes. The calculated length-weight equation (Fig. 4) for pooled data was $W = 0.0108\ L^{3.1282}$ with $r^2 = 0.97$. The 95% confidence interval for b was 3.128 - 3.071 indicating that the growth of *L. kasmira* is positive allometric (b>3). The same finding was observed in the work of **Ralston (1988)** who gave b value at 3.154 in North Marianas, **Letourneur *et al.* (1998)** estimated the b value at 3.136 in New Caledonia, **Kulbicki *et al.*** (2005) determined b at 3.247 in New Caledonia and **Kanikawa *et al.*** (2015) gave b-value at 3.120 in Guam.

The LWR in fish is affected by several factors including gonad maturity, sex, diet, stomach fullness, differences in the observed length ranges of the caught specimen, and health as well as season and habitat (**Ricker, 1975; Froese, 2006; Mehanna and Farouk, 2021**).

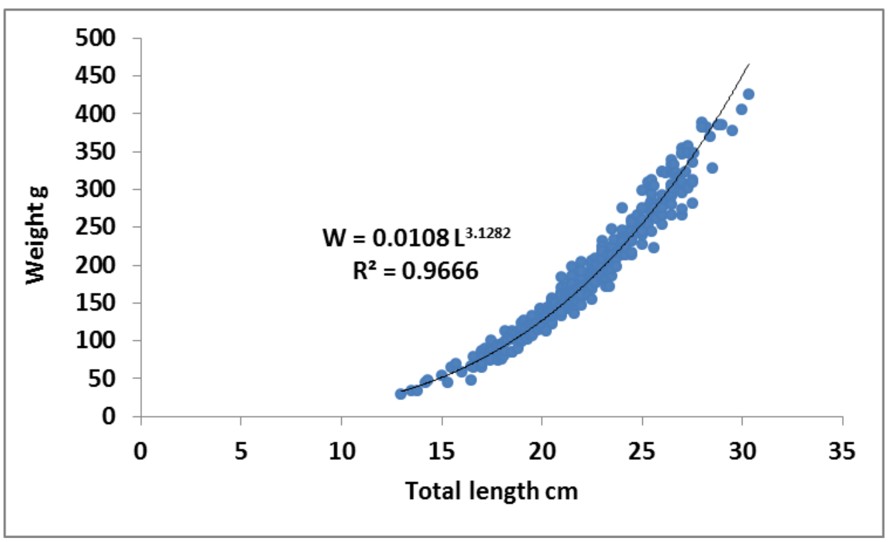

Fig. 4. Length-weight relationship of *Lutjanus kasmira* from Shalatein, Red Sea

3. *Growth parameters*

The results showed that females and males growth parameters are not significantly different (Max. likelihood test: $\Lambda = 2.87$, $\chi^2_{0.05,3} = 6.89$, P>0.05). Accordingly, the parameters of the von Bertalanffy growth equation were determined for pooled samples. The growth parameters "$L\infty$, K, $W\infty$ and t_0" for *L. kasmira* were 33.76 cm, 0.35 yr^{-1}, 651.78 g and -1.15 yr respectively. The value of the growth performance index obtained for the whole population was 2.60. Our estimate of growth parameters was compared to those reported in the previous studies in Table 1.

Table 1. Growth parameters of *L. kasmira* reported by various studies

Locality	**L∞**	**K**	**t_0**	**Ø**	**Author**
New Caledonia	21.1 SL	0.380	---	2.23	Loubens (1980)
American Samoa	29.6 FL	0.384	-1.35	2.53	Raleston and Williams (1988a)
Hawaii	33.7 NG	0.270	---	2.49	Morales-Nin (1989)
American Samoa	39.6 FL	0.212	-0.75	2.52	Raleston and Williams (1988a)
North Marianas	40.0 FL	0.212	-0.75	2.53	Raleston and Williams (1988b)
Shalatein, Red Sea	33.76 TL	0.35	-1.15	2.60	Present study

4. Mortality and exploitation rates

The mean rate of total mortality (Z) estimated from different methods was 1.58 $year^{-1}$, the mean natural mortality rate (M) was 0.59 $year^{-1}$, the fishing mortality (F) was $0.99 \cdot year^{-1}$. The M/K ratio obtained in the present study (1.69) was well within the normal range of 1.12 – 2.5, as suggested by **Beverton and Holt (1957)**. The exploitation rate can be defined as the proportion of harvestable-sized fishes that are removed from a population annually through different fishing activities (**Meyer and Schill, 2014**). Considering the calculated mortality parameter results, the current exploitation rate (0.62) is greater than the optimum value (E= 0.5 that given by Gulland, 1971 and E= 0.4 that given by Pauly, 1984) proofing the high fishing pressure on this population.

5. Critical lengths and ages

The length at first maturity L_m along with the length at first capture Lc are important tools that enable fishery managers to determine what should be the minimum size of the target species of a fishery. Length at recruitment (the smallest length in the catch) was 13 cm (0.24 year) while the length at first capture Lc estimated from the selection ogive (Fig. 5) was 17.97 cm (1.02 year). The results showed that the *L. kasmira* reached first maturity at about 19.70 cm TL (1.35 year) (Fig. 6) which is greater than L_c and T_c. It has been demonstrated that the capture of fish prior to attaining sexual maturity can result in a depletion of the spawner biomass and therefore recruitment. As the length at first sexual maturity resulting from this study is greater than the length at first capture, it may be necessary to improve the fishing techniques in Shalatein fishing area in order to avoid recruitment overfishing.

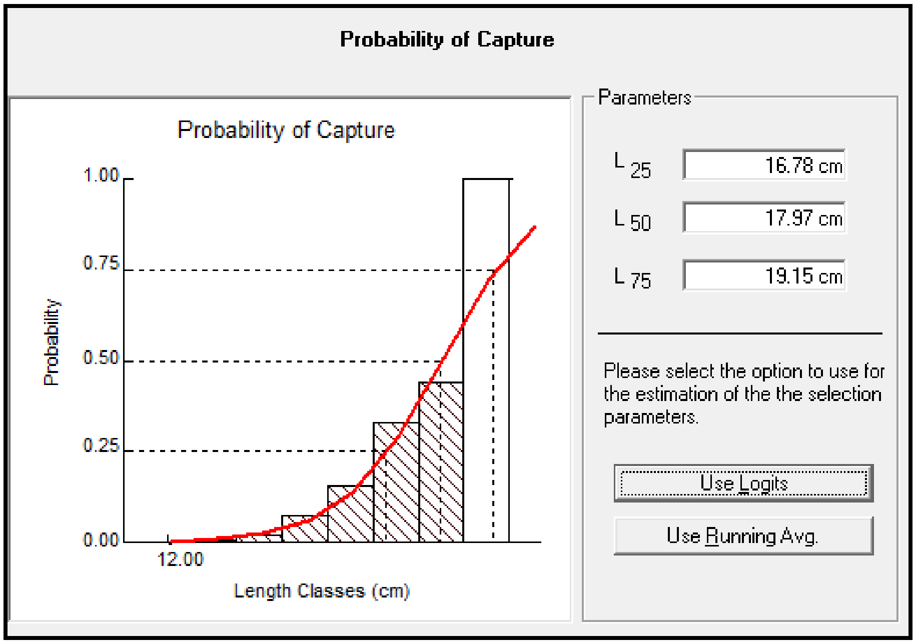

Fig. 5. Length at first capture of ***L. kasmira*** from Shalatein, Red Sea

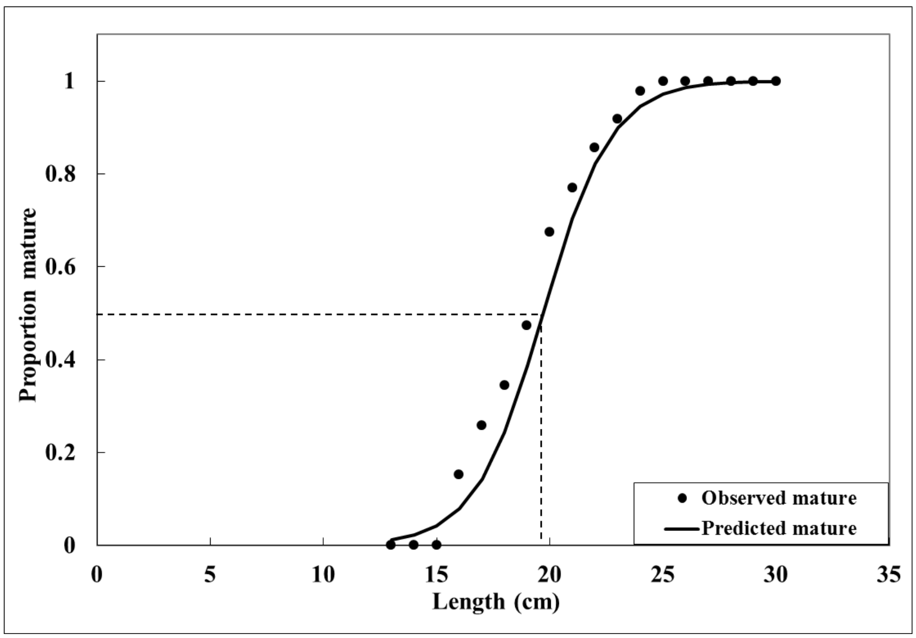

Fig. 6. Length at first sexual maturity of ***L. kasmira*** from Shalatein, Red Sea

CONCLUSION

In conclusion, the results of this study showed that common bluestripe snapper fishery in the Shalatein fishing area, Red Sea is exploited above its optimum level, as both fishing mortality and exploitation rate were higher than those of optimum situation. Red Sea fisheries are multifleet and multispecies fisheries and all the commercial and famous fish stocks are overexploited (**Mehanna, 2021**b), so any management regulations should consider consider all the components of that fishery. However, a study of the population dynamics of different fish species along with the evaluation of different fishing gears in this area is required to determine appropriate management recommendations via more sustainable local fishing management measures (e.g. using a larger mesh size to avoid harvesting immature individuals and/or reducing or eliminating fishing mortality in buffer or no-take areas, respectively). Although, detailed research is recommended to develop the fishing fleet and to improve the fishing techniques in this important area, the obtained results will help fisheries scientists to enforce regulations on commercial fisheries concerning minimum landing size restrictions for *L. kasmira*.

REFERENCES

Alagaraja, K. (1984). Simple methods for estimation of parameters for assessing exploited fish stocks. Indian J. Fish. 31: 177–208.

Allen, G. R. (1985). FAO species catalogue. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fisheries Synopsis no. 125, volume 6. Food and Agricultural Organization of the United Nations, Rome. 208 p.

Allen, G. R. and Talbot, F. H. (1985). Review of the snappers of the genus *Lutjanus* (Pisces: Lutjanidae) from the Indo-Pacific, with description of a new species. Indo-Pacific Fishes, 11: 1-87.

Al-Zahaby, A. S.; El- Serafy, S. S. and El-Drawany, N. A. (1987). On the Biology of *Lutjanus lineolatus* (Bloch) in the Gulf of Suez . 11 Maturity and Spawning Season. Proc . Zoo.Soc .ARE 3rd Cong. 1987.

Anderson, W. D. Jr. (1986). Lutjanidae. (Genus *Lutjanus* by G.R. Allen). pp. 572-579. In M.M. Smith and P.C. Heemstra (eds.) Smiths' sea fishes. Springer-Verlag, Berlin.

Basmidi, A. A. M. (2004). Studies on the population dynamics of somespecies of genus *Lutjanus* (family: Lutjanidae) from the Red Sea, Egypt. Ph.D., Thesis, Assiut University, Egypt.

Beamish, R. J. and Fournier, D. A. (1981). A method of comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci., 38: 982-983.

Bertalanffy, L. von (1938). A quantitative theory of organic growth (Inquiries on growth Laws. 2). Hum. BioL, 10: 181-213.

Beverton, R. J. H. and Holt, S. J. (1957). On the dynamics of exploited fish population UK Ministry Articulature and fish, fisheries, 19.533 p.

Campana, S. E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology, 59: 197–242. doi: 10.1006/jfbi.2001.1668

El-Serafy, S. S.; AL-Zahaby, A. S. and El- Darwani, M. A .(1987). On the Biology of *Lutjanus lineolatus* (Bloch) in the Gulf of Suez ; 1 age and growth proc. Zool. Soc . ARE,3rd .cong. 1987.

El-Serafy, S. S; AL-Zahaby, A. S. and El- Darwani, M. A. (1988). On the Biology of *Lutjanus lineolatus* (Bloch) in the Gulf of Suez : Length -weight –relationships relative Condition factor and fecundity Bull. Nat. Oceanegr. And Fish , ARE . 14(2): 113-122.

El-Sharkawy, S. M. (1984). Physical investigations in Foul Bay of the Red Sea. Tech. Rep., 1 part 1: 78 p.

Fishbase (2023). Froese, R. and Pauly, D. (Eds): FishBase version (02/2023). World Wide Web electronic publication. <http://www.fishbase.org>

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol., 22: 241–25.

Gulland, J. A. (1971). The fish resources of the Ocean. West Byfleet, Surrey, Fishing News (Books), Ltd., for FAO, 255 p.

Jones, R. and Van Zalinge, N. P. (1981). Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bull. Mar. Sci., 2: 273-288.

Kanikawa, K.T.; Cruz, E.; Essington, T. E.; Hospital, J.; Brodziak, J. K. T. and Branch, T.A. (2015). Length–weight relationships for 85 fish species from Guam. J. Appl. Ichthyol., 31: 1171–1174.

Katsanevakis, S. and Maravelias, C. D. (2008). Modelling fish growth: multi-model inference as a better alternative to a priori using von Bertalanffy equation. Fish and Fisheries 9(2): 178-187.

Kulbicki, M.; Guillemot, N. and Amand, M. (2005). A general approach to length-weight relationships for New Caledonian lagoon fishes. Cybium 29(3): 235-252.

Karakulak, F. S.; Erk, H. and Bilgin, B. (2006). Length-weight relationships for 47 coastal fish species from the northern Aegean Sea, Turkey. Journal of Applied Ichthyology, 22 (4): 274-278.

Le-Cren, C. P. (1951). Length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). J. Anim. Ecol., 20: 201-219.

Letourneur, Y.; Kulbicki, M. and Labrosse, P. (1998). Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: an update. Naga ICLARM Q. 21(4): 39-46.

Loubens, G. (1980). Biologie de quelques espèces de poissons du lagon Néo-Calédonien. III. Croissance. Cah. Indo-Pac. 2:101-153.

Mehanna, S .F. (2003). population dynamics of the bigye snapper *Lutjanus lineolatus*; , ruppeIl, 1829 (Family: Lutjanidae) from the Gulf of suez, Egypt .J,Aqat. Biol& fish. 7(3): 71-85.

Mehanna, S. F. (2021). Egyptian Marine Fisheries and its sustainability, pp. 111-140. In: Sustainable Fish Production and Processing (Ed. Galanakis, Ch. M.). Academic Press, Elsevier, 325 pp.

Mehanna, S. F. and Farouk, A. (2021). Length-weight relationship of 60 fish species from the eastern Mediterranean Sea, Egypt (GFCM-GSA 26) Front. Mar. Sci. doi: 10.3389/fmars.2021.625422

Mehanna, S. F.; Soliman, F. M.; Soliman, H. A. and Baker, T. S. (2017a). Age, growth and length-weight relationship of *Lutjanus ehrenbergii* (Petere, 1869) from the Red Sea, Egypt. Al-Azhar University, Assiut Branch annual conference, Hurghada.

Mehanna, S. F.; Baker, T. S.; Soliman, F. M. and Soliman, H. A. (2017b). Some biological aspects and population dynamics of the five-lined snapper, *Lutjanus quinquelineatus* (Family: Lutjanidae) from Red Sea off Hurghada, Egypt. International Journal of Fisheries and Aquatic Studies, 5(5): 321-326.

Morales-Nin, B. (1989). Growth determination of tropical marine fishes by means of otolith interpretation and length analysis. Aquat. Living Resour. 22: 241-253.

Myers, R. F. (1999). Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics, Barrigada, Guam. 330 pp.

Meyer, K. A. and Schill, D. J. (2014). Use of a statewide angler tag reporting system to estimate rates of exploitation and total mortality for Idaho sport fisheries. North American Journal of Fisheries Management 34(6): 1145–1158.

Pauly, D. (1980). A selection of simple methods for the assessment of tropical fish stocks. FAO Fisheries Circular (729): 54 pp.

Pauly, D. (1983). Length-converted catch curves. A powerful tool for fisheries research in the tropics. Part1. ICLARM Fish byte, 1(2):9-13.

Pauly, D. (1984). Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM Stud. Rev. 8. ICLARM, Manila, Philippines, 325 pp.

Pauly, D. and Munro, J. L. (1984). Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2: 21-21.

Ralston, S. (1988). Length-weight regressions and condition indices of lutjanids and other deep slope fishes from the Mariana Archipelago. Micronesica, 21: 189-197.

Ralston, S. and Williams, H. A. (1988a). Age and growth of *Lutjanus kasmira*, *Lethrinus rubrioperculatus*, *Acanthurus lineatus* and *Clenochaetus striatus* in American Samoa. Adminstrative Report 11-18-18, Southwest Fisheries Center: NMFS (Honolulu Laboratory): 11 pp.

Ralston, S. and Williams, H. A. (1988b). Depth distributions, growth, and mortality of deep slope fishes from the Mariana Archipelago. NOAA Tech. Memo. NMFS. NOAA-TM-NMFS-SWFC-113, 47 pp.

Randall, J. E. (1995). Coastal fishes of Oman. University of Hawaii Press, Honolulu, Hawaii. 439 p.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can., 191: 1–382.

Rikhter, V. A. and Efanov, V. N. (1976). On one of the approaches to the estimation of natural mortality of fish populations. ICNAF Res. Doc., 76/VI/8: 12 pp.

Taylor, C. C. (1960). Temperature, growth and mortality – the Pacific cockle. J. Cons. CIEM, 26: 117-124.

Vitale, F.; Clausen, L. W. and Chonchúir, G. N. (2019). Handbook of fish age estimation protocols and validation methods. International Council for the Exploration of the Sea, Copenhagen, 180 pp.

Zhang, K.; Zhang, J.; Li, J. and Liao, B. (2020). Model selection for fish growth patterns based on a Bayesian approach: A case study of five freshwater fish species. Aquatic Living Resources, 17(33).