Age, growth and length at first maturity of *Otolithes ruber* in the Northwestern part of the Persian Gulf, based on age estimation using otolith

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Abstract

Estimates of age, growth parameters, length-weight relationship and length and age at first maturity of the *otolithes ruber* are required for fishery management. We used counting annuli on the section of sagittal otoliths to age *O.ruber* from the Northwest Persian Gulf in south of Iran. Estimated ages ranged from 0 to 6 years, and maximum frequency of fishes was observed in age-group 1. The values of growth parameters L_∞, k and t_o were calculated by von Bertalanffy model and the results were 67.57 (cm), 0.27 ($year^{-1}$) and -0.43 respectively. Parameters b and an in length-weight relationship were calculated 3.19 and 0.005 respectively. Length and age at first maturity were estimated 28 cm and 1.55 year.

Keywords: *Otolithes ruber*, Age composition, Growth, Length at first maturity, Persian Gulf

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Introduction

Otolithes ruber belongs to the Sciaenid family, which can be found all across the West Indian Ocean from East to Queen's lands of Australia and Japan except the Red Sea. They live in the marine coastal waters at the depth of 40 meters and mostly on the muddy surfaces and mouths of the rivers (Fischer and Bianchi, 1984: Novaluna, 1982). This species extends across the Iranian coasts, Oman Sea, and Northwest of Persian Gulf especially in Khuzestan Seashore. The catch rate of *O. ruber* in Khuzestan province reached to 6203 tons in 2009. The length at first maturity in Oman Sea was 40 cm (Azhir 2007), in Hormozgan 33.7 cm (Kamali et al., 2007), 30 cm in Booshehr (Nia Meimandi, 1999) and 35 cm in Khuzestan (Emami, 2006). In South Africa, the sizes of maturity were between 220 and 240 mm (Brash and Fennesssy 2005).Length-weight relationship and growth parameters were calculated with different methods in various areas (Ingles and Pauly, 1984; Schultz 1992; safahie 1996; Niameimandi 1999; Taghavi et al. 2004; Barash and Fennessy, 2005; Emami, 2006; Kamali et al. 2007; Azhir 2008; Hakimelahi et al., 2010).Age and growth studies are important factors for fishery sciences. Age, length, and weight data are important factors for fishery biologists in growth studies. Growth, mortality rate, age at maturity and longevity are determined by using these data. The aim of the present study was to determine the age composition, growth parameters, length-weight relationship, age and length at maturity of *O. ruber*, in the Persian Gulf.

Materials and methods

This study was done in Khuzestan Coastal waters, southwest of Iran between nearly 48º45´and 49º50´ East and 29º48´and 30º06´ North, during the period of 2007-2008 (Fig.1). Monthly sampling was carried out using bottom trawl survey from random locations in the northwestern part of the Persian Gulf. The *O. ruber* samples were transported to the laboratory in ice-box, where they were frozen.

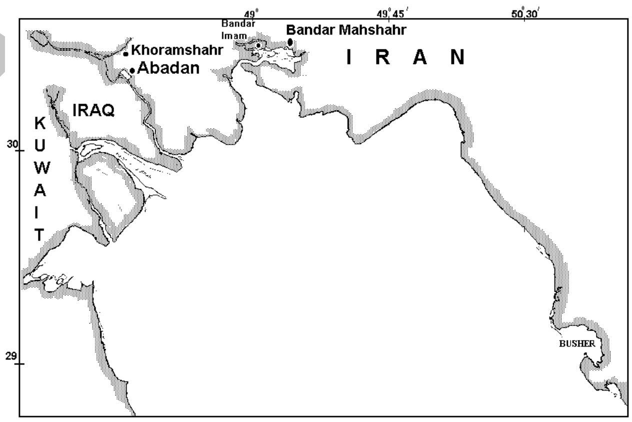

Figure1: Sampling area in Northwest of Persian Gulf

In the laboratory, fish were measured for total length (TL) to the nearest millimeter and weighed whole to the nearest gram. All the fish collected were grouped into size classes of 2 cm. The sex and maturity stage of the fish were determined by macroscopic examination using 8-stage keys (Farmer et al., 2005). After all external measurements were recorded, the sagitta were removed from each side of the head. They were cleaned, air dried and stored in dry paper bags. Finally, nearly 1000 *O. ruber* specimens were used for the age and growth analysis. Right otoliths were embedded in clear epoxy resin blocks. A thin dorso-ventral wafer was obtained from each otolith by placing each block with its otolith on a Maruto micro cutter model MC-201. An initial cut was made using a single diamond edge blade. The otolith was then moved so that a second cut could be made, producing a 0.5 mm wafer. Sections were cleaned of excess water and residues prior to mounting on microscope slides with Canada balzam mountant (Farmer et al., 2005). The mounted sections were viewed with a Nikon stereo dissecting microscope (blue light model equipped with monitor system and photographer with magnifying range of 70 to 450) under transmitted or reflected light. otoliths were read without reference to the date of capture or length of the fish. A translucent and an opaque zone (Fig. 2 and Fig. 3) together constituted a complete growth zone (Chilton and Beamish, 1982). Age validation with sectioned otolith and reading annual rings were already determined (Safahie, 2006). The average, standard deviation, age-group range and confidence interval were also calculated. The age-length keys obtained from these age estimations allow length structures to be converted into age structures except for *O. ruber*. The von Bertalanffy growth parameters were estimated from length at age distribution of the samples. Growth parameters were estimated by non-linear regression from otolith readings.

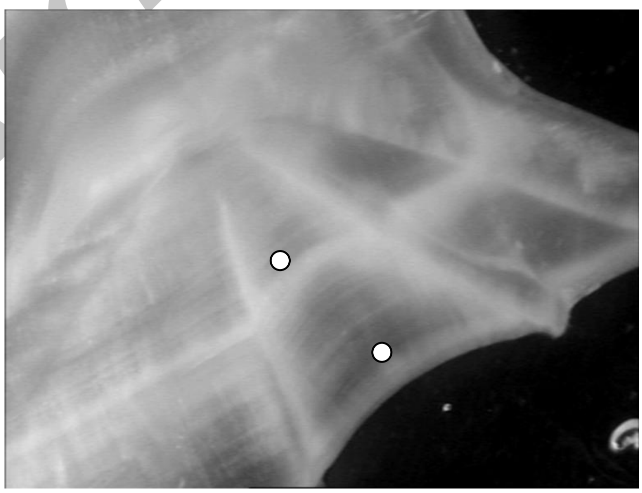

Figure 2: Photograph of a sectioned sagittal otolith from a 2-year-old *O. ruber* (with reflected light)

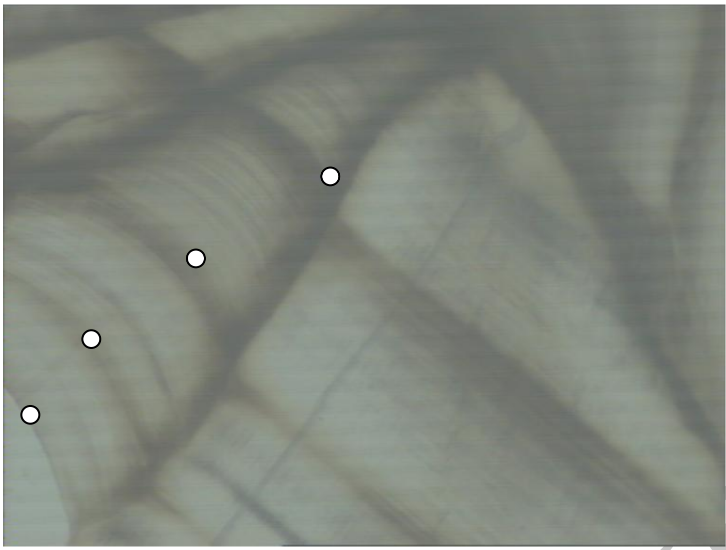

Figure 3: Photograph of a sectioned sagittal otolith from a four year-old *O. ruber* (with transmitted light)

The base of least squares is the best data fit with data which was calculated by the von Bertalanffy model (Lassen and Medley, 2000). The von Bertalanffy growth curve is:

$$L_t = L_\infty (1 - e^{-k(t - t_0)})$$

Where:
L_t = mean length at age t
k = growth constant
t_0 = theoretical age at zero length
L_∞= theoretical maximum length according

Length-weight relationship parameters were also used by least squares and solver analyzed tools in Microsoft Excel for nonlinear regression (Jensen, 2009). A t-test analysis was used to determine the difference between b and three (Cinco, 1982). The length at first maturity was determined in the spawning season. When their maturity was in stages one and two, they were considered as immature, and those which were in stages three to eight, were considered as mature (Farmer et al., 2005). The relation between length and maturity in length classes was demonstrated on a logistic diagram for estimating the total lengths at 50% maturity. Using the logistic model by fitting parameters a and b to the data given in spawning season where p=0.5, total lengths at 50% maturity were obtained (Pastor, 2002). The form of the logistic equation is;

$$P = 1/1+e^{(a+b\times L)}$$

Where:
P is the proportion of mature fish,
L is the length,
a and b are the parameters estimated by the regression,
and length at sexual maturity is calculated as L_{50}= -a/b.

The age may be determined from reverse von Bertalanffy equation regarding maturity length calculation.

Results

Age composition

Seven age-groups of *O. ruber* were observed in the present study. The maximum and minimum frequencies were in age-group 1 and age-group 6 respectively (Fig. 4).

Average length, weight and SD of each age group are illustrated in figures 6 and 7. The minimum length and weight for age-group 0 were 6 cm and 1g respectively, and maximum length and weight of age-group 6, were 59 cm and 2292 g, respectively.

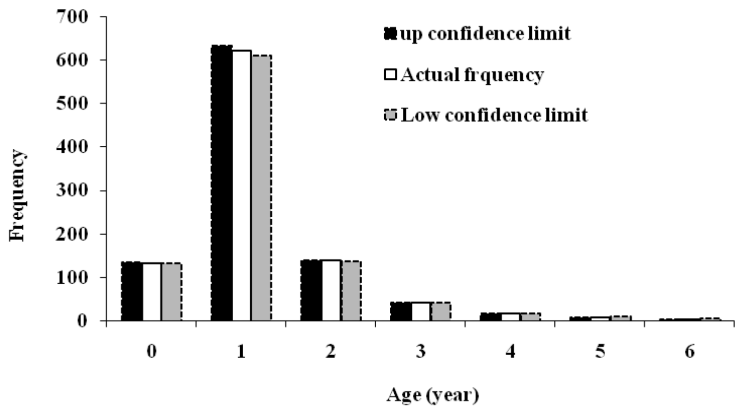

Figure 4: Age-group frequencies of *O. ruber* in Khuzestan coastal waters

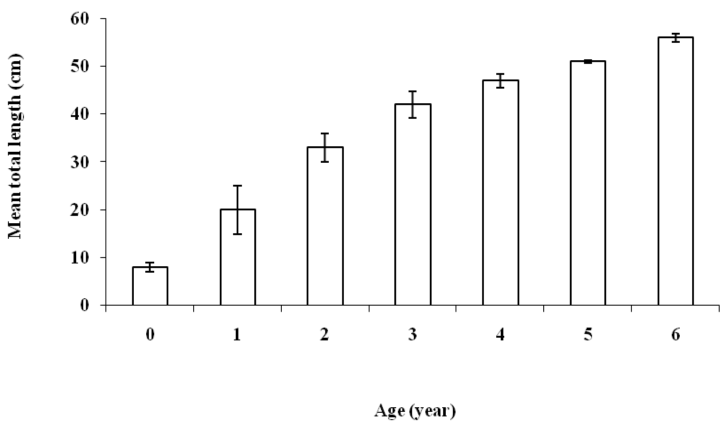

Figure 5: Average (±SD) of the total length of *O. ruber* in different age-groups in Khuzestan coastal waters

Age-length key

Table 1 shows that age-length key and length range of age-group 1 is greater than other age-groups. From age-group 1 to 6, the groups almost overlap each other.

Table 1: Age-length key of *O. ruber* in coastal waters of Khuzestan

Length group	Age (year)							Numbers
	0	1	2	3	4	5	6	
6	14							14
8	106							106
10	14							14
12		54						54
14		86						86
16		90						90
18		80						80
20		61						61
22		68						68
24		64						64
26		65	5					70
28		38	11					49
30		13	38					51
32		2	30					32
34			34					34
36			16	6				22
38			3	4				7
40			1	9				10
42			1	13				14
44				9	2			11
46				2	8			10
48					6			6
50					1	6		7
52						2	1	3
54						1	2	3
56							1	1
58							1	1
Total	134	621	139	43	17	9	5	968

Growth parameters

Otolithes of 968 fishes were used to estimate L_∞, K and t_0. L_∞ and K were 67.57 cm, 0.27 $year^{-1}$respectively and t_0 were 0.43 $year^{-1}$. Growth equation is described by the following equation:

$$\mathbf{L_t = 67.57\ (1 - e^{-0.27(t+0.43)})}$$

Figure7 shows growth curve using calculated lengths from the above function.

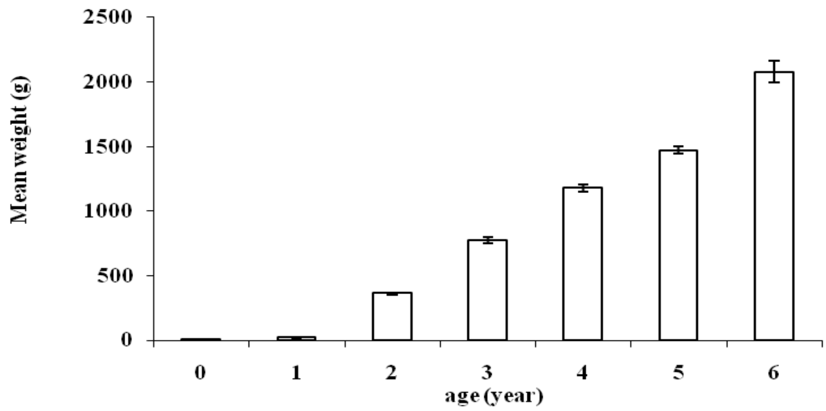

Figure 6: Average (±SD) of the total weight of *O. ruber* in different age-groups in Khuzestan coastal waters

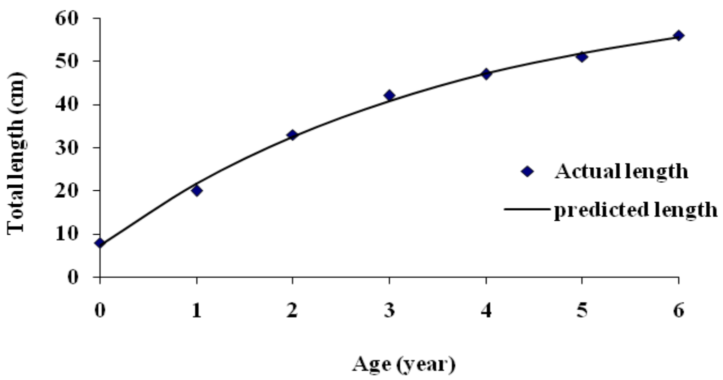

Figure7: Growth curve of *O. ruber* in the Khuzestan coastal waters

Length-weight Relationship

Length-weight relationship is illustrated in Fig.8. Maximum and minimum length in monthly sampling was 59 and 6 cm and the maximum and minimum weights were 2292g and 1g. The rate of b and a were 3.19 and 0.005 respectively. b with 3 did not show a significant difference (t=2.97, df=2116, p>0.05).

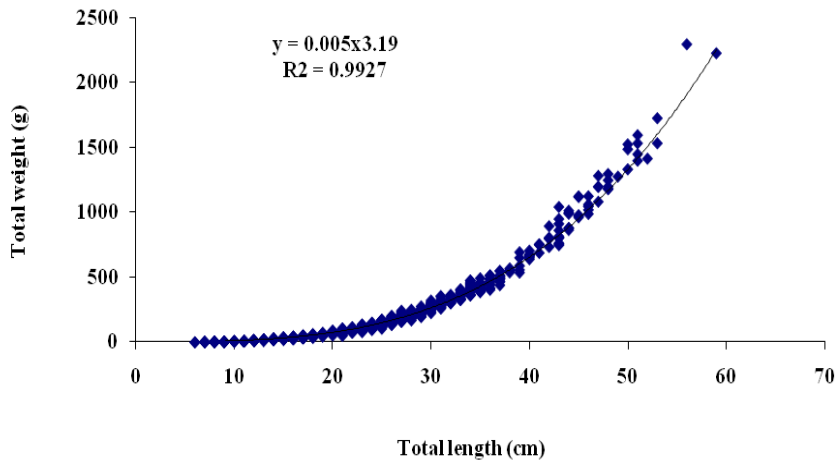

Figure 8: Length-weight relationship of *O. ruber* in Khuzestan coastal waters

Length and weight at first maturity

Length at the first maturity was obtained 28 cm by using the logistic model. Age was estimated 1.55 yr. by using the reverse method of von Bertalanffy (Fig.9) and Growth function index was estimated 3.09 by using growth parameters.

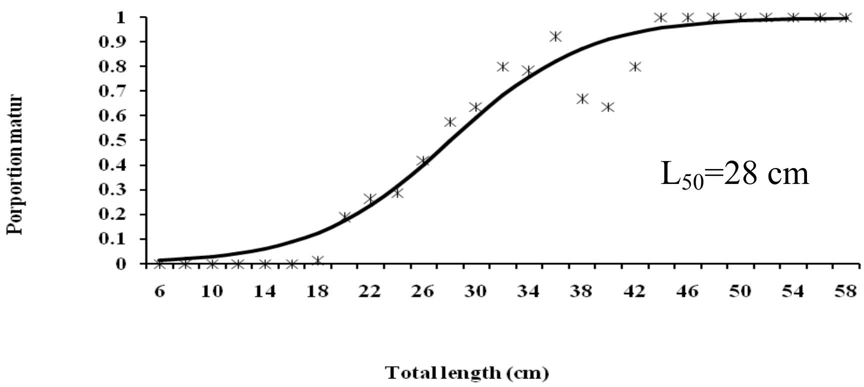

Figure 9: Maturity rate of length group of *O. ruber* in Khuzestan Coastal waters

Discussion

Age

Age information forms the basis of growth rate calculation, mortality rate and productivity therefore ranking it among the most influential biological variables. Calculations as simple as that of growth rate or as complex as that of virtual population analysis all require age data, since any rate calculation requires an age or elapsed time term (Campana, 2001). In the present study Sagittal Otolith and its size, was used to find age-groups.

The opaque zone deposition in tropical species generally occurs in the spring and summer months during the period of rapid growth, whereas the translucent zone is formed when there is reduced metabolic activity (Grandcourt et al., 2005). In several studies on *O. ruber*, the formation of transparent zone and an opaque zone have been reported every year (Safahie, 2006; Kamalli et al., 2007 and Brash and Fenness, 2005). Transparent and opaque zones are different in reflecting and transiting light of the stereomicroscope. The highest frequency among age-groups was in age-group 1. In the Persian Gulf water, India and South Africa, age-group ranges were different (Safahie 1996; Kamali et al., 2007; Brash and Fennesss 2005; Almatar 1993). Age composition of the samples in the sea survey sampling has been formed from seven age-groups at present. The differences among the studies probably result from gear selectivity and the sampling areas (Ciloglu, 2005) and other factors such as fishing pressure, sampling season, method and food ability (Emre et al. 2009).

Length range of *O. ruber* in some age-groups like age-group 1 is higher than that of other groups and its range is 12 to 32 cm. This variation has also been observed in *A. japonicous*. The reason for this variability may relate to a larger size of first spawner in contrast to those latter spawns during the spawning period. This difference is illustrated by a wide range of *A. japonicus* total lengths from 214 to 302 mm, which on average would have been about six months old. It is also possible that variations in size reflect differences in the productivity of the habitats occupied during early life. The females of *A. japonicus* also grow at a slightly faster rate and attain a larger size than their males (Farmer et al., 2005). A situation also recorded for the Sciaenids *O. ruber* and *Atrobucca nibe.* (Fennessy, 2000).

In the present study both sexes have been used together, and growth and maturity in both sexes are different which can affect the expansion of the range in original age-groups especially one and two year old groups.

Growth parameters

Age and growth study of fishes have vital importance in fisheries management. Information on age and growth parameters is used for evaluation of the population structure and yield per recruit of an exploited fish stock (El-halfawy et al., 2007). The mathematical growth models permit the description and comparison of growth of different species at different times and localities. The constant obtained from the fitting of the observed growth data in mathematical models is used in yield equation and fishery management

(El-halfawy et al, 2007). The von Bertalanffy growth model has been successfully used for a number of sciaenids. The von Bertalanffy model was selected to fit the *O. ruber* age and length data which is often used to explain fish growth. The k values indicate that most members of this family, including *O. ruber,* are generally slow-growing and long-lived. (Brash and Fenness, 2005). The age range was different in different reports. In the present study the maximum age was 6 years but in Bandar Abbas it was 8 years (Kamali et al., 2007) which represents that longevity and growth rate is moderate in these species. As compared with other species with more than 20 years of life span it can't be concluded that *O. ruber* is a fish with a long life period. Growth parameters including L_{∞}, growth coefficient, and age at zero length of *O.ruber* in some regions of the Persian Gulf and other areas have been determined. These parameters were different among different regions (Niamamandi 1999; Imami 2006; kamali et al., 2007; Safahie 1996; Azhir 2008; Brash and Fenness 2005 and Almatar 1993). The differences among the studies probably result from sea temperature, genetic features and feeding (Ciloglu, 2005). Moreover, the methods applied for estimating growth parameters and also the size range of the samples may affect the growth parameters in different areas. One of the factors that may affect the fish growth is temperature which has an influence on fish physiological processes (feeding, assimilation, metabolism, transformation and excretion) and can affect their growth (Otterson et al., 2010). Nakken and Raknes (1987) readily showed that young Cod has a higher growth rate in higher temperature. The length of 3 year old Cods has showed a decreasing trend from west to east due to decreasing temperature (Loeng, 1989). Also Capelin seems to have the best growth in the areas where temperature is the highest (Klungsoyr et al., 1996).

L_{∞} of this species in locations near the equator (Ingles and Pauly 1984; Schultz 1992; Brash and Fennessy 2005) is lower than that of Iran. Hence, *O. ruber* seemingly reaches L_{∞} faster, since water temperature in equatorial regions is more constant, and the average of water temperature is higher than that of the Persian Gulf. In the Persian Gulf, growth coefficients which were obtained from different methods were lower than other areas where fish reach their L_{∞} at larger sizes. Some species like *Boops boops* grow faster in length and in the first year of their life, it reaches 53.49 percent of their L_{∞}, and their growth rate decreases simultaneously with their maturation (Allam 2003). Ezzat et al. (1992) stated that during the first year of life most of the consumed food is used for growth in length while at sexual maturity food is used for maintenance of gonad formation and growth in weight. The growth of *A. japonicus* in Western Australian waters is particularly rapid during the first six years of life, but it slows down markedly as fish become sexually mature. The change in the pattern of growth at sexual maturity implies that energy resources become directed towards gonadal development rather than mainly towards somatic growth. This pattern of change in energy allocation, which maximizes reproductive potential, has been recorded for many other fish species, including some in Western Australian waters and for other sciaenid (Farmer et al., 2005). The growth rate of immature *O. ruber* is higher than adults and it showed a decreasing trend after sexual maturity.

Length-weight relationship

The sample size and individual size range are important factors that could affect the results of length-weight relationship. The larger sample size and the wider size range of samples could describe the better *W–TL* relationship for shortfin mako (Chang and Liu, 2009). The value of the constant (b) of the length-weight relationship of *Saurida undosquamis* has been obtained similarly in different studies, this is due to the similarity of environmental factors (El-halfaway et al., 2007). b in various studies of *O. ruber* has been different. In the previous studies in the Persian Gulf, b was lower than the present study, but significance of difference between b and 3 was not analyzed, however in the present study b and 3 showed no significant difference. So it can be inferred that differences are mostly caused by sample rate and range of the fish sizes rather than the feeding and environmental differences. Therefore, it can be concluded that this species has isometric growth in Persian Gulf waters especially in Khuzestan.

Length and age at first maturity

Maturity analysis is based on correct determination of length, age and reproductive situation. Beside natural mortality and longevity, age at maturity is also one of the uncertainties that may affect the results of spawning per recruit analysis (Chang and Liu, 2009) and reproductive potential analysis (Liu et al., 2009). Length at first maturity of *O. ruber* is different in various areas. In the Oman Sea and the Persian Gulf, length range at first maturity was reported between 30 and 40 cm, and in South African it was between 22 and 42 cm (Azhir 2008; Kamali et al., 2007; Imami 2006; Brash and Fennessy 2005). Age and length at sexual maturity of vermilion snapper declined over time. This decline may have resulted from increased fishing pressure, because the total landings consistently increased during the 1980's (Zhao and McGovem2). The demonstration that the harvest of a fish stock can lead to declines in length or age at maturity has been reported for many fishes (Zhao and McGovern, 1997). Jorgensen (1990) attributed a decline in median age at maturity in the northeast Arctic Cod to an increase in length at age (i.e. faster growth) coincident with declining stock density, an idea that implicitly assumes a minimum threshold for size-at-maturity. If the scenario of Jorgensen (1990) is correct, declines in length and age should not occur concurrently. Furthermore, Zhao et a1. (1997) indicated that the size at age of vermilion snapper has decreased with time. If intensive fishing pressure continues, and the early- maturing trait is heritable, length and age at maturity in the population will decrease with time. Harvesting can reverse the relative fitness of genotypes, because an inferior genotype (e.g. slow-growing and early-maturing) in an unexploited population may be more fit under increased fishing pressure (Zhao and McGovern, 1997). Early maturing genotypes reproduce before being fully recruited to the fishery, whereas genotypes that mature at larger sizes or older ages tend to be removed before reproduction. This process would explain the decreasing abundance of larger, immature fish with time and would account for declines in both size and age at maturity (Zhao and McGovern, 1997). The long-term impacts of size-selective fish harvests may have caused the decline in size at age of vermilion snapper through disproportionate harvesting of fast growing individuals (Zhao et al., 1997). Similarly, it may be that late maturing genotypes were removed from the vermilion snapper population in the 1980's when fishing pressure was intensive. Differences between previous and present results could be partially due to differences in methods used to determine maturity or may truly reflect the changes in maturity that occurred in the 1970's (Zhao and Mc Govern, 1997).

In the present study length is lower than the previous studies but it cannot be well compared because fish sizes of landing samples are usually higher than research catches. However, the lengths at first maturity of *O. ruber* were reported between 32 and 35 cm by Eskandari (1997) which is higher than the present study. In order to increase pressure of fishing, these variations could be effective through genetic changes because the average length of the catch was not fluctuated dramatically during the last ten years (Eskandari, unpublished). Because of different growth rate and age, length at maturity is different among individuals. Fifty percent of individuals reach the adult stage at 28cm which is half of the maximum length. The L_{50} for females of *A. japonicus* in Western Australia corresponds to 75% of the L_{max}, which is similar to that reported for the females of this species in South Africa (Farmer et al., 2005).

We can finally conclude that determination of age and growth parameters with sectioned otolith can be a base for better estimation of other parameters in management of total and natural mortality and fishing rate as compared to the other methods. Also, determination of age-length key can be used to stock assessment of this species. Considering growth parameters, *O. ruber* has a moderate age and small length at maturity. According to the growth rate difference of both sexes, it seems that *O. ruber* males and females become mature at 1 and 1.55 year old, respectively.

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