Age, Growth and Mortality Rate of the Narrow-Barred Spanish Mackerel (*Scomberomerus commerson* Lacepède, 1800) in Coastal Waters of Iran from Length Frequency Data

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Received 23 December 2006
Accepted 19 June 2007

Abstract

Monthly data of length composition for narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepède), landed between April 2003 to March 2005 along the Persian Gulf and Oman Sea were used to estimate the growth, mortality and exploitation parameters of the stock. Maximum fork length and weight were 132 cm and 18.4 kg respectively. Nonlinear least square fitting provided a complete set of von Bertalanffy growth estimates: L_∞=140 cm fork length; K=0.42 and t_0= -0.26 years. The estimated value of total mortality based on length converted catch curve using these growth parameters is Z=1.47 $year^{-1}$. Natural mortality based on growth parameters and mean environmental temperature (T=26.5ºC) is M=0.49 $year^{-1}$. Furthermore, the annual instantaneous fishing mortality rate of 0.98 $year^{-1}$ was by far in excess of the precautionary target (F_{opt}=0.49 $year^{-1}$) and limit (F_{limit}=0.65 $year^{-1}$) biological reference points, indicating that the resource was heavily over-exploited, and that management of this species should have been implanted rapidly if they were to remain sustainable.

Key words: *Scomberomorus commerson,* Growth, Mortality, Overexploitation, Iran.

Introduction

The narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepède, 1800) is an epipelagic species found throughout the coastal tropical waters of the Indo-Pacific from the Red Sea and South Africa to Southeast Asia, North to China, Japan, and south to Australia (Randal, 1995).

Along the 4 Iranian coastal provinces, including (from east to west) Sistan and Baluchestan, Hormozgan, Bushehr and Khozestan, it was catched by local traditional and artisanal fishers who used different fishing methods and gears; mostly pelagic gillnets (>95%), hook and lines and long lines. Vessels used for this activity are small outdoor boats for the inshore fishing and also wooden larger vessels for offshore fishing. Consequently, there were no restrictions on the numbers of size of *S. commerson* landed by traditional Iranian fishermen.

The total annual catch of kingfish in Iran has been about 8,000 metric tones in 2004, which is more than about twice comparing to year of 1997 with a total catch of about 4,000 metric tones.

Although several long-term studies have been carried out to evaluate its stock dynamics of Oman (Al-Hosni and Siddeek, 1999; Claerboadt *et al.*, 2005), South Africa (Govender, 1994) and Australia (Mc-Pherson, 1992; Welch *et al.*, 2002) there have been few studies of the dynamics of king fish of Iran (Taghavi *et al.,* 2005).

The objectives of this study are therefore to answer some of the questions pertaining to growth, mortality and exploitation rate of *S. commerson* in Iranian waters.

Materials and Methods

In total, 14968 fish were collected from April 2003 to March 2005 from the Persian Gulf and Oman Sea, south coast of Iran (Table 1). Fish were selected regularly and directly from artisanal fishermen at several landing sites in each of four regions of Iran- Jask, Salakh, Kong and Gavbandi (Figure 1). Fork length (FL) was taken to the nearest cm for all fish and total weight (TW) of individual fish to the nearest 0.01 kg was measured wherever possible.

The relationship between length (FL) and weight (TW) was estimated using linear regression analysis. To linearalize the power curve ($W = aL^b$) that best described this relationship, both variables were transformed using lnx. The line of best fit for the linear relationship was described by Pauly (1983):

$$\ln TW= \ln a + b \ln FL.$$

The length frequency data were pooled into groups with 3 cm length intervals.

Growth was investigated by fitting the von Bertalanffy growth function to length frequency data. The von Bertalanffy growth equation is defined as follows (Sparre and Venema, 1998):

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

Table 1. Length frequency data for *S. commerson* collected monthly from April 2003 through March 2005

	2003	→								2004	→	
Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Length (cm)												
55-57									3			
58-60									34			
61-63									45	3		
64-66				24					22	23		
67-69				42	6			18	1	30	1	
70-72	7	42		46	50	46		20	3		4	22
73-75	55	50	13	39	54	61	56	43	12	51	20	39
76-78	69	50	35	46	58	55	90	48	21	23	42	59
79-81	59	47	41	56	69	47	103	79	50	39	72	58
82-84	51	46	46	61	72	49	106	109	69	58	63	57
85-87	52	55	58	51	71	54	98	117	72	45	78	79
88-90	78	62	51	62	45	45	104	134	71	122	69	65
91-93	65	62	49	57	54	56	91	169	68	113	87	67
94-96	54	62	44	63	52	39	112	162	69	121	90	56
97-99	58	68	49	61	43	41	92	72	55	68	54	54
100-102	30	16	14	28	8	10	53	11	9	60	1	
103-105		21		3			47	4		37	18	28
106-108							22			19		
109-111							15	10		3	4	3
112-114										9	3	
115-117							12			6		
118-120							10	5		6		
121-123											3	
124-126											2	
127-129												
130-132												
Total	578	581	400	639	582	503	1011	1001	604	836	611	587

	2004	→								2005	→	
Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Length (cm)												
55-57												
58-60												2
61-63							2			2		9
64-66							5	4		7		23
67-69	2				1		6	12	9	14	1	41
70-72	12	3	5	1	16		9	22	38	26	21	45
73-75	29	49	19	7	54	6	24	33	46	59	37	47
76-78	60	69	48	18	57	14	24	63	57	50	66	54
79-81	61	90	62	22	55	25	35	77	64	57	60	59
82-84	36	102	71	22	56	34	54	85	56	64	76	47
85-87	62	96	92	20	49	49	158	73	56	63	65	38
88-90	71	99	78	17	61	31	194	64	47	62	58	36
91-93	64	113	78	31	56	36	189	52	54	52	53	50
94-96	58	89	70	27	45	30	179	42	41	30	34	34
97-99	30	48	46	14	23	23	219	32	34	14	23	25
100-102	5	2	2		2	1	121	2	1	2	1	3
103-105			3	3		7	96					5
106-108	21			2			166					4
109-111	5			5			6					5
112-114						1			7			5
115-117	1	3							10			8
118-120	3	2					60		13			15
121-123	1								5			10
124-126												11
127-129												13
130-132									12			10
Total	521	765	574	189	475	257	1547	561	550	502	495	599

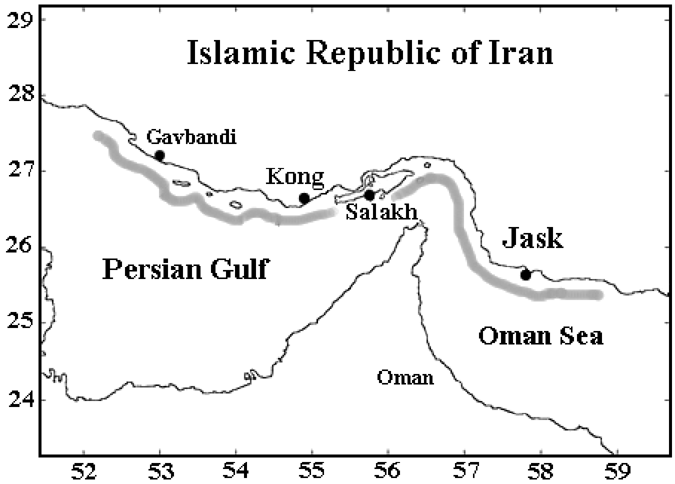

Figure 1. Location of four landing areas where *S. commerson* were sampled.

Where L_t 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 response surface analysis routine from the FISAT program provided estimates of L_∞ and K.

t_0 was estimated by employing the equation of Pauly (1980):

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K$$

And φ′ was calculated using the following formula (Pauly and Munro, 1984):

$$\varphi' = \log K + 2 \log L_\infty$$

The total mortality rate (Z) was estimated by using length converted catch curve analysis. Natural mortality (M) was calculated using the equation of Pauly (1980) which incorporates water temperature and the VBGF growth parameters L_∞ and K. The annual mean water temperature for the study was 26.5 ºC. The instantaneous fishing mortality (F) was taken as the difference between total and natural mortality: F=Z-M.

The exploitation ratio (E) is equal to the fraction of death caused by fishing. Maximum constant yield (MCY) is defined as “the maximum constant catch that is estimated to be sustainable” (New Zealand Ministry of Fisheries, 2002). MCY represents the average catch that can be taken from a stock taking into account the natural variability inherent in the particular stock. MCY is calculated by the the equation, $MCY=cY_{av}$ where c is the natural variability factor related to natural mortality (Table 2) and Y_{av} is the average catch across the appropriate time series.

Resource status was evaluated by comparing estimates of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points (BRP) which were defined as: F_{opt}=0.5M and F_{limit}=2/3M (Patterson, 1992).

Table 2. Guide to the relationship between natural mortality, M, and natural variability factor, c (New Zealand Ministry of Fisheries, 2002)

M	c
<0.05	1
0.05-0.15	0.9
0.16-0.25	0.8
0.26-0.35	0.7
>0.35	0.6

Results

The linear regression analysis of the length-weight data allowed the estimation of the constants, a and b of the length–weight relationship represented by the equation $W= 0.0076 \text{ FL}^{2.9826}$ with a regression coefficient R^2= 0.93 (Figure 2).

As the study has allowed the estimation of several pairs of growth constant values, a mean value was sought by trying the Response Surface Analysis routine. The best fit given by method, L_∞=140 cm and K=0.42, is used in all the future analysis involved in this study.

The yearly growth curve of this species using the von Bertalanffy growth parameter and above parameters indicate that it attained 57.53 cm, 85.80 cm, 104.39 cm, 116.6 cm, 124.63 cm, 129.86 cm and 133.36 cm, respectively from I to VII years (Figure 3).

The value of t_0 was taken as –0.26 and φ′ was estimated from the growth parameters as 3.916.

The annual instantaneous rate of total mortality (Z) derived from length-frequency catch curve was 1.47 year^{-1} (Figure 4). The annual instantaneous rate of natural mortality (M) derived from the Pauly equation (1983) was estimated as 0.61. The value of 0.61 obtained with the use of the equation multiplied

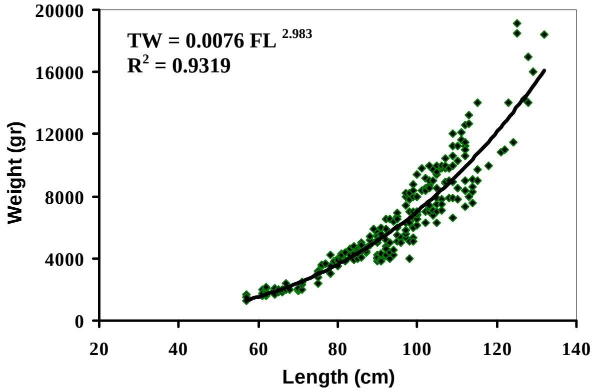

Figure 2. The length-weight relationship curve for *S. commerson*.

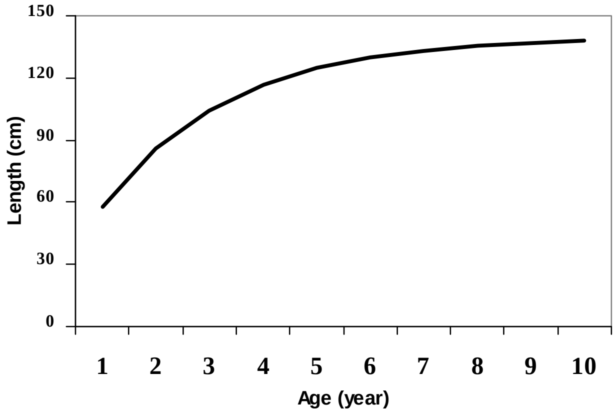

Figure 3. Growth curve of *S. commerson* (L_∞=140 cm, K=0.42, t_0= -0.26).

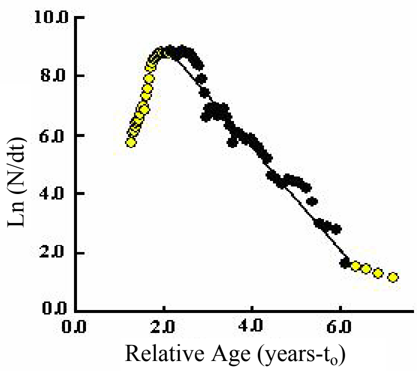

Figure 4. FISAT graphic output of the catch curve analysis.

by 0.8 as annual recommended by Pauly (1983) for pelagic species gave a coefficient value of M= 0.49. Annual instantaneous rate of fishing mortality was 0.98 year^{-1} and the exploitation rate (E) was 0.66. The annual instantaneous rate of fishing mortality (F= 0.98 year^{-1}) was considerably greater than the target (F_{opt}= 0.49) and limit (F_{limi}= 0.65) biological reference points, suggesting that the stock was heavily overexploited.

The estimate of MCY was calculated here using the more reliable time series of commercial catch data from 1997-2005. The resulted in an estimate of MCY for the south coast Spanish mackerel fishery of 1358.64 t.

M=0.49
c= 0.6 (see Table 1)
Y_{av} (1997-2005) = 2264.4t
MCY= 2264.4 * 0.6=1358.64t

Discussion

It was assumed for the analysis that sampling was randomly done despite the fact that the migration of pelagic fish stocks might have affected the representatives of the samples, and that bias could have been due to the introduction by the schooling behaviour of migratory species (Kedidi *et al*., 1993).

The length-weight relationship observed during the present study is given below:

$$W= 0.0076\ L^{2.9826}$$

The b parameter values in the weight-length model, $W= aL^b$ are close to 3 for the *S. commerson* in Area 51, indicating isometric growth (King, 1995) (Table 3). This is expected for fusiform fish. The reasons for the variation of b in the different regions are said to be due to seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions in the environment of fish (Biswas, 1993).

The values of L_∞ and K were calculated as 140 cm and 0.42 ($year^{-1}$). Our results also appeared to be of the right order in comparison with a range of published estimates of von Bertalanffy growth equation derived from length frequency (Table 4). For *S. commerson*, differences in growth rates between regions indicated stock separations (Devries and Grimes, 1997) which has, in some cases, supported a genetic difference (Begg and Sellin, 1998).

In general, the correlated parametric values adjust themselves to provide a similar growth pattern represented by φ′ (Sparre and Venema, 1998). Notably, the φ′ values estimated for Iranian south coast stock were comparable to those for other stocks of *S. commerson* in the western Indian Ocean (FAO area 51), suggesting a similar growth pattern across different population (Table 4).

Age at zero length (t_0) was calculated as -0.26. With negative t_0 values, juveniles grew more quickly than the predicted growth curve for adults, and with positive t_0 values, juveniles grew more slowly (King, 1995). Life history of *S. commerson* stocks in Oman Sea is comprised of two distinct phases. The first phase is distinguished by extremely rapid growth from the larva stage to 18 months of age (Claereboudt *et al*., 2005). The second phase can be described as the period when growth decelerated considerably. The start of the second phase coincides with the time at which kingfish reaches age at first reproduction (Claereboudt *et al*., 2005).

The data set for estimating Z by the length converted catch curve method should satisfy the primary assumption that the stock was is in equilibrium (Al-Hosni and Siddeek, 1999). In a declining stock, such as that of Iranian *S. commerson*, this assumption may have been violated because of a declining trend in recruitment tends to under estimate Z by roughly the some percentage of decline. Thus,

Table 3. Length- weight relationship of *S. commerson* in FAO Area 51

Area	Type of Measurement	a	b	References
South of Iran	FL	0.0076	2.9826	Present paper
Oman Sea	FL	0.01530	2.8335	Taghavi *et al*., 2007
Gulf of Aden, Yemen	FL	0.011	2.85	Edwards *et al*., 1985
Red Sea	TL	0.0012	2.812	Kedidi and Abushusha, 1987
Oman	FL	1.72×10^{-6}	3.31	Dudley *et al*., 1992
India	TL	0.0154	2.8138	Pillai *et al*., 1993
Saudi Arabia	TL	0.0056	2.979	Kedidi *et al*., 1993
Oman	FL	8.27×10^{-6}	3.02	Al-Hosni and Siddeek, 1999
India	TL	0.0096	2.857	Devaraj, 1981

Table 4. Summary of the growth parameters estimates of *S. commerson* in FAO Area 51

Area	L_∞(cm)	K(1/year)	t_0(year)	φ′	References
South of Iran	140 (FL)	0.42	-0.26	3.916	Present paper
Oman Sea	170 (FL)	0.28	-0.36	3.948	Taghavi *et al*., 2007
Southwest India	146 (TL)	0.78			Pillai *et al*., 1993
Saudi Arabia	183.6 (TL)	0.26		3.94	Kedidi *et al*., 1993
Oman	173.6 (FL)	0.28	-0.86	4.01	Al- Hosni and Siddeek, 1999
Oman	140.44 (FL-♂)	0.309	-1.501		McIlwain *et al*., 2004
	118.80 (FL-♀)	0.595	-0.730		
Oman	138.6 (FL)	0.21	-1.9		Grandcourt *et al*., 2005

the true values for F and E should have been higher than what we mentioned above. Total mortality values of 0.61 and 0.66 $year^{-1}$ were obtained by Govender (1995) for *S. commerson* in South Africa. Kedidi *et al*. (1993) estimated total mortality as 1.5 $year^{-1}$ for the commercial fisheries, respectively in Saudi Arabian coast. Al-Hosni and Siddeek (1999) established a total mortality rate as 1.21 to 1.8 $year^{-1}$ for *S. commerson* in Omani waters.

Reliable estimate of M can only be obtained for an unexploited stock (Al-Hosni and Siddeek, 1999). In this case, it is equal to Z. Separating M and F from Z in a heavily exploited stock was a difficult task. Excessive fishing and inappropriate effort data prevented the use of the total mortality effort relation to estimate M. Therefore, methods based on life history and environmental parameters were used (i.e. Pauly equation). Our estimate of the natural mortality rate (M= 0.49 $year^{-1}$) was considerably lower than the estimates of Pillai *et al*. (1993) who calculated as 0.78 $year^{-1}$. Dudley *et al*. (1992) estimated the natural mortality rate of *S. commerson* as 0.44 $year^{-1}$ in Oman Sea and McIlwain *et al*. (2005) estimated a rate of 0.38 and 0.49 for females and males for this species in the same region.

The fishing mortality rate of 0.98 $year^{-1}$ was substantially greater than both the target (F_{opt} = 0.49 $year^{-1}$) and limit (F_{limit} = 0.65 $year^{-1}$) biological reference points. These results are important to 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. Accordingly, the Iranian South king fish stock appears to have been overexploited during the whole study period (2003-2005).

MCY is calculated based only on commercial catch and any catch reductions would necessitate commensurate reductions in all sectors of the south-eastern coast fishery.

Conclusions

The results of this study have raised several questions that need to be answered before the implementation of a successful management strategy; for instance, where do kingfish migrate during its life cycle, and does their appearance correspond to spawning migration? More research and, if possible, international collaboration are needed to provide answers to these fundamental questions.

Acknowledgments

We thank the manager and experts of the Persian Gulf and Oman Sea Ecological Research Institute. We are also grateful to Reza Noori and Mokhtar Akhondy at the Iranian Fishery Organization, for helping the project work.

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