Population biology and assessment of Kawakawa (*Euthynnus affinis*) in Coastal Waters of the Persian Gulf and Sea of Oman (Hormozgan Province)

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Abstract

Length composition data (fork length) of kawakawa(*Euthynnus affinis*), landed between April 2003 to March 2005 in Coastal Waters of Hormozgan province in Iran (Persian Gulf and Sea of Oman), were monthly used to estimate the population parameters and for the assessment of the stock. The growth parameters of von Bertalanffy equation were estimated as L_∞: 87.66 cm, K: 0.51 per year and t_0: -0.23 year. The estimated value of total mortality, natural mortality and fishing mortality were Z: 2.37, M: 0.65, F: 1.72 per year, respectively. Exploitation ratio (E) and Exploitation rate (U) were estimated as 0.72 and 0.65. The Annual total stock at beginning of year was calculated to be 7924 t and Annual average standing stock (S) was equal to 2994 t. By using analyses knife-edge selection method, biological reference points for kawakawa stock was calculated as, Y'/R (relative yield per recruitment) =0.062, B'/R (relative biomass per recruitment) =0.13, Fmax (Fishing mortality at maximum sustainable yield) =1.6, Emax (Exploitation ratio at maximum sustainable yield) = 0.68; Fopt (Precautionary average target) =0.33 $year^{-1}$ and Flimit=0.43 $year^{-1}$. As the exploitation ratio of kawakawa stock in this study was calculated to be over 0.5, it strongly recommended minimizing the fishing activity in this area.

Key words: *Euthynnus affinis*, Population biology, Assessment, Persian Gulf, Oman Sea

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Introduction

Overall purpose of fisheries science is to provide decision-markers with advice on the relative merits of alternative management (King, 2007). This advice may include predictions of reaction of a stock and fishers to varying levels of fishing effort and, conventionally, include an estimate of the level of fishing effort required to obtain the maximum weight or yield that may be taken from a stock on a sustainable basis (King, 2007). For a given level of fishing mortality to be sustainable, there must be a balance between the mortality, which reduces population biomass, and reproduction and growth, which increase it (Jennings *et al*., 2000).Yet understanding the population biology of fish species is essential to meet one of the main objective of fishery science, that of maximizing yield to fisheries, while safeguarding the long-term viability of populations and ecosystem (Jennings *et al*., 2000). Kawakawa (*Euthynnus affinis*) is an epipelagic migratory tuna species that is widely distributed in the tropical and subtropical waters of the Indo-Pacific region. In the western Pacific Ocean, this species is distributed along the Asian continent from Malaysia northeastward through Mainland China, Taiwan, and to the southern Japan (Yasaki, 1994). Kawakawa is also a merit species and is most commonly seen in the set net catches, although few of them also were caught by gill net, long line and small purse seine (Yasaki, 1994). The average annual catch of kawakawa during 1997 to 2005 was around 4000 tones (Iranian Fisheries Statistical Yearbook, 1990-2005). Apparently, total catch of kawakawa has been decreased dramatically since the last decade. Despite the economical importance of this species, little is known about the biology of this fish. Different aspects of biological work of kawakawa have been done by different authors (Talebzadeh., 1997, Darvishy *et al*., 2003) but no work has been done on stock assessment of this species in Iranian south coastal waters. In this context, the main objective of this study provides biological reference points and other population dynamics information required for management of *E. affinis*.

Materials and methods

Length-frequency (fork length) data of Kawakawa were collected monthly from the landing sites of Hormozgan Province waters, Gavbandy, Kong, Salakh and Jask during April 2003 to March 2005 (Fig. 1). Fork length (FL) was taken to the nearest cm for all fish and total weight (TW) of individual fish to nearest 0.01 kg was measured. The samples were mainly caught by gill net method in study area. The data were then pooled monthly from different landing sites and subsequently grouped into classes of 4cm intervals. The data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo *et al*., (2003). The fitting of the best growth curve was based on the ELEFAN I program (Pauly and David, 1981), which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the aid of the best growth curve, the growth constant (K) and asymptotic length (L_∞) were estimated. The von Bertalanffy growth equation was defined as follows (Sparre and Venema, 1998):

$L_t=L_\infty [(1-\exp(-K(t-t_0))]$

Where Lt is length at time t, L_∞, the asymptotic length, K, the growth coefficient and t_0, is the hypothetical time at which length is equal to zero. The t_0 value estimated using the empirical equation (Pauly, 1979). $\text{Log}_{10}(-t_0) = -0.3922 - 0.2752\ \text{Log}_{10}L_\infty - 1.038\ \text{Log}_{10}K$.

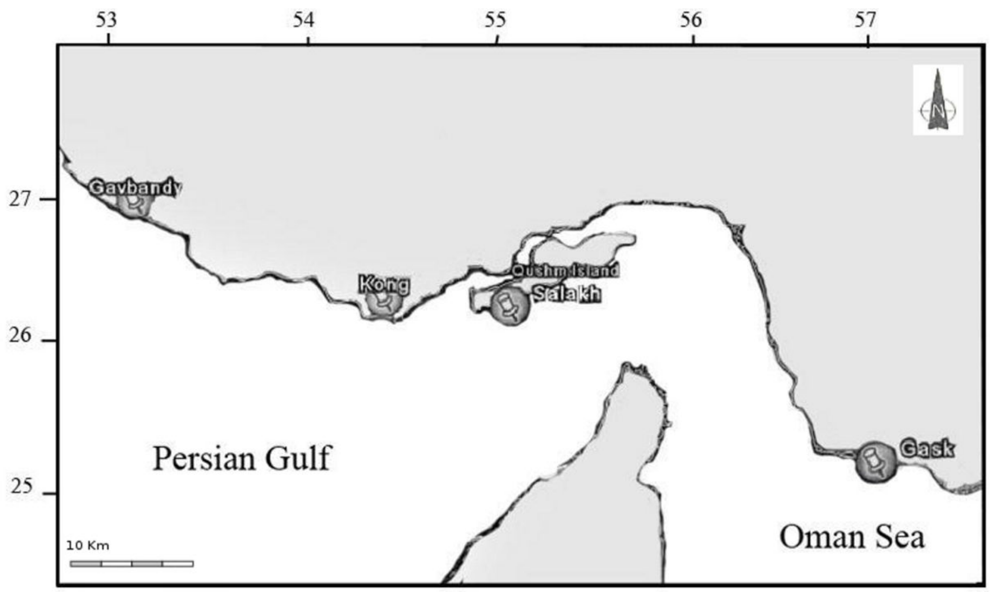

Figure1: Location of four sites in Coastal Waters of the Persian Gulf and Sea of Oman

To compare the growth parameters obtained in this study with those reported by other authors for the same species, the growth performance index (Φ) was used (Munro and Pauly, 1984): This index has the form: $\Phi = \text{Ln}(K) + 2*\text{Ln}(L_\infty)$; where K is the growth coefficient, and L_∞ is the asymptotic length.

Total mortality (Z) was estimated using the length converted catch curve method, which has been incorporated into the FISAT program (Gayanilo *et al.*, 2003). The natural mortality rate (M) was estimated using Pauly's empirical relationship as follow (Pauly, 1980):

$\text{Log}_{10}M = 0.0066 - 0.279\ \text{Log}_{10}L_\infty + 0.6543\ \text{Log}_{10}K + 0.4634\ \text{Log}_{10}T$,

Where:

L_∞ is expressed in cm and T the mean annual environmental water temperature which equals to 26C for the sampling area.

Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained from F/Z.

Backwards extrapolation of the length converted catch curve was used to estimate probability of capture data.

Relative yield and biomass per recruit analyses were conducted using growth and mortality parameters and selectivity ogives derived from probability of capture data. The Beverton and Holt (1966) yield per recruit model modified by Pauly and Soriano (1986) was used to predict the effects of increasing the existing mean size at first capture ($L50$) to that at which yield per recruit would be maximized (Lmax). Fishing mortality rates associated with the point on the Y/R curve where the marginal increase in relative yield per recruit was 0.1 of its value at the origin ($F_{0.1}$), and maximum yield (F_{max}) were derived from the Y/R model for the various mean sizes at first capture (L_{50} and L_{max}). Evaluations of resource status were made using estimates of exploitation rates associated with a marginal increase of relative yield per recruit which is of its value at maximum sustainable yield E_{max}. Precautionary target and limit biological reference points were defined as: F_{opt}=0.5 and F_{limit}=2/3 M, respectively (Patterson, 1992).

The total annual stock size and average standing stock size of *E. affinis*, were also estimated. For this purpose, first exploitation rate (U) was estimated using the equation given by Beverton and Holt (1957) as $U = F (1- e^{-Z}) /Z$.

Annual catch (Y) is (5151 tons) collected from the Department of Fisheries, Iran (Hormozgan). Then by using the values of U, b and S the total annual stock (Y/U) and average standing stock (Y/F) were estimated (Pillai *et al*, 2002).

Results

Length frequency distribution

A total of 9988 kawakawa were investigated. Analysis of the total length composition of the kawakawa in the southern part of Iranian waters (Persian Gulf and Sea of Oman) showed that, minority of catch was 41 to 45 cm, and majority of catch ranged between 69 to 73 cm (Fig 2).

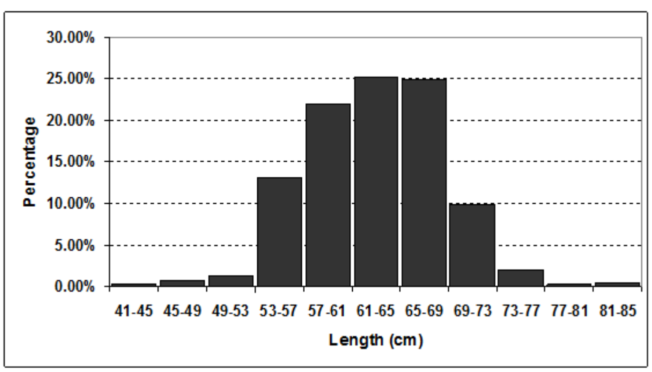

Figure 2: Percentage frequency of length *E. affinis* in Coastal Waters of Iran during 2003-05

The von Bertalanffy growth parameters were estimated as:

L_∞= 87.66 cm, K = 0.51 y^{-1} and

t_0 = -0.23 year (Fig. 3).

The value of Φ´for pooled data were calculated as 3.5832

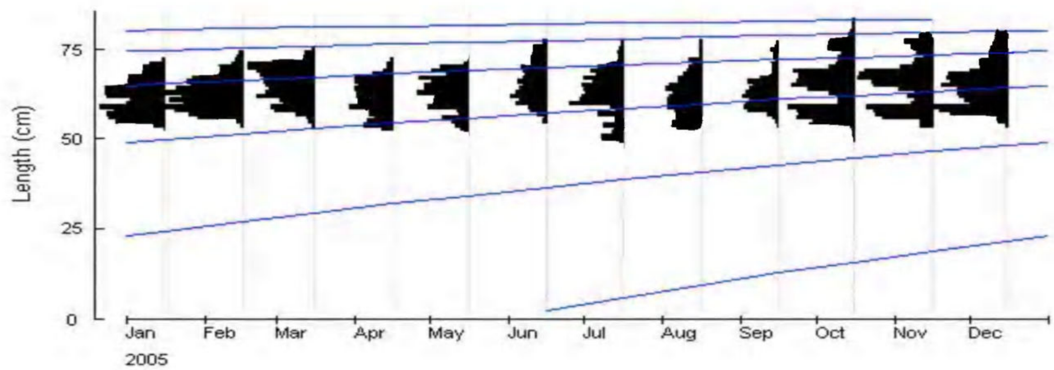

Figure 3: Growth curve of *E. affinis* by ELEFAN I superimposed on the restructured length-frequency diagram (L∞ = 87.66 cm and K = 0.51 year $^{-1}$)

The total mortality (Z), fishing mortality (F), natural mortality (M) and exploitation rate (E), relative yield per recruit (Y'/R) , relative biomass per recruit (B'/R), Exploitation rate (U), annual total stock at beginning of year (b) and annual average standing stock (S) were estimated and shown in (Table 1).

Table 1: Estimate mortality and yield of *E. affinis* in the southern waters of Iran (Persian Gulf and Sea of Oman, Hormozgan Province)

Year	Z	F	M	E	Y'/R	B'/R	U	b (t)	S (t)
2003-05	2.37	1.72	0.65	0.72	0.062	0.13	0.65	7924	2994

Values of the sizes where the probability of capture was 50% (L_{50}) and 100% (L_{100}), were estimated to be 46.88 and 60.1 cm (FL), respectively, i.e., the fish will recruited to the fishery at a mean size of L_{50} = 46.88cm.

The size at which yield per recruit would be maximized L_{max} = 60.1 cm FL, approximated the mean size of fish that were 2.1 years old and was considerably greater than the mean size at first capture (Fig. 4). The yield per recruit function predicted that an increase in the size at first capture to that which would maximize yield per recruit would be associated with a substantial increase in yield at the current level of exploitation, despite the high level of fishing mortality. The relative biomass per recruit at the current exploitation rate was less than 15% of that at the theoretical unexploited level. An increase in the mean size at first capture to that which would maximize yield per recruit was predicted to be associated with a small increase in biomass per recruit (Fig 5). The reference points estimated from the yield per recruit

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function ($F_{0.1}$ and F_{max}) for all sizes at first capture were greater than values of the natural mortality rate of 0.65 year^{-1} (Table 2). The fishing mortality rate was also substantially greater than both the precautionary target (F_{opt} = 0.33 year^{-1}) and limit (F_{limit} = 0.43 year^{-1}) biological reference points.

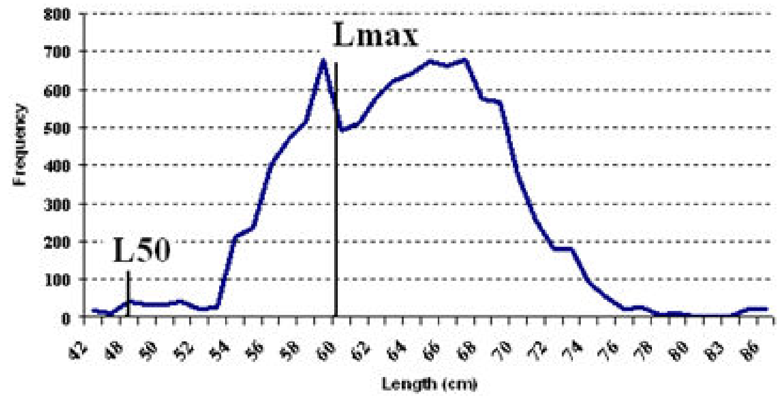

Figure 4: Aggregated length frequency distribution for *E. affinis*,showing the size at first capture (L_{50}), and maximum yield per recruit (L_{max}).

Table 2: Biological reference points derived from the yield per recruit model ($F_{0.1}$ and F_{max}) at the existing size at first capture (L_{50}) and relative biomass per recruit at precautionary reference points (F_{opt} and F_{limit}) corresponding to the existing size at first capture (L_{50})

Year	$F_{0.1}$	F_{max}	E_{max}	F_{opt}	F_{limit}
2003-05	1.44	1.60	0.68	0.33	0.43

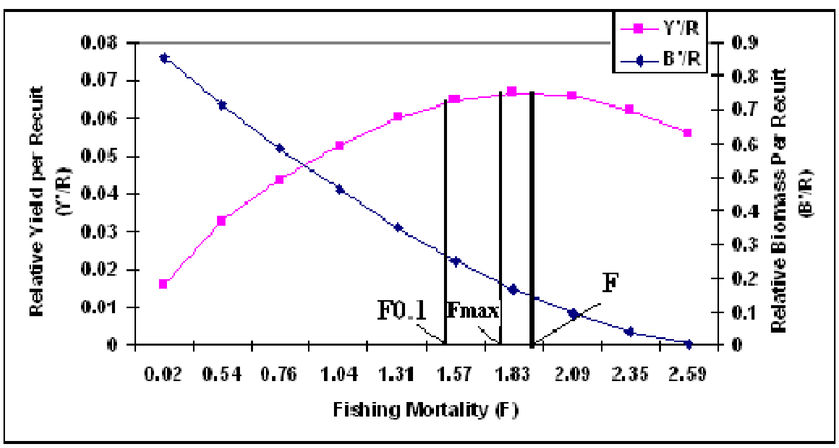

Figure 5: Relative yield and biomass per recruit curves (descending lines) for *E. affinis* showing the existing fishing mortality (*F*), the fishing mortality rate at which the slope of the yield per recruit curve is 0.1 of its value at the origin ($F_{0.1}$) and the fishing mortality rate which would maximise yield per recruit (F_{max})

Discussion

The morphological and reproductive characteristics, population sizes and genetic frequencies of species are adjusted to their environments by natural selection and species inhabiting different environments show different patterns of life history characteristics (Adams, 1980).

Darvishy *et al.,*(2003) estimated infinity length of *E. affinis* 94 cm in Hormozgan Coastal waters. In the present study length infinity of *E. affinis* were 87.66 cm which indicated lower infinity length. Different L_∞ and K, might be associated with sampling error or variation in fishing intensity or environmental conditions. An increasing trend was observed in *E. affinis* catches, in Hormogan Province since 1995. The annual catch varied from 2560t in 1995 to 6160t in 2005 (Iranian Fisheries Statistical Yearbook, 1990-2005).The L_∞ obtained in this study for the kawakawa was higher than the estimate given by some previous studied (Yasaki, 1982; Silas *et al*., 1985; Joseph *et al*., 1987; Supongpam and Saikliang, 1987; Yasaki , 1982; Yasaki , 1989) but lower than that by Shahersaeed (1995), Pillai *et al*. (2002) and Darvishy *et al*., (2003).In this study K value was higher than the estimate by Yasaki (1982), Silas *et al*. (1985) and Shahersaeed (1995) and K lower than that by Joseph *et al*.(1987), Supongpam and Saikliang , (1987), Yasaki (1982and 1989), Talebzade (1997), Pillai *et al*. (2002) and Darvishy *et al*., (2003) (Table 3).Growth comparison of fish based on a single parameter K or L_∞ (W_∞) is misleading (Pauly, 1979) and some authors such as Pauly and Munro (1984) and Moreau (1987) have proposed indices of overall growth performance (**Φ′**) based on the two parameters L∞ and K, because these are correlated and growth curves themselves are produced by growth rates that are constantly changing with time and size. Growth performance index (**Φ′**) was found to be 8.28 that is in range of 7.60 - 8.82 in others reported study (Table3).

Table 3: Summary of the growth parameters estimates of *E. affinis* from different areas of the world

Resercher	Local	L∞	K	t_o	′ Φ
Yasaki, 1982	Thailand	76	0.46	_	7.80
Silas *et a.l*,1985	India	81	0.34	-0.34	7.79
Joseph *et al.* ,1987	Seri lanka	59.5 63 59.5	0.63 0.67 0.69	-	-
Supongpan & Saikliang ,1987	Thailand	55.1	2.23	-0.015	8.82
Yasaki ,1989	Thailand	76	0.96	-	8.62
Shahersaeed, 1995	Yemen	92	0.23	-	7.60
Pillai *et al*., 2002	India	81	0.9	-	8.87
1995 , hTalebzade	Iran(Hormozgan)	86	0.69	-	8.50
2003 .,Darvishi *et a*l	Iran(Hormozgan)	94	0.53	-0.024	8.45
Present study	(Hormozgan) Iran	87.66	0.51	0.23-	*8.28*

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As age at zero length (t_0) was calculated to be -0.23 year, which means juveniles *E. affinis* grow more quickly than adults (King, 2007).The natural mortality coefficient (M) for kawakawa were 0.65 per year, which agreed with the estimates reported by earlier workers in Hormozgan Costal waters and Value of Z and F obtained in this study were marginally higher than that in earlier works in Hormozgan Coastal waters. According to Gulland (1971, 1979), the yield is optimized when F=M; therefore, when E is more than 0.5, the stock is over fished. The fishing mortality rate of 1.72 year^{-1} was substantially greater than both the target (F_{opt} = 0.33 year^{-1}) and limit (F_{limit} = 0.43 year^{-1}) biological reference points. These results are important for fisheries management authorities as they suggest that the resource is heavily overexploited and in addition to a revision of mesh size regulations, a substantial reduction in fishing effort would also be required if management objectives are to be achieved. Patterson (1992) observed that the fishing rate satisfying optimal E level of 0.5 tended to reduce pelagic fish stock abundance, and hence, the former author suggested that E should be maintained at 0.4 for optimal exploitation of those stocks. Increase in the size at first capture to that which would maximize yield per recruit would be associated with an increase in yield at the existing fishing mortality rate. However, the existing fishing mortality rate (1.72 year^{-1}) was greater than that which would maximize yield per recruit (F_{max} = 1.6 year^{-1}) at the existing size at first capture, clearly demonstrate that growth over fishing is occurring for this species (Fig 4).

The relative biomass per recruit at the estimated fishing mortality rate was particularly low at less than 15% of the unexploited level. If the critical spawning stock biomass is between 20 and 50% of the unexploited level, as suggested by King (2007), recruitment over fishing is also likely to be occurring for *E. affinis*. The specified precautionary target (F_{opt} = 0.5 M) and limit (F_{limit} = 2/3 M) values are considered to be more appropriate biological reference points in light of the constraints of the yield per recruit model. The value of fishing mortality rates estimated for *E.affinis* (1.72 year^{-1}) was substantially greater than both the target (F_{opt} = 0.33 year^{-1}) and limit (F_{limit} = 0.43 year^{-1}) biological reference points. Again, this demonstrates that growth over fishing is occurring and in combination with the results of the yield per recruit analyses shows that substantial effort reductions are also required as target reference points cannot be achieved by modification of the gear selectivity characteristics alone. As the size at first capture (46.88 cm FL) was considerably smaller than the size at which yield per recruit would be maximized (61 cm FL), an increase in the mesh size for fishery should be considered by management authorities. Total annual stock of this species in east and west India were reported 23130 tons (*Pillai et al.*, 2002) and 31755 tons (Silas *et al.*, 1985) respectively. FAO (1993) while discussing the reference points (RP) used in fishery management, like maximum sustainable yield (MSY), reports that they are mostly useful for assessment of single stocks and less applicable to highly migratory resources such as tunas. Because, multiple fisheries occur at different Local on the overall migratory routes of tuna and these local fisheries are seasonal and very short. The results indicated that the stock of *E. affinis* is overexploited. Any increase in the existing fishing level/exploitation will most likely result in a reduction in the yield per recruit and thereby hamper the optimum level. It is necessary to immediately impose fishing regulation on the stock and this can be done by gradually increasing the mesh size of the gears or by restricting fishing for certain seasons or declaring fish sanctuaries in certain areas, especially in spawning grounds.

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