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AGE, GROWTH AND REPRODUCTIVE BIOLOGY OF SPANGLED EMPEROR, *LETHRINUS NEBULOSUS* (FORSSKÅL, 1775), FROM THE ARABIAN SEA, OMAN

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ABSTRACT

Spangled emperor, *Lethrinus nebulosus* (N=2306) were caught off at Doqum and Salalah in the Arabian Sea, Oman from January 2001 to December 2002. Total length (L_T) ranged from 11 to 70 cm. Sagittal otoliths of 363 *L. nebulosus* were pretreated and examined for age determination. Growth rings in the otoliths of different sizes were read and the marginal increments of selected otoliths were measured using light microscopy. The estimated parameters from the VBG equation were (L_∞ = 72.2 cm L_T, k = 0.086, t_0 = -3.041) were estimated using observed age. A significant linear relationship was found between otolith weight and age (P<0.05). Growth parameters were then calculated using estimated age from otolith weight, the values were comparable to those calculated using the observed age. The maximum age recorded was 29 years old and the largest fish in the sample was 70 cm L_T. Seasonal changes in gonado-somatic index (GSI) demonstrated that the spawning season of *L. nebulosus* occurred between September and December. The estimated length and age at 50% of maturation was 33.7 cm L_T and 4.2 yrs. Chi squared test of variance showed no significant different between the distributions of mature males and females amongst the different size classes. Sex ratio study showed that male-female distributed by 1.09:1 proportion in the *L. nebulosus* population.

1. INTRODUCTION

The spangled emperors, *Lethrinus nebulosus* are widely distributed in the Indo Pacific region; they spend most of their life associated with coral reefs (Carpenter and Allen, 1989). They constitute one of the most economically important species in the hand-line fishery of Oman. Despite the economic importance of *Lethrinus nebulosus* in Omani waters there were little information about its growth and reproductive biology. The work prescribed in this paper is comprehensive and detailed following the first study by McIlwain *et al* (2006) which was done on the reproduction for this species. It has been reported that the fertilized eggs of lethrinids (including *L. nebulosus*) are pelagic with an oil globule, spherical, colouress and between 680 to 830 µm in diameter (Carpenter and Allen, 1989). Hatching is normally occur 21 to 40 hrs after fertilization and newly hatched larvae are 1.3 - 1.7 mm long with an unopened mouth, un-pigmented eyes, a large yolk sac and variable body pigmentations (Carpenter and Allen, 1989).

The age of fishes can be determined from the annual rings on their hard parts (e.g. Al-Husaini *et al*., 2002; El-Ganainy, 2004). Growth rates of fishes are influenced by environmental conditions such as the relative abundance of food, the relative density of the fish population and sea water temperature (Fonds *et al*., 1992). (Ferreira and Russ, 1994) mentioned that counting rings in sectioned otoliths for a number of fish taken from the catch can derive the age structure of the fish population. However, this technique has disadvantages, e.g. reading age rings needs a certain degree of skill, and this method is time-consuming and expensive. Therefore, this method has to be improved by developing alternative ways of ascertaining the age structure for fish populations. If otolith weight can be related to age, a calibration curve could be developed in order to estimate the age structure of the population. This method has been proven to be even better than age reading for estimating pilchard, *Sardinops neopilchardus* recruitment and has been suggested as the standard procedure for estimating the age of individuals from commercial catches for this species (Fletcher and Blight, 1996). In temperate waters, the opaque rings are deposited during winter when seawater temperatures are minimal (Campana and Neilson, 1985). Seasonal changes in seawater temperature and productivity of the Arabian Sea are influenced by the monsoon winds. Between May and September, when the south east Omani coast is affected by strong winds and upwelling in the Arabian Sea, seawater temperatures decrease from 26 to 20 ºC and there is an increase in productivity in the area (Al-Aisari *et al*., 2004). These seasonal environmental changes might initiate the formation of an opaque ring in the otolith and fish reproduction activity in the Arabian Sea.

The objectives of the present study are (1) to investigate the periodicity of otolith ring formation in *L. nebulosus* and to determine whether the hyaline/opaque rings are laid down on an annual basis and to use marginal increment analysis to ascertain birth dates and (2) to examine the age structure in *L. nebulosus* and to construct von Bertalanffy growth curves for both sexes (males and females). (3) to determine spawning season, including, seasonal cyclical changes in the gonads, the Gonado-Somatic Index (GSI), Liver-Somatic Index (LSI) and condition factor (K) between length classes and for male and female *L. nebulosus*, (4) to estimate length and age at first sexual maturity, and the sex ratio for *L. nebulosus* in the Arabian Sea.

2. MATERIALS AND METHODS

2.1. Sampling

Samples of *Lethrinus nebulosus* were obtained monthly from the commercial catch of the hand-line fishery landed at Doqum and Salalah on the Arabian Sea coast of Oman operating in depths ranging from 20 to 70 m between January 2001 and December 2002. Each month, 40 freshly caught fish, ranging in total length (L_T) between 11 and 70 cm were selected randomly from the landed catches. Each fish was measured to the nearest cm for total length (L_T) and weighed to the nearest g for total weight (W_T) and carcass (gutted) weight (W_C). The fish dissected and the sex was determined. The weight of the gonads and livers were measured to the nearest 0.01g. The size at maturity was analyzed from the distribution of mature and immature fish of each sex. Maturity stages were classified according to Young and Martin, 1982.

For counting rings and age determination one otolith from each fish (363 specimens) was embedded in small moulds (<2cm) containing epoxy resin (Brothers *et al*., 1983). The embedded otoliths were cut, grounded and polished prior to be read of the age determination. Each section was mounted on a microscope slide and examined using reflected light, using a stereomicroscope, or using transmitted light and a compound microscope. Only otolith sections that displayed clear increments and rings were used to determine the age of the fish. Any damaged otolith sections, or those that did not have clear growth rings, were rejected. For estimation of age from otholith weight about 303 otoliths of *L.nebulosus* were weighed to the nearest 0.01 g (O_{WT}).

2.2. Data analysis

Otolith ring measurements were made using otoliths from large fish (>40 cm L_T) for marginal increment analysis (MIA) study. The distance (in mm) between the last clear opaque zone and the otolith margin, i.e. the marginal increment (d_1) and the width of the preceding increment (d_2) were measured. The marginal increment, d_1, was expressed as a proportion of d_2 (d_1/d_2). Mean marginal increments (d_1/d_2) were plotted against the sampling month during the calendar year to determine in which month the opaque zone was deposited, and hence to determine the annual birth date of the fishes.

The age of each fish was determined by counting the number of annual rings and also by the otolith weight. The relationship between size and age was determined using the Von Bertalanffy growth function (VBGF; Von Bertalanffy, 1938): $L_t = L_\infty \{1- e^{[- K (t - t_0)]}\}$, VBGF curves were fitted using the non-linear least squares estimation procedure in SPSS statistical package (Nie *et al.,* 1975). The likelihood ratio (LR) was calculated as

$$LR= - n \times Ln (Res\text{-}SS_{no\ constraints} / Res\text{-}SS_{constrained})$$ (Kimura, 1980).

Where n is the total number of observations used in the curve fitting procedure, $Res\text{-}SS_{no\ constraints}$ is the total residual sum of squares for the two VBGCs without any constraints and $Res\text{-}SS_{constrained}$ is the total residual sum of squares for the two VBGCs when L_∞, K, t_0 or all the three parameters were constrained. The likelihood ratio was compared with tabulated chi squared values for 1 degree of freedom (i.e. one VBG parameter constrained) or 3 degrees of freedom (i.e. all three VBG parameters constrained) to determine significance. These analyses were conducted to determine whether individual VBG parameters were not different between the two VBG curves and whether the overall shape of the two growth curves were not significantly different.

In order to determine the spawning season a number of factors were considered in this study. The GSI was estimated on the gutted weight, instead of the fish total weight to exclude any effect of stomach fullness or liver fattinesses which might cause bias in fish weight. The mean monthly GSI values were estimated using the equation,

GSI = (Gonad Weight / Gutted Weight × 100 (Kuo, 1988).

Similarly, LSI was calculated using: LSI = (Liver weight / Gutted weight) × 100. Condition Factor (K) was calculated using: K = Carcass Weight / (Total Length)^3 ×100.

The size at first sexual maturity was then analyzed taking into account the distribution of mature and immature fish within the different length classes. To estimate L_T at 50% maturity (L_{50}), a logistic function was fitted to the fraction of mature fish per 1 cm length interval using the following model:

$P_L = l/ (l+ Exp (-r (L- L_m))$ (King, 1995).

Where: P_L is the proportion of sexually mature fish at length (L), L_m is the mean length at 50% maturity, L is the total length in cm and r is the slope of the fitted curve.

Age at first sexual maturity was also estimated using the model: Age at first maturity (t_m) = t_0 - (1/k) Ln(1-Lt/L_∞). Where: t_0 = age at length equal to 0, k = growth constant, L_t = length at 50% maturity and L_∞ = asymptotic length. The sex ratio was estimated using the following equation: Sex ratio = (male/ female) (Kuo, 1988).

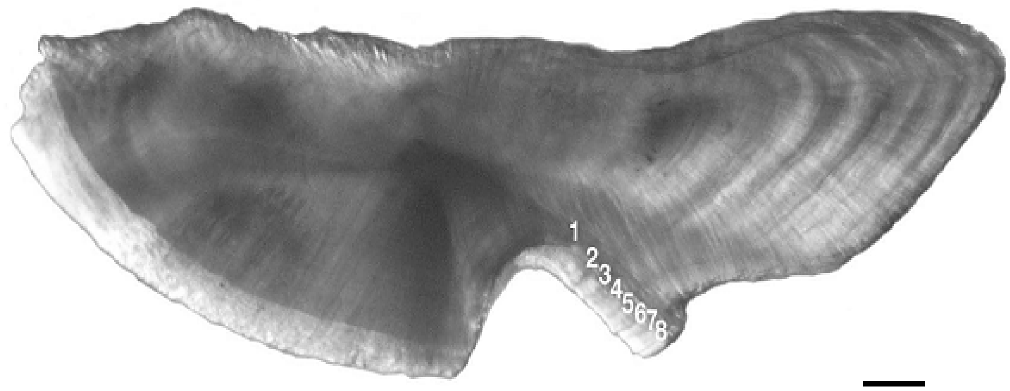

Fig. (1): Photomicrograph of a transverse section through the sagittal otolith of an 8 year old spangled emperor, *Lethrinus nebulosus* (scale bar = 1mm). Each annual ring is numbered.

3. RESULTS

3.1 Periodicity of ring formation and marginal increment

A sagittal section through the otolith of 8 year old *L. nebulosus* (Fig. 1) showed that the distance between the growth rings can be seen to narrow with increasing age. In most of the sectioned otoliths (n = 363), the rings were clearly visible and the age of the fish could be determined. In the fish selected for marginal increment analysis (i.e. > 40 cm L_T), the marginal rings were clearly spaced and could be identified and measured. The seasonal change in the width of the marginal increments from the monthly otolith collections indicates an abrupt change in width between April and June (Fig. 2). By the end of April, the opaque zone in the otolith had been deposited and in May there was evidence of the start of the formation of the translucent zone (Fig. 2). These results demonstrate an annual periodicity of ring deposition and based on this interpretation, each pair of opaque and translucent rings was counted as one year and the age of each fish determined, the maximum age recorded was 29 years. A summary of the seasonal variation in seawater temperature in the Arabian Sea (Fig. 3) indicates a decrease in temperature (especially sea surface temperature) in May. This may help to promote the deposition of the opaque ring in the otoliths in May for this species. During the monsoon season (May-September), seawater temperatures remained at low levels ($\leq 23^o$ C) for both surface and deep water, before a sharp increase in October-December.

3.2 Age and growth

The VBGC for male and female *L. nebulosus* are illustrated in Figure 4 and the corresponding growth parameters are presented in Table 1. For both males and females, growth rates were highest during the first 12 years of life (TL ≈52.4 cm L_T at 12 years of age) and reduced as the fish increased in age. The VBGCs suggest that the male fish had a higher growth rate when younger and attained a smaller theoretical maximum size than the females. However, a comparison of the male and female VBGCs using the likelihood technique revealed that the VBG parameters and the two growth curves for male and female fish were not significantly different (Table 2). Therefore, the data from the male and female fish were combined to produce a single growth curve for *L. nebulosus* (Fig. 4B; Table 1).

3.3 Estimating the age from otolith weight

The second approach to derive a VBGC was to use otolith weight to estimate age and to use estimated age to derive the VBG curve. The relationship between otolith weight and age for *L. nebulosus* was linear and was described by the following equation:

$$\text{Age (yrs)} = 0.764(\pm 0.273) + 50.662(\pm 1.304) \times O_{WT},\ (r^2 = 0.834).$$

The significant relationship between otolith weight and age allowed age to be estimated for the 303 fish and the estimated age used to fit a VBG curve (Table 1). The likelihood test was used to compare the estimated age $VBG_{N=303}$ curve with the $VBG_{N=363}$ curve. There were no significant differences between the VBG constants for either growth curve in the overall shape of the two growth curves ($P>0.05$) (Table 3).

3.4 Spawning Season

The Gonado-Somatic Index (GSI) for *L. nebulosus* (Fig. 5) confirmed that the spawning season occurred between September and December. The GSI values were highest during autumn with a peak recorded for males and females in October (Fig. 5A). The LSI was high in both sexes during the monsoon season (May – September) for both sexes (Fig. 5B). However, one beak of a highest LSI percentage was recorded in November 2001 (1.86) after this season for males. Another higher LSI percentage was also recorded for females in October 2001 (1.68), the LSI were then declined in the following months for both sexes. Male and female *L. nebulosus* showed a similar seasonal pattern of the condition factor K values, where the K factor fluctuates around 0.0013 (Fig 5C).

3.5 Length and age at first maturity and sex ratio

Based on the maturation data obtained during the spawning season between September and December in 2001 and 2002, the average length of *L. nebulosus* when 50% of fish were mature (L_{50}) was estimated to be 33.7 cm L_T (N = 352). The estimated lengths at first maturity were 33.5 cm L_T (N = 174) and 33.8 cm L_T (N = 178) for male and female fish, respectively (Fig. 6). These data demonstrate that both male and female fish mature at a similar size. The average age at first maturity (A_{50}) for the total population was estimated to be when fish reach an age of 4.2-year old. No significant different was recorded between the distributions of mature males and females amongst the different size classes (χ^2 = 12.3, 7 df, $P > 0.05$). Approximately 19.4 % of the total number of fish sampled during the spawning season was below the length and age at first maturity. The estimated average male to female ratio was 1.09:1 indicating that both sexes were present in the fishing ground in equal numbers.

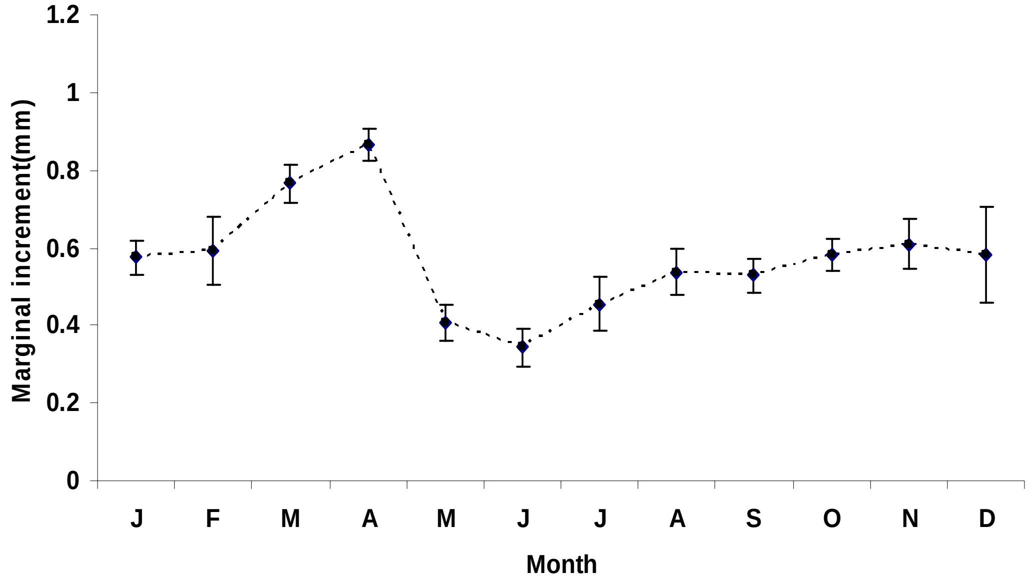

Fig. (2): Monthly variations in the mean (±SE, N=10) marginal otolith increment (mm) of spangled emperor, *Lethrinus nebulosus* from the Omani hand-line fishery in the Arabian Sea (2001-2002).

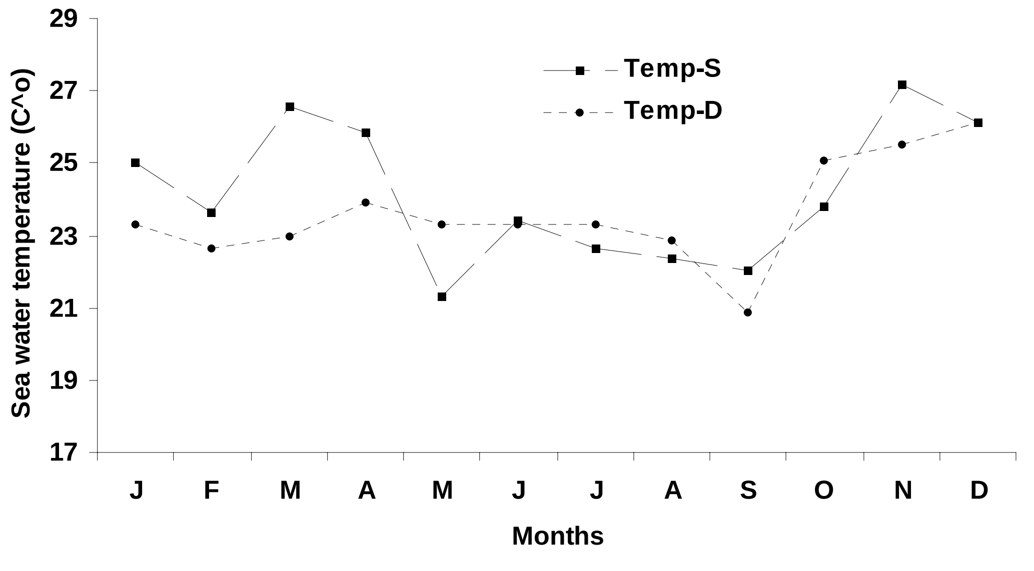

Fig. (3): Monthly variations in the average surface (S) (Temp-S, 5 m water depth) and deep-water (Temp-D, > 5 m water depth) seawater temperatures (°C) in the Arabian Sea. Readings were taken during the fishing seasons 2001-2002 by the marine ecology staff at the Marine Science and Fisheries Centre (Anon 2004).

Table (1): Von Bertalanffy growth constants (± SE) for *Lethrinus nebulosus* caught in the Omani hand-line fishery in the Arabian Sea (2001-2002). Data are presented for (a) male and female fish, (b) all the fish that were aged (i.e. including fish that could not be sexed) and (c) the fish that were used in the otolith weight analyses ($Fish_{Owt}$).

		N	L_∞ ±SE	K ±SE	t_o ±SE	r^2
a)	Males	133	68.7 ±1.8	0.098 ± 0.008	-2.531 ± 0.371	0.943
	Females	228	75.4 ± 2.0	0.076 ± 0.006	-3.637 ± 0.435	0.931
b)	All fish	363	72.2 ± 1.3	0.086 ± 0.005	-3.041 ± 0.278	0.935
c)	$Fish_{Owt}$	303	68.2 ± 1.8	0.105 ± 0.009	-1.986 ± 0.410	0.852

Table (2): Likelihood ratio tests (Kimura, 1980) comparing the Von Bertalanffy growth constants, for male and female *Lethrinus nebulosus*. N: number of observation = 48, Note: VBG curve were calculated using average length at age and not individual length at age as in Table 2.

Constraint	Male L_∞ (cm)	Female L_∞ (cm)	Male k	Female k	Male t_0	Female t_0	Res-SS	LR	*P*	df
None	70.4	73.4	0.087	0.084	-3.346	-3.048	123.059			
L_∞ : ♂ = ♀	71.8	71.8	0.082	0.091	-3.675	-2.692	126.214	1.215	>0.05	1
k : ♂ = ♀	70.4	72.8	0.087	0.087	-3.361	-2.890	200.965	0.103	>0.05	1
t_0 : ♂ = ♀	69.8	73.5	0.091	0.084	-3.098	-3.098	123.324	0.172	>0.05	1
All above	71.8	71.8	0.087	0.087	-3.098	-3.098	142.780	7.135	>0.05	3

None = no constraints, Res-SS = Residual sum of squares,LR = Likelihood ratio = N* Ln (Res SS_{no} constrained/Res SS $_{constrained}$) where N is the total number of observations (= 45). df = degrees of freedom, $\chi^2_{0.05,\,1\,df} = 3.84$, $\chi^2_{0.05,\,3\,df} = 7$.

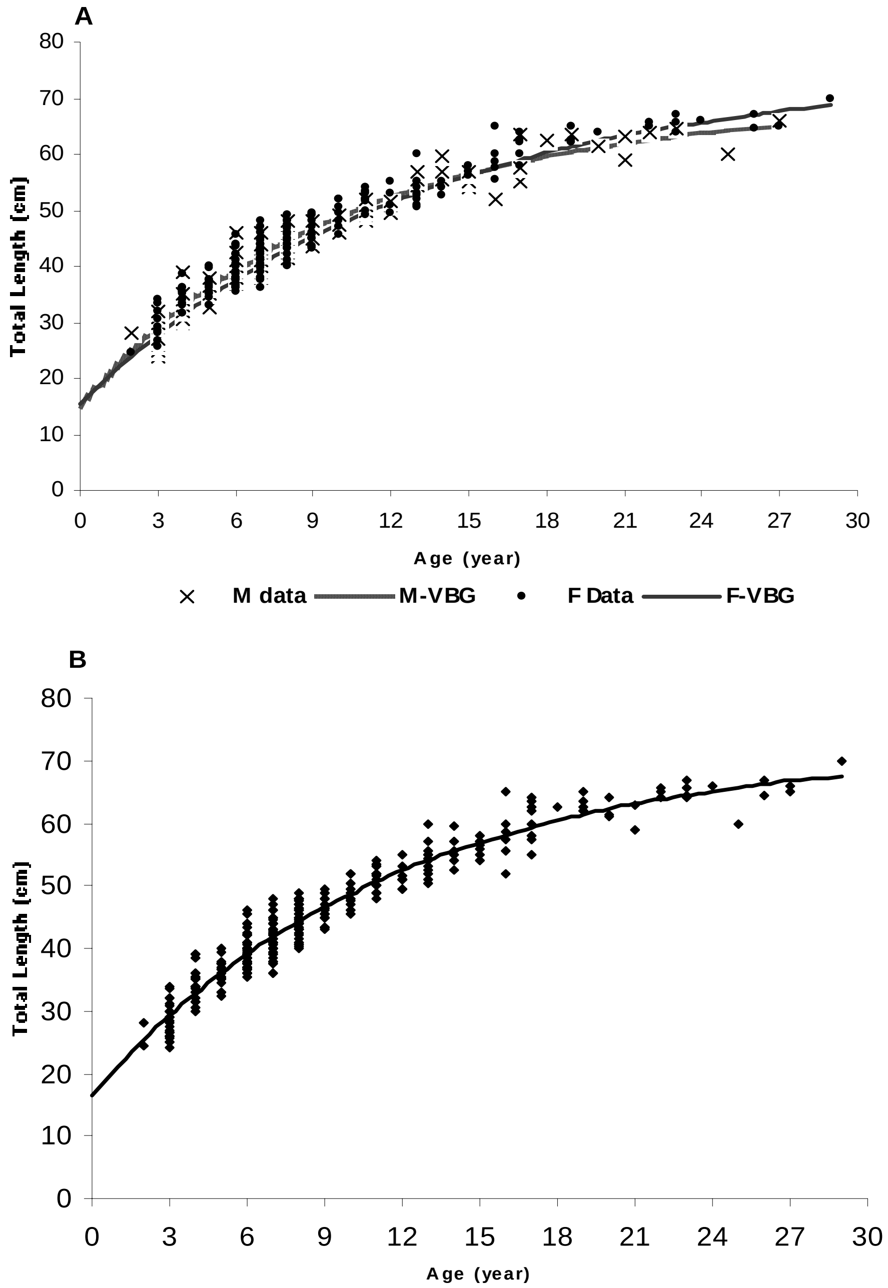

Fig. (4): Von Bertalanffy growth curves for spangled emperor *L. nebulosus* caught in the Omani hand-line fishery in the Arabian Sea (2001-2002). (A) Male (crosses) and female (solid) fish. (B) All fish (including those fish that could not be sexed).

Table (3): Likelihood ratio tests (Kimura, 1980) comparing the Von Bertalanffy growth constants between 303 individuals, where age has been estimated from the otoliths weight -age relationship, and for 363 *Lethrinus nebulosus* where age has been estimated from sectioned otoliths.

Constraint	E303 L_∞ (cm)	363 L_∞ (cm)	E303 k	363 k	E303 t_0	363 t_0	Res-SS	LR	P	df
None	68.3	71.8	0.106	0.087	-1.975	-3.098	171.113			
L_∞ : E303 = 363	70.0	70.0	0.096	0.096	-2.344	-2.646	177.788	1.95	>0.05	1
k : E303 = 363	70.0	70.17	0.096	0.096	-2.423	-2.579	177.176	1.78	>0.05	1
t_0 : E303 = 363	70.0	70.43	0.096	0.095	-2.512	-2.512	177.796	1.95	>0.05	1
All above	70.0	70.0	0.096	0.096	-2.512	-2.512	181.387	2.97	>0.05	3

None = no constraints, Res-SS = Residual sum of squares, LR = Likelihood ratio = N* Ln (Res SS_{no} constrained/Res SS $_{constrained}$) where N is the total number of observations (= 51). df = degrees of freedom, $\chi^2_{0.05,\,1\,df}$ = 3.84, $\chi^2_{0.05,\,3\,df}$ = 7.82,

Table (4): Estimates of growth parameters of *Lethrinus nebulosus* in different localities.

Locality	L_∞	K	t_o	Source
Gulf of Aden	71.60	0.21		Aldonov & Druzhinin (1979)
Gulf of Suez	86.00	0.11		Sanders *et al*., (1984)
Persian Gulf	89.4	0.13	0.50	Ibrahim *et al*., (1988)
Fiji	80.00	0.23		Carpenter & Allen (1989)
Gulf of Aden	87.00	0.09	-0.54	Sanders & Morgan (1989)
Southern Arabian Gulf	66.20	0.11	-3.00	Grandcourt *et al*., (2006)

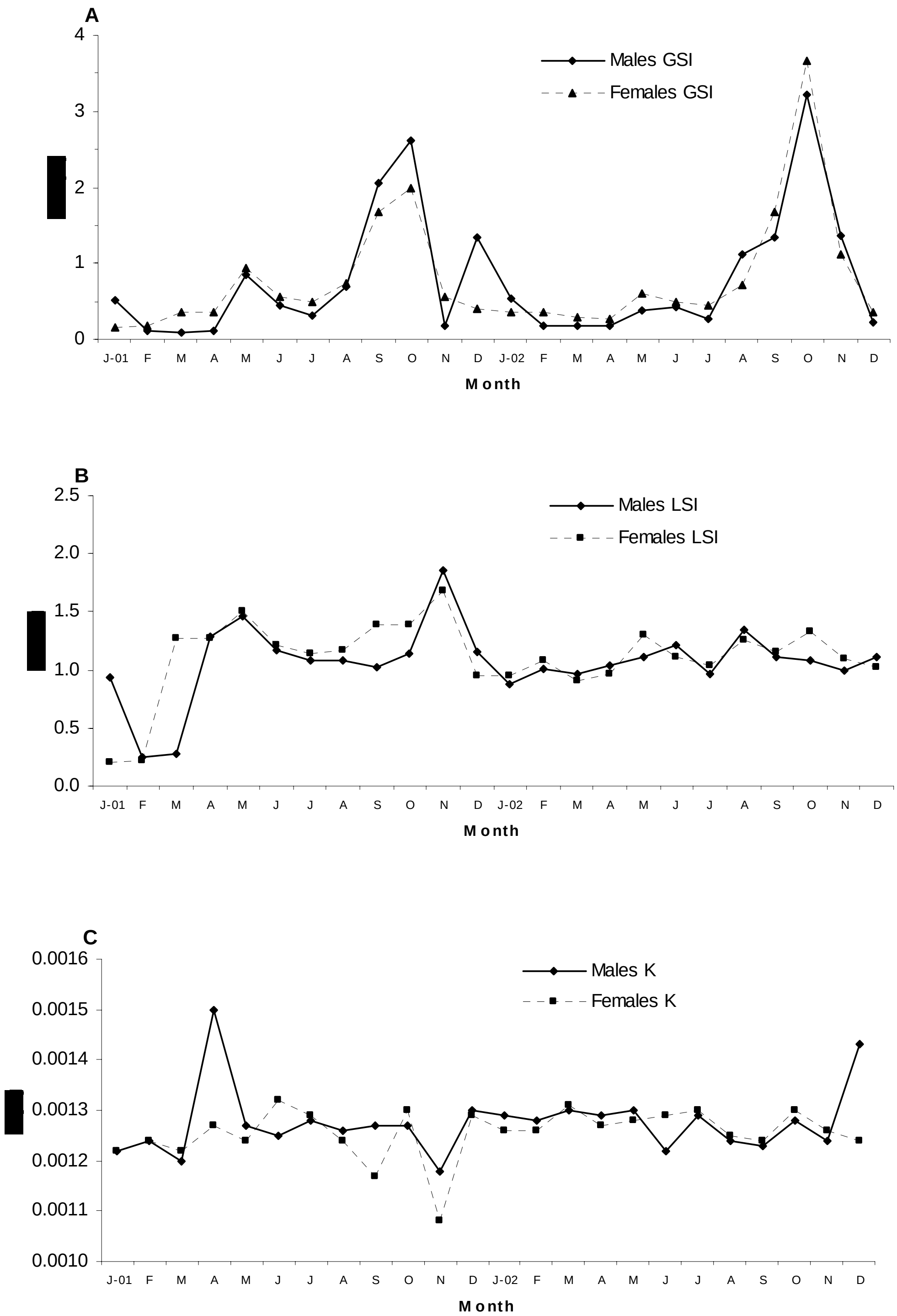

Fig. (5): Seasonal changes in (A) Gonado-Somatic Index (GSI), (B) Liver-Somatic-Index (LSI) and (C) Condition Factor (K) for Male and Female *Lethrinus nebulosus,* between January 2001 and December 2002. No male fish were collected during March 2002.

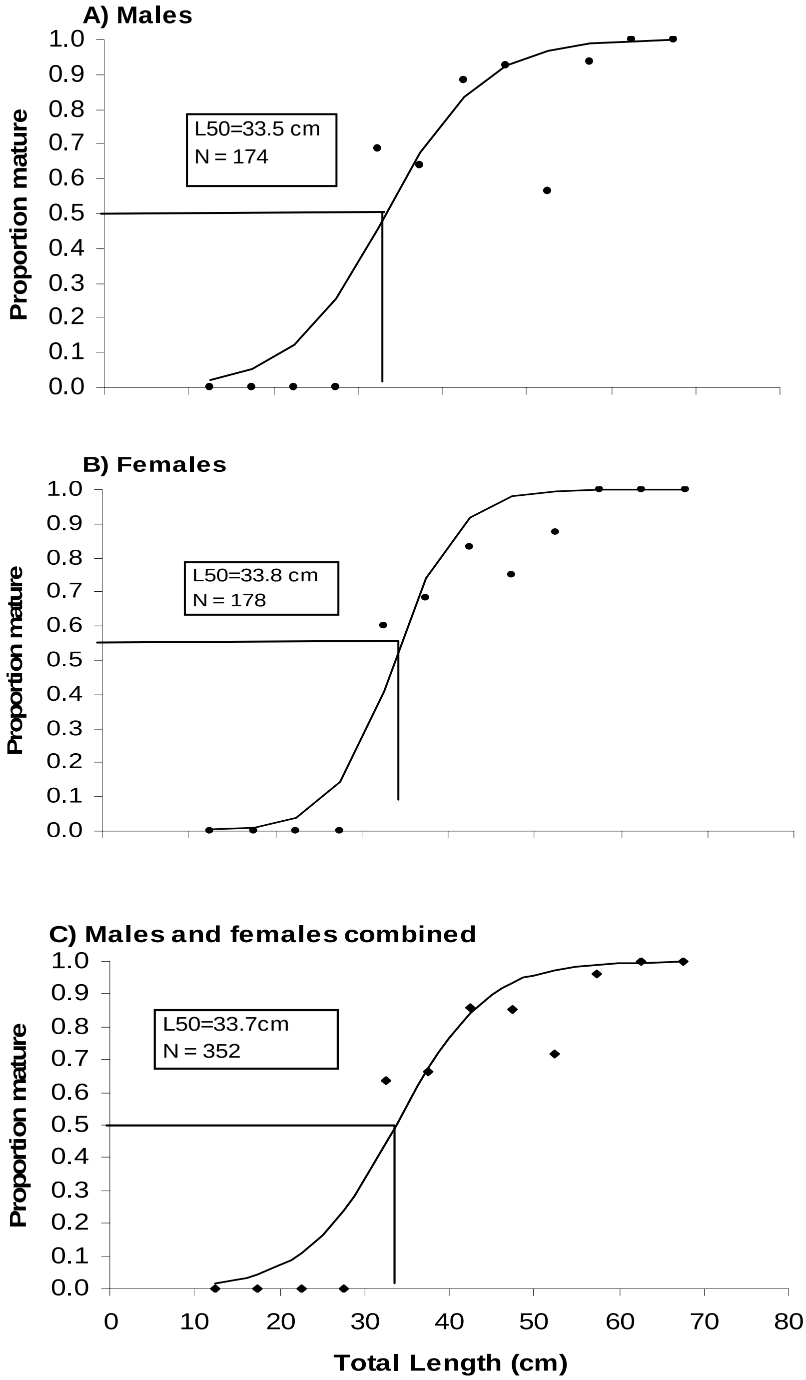

Fig (6): The estimated length at first maturity for A) male, B) female and C) the population of spangled emperor, *L. nebulosus,* collected during the spawning season (September to December) in 2001 and 2002.

4. DISCUSSION

Age and growth which have been examined for this economically important species in Omani waters demonstrated the utility of size frequency distributions and size at age estimates for assessing the status of tropical demersal species and providing information needed for resource management in the Oman fishery sector. The baited hand-lines used by Omani fishermen in the Arabian Sea tend to target the larger sizes of *L. nebulosus* (age classes 2 to 29 year old). The smaller and younger size classes (0 & 1 year) are usually absent from the landed hand-line catch. Their absence could be due to the selectivity of the hand-line gear; e.g. large hook sizes and baits are used in hand-line fishing and this gear might deter and prevent the smaller sized fish from being hooked. Growth of the otoliths is initially based on the successive deposition of opaque zones, which are deposited during the cool season, and translucent zones that are built mainly during the warm season. The wider and lighter rings are due to the faster growth benefiting from the active metabolism in the fish body, whilst the opaque layer is thinner and darker because of the decrease in fish growing during the cool season (Newman and Dunk, 2002). Mean size at age values were used to establish the VBG curve in order to model growth of the fish population. The timing of formation of the translucent zone was approximately 10 months (June – March) for the species and the opaque zone formed in April. However, an understanding of the factors affecting increment in otoliths is required before increment number and ring width can be used to assess growth rate (Nelson and Geen, 1982). In the Arabian Sea, the average seawater temperature in the fishing ground decreases from around 26 to 20^{O}C in May every year, which may causes the deposition of the opaque zone and the completion of the annual ring cycle. This change in seawater temperature occurs annually during the monsoon season in the Arabian Sea (Sheppard *et al*., 1992), and is associated with up welling that bring high levels of nutrients and food to the area which is reflected in the growth of the translucent zone over the following months. The associated decrease in seawater temperature and change in seawater quality during the monsoon season in the western Indian Ocean and Arabian Sea are the two factors which markedly affect the formation of the rings and the growth and spawning cycles of the species. The increase in seawater temperature between September and April helps the post-larval and juvenile fish to settle and feed on inshore coral reefs; the month of May therefore is the birth date for *L. nebulosus* as the first opaque ring forms then. The maximum number of opaque bands counted or the longevity estimates of 29 years in the present study was considerably higher than the maximum age of 20 years estimated by Mathews and Samuel (1991) and 21 years by Edwards and Shaher (1991) for this species in the northern Arabian Gulf and Gulf of Aden, respectively; and it is much higher than that recorded by Ibrahim *et al* (1989) (11 years) and Grandcourt *et al* (2006) (14 years) for the same species in southern Arabian Gulf.

The von Bertalanffy growth curves for both sexes fit the observed data relatively well. The VBGCs suggest that the male fish had a higher growth rate when younger and attained a smaller theoretical maximum size than the females; however a comparison of the male and female VBGCs using the likelihood technique revealed that the VBG parameters and the two growth curves for male and female fish were not significantly different. Table (4) summarizes the growth parameters estimated for *L. nebulosus* in various tropical fisheries, by different authors. It seems that there is no agreement in the growth pattern estimated by the different authors and even in works in the same geographical area. The difference in environmental conditions and ecosystem characteristics in the different areas may explain the amount of variation in the estimates. However, the present estimates of L_∞ are in a general accord with Aldonov & Druzhinin (1979), while the present estimate of K is lower than their estimate.

Seasonal changes in the ovary and testis of *L. nebulosus,* based on analysis of the GSI, LSI, and K factors, confirmed that the spawning season extends from September to December. The present results indicate a correlation between the timing of spawning and seawater temperature; when spawning started in September as indicated by GSI values, the deep seawater temperature was at its lowest, approximately 23 ºC, increasing towards 26ºC in January at the time when the spawning season ended. A similar correlative pattern has been reported for *L. nebulosus* in Okinawan waters (Ebisawa, 1990). The occurrence of a number of mature *L. nebulosus* during May - June 2001 could also be related to environmental changes during the summer season in the Arabian Sea. Some individuals matured early in May. Similar observations have been also made by Ebisawa (1990) in Okinawan waters off Japan where spawning of some *L. nebulosus* also occurred outside the intensive spawning season. In the present study, May can be considered to be a minor spawning period as only 48.6% and 46.3% of male and female *L. nebulosus,* respectively, were found to be mature in May 2001 compared with 93.2% and 93.5% respectively in October 2001. No mature fish were recorded in May 2002 whilst 100% of both sexes were found to be mature in October 2002.

Wilson (1998) stated that juvenile *L. nebulosus* > 12 mm standard length at Green Island off Australia, resided in shallow water habitats (5 - 15 m), inhabiting areas of soft substrate, patch reefs and in the surrounding reef flat. Moreover, Kanashiro (1998) followed the distribution, migration and post-settlement of juvenile *L. nebulosus* in Okinawan waters off Japan, and found that juveniles first settled at 17 mm fork length in sea grass beds in 3 m water depths in May and then moved to the coral reef areas at about one year of age. Such a pattern of movement of juvenile fish into the deep-water fishery may also occur at Doqum and Salalah of Oman.. *L. nebulosus* is a benthic feeding fish and lives mainly on and around coral reefs, feeding on a variety of prey surrounding them (Personal observations by Al Mamry, 2006). Male *L. nebulosus* comprised 49.3% of the total mature fish sampled during the two years spawning seasons and there was no difference between the occurrence of mature males and females. Both sexes mature at the same size and age. Kuo (1988) also found no significant difference between the occurrence of male and female *L. nebulosus* during the spawning season. Since male and female *L. nebulosus* were distributed equally in the population this may possibly enhance the spawning activities of the fish population. Ebisawa (1990) reported that juvenile *L. nebulosus* remained hermaphroditic until 30 cm fork length before sexes could be distinctively identified. In the present study only one male and one female of *L. nebulosus* could be identified amongst the fish under 30 cm TL. Male and female *L. nebulosus* showed no significant difference in their GSI, LSI and K factors with the species acting as a multiple spawner during the 4 month spawning season from September to December. Several studies have shown that *L. nebulosus* spawns in a New Caledonian lagoon during August & September (Loubens, 1980), March to June in Okinawa (Ebisawa, 1990), April to July in the Red Sea (Sanders *et al.,* 1985), April to May in the Arabian Gulf, (Ibrahim *et al*., 1988; Grandcourt *et al*., 2006) and August to November in Australian waters (Kuo, 1988**.** These differences in the spawning season have been related to the environmental conditions in these different geographical locations (Gibson, 2005). Generally, the spawning season of this species in the Arabian Sea occurs immediately after the monsoon season, which may trigger fish productivity (FAO report, 1997), as sea water temperatures increase through the spawning period toward January and the end of spawning productivity.

The results indicate that *L. nebulosus* populations attain 50% maturation at 33.7 cm TL and 4.2 years of age; this is in agreement with that recorded by Lee and Al Baz (1989) in the Arabian Gulf (32.5 cm). Sanders *et al.* (1985) estimated relatively higher lengths at first maturity for the species in the Gulf of Suez (40.0 cm for males and 45.6 cm for females).

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