FISHERY STATUS, GROWTH, REPRODUCTION BIOLOGY AND FEEDING HABIT OF TWO SCOMBRID FISH FROM THE GULF OF AQABA, RED SEA

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ABSTRACT

The fishery and some biological aspects of two Scombrid fish species, Katsuwonus pelamis and Euthynnus affinis from the Gulf of Aqaba were studied during one year period (1999-2000). Monthly samples of the two species were collected to investigate growth, reproduction and feeding habit. Results showed that the Scombridae family form more than 60% of the total catch of Jordanian fishery. The length-weight relationships (LWr) in the two fish species demonstrated that the growth is of an allometric type (around 3). The condition factor (k) showed relatively consistent values in both species but revealed slight variability in growth periods. This could be attributed to the limited food availability in fish natural habitat. Different age classes were observed in the catch of the two species irrespective of season. The mean GSI exhibited similar change pattern with season in both sexes of the two fish. Spawning behavior and planktonic larvae of both fish were not observed in the field. This could be inferred that these fish are not migrating to the region for reproduction. The food composition of K. pelamis and E. affinis suggests that the fish compete for the same food items. These are the fish Atherinomorous lacunosus, crustacean and molluscans. Prey occurrence in fish stomachs is attributed mainly to the seasonal availability of food in the Gulf of Aqaba. High abundance of food items in winter may indicate that the two species migrate at the climax of primary productivity in the Gulf.

Keywords: Scombridae, *Katsuwonus pelamis*, *Euthynnus affinis*, Gulf of Aqaba, Red Sea

INTRODUCTION

The family Scombridae, mackerels and tunas, includes 15 genera with 49 species that form the basis for some of the world's most important commercial fisheries (Randall, 1995). Albacore, northern and southern bluefin, Skipjack, and yellowfin tuna are among the most commercially valuable fishes (FAO, 1994). Eleven species of tuna and mackerels were recorded from the Gulf of Aqaba. Namely, *Auxix thazard, Euthynnus affinis, Gymnosarda unicolor, Katsuwonus pelamis, Rastrelliger kanagurta, Sarda orientalis, Scomber japonicus, Scomberomorus commerson, Thunnus alalunga, Thunnus albacares*, and *Thunnus tonggol* (Khalaf & Disi, 1997). Scombridae represented an average of 91% of the total catch in the

Gulf of Aqaba. *K. pelamis* occupies top priority in fish market compared to other species of Scombridae in Jordan. This fish usually appears in spring having an average weight of 4-5 kilograms, while *E. affinis* is found in smaller size (~2 kg) during a wider period (winter-spring). Both fish are usually caught by surface long line trawling and with gill nets during their migration to the area. Skipjack occurred within the 15 ^{o}C or warmer isotherms of the world oceans with similar LWr for fish caught from different oceanic regions (Matsumoto *et al.,* 1984). They reported on spawning season of Skipjack based on gonadosomatic indices from the Pacific, Atlantic and Indian Ocean and found that the fishes spawn throughout the year in tropical waters and from spring to fall in subtropical waters. A multiple spawning pattern was reported in the Indian Ocean Skipjack and the Atlantic mackerel (BuDag, 1956; Raju, 1964; Matsumoto *et al.,* 1984; Grégoire, 2000). The vertebrae and dorsal spines were used for age estimation in *E. affinis* from the Red Sea and Gulf of Aden (Landan, 1965; Shabotiniets, 1968). The growth parameters were derived from the relative ages in Skipjack tuna based on the length frequency distributions and age (Silar *et al.,* 1985; Joseph & Miller, 1988). Scombrid fishes represent the major volume of Jordanian fishery and its management depends on the provision of detailed information on growth, age, reproduction and feeding habit. Yet, studies are still lacking on the biology and population dynamics of the different species of Scombridae in Jordan. The aim of this study is to describe some important biological aspects of *K. pelamis* and *E. affinis* and to provide information on stock size and composition needed for fishery managers in Gulf of Aqaba.

MATERIALS AND METHODS

Scombridae fishery and catch estimation

Data on commercial fishery of this family were collected from July 1999 to June 2000. Investigation was conducted in full cooperation with the local fishermen. Fishing was mainly dependent on long lines which is the most efficient method for commercial exploitation. Catch of Scombrid fish was estimated based on monthly records of fish landing at the two landing sites in Aqaba (Fig. 1).

Length-weight relationship and age determination

Growth was determined by analyzing the length-weight relationship (LWr) and the condition factor (k). A total of 225 and 140 fish specimens of *K. pelamis* and *E. affinis* were examined, respectively. Total length of each specimen was measured to the nearest centimeter from the tip of the snout to the end of caudal ray and the weight was recorded to the nearest gram. All measurements of weight and length were made at the landing sites and at the fish market.

LWr and k were obtained following Nielsen & Johnson (1983) and Le Cren (1951).

$Wt = a\ L^{b}$ *or* $Log_{10}\ W = Log_{10}\ a + b\ Log_{10}\ L$

where, W is the total fish weight in g and L the total length in cm, a and b being two constants.

$K = (W / L^{3})\ X100$. Where, W is the total fish wet weight in g and L the standard length in cm.

The first dorsal spines were used for age determination in both fish. Spines were isolated and cross-sectioned (1.0 to 1.2 mm) near the condyle base following Batts (1972) and

then mounted on slides. Annual rings were counted under a binocular microscope using incident light and dark background. Typical growth patterns that can be seen on tuna spines include a narrow translucent zone that represent a slow growth stage and wider opaque zones that represent faster growth.

Reproduction

Investigation was based on gonadosomatic indices (GSI) in order to assess the reproductive development of gonads with season (Caillier *et al.,* 1986). GSI was calculated by the formula (Wt/W) * 100
where Wt is the gonad weight in g, and W is the total fish weight in g.

Food and feeding habit

A total of 135 specimens of *K. pelamis* and 135 of *E. affinis* were sampled over nine months to study the food and feeding habit in both species. Stomachs were isolated and preserved in 4% formalin for food content analysis and identification (Newell, 1993; Smith, 1996). Gut content analysis was performed by a combination of numerical, frequency of occurrence and gravimetric methods (Hyslop, 1980). Main food items were determined using the index of relative importance approach (George & Hadley, 1979)
$RI = (AI / \sum AI) 100$
where AI= % frequency of occurrence + % total number + % total weight
Food consumption (FC) was calculated as follows:
$FC = (w / W) 100$
where w; weight of stomach content in g and W; total fish weight in g.

RESULTS

Scombridae fishery and catch estimation

Fishing ground extends about 27 km along the Jordanian coastline of the Gulf of Aqaba, which is mainly characterized by fringing coral reef and sea grass beds (Fig. 1). Fishing gear were mostly the long lines and gill nets. Fishermen usually use small boats (2.5-13 m length) made of fiberglass or wood and equipped with outboard engines (40-60 Hp). The number of fishing trips varies according to season but average number of trips reaches 50 per day. Two major landing sites, in the north and the south of the Jordanian coastline, receive most of the fish catch (Fig. 1). These sites are located near the local fish markets. Tunas and sardines are the most abundant fish stocks during winter. Results showed that the Family Scombridae accounts for about 60.3 % of the total catch in the Jordanian Gulf of Aqaba. The monthly catch variation of Scombridae revealed that the maximum catch occurred in December and the minimum in June (Fig. 2). The catch percentage by weight of the different Scompridae species showed that 52% of the catch is composed of *K. pelamis*, followed by *E. affinis* (40%). Other species however such as *Scomberomorous commerson, Thunnus tonggol* and *Thunnus albacares* accounted for only 8 % of the total catch (Fig. 3).

Length-weight relationship and age determination

LWr calculated for both species are presented in Fig. 4. The regression values (R^2) were significantly high and exhibited a value of 0.899 for *E. affinis* and 0.812 for *K. pelamis*

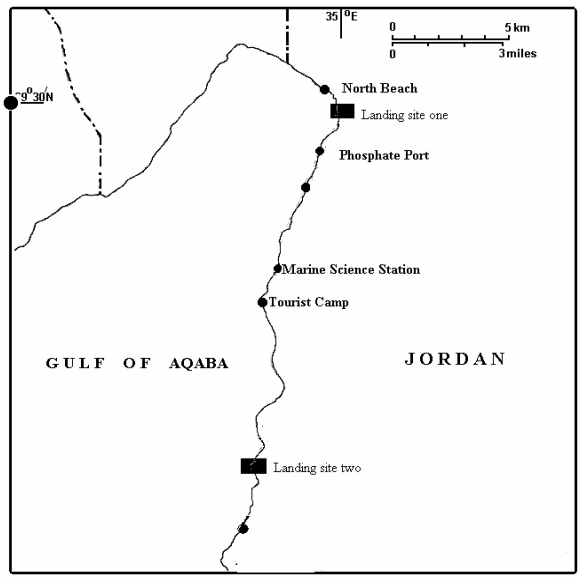

Figure 1. The two landing sites of fish catch along the Jordanian coast of Gulf of Aqaba.

TABLE 1

LWr in all Fish Specimens of *K. pelamis and E. affinis*

Species	n	Equation	r^2	a	b
Katsuwonus pelamis	225	Log W = -1.787 + 2.9724 Log L	0.812	0.016	2.972
Euthynnus affinis	140	Log W = -2.11 + 3.1399 Log L	0.899	0.008	3.14

k exhibited highest values during the period October- December and lowest values in February - April for males and females of both fishes (Fig. 5). However, the range of change between these values was about 0.3 revealing a slight change in the growth pattern of both fishes which could be attributed to the feeding activity during the two periods.

Clearly, defined rhythmic growth marks were observed on the dorsal spine sections from almost all specimens of *E. affinis* and *K. pelamis*. The marks appeared as either translucent or opaque zones when viewed under the microscope. A total of 153 specimens of *K. pelamis* were examined of which 43.1%, 28.1%, 17.6% and 11.1% were found to have the ages of 5, 6, and 7 and 8 years, respectively. While, in the 131 examined fish specimens of *E. affinis*, 47.3%, 35.9% and 16.8% have the ages of 2, 3 and 4 years, respectively. Sections of age classes in both species are shown in Fig. 6. Difference in ages in the present study could be attributed to the heterogeneity of populations of the two species which seems to appear

during water mixing season that was associated with food abundance in the Gulf of Aqaba (Al-Najjar, 2004; Badran, 2001).

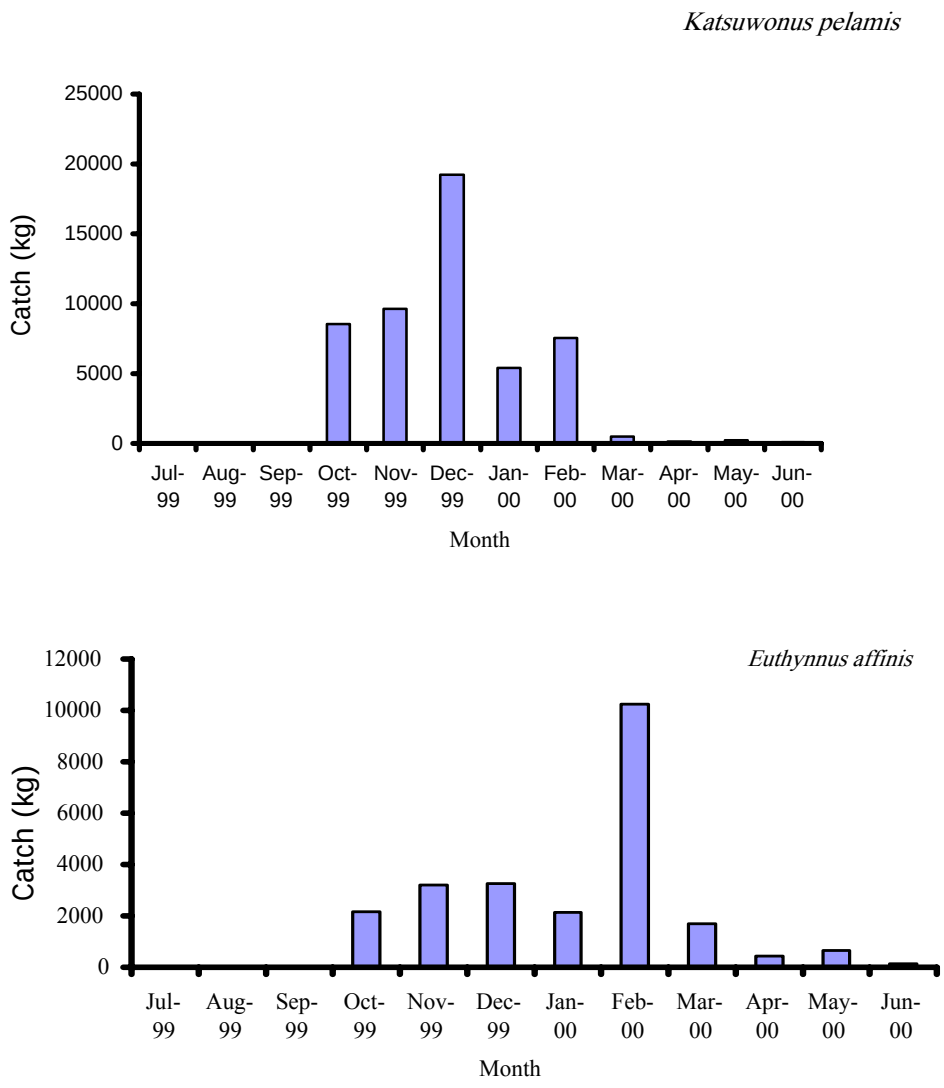

Figure 2. Monthly variations in catch size of *K. pelamis* and *E. affinis* during the period from July 1999 to June 2000.

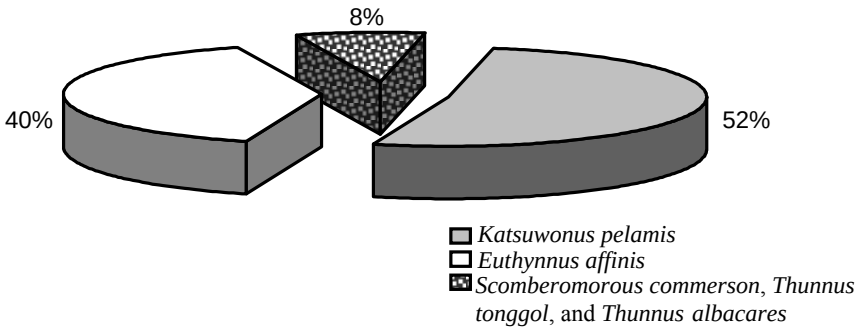

Figure 3. Percent catch of three main species of the family Scombridae caught during the period from July 1999 to June 2000 in the Gulf of Aqaba.

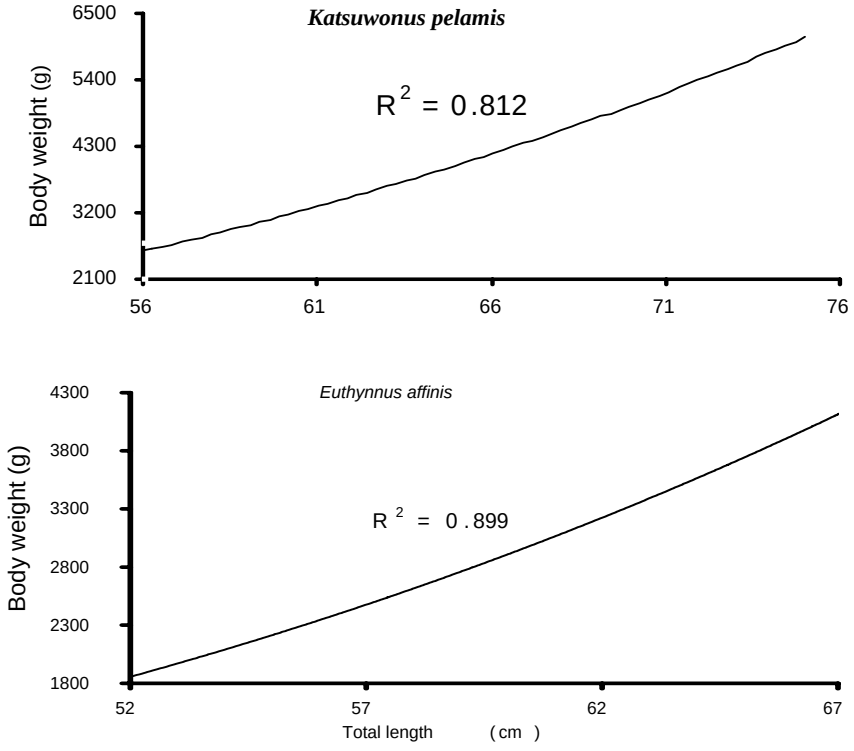

Figure 4. LWr and the correlation coefficient calculated for the two species of *K. pelamis* and *E. affinis*.

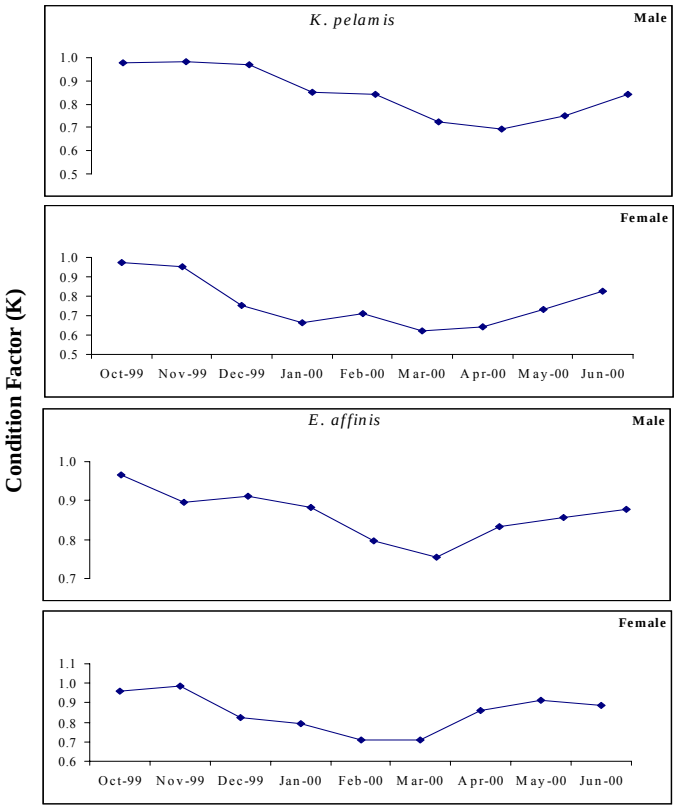

Figure 5. Monthly changes in condition factor (k) of males and females of *K. pelamis* and *E. affinis* during the examined period.

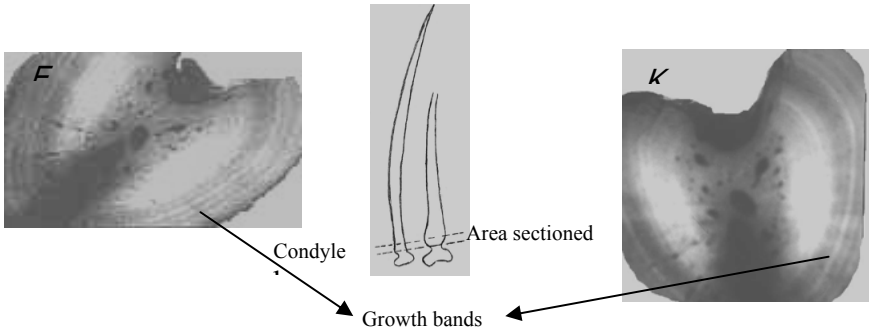

Figure 6. Sections from the first dorsal spine made from both species showing the translucent and the opaque growth bands. *K. pelamis* estimated to have ages between 5 to 8 years whereas *E. affinis* between 2 and 4 years.

Gonado-somatic index (GSI)

Monthly variations in the GSI were relatively low in both fishes (Fig. 7). It can be observed that the range in GSI fluctuated between 0.7-2.5 for *K pelamis* and 0.5-1.5 for *E. affinis* with noticeable seasonal variability in both fish.

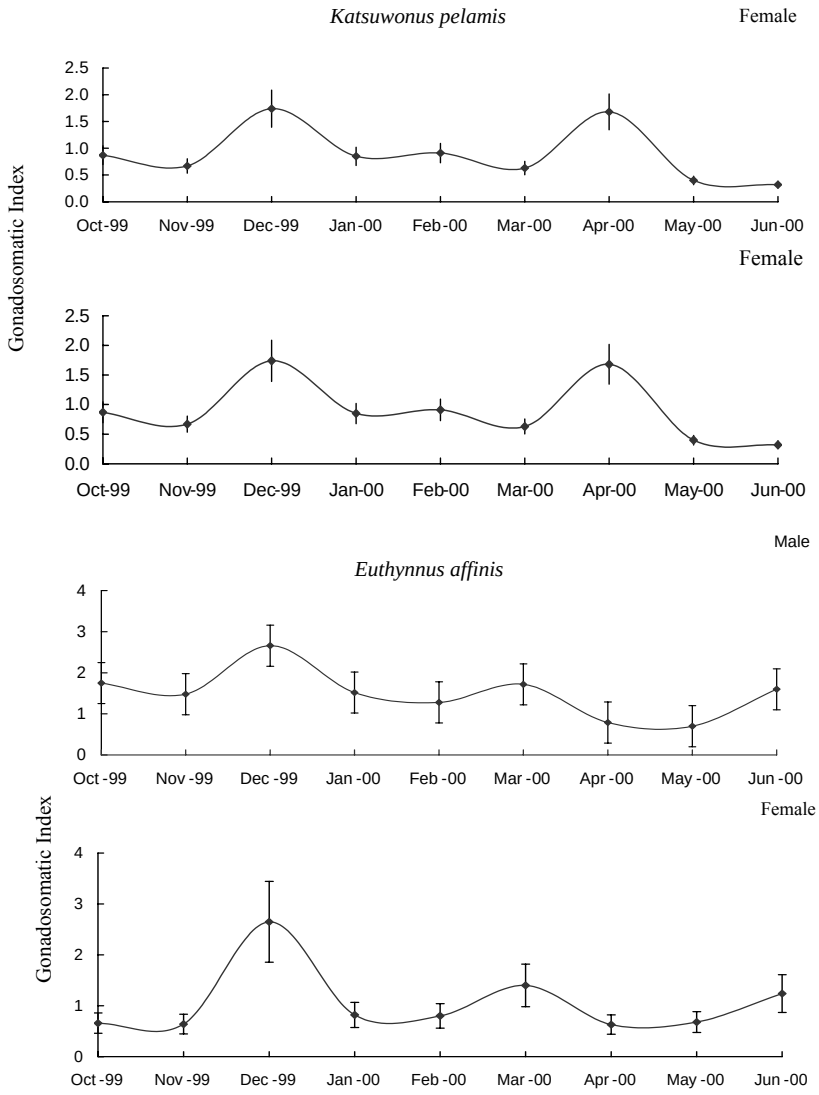

Figure 7. Monthly changes in the gonadosomatic index (mean ± SD) of males and females of the two fish, *K. pelamis* and *E. affinis*.

TABLE 2

Composition of Stomach Contents of *K. pelamis* and *E. affinis* Expressed by Percent Number, Frequency of Occurrence (% F) and Weight (% W) as well as the Index of Relative Importance (RI)

K. pelamis

Food items	N	%N	F	%F	W (g)	%W	RI
Small fish	988	53.9	129	100	8892	99	64.3
Crustacea	320	17.2	80	32	19.2	0.21	20.3
Mollusca	511	27.9	36	27.9	16.8	0.19	14.2
Digested material			74	75.4	27.8	0.31	

Total fish number 135
Number of fish feeding 129

E. affinis

Food items	N	%N	F	%F	W(g)	%W	RI
Small fish	978	53.3	121	100	5868	99.1	65
Crustacea	484	26.4	71	58.7	8.6	0.15	22
Mollusca	363	19.8	33	27.3	7.3	0.12	12.1
Digested material			55	45.5	24.3	0.6	

Total fish number 135
Number of fish feeding 121

Food and feeding habit

Analysis of gut content in 135 specimens of *K. pelamis* revealed 4.4% of empty stomachs. The numerical method showed that the silverside fish *Atherinomorus lacunosus*, accounted for 53.9%, mollusca 27.9% and planktonic crustacea for 17.2% of the total stomach contents (Table 2). Whereas, the gravimetric method revealed that the fish *A. lacunosus* constitute 99% of food content. *A. lacunosus* represented the major food item and showed 100% occurrence as noted in almost all of the examined specimens. Similarly, the index of relative importance showed *A. lacunosus* as a major food component followed by planktonic crustacea and mollusca. In the 135 specimens of *E. affinis* examined only 10.4% had empty stomachs. The numerical method however, revealed that *A. lacunosus* accounted for 35.3%, planktonic crustacea 26.4% and molluscs 19.8% (Table 2). The frequency of occurrence of *A. lacunosus* was almost similar to those observed in *K. pelamis*. The gravimetric method indicated that *A. lacunosus* also accounted for 99.1% of other food items. Index of relative importance also suggested that *A. lacunosus* is the main food component for *E. affinis*.

Based on percentage occurrence and weight of the different food items guts of *K. pelamis* and *E. affinis*, the fish *A. lacunosus*, crustacea and molluscs occurred in fish stomachs almost throughout the whole study period (Table 3). Monthly variations in the composition of the diet expressed as a percentage of total food items by weight for both *K. pelamis* and *E. affinis* are shown in Fig. 8. The fish *A. lacunosus* represented most food volume in both species. The fish *A. lacunosus* exhibited a maximum percentage in *K. pelamis* diet in November, in June, for *E. affinis*.

TABLE 3

Monthly Changes in the Percentage Occurrence of Various Identifiable Food Items in the Stomachs of *K. pelamis and E. affinis*

Month	Small fishes		Crustaceans Crustaceans		Molluscs Molluscs	
	E. affinis	*K. pelamis*	*E. affinis*	*K. pelamis*	*E. affinis*	*K. pelamis*
Oct-99	81.3	80.6	18.1	17.3	9.8	10.3
Nov-99	78.6	72.8	16.7	15.3	7.0	7.1
Dec-99	79.7	81.6	22.4	24.0	18.1	17.4
Jan-00	73.1	71.2	25.1	20.5	17.2	18.3
Feb-00	80.3	83.2	10.7	9.7	12.9	13.1
Mar-00	77.5	79.2	18.8	19.8	0	0
Apr-00	74.8	75.7	11.8	12.7	8.6	8.8
May-00	59.4	58.0	0	0	7.8	7.3
Jun-00	66.9	67.0	13.1	12.4	15.4	14.6

Monthly variation in the food consumption [food weight (g)/ fish weight (g)] of *K. pelamis* and *E. affinis* are presented in Fig. 9. The maximum food consumption for *K. pelamis* (4.34 %) was observed in December and the minimum (0.54 %) was in February. In *E. affinis*, the maximum consumption was 6.3% in March and showed a minimum value (2.32 %) in October.

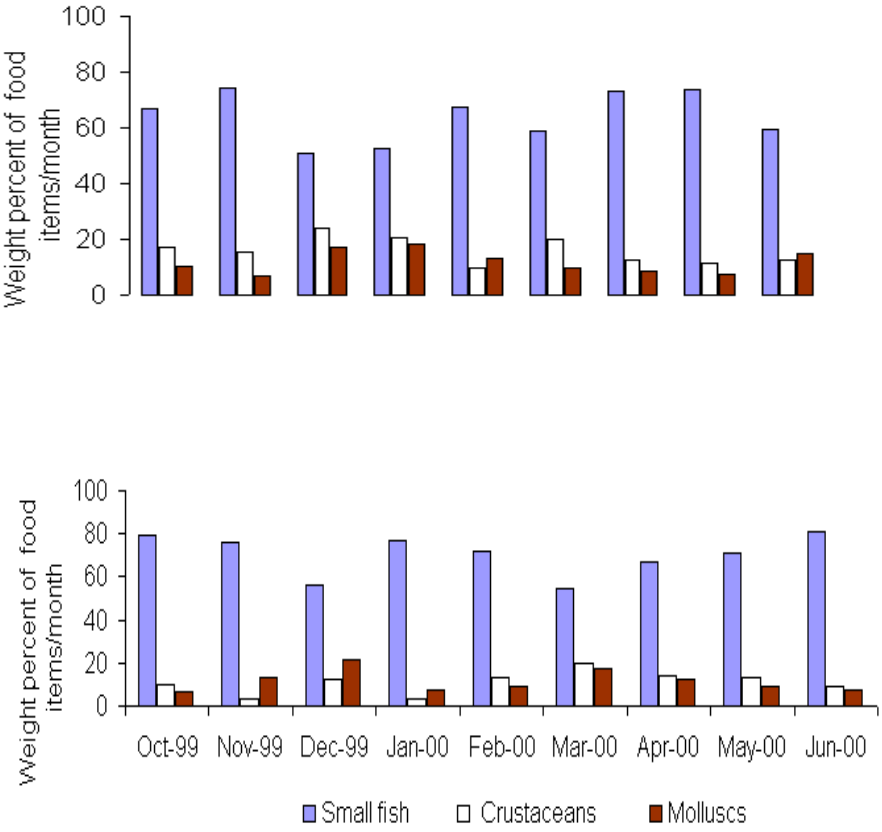

Figure 8. Monthly variation in dietary composition of *K. pelamis* and *E. affinis* expressed as a percentage of total weight of food items per month.

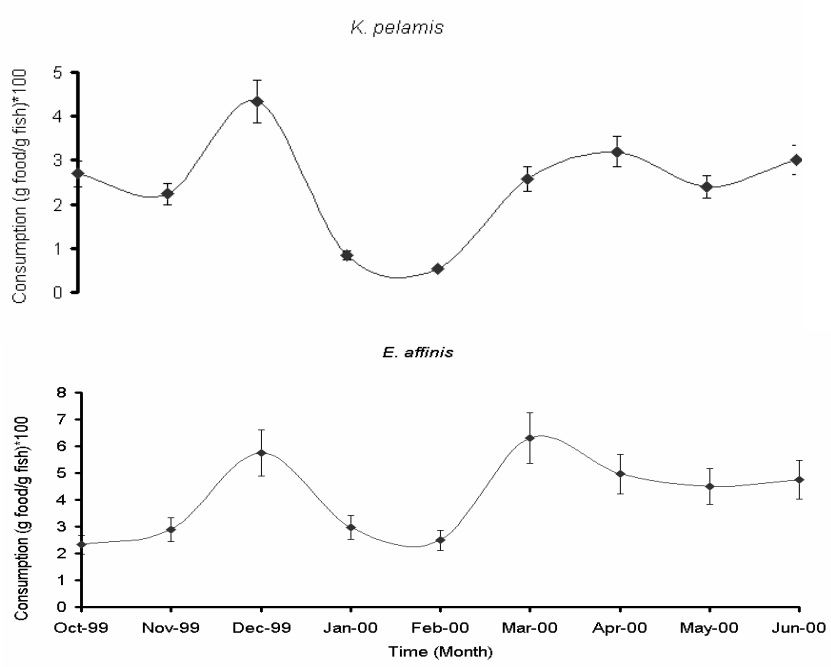

Figure 9. Monthly variations in the food consumption expressed as [food weight (g)/ fish weight (g)] of *K. pelamis* and *E. affinis.*

DISCUSSION

LWr of both fish demonstrated that the growth is of an allometric type (Nielsen & Johnson, 1983). The total length of *K. pelamis* ranged from 56 to 75 cm while in *E. affinis* it ranged from 46 to 64 cm. Matsumoto *et al.,* (1984) reported similar LWr for *K. pelamis* from different oceanic regions. Batts (1972) mentioned that Skipjack exhibited the 50-60 cm range from the western Atlantic and appear to be relatively heavier than elsewhere. Nonetheless, to further understand the growth of individuals of various sizes we might suggest tag-recapture experiments to produce data useful for the analysis of length frequencies of such valued fishes for the Jordan's fishery management.

K is a good indicator of fish well being in the natural habitat over time since k equation is based on body weight and length. Both revealed the growth profile either speed up or retard. The results showed that k varied mainly with season. This could be attributed to the

fluctuation in food availability and consumption of both species following the seasonal variation in the primary productivity in Gulf of Aqaba (Badran, 2001, Al-Najjar, 2004; Al-Zibdah *et al.,* 2005). The minimum food consumption of the Skipjack was observed to behave similarly probably due to limited food availability (Matsumoto *et al.,* 1984). In addition, fecundity of Scombrid fish can reach up to $60X10^4$ eggs following the spawning period and that the weight loss in fish body is a reduction in the condition factor (Matsumoto *et al.,* 1984). However, no correlation was observed between spawning period and k of *K. pelamis*. Similar observation was found for *E. affinis* that showed even slight changes in k compared to that of *K. pelamis*. This might suggest a least effect of variation in food consumption of the later fish and not invest as much effort in reproduction as *K. pelamis*. This could be further investigated by comparing the fecundity of the two species. Nevertheless, the k for both species was relatively high indicating a good well being of the two species and the suitability of the prevailing environmental conditions in the Gulf of Aqaba.

Information on growth, mortality rate and age at maturity are important factors that explain fisheries biology (Gulland, 1983). Different ways are used to determine the age of Scombrid fish including the use of growth rings or marks on the vertebrae or dorsal spines (Landan, 1965; Sosa-Nishizaki *et al.,* 1989) as well as the use of the daily increments from otoliths (Uchiyama & Struhsaker, 1981). In the present study the use of otoliths to determine ages was not possible mainly due to the difficulty in isolating the small otoliths in both species. Growth bands on the dorsal spines however were used for age estimation. Growth bands are well defined when there is a large difference between the opaque and translucent areas, which represent different growth rates, fast and slow, respectively. The growth bands observed from the dorsal spines of *E. affinis* were more clear and easy to count than those from the spines of *K. pelamis*. The observations between the two species suggest that the growth rate for *E. affinis* is variable with time in comparison to *K. pelamis* where the growth seems to be more constant as the rings were not as distinguishable as the case in *E. affinis*. The influence of the amount and quality of food could be the possible reasons for such variations. Some of the growth bands of *K. pelamis* were overlapped together and fused which could be related to the narrow range of the temperature in the Gulf of Aqaba (Manasrah, 2002). Extreme temperature difference between summer and winter could widen differences of seasonal growth rates with more distinguishable annual marks. Normally two growth bands are deposited per year however if conditions are quite variable or continually constant, this can produce either more than two annual growth bands or just one, respectively. Chi &Yang, (1973) reported the deposit of two growth bands each year in the dorsal spines of Skipjack collected from the waters of Taiwan. In contrast, Aikawa (1937) pointed that only one band is deposited yearly. Our results indicated that there are different age classes in the catch and that the observed length range can be related to the age seen. *K. pelamis* ranged from 56 to 75 cm and had ages between 5 and 8 years of age based on single growth band per year. The ages observed neither represent young juveniles (less than 2 years) nor individuals older than 8 years of age. It is possible that the behavioral migration of these pelagic species is only undertaken by older mature individuals to the Jordanian Gulf of Aqaba. Perhaps food availability, water temperature and water current are suitable for these age classes only (Al-Zibdah *et al.,* 2004; Manasrah, 2002). Juveniles possibly remain in breeding grounds or elsewhere in the Red Sea and take advantage of other areas rather than migrate north to Aqaba. *E. affinis* ranged from 46 to 64 cm and have ages between 2 and 4 years. Mature females of the same species from the Philippines were found at a smallest size that ranged between 40 and 45 cm (Wade, 1950). This is also smaller than our observations and therefore individuals even the young ones (2 years) that found in Aqaba could be close to maturity. It is

therefore important to relay the size of the fish to age in order to estimate the size at first maturity and thus the minimum landing size. Minimum landing size should be greater than the size at first maturity. If the catch contain sizes that are reproductively immature then the fish stocks will be eventually over fished. This has been confirmed actually from our calculation on the age classes that were observed and the value of Z as a sum of natural mortality and fishing mortality (instantaneous rate of total mortality). Our data suggested that the total mortality is high in both species. Therefore, we suspect that the fishing effort on the two species is high. The calculated Z values for the two fishes are 0.45 and 0.52 respectively, and this means that the exploitation rates are considerably high (Fig. 10).

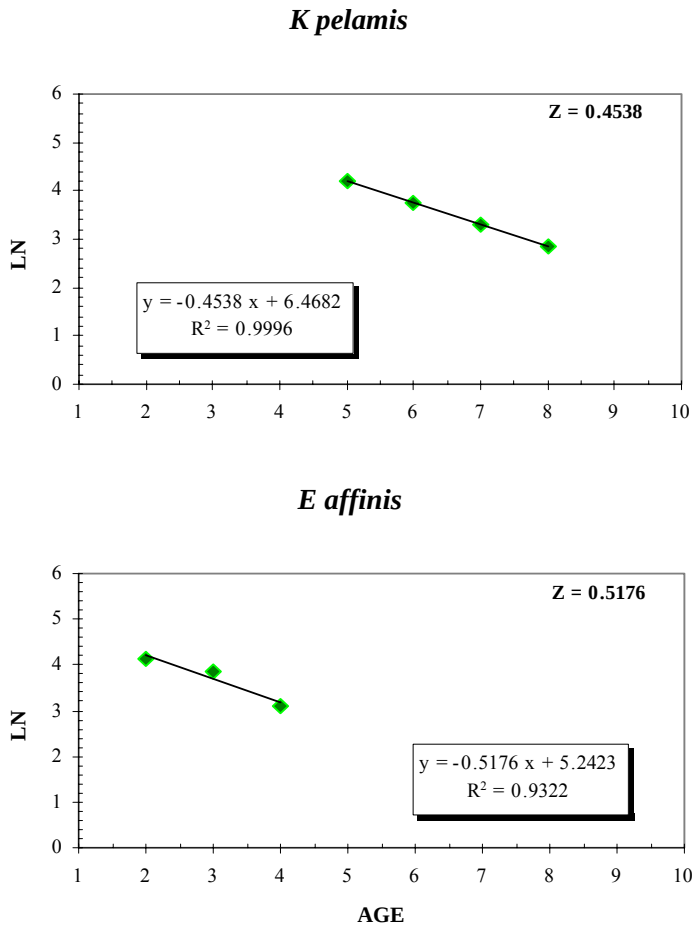

Figure 10. Calculated instantaneous rate of total mortality (Z) in the two fish *K. pelamis* and *E. affinis.*

The color of female gonads in both species ranged from orange to red and no creamy color was observed. In general, immature fish have creamy gonads while mature fish have orange or red. It can therefore be inferred that only mature individuals of both species are heading to the region. The mean GSI for males and females of the two species were almost similar. In addition, no spawning behavior was observed in the field which may be inferred that the two species are coming to the area for food only following the high abundance of small fishes that feed on the high abundant zooplankton during certain season mainly winter and spring (Al-Najjar *et al.,* 2003; Al-Najjar, 2004). Nevertheless, verification of the reproduction cycle of these fish can be investigated further considering incidence of egg collection using plankton net in the Gulf of Aqaba. In addition, the seasonal occurrence of Scombridae larvae in the waters of Aqaba would also be indicative (Froukh, 2001). Such information could be used in the future to correlate the observed Scombrid stocks with larval recruitment in the Jordanian waters.

Identifying the food items is necessary to understand food availability in fish natural habitat, which in turn has a potential in fisheries yield as fish grow. Heterogeneous food availability may influence the distribution of these fishes and consequently its migration. The food composition of both *K. pelamis* and *E. affinis* suggests that these fishes are carnivorous that have variety of preys. However, the results revealed that both compete for the same food items mainly *A. lacunosus* and to a lesser extent crustacean and molluscans. Yesaki (1983) reported similar finding for the food items of Skipjack and Yellowfin tuna in Philippine waters. The occurrence of these food items in both fish could be attributed to the seasonal availability of such items in Gulf of Aqaba. The notable appearance of different food items in winter suggests that the two species migrate at the peak of primary productivity in Gulf of Aqaba (Klinker *et al.,* 1978; Badran, 2001). *A. lacunosus* was the only fish item found in the stomach of both species, which might elucidate possible relationship between the small fish and the feeding behavior of Scombrid fish in Gulf of Aqaba. In general, the food consumption of most fishes is correlated with water temperature and spawning activities. The highest consumption of food of *K. pelamis* was during December and April whereas the minimum consumption occurred during January and February. The seasonal pattern of food consumption for *E. affinis* look similar to that of *K. pelamis*. Maximum values were observed in December and March and minimum during January to February and that could be related to the change in the water temperature. Nikouyan (1988) reported an increase in the abundance of *E. affinis* in the Gulf of Oman with the beginning of summer and increase in seawater temperature.

Finally, the fishery resources in Gulf of Aqaba are not restricted to Jordan's water but stretches to other parts of the Red Sea. Scombridae represent the most important commercial fish in Jordan's fishery that form more than 60% of the total catch with annual landing of about 92 tones. Consequently and for sustainable management purposes, exploitation levels and regulations for the tuna fishing should be coordinated between the countries that exploit the same stocks. These results revealed that the catch of Scombridae is considerably high or probably over exploited. Therefore, management of tuna fishery in general requires building of capacity and the need to apply fishing technology on large scale. At the same time the considerable landing of such species would require information on the population that migrates to Jordanian waters together with the size of catches of other countries around the red sea. It may be useful still to impose a known landing size in Jordan that would guarantee the fishing of adults only. It might be in the range of above 50 cm for both *K. pelamis* and *E. affinis* as fish greater than these sizes could be reproductively mature.

CONCLUSION

It could be concluded from the present investigation that 1) the catch of both species composed of two different size ranges. 2) The observed seasonal variation in k might be as a result of fluctuation in food availability following primary productivity change in Gulf of Aqaba. 3) Temporal variability in growth rate between *E. affinis* and *K. pelamis* is influenced by the amount and quality of food during different seasons in Gulf of Aqaba. 4) Values of the instantaneous rate of total mortality (Z) in both fishes revealed high fishery exploitation rate. 5) Only mature individuals of both species are heading to the region for food search and both were found competing for the same food items mainly *A. lacunosus* following the high abundance of silverside fishes during winter and spring. 6) Scombridae represents the most important commercial fish in Jordan's fishery. 7) Migratory species like the present species are Trans-boundaries and that its fishery management must be coordinated among regional countries to sustain such resources in the Red Sea. Generally, proper management controls for fishing activities needs adequate biological and statistical data on the status of fishery in the Jordan Gulf of Aqaba.

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