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Estimation of *Otolithes ruber* stock with virtual population analysis in the Northwest area of the Persian Gulf

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Abstract

Stock assessment of *Otolithes ruber* was carried out using Virtual Population Analysis (VPA) method in the coastal waters of Northwest area of the Persian Gulf. Catch and length frequency data during 2002-2012 were converted to age frequency. The maximum of stock number and biomass were observed in age group 1 and 2, respectively. The minimum stock number and biomass were observed for age group 6. The maximum and minimum catch numbers were in age groups 2 and 6, respectively. The maximum and minimum of weight were in age group 3 and 1, respectively. The maximum and minimum of instantaneous fishing mortality were in age groups 4 and 1, respectively. The maximum fishing mortality was estimated in 2010-2011 and minimum value was in 2002-2003 and 2008-2009. During 2011-2012 the stock number and biomass were estimated 29558 ($*10^3$) specimens, 7302 tones and the catch number and weight were calculated 7562 ($*10^3$), 2364 tones and fishing mortality was obtained 0.47 per year. The calculated parameters showed over-exploitation in age-groups 3 and 4. To preserve stocks and to guarantee sustainable exploitation, the prevention of increasing fishing efforts and the control of fishing activities are crucial.

Keywords: Virtual population analysis, Stock number and biomass, Catch number, Catch weight, *Otolithes ruber*

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Introduction

Tiger tooth croaker (*Otolithes ruber*) is a valuable species in fisheries, which plays an important role in the economy of fishing in the study area and caught by bottom trawl, gill-net and hook in coastal waters (Fischer and Bianchi, 1984). They are found over sandy and muddy substrata but do not inhabit rocky areas (Navaluna, 1982). *O. ruber* is widely distributed in the Indo-West Pacific (Fischer and Bianchi, 1984) and along the coast of Iran in the Oman Sea and Persian Gulf (Eskandari, 1997).

There are several assessment models to assess population structure. However, models which divide population into different age groups, can provide better demonstration. Stock assessment models require accurate estimate of the age structure of fish populations. Age structure is often derived by interpreting annual rings in sectioned otoliths from a number of individuals, thus giving a relative proportion of fish in each age class (Cardinale *et al*., 2000). Two of the most significant developments in fisheries science are the single species virtual population analysis (SSVPA) and multi-species virtual population analysis (MSVPA). SSVPA has been applied successfully in modeling the dynamics of fish populations (Xiao, 2007). Virtual population analysis (VPA) is basically an analysis of the catches of commercial fisheries, obtained through fishery statistics, combined with detailed information on the contribution of each cohort to the catch, which is usually obtained through sampling programs and age reading (Sparre and Venema, 1998). The VPA method in fish stock assessment is widely used. For example, it is used for assessing most fish stocks in the Northeast and Northwest Atlantic, and many other stocks in the Northern Pacific, Australia, New Zealand, South Africa, Argentina, Chile, Peru (Lassen and Medley, 2000). The advantage of doing a VPA is that, once the history is known it becomes easier to predict the future catches, which is usually one of the most important tasks of fishery scientists (Sparre and Venema, 1998).

Several studies have been conducted on stock status and growth parameters of *O. ruber* (Novaluna, 1982; Ingles and Pauly, 1984; Apparao, 1992; Schultz, 1992; Iqbal, 1995; Safahiie, 1996; Mohamed *et al*., 1998; Bandani, 1999; Niamamandi, 1999; Fennessy, 2000; Parsamanesh *et al*., 2000; Chakraborty, 2001; Ali *et al*., 2002; Taghavi Motlagh *et al*., 2004; Brash and Fennessy, 2005; Emami, 2006; Kamali *et al*., 2006; Azhir, 2008). However, catch-age data were not used to assess the stock status.

The average catch (2002 - 2012) in Khuzestan province was estimated 3400 mt (Khuzestan Fisheries Office, 2002-2012). The annual average price of *O. ruber* was $3.5 per kg and it generates an average of $11,900,000 in annual revenues (Khuzestan Fisheries Office, 2012). In Khuzestan Province about 2082 boats are effectively engaged in fishing during a year. *O. ruber* was caught especially in October to March (Khuzestan Fisheries Office, 2012). Large fluctuations in catches and stock decreasing have an adverse effect on economy of fishing community. Monitoring of stock status and recommended management strategy is need for sustainable exploitation. The objective of this study is to provide the first evaluation of the population status of *O. ruber* in the Northwest area of the Persian Gulf by using virtual population analysis (VPA).

Materials and methods

The study area , is was a part of the Southwest coast of Iran in the Persian Gulf included two main fishing grounds of Lifeh, Bouseif and Bahrekan which are approximately 738.9 nm^2 (Fig. 1). Catch data (weight) from 2002 to 2012 were collected at the Fishery Office. About 138,613 length measurements were recorded during the period from 2002 to 2012. To estimate catch in numbers at age (Table 1), the input data consists of:

a) The age length key, obtained as described in Eskandari *et al*. (2012)

b) Catches in numbers at length

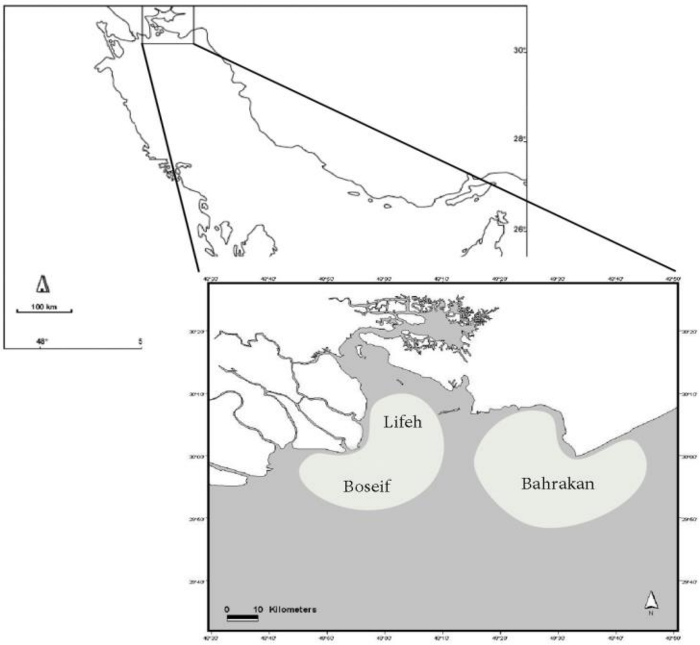

Figure 1: The study area: Khuzestan fishing ground in Northwest area of the Persian Gulf.

Table 1: Catch number in different age groups of *Otolithes ruber* in the NW area of the Persian Gulf (2002 to 2012)

Year	Total catch number	Catch number in age group (*10^3)					
		1	2	3	4	5	6
2002-2003	2347	530	799	643	283	68	24
2003-2004	3603	660	1437	1000	392	84	30
2004-2005	5945	1282	2597	1381	511	127	47
2005-2006	4827	1100	1765	1353	462	108	39
2006-2007	5338	1158	2118	1500	458	82	22
2007-2008	9774	2393	4023	2515	668	133	42
2008-2009	10966	2326	4725	2944	784	143	44
2009-2010	4763	735	2018	1382	458	121	49
2010-2011	8432	3149	3776	1260	185	56	6
2011-2012	5757	1563	2673	1203	172	112	34

Raising factor was used for converting the number of fish in the samples to catches in number data. The ratio of the estimated sample weight and the total landings gives the raising factor (RF) (Pastor, 2002):

RF = W(tl) / W(s)

Where W (tl) is the total landings weight in kg and W(s) is the sample weight in kg. The RF multiplies the numbers at length in the sample, giving the catches in numbers at length. Then catch number is estimated from the frequency of catches in numbers at length and frequency of age in length group (age length key).

Between observed and calculated frequency in the 2002-2012 years, was showed no significant difference at 5% level. There is no significant differences (at 5% level) between observed and calculated frequency in 2002 and 2012.Editor not 55 level means $p<0.05$.

The percentage relative error (Coggins and Quinn, 1998) of frequency in length group was less than 10% and Kolmogrov-Smirnov normality test was performed at the 95% confidence level.

The catch numbers at age (Table 1), natural mortality (0.56), growth parameters (L∞=67.57 cm, k=0.27 year-1, and t0=-0.43 year), length-weight (Tw=0.005Tl3.19) and age at first maturity (1.55 yr) data (Eskandari *et al*., 2012) were used to estimate stock number by VPA. The following equations were used to reconstruct the instantaneous rate of fishing mortality (Fi,t) for the year t (2002-2012) and age i (1-6) (Weizhong *et al*., 2003).

$$C_{i,t}=F_{i,t}/Z_{i,t}(1-e^{-zi})N_{i,t} \qquad (1)$$

$$C_{i,t}/N_{i+1,t+1}=F_{i,t}/Z_{i,t}(e^{z}{}_{i,t}-1) \qquad (2)$$

$$N_{i+1,t+1}=N_{i,t}e^{-z}{}_{i,t} \qquad (3)$$

Where: $C_{i,t}$ is the total number of fish caught at age i in year t, Z_i is total mortality at age i, $F_{i,t}$ is the fishing mortality at age i in year t, $N_{i,t}$ is the stock number of fish at age i in year t, $N_{i+1,t+1}$ is the stock number of fish at age i+1 in year t+1.

The initial F values for the oldest age group for each year and each age group for the last year was calculated by "replacing and difference measuring" method (Weizhong *et al*., 2003). The sensitivity of the choice of initial F values was tested by predicting catch for the years 2011-2012 with difference initial F values. The initial F values ranged from 0.1 to 10 (Weizhong *et al*., 2003).

One-way ANOVA was used for analyzing differences between the observed and calculated catch number.

Results

The observed and calculated catch number

The catch were increased approximately from 2002 to 2009 and then declined in 2010 (Fig. 2). The observed catch compared to calculated catch number with normal distribution, and VPA showed no significant differences at the 95% level.

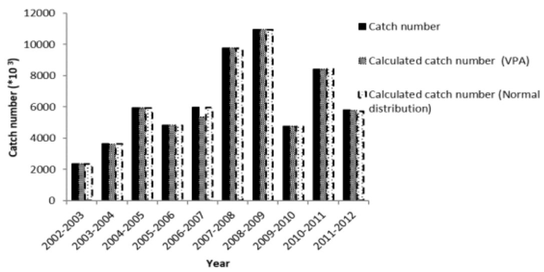

Figure 2: Observed and calculated catch number on *Otolithes ruber* in the NW area of the Persian Gulf (2002-2012).

Effect of different initial F values on predicted catch weight

The result of the sensitivity analysis of initial F values on the predicted catch is shown in Table 2. The VPA results showed that the effect of variation of initial F values (0.1 to 10) on the predicted catch is very small.

Table 2: Variation of the predicted catch in weight when different initial F values are used (F = 0.5 as the reference value), in *Otolithes ruber*, 2011-2012.

F	0.1	0.5	0.8	1.0	1.5	2.0	5.0	10.0
Predicted catch in weight	2277	2390	2391	2392	2393	2393	2393	2393
Variation (%)	-4.728	0	0.042	0.084	0.126	0.126	0.126	0.126

Stock number and biomass in age group

Population size estimates showed that the number of O. ruber on the Northwest area of the Persian Gulf increased from 17305(*103) in 2002-2003 to 60703(*103) in 2008-2009. The index then decreased to 29558(*103) during 2011-2012. The fluctuation of stock numbers was approximately similar in all the age groups. The maximum and minimum stock numbers were observed in age groups 1 and 6, respectively (Fig. 3). Stock biomass was 5,309 mt in 2002-2003 and it increased to 14,980 mt in 2008-2009 and then declined gradually to 7,302 mt in 2011-2012 (Fig. 4). The maximum and minimum biomasses were observed in age groups 2 and 1, respectively (Fig. 4).

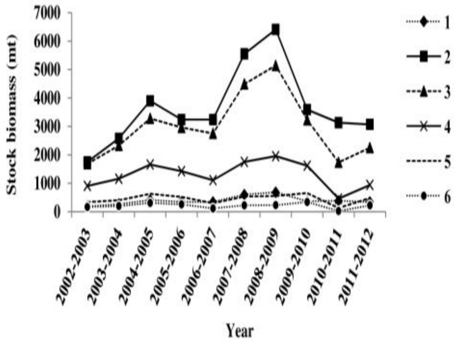

Figure 4: Stock biomass of *Otolithes ruber* in the NW area of the Persian Gulf (2002-2012).

Catch number and weight of age group

Catch number was ranged from a low number of 2,347(*103) in 2002-2003 compare to a high number of 10,966 (*103) in 2008-2009 (Fig. 5). Catch weight was ranged between 1295-5322 mt (Fig. 6). Age groups 2 and 3 is the most prevalent in the catch number and catch weight, respectively, and peaked in 2008-2009 (Figs. 5 and 6).

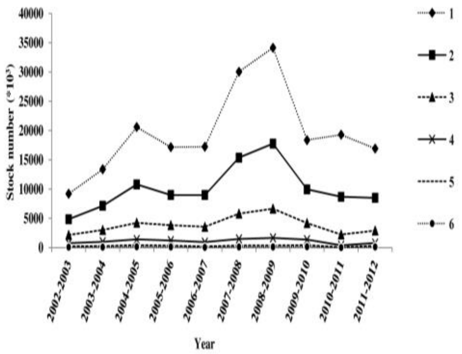

Figure 3: Stock number of *Otolithes ruber* in the NW area of the Persian Gulf. Each line represent one age-group (2002-2012).

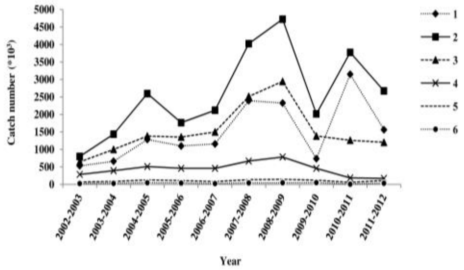

Figure 5: Catch number of *Otolithes ruber* in the NW area of the Persian Gulf. Each line represent one age-group (2002-2012).

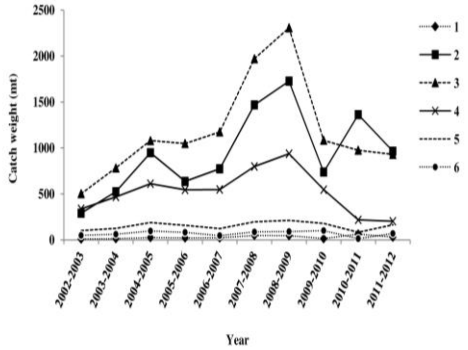

Figure 6: Catch weight of *Otolithes ruber* in the NW area of the Persian Gulf. Each line represent one age-group (2002-2012).

Average stock number and biomass, catch number and weight from 2002 to 2012

The minimum values for stock number, biomass and catch number were observed in age group 6 but the lowest catch weight was at age group 1. Their maximum values were observed in age group 1, 2, 2 and 3 for stock number, biomass, catch number and catch weight respectively (Fig. 7).

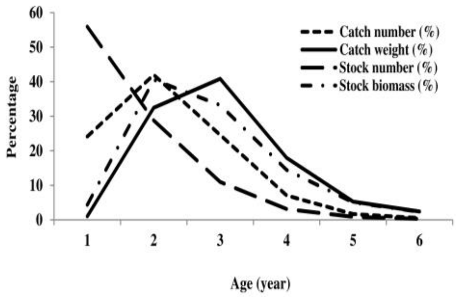

Figure 7: Average present stock number and biomass, catch number and weight of *Otolithes ruber* in the NW area of the Persian Gulf from 2002 to 2012.

Stock and catch number, biomass and catch weight during 2011-2012

The stock and catch number was calculated 29558(*103) and 5756(*103) specimens respectively. The stock biomass and catch weight was calculated 7302 and 2364 mt, respectively in 2011-2012. The maximum and minimum stock number was observed in age group 1 and 6 respectively. The maximum and minimum catch number was observed in the age group 2 and 6 respectively (Fig. 8). The maximum and minimum of stock biomass was observed in age group 2 and 6, respectively. The maximum and minimum catch weight was observed in the age group 2 and 1 respectively (Fig. 9).

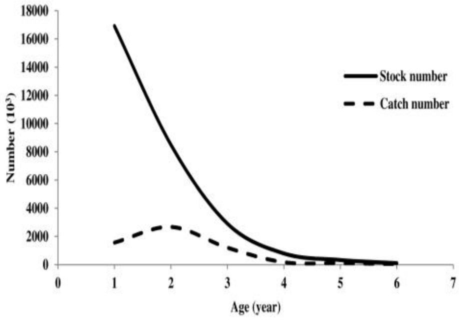

Figure 8: Stock and catch number of *Otolithes ruber* in the NW area of the Persian Gulf (2011-2012).

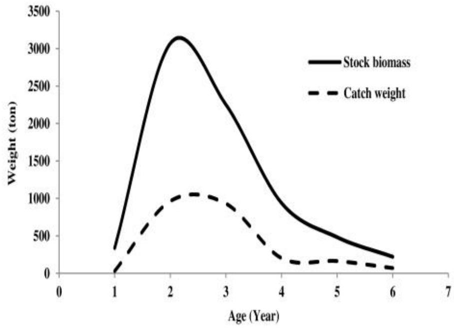

Figure 9: Stock biomass and catch weight of *Otolithes ruber* in the NW area of the Persian Gulf (2011-2012).

Fishing mortality in age group

From 2002 to 2012, estimates of fishing mortality rates (F) for ages 1-6 were variable, fluctuating around an average F of 0.53 per year. In 2010-2011 the fishing mortality rate in age group 6 abruptly increased to 1.06 per year and recent estimates of F for 2011-2012 were 0.52 per year (Fig. 10).

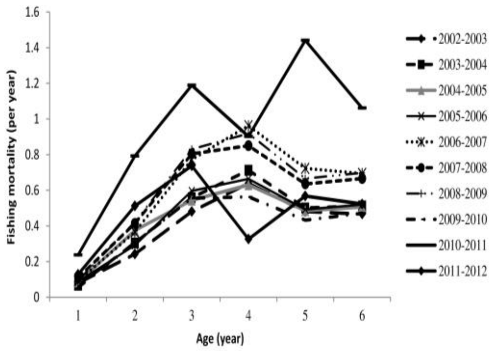

Figure 10: Fishing mortality of *Otolithes ruber* in the NW area of the Persian Gulf (2002-2012).

The average fishing mortality rates were low in age group 1 from 2002 to 2012. The highest fishing mortality measured at age group 4. Fishing mortality in older age groups (5 and 6) was on a decreasing trend (Fig. 11).

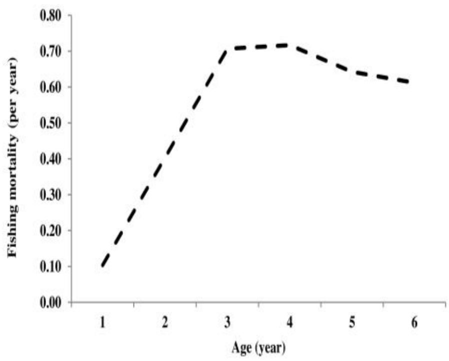

Figure 11: Average fishing mortality of *Otolithes ruber* in the NW area of the Persian Gulf in 2002 to 2012.

Discussion

Virtual population analysis is a standard method to estimate the abundance of fish stock. However, this method can be applied only if natural mortality, age composition and fishing mortality of the oldest fish were known (Liu *et al*., 2006) and it is a standard method to estimate fishing mortality of fish stock. The representative of VPA results relies upon the initial estimation of terminal F; however, it is less sensitive if back calculation is chosen as the estimation procedure (Chang and Liu, 2009).For calculating effect of initial Fishing mortality on the model, catch weight at different initial F was calculated and the percentage difference between the measured weight at Fishing mortality equal to 0.5 with the other values were determined (Table 2). Slight difference in percentage of catch weight showed that the mortality rate had no effect on the model. Therefore, although the estimations are also sensitive to M, catch at age estimations and migration, VPA is still fairly robust for analyzing the historical change of the F (Chang and Liu, 2009).

The reconstruction results of the population using virtual population analysis showed that population of *O. ruber* in the last ten years had almost large fluctuation. The highest stock number, biomass and catch were observed in 2007-2008 and 2008-2009 (Figs. 3, 4, 5 and 6). It appears that strong age class has been formed in 2004-2005 that had greatly affected the next years and increased the catch. Probably climate and river input had an important role in forming strong age classes. The maximum of stock number (Fig. 3), biomass (Fig. 4), catch number (Fig. 5) and catch weight (Fig. 6) occurred at early age classes. Moreover, the age class 1 consist 24% of catch number and 1% of catch weight, and the age class 2 consist 42% of catch number and 32% of catch weight (Fig. 7). Therefore using larger mesh size can provide more opportunity for earlier age classes to grow, which consequently can increase catch. The trends of age classes in 2011-2012 were similar to the last years but the age class 2 had more weight proportion. It was showed had been proved that the increasing trend of bottom trawl net caused the decreasing stock of larger age classes.

Fishing operations have the most significant anthropogenic impact on the marine environment (Blindheim and Skjoldal, 1993). The impact of fishing on bottom sediments and thus also on the benthic fauna is mainly caused by dragged gear like beam trawls and demersal trawls. The use of bottom trawls in the fishery for demersal fish, shellfish and shrimps can cause destruction at the seabed and in the benthic epi- and infauna communities (Klungsoyr *et al*., 1995). Bycatch of non-target species and undersized fish takes place. Most of this bycatch is discarded at sea and enters the food chain via sea birds, fish and benthic organisms. Net bursts of purse seines as well as trawls and seines can cause accumulation of large quantities of dead fish on the bottom in a restricted area (Klungsoyr *et al*., 1995). In Northwest area of the Persian Gulf illegal trawl fishing take place in all seasons. Trawl fishing have severe impact on frequency of crustacean which is main food of young *O. ruber*. Therefore, illegal trawl fishing can lead to stock and catch decline.

Beside man-made influences such as fishing activity, it is apparent that apparently the climate, salinity and temperature have a significant effects on the population responses in terms of recruitment and adult stock fluctuations. However, it is notable that, while the fishing activity affects recruitment immediately (through fishing of juveniles), all environmental effects appear to have substantial lag periods of from 3 to 5 years (Gröger *et al*., 2007). Favorable climate conditions during reproduction and early life may produce larger cohorts with larger individuals, which in turn may survive at a higher rate (Ottersen *et al*., 2010). Increasing trends of *O. ruber* abundance in 2007-2008 and 2008-2009 can be due to climate conditions in the last years and this likely resulted in strong age classes. In addition, high oil activities including drilling, loading and transportation in Northwest area of the Persian Gulf can have possible impact on earlier life stages of fish stocks. More researches need to be performed on this field to understand the effects of oiling activities on fish stocks.

The maximum fishing mortality coefficient of *O. ruber* was in age groups 4 and the minimum was in age groups 1 (Figs. 10, 11). Fishing mortalities in age group 1 and 2 were lower than 0.5 in most years, but age group 3, 4, 5 and 6 had larger fishing mortality. With regard to total mortality, age group 3, 4, 5 and 6 are subjected to over-exploitation. In addition, ten years average of fishing mortality indicated over-exploitation of these age groups. Therefore, reductions in fishing pressure can provide more opportunities for earlier age groups and decrease the pressure on larger fish. Implementing management policies such as increasing mesh size of trawl nets and determining the proper time for closing season considering spawning season can preserve spawning stock and optimize sustainable yields. The yearly fishing mortality fluctuated between 0.4 and 0.94 (Fig. 10). Notably, the increases in fishing mortality were significant 2009-2010 while the estimated population number peaked from 2007-2008 to 2008-2009.

This staggering phenomenon was introduced in walleye Pollack fishery in Funka Bay as the phase of development of "uncontrolled" fisheries (Ueda *et al*., 2001). Though the tiger tooth croaker fishery in Khuzestan coastal water is "uncontrolled", the staggering phenomenon may occur.

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