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Size Selectivity of Gillnets Applied for *Liza carinata* in Small-Scale Fisheries in Suez Bay, Gulf of Suez, Egypt

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ABSTRACT

Four stretched mesh sizes (30, 34, 38, and 40mm) were used to examine the mesh selectivity of gillnets for the keeled mullet (*Liza carinata*). In 2021, the experimental fishing operations were carried out in the Suez Bay and Gulf of Suez, the Red Sea. Selectivity on *L. carinata* was evaluated with the PASGEAR´ software's SELECT technique (version 2017). The length frequency data were fitted using five different models: bi-normal, normal location, gamma, normal scale, and lognormal distributions. It was found that the normal location model is the ideal selectivity of the gillnet data for *Liza carinata*. The optimal lengths (100% retention probability) for the 30, 34, 38, and 42mm mesh sizes were 13.6, 13.7, 14.3, and 16.3cm, respectively, for the selectivity curves on the normal location model. According to the study, in order to prevent overfishing of the fish population, gillnets employed in the Suez Bay fishery should have a mesh size of at least 38mm for *Liza carinata*.

INTRODUCTION

The order Mugiliformes and family Mugilidae include the group of fish known as the mullets. Fish in the Mugilidae family range in size from medium to big, with elongated bodies that are subcylindrical. Large concentrations of them can be found in tropical and temperate seas. The Mediterranean Sea is populated to the mullet, *Liza carinata*, also referred to as the keeled mullet and locally called Sehlia, which recorded a Lessepsian migration from the Red Sea via the Suez Canal. According to **GAFRD (2017)**, the mullet account for around 0.31% of the Red Sea's yearly production **(Abd El-Ghaffar *et al.*, 2020)**.

Over 64% of the fish produced in the Egyptian section of the Red Sea is gathered in the Gulf of Suez, which is the most abundant fishing location along the Egyptian side of the sea **(El-Deep & Abozied, 2013)**. The Red Sea's Gulf of Suez is the shallow extension that forms the Suez Bay. Small-scale fisheries are essential to the Suez Bay. The most significant economic activity in the Gulf of Suez is small-scale fishing (SSF), which is mostly focused on gill and trammel nets with different mesh sizes. Gill nets are passive walls of netting that operate by entangling or wedging fish that swim into them **(Von Brandt, 1984; Saber *et al.*, 2020)**. Since the mesh size of a gill net must match the girth of the fish, it is mostly used to capture fish with nearly similar body sizes. The mesh size used varies depending on the targeted size and the species **(Karakul, 2008)**.

The SELECT technique was utilized to evaluate the selectivity characteristics of trammel and gill nets at several fishing sites throughout the whole world **(Çetinkaya *et al.*, 1995; Özyurt & Avsar, 2005; Aydın & Metin, 2008; Saber *et al.*, 2020; Saber *et al.*, 2022; Saber & Aly 2023)**. It is best to consider the concept of gill net size selectivity—the probability of catching a certain size of fish in a single unit of operation of the gear—as a feature of the whole fishing operation **(Lagler, 1968; Hamley, 1975)**.

The possibility that a fish will come into contact with the net and the probability that it would be caught and retained by it define the selectivity of the gear **(Hamley. 1975; Regier, 1975)**. Gillnet selectivity is affected differently by a number of factors, including mesh size, net construction material, net visibility in the water, and hanging ratio, as several studies have previously shown **(Hamley, 1975; Millar, 1992; Samayaranaka *et al.*, 1997)**.

The purpose of this study was to evaluate the selectivity parameters of the gillnet at 4 different mesh sizes. In addition to determining the species' length at first maturity, found out how mesh size affects the population of *Liza carinata*.

MATERIALS AND METHODS

1. Study area

The northern part of the Gulf of Suez is located to Suez Bay, where the research was carried out. According to Fig. (1), the area under investigation lies between latitudes 28° 32' 26" N and longitudes 33° 13' 11.7" E.

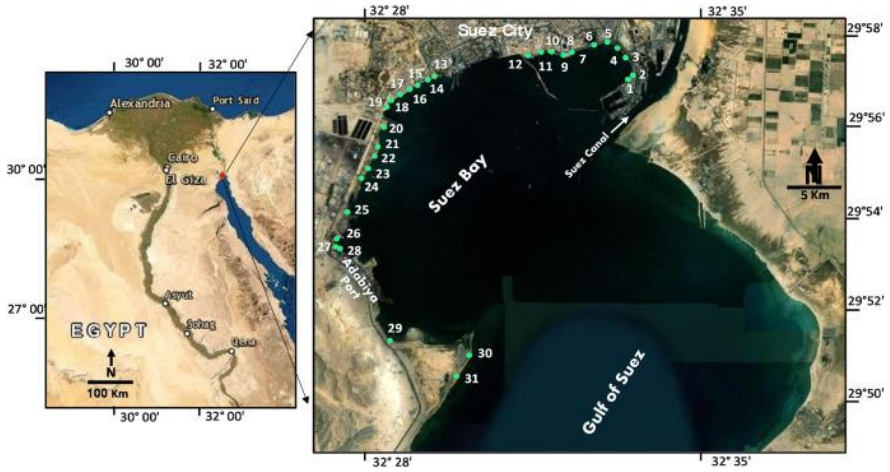

Fig. 1. A map of the study area (Suez Bay)

2. Experimental surveys

Six gillnet fishing shots were conducted in the Suez Bay fishing zones in December 2021, with fishing depths ranging from 2 to 5m. Four gillnets were constructed with four mesh sizes (30, 34, 38, and 42mm). The experimental nets, made using 0.3mm green polyamide (PA) monofilament, are shown in Fig. (2). The coordinates of the stations are 29˚ 56′ 614″ N; 32˚ 30′ 029′E, 29˚ 56′ 500″N; 32˚ 30′ 790′E, 29˚ 56′ 747″N; 32˚ 31′ 150″ E, 29˚56′ 775″ N; 32˚ 30′ 003″E, 29˚ 56′ 726″ N; 32˚ 29′ 883″ E, 29˚ 56′ 772″N; 32˚ 29′ 005″E, respectively.

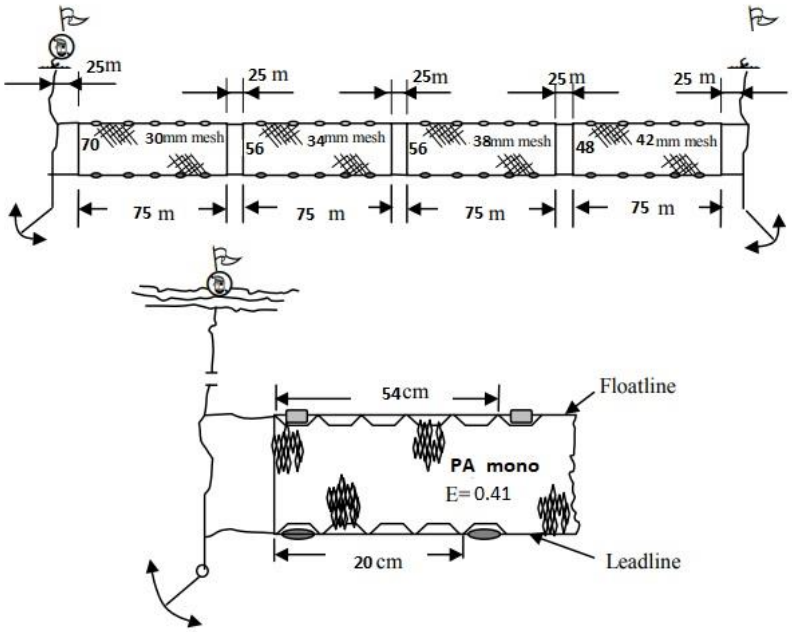

Fig. 2. Specification of gill net modified with four mesh sizes (30, 34, 38 and 42mm)

A total of 307 fish specimens belonging to *Liza carinata* species were caught by four different mesh-size gillnets and sorted by mesh size. The sample was transported

from the fishing vessel to the laboratory at the Suez University. Data of total length were grouped at 1cm interval. For the four mesh sizes of nets, the hanging ratio was 0.41.

3. Selectivity analysis

PASGEAR Ⅲ software (version 2017) was used to estimate the gillnet selectivity for *L. carinata.* Based on **Millar's (1992)** common statistical model (SELECT), **Millar and Holst (1997)** and **Millar and Fryer (1999)** discussed the specific use of gillnets and hooks. The selectivity of the gillnet was estimated using the SELECT (share each length class catch total) method**p**. The method assumes a Poisson distribution for the catches (nlj) by length class (l) and gear size (j); rj (l) is the probability of keeping a fish of length l in gear size j, and pj (l) is the relative fishing intensity; λl is the abundance of fish of length l contacting the combined gear, which is the likelihood that a fish of length l contacts the gear size j given that it contacts the combined gear.

$$nlj \approx Pois\ (pj\ \lambda l\ rj\ (l)) \quad \textbf{(1)}$$

$$\{nl\ loge\ [pj\ \lambda l\ rj\ (l)] - pj\ \lambda l\ rj\ (l)\} \quad \textbf{(2)}$$

This study investigated the characteristics of five different models included in PASGEAR: gamma, - binormal,- normal location, -log-normal, and normal scale (Millar and Fryer, 1999). **Normal location:** $exp\left(-\frac{(l-k.m)^2}{2\sigma^2}\right)$

(3)

Normal scale: $exp\left(-\frac{(l-k_i m_i)^2}{2k_2^2.m_j^2}\right)$ **(4)**

Log-normal: $\frac{m_j}{l.m_i}\ exp\left(\pi - \frac{\sigma^2}{2} - \frac{\left[\log(l)-\mu-\left[\log(\frac{m_i}{m_I})\right]\right]}{2k_2^2.m_j^2}\right)$ **(5)**

Gamma: $\left(\frac{l}{(\alpha-1).k.m_j}\right)^{\alpha-1}\ exp\left(\alpha-1-\frac{l}{k.m_j}\right)$ **(6)**

Bi-normal: $exp\left(-\frac{(l-K_1\ m_j)^2}{2k_2^2.m_j^2}\right) + c.exp\left(-\frac{(l-K_3\ m_j)^2}{2k_4^2.m_j^2}\right)$ **(7)**

μ_i- ; mean length of species collected by mesh size i (mi).

σ_i -- standard deviation of the total length of species collected by mesh size i (mi).

L_j-- the mean length of species with length class j. m_1-- the lowest mesh size.

k, α, and ω are constants.

The best-fitting model had the lowest ratio D/df. The goodness of fit was assessed by comparing the values of the deviance degrees of freedom D/df and looking at the deviance residual plots. Fonseca *et al* (2005).

4. Length at sexual maturity

To calculate the size at the peak of sexual maturity (L_m) for *L. carinata*, the frequency percentage of immature and mature fish were grouped into a 1cm length group, and then the maturity curves were fitted according to **King (1995)** to estimate the size at L_{m50} mature.

RESULTS

1. Selectivity analysis

1.1. Length-frequency distribution

Analysis of the total catch indicates that 48.2% of *L. carinata* are in gillnets with average mesh size A (30mm), while 34.5% are in B (34mm), 11.1% are in C (38mm) and 6.2% are in D (42mm), respectively (Table 1 & Fig. 2). Fig. (3) displays the corresponding residuals of deviation. The net with the smallest mesh size produced the greatest number of catches (48.2%), and as the mesh size increased, less individuals were caught throughout the fishing period. Fish with greater mesh sizes (e.g., 13.6cm for 30mm mesh size, 13.7cm for 34mm mesh size, 14.3cm for 38mm mesh size, and 16.3cm for 42mm mesh size) had mean lengths that were higher when collected. Fish mean length seems to be related directly to increasing mesh size, according to observed and calculated capture curves (Fig. 3).

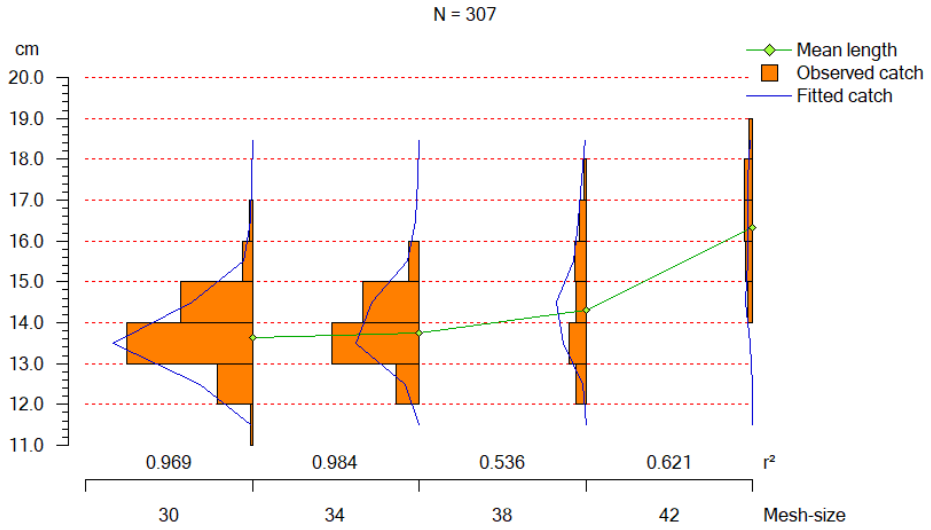

Fig. 3. Length frequency distribution of *Liza carinata* caught by gillnets with mesh sizes 30, 34, 38, and 42mm in the Suez Bay

Table 1. Gillnet selectivity parameters for *Liza Carinata* estimated using the SELECT method for four different mesh sizes. (SD= Standard deviation, NO= Number of specimens)

Species	Mesh size (mm)	NO.	NO%	Mean length (cm)	SD Length (cm)	Mean weight (gm)	SD. weight (gm)
Liza Carinata	30	148	48.2	13.6	0.8	31	4.4
	34	106	34.3	13.7	0.8	31	4.3
	38	34	11	14.3	1.4	38	10.7
	42	19	6.5	16.3	1.2	55	11.4

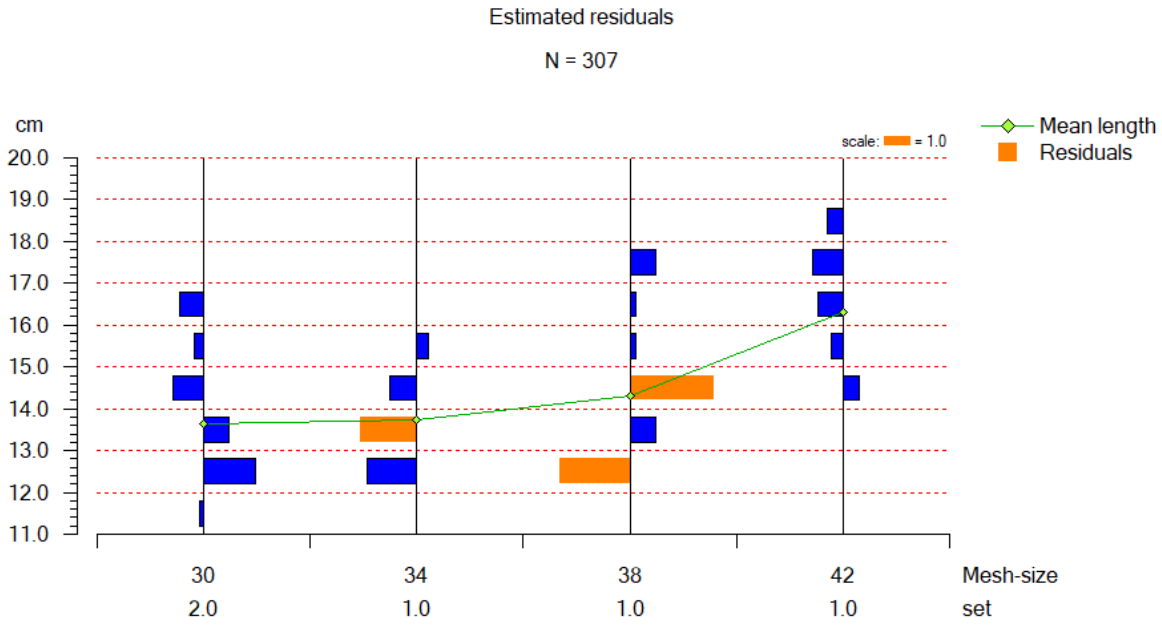

Fig. 4. The selectivity curves' variation residuals that were computed for *Liza carinata*

1.2. Selectivity analysis

The best selectivity model that fitted for *L. carinata* was determined by the PASGEAR II computer software. In this study, we applied five models, log-normal, normal scale, gamma, normal location, and bi-modal models independently, and the results are recorded in Table (2).

Based on the results of model comparisons, the normal location for *L. carinata* was found to be the best model. It had the lowest values for the ratio D/df 2.005 and model deviance 38.108. Figs. (3, 4) illustrate the selectivity and catch curves for the four different mesh sizes for the dominating species in the catch. The size-frequency distributions of the *L. carinata* captured with 30, 34, 38, and 42mm have been shown to shift the mean length to the right as the mesh size increases. On the other hand, Fig. (4) shows *Liza carinata's* typical overall length.

Table 2. The gill net selectivity's estimated SELECT model parameters (MD: Deviance of the model and df: degree of freedom

Model	Parameter	M. D.	d.f.
Normal location	**(k, σ)** =0.43, 1.866	38.108	19
Normal scale	**(k1, k2)** =0.435, 0.051)	45.166	19
Gamma	**(k,α)** = 0.006,70.273	44.0.13	19
Log normal	**(μ, σ)**= 2.572,0.122	44.184	19
Bi-modal	**(k1, k2, k3, k4, w)**= 0.413,0.037, 0.493,0.034,0.561	41.898	16

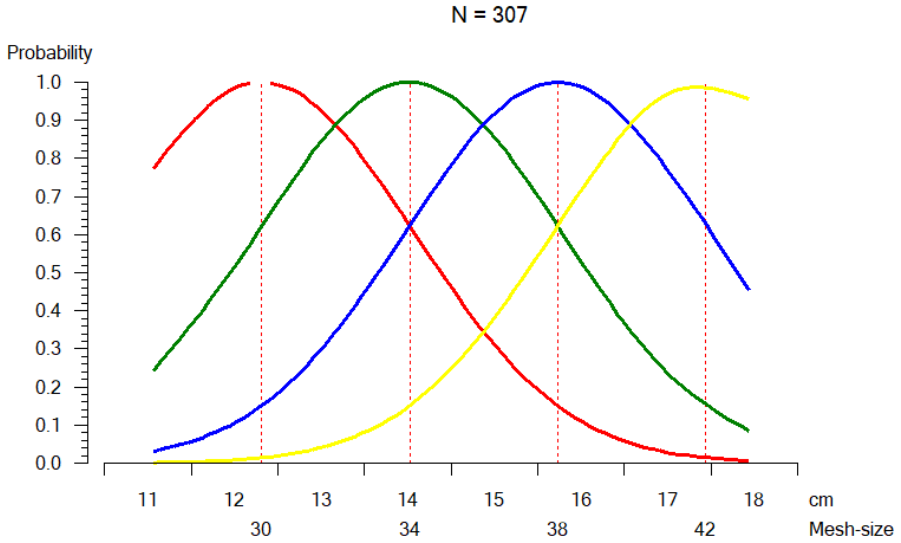

Fig. 5. *Liza carinata* selection curves using different mesh sizes (mesh 30, 34, 38, and 42mm) were captured. N = Total number of fish caught in

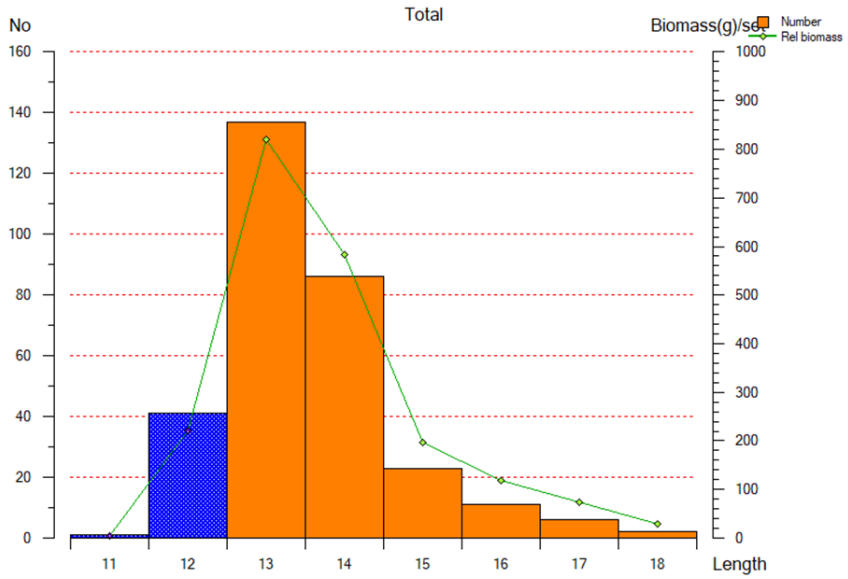

Fig. 6. Catch curve for *Liza carinata*

2. Size at sexual maturity (L_{m50})

Based on an analysis of the proportion of mature and immature fish in each length class, the minimum size of maturity for female fish is 11.0cm, and for male fish it is 12.0cm. However, Fig. (7) indicates that for female fish, the size at which 50% of them attain maturity is 13.5cm, and for male fish, it is 13.1cm.

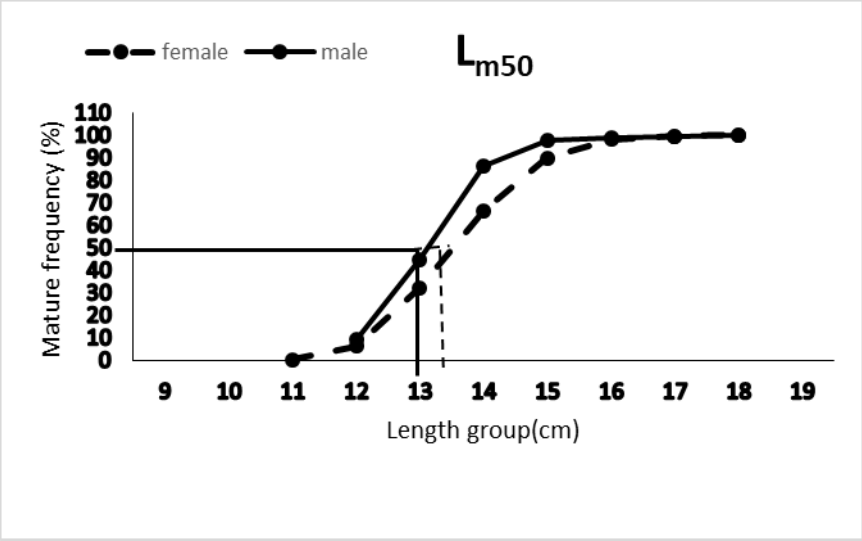

Fig. 7. Length of *L. carinata* from the Suez Bay at 50% maturity

DISCUSSION

Choosing the ideal mesh size to minimize by-catch and increase the proportion of targeted species is the foremost objective of selectivity in order to achieve sustainable fishing. Net selectivity is one of the most effective methods to regulate fisheries resources **(Louette & Declerk, 2006; Ozekinci *et al*., 2007; Saber *et al* 2020)**. Since gill nets are very selective, they may be employed to collect fish with a small variety of sizes **(Hamley, 1975; Borgstrøm, 1989)**.

Several factors should be considered when using the selectivity technique. Examples include fish size, shape, and swimming speed, determining a fish's length frequency distribution, and calculating the population size from capture. Furthermore, different fishing grounds may yield different sizes of the fish species that are caught **(Lagler, 1968; Rudstam *et al*., 1984)**. Larger mesh sizes were used in this investigation, which i consistent with the findings of **Thomas *et al*. (2003)**, **Carol and García-Berthou (2007)** and **Saber *et al.* (2022)**, who explained that the mean length of the collected fish increased and their number reduced.

The normal location model selectivity curve was found to be the most appropriate for *L. carinata* based on a comparison of the four tested mesh sizes. Based on the lowest ratio of model deviance to degrees of freedom and the greatest *P*-value, the normal location selectivity model selected the best fits the length distributions of *L. carinata*, is in agreement with **Carol and Garcia-Berthou**'s **(2007)** findings, which indicate that for gill net-caught *Alburnus alburnus*, *Cyprinus carpio*, *Chondrostoma miegii*, and *Scardinius erythrophthalmus*, the normal location is the best-fit model for all species.

Normal, log-normal, and gamma selection curves can all be used to describe bell-shaped selection curves, often known as unimodal curves. The second two formulations enable a reasonable level of skewness; however in practice, these expressions generally result in quite similar selection curves **(Millar & Holst, 1997; Hovgård *et al*., 1999)**.

The modal lengths in the 30, 34, 38, and 42mm mesh sizes, using the normal location model, were 13.6, 13.7, 14.3, and 16cm for *Liza carinata*. For *Liza carinata*, the modal lengths, spread values, and selectivity parameters are all positively impacted by an increase in mesh size. *Liza carinata* mean lengths and weights increased with increasing mesh size, according to experimental fishing, which is consistent with the findings of **(Thomas *et al*., 2003; Carol & García-Berthou, 2007)**.

Males typically grow before females in the natural fish community (Mugillid family) and are ready to participate in spawning activity which coincides with the results of **Ezzat (1965)**, **El-Mor (1993)**, **Cardona (2006)**, **El-Ganainy *et al*. (2014)** and **Hefiny *et al*. (2016)**. In the current study, the length at first maturity of *L. carinata* is 13.5 and 13.1cm for females and males, respectively. These values are similar to those recorded in

Bitter Lakes, Suez Canal, Egypt, where length at 50% maturity was 13.5 and 13.2cm for females and males, respectively (**El-Mor *et al*., 2021)**. However, the values of the current study differ from the results recorded by **El-Ganainy *et al.* (2014)**, who concluded that L_m = 13.0 and 12.5cm for females and males, respectively. These slight differences may be attributed to the different environmental conditions in different habitats. From one species to another, and in the same species under different ecological conditions such as the degree of water salinity and temperature, L_m differs significantly, also these lengths differ between pelagic and demersal fishes. The common mullet fish that live in warm waters mature earlier than those living in cold water **(Koutrakis, 2011)**.

Multiple methods of management have been developed to address overfishing, with various levels of efficacy. In fact, mesh size regulations, which are often based on fish size at maturity (Lm), have long been a common way to apply minimum size limitations **(Ricker, 1945; Beverton & Holt, 1957; Froese, 2004)**.

The length at first capture (L_c) with the length at first sexual maturity (L_m), as well as their corresponding ages, are considered as indicators for the stock status. L_c in the present work was estimated at 13.2cm for *L. carinata*. L_c is smaller than L_m. These results revealed that this fish suffers from overexploitation. To ensure that the mullet fish have the opportunity to spawn at least once before capture, increasing the mesh size of fishing nets is essential. In fisheries management, both the length at first capture and the exploitation rate are influenced by the characteristics of the fishery, particularly the mesh size of the fishing gear used. Consequently, estimates of these parameters are specific to the individual characteristics of each fishery.

CONCLUSION

In conclusion, it was determined that the 30 and 34mm mesh size gillnets were unsuitable for fishing in the Suez Bay due to the possibility that *Liza carinata* would not have the opportunity to spawn even once before they are captured, based on the values of the length at first maturity (Lm) and length at first catch (Lc). In Suez Bay, however, the use of monofilament gillnet with a mesh size of 38mm need to be advised as a preventative measure for proper fisheries management of *Liza carinata*. The primary intent of the fisheries regulations is to permit adult participation in recruitment prior to capture.

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