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# Life History Parameters and Stock Status of the Kawakawa, *Euthynnus affinis* (Cantor, 1849) from the Gulf of Aqaba, Red Sea, Egypt

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**ABSTRACT**

The kawakawa *Euthynnus affinis*, is a highly commercial tuna species in the Red Sea. To assess the species' fishery status, the life history and population dynamic parameters have to be identified. A total of 615 length measurement data were randomly collected during the period from February 2021 to May 2023 from the Gulf of Aqaba, Red Sea, Egypt. Life history characteristics comprising age and growth, mortality, and utilization rate were evaluated based on the length frequency analysis. The average total length was 55.32±6.53 cm for males and 54.95±6.50 cm for females. The "b" values in length-weight relationship were estimated at 2.981 and 2.962 for males and females respectively which designated that *E. affinis* grows isometrically. The combined sexes' growth parameters were computed for as $L_\infty$= 83.64 cm, K= 0.47 year$^{-1}$ and $t_{0}$= -0.22 year. Total mortality, natural mortality and fishing mortality were valued at 1.413, 0.77 and 0.643 year$^{-1}$ respectively, with an exploitation rate of 0.455. The biological reference points $F_{opt}$ and $F_{limit}$ were calculated at 0.39 and 0.51 year$^{-1}$ respectively. The results revealed a good situation for *E. affinis* stock in the Gulf of Aqaba, since the majority of captured kawakawa had achieved its maturation as indicated by Lc > Lm. The results demonstrating that *E. affinis* fishery in the Gulf of Aqaba, Egypt has a potential for development nevertheless any recommendations should be consider the tuna species' migratory behavior and the multi-species nature of Gulf of Aqaba fisheries in Egypt. Furthermore, for the species' sustainable management, there is a need for continuous monitoring of fishing effort and improve fishery data gathering.

## INTRODUCTION

Tuna, skipjack, and mackerel tuna are economically important for fisheries and they are export supplies. Kawakawa, *Euthynnus affinis* is the dominant species among the neritic tunas inhabiting the Indian coastal waters. *E. affinis* are medium-sized schooling pelagic fish spread all over the Indo-West Pacific between latitudes 35°N and 38°S, longitudes 19°E and 137°W, in water of temperature range 18–29°C (**Froese and Pauly, 2023**). People preferred mackerel tuna owing to its cheap price and high nutritional value. There are numerous mackerel tuna species in Red Sea of which kawakawa (*E. affinis*), is the most plentiful one. These species have great potential in the

Egyptian Red Sea, and are able to become a source the fishers can rely due to deteriorating status of the most commercial species in the area.

Gulf of Aqaba (28°45′N 34°45′E / 28.750°N 34.750°E) is semi-enclosed, deep, narrow body of water is approximately 177 km long and has a maximum width of 27 km and a depth of 1,850 m at its deepest point. It is the northeastern arm of the Red Sea, extending between Saudi Arabia and the Sinai Peninsula and covering an area of 239 $km^2$ (Fig. 1). The Tiran Strait connects the Gulf of Aqaba to the Red Sea. The Gulf of Aqaba contains a varied range of habitats for exceptional and diverse aquatic animals and serves as a vital home for some of the world's richest coral reefs. The Gulf houses more than 100 coral species, 800 fish species as well as several species of crustaceans and mollusks. Unfortunately, Egypt did not report catches of kawakawa or any other species or species composition by gear in the Gulf of Aqaba and the reported catch (27 ton in 2020) does not reflect the actual catch by anyway.


**Fig. 1.** Map of the study area, Gulf of Aqaba, Red Sea, Egypt

For the economy, ecological and biological importance of tuna and tuna-like species, the Indian Ocean Tuna Commission (IOTC) has been established as an intergovernmental organization to assess tuna and tuna like species in the Indian Ocean. The IOTC's key work is to promote cooperation among its members in order to conserve tuna and encourage sustainable exploitations and management. In addition, much research has been conducted in their diverse geographical distribution, however there are no studies on these species in the Egyptian Red Sea. From this point, the present study was carried out to give detailed information about the kawakawa in the Gulf of Aqaba, Egypt for the first time. The study investigated the age, growth, and mortality as the essential data required for building the strategies for sustainable exploitation. Studies on the tuna fishery in Egypt are very limited and not covered all fishing grounds where it distributed. The lack of information has delayed strategic tuna management interventions in Egypt, despite the recent development of a National Tuna Strategy. The obtained results will provide a basis for stock assessment and as a guideline for the sustainable management of the tuna fishery in the Gulf of Aqaba, Egypt.

## MATERIALS AND METHODS

### *Data collection*

The data were collected in the period from February 2021 to May 2023, from the local fishermen operating in the area between Taba and Dahab cities, Gulf of Aqaba, Egypt (Fig. 1). The data on the locations of the fishing grounds were collected by conducting interviews the fishers and taking the whole catches of the selected boat. The fishery in the Gulf of Aqaba is small-scale with boats don't exceed 12 m length (7-9 m length) and the fishing gears that used in the area were gillnets and lines. The fishing time starting with the sunset and ending with sunrise (about 12 hour/day) with an average catch of 70 kg/day. The data on the fish size were collected by measuring the total TL, standard length SL and fork length (FL) of the kawakawa using a measuring tape on a total of 615 fish. Then the weight of each specimen was taking using an electronic scale of one gram decimal point and the sex was determined after dissecting the fish.

### *Data analysis*

The total length (TL) of the fish were tabulated monthly and analyzed to acquire the distribution of the fish size and the dominant size of the caught fish. The distribution of the caught fish was used as a basis for calculating the mean length at first capture ($L_c$) of the fish. The analysis was carried out using a standard logistic curve and an intersection point of 50% of the cumulative frequency (**King, 2007**). Population dynamics such as growth rate (K), asymptotic length ($L\infty$), natural mortality (M), total mortality (Z), and fishing mortality (F) were analyzed to serve as the basis to determine the stock status of the fish. Estimation of the asymptotic length ($L\infty$) and the growth rate (K) were done using ELEFAN program (Electronic Length Frequency Analysis) involved in TropfishR (**Mildenberger *et al.* 2017**) incorporated in R-statistical Program version 3.6.3 (**R CoreTeam, 2020**). The TropFishR is a package that contains the procedures such as ELEFAN, length-converted catch curve (LCC), and virtual population analysis (VPA) for estimating the growth rates, mortality rates, length at capture, VPA, and biological reference points.

The estimation of the theoretical age when the fish length equals to zero was carried out using the rearranged formula of the von Bertalanffy equation as:

$$-\ln [1 - (Lt/L\infty)] = -k*t0 + k*t.$$

The growth performance index was drawn through the Phi Prime test ($\Phi$) by applying the equation $\text{Ø}' = \text{Log}_{10}K + 2\text{Log}_{10}L\infty$ (**Pauly and Munro 1984**).

Natural mortality M per age was estimated using the online tool (barefootecologist.com) with three empirical formulae.

The length at first sexual maturity ($L_m$); the length at which 50% of kawakawa reach their sexual maturity was estimated by fitting the percentage maturity against mid lengths.

The exploitation status (E) was calculated as E = F/Z where F is the fishing mortality rate. While, the specified precautionary target ($F_{opt}$= 0.5M) and limit ($F_{limit}$= 2/3M) values as biological reference points were estimated.

The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of E were estimated using (**Beverton and Holt, 1966**) model.

## RESULTS AND DISCUSSION

### *1. Size structure, length at first capture and length at first maturity*

Length frequency data have a practical applications in the fisheries science. The analysis of length-frequency data allows the estimation of age, growth, survival and mortality rates. The structure of the kawakawa total length (TL) caught in Gulf of Aqaba, Egypt consisted of the size 33-77 cm with an average length of 55.32±6.53 cm for males and 33–78.5 cm with an average length of 54.95±6.50 cm for females. The dominant size of the fish was varied from 52 to 64 cm for both sexes (Fig. 2). There is no significant difference between the two sexes in respect to the average size (t-test: $P$= 0.076). Size-frequency distribution was not significant different between males and females for Kawakawa (Kolmogorov-Smirnov two sample test: d = 0.109, $P$ = 0.7218). The sample comprised of 270 males, 326 females and 19 undetermined fish giving an overall sex ratio of 1:1.21 which is differ meaningfully from the predictable 1:1 ratio (Chi square= 5.26, $P$= 0.02). Based on the length frequency analysis, the length at first capture ($L_c$) of kawakawa in the Gulf of Aqaba was 51.74 cm (Fig. 3). The $L_c$ indicated that the kawakawa was caught in appropriate sizes compared to the size at first sexual maturity in the area ($L_m$ = 43.7 cm, Fig. 4). Based on the estimated $L_c$ and $L_m$, the most caught kawakawa were at sizes that reached their sexual maturity.

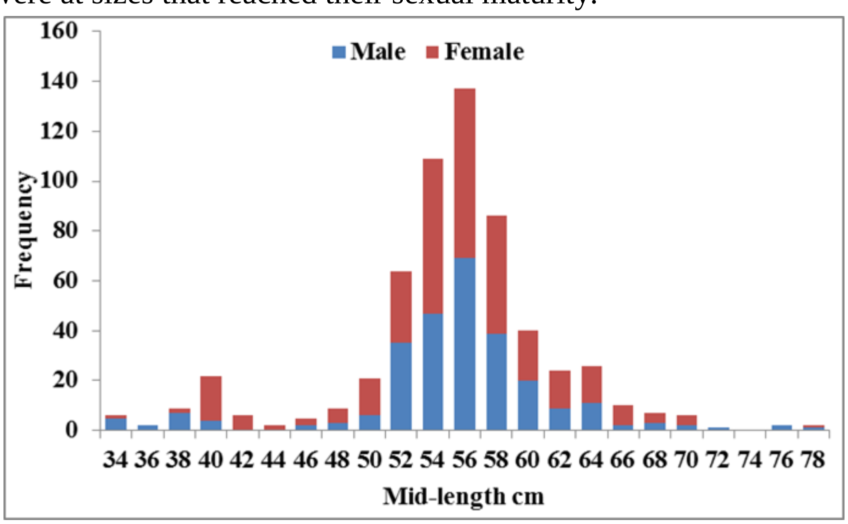



**Fig. 2.** Length frequency distribution for kawakawa from Gulf of Aqaba, Egypt

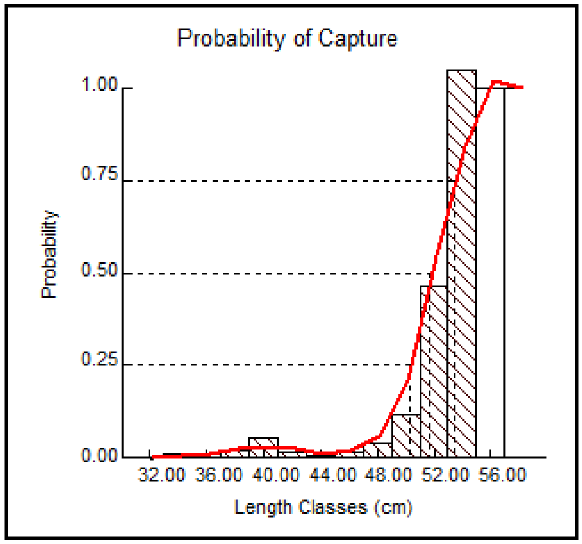



**Fig. 3.** Length at first capture for kawakawa from Gulf of Aqaba, Egypt

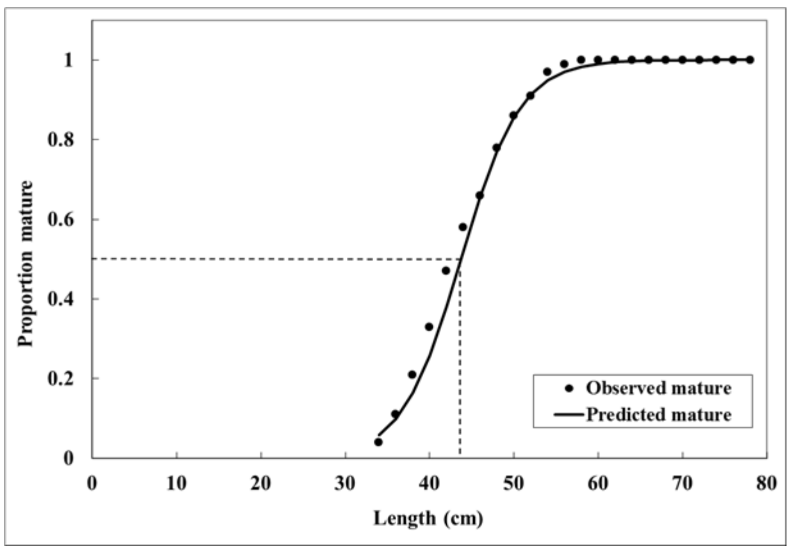



**Fig. 4.** Length at first sexual maturity for kawakawa from Gulf of Aqaba, Egypt

***2. Length- length relationships LLRs***

Length–length relationships are needed to transform length measurements from one type to another and they are also useful in comparative growth studies. The total length TL and fork length FL relationships of Kawakawa in the Gulf of Aqaba were determined using a linear regression analysis as FL= a + bTL; where a is intercept, b is the slope (Fig. 5). The TL-FL equations were:

FL= 0.0447 + 0.9347 TL for male (95%CI: a= -0.9515–1.0410; b= 0.9168–0.9526; *P*= 0.9296)

FL= -0.0287 + 0.9361 TL for females (95%CI: a=-1.0882–1.0308; b= 0.9169–0.9552; *P*< 0.001)

The LLRs were highly significant ($p< 0.001$), with $R^2$ values around 0.97. Although, kawakawa is heavily studied in various parts of its geographic distribution, a variety of measurements were used. So, the present results will be helpful for comparative research among different geographic regions for the species.

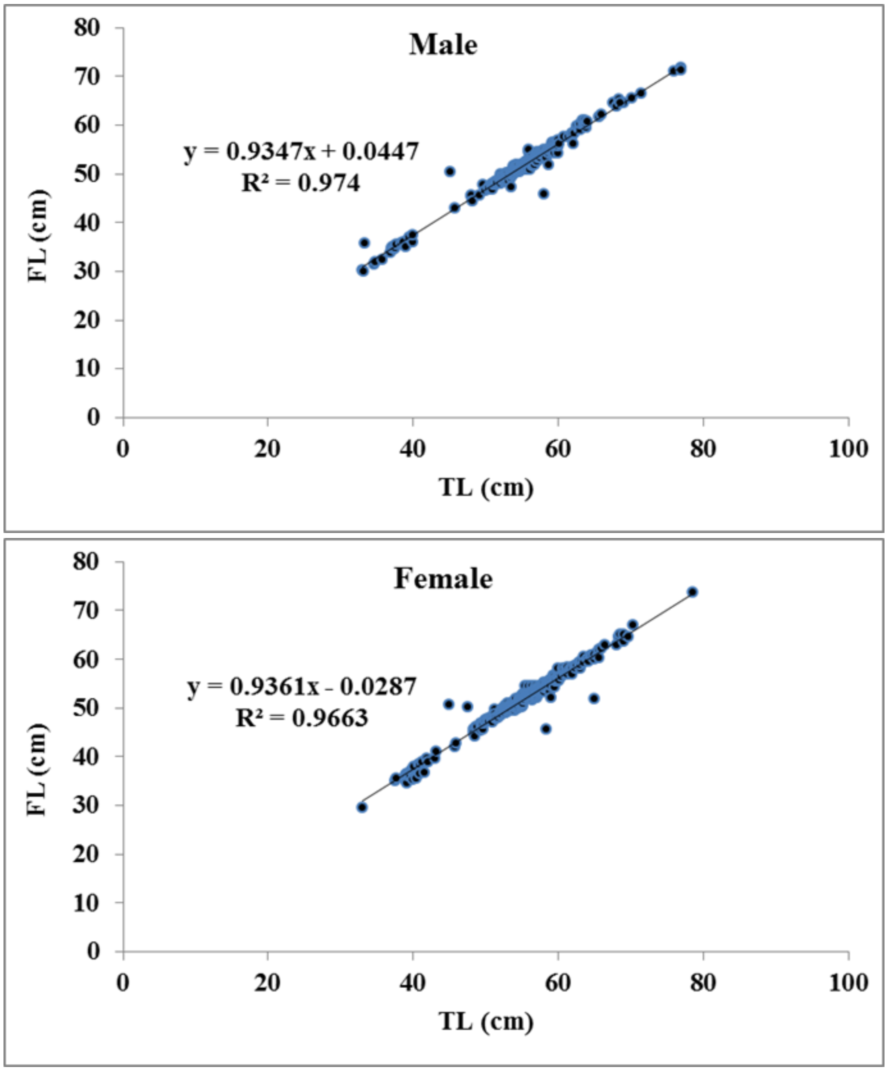



**Fig. 5.** Total length – fork length relationship for kawakawa from Gulf of Aqaba, Egypt

### *3. Length weight relationship LWRs*

LWRs are essential tools and have many applications in assessing fish stocks, estimating biomass, ecological studies and modeling aquatic ecosystems. LWRs also deliver valued information on the fish habitat, condition, reproduction history, life cycle and the overall health of fish species (**Froese, 2006; Froese *et al.* 2011; Mehanna and Farouk, 2021**). The mean total length was 55.32±6.5 cm for males and 54.95±6.5 cm for females while the average weight was 2415.3±795.3 g (390 – 6137 g) for males and 2349.7±792.8 g (376 – 6153 g) for females during the study period. The length-weight relationship of kawakawa was estimated as $W = 0.0148\ TL^{2.9814}$ ($R^2$ = 0.9432, n = 270), $W = 0.0158\ TL^{2.9618}$ ($R^2$ = 0.9424, n = 326), and $W = 0.0142\ TL^{2.9898}$ ($R^2$ = 0.9481, n = 615) for males, females and combined sexes respectively (Fig. 6). The values of ‘b’ is close to the

3 designating isometric growth (*P*> 0.005). The coefficient of determination'$R^2$' value is high indicating the high degree of correlation and better fit of length weight relationship. Previous studies gave different types of growth based on their b-values, **Al-Zibdah and Odat (2007)** reported b-value at 3.1399 in the Gulf of Aqaba, Jordan, **Kaymaram and Darvishi (2012)** estimated b-value at 2.87 for the pooled samples from the Northern part of Persian Gulf and Oman, **Johnson and Tamatamah (2013)** determined the b-value at 2.91 for male and 3.2 for female in Tanzania, **Vera *et al.* (2016)** in Sunda Strait gave value of b 2.966, **Rudy and Agustinus (2016)** in Java Sea gave value of b 2.6497, **Mudumala *et al.* (2018)** estimated it at 2.86 for the same species in the North west coast of India, **Hamid *et al.* (2018)** in East Halmahera has b value 3.2982, **Lactumi (2021)** indicated a negative allometric growth in Nibung Bay, **Hasibuan *et al.* (2022)** gave b-value of 3.0037 in Sumatera. Nevertheless, this variations in b-values among different localities are acceptable, **Beverton (1963)** mentioned that the b-value depends on the shape and fitness of the fish as well as on various factors like the sex, sampling time and environmental conditions. Also, **Ghosh *et al.* (2010)** reported that these variations are probably due to factors related to ecosystem and biological condition like spawning time, sexual maturity, feeding behavior and competition for food. **Froese (2006)** and **Froese *et al.* (2011)** stated that the variation in the exponent (b) of the WLRs of fish species could be also affected by geographic locations, sampling area, seasons, size range and ecological factors such as temperature.

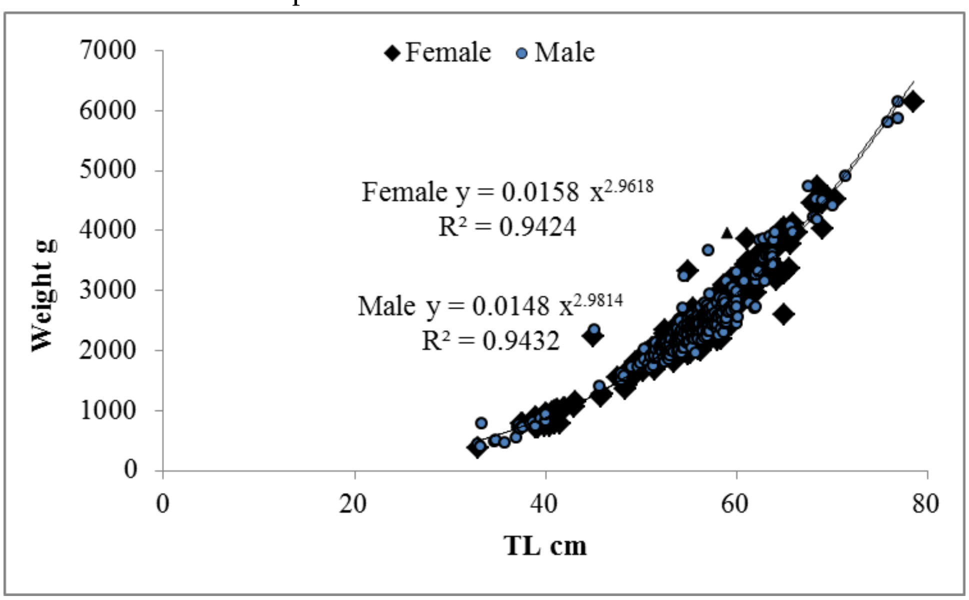



**Fig. 4.** Length-weight relationship for kawakawa from Gulf of Aqaba, Egypt

### 4. *Age composition*

Age distribution of marine fish species is an vital tool for assessing the population's health (**Berkeley *et al.* 2004**). Typically, an established, healthy population will display a 'well balanced' age structure (**Brunel and Piet, 2013**) with numerous larger, older individuals. In the Gulf of Aqaba, kawakawa showed an age distribution of 92% of fish

≥ 2 years (> 46 cm TL) (Fig. 7). The length at age resulting from length frequency analysis revealed that, this species attains lengths of 37.43, 55.54, 64.62. 71.95 and 77.03 cm TL at the end of the first year to the fifth year of life, respectively.

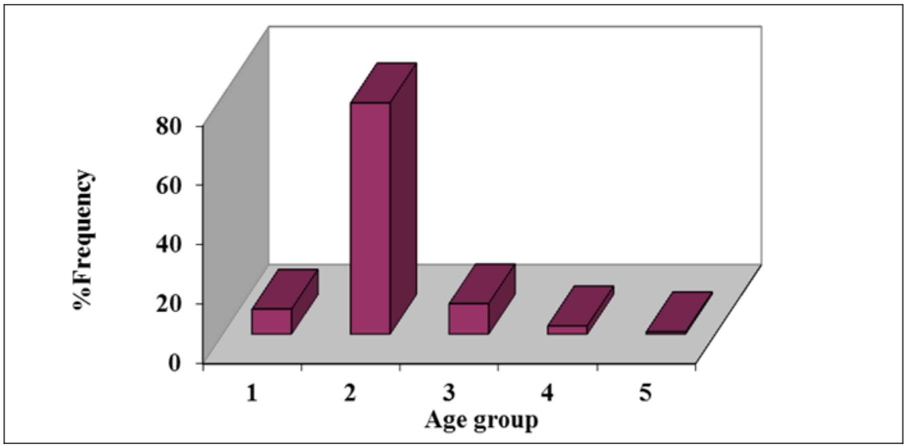



**Fig. 7.** Age distribution for kawakawa from Gulf of Aqaba, Egypt

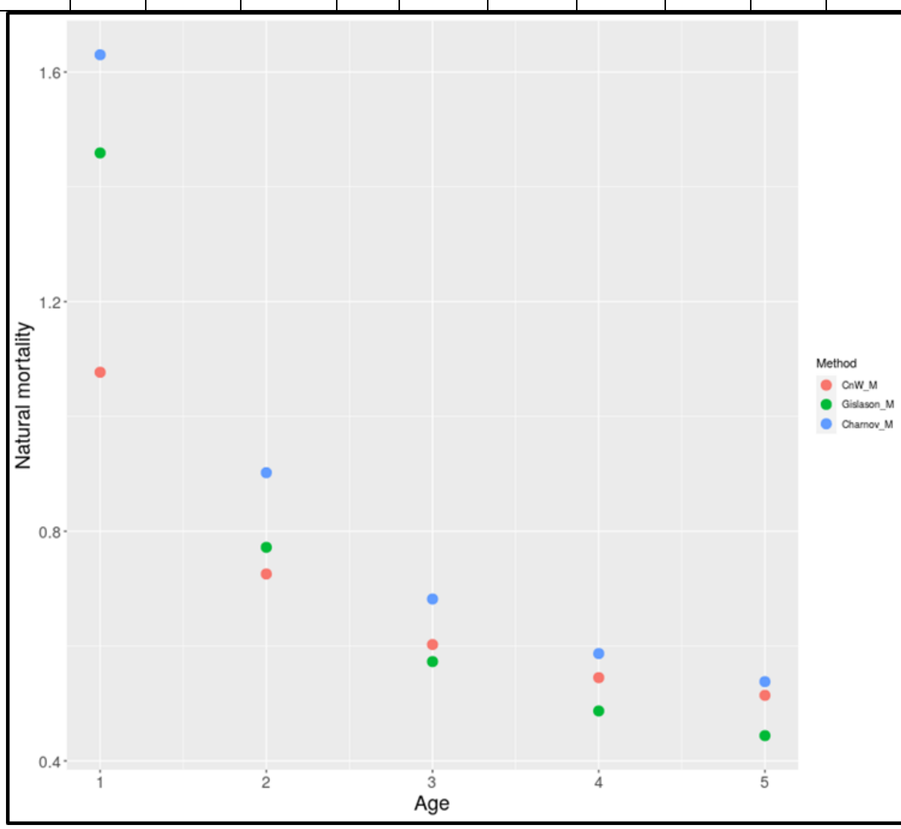
### *5. Population Dynamics and Exploitation Status*

The size structure examination gave a growth rate (K) at 0.47 per year, an asymptotic length ($L\infty$) at 83.64 cm TL and $t_0$ = -0.22 year for kawakawa. Growth parameters of the von Bertalanffy equation as calculated by earlier researches and those of the present study are given in Table 1. Kawakawa *E. affinis* in the Gulf of Aqaba is a fast growing fish attaining a maximum length of around 79 cm TL. The $L\infty$ estimated by earlier workers is comparable with that in the present study where the values ranged from 67 cm to 89 cm. The 'k' value however, showed a wide range between 0.34 to 0.8 (Table 1) indicating variations in the length attained in different years. All previous investigations indicated *E. affinis* to be fast growing species, attaining a length of 31-44 cm in the first year of life. The variability among growth parameters may be owed to particular characteristics of sampling region such as biotic and abiotic factors, state of the different exploited stocks, different length ranges and differences of growth estimation methods.

The natural mortality (M) was high in the early ages and decrease with age increase (Fig. 8). The obtained average M (0.77 per year) was somewhat greater than the fishing mortality F (0.643 per year), indicating that kawakawa fishery in the Gulf of Aqaba was operated around its optimum situation. The exploitation ratio of the fish was E= 0.455, indicating that the exploitation of this fish is nearly about its optimum one, i.e. E= 0.5 (**Gulland, 1971**). **Patterson (1992)** observed that the E value of 0.5 tended to reduce pelagic fish stock abundance, so he suggested that E should be at 0.4 to maintain these stocks. On the other hand, fishing mortality (0.643/year) was greater than both the target ($F_{opt}$= 0.39/year) and limit ($F_{limit}$= 0.51/year) biological reference points. From fisheries management point of view, the fishing effort should be controlled as well as the mesh and hooks size should be regulated.

**Table 1.** Growth parameters of *E. affinis* from different localities compared to the present work

| Locality | K/ year | TL∞ cm | $t_o$ year | Φ' | Length by age cm | | | | | Author |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1st | 2nd | 3rd | 4th | 5th | |
| Thailand | 0.46 | 76.0 | | | | | | | | Yasaki, 1982, 1989 |
| India | 0.34 | 81.0 | -0.34 | | | | | | | Silas *et al.*, 1985 |
| Indian waters | -- | -- | -- | -- | 31.4 | 46.6 | 57.1 | 64.4 | | Pillai & Gopakumar, 2003 |
| India | 0.79 | 81.7 | -0.02 | 5.7 | 44.6 | 64.9 | 77.4 | | | Khan, 2004 |
| Iran | 0.51 | 87.66 | -0.23 | 3.58 | 40.3 | 58.9 | 70.2 | 77.1 | | Taghvai *et al.*, 2010 |
| India | 0.56 | 72.5 | 0.03 | | 31.84 | 49.27 | 59.23 | 64.9 | | Ghosh *et al.*, 2010 |
| India | 0.56 | 81.92 | -0.03 | | 42.7 | 59.5 | 69.1 | | | Rohit *et al.*, 2012 |
| Tanzania | 0.78 | 89.25 | -- | | -- | -- | | | | Johnson&Tamatamah, 2013 |
| India | 0.70 | 67.86 | -0.26 | 3.5 | 33 | 52 | 64 | 70 | 75 | Mudumala *et al.*, 2018 |
| Gulf of Mannar | 0.63 | 79.0 | | | | | | | | Kumar *et al.*, 2019 |
| Gulf of Aqaba, Egypt | 0.47 | 83.64 | -0.22 | 3.52 | 37.43 | 55.54 | 64.62 | 71.95 | 77.03 | Present study |



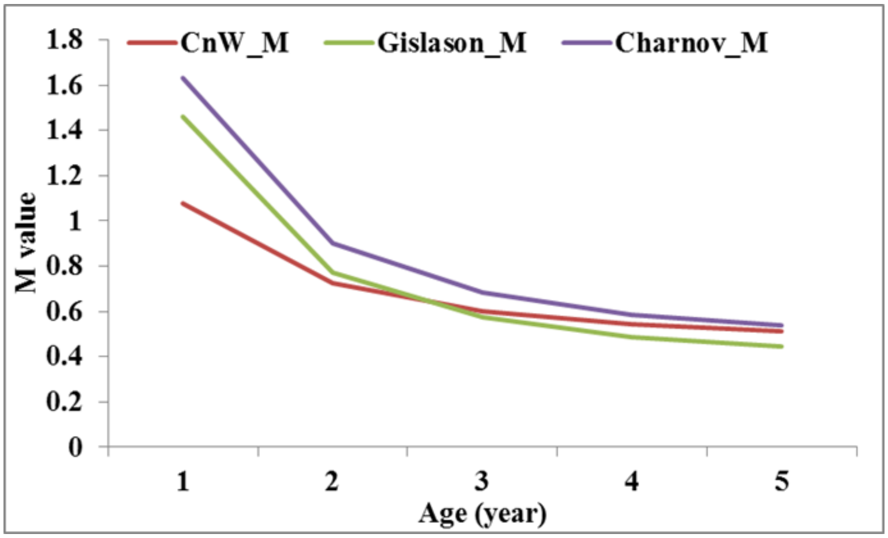



**Fig. 8.** Natural mortality per age from three different scenarios for kawakawa

According to virtual population analysis (VPA), main loss in the stock up to 48 cm size was due to natural causes (Fig. 9). Fish were increasingly sensitive to the fishing gear after this size and mortality due to fishing increased. The most susceptible lengths for fishing gears were from 52 to 60 cm TL. However, loss due to fishing was very low for big-sized fish.

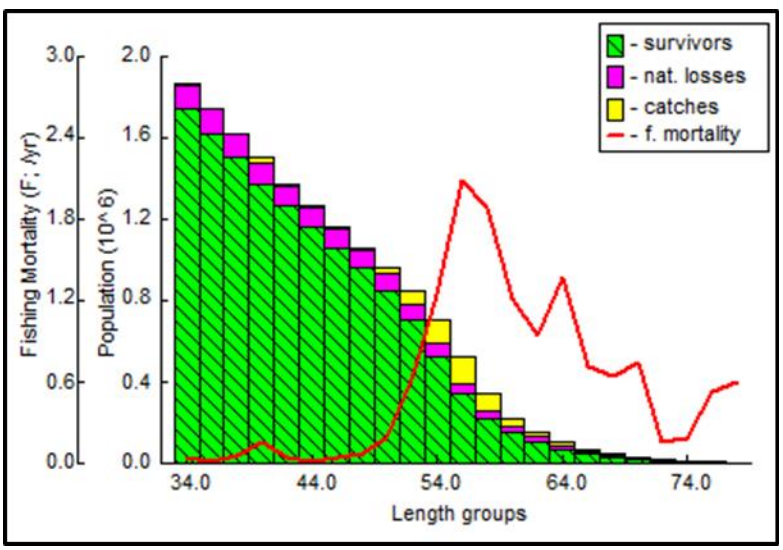



**Fig. 9.** VPA of kawakawa from Gulf of Aqaba, Egypt

The outcomes of relative yield per recruit analysis as a function of length at first capture ($L_c$) and M/K value (Fig. 10) revealed that, the maximum exploitation rate ($E_{max}$= 0.94), was greatly higher than the present level of exploitation rate (0.455). The exploitation rate which maintains 50% of the stock biomass as spawning stock ($E_{0.5}$) and considered as a target reference point was estimated at 0.40 which is slightly lower than the current one. Also, the yield per recruit analysis indicated considerable increase in yield with increase in effort to unacceptable levels especially the Gulf of Aqaba fisheries in Egypt is a multi-species fishery that requires careful consideration of any increase in effort. Tunas management is complex process owing to their migratory nature, necessitating international collaboration as no one nation can effectively manage them.

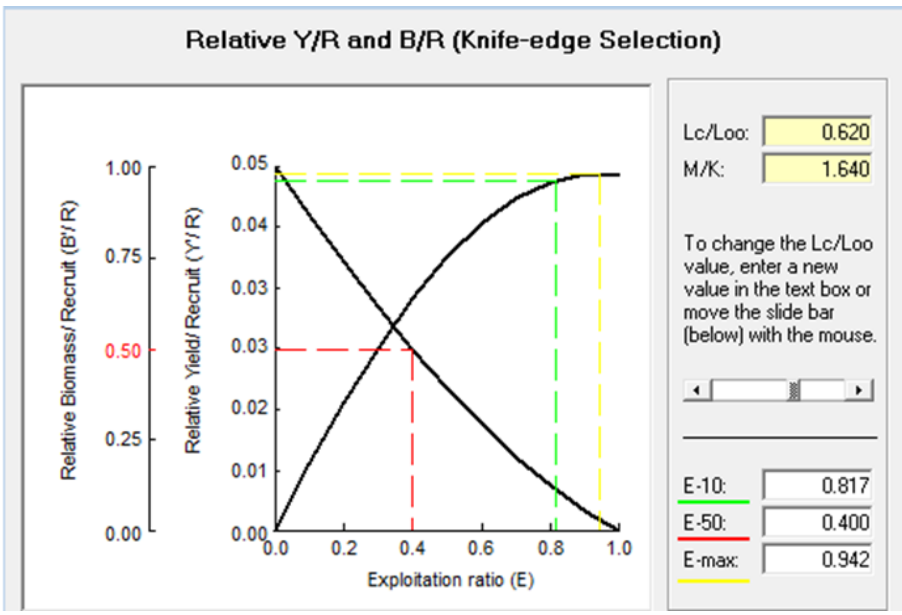



**Fig. 10.** Yield per recruit analysis of kawakawa from Gulf of Aqaba, Egypt

## CONCLUSION

Although small tunas such as kawakawa are economically important fishery resources for coastal communities, the available data required for its management is still rare. Therefore, the present study provides the essential information on the kawakawa, *Euthynnus affinis* in the Gulf of Aqaba, Red Sea, Egypt where no previous investigations on age, growth and stock status have been conducted. In Egypt, there are no management guidelines for the tuna's fishery and their catches are underestimated, and in many areas not recorded. The study highlights the importance of regional studies of a particular stock and its mode of exploitation to develop specific management plan for the studied region. Kawakawa fishery along the Egyptian Gulf of Aqaba is working around its optimum, and any regulations should be consider the multi-species nature of the fishery and the migratory behavior of the species. The development of observer programs and the improvement of fisheries monitoring and fisheries data gathering should be done to improve the management of Egyptian tuna stocks.

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