ANSF® APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
16(4), 1552 - 1563 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Growth, mortality and stock assessment of *Metapenaeus affinis* (Decapoda, Penaeidae) from Iraqi waters

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Article Info
https://doi.org/10.31018/jans.v16i4.5910
Received: July 4, 2024
Revised: November 13, 2024
Accepted: November 17, 2024

How to Cite
Hassan, K. A. *et al.* (2024). Growth, mortality and stock assessment of *Metapenaeus affinis* (Decapoda, Penaeidae) from Iraqi waters. *Journal of Applied and Natural Science*, 16(4), 1552 - 1563. https://doi.org/10.31018/jans.v16i4.5910

Abstract
Jinga shrimp (*Metapenaeus affinis*) is one of the most productive shrimp fisheries in Iraqi waters. The study aimed to evaluate the growth, mortality, recruitment, yield-per-recruit, and virtual population analysis (VPA) of the *M. affinis* shrimp in these Iraqi waters. Samples were collected from the nursery grounds of the species in east Hammar marsh and the fishing grounds in Iraqi marine waters between November 2022 to October 2023. A total of 8021 *M. affinis* ranged from 2.0 to 15.6 cm TL (0.6-6.0 cm CL) were examined. The length-weight relationship exhibited a positive allometric growth pattern. Total length-frequency data for combined sexes was analyzed using the FiSAT II software. The asymptotic length, growth coefficient and growth performance index were 16.3 cm, 0.92 and 2.388, respectively. Total, natural and fishing mortalities were 3.69, 1.82 and 1.87, respectively. The current exploitation rate (E_{cur}) was 0.51. Length at first capture (L_{c50}) was higher than at first maturity length (L_{m50}). Recruitment continued throughout the year, with one major peak in April. The analysis of relative yield per recruit and relative biomass per recruit indicated that the E_{cur} of the stock was equal to its optimal level ($E_{0.1}$= 0.520) and below its maximum sustainable yield (E_{max}= 0.628). To effectively manage the *M. affinis* stock, it is essential to adjust the mesh size so that the total length of the species at first capture must not be less than the length at first maturity. Consequently, it may have a chance to breed, and the nursery grounds should be protected from illegal fishing.

Keywords: Arabian Gulf, East Hammar marsh, Growth and mortality, *Metapenaeus affinis*, Yield-per-recruit

INTRODUCTION

The Jinga shrimp *Metapenaeus affinis* (Milne Edwards, 1837) (Decapoda, Penaeidae) inhabits the Arabian Gulf area, coasts of India, Pakistan, Sri Lanka, the east and west coasts of Malaya to Taiwan Province of China, the Philippines, and Papua New Guinea. It is found in depths of about 55 m (occasionally in deeper water to 90 m) from the coastline, mainly on mud or sandy mud (Holthius, 1980; Fischer and Bianchi, 1984; Carpenter and Niem, 1998). In addition, it was first recorded in the Turkish and Egyptian waters of the Mediterranean Sea by Aydin *et al*. (2009) and Ahmed *et al*. (2021).
Due to its significance in fisheries, many researchers have studied the stock assessment and population dynamics of the *M. affinis* population in different waters around the world using ELEFAN I or FiSAT II Software. Some of these include Kuwait waters in the Arabian Gulf (Mohammed *et al*., 1998), Terengganu Waters in Malaysia (Ibrahim, 2001), the Mekong Delta in Vietnam (Dinh *et al*., 2010), Hormozgan Province in Iran (Gerami *et al*., 2012), Qeshm Island in the Arabian Gulf (Safaie, 2012), the Coast of Khoozestan Province in the Arabian Gulf (Ansari *et al*., 2014), Kotabaru waters in Indonesia (Tirtadanu *et al*., 2017), Gujarat waters in India (Dash *et al*., 2018), North Coast of Central Java in Indonesia (Saputra *et al*., 2018), Mediterranean Sea in Egypt (Abdel Razek *et al*., 2022), Samboja Kuala waters in Indonesia (Jahrah et al., 2023), and Ratnagiri coast of Maharashtra in India (Dongre *et al*., 2023).

In Iraqi waters, the family Penaeidae is prevalent in the fisheries, particularly the shrimps *Metapenaeus affinis, Penaeus semisulcatus* and *Parapenaeopsis stylifera*. The shrimp fishery in these waters is entirely artisanal, and the marine landings have varied over the past two decades. From 2008-2009 to 2020-2022, the total landings have increased from 123.4 t (1.85% of the total catch) to 7,288 t (14.4% of the total catch), according to Mohamed and Abood (2024).

It is a widely accepted fact that the postlarval and/or juvenile stages of *M. affinis* migrate from the northern part of the Arabian Gulf towards the Shatt Al-Arab River to reach the nursery grounds in the marshes of Basrah, which is synchronized with the tide in August and September. Recruitment to the marshes stock showed a single peak in autumn. *M. affinis* of varying sizes ranging from 0.3-12.5 cm total length have been found in the marshes, supporting the belief that the marshes may be the primary nursery grounds for this species in the north Arabian Gulf. The large shrimp migrate from the marsh back to the spawning grounds to mature sexually and spawn (Mathews *et al*., 1986; Salman *et al*., 1990; Mohammed *et al*., 1998). Garcia (1985) noted that a typical Penaeus spawns at the sea and enters inshore waters as a postlarva at about three weeks to one month old. It stays there for nearly three months, during which it grows. Subsequently, it migrates back to the sea when it is about four months old and measures 8.0 to 10.0 cm in total length. Therefore, *M. affinis* is caught in two different regions within Iraqi waters: marine waters in the Arabian Gulf and brackish inland waters in the marshes. Ali (2001) stated that the total annual catches of *M. affinis* in Iraqi marine waters during 1998/1999 ranged from 174.6-279.4 t/yr, and in inland waters (marshes) was 1200 t from April 2000 to January 2001. Abbas and Ghazi (2021) indicated that the lowest landings of *M. affinis* in two main fish markets in Basrah province was 503 kg in November or December and the highest landing was 994 kg in July. Al-Maliky (2022) found that the size of *M. affinis* varied between 1.0 and 10.0 cm TL. The overall catch rate was 124±10.6 kg/h, with the highest catch in September and the lowest in December-February in the Masshab area near Al-Hammar marsh, Basrah.

All studies have focused on the fishery of *M. affinis* in Iraqi waters, including Ali (2001), Ali *et al*. (2001), Ali and Ahmed (2015), Abbas and Ghazi (2021) and Al-Maliky (2022). Consequently, the present study was the first attempt to assess the growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit, and virtual population analysis of *M. affinis* in Iraqi waters.

MATERIALS AND METHODS

In Iraq, the shrimp *M. affinis* is exploited at different life stages, including post-larval, sub-adult, and adult stages. The study was conducted at two locations in Iraqi waters from November 2022 to October 2023. The first location was the nursery ground in the east Hammar marsh, north of Basrah. The second location was the fishing ground located northwest of the Arabian Gulf, within the Iraqi marine waters (Fig. 1).

The East Hammar marsh is an extensive area of wet-

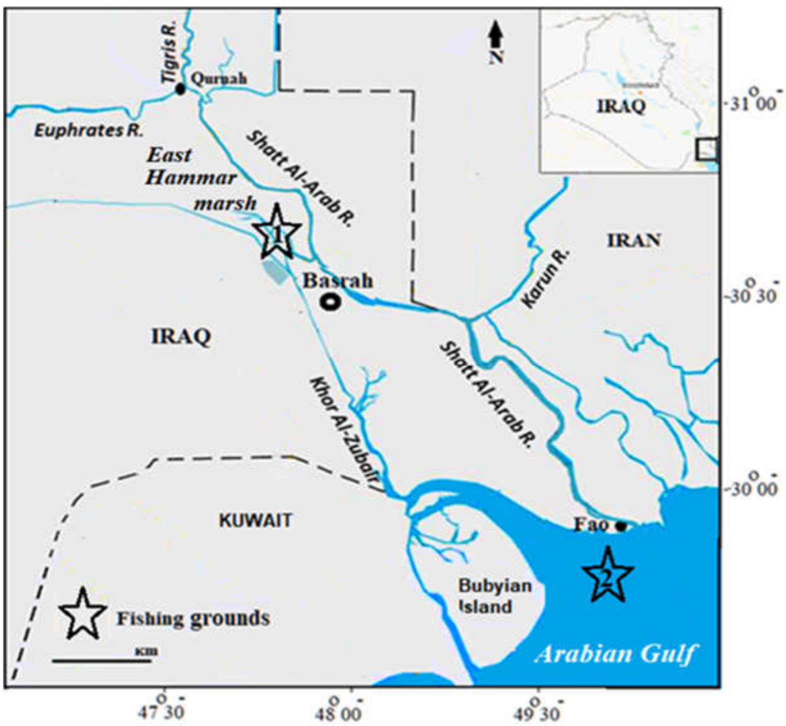

Fig. 1. *Fishing grounds of Metapenaeus affinis in Iraqi waters*

lands, located at the upper corner formed by the meeting of the Euphrates and Shat Al-Arab Rivers and extends west to the oilfields of West Qurna, the marsh received water mainly from the Shatt Al-Arab River through the Garmat Ali River, therefore, it is tidal marsh affected by the semidiurnal tide from Arabian Gulf (Mohamed *et al*., 2017). The marsh was covered by tall reed beds of *Phragmites australis* and *Typha domingensis*, in addition to *Ceratophyllum demersum*, *Nagas* sp., *Potamageton pectinatus*, *P. perfiolatus*, *Meriophylum sipctum*, *Salvinia natans* and *Vallisiniria spirlais* (Al-Abbawy and Al-Mayah 2010). A variety of freshwater fish species established in this marsh such as *Carasobarbus luteus*, *Leuciscus vorax, Luciobarbus xanthopterus, Mesopotamichthys sharpeyi, Planiliza abu, Cyprinus carpio, Carassius auratus, Oreochromis aureus* and *O. niloticus*. Additionally, several marine fish, including anadromous species *like Tenualosa ilisha, P. subviridis, P. klunzingeri*, and Penaeidae shrimps *Metapenaeus affinis*, migrate to the marsh for spawning, feeding, or as a nursery (Mohamed *et al*., 2009; Mohamed *et al*., 2017).

Shrimp samples were obtained from the fishermen who caught the shrimps from the areas of Al-Masshab and Al-Assafiya Creek, south of the east Hammar marsh, using a traditional method known locally as 'Kasrah', the trawl (Gufa) and seine nets (Salman *et al*., 1990; Al -Maliky, 2022).

The second sampling location was in the marine waters of Iraq, northwest Arabian Gulf. Although the Iraqi coastline along the Gulf is only 105 km long, it has a continental shelf of 1034 km2 and a territorial sea of 716 km2 (Earth Trends, 2003). In this region, a large river delta formed by the Euphrates, Tigris, and Karun rivers converge in the Shatt Al-Arab and flow into the Arabian Gulf (Pohl *et al*., 2014). This region is distinguished by its shallow and highly turbid waters supporting a diverse range of marine species due to the substantial input of nutrients from the Shatt Al-Arab River, serving as a significant nursery, feeding, and reproduction ground for various commercially important species, including shrimp due to nutrient-rich freshwater from the river to the northwestern Arabian Gulf (Food and Agriculture Organization, 2014; Al-Yamani, 2021). The waters have a long history of artisanal fishing, targeting a variety of fish and shrimp species. These include river shad (*Tenualosa ilisha*), silver pomfret (*Pampus argenteus*), mullets (*Planliza subviridis* and *P. klunzingeri*), Emperor (*Lethrinus nebulosus*), Seabream (*Acanthopagrus arabicus* and *A. berda*), croakers (*Otolithes ruber* and *Johnieops belangerii*), and shrimp species such *as Penaeus semisulcatus* and *Metapenaeus affinis*. Additionally, some stocks are shared with neighboring countries (Kuwait and Iran), including river shad, silver pomfret, mullets, and shrimps (Mohamed and Abood, 2024). Fishing activities are primarily concentrated in the Shatt Al-Arab estuary, Khor Abdulla, and Khor Al-Amaya regions. Different gear, such as drift gillnets, trawl nets, traps (gargoor), and stake nets (hadra) are utilized (Mohamed and Jawad, 2021). Despite the restriction of the Iraqi coastline of 105 km, continental shelf of 1034 km^2 and territorial sea of 716 km^2 (Earth Trends, 2003), it is characterized from other parts of the Gulf by having shallow and high turbidity (Albadran *et al*., 2016) and the productive by having numbers of marine species coexist and thrive here due to receiving massive amounts of fluvial input via the Shatt Al-Arab River, which historically plays an important role in providing the northwestern Arabian Gulf with nutrient-rich fresh (Al-Yamani, 2021) and serves as a significant nursery, feeding and reproduction grounds for several economic shares between countries, include shrimp (Food and Agriculture Organization, 2014). These waters have a long history of artisanal fishing, which catches various fish and shrimps. The fishing activities are mainly concentrated in the Shatt Al-Arab estuary, Khor Abdulla, and Khor Al-Amaya regions using different fishing gear including drift gillnets, trawl nets, traps (gargoor), and stake nets (hadra) (Mohamed and Jawad, 2021). Shrimp samples were collected from the main site for marine resource landing at Fao (Fig. 1). Specimens were stored in the iceboxes and transported to the Department of Fisheries and Marine Resources laboratory for further examination in the laboratory.

In the laboratory, the shrimp samples were sorted by species using identification keys from Fischer and Bianchi (1984), with *M. affinis* being one of the identified species. Each shrimp specimen was measured for total length (TL) and carapace length (CL) to the nearest 0.1 cm using a digital Vernier calliper. The weight of the shrimp and gonad was measured to the nearest 0.1 g using a digital scale. The lengths were grouped into 1.0 cm length groups for males and females. The length at 50% maturity (L_{m50}) was designed using the following equation (Binohlan and Froese, 2009): log (L_{m50})= -0.1189 + 0.9157* log (L_{max}), where L_{max} is the largest individual observed in the samples. The total length (TL)-carapace length (CL) relationship of *M. affinis* was estimated using the linear regression formula: CL= a + b TL, where, a and b are constants determined by the least squares method. The length-weight relationship was determined using the power equation W= a L^b (Le Cren, 1951), where, W= weight of shrimp in grams, L= total length in cm, *a* is a coefficient related to the body form and *b* is an exponent indication growth. Significant deviations from the b values were observed by a t-test to detect growth types, isometric and allometric (Froese, 2006). The t-test was executed to check the similarity of the regression line between males and females.

The total length-frequency data for combined sexes of

M. affinis were analyzed using the FAO-ICLARM Stock Assessment Tools II (FiSAT II) software (Gayanilo *et al*., 2005). The growth parameters, asymptotic length $L\infty$ and annual growth coefficient K were computed by ELEFAN I module implemented in the FiSAT II software package using the initial seed value for $L\infty$ as the largest individual (L_{max}) seen in the samples, thus: $L\infty = L_{max}/0.95$ (Taylor, 1958). The best growth curve was then fitted based on a non-parametric scoring from the goodness of a fit index, the so-called "R_n value". The theoretical age at birth (t_o) was estimated independently using the equation of Pauly (1983):

$$\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L\infty - 1.0381 \log_{10} K \quad (1)$$

The growth performance index was generated using the formula of Pauly and Munro (1984):

$$(Ø) = 2\log L\infty + \log K \quad (2)$$

The total mortality rate (*Z*) was estimated using the length-converted catch curve method (Pauly, 1984), as implemented in the FiSAT II software. The natural mortality rate (*M)* was calculated by using the formula suggested by Pauly (1980) as follows: $\log_{10} M = -0.0066 - 0.279 \log_{10} L\infty + 0.6543 \log_{10} K + 0.463\log_{10}$, where, $L\infty$ and K are the growth parameters and T is the annual mean water temperature, 22.8°C (Raadi *et al*., 2023). The fishing mortality rates (F) were then calculated by the difference between (Z) and (M). The current exploitation ratio (E_{cur}) was calculated from the ratio F/Z (Gulland, 1971).

The catch-curve analysis was extended to estimate the capture probabilities by the backward projection of the length-converted catch curve using $L\infty$ and K parameters as input in FiSAT. The probability of capture of sequential length classes was regressed using a logit curve to estimate L_{C25}, L_{C50} and L_{C75}.

The recruitment pattern was obtained following the procedure described in the FiSAT routine, which involves the backward projection of length frequencies onto the time axis based on growth parameters (Pauly 1983).

Relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were estimated for *M. affinis* using the knife-edge analysis of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and incorporated in FiSAT software. The $L_c/L\infty$ and M/K values were used to estimate $E_{0.1}$ (the exploitation rate at which the marginal increase in relative yield-per-recruit is 10% of its value at E= 0, the optimum fishing mortality), $E_{0.5}$ (the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit) and E_{max} (the exploitation rate giving maximum sustainable yield per recruit). The current exploitation rate (E_{cur}) and the biological target reference points ($E_{0.1}$ and E_{max}) were used to indicate the stock status (Cadima, 2003).

The length-frequency data used to carry out virtual population analysis (VPA) using the length convert curve procedure of Jones and van Zalinge (1981) in the FiSAT routine. The values of the $L\infty$, K, M, F and the constants (a and b) of the length-weight relationship for the species were used as inputs to VPA analysis. The results of the VPA analysis were the population size, catches and natural and fishing rates by length group.

Ethical approval

The work is based on commercial shrimp species and the specimens were collected from a commercial catch. Therefore, ethical aspects are not applicable.

RESULTS

Length-frequency distributions and maturity

In this study, 8021 *M. affinis* shrimp species were measured with a total length range of 2.0 to 15.6 cm and the length-frequency distribution showed an unimodal type (Fig. 2). The lengths from 6.0 to 10.0 represented 73.6 % of the total fish number. The 7.0 cm size group was numerically dominant (19.51%), followed by 6.0 cm, and constituted 18.93% of the total number. The total length at which *M. affinis* first reaches sexual maturity (L_{m50}) is 9.4 cm (3.5 cm CL).

Length-length relationship

The relationship of total length (TL) to its carapace length (CL) for all individuals of *P. semisulcatus* was CL= 0.3965*TL - 0.1994, r^2= 0.976 for 714 specimens (Fig. 3).

Length-weight relationship

A study was conducted to determine the relationship between length and weight for 4048 individuals of *M. affinis* (Fig. 4). The total length and weight of the species ranged from 3.0-15.6 cm and 0.22-30.71 g. The length-weight equation was estimated to be $W = 0.0079TL^{2.939}$. The b-values was significantly different from 3 (t= 7.090, $p<0.05$), indicating negative allometric growth.

Growth and mortality

The ELEFAN I routine used response surface (R_n) analysis to identify the optimal growth parameters ($L\infty$ and K) of *M. affinis* based on an initial seed value of $L\infty$ (15.6 cm). The greatest estimate of the R_n value selected from the restructured length-frequency curve was 0.276 (Fig. 5). The restructured length frequency of the species with superimposed growth curves is shown in Figure 6. The best growth constants ($L\infty$ and K) values were estimated as 16.3 cm and 0.92, respectively, so the theoretical age at zero (t_o) was -0.084. The growth performance index (Ø) was estimated to be 2.388.

The length-converted catch curve analysis was used to estimate the mortality rates of *M. affinis* (Fig. 7). The analysis predicted the value of the total mortality (Z) at 3.69, with the coefficient of determination (r^2) of this

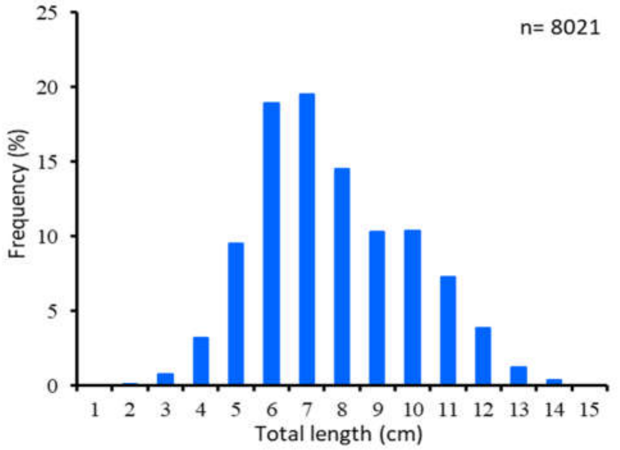

Fig. 2. *Overall length-frequency distribution of Metapenaeus affinis*

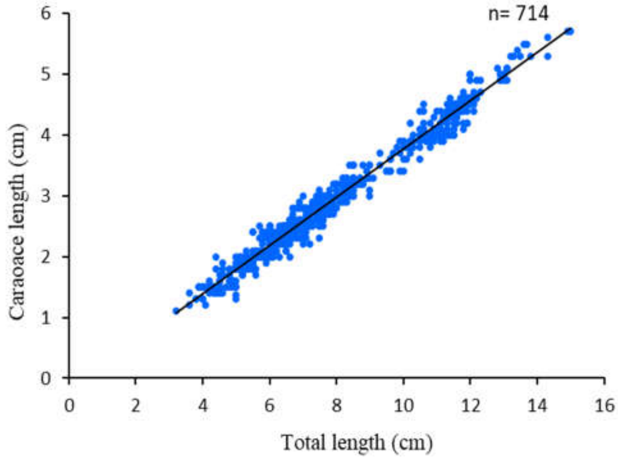

Fig. 3. *Total length and carapace length relationship of Metapenaeus affinis*

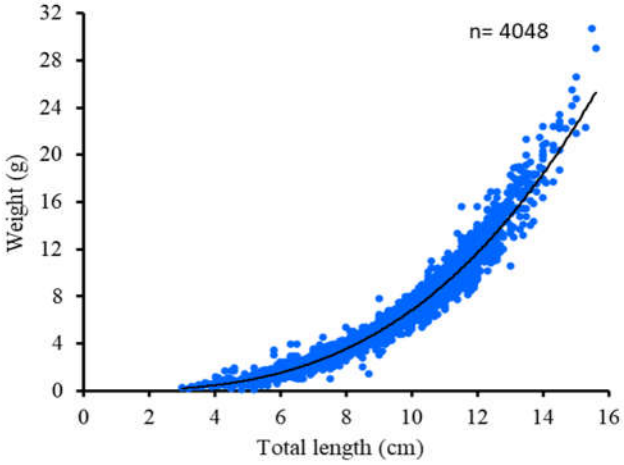

Fig. 4. *Length-weight relationship of the whole sample of Metapenaeus affinis*

estimation being 0.990. The natural mortality was 1.82 and the fishing mortality rate was 1.87. The current exploitation rate (E_{cur}) was 0.51.

Capture Probability

Figure 8 displays the logistic probability of capturing *M. affinis*. The study's findings indicate that the species' L_{25}, L_{50}, and L_{75} values are 5.59, 6.32, and 7.06 cm, respectively. The estimated length at which 50% of the stock biomass is susceptible to capture is L_{c50}= 6.32 cm.

Recruitment pattern

As shown in Figure 9, the annual recruitment pattern of *M. affinis* revealed one main pulse that contributed 78.0% of the total recruits, extended from February to June with a peak in April (22.2%).

Yield per Recruit (Y'/R) and Biomass per Recruit (B'/R)

The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) analyses for *M. affinis* were conducted using a function of M/K (1.978) and L_c/L_∞ (0.40), which derived from the previous analyses (Fig. 10). The analyses gave an $E_{0.1}$= 0.511, $E_{0.5}$= 0.333 and E_{max}= 0.628. The current exploitation rate (E_{cur}= 0.51) was equal to its optimal level ($E_{0.1}$) and lower than its maximum sustainable yield (E_{max}). The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.026 and 0.263, respectively.

Virtual population analysis

Figure 11 demonstrates the results of the virtual population analysis (VPA) of *M. affinis* regarding natural losses, survivability, catches, and fishing mortality. The data indicates that individuals with lengths between 2.0 and 6.0 cm have the highest natural mortality rates. Survivorship was highest among individuals measuring

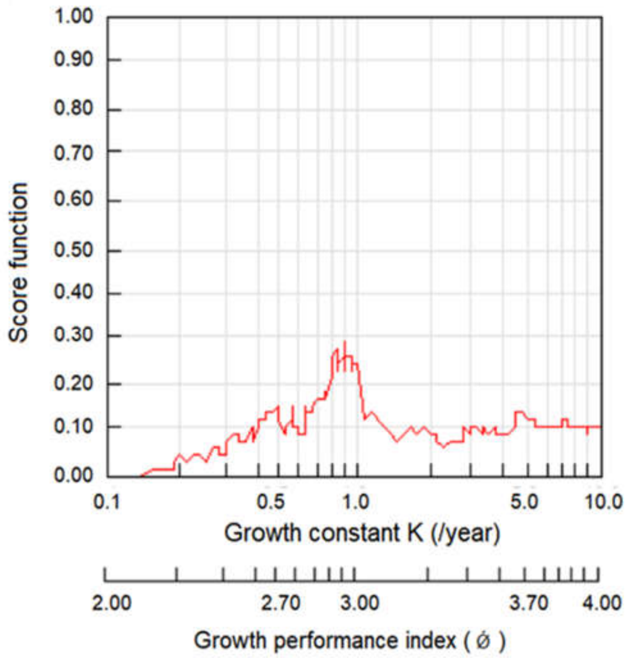

Fig. 5. *K-scan routines of M. affinis*

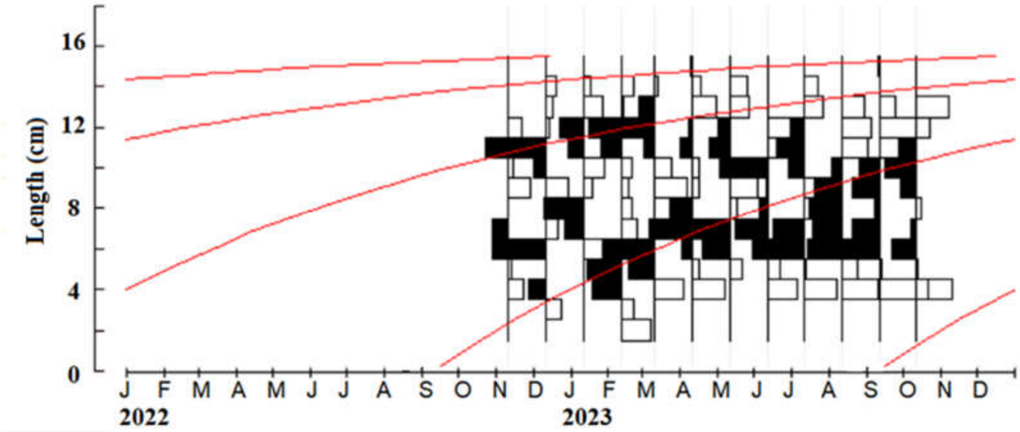

Fig. 6. *Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for Metapenaeus affinis*

Table 1. Results of the FiSAT analyses for *Metapenaeus affinis* in different ecosystems.

Author	Sex	L_∞ (cm)	K	Ø	L_c	Z	M	F	E	Location
Mohammed *et al.* (1998)	M F	3.48 [a] 4.40	1.45 1.54	3.24 3.47	2.3 [a] 2.2	5.03 4.53	2.38 2.17	2.65 2.36	0.53 0.52	Kuwait waters, Arabian Gulf
Ibrahim (2001)	M F All	4.1 [a] 4.8	0.8 0.9	-	2.2 [a] 2.4	4.55 3.31	2.68 2.71 2.69	-	0.45 0.25 0.36	Terengganu Waters, Malaysia
Dinh *et al*. (2010)	M F	19.0 [b]	1.0		7.5 [b]	5.78	2.00	3.78	0.65	Mekong Delta, Viet Nam
Gerami *et al.* (2012)	M F	3.5 [a] 4.7	1.1 1.2	7.29 7.79	-	4.04 4.93	2.52 2.20	2.08 3.18	0.51 0.64	Hormozgan Province, Arabian Gulf
Safaie (2012)	All	3.1 [a] 3.6	1.2 1.3	7.05 7.43	-	3.05 3.01	1.94 1.96	1.11 1.05	0.36 0.35	Qeshm Island, Arabian Gulf
Kapiris *et al.* (2013)	M F	3.54 [a] 4.98	1.3 0.7	3.22 2.84	-	-	-	-	-	Bay of Izmir, Turkey
Ansari *et al.* (2014)	All	13.5 [b] 15.7	1.8 2.1	-	-	5.25 7.01	1.64 1.74	3.62 5.26	0.69 0.75	Coast of Khoozestan Province, Arabian Gulf
Tirtadanu *et al*. (2017)	M F	3.6 [a] 3.8	2.0 1.9	-	2.2 [a]	9.00 9.47	2.73 2.60	6.27 6.87	0.70 0.73	Kotabaru waters, Indonesia
Dash *et al.* (2018)	M F	18.6 [b] 20.5	1.9 1.7	2.82 2.85	12.4 [b] 13.6	8.37 6.76	2.93 2.61	5.45 4.15	0.65 0.61	Gujarat Waters, India
Saputra *et al.* (2018)	M F	16.8 [b] 17.9	1.8 1.9	-	7.6 [b] 6.3	6.9 4.6	1.23 1.6	5.68 3.02	0.82 0.62	North Coast of Central Java, Indonesia
Abdel Razek *et al*. (2022)	All	19.9 [b]	0.24	1.98	8.3 [b]	1.13	0.71	0.43	0.38	Mediterranean Sea, Egypt
Jahrah *et al*. (2023)	M F	14.6 [b] 16.1	0.58 1.40	-	-	1.63	1.11	0.52	0.32	Samboja Kuala Waters, Indonesia
Dongre *et al*. (2023)	M F	18.0 [b]	1.8	-	11.9 [b]	7.2	3.02	4.18	0.58	Ratnagiri coast of Maharashtra, India
Present study	All	16.3 [b] 6.26 [a]	0.92	2.39	6.3 [b] 2.3 [a]	3.69	1.82	1.87	0.51	Iraqi waters

[a] CL = carapace length in cm; [b] TL = total length in cm.

2.0 cm in length. The highest fishing mortality rate was observed among individuals measuring 6.0-15.0 cm and peaked at 12 cm with a maximum mortality rate of 2.635.

DISCUSSION

Kebtieneh *et al.* (2016) stated that the basic purpose of stock assessment is to provide decision-makers with the information necessary to make rational choices on the optimum level of exploitation of aquatic living resources. In this study, the length range (2.0-15.6 cm TL, 0.6-6.0 cm CL) of *M. affinis* individuals was found to be similar to that of male *M. affinis* in Mumbai waters, India (6.5 – 15.0 cm TL) as observed by Leena and Deshmukh (2009) and Abdel Razek *et al*. (2022) from the Mediterranean Sea, Egypt (5.4-16.0 cm TL). However, the length range was higher than that by Ibrahim (2001) in the Terengganu Waters, Malaysia (1.3-4.2 cm CL). Conversely, the length range of *M. affinis*

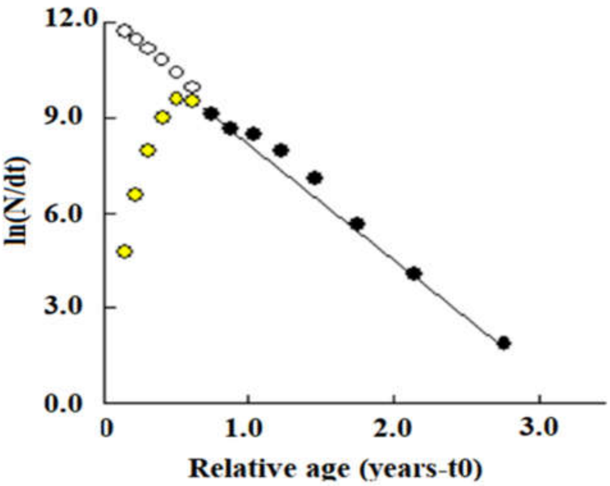

Fig. 7. *Length converted catch curve for estimation of Z for Metapenaeus affinis*

in this study was lower than those indicated by Leena and Deshmukh (2009) for female *M. affinis* in Mumbai waters, India (6.6-19.0 cm TL), by Metin and Aydin (2017) from the Izmir Bay, Turkey (7.3-17.5 cm TL), Dash *et al*. (2018) from the Gujarat Waters, India (2.0-19.8 cm TL) and Dongre *et al.* (2023) from the Ratnagiri coast of Maharashtra, India (8.5-17.4 cm TL). The environmental factors, food supply, population density, fishing pressure, and possibly using different fishing gears may be responsible for the differences in the sizes of the species in different geographic localities (Nikolsky, 1963; Riedel *et al*., 2007).

The growth coefficient (b) of the length-weight relationship for *M. affinis* was significantly different from the isometric value (b=3). This indicates a negative allometric growth pattern (b < 3), meaning that the shrimps get moderately thinner as they increase in length (Ricker, 1975; Pauly, 1984; Riedel *et al.,* 2007). A similar growth coefficient pattern for the species was reported by Ibrahim (2001) in the Terengganu Waters Malaysia; and Dash *et al*. (2018) for males of the species in Gujarat Waters, India. In contrast, Abdel Razek *et al*. (2022) showed an isometric growth pattern for males *M. affinis* and a positive allometric growth pattern for females and combined sexes in the Mediterranean Sea, Egypt. The growth coefficient (b) is affected by several factors, including habitat, season, gonad maturity, sex, stomach fullness and health (Riker, 1975; Froese, 2006; Mili *et al.*, 2017; Cuadrado *et al.*, 2019).

The total length-frequency data for the combined sexes of *M. affinis* were analyzed using the FiSAT II software, and the results of previous studies are presented in Table 1. The study found that the asymptotic length (L∞= 16.3 cm TL) for *M. affinis* was similar to the values obtained by Saputra *et al*. (2018) for males on the North Coast of Central Java, Indonesia, and Jahrah *et al.* (2023) for female in the Samboja Kuala Waters, Indonesia. However, the value of L∞ in the present study was lower than those reported by Dinh *et al.* (2010) in the Mekong Delta, Viet Nam; Dash *et al*. (2018) in the Gujarat Waters, India; Saputra *et al.* (2018) for female in the North Coast of Central Java, Indonesia, and Abdel Razek *et al*. (2022) in the Mediterranean Sea, Egypt. On the other hand, the value of L∞ in the present study, was higher than the values reported by other authors in Table 1. The present value growth coefficient (K) for *M. affinis* was comparatively higher than those stated for the species in some studies, such as Ibrahim (2001) in the Terengganu Waters, Malaysia; Kapiris *et al*. (2013) in the Bay of Izmir, Turkey; Abdel Razek *et al.* (2022) in the Mediterranean Sea, Egypt and Jahrah *et al.* (2023) in the Samboja Kuala Waters, Indonesia, while was lower than the values informed by other authors (Table 1). According to Pauly and Munro (1984), the K value for penaeid shrimps ranges from 0.39 to 1.6. The present growth index (Ø) of *M. affinis* was intermediate with those reported for the species in the other studies (Table 1). The differential in the

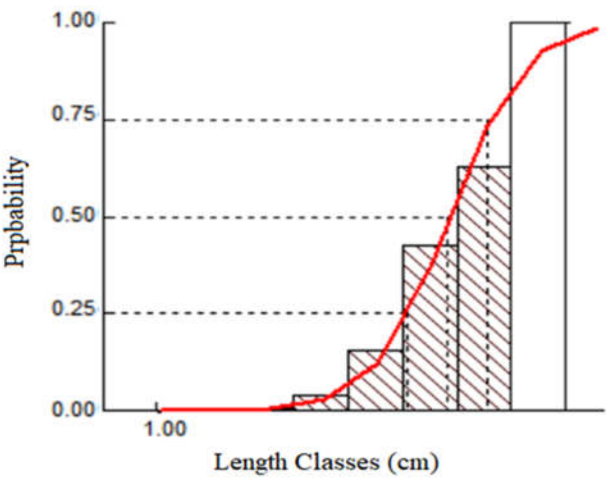

Fig. 8. *Probability of capture for Metapenaeus affinis*

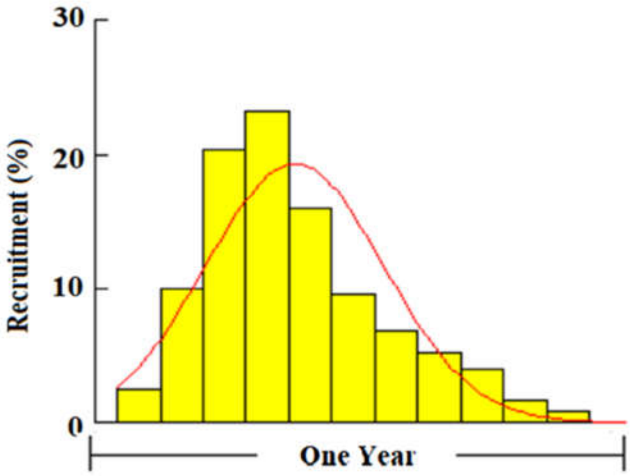

Fig. 9. *Recruitment pattern of Metapenaeus affinis*

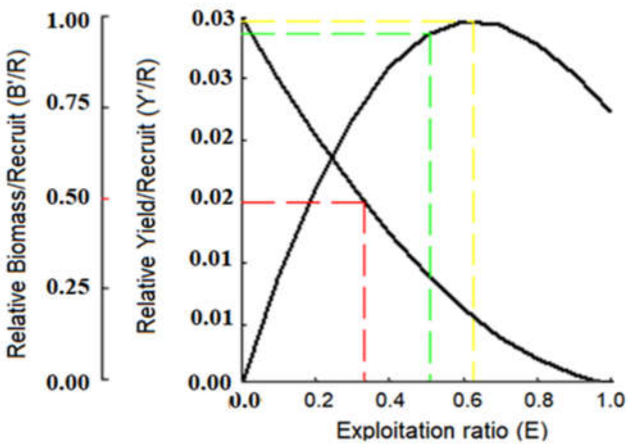

Fig. 10. *Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for Metapenaeus affinis*

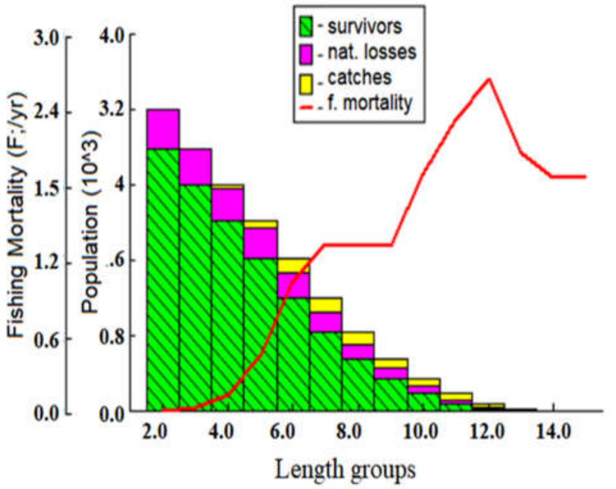

Fig. 11. *Length-structured virtual population analysis of Metapenaeus affinis*

growth parameters of the same species in various regions could be influenced by many factors, like environmental conditions, nutrient abundance, reproductive activities, genetic makeup of the individual, fishing pressure, and sampling method (Nikolsky, 1963; Spare and Venema, 1998; Wootton, 2011; Panda *et al.* 2018; Çiloğlu and Ateş, 2022).

According to the result, the total length of the first capture (L_{c50}) for *M. affinis* was 6.3 cm TL (2.3 cm CL), which was similar to the values obtained by Mohammed (1995) and Mohammed *et al*. (1998) in Kuwait waters, Arabian Gulf; Ibrahim (2001) in Terengganu Waters, Malaysia and Tirtadanu *et al*. (2017) in the Kotabaru waters, Indonesia. However, the value of L_{c50} in this study was lower than those reported by Dinh *et al*., 2010; Dash *et al.,* 2018; Saputra *et al*., 2018; Abdel Razek *et al*., 2022; Dongre *et al*., 2023 (Table 1). Beverton and Holt (1966) have stated that the length at the first capture is a critical factor that depends on the mesh size and gear selectivity. The dissimilarities in the mesh size of fishing gears used in fishing may have accounted for the observed variation in length at first capture in the various studies, where fishing gears with large mesh sizes were likely to capture shrimps of larger sizes and vice versa (Ofori-Danson *et al*., 2018; Amponsah *et al*., 2021). Based on the present study's findings, it can be inferred that the estimated length at first capture (L_{c50}) was lower than at first maturity (L_{m50}= 9.4 cm). This indicated that most of the catches were immature, and the species caught did not meet the criteria for good management ($L_{c50} < L_{m50}$). Similar findings by Tirtadanu *et al*. (2017) found that the length at first captured (L_{c50}= 2.17 cm CL) of *M. affinis* was shorter than the length at first matured (L_{m50}= 2.85 mm CL) in Kotabaru waters, Indonesia and Saputra *et al.* (2018) stated that the length at first capture (L_{c50}) was 7.6 cm for male and 6.3 cm for female, while the size at first maturity (L_{m50}) of *M. affinis* female was 11.6 cm in the North Coast of Central Java, Indonesia. However, Dash *et al.* (2018) reported that the length at first capture (L_{c50}) for *M. affinis* was higher than the length at first maturity (L_{m50}) in Gujarat Waters, India.

Table 1 presents the total (Z), natural (M), and fishing mortality rates for *M. affinis* in the present study, along with the findings of previous studies. All rates recorded in this study fall within the reported ranges for this species. The lowest rates were found in the Mediterranean Sea in Egypt (Abdel Razek *et al*., 2022). The highest recorded values for Z and F were 9.47 and 6.87, respectively, for female *M. affinis* in the Kotabaru waters of Indonesia (Tirtadanu *et al*., 2017). Additionally, the maximum recorded value of M was 3.02, as reported on the Ratnagiri coast of Maharashtra, India (Dongre *et al*., 2023). The natural mortality of stock can decrease when exposed to heavy exploitation, as lower density and competition can have an impact (Powers, 2014). Most of the Penaeid fisheries around the world have high fishing mortalities due to high demand and thus show high Z values. However, natural mortality is also affected by various biological and environmental factors such as water temperature, salinity, predation, food availability, and disease (Pauly, 1980; Allen and Hightower, 2010; Momeni *et al*., 2018; Björnsson *et al*., 2022). The fishing effort and catchability coefficient can affect the F value through the activity of the fishermen (Sparre and Venema, 1998).

The current exploitation ratio (E_{cur}) for *M. affinis* in the present study estimated at 0.51 suggested that stock was lightly over-exploited. To maintain the yield of the species, it is necessary to reduce the exploitation level from its current value of 0.51 to below 0.5. When the natural and fishing mortality is equal, the exploitation rate is equal to 0.5, while less than 0.5 refers to under-exploitation and greater than 0.5 refers to overexploitation (Gulland, 1971). On the other hand, this value of E_{cur} for *M. affinis* in the present study falls within the range reported for the species in other geographic locations (Table 1). The lowest rate was 0.25 recorded for female *M. affinis* in the Terengganu Waters, Malaysia and the highest value was 0.82 noted for males on the North Coast of Central Java, Indonesia (Saputra *et al*., 2018). However, Mohammed (1995) stated that the stock of *M. affinis* in Kuwait, Arabian Gulf was under-exploited (E= 0.39).

Based on the analysis of recruitment patterns in this study, *M. affinis* was found to be recruited into fisheries throughout the year with one main pulse that contributed 78.0% of the total recruits, extended from February to June with a peak in April (22.2%). Mohammed (1995) stated that the peak recruitment of male *M. affinis* to the fishing grounds in Kuwait waters occurred from February-March to April-May, while the recruitment of females occurred from March-June and July-August. Mohammed also said that the large spring recruitment pulse was likely due to the autumn spawning. Some authors found two peaks of unequal strength for the recruitment pattern of *M. affinis* in some waters, such as Terengganu, Malaysia (Ibrahim, 2001) and in the Mekong Delta, Viet Nam (Dinh *et al.*, 2010).

Through the yield per recruit (Y'/R) and biomass per recruit (B'/R), the exploitation status of *M. affinis* was assessed using a function of M/K (1.978) and L_c/L_∞ (0.40) to determine the biological target reference points. These reference points are indicators of the stock's performance, reflecting various parameters such as growth, recruitment, and mortality into a single index (Collie and Gislason, 2001; Cadima, 2003). The analysis showed that the current exploitation rate (E_{cur}= 0.51) was equal to its optimal level ($E_{0.1}$= 0.511) and lower than its maximum economic yield (E_{max}= 0.628), which suggests that the species was optimally exploited. However, according to Gulland (1971) and Patterson (1992), the current exploitation rate was found to be higher than the optimal level of exploitation. The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.026 and 0.263, respectively. Ibrahim (2001) stated that E_{cur} (0.43) of females *M. affinis* in the Terengganu Waters, Malaysia was lower than E_{max} (0.87) and the optimal level ($E_{0.1}$= 0.77), while E_{cur} (0.26) of males was greatly lower than E_{max} (0.92) and $E_{0.1}$ (0.81), which indicates that both sexes were under-exploited. Dash *et al*. (2018) obtained E_{cur} values of 0.65 and 0.61 for males and females, respectively, and E_{max} value of 0.75 for both male and female *M. affinis* shrimp stock in Gujarat Waters, India. Saputra *et al*. (2018) showed that E_{cur} (0.620) of females *M. affinis* on the north coast of central Java, Indonesia was higher than E_{max} (0,595) and $E_{0.1}$= 0,521, while E_{cur} (0.82) of males was greater than E_{max} (0.637) and $E_{0.1}$= 0.56, which designates that females were optimally exploited while males were fully exploited. Moreover, Abdel Razek *et al*. (2022) found that E_{cur} (0.347) was lower than $E_{0.1}$ (0.50) and E_{max} (0.74) for *M. affinis* shrimp in the Mediterranean Sea, Egypt. Jahara *et al*. (2023) noted that the species in the Samboja Kuala Waters, Indonesia appeared to be unexploited, where the current exploitation rate (E_{cur}= 0.316) was lower than the E_{max} (0.420).

Virtual population analysis (VPA) data were utilized to make management decisions and provide more information about the status of fish stocks regarding growth, recruitment, and overfishing (Chen *et al.,* 2008). According to the VPA, most of the catches of *M. affinis* occurred in individuals of different sizes (6.0-15.0 cm TL), with a maximum fishing mortality (2.635) at the length of 12 cm. This situation is also described by Dash *et al*. (2018) as the fishing increased with the increase in the size of shrimps and attained a maximum value of 5.60 at total length ranging from 13.0 to 14.0 cm for males and 4.62 at total length 15.0-16.0 cm for female shrimps in Gujarat Waters, India.

Conclusion

The present study is the first attempt to assess the stock of *M. affinis* in Iraqi waters. The study found that the recruitment of the species continued throughout the year, with one major peak in April. It was also exposed that the length at first capture was shorter than the size at first maturity. Furthermore, the current level of exploitation of the species was greater than the standard criteria, which was equal to its optimal level and below its maximum sustainable yield. This indicates that most of the caught shrimp have not yet spawned, which could harm the sustainability of the population in the long term by hindering the breeding of shrimp in Iraqi waters. To effectively manage the *M. affinis* stock, it is essential to increase the mesh size of the fishing gears so that the total length of the species at first capture must not be less than the length at first maturity (9.4 cm) so that every individual would get at least one chance to breed in their lifetime, as well as the nursery grounds in the marsh should be protected from illegal fishing, which would help renew the stock over the long term to ensure resource availability and sustainability.

ACKNOWLEDGEMENTS

The authors thank the Department of Fisheries and Marine Resources/ College of Agriculture/ University of Basrah for providing the essential research facilities required for this study.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Abbas AT & Ghazi AH. (2021). Commercial shrimp landings of two penaeid shrimps in the main markets of Basrah Province, Iraq. *Mesopotamian Journal of Marine Sciences*, 36(1): 73-78. https://doi.org/10.58629/mjms.v36i1.18.
2. Abdel Razek FA, Ragheb E, El-Deeb RS & Ahmed HO. (2022). Growth pattern and stock assessment of Jinga shrimp *Metapenaeus affinis* (H. Milne Edwards, 1837) (Decapoda, Penaeidae) from the southeastern Mediterranean of the Egyptian coasts. *Egyptian Journal of Aquatic Research*, 48: 83-90. https://doi.org/10.1016/j.ejar.2021.11.008
3. Ahmed HO, Abdel Razek FA, Khafage AR, Sarhan M, Soliman T, Aly H, El-Deeb RS & Abd Al-Aziz E. (2021). A new record of the Jinga shrimp *Metapenaeus affinis* (H. Milne Edwards, 1837) (Decapoda, Penaeidae), on the Egyptian Coasts, the Mediterranean Sea. *Egyptian Journal of Aquatic Research,* 47: 143-150. https://doi.org/10.1016/j.ejar. 2021.04.001
4. Al-Abbawy DAH & Al-Mayah AA. (2010). Ecological survey of aquatic macrophytes in restored marshes of southern Iraq during 2006 and 2007. *Marsh Bulletin*, 5(2): 177-196.
5. Albadran BN, Al-Mulla ST & Abd-Alqader MM. (2016). Physiographic study of Shatt Al-Arab delta south of Iraq by application of remote sensing technique. *Mesopotamian Journal of Marine Science*, 31(2): 169-180.
6. Ali MH. (2001). The fisheries of commercial shrimps in Iraq. *Marina Mesopotamica*, 16(2): 405-417.
7. Ali MH & Ahmed HK. (2015). Socioeconomic study for the wealth of marine shrimp in the territorial sea of Iraq. *Iraqi Journal of Aquaculture*. 12(2): 59-70.
8. Ali MH, Abdullah DS & Ahmed HK. (2001). The fishery assessment and the annual population structure of the catches of the commercial shrimp *Metapenaeus affinis* in Iraqi marine waters. *Marina Mesopotamica*, 16(1): 209-219.
9. Allen MS & Hightower JE. (2010). Fish Population dynamics: mortality, growth and recruitment. In: *Inland fisheries management in North America* (pp 43-79). Berthes-da, Maryland: American Fisheries Society.
10. Al-Maliky THY. (2022). The Study of annual shrimp stocks in Masshab (Al-Hammar Marsh), Basrah, Southern Iraq. *International Journal of Applied Science*, 5(4): 9-16.
11. Al-Yamani FY. (2021). *Fathoming the table of contents northwestern Arabian Gulf: Oceanography and Marine Biology.* Kuwait Institute for Scientific Research, Kuwait. 408 p. https://doi.org/10.1016/J.DSR2.2018.10.003.
12. Amponsah S, Amarquaye N, Alaba Olopade O & Baset A. (2021). Length-based population dynamics of Lesser African Threadfin (*Galeoides decadactylus*, Bloch, 1795) from the coastal waters of Ghana. *Journal of Wildlife and Biodiversity*, 5(2): 56-68. https://doi.org/10.22120/jwb.2020.137846.1190
13. Ansari H, Khoadadi M & Eskandari G. (2014). Growth and mortality Parameters of Jinga Shrimp (*Metapenaeus affinis* H. Milne Edwards, 1837) in western coast of Khoozestan Province. *Journal of Marine Biology*, 6: 1-11.
14. Aydin I, Bakir K & Galil BS. (2009). The first record of the Jinga shrimp *Metapenaeus affinis* (H. Milne Edwards, 1837) (Decapoda: Penaeidae) from the Mediterranean Sea. *Crustaceana*, 82(8): 1091-1095. https://doi.org/10.1163/156854009X448907
15. Beverton RJH & Holt SJ. (1966). *Manual of methods for fish stock assessment*. Part II. Tables of yield functions. FAO Fisheries Biological Technical Paper, No. 38 (Rev. 1), 67p.
16. Binohlan C & Froese R. (2009). Empirical equations for estimating maximum length from length at first maturity. *Journal of Applied Ichthyology*, 25(5): 611-613. https://doi.org/ 10.1111/j.1439-0426.2009.01317.x
17. Björnsson B, Sólmundsson J & Woods PJ. (2022). Natural mortality in exploited fish stocks: annual variation estimated with data from trawl surveys. *ICES Journal of Marine Science*, 79: 1569-1582. https://doi.org/10.1093/icesjms/fsac063
18. Cadima EL. (2003). *Fish stock assessment manual*. Food and Agriculture Organization Fisheries Technical Paper. No. 393. Rome, Food and Agriculture Organization. 161p.
19. Carpenter KE & Niem VH. (1998). *The living marine resources of the Western Central Pacific. Vol. 2. Cephalopods, crustaceans, holothurians and sharks*. Rome, Food and Agriculture Organization.
20. Chen Y, Jiao Y, Sun C & Chen X. (2008). Calibrating virtual population analysis for fisheries stock assessment. *Aquatic Living Recourses*, 21: 89-97. https://doi.org/10.1051/ ALR:2008030
21. Çiloğlu E & Ateş C. (2022). Population dynamics of deep-water pink shrimp (*Parapenaeus longirostris* Lucas, 1846) (decapoda, Paenaeidae) in the coastal waters of Tuzla (Eastern part of the Sea of Marmara). *Aquatic Research*, 5(3): 196-208. https://doi.org/10.3153/ AR22019
22. Collie JS & Gislason H. (2001). Biological reference points for fish stocks in a multispecies context. *Canadian Journal of Fisheries and Aquatic Sciences*, 58(11): 2167-2176. https://doi.org/10.1139/cjfas-58-11-2167
23. Cuadrado JT, Lim DS, Alcontin RMS, Calang JL & Jumawan JC. (2019). Species composition and length-weight relationship of twelve fish species in the two lakes of Esperanza, Agusan del Sur, Philippines. *FishTaxa*, 4(1): 1-8.
24. Dash G, Mohammed KK, Swatipriyanka S, Sreenath KR1, Vinaya KV, Pradhan RK, Sukhdhane K, Divu D, Solanki V & Maheswarudu G. (2018). Fishery, Population Dynamics and Stock Status of Jinga Shrimp, *Metapenaeus affinis* (Milne-Edwards, 1837) from Gujarat Waters of India. *Indian Journal of Geo-Marine Sciences*, 7(11): 2267-2277.
25. Dinh TD, Moreau J, Van MV, Phuong NT & Toan VT. (2010). Population Dynamics of Shrimps in Littoral Marine Waters of the Mekong Delta, South of Viet Nam. *Pakistan Journal of Biological Sciences*, 1(14): 683-690. https://doi.org/10.3923/pjbs.2010.683.690
26. Dongre SJ, Metar SY, Nirmale VH, Chogale ND, Naik SD & Gangan SS. (2023). Preliminary observation on the stock of Jinga shrimp, *Metapenaeus affinis* (H. Milne Edwards, 1837) along the Ratnagiri coast of Maharashtra, India. *Journal of the Marine Biological Association of India*, 65(2): 95-99. https://doi.org/10.6024/jmbai. 2023.65.2.2372-14
27. Earth Trends. (2003). Coastal and Marine Ecosystems-Iraq. Retrieved on 6 Feb 2010, https://earthtrends.wri.org.

28. Food and Agriculture Organization. (2014). Report of the Expert Meeting on the Review of Fisheries and Aquaculture Activities in the Tigris Euphrates Basin, Erbil, Iraq, 11-12 November 2012. Food and Agriculture Organization, Fisheries and Aquaculture Report No. 1079. Rome. 125 pp.
29. Fischer W & Bianchi G. (1984). *FAO species identification sheets for fisheries purposes Western Indian Ocean (Fishing area 51).* Volume 5, Food and Agriculture Organization, Rome.
30. Froese R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22(4): 241-253. https://doi.org/10.1111/J.1439-0426.2006.00805.X.
31. Garcia SM. (1985). Reproduction, stock assessment models and population parameters in exploited penaeid shrimp populations. In: *Second Australian National Prawn Seminar* (pp 139-158). Kooralbyn, Australia.
32. Gayanilo FCJr, Sparre P & Pauly D. (2005). *FAO-ICLARM Stock Assessment Tools II (FiSAT II).* Revised version. User's guide. Food and Agriculture Organization Comp. Info. Ser. (Fisheries), 8: 1-168.
33. Gerami MH, Paighambari SY, Ghorbani R & Mohammad M. (2012). Population Structure, Growth and Mortality Rates of Jinga Shrimp, *Metapenaeus affinis* in Fishing Grounds of Hormozgan Province, Iran. *Caspian Journal of Applied Sciences Research*, 1(8): 29-35.
34. Gulland JA. (1971). *Fish resources of the Ocean*. Fishing News Books, Surrey, London, England. 255pp.
35. Holthius LB. (1980). *FAO Species Catalogue. Shrimps and Prawns of the World. An Annotated Catalogue of Species of Interest to Fisheries*. Food and Agriculture Organization Fish, 1: 1-261.
36. Ibrahim J. (2001). Population dynamics of the Jinga Prawn, *Metapenaeus affinis* (H. Milne Edwards, 1837), in Terengganu Waters, East Coast of Peninsular Malaysia. *Malaysian Fisheries Journal*, 2(1): 207-220.
37. Jahrah F, Ramang MS, Susilo H, Susanto A & Erwiantono AI. (2023). Population Dynamics of Jinga Shrimp (*Metapenaeus affinis*) in Samboja Kuala Waters Kutai Kartanegara Regency. Torani: *Journal of Fisheries and Marine Science*, 6(2): 73-85. https://doi.org/10.35911/torani.v6i2.25187
38. Jones R & van Zalinge NP. (1981). Estimations of mortality rate and population size for shrimp in Kuwait waters. *Kuwait Bulletin of Marine Sciences*, 2: 273-288.
39. Kapiris K, Metin G & Aydin I. (2013). Age and growth of the Jinga shrimp, *Metapenaeus affinis* (H. Milne Edwards, 1837) in the Bay of Izmir, Turkey. *Rapp. Comm. int. Mer Médit*., 40: 451.
40. Kebtieneh N, Alemu Y & Tesfa M. (2016). Stock Assessment and Estimation of Maximum Sustainable Yield for Tilapia Stock (*Oreochromis niloticus*) in Lake Hawassa, Ethiopia. *Agriculture, Forestry and Fisheries*, 5(4): 97-107. https://doi.org/10.11648/j.aff. 20160504.12
41. Le Cren ED. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecol*ogy, 20: 201–219.
42. Leena K & Deshmukh VD. (2009). Age and growth of Jhinga prawn *Metapenaeus affinis* Milne Edwards (Decapoda, Penaeidae) in Mumbai waters. *Indian Journal of Fisheries*, 56(1): 1-5.
43. Mathews CP, Bishop JM & Salman SD. (1986). *Stocks of Metapenaeus affinis in Kuwait and Iraq waters*. Final Report. Kuwait Institute for Scientific Research and Marine Science Centre, University of Basrah, 55 pp.
44. Metin G & Aydin I. (2017). Some reproductive characteristics of *Metapenaeus affinis* (H. Milne Edwards, 1837) in Izmir Bay (Eastern Aegean Sea, Turkey). *Pakistan Journal of Zoology*, 49(5): 1-4. https://doi.org/10.17582/journal.pjz/2017.5.sc2
45. Mili S, Ennouri R, Chhibi M, Laouar H, Romdhane N & Missaoui H. (2017). Length-weight relationships (LWRs) of endemic and introduced freshwater fish species in 13 Tunisian reservoirs. *Journal of New Sciences, Agriculture and Biotechnology*, 41(8): 2253-2259.
46. Mohamed ARM, Al-Saboonchi AA & Raadi FK. (2017). Ecological assessment of East Hammar marsh, Iraq using a number of ecological guides. *JKAU: Marine Sciences*, 26(2): 11-22. https://doi.org/10.4197/Mar.26-2.2
47. Mohamed ARM & Abood AN. (2024). The current status and recent trends of Iraqi marine fisheries in the northwest Arabian Gulf. *Indiana Journal of Agriculture and Life Sciences*, 4(1): 9-20. https://doi.org/10.5281/zenodo.10722694
48. Mohamed ARM & Jawad LA. (2021). Marine artisanal fisheries of Iraq. In: *The Arabian Seas: Biodiversity, Environmental Challenges and Conservation Measures.* (pp 917-948). https://doi.org/10.1007/978-3-030-51506-5_41.
49. Mohamed ARM, Hussain NA, Al-Noor SS, Coad BW & Mutlak FM. (2009). Status of diadromous fish species in the restored East Hammar marsh in southern Iraq. *American Fisheries Society Symposium*, 69: 577-588. https://doi.org/10.47886/ 9781934874080. ch35
50. Mohammed HM. (1995). Population dynamics and exploitation of *Metapenaeus affinis* in Kuwaiti waters. *Naga, the ICLARM Quarterly*, 18(2): 38-41.
51. Mohammed HM, Bishop JM & Ye Y. (1998). Kuwait's Post Gulf-War Shrimp Fishery and Stock Status from 1991/92 Through 1995/96. *Reviews in Fisheries Science*, 6(3): 253-280. https://doi.org/10.1080/ 10641269891314276
52. Momeni M, Kamrani E, Safaie M1 & Kaymaram F. (2018). Population structure of banana shrimp, *Penaeus merguiensis* De Man, 1888 in the Strait of Hormoz, Persian Gulf. *Iranian Journal of Fisheries Sciences*, 17(1): 47-66. https://doi.org/10.22092/IJFS.2018.115584
53. Nikolsky GV. (1963). *The ecology of fishes*. Academic Press, London and New York, 352 p.
54. Ofori-Danson GPK, Addo S, Animah CA, Abdulhakim A & Nyarko JO. (2018). Length at first capture (L_{C50}) of *Sardinella aurita* and *Sardinella maderensis* landed from purse seines at the Tema Fishing Harbour, Ghana. *International Journal of Fisheries and Aquatic Research*, 3(3): 08-13.
55. Panda D, Mohanty SK, Pattnaik AK, Das S & Karna SK. (2018). Growth, mortality and stock status of mullets (Mugilidae) in Chilika Lake, India. *Lakes & Reservoirs*, 2018: 1-13. https://doi.org/10.1111/LRE.12205
56. Patterson K. (1992) Fisheries for small pelagic species: an empirical approach to management targets. *Review in Fish Biology and Fisheries*, 2: 321-338. https://doi.org/10.1007/BF00043521
57. Pauly D. (1980). On the interrelationships between natural mortality, growth parameters and mean environmental

temperature in 175 fish stocks. *J. Cons. CIEM*, 39(3): 175-192.
58. Pauly D. (1983). *Some simple methods for assessment of tropical fish stocks*. Food and Agriculture Organization Fish. Tech. Pap., 234: 52.
59. Pauly D. (1984). *Fish population dynamics in tropical waters: A manual for use with programmable calculators.* ICLARM Studies and Reviews No. 8. International Centre for Living Aquatic Resources Management, Manila, Philippines, 325 pp.
60. Pauly D & Munro JL. (1984). Once more on the comparison of growth in fish and invertebrates. *ICLARM Fish byte*, 2: 21.
61. Pauly D & Soriano ML. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: *The First Asian Fisheries Forum*. Asian Fisheries Society, Manila. (pp 491-496).
62. Pohl T, Al-Muqdadi SW, Ali MA, Al-Mudaffar NF, Ehrlich H & Merkel B. (2014). Discovery of a living coral reef in the coastal waters of Iraq. *Scientific Reports*, 4: 4250. https://doi.org/10.1038/srep04250
63. Powers JE. (2014). Age-specific natural mortality rates in stock assessments: size-based vs. density-dependent. *ICES Journal of Marine Science*, 71: 1629-1637. https://doi.org/ 10.1093/ ICESJMS/FST226
64. Raadi FKH, Resen AK & Najim SM. (2023). Effect of tidal zones on some aspects of fish biodiversity in East Hammar marsh, Basrah, Iraq. *Journal of Survey in Fisheries Sciences,* 10(3S): 5180-5194.
65. Ricker WE. (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board. Can.,* 191: 382 p. https://doi.org/10.2307/3800109
66. Riedel R, Caskey LM & Hurlbert SH. (2007). Length-weight relations and growth rates of dominant fishes of the Salton Sea: implications for predation by fish-eating birds. *Lake and Reservoir Management*, 23: 528-535. https://doi.org/10.1080/07438140709354036
67. Safaie, M. (2012). Population dynamics of dominant shrimps in northeast of Qeshm Island. *Iranian Scientific Fisheries Journal*, 21(3): 85- 98.
68. Salman SD, Ali MH & Al-Adhub AHY. (1990). Abundance and seasonal migrations of the penaeid shrimp *Metapenaeus affinis* (H. Milne-Edwards) within Iraqi waters. *Hydrobiologia*, 196: 79-90. https://doi.org/10.1007/BF00008895
69. Saputra SW, Solichin A & Taufani WT. (2018). *Stock Analysis of Metapenaeus affinis (H.Milne Edwards, 1837) on the North Coast of Central Java, Indonesia*. IOP Conference Series: Earth and Environmental Science, 116: 1-8. https://doi.org/10.1088/1755-1315/116/1/012004
70. Sparre, P. & Venema, S.C. (1998). *Introduction to tropical fish stock assessment. Part 1. Manual.* FAO fisheries technical paper. No. 306. 1, Rev. 2. Food and Agriculture Organization, Rome, Italy. 407 p.
71. Taylor, C. C. (1958). Cod growth and temperature. *ICES Journal of Marine Science,* 23(3): 366-370. https://doi.org/10.1093/icesjms/23.3.366
72. Tirtadanu,T., Suprapto S & Suman A. (2017). Biological aspects and population parameters of jingo shrimp (*Metapenaeus affinis* H. Milne Edwards, 1837) in Kotabaru waters, south of Kalimantan. *BAWAL*, 9(1): 11-20. https://doi.org/10.15578/BAWAL. 9.1.2017.11-20
73. Wootton RJ. (2011). Growth: environmental effects. In: *Encyclopedia of fish physiology: from genome to environment Elsevier Science Publishing Co* (pp 1629-1635). Inc, United States.