Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(5): 1611 – 1628 (2024)
www.ejabf.journals.ekb.eg

Assessment of Growth, Reproduction and Longline Soaking Time of the Spangled Emperor, *Lethrinus nebulosus*, in the Red Sea, Egypt

Hanan M. Osman, Azza A. El-Ganainy, Mahmoud A. Saber, Tamer A. El-Betar*

National Institute of Oceanography and Fisheries (NIOF), Egypt

***Corresponding author: tamer4egypt@gmail.com**

ARTICLE INFO

Article History:
Received: Sept. 7, 2024
Accepted: Oct. 3, 2024
Online: Oct. 10, 2024

Keywords:
Spangled emperor,
Growth,
Spawning sites,
Longline fisheries,
Red Sea

ABSTRACT

This investigation explored the growth patterns and reproductive strategies of *Lethrinus nebulosus*, identifying key spawning aggregation zones within the Red Sea. Additionally, it evaluated catch per unit effort (CPUE) using longline techniques through various fieldwork strategies. The CPUE of longline fishing was influenced by both soaking time and fishing season. Collected specimens ranged in total length from 14.3 to 71.3cm. The length-weight relationship indicated an almost isometric growth pattern, with the body shape parameter (b) = 2.95. *L. nebulosus* exhibiting a long lifespan, with a maximum age of 18 years, identified through transverse sections of sagittal otoliths. The growth parameters derived from the von Bertalanffy model were L_∞ = 73.0cm, K = 0.12 year^{-1}, and t_0 = -0.32. Spawning likely occurs in spring, with aggregations recorded from mid-April to mid-May in specific locations. Six spawning aggregation sites were identified and documented. The observed sex ratio of 1:1.15 did not show a statistically significant deviation from the hypothesized 1:1 ratio (χ^2, $P > 0.05$). Males reached sexual maturity (Lm) before females, with lengths of 33 and 36cm, respectively. The length at first capture (Lc = 29cm) was much lower than the length at first maturation, raising concerns about overexploitation. It is proposed that management interventions be implemented to prevent the capture of immature fish, thereby protecting the stock and ensuring its long-term sustainability.

INTRODUCTION

Coral reef ecosystems are invaluable not only for their visual appeal, biodiversity, and tourism value but also for their significant role in global marine fish production, contributing up to 9% of the total **(Smith, 1978)**. The Lethrinidae family is commonly found in the littoral tropical and subtropical expanses of the Indo-Pacific **(Young & Martin, 1982)**; the spangled emperor (*Lethrinus nebulosus*) is disseminated throughout the Indo-West Pacific realm, from the Red Sea and East Africa to the southern reaches of Japan. This species inhabits a range of ecological niches, including coral reef ecosystems, sea grass assemblages, and mangrove biotopes, at depths reaching up to 75 meters **(Randall, 1995)**. While adults are typically solitary or observed in small aggregations, juveniles are inclined to form extensive schools in shallow, protected sandy habitats **(Grandcourt *et al.*, 2009)**. Although coral reef areas are typically protected from fishing, longline fishing has been identified as an effective method for targeting large, high-value fish species prevalent in these environments. Traditionally, spawning aggregations of the spangled emperor, which occur annually from April to June, have been exploited **(Russell *et al*., 2014)**. However, such practices have led to the overexploitation of these aggregations, resulting in the depletion of entire stocks beyond their maximum sustainable yield **(Domeier & Colin, 1997)**.

Sustainable development is critical for addressing global food security issues. Countries must manage their resources sustainably to ensure food safety, with fish resources being a crucial source of affordable dietary protein. Despite Egypt's abundant natural fish resources capable of providing essential proteins, effective management is necessary to optimize these fisheries **(Osman, 2016)**. Prior research has explored various aspects of the spangled emperor, including protandrous hermaphroditism **(Young & Martin, 1982)**, population dynamics and distribution **(Randall, 1995)**, reproductive strategies and fisheries management data **(Marriott *et al*., 2010)**, and spawning behavior and environmental influences **(Babcock *et al*., 2017)**.

The current investigation was designed to accomplish two principal aims:

(1) To assess the impact of soaking time on the catch ratio of *Lethrinus nebulosus* during different fishing seasons.

(2) To provide insights into fisheries management by analyzing fish population dynamics, including maturation size, spawning phenology, and growth.

These factors are essential for managing the *Lethrinus nebulosus* fishery in the Red Sea, aiming to conserve its stock and achieve maximum sustainable yield.

MATERIALS AND METHODS

- Longline specification

A bottom longline, which is used to catching grouper as target species, was utilized experimentally to evaluate the impact of soaking duration on catch ratios and length frequency distribution. The mainline, with a length of up to 1000m and a thickness ranging from 100 to 120mm, was constructed from monofilament, which is preferred in fishing due to its superior catch efficiency compared to multifilament lines. Branch lines, each with a length of 80 to 100cm and a diameter of 90mm, were attached to the mainline (Fig. 1). The longline used in the current study contains 1000 hooks, each of size 8/0. This setup was critical for evaluating the impact of soaking time on fishing performance.

- Sampling

Sampling of *Lethrinus nebulosus* (Fig. 2) was conducted seasonally using two strategies. The first strategy involved collecting samples through longline fishing experiments at various sites, including Abu Melh, Abu Nahaas, Al Erok, Shadwan, Magawish, and Disha (Fig. 3). During these experiments, two methodologies were employed for the longline operation:

1. The longline was deployed from 8:00 PM to 4:00 AM.
   A collection of 95 individuals was amassed for the study throughout different seasons.
2. The longline was deployed from 8:00 PM to 8:00 AM.
   A sum of 190 specimens was procured throughout different seasons.

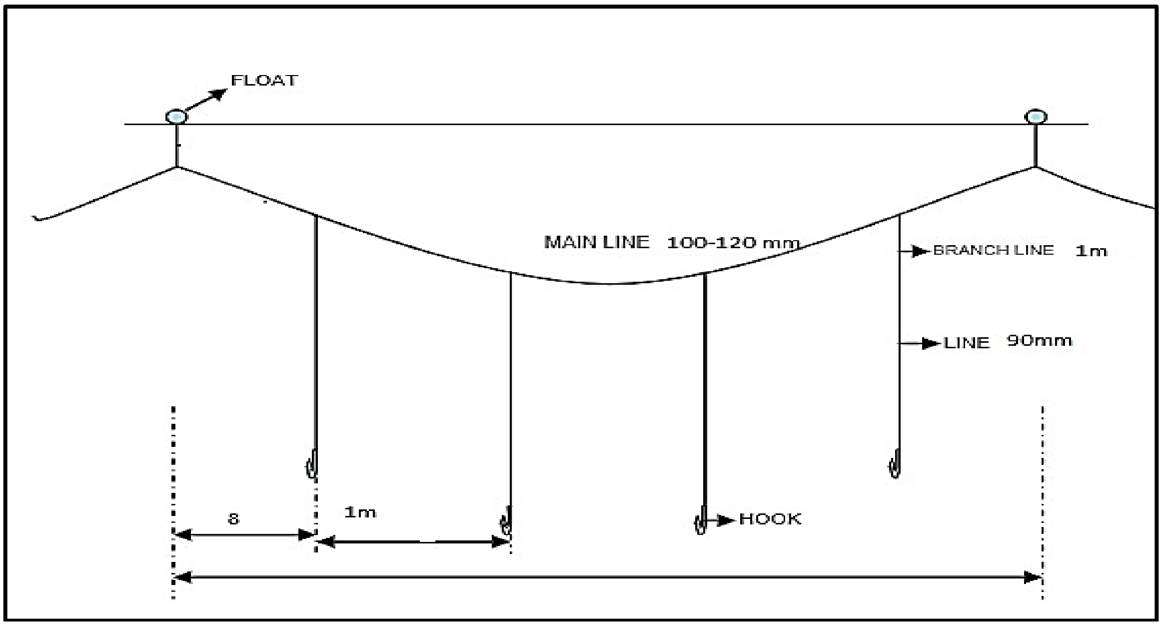

Fig. 1. A diagram illustrating the design and specifications of bottom longline

Fig. 2. Spangled emperor, *Lethrinus nebulosus*, in the Red Sea, Egypt

The second strategy involved the seasonal collection of *Lethrinus nebulosus* specimens from landing sites in Hurghada and Shalatin, resulting in a total sample size of 205 individuals.

- **Measurements**

Specimens were measured for total length (TL) to the nearest centimeter, and weighed for total weight (TW) and gonad weight (GW) to the nearest gram. When feasible, sex determination was carried out through gonadal macroscopic examination. Otoliths were extracted for age assessment; one sagittal otolith was embedded in epoxy resin. Transverse sections, approximately 200–300µm thick, were sliced using a high-speed twin-blade diamond saw. These sections were then examined under a low-power microscope with transmitted light (×20). Age estimation was based on counting opaque bands, which had been validated as annuli **(Grandcourt *et al*., 2009)**.

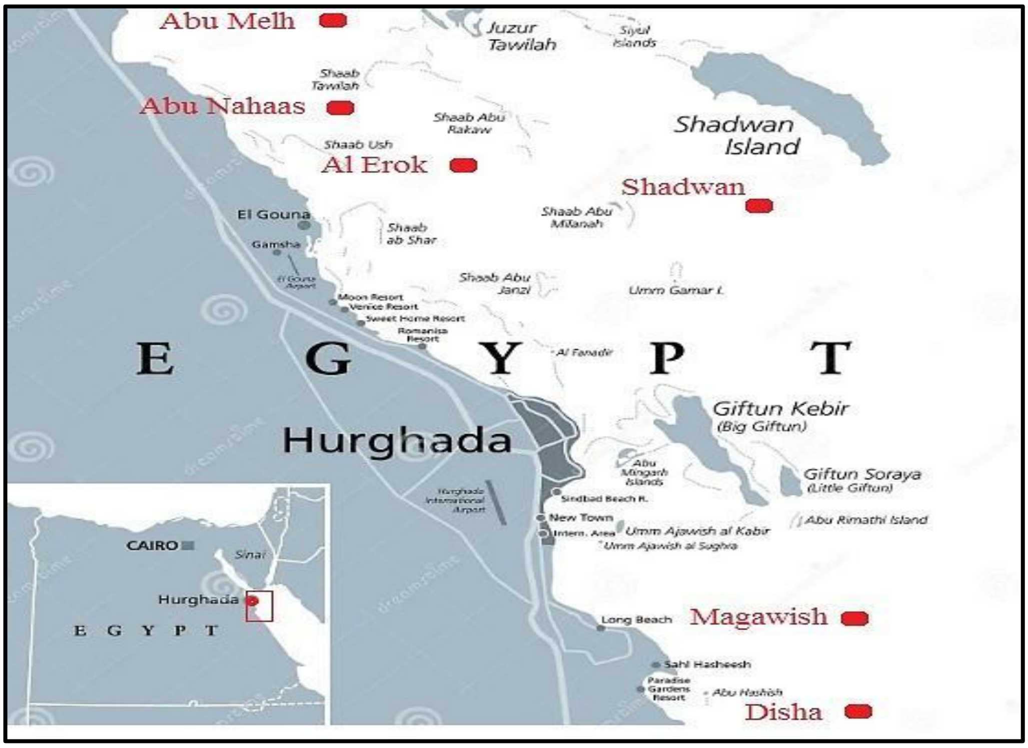

Fig. 3. Map showing sampling sites and longline operating locations in the Red Sea

The equation for catch per unit effort (CPUE) is:

$$\text{CPUE} = \text{Total catch/Effort} \qquad \textbf{(Sparre \& Venema, 1998).}$$

Where, Effort is the number of hooks.

The relationship between length and weight was determined using the equation provided by **Sparre *et al*. (1989)**:

$$W = aL^b$$

Where, W represents total body weight (g); L denotes total length (cm), and a & b are constants.

Growth was defined employing the following form of von Bertalanffy:

$$L_t = L_\infty\,(1-e^{-K\,(t-t_o)})$$

The von Bertalanffy growth parameters, including the asymptotic length (L_∞) and the growth coefficient (K), were estimated following the method described by **Fabens (1965)**.

To compare the growth performance of this species with that in other regions, The growth performance index (Φ) was obtained using the given formula of **Pauly and Munro (1984)**:

$$\Phi = \log K + 2\log L_\infty$$

Where, K and L_∞ are von Bertalanffy's growth variables.

Length at first capture (L_c) was determined by applying the plot of capture probability against length, following the method of **Pauly (1984)**.

Fulton's condition factor was generated using the formula:

$$K = (W * 100) / L^3$$

In which K represents condition factor, W represents total weight in gram, and L symbolizes length in centimeters**,** as described by **Hile (1936)**.

Gonado-somatic index (GSI) was computed for each specimen by the following equation:

$$GSI (\%) = GW/W * 100$$

In which, GW is the gondal weight in gram, and W is the total body weight in gram, following **Render *et al*. (1995)**.

- Statistical analysis

Non-parametric pairwise tests were employed during the study to assess various independent samples from subgroups of CPUE (Catch Per Unit Effort) for *Lethrinus nebulosus* across multiple timescales. The statistically significant result was assessed at the probability degree <0.05. Additionally, a Chi-square test was conducted using SPSS software (version 16) to examine differences in the sex ratio.

RESULTS

1- The catch of the spangled emperor

A commercial species in the Red Sea's coral reef fishery, emperor contributes around 1914 Mt (4.23%) of the region's annual yield (45243 MT) **(LFRPDA, 2021)**. The annual catch of the Red Sea as well as that of the spangled emperor during the past decade are represented in Fig. (4).

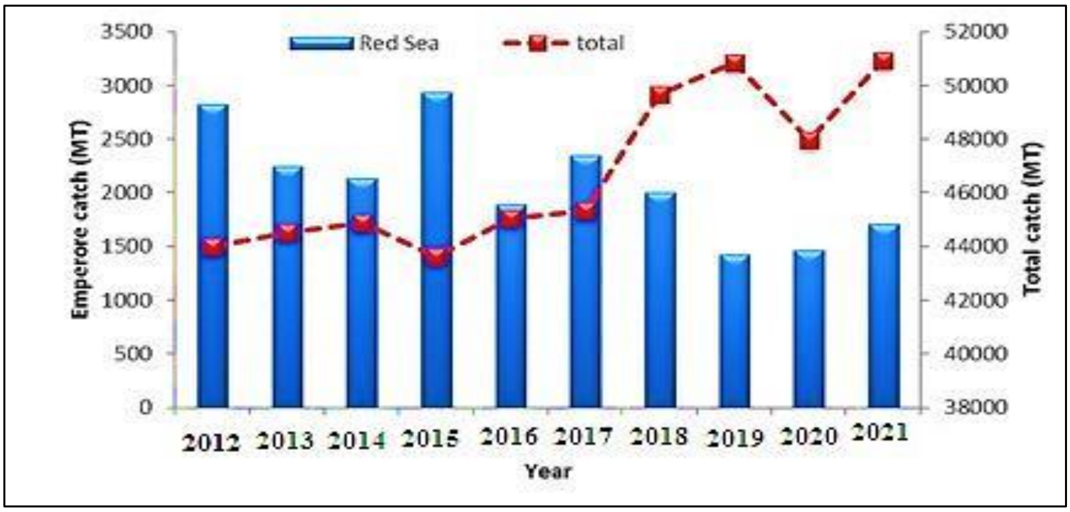

Fig. 4. *L. nebulosus* production compared to the Red Sea production over the past decade

2- Catch statistics with two soaking time

A seasonal survey was conducted using longlines in the Red Sea, with soak times of 8 and 12 hours. The nominal CPUE (Catch Per Unit Effort) was significantly influenced by soak time (*P*< 0.05). CPUE varied across the seasons, with a higher CPUE observed during spring and summer when the soak time was 12 hours. In contrast, during winter and spring, the CPUE was lower with a 12-hour soak time compared to the 8-hour soak time (Table 1 & Fig. 5).

Table 1. Catch statistics and CPUE by soak time for *Lethrinus nebulosus* using bottom longline in the Red Sea, Egypt

Season	Weight (kg) / 12hr	Weight (kg)/ 8hr	CPUE (12hr)	CPUE (8hr)
Winter	15.436	33.250	0.0154	0.0333
Spring	64.565	66.512	0.0646	0.0665
Summer	54.474	40.250	0.0545	0.0403
Autumn	38.234	33.256	0.0382	0.0333
Mean	43.177	43.317	0.04317	0.0433
Standard Error	10.761	7.964	0.0106	0.0078
Confidence Level (95.0%)	±25.610	±18.955	±0.0252	±0.0186
Standard Deviation	21.524	15.929	0.0212	0.0157

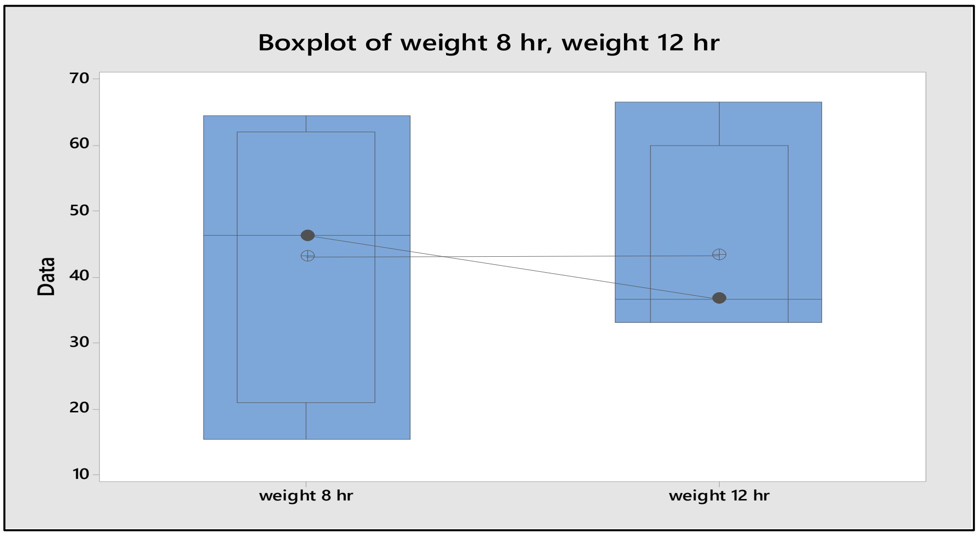

Fig. 5. Boxplot of CPUE for *Lethrinus nebulosus* with two soak times (8 and 12 Hours per fishing set) using bottom longline in the Red Sea, Egypt

3- Growth

3.1. Length frequency distribution

The size frequency distribution for *Lethrinus nebulosus* captured during the soaking time of 12 and 8h revealed an increase in the presence of large length classes with the decrease of soaking time (Figs. 6, 7).

The overall individuals of *L. nebulosus* were grouped according to total length, with 4cm for length interval, due to the wide range of the observed length. The occurrence percentages of the different length groups showed that the majority of population was corresponding to small and medium sizes (14.0-50.0cm). There was no absolute dominance for a specific length group, but rather close percentages for multiple groups, as shown in Fig. (8).

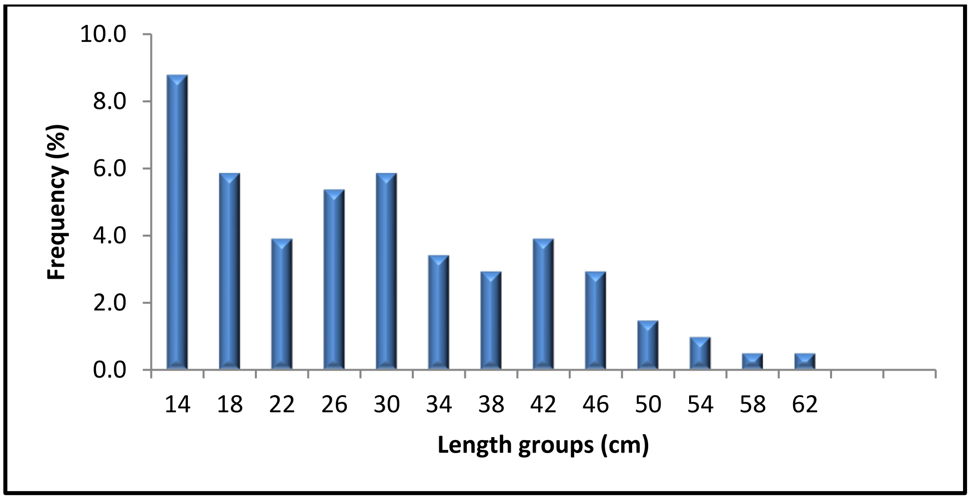

Fig. 6. The frequency distribution of length groups of *Lethrinus nebulosus* with a 12-hour soak time per Fishing shoot using longline in the Red Sea, Egypt

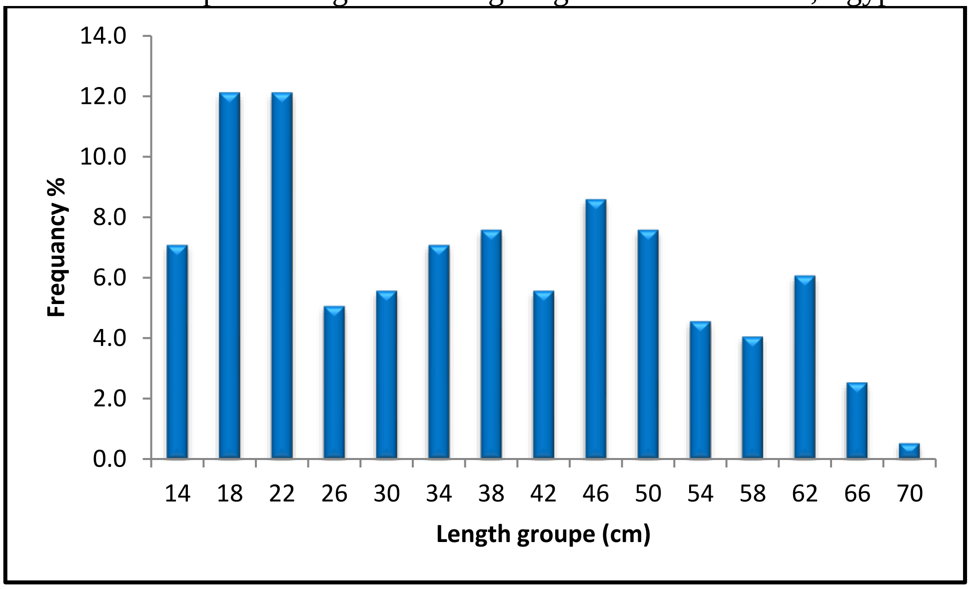

Fig. 7. The frequency distribution of length groups of *Lethrinus nebulosus* with an 8-hour soak time per fishing shoot using longline in the Red Sea, Egypt

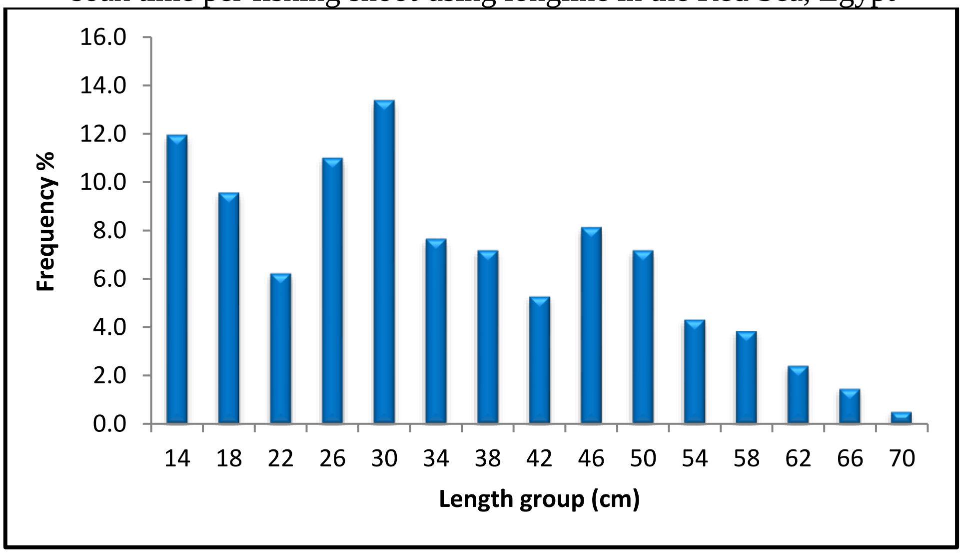

Fig. 8. Overall frequency distribution of length groups for *Lethrinus nebulosus* specimens from the Red Sea, Egypt

3.2. Length weight relationship

According to the detected ranges of 14.3-71.3cm and 46.1-4650g for total length and total weight, respectively, the relationship of length and weight was generated as $W= 0.016L^{2.954}$. The value of the slope (b) shows that *L. nebulosus* have an almost isometric growth pattern (Fig. 9).

3.3. Condition factor

During the current investigation, the condition factor (*K*) of *Lethrinus nebulosus* was assessed seasonally for both males and females. Males displayed the highest mean condition factor of 1.37 during winter, whereas females had their peak mean condition factor of 1.36 in summer. The least mean values were noted in spring for males (1.31) and females (1.35), as shown in Fig. (10).

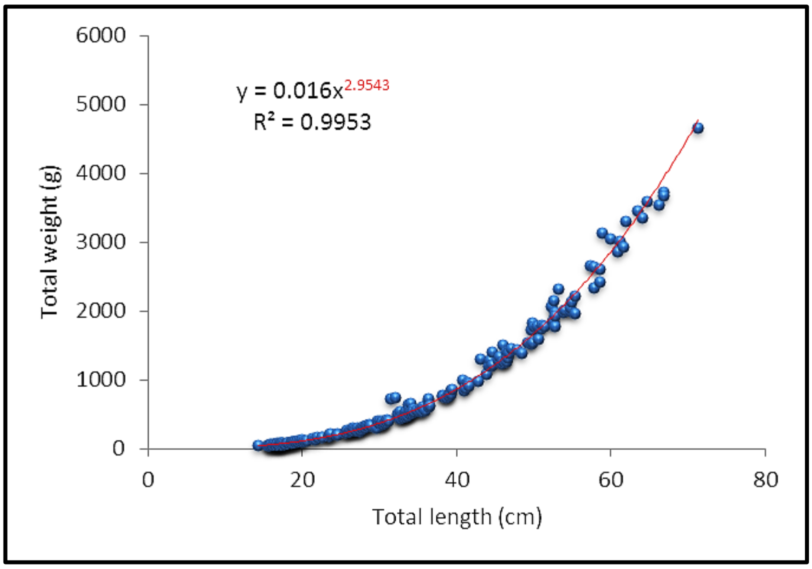

Fig. 9. The length weight relationship of *L. nebulosus* from the Red Sea, Egypt

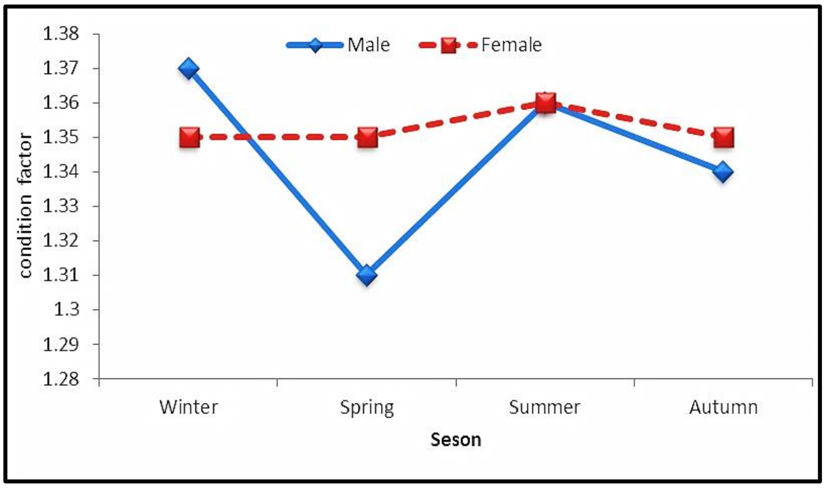

Fig. 10. The condition factor for male and female of *L. nebulosus* from the Red Sea

3.4. Age and growth

The microscopic examination of sectioned otoliths; through individuals whose total length ranged between 14.3 to 71.3cm, indicated a long lifespan, extending to 18 years (Fig.

11). The von Bertalanffy growth model was applied to determine length at age, yielding the following equation: L_t= 73.0 $(1-e^{-0.12(t+0.32)})$.

3.5. Length at first capture

The length at first capture of *L. nebulosus* collected from the Egyptian Red Sea was estimated as 29cm (Fig. 12).

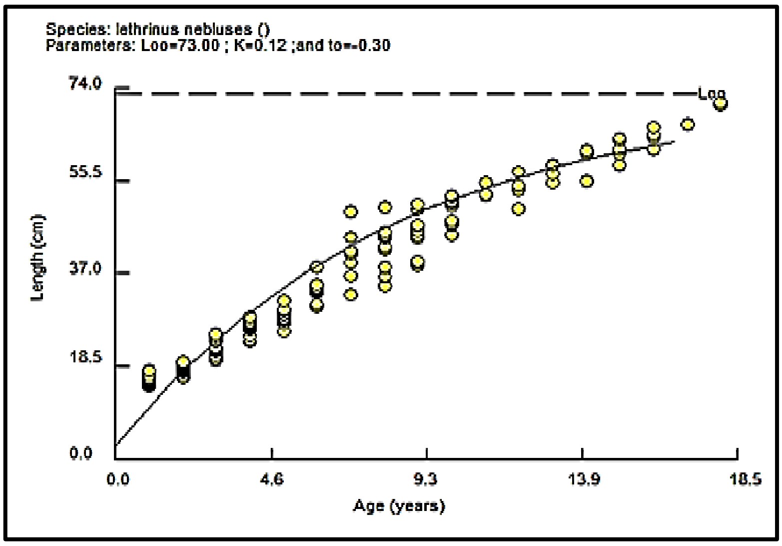

Fig. 11. The growth curve of length at age for *L. nebulosus* from the Red Sea, Egypt

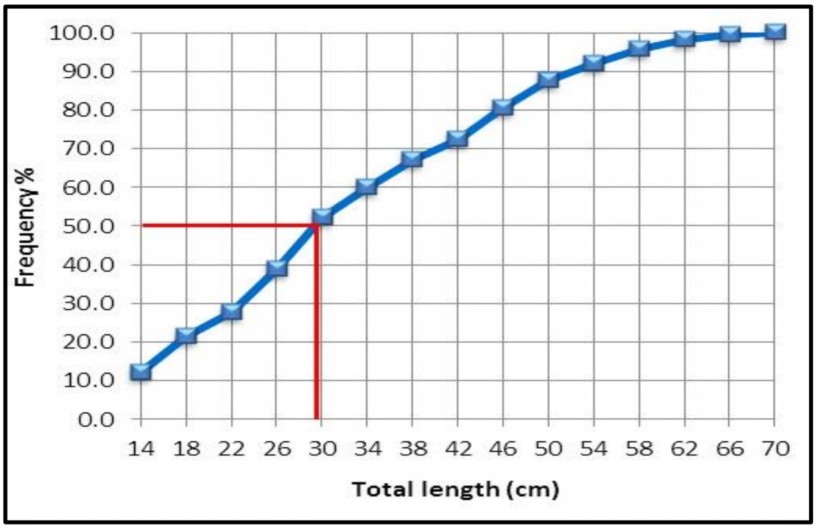

Fig. 12. The length at first capture for *L. nebulosus* from the Red Sea, Egypt

4. Reproductive biology

4.1. Sex ratio

The sex ratio of *Lethrinus nebulosus* was determined to be 1:1.15 (males to females), showing a non-significant deviation from the expected 1:1 ratio (Chi-square test, $P<0.05$). Seasonal variations revealed that females predominated in winter, spring, and autumn, with the highest proportion recorded in winter at 77%. Conversely, males were more dominant during summer, comprising 62.3% of the population (Fig. 13).

4.2. Gonado-somatic index

The peak of gonado somatic index was detected during spring, which was achieved simultaneously for both sexes, expressing the spawning period (Fig. 14).

4.3. Length at first sexual maturity

The length at first maturity for male and female of *L. nebulosus* was achieved at 33 and 36.1cm, respectively (Figs. 15, 16).

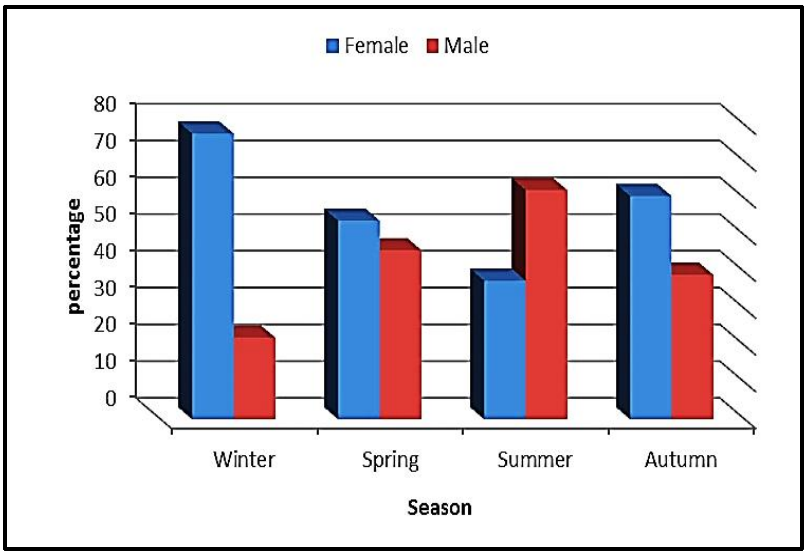

Fig. 13. Seasonal variations in the percentage of males and females of *L. nebulosus* from the Red Sea, Egypt

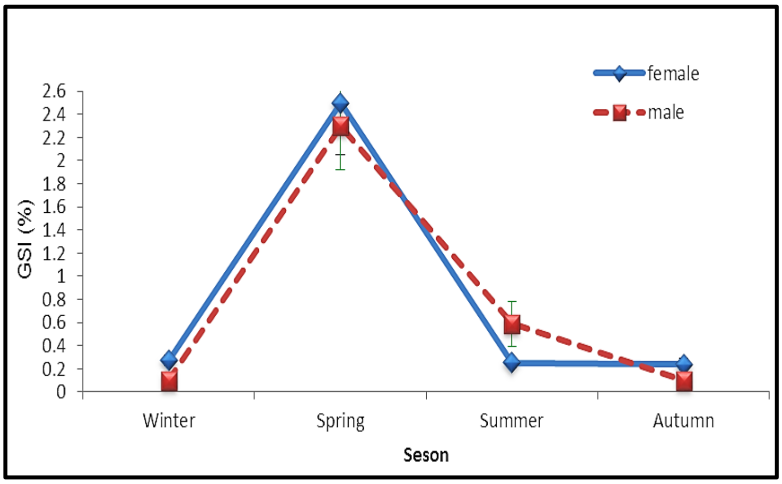

Fig. 14. Seasonal gonado somatic index for male and female of *L. nebulosus* from the Red Sea, Egypt

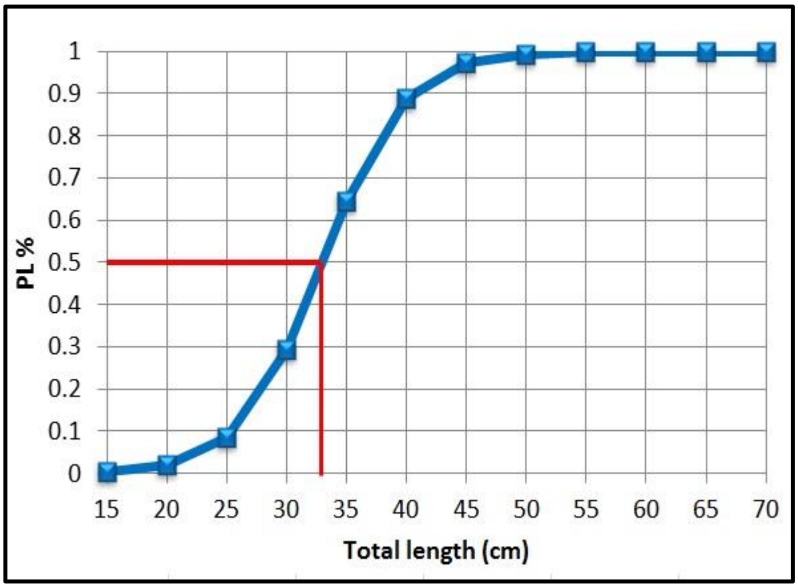

Fig. 15. The length at first maturity for males of *L. nebulosus* from the Red Sea, Egypt

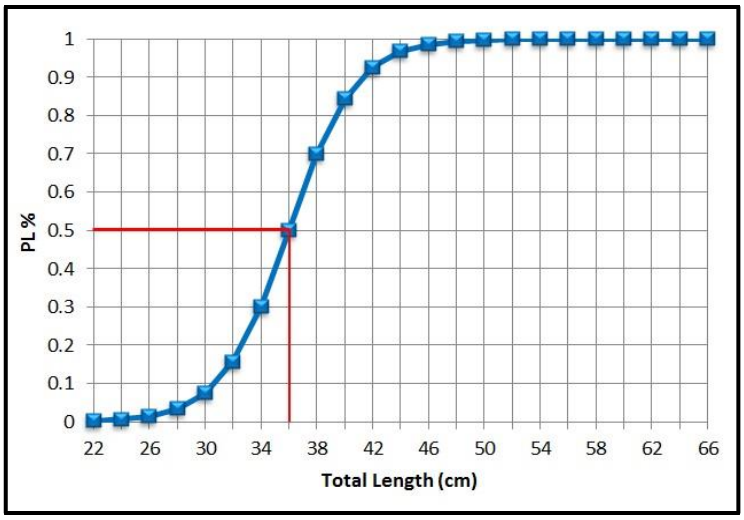

Fig. 16. The length at first maturity for females of *L. nebulosus* from the Red Sea, Egypt

4.4. Spawning aggregation sites

Most Red Sea species spawn in aggregations locally referred to as "Farshat." These aggregation sites have been specifically identified for the economically significant species *Lethrinus nebulosus* (Fig. 3). Site identification was conducted through interviews with experienced fishermen, a critical step for effective resource management. This process is essential for optimizing both biological and economic yields and ensuring the sustainability of marine resources. The reported locations provided by fishermen were validated using bottom longline methods, and the coordinates of these sites were recorded, as detailed in Table (2).

Table 2. Location and coordinates of the reported spawning aggregation sites of *L. nebuloses* in the Egyptian water of the Red Sea

Location (Local name)	Coordinates (Lat. & Long.)
Abu Melh	27.7373575 & 33.7203338
Abu Nahaas	27.6045727 & 33.7444368
Al Erok	27.5144387 & 33.7903237
Shadwan	27.4688645 & 33.8710166
Magawish	27.2781939 & 33.9490464
Disha	26.8922255 & 34.0622262

DISCUSSION

The ultimate objective of fisheries management was to achieve optimal and sustainable use of fishery resources while preserving the ecosystem **(Hilborn, 2007)**. The availability of up to dated scientific base is an effective tool for modern fisheries management and utilized operation. Updated biological measurements are an essential element of this system, which determining the amount and time of yielding and prevention to achieve the desired sustainability **(Tacconi *et al.*, 2020)**.

The annual production of *Lethrinus nebulosus* (spangled emperor) in the Red Sea has exhibited fluctuations throughout the past decade, with a general trend of decline **(LFRPDA, 2021)**. This decline is likely attributable to intense fishing pressure, driven by the species' high market demand and value. Local fishermen, who are well-acquainted with the species' spawning aggregation sites, known locally as Farshat, heavily exploit these areas during the spawning season.

Length-frequency analyses of *L. nebulosus* populations indicate a predominance of small to medium-sized individuals, a common indicator of overfishing **(Atar & Seçer, 2003)**. This size distribution may also be influenced by the sampling methods and gear employed in these studies **(El-Betar *et al.*, 2022)**.

Longline is among the foremost traditional and extensively used fishing methods globally, ranging from small-scale artisanal operations to sophisticated mechanized systems **(Bjordal & Løkkeborg, 1996)**. Longlines are often regarded as environmentally sustainable fishing gear due to their low energy consumption, reduced bycatch rates, and high selectivity **(Ingólfsson *et al.*, 2017)**. Soak time, the duration for which a longline remains deployed, is a crucial factor affecting its catch efficiency **(Løkkeborg & Pina, 1997; Peterson *et al.*, 2017)**. The ideal soak time fluctuates according to the target species and environmental conditions **(Løkkeborg & Pina, 1997)**. The study evaluated the effect of soak time on CPUE across four fishing seasons, finding that both soak time and fishing season had an impact on CPUE. These results align with those of **Vega and Licandeo (2009)**, who observed an increase in catch rates with extended soak times. However, contrary to their findings, this study did not identify a significant relationship between soak times and overall catch rates. While the soak time was crucial with the CPUE of sparedae, it did not appear to notably influence other target taxa. For example, **Echwikhi *et al*. (2012)** found that the soak duration had no significant effect on the

CPUE of groupers (*Epinephelus aeneus* and *Epinephelus marginatus*) in the Gulf of Gabès, Tunisia.

The relationship between length and weight is fundamental in understanding various aspects of growth and population dynamics in marine species. In the case of *Lethrinus nebulosus*, the length-weight relationship indicates an almost isometric growth pattern, with the exponent "b" calculated at 2.95. This suggests a proportional increase in both length and weight, reflecting similar growth rates in these two dimensions. Comparable values of "b" have been reported by **Sabrah and El-Ganainy (2013)** for populations in the Red Sea, and by **Vasantharajan *et al.* (2014)** for populations in Tamil Nadu, India. These findings support the notion of a consistent growth pattern across different regions. However, contrasting growth patterns have also been observed; **Taghavi Motlagh *et al.* (2010)** reported a negative allometric growth, while **Raeisi *et al.* (2011)** documented a positive allometric growth in other studies.

It is vital to notice that, variations in the "b" value can occur due to a range of factors, and this variation may not be attributed to any specific cause. Consequently, while there may be a general growth pattern for *L. nebulosus*, it is neither fixed nor universally applicable across all populations **(Chakraborty *et al.*, 2019)**.

The current study examined the longevity of *Lethrinus nebulosus* (spangled emperor) through age estimation using transverse sections of otoliths, revealing a maximum lifespan of 18 years. This finding is consistent with the reported result of **Sabrah and El-Ganainy (2013)** for the same species in the Gulf of Suez. Previous research using otolith sections has also suggested a relatively long lifespan for *L. nebulosus*, with maximum age estimates of 14 years **(Grandcourt *et al.*, 2006)** to 29 years **(Al-Mamry *et al.*, 2007)**. Notably, the oldest age determined from sectioned otoliths was 27 years **(Loubens, 1980)**, with **Al-Mamry *et al.*, (2007)** reporting an age of 29 years. In contrast, studies utilizing scales for age determination yielded significantly lower maximum ages, such as 14 years **(Aldonov & Druzhinin, 1979)** and 6 years **(Kuo & Lee, 1986)**. This analysis underscores the importance of using otolith sections for accurate age estimation in *L. nebulosus*, as it provides a more reliable indication of the species' potential longevity.

The estimated values of von Bertalanffy growth parameters were $L\infty$=73cm, K =0.12 year^{-1} and t_0 = -0.32, expressing a long lifespan and a slow growth rate, which coincided with the reported values of **Taghavi Motlagh *et al.* (2010)** for the same species in the Oman Sea and Persian Gulf.

Males attained the first sexual maturity (L_m) before females, at lengths of 33 and 36cm for each, respectively. Length at first capture (L_c=29cm) was much lower than that of the first maturation, which outbalance toward overexploitation and in agreement with dominancy of length group 30.

The spawning season for *L. nebuloses* likely occurs in spring, as derived from the seasonal values of GSI, which peaked in the specific season. The same trend line for spawning was observed by **Grandcourt *et al.* (2010)** in the southern Arabian Gulf and **Taghavi Motlagh *et al.* (2010)** in the Persian Gulf and Oman Sea. **Ebisawa (1990)** reported that the GSI for *L.*

nebuloses was gradually promoted and reaching their highest in March and April, then decrease gradually toward August in Okinawan Waters.

Among the relationships based on length and weight is the condition factor, which is a vital criterion for expressing the suitability of the environment for balanced growth and maturation **(Hile, 1936)**. The spangled emperor in the Red Sea showed a seasonal mean value of 1.36, providing habitat suitability. The lowest mean value, recorded in spring, was coincided with the peak of GSI. The inverse relationship between K and GSI is clear and evident, as a result of the depletion of the body's vital energy for the gonadal construction **(Froese, 2006; Dubey *et al*., 2014)**.

Many fish species dwelling the coral reef, particularly Lethrinidae, and groupers have been observed congregating in considerable numbers at specified times and locations for reproduction **(Osman *et al*., 2021)**. Some areas have exceptional ecological value and thus require protection to ensure the survival of species that settle down. Fish breeding grounds are examples of such habitats, but they are becoming extinct due to overfishing around the world **(Chollett *et al*., 2020)**. Detecting aggregation sites is critical for developing a management strategy and creating aggregation-based preserved regions. Overfishing has completely wiped out spawning aggregations in multiple locations in both the Atlantic and the Pacific oceans. **(Johannes *et al*., 1999)**. The temporal distribution of spawning aggregations of *L. nebuloses* was recorded from mid-April to mid-May in specific spawning sites, Abu Melh, Abu Nahhas, Al Erok, Shedwan, Magaweish and Disha.

Fish spawning aggregation (FSA) sites are of paramount importance for both ecological sustainability and conservation efforts. These sites are critical for the long term preservation of colonized species, holding a vital role in supporting the reproduction of many fish species **(Erisman *et al*., 2017)**. FSAs are hotspots of marine productivity, found across the most of marine ecoregions and habitat type, including coral reefs in warm, shallow waters, estuaries in subtropical regions, and submerged banks in temperate zones, and deep ocean seamounts.

There have been 906 documented instances of spawning aggregation sites across all five global oceans, involving 53 countries, 44 taxonomic families, and more than 300 fish species, making it the most extensive and detailed compilation of such data available **(Russell *et al*., 2014; SCRFA, 2014)**. The dataset, although extensive, exhibits a pronounced emphasis on tropical reef species, which may inadvertently marginalize numerous documented aggregations, particularly those occurring in non-reef and temperate habitats. For instance, various triggerfish (Balistidae) species are known to engage in nesting aggregations over sandy substrates adjacent to reef systems **(Domeier & Speare, 2012; Erisman *et al*., 2015)**.

Given the critical role of FSAs in fish reproduction and marine ecosystem health, the current study recommends completing further fieldwork at these identified sites to gather detailed information on reproductive behaviors.

CONCLUSION

Lethrinus nebulosus, commonly known as the spangled emperor, is a species of considerable commercial value and is heavily targeted by fishermen wherever it is found. The longline fishery in the Red Sea was assessed experimentally in the context of targeting this species. Two soaking times (12 and 8 hours) were examined, with the catch per unit effort (CPUE) of *L. nebulosus* and fish size increasing with longer soaking times.

Mathematical relationships based on length and weight indicated an isometric growth pattern, suggesting that the species thrives in an appropriate environment for good growth. The majority of individuals were small to medium-sized. This species demonstrates a long lifespan, with a maximum age of 18 years. It was found that 50% of the population had been caught before reaching sexual maturity, signaling concerns of overfishing.

Specific sites of aggregation and spawning were identified. Reducing fishing effort is an urgent priority, and continued fieldwork in these critical locations is essential for further understanding the species' reproductive behavior and ensuring its sustainable management.

REFERENCES

Al Mamry, J.M; El Ganainy, A.A.; McCarthy, I.; Richardson, C. and **Ben Meriem, S. (2007).** Age, growth and reproductive biology of the spangled emperor, *Lethrinus nebulosus*, Lethrinidae (Frosskal, 1775) from the Arabian Sea, Oman. *Egyptian Journal of Aquatic Research*, **33**(1): 395-410.

Aldonov, V.K. and **Druzhinin, A.D. (1979).** Some data on scavengers (Family Lethrinidae) from the Gulf of Aden region. *J. Ichthyol*., **18**: 527-535

Atar, H.H. and **Seçer, S. (2003).** Width/length-weight relationships of the blue crab (*Callinectes sapidus* Rathbun, 1896) population living in Beymelek Lagoon Lake. *Turkish Journal of Veterinary and Animal Sciences*, **27**(2): 443-447.

Babcock, C.; Pillans, D. and **Rochester, A. (2017).** Environmental and individual effects on the behaviour and spawning movements of *Lethrinus nebulosus* on a coral reef. *Marine and Freshwater Research*, **68**: 1422–1437 http://dx.doi.org/10.1071/MF16194.

Bjordal, Å. and **Løkkeborg, S. (1996).** Long lining .Oxford: Fishing News Books.Osney Mead.

Chakraborty, M.; Mandal, B. and **Chanda, A. (2019).** Seasonal variation of length-weight relationship of *Mystus vittatus* (Bloch, 1794) in two different aquatic habitat. *International Journal of Fisheries and Aquaculture Sciences*, **9**(1): 1-13.

Chollett, I.; Priest, M.; Fulton, S. and **Heyman, W.D. (2020).** Should we protect extirpated fish spawning aggregation sites? *Biological Conservation*, **241**: 108395.

Domeier, M.L. and **Speare, P. (2012).** Dispersal of adult black marlin (*Istiompax indica*) from a Great Barrier Reef spawning aggregation. *PLoS One*, **7**(2): e31629.

Domeier, M.L. and **Colin, P.L. (1997).** Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science,* **60:** 698–726.

Dubey, S.K.; Chakraborty, D.C.; Bhattacharya, C. and **Choudhury, A. (2014).** Allometric relationships of red ghost crab *Ocypode macrocera* (H. Milne-Edwards, 1852) in Sundarbans mangrove eco-region, India. *World Journal of Fish and Marine Sciences*, **6**(2): 176-181.

Ebisawa, A. (1990). Reproductive Biology of *Lethrinus nebulosus* (Pisces: Lethrinidae) Around the Okinawan Waters. Nippon Suisan Gakkaishi: Formerly Bull. *Japan. Soc. Sci. Fish*., **56**(12): 1941-1954.

Echwikhi K., Jribi I., Bradai M.N. and **Bouain A. (2012)**. Interactions of loggerhead turtle with bottom longline fishery in the Gulf of Gabès, Tunisia. *Journal of the Marine Biological Association of the United Kingdom*, **92**(4): 853–858. DOI: 10.1017/S0025315411000312.

El-Betar, T.; El-Aiatt, A. and **Shalloof, K. (2022).** Population structure and growth aspects of blue swimming crab, *Portunus pelagicus*, in Lake Bardawil, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries,* **26**(4): 885- 903.

Erisman, B.; Heyman, W.; Kobara, S.; Ezer, T.; Pittman, S.; Aburto-Oropeza, O. and **Nemeth, R.S. (2017).** Fish spawning aggregations: where well-placed management actions can yield big benefits for fisheries and conservation. *Fish and Fisheries*, **18**(1): 128-144.

Erisman, B.; Mascareñas, I.; Lopez-Sagastegui, C.; Moreno-Baez, M.; Jimenez-Esquivel, V. and **Aburto-Oropeza, O. (2015).** A comparison of fishing activities between two coastal communities within a biosphere reserve in the Upper Gulf of California. *Fisheries Research*, **164**: 254–265.

Fabens, A.J. (1965). Properties and fitting of the von Bertalanffy growth curve. *Growth*, **29**: 265-289.

Froese, R. (2006). Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendation. *Journal of Applied Ichthyology*, **22**: 241-253.

Grandcourt, E.M.; Thabit, Z. and **Al Shamsi, F.F. (2006).** Biology and assessment of the painted sweetlips *Diagramma pictum* (Thunberg, 1792) and the spangled emperor *Lethrinus nebulosus* (Forsskål, 1775) in the southern Arabian Gulf. *Fishery Bulletin*, **104**: 75–88.

Grandcourt, E.M; Al abdessalam, T.Z.; Francis, F.; Shamsi, A.T. and **Hartman, S.A. (2009).** Reproductive biology and implications for management of the orange spotted grouper *E. coioides* in the southern Arabian gulf. *Journal of fisheries biology*, **74**: 820- 841

Grandcourt, E.M.; Al Abdessalaam, T.Z.; Francis, F. and **Al Shamsi, A.T. (2010).** reproductive biology and implications for management of the spangled emperor *Lethrinus nebulosus* in the southern arabian gulf. *Journal of Fish Biology*, **77**: 2229–2247 doi:10.1111/j.1095-8649.2010.02799.x.

Hilborn, R. (2007). "Managing fisheries is managing people: what has been learned?". *Fish and Fisheries,* **8** (4): 285–296. doi:10.1111/j.1467-2979.2007.00263_2.x

Hile, R. (1936). Age Determination of Fish from Scales; Method and Application to Fish Cultural Problems. *The Progressive Fish-Culturist*, **3**(23): 1-5, DOI: 10.1577/1548-8640(1936)323[1:ADOFFM]2.0.CO;2

Ingólfsson, Ó.; Einarsson, H.A. and Løkkeborg, S. (2017): The effects of hook and bait sizes on size selectivity and capture efficiency in Icelandic longline fisheries. *Fisheries Research*, **19**:10-16.

Johannes, R.E.; Squire, L.; Graham, T.; Sadovy, Y. and **Renguul, R. (1999).** Spawning Aggregations of Groupers (Serranidae) in Palau. *The Nature Conservancy Marine Conservation Research Series Publication*, **l**: 144 pp

Kuo, C.L. and **Lee, S.S. (1986).** Age and growth of common porgy, *Lethrinus nebulosus* (Forsskål) in shelf waters off northwest Australia. *J. Fish. Soc. Taiwan*, **3**: 39-57.

LFRPDA. (2021). Lakes and Fish Resources Protection and Development Agency (LFRPDA). In: Fisheries Statistics Yearbook.

Løkkeborg, S. and **Pina, T. (1997).** Effects of setting time, setting direction and soak time on longline catch rates. *Fisheries Research*, **32**(3): 213-222.

Loubens, G. (1980). Biologie de quelques espe`ces de Poissons du lagon Ne´o-Cale´donien. III.Croissance. Cah. Indo-Pac., **2**: 101–153.

Marriott, R.J.; Jarvis, N.D.C.; Adams, D.J.; Gallash, A.E.; Norriss, J. and **Newman, S.J. (2010).** Maturation and sexual ontogeny in the spangled emperor, *Lethrinus nebulosus*. *Journal of Fish Biology*, **76:** 1396–1414.

Osman, H.M. (2016). Biological and Fisheries Studies on barracuda fish (Family: Sphyraenidae) in the Gulf of Suez Ph.D. Thesis. Fac. Sci. Suez Canal, Uni., Ismailia, Egypt.

Osman, H.M.; El Ganainy, A.A.; Shaaban, A.M. and **Saber, M.A. (2021).** Reproductive biology of the two commercially important grouper species *Epinephelus summana* and *E. polyphekadion* in the Egyptian coast of the Red Sea. *Egyptian Journal of Aquatic Biology & Fisheries*, **25**(1): 665 – 679.

Pauly, D. and **Munro, J.I. (1984).** Once more on the comparison of growth in fish and invertebrates. *Fish Byte*, **2**: 21–23.

Pauly, D. (1984). Length-converted catch curves. A powerful tool for fisheries research in the tropics. (III: conclusion). *ICLARM Fish byte*, **2** (3): 9–10.

Peterson, C.D., Gartland, J. and **Latour, R.J. (2017).** Novel use of hook timers to quantify changing catchability over soak time in longline surveys. *Fisheries Research*, **194**: 99-111.

Raeisi, H.; Daliri, M.; Paighambari, S.Y.; Shabani, M.J.; Bibak, M. and **Davoodi, R. (2011).** Length-weight relationships, condition factors and relative weight of five fish species of Bushehr waters, Northern Persian Gulf. *African Journal of Biotechnology*, **10**(82): 19181-19186.

Randall, J.E. (1995). Coastal Fishes of Oman. Honolulu, HI: University of Hawaii Press.

Render, J.H.; Thompson, B.A. and **Allen, R.L. (1995).** Reproductive development of striped mullet in Louisiana Estuarine waters with notes on the applicability of reproductive assessment methods for isochronal species. *Transactions of the American Fisheries Society*, **124**(1): 1-15.

Russell, M.W.; Sadovy de Mitcheson, Y.; Erisman, B.E.; Hamilton, R.J.; Luckhurst, B.E. and **Nemeth, R.S. (2014).** Status report–world's fish aggregations 2014. science and conservation of fish aggregations, California, USA. *International Coral Reef Initiative*, **2**.

SCRFA. (2014). Science and Conservation of Fish Aggregations. Spawning aggregation database by Science and Conservation of Fish Aggregations. World Wide Web electronic publication. Available at: http://www.scrfa.org/database/ (accessed 25 June 2015).

Sabrah, M. and **El-Ganainy, A. (2013).** Some considerations on overexploitation of coral reef fish in relation to coral reef degradation in El-Tour, south Sinai, Egyptian Red Sea coast. *Journal of fisheries and aquatic sciences,* **8**(6): 673-685.

Smith, S.V. (1978). Coral-reef area and the contributions of reefs to processes and resources of the world's oceans. *Nature*, **273**: 225–226. https://doi.org/10.1038/273225a0

Sparre, P.; Ursin, E. and **Venema, S.C. (1989).** Introduction to tropical fish stock assessment. part 1- manual. *FAO Fish Tech. Pap.*, No. 306, 337

Sparre, P., and **Venema, S.C. (1998).** *Introduction to Tropical Fish Stock Assessment - Part 1: Manual*. FAO Fisheries Technical Paper No. 306/1, Re

Tacconi, L.; Williams, M. and **Aled, D. (2020).** Corruption and Anti-Corruption in Environmental and Resource Management. *Annual Review of Environment and Resources*. **45**: 305–329. doi:10.1146/annurev-environ-012320-083949

Taghavi Motlagh, S.A.; Vahabnezhad, A.; Seyfabadi, S.J.; Ghodrati Shojaei, M. and **Hakimelahi, M. (2010).** Growth, mortality and spawning season of the spangled emperor (*Lethrinus nebulosus* Forsskal, 1775) in coastal waters of Hormozgan Province in the Persian Gulf and Oman Sea. *Iranian Journal of Fisheries Sciences,* **9**(1): 161-172

Vasantharajan, M.; Jawahar, P.; Sundaramoorthy, B. and **Venkatasamy, M. (2014).** Length - weight relationship of *Lethrinus lentjan* (lacepede, 1802) and *Lethrinus nebulosus* (forsskal, 1775) exploited in thoothukudi coast, tamil nadu, india. *Ind. J. Vet & Anim. Sci. Res.,* **43**(1): 14 - 18.

Vega, R. and **Licandeo, R. (2009).** The effect of American and Spanish longline systems on target and non - target species in the eastern South Pacific swordfish fishery. *Fisheries Research,* **98**: 22 -32.s

Young, P.C. and **Martin, R.B. (1982).** Evidence for protogynous hermaphroditism in some Lethrinid fishes. *Journal of Fish Biology***, 21:** 475–484.