

Population dynamics of the Spanish mackerel (*Scomberomorus commerson*) in coastal waters of Oman Sea

Taghavi Motlagh, S.A.^{1*}; Seyfabadi, S.J.²; Ghodrati Shojaei,
M.³; Abtahi, B.² and Taheri Mirghaed A.⁴

s_taghvimotlagh@hotmail.com

- 1- Iranian Fisheries Research Organization, P.O.Box:14155-6116, Tehran, Iran
- 2- Marine Biology Department, Faculty of Marine Science, Tarbiat Modares University, P.O.Box: 46414-356 Noor, Iran
- 3- Persian Gulf and Oman Sea Ecological Research Center, P.O. Box: 1597 Bandar Abbas, Iran
- 4- Ministry of Science, Research and Technology, Tehran, Iran

Received: November 2006

Accepted: March 2008

Abstract: Length composition data of narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepède 1800), landed between April 2002 to March 2004, were monthly used to estimate the growth, mortality and exploitation parameters of the stock. Maximum fork length and weight were 170 cm and 38 kg, respectively. Nonlinear least square fitting provided a complete set of von Bertalanffy growth estimates: L_{∞} = 178 cm (FL); K =0.28 and t_0 = -0.36 years. The estimated value of total mortality based on length converted catch curve using these growth parameters is Z =0.95 year⁻¹. Natural mortality based on growth parameters and mean environmental temperature (T =26.5°C) is M =0.36 year⁻¹. Furthermore, the annual instantaneous fishing mortality rate of 0.59 year⁻¹ was by far in excess of the precautionary target (F_{opt} =0.18 year⁻¹) and limit (F_{limit} =0.24 year⁻¹) biological reference points, indicating that the resource is heavily over-exploited and the management of this species should be implanted rapidly if they are to remain sustainable.

Keywords: *Scomberomorus commerson*, Population dynamics, Oman Sea, Iran

* Corresponding author

Introduction

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 (Randall, 1995).

Spanish mackerel is fished along the 4 Iranian coastal provinces, including (from east to west) Sistan-Baluchestan, Hormuzgan, Bushehr and Khuzestan by local fishers who use different fishing methods and gears (mostly pelagic gillnets), hook and lines and trolling. Vessels used are small outboard boats for the inshore fishing and also wooden larger vessels for offshore fishing. Consequently, there are no restrictions on the numbers and size of *S. commerson* landed by traditional Iranian fishermen.

The total annual catch of this fish was about 8000 metric tonnes in 2004, which is almost twice that of the year 1997 with a total catch of about 4000 metric tonnes (Anon, 2005).

Several long term studies have been carried out to evaluate its stock dynamics off Oman (Al Hosni & Siddeek, 1999; Claereboudt *et al.*, 2005), South Africa (Govender, 1994) and Australia (McPherson, 1992; Welch *et al.*, 2002). Although population dynamics of some species of fish have been studied in Iran (e.g. Fazli *et al.*, 2007), dynamics of Iranian king fish is poorly known (Hosseini *et al.*, 2003; Shojaei *et al.*, 2007).

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

Materials and methods

In total, 7056 fish were collected from April 2002 to March 2005 from the Oman Sea. Fish samples were randomly selected from fishermen directly at several landing sites in each of four regions along the Oman Sea, i.e. Beris, Ramin, Pozm and Jask (Fig. 1). Most of the catches were taken by gillnets. Fork length was taken to the nearest cm for all fishes and total weight (TW) of individual fishes to the nearest 0.01kg was measured wherever possible.

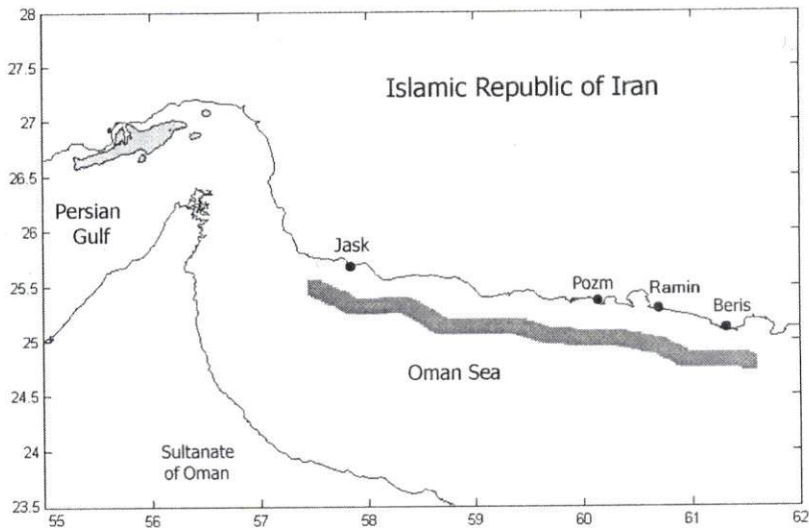


Figure 1: Location of four landing areas to collect *S. commerson* samples

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

$$\text{Ln TW} = \text{Lna} + b\text{LnFL}$$

If the calculated number for b does not have a significant difference with 3, the species has isometric growth. To test this difference, we used the below equation (Pauly, 1984):

$$t = \frac{[(s.dx)/(s.dy)] * [(|b-3|) / (\sqrt{(1-r^2)})]}{[\sqrt{(n-2)}]}$$

The length frequency data were pooled into groups with 1cm length intervals. Growth was investigated by fitting the von Bertalanffy growth function to length frequency data. The von Bertalanffy growth function is defined as follows (von Bertalanffy, 1934 Cited in Sparre & Venema, 1998):

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

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 formulae (Pauly & Munro, 1984):

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

Preliminary analyses suggest that the C.V. of ϕ' for several stocks of the same species should not exceed 5 percent, which may provide some guideline as to which values of ϕ' are credible or not (Gayanilo & Pauly, 1997).

$$\text{C.V.} = \text{s.d./mean}$$

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 sea surface water temperature and the VBGF growth parameters L_∞ and K . The mean annual water temperature for the Oman Sea is 26.5°C. 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 following equation $MCY=cY_{av}$ where c is the natural variability factor related to natural mortality (Table 1) and Y_{av} is the average catch across the appropriate time series (Table 2).

Table 1: 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

Table 2: Nominal catch (tones) of *S. commerson* in the study area

Years	1997	1998	1999	2000	2001	2002	2003	2004
Catch (tones)	751	915	1145	659	780	1501	1444	1876

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

The Jones method, also known as virtual population analysis (VPA) was applied for the length cohort analysis. This uses as inputs the length frequencies of the catches, the growth constants and a terminal arbitrary fishing mortality coefficient supposed to prevail in the fishery and chosen as $F=0.5$ (Sparre & Venema, 1998).

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 $W = 0.0153 FL^{2.8335}$ with a regression coefficient $r^2 = 0.97$ (Fig. 2).

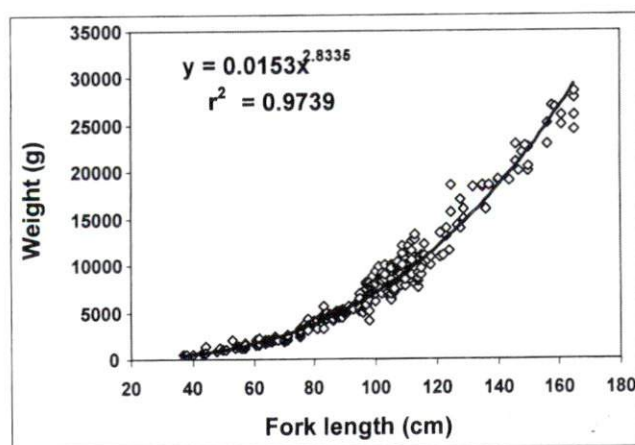


Figure 2: The length-weight relationship curve for *S. commerson* in the Oman Sea

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_{∞} 178 cm and $K=0.28$, are 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 indicated that it attained 56.96, 85.44, 108.58, 126.38, 138.84, 149.52 and 156.64 cm, respectively, from I to VII years.

The value of t_0 has been taken as -0.36 and the ϕ' was estimated from the growth parameters as 3.948 (The C.V. of ϕ' calculated as 1.01%)

The annual instantaneous rate of total mortality (Z) derived from length-frequency catch curve was 0.95 year^{-1} (Fig. 3). The annual instantaneous rate of natural mortality (M) derived from the Pauly (1983) equation was estimated as 0.45 year^{-1} . The value of 0.45 obtained with the use of the equation multiplied by 0.8 as annual recommended by Pauly (1983) for pelagic species gave a coefficient value of $M=0.36 \text{ year}^{-1}$. Annual instantaneous rate of fishing mortality was 0.59 year^{-1} and the exploitation rate (E) was 0.62. The annual instantaneous rate of fishing mortality ($F=0.59 \text{ year}^{-1}$) was considerably greater than the target ($F_{\text{opt}}=0.18$) and limit ($F_{\text{limi}}=0.24$) biological reference points, suggesting that the stock is heavily overexploited.

The estimate of MCY was calculated here using the more reliable time series of commercial catch data from 1997-2004, which resulted in an estimate of MCY for the Oman Sea Coast Spanish mackerel fishery of 680.32 t.

The VPA analysis gave a mean fishing mortality estimate as $F=0.46$. It also showed three peaks in the different estimates, 0.86, 0.74 and 0.72, respectively, corresponding to the lengths 99, 105 and 147 cm (Fig. 4). Tables 3 and 4 show some estimates of a and b in length-weight relationship and growth parameters of *S. commerson* in FAO area 51 (Western Indian Ocean).

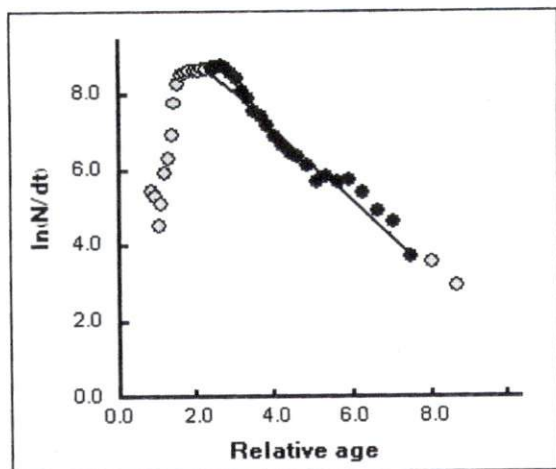


Figure 3: FISAT graphic output of the catch curve analysis for *S. Commerson*

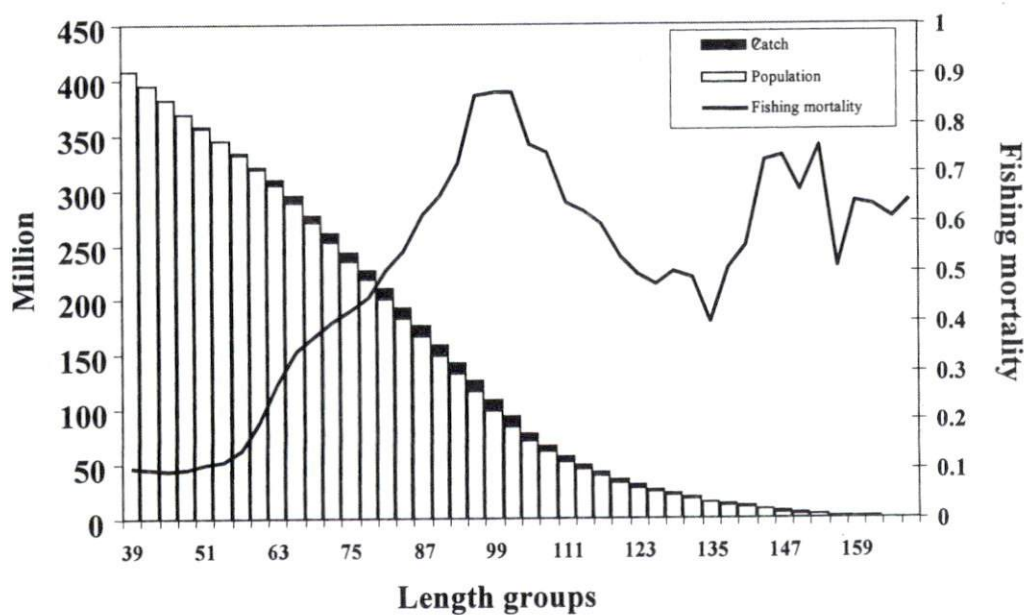


Figure 4: Length-structured virtual population analysis of *S. commerson* in the Oman Sea

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

Area	Type of Measurement	a	b	References
Oman Sea	FL	0.0153	2.8335	Present study
Persian Gulf and Oman Sea (Strait of Hormuz)	FL	0.0076	2.9826	Shojaei <i>et al.</i> , 2007
Gulf of Aden, Yemen	FL	0.011	2.85	Edwards <i>et al.</i> , 1985
Southern Saudi Red Sea coast, Oman	TL	0.0012	2.812	Kedidi & Abushusha, 1987
Oman Sea and Arabian Sea coasts	FL	1.72×10^{-6}	3.31	Dudley <i>et al.</i> , 1992
South west coast of India	TL	0.0154	2.8138	Pillai <i>et al.</i> , 1993
Persian Gulf, Saudi Arabia coasts	TL	0.0056	2.979	Kedidi <i>et al.</i> , 1993
Oman Sea and Arabian Sea coasts, Oman	FL	8.27×10^{-6}	3.02	Al-Hosni & Siddeek, 1999

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
Oman Sea	178 (FL)	0.28	-0.36	3.948	Present study
Persian Gulf and Oman Sea (Strait of Hormuz)	140 (FL)	0.42	-0.26	3.916	Shojaei <i>et al.</i> , 2007
Oman Sea (Sistan and Baluchestan Province)	186 (FL)	0.26	-0.17	-----	Hosseini <i>et al.</i> , 2003
South-west coast of India	146 (TL)	0.78	-----	-----	Pillai <i>et al.</i> , 1993
Persian Gulf, Saudi Arabia coasts	183.6 (TL)	0.26	-----	3.94	Kedidi <i>et al.</i> , 1993
Oman Sea and Arabian Sea coasts, Oman	173.6 (FL)	0.28	-0.86	4.01	Al Hosni & Siddeek, 1999
Oman Sea and Arabian Sea coasts, Oman	140.44 (FL-♂)	0.309	-1.501	-----	McIlwain <i>et al.</i> , 2004
	118.80 (FL-♀)	0.595	-0.730	-----	
		-----	-----	-----	
Oman Sea and Arabian Sea coasts, Oman	138.6 (FL)	0.21	-1.9	-----	Grandcourt <i>et al.</i> , 2005

Discussion

It has been assumed for the analysis that sampling was random despite the fact that the migration of pelagic fish stocks might affect the representatives of the samples and that bias could be introduced by the schooling behavior of migratory species (Kedidi *et al.*, 1993).

The length weight relationship observed during the present study is given below $W = 0.0153 L^{2.8335}$. The calculated number for b has not significant differences with 3. 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 of the environmental of the fishes (Biswas, 1993).

The values of L_{∞} and K were calculated as 178 cm and 0.28 (year^{-1}). Our results also appear to be of the right order by comparison with a range of published estimates of von Bertalanffy growth function parameter derived from length frequency (Table 4).

In general, the correlated parametric values adjust themselves to provide a similar growth pattern represented by ϕ' (Sparre & Venema, 1998). Notably, the ϕ' values estimated for Oman Sea 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). (ϕ' for several stocks of the *S. commerson* was not exceed 5 percent).

Age at zero length, t_0 , calculated as -0.36. With negative t_0 values, juveniles grow more quickly than the predicted growth curve for adults; with positive t_0 values, juveniles grow more slowly (King, 1995). Life history of *S. commerson* stocks in the Oman Sea is comprised of two distinct phases. The first phase is distinguished by extremely rapid growth from the larval stage to 18 months of age. The second phase can be described as the period when growth slows considerably. The start of the second phase coincides with the time at which kingfish reach 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 in equilibrium (Al Hosni & Siddeek., 1999). In a declining stock, such as that of Oman Sea narrow-barred Spanish mackerel stock, this assumption may have been violated because of a declining trend in recruitment trends to underestimate Z by roughly the same percentage of declines. Thus, the true values for F and E should be higher than what were mentioned above. Total mortality values of 0.61 and 0.66 year⁻¹ were obtained by Govender (1994) for *S. commerson* in South Africa. Kedidi *et al.* (1993) estimated total mortality as 1.5 year⁻¹ for the commercial fisheries in Saudi Arabian coast. Al Hosni and Siddeek (1999) established a total mortality rate as 1.2 to 1.8 year⁻¹ for *S. commerson* in the Omani waters.

Reliable estimate of M can only be obtained for an unexploited stock (Al Hosni & Siddeek, 1999). In this case, it is equal to Z . Separating M and F from Z in a heavily exploited stock is 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 ($M=0.36$ year⁻¹) was considerably lower than the 0.78 year⁻¹ estimated by Pillai *et al.* (1993). 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, respectively, for this species in the same region.

The fishing mortality rate of 0.59 year⁻¹ was substantially greater than both the target ($F_{opt}=0.18$ year⁻¹) and limit ($F_{limit}=0.24$ year⁻¹) biological reference points. These results are important to fisheries management authorities as they suggest that the resource is 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, he suggested that E should be maintained at 0.4 for optimal exploitation of that stock. Accordingly, the

king fish stock appears to have been overexploited during the whole study period (2002-2005).

MCY is calculated only based on commercial catch and any catch reductions would necessitate commensurate reductions in all sectors of the Iranian coasts of the Oman Sea fishery.

The results of this study suggest that kingfish stocks are under intense pressure and that management of this species should be implemented rapidly if they are to remain sustainable.

Acknowledgments

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

References

- Al-Hosni, A.H. and Siddeek, S.M., 1999. Growth and mortality of the narrow barred Spanish mackerel, *Scomberomorus commerson* (Lacepede), in Omani waters. Fisheries Management and Ecology, 6:145-160.
- Anon., 2005. Indian Ocean tuna fisheries data summery, 1993-2002. IOTC data summery, No. 24, 110P.
- Biswas, S.P., 1993. Manual of methods in fish biology. South Asia publishers. Pvt. Ltd, New Delhi, India. 61P.
- Claereboudt, M.R., McIlwain, J.L., Al Onfi, H.S. and Ambu-Ali, A.A., 2005. Patterns of reproduction and spawning of the kingfish (*Scomberomorus commerson* Lac'ep'ede 1800) in the coastal waters of the Sultanate of Oman. Fisheries Research, 73:73-282.
- Dudley, R.G., Aghanashinikar, A.P. and Brothers, E.B., 1992. Management of the Indo Pacific Spanish mackerel (*Scomberomorus commerson*) in Oman. Fisheries Research, 15:17-43.

- Edwards, R.R.C., Bakhader, A. and Shafer, S., 1985.** Growth, mortality, age composition and fishery yields of fish from the Gulf of Aden. *Journal of Fish Biology*, **27**:13-21.
- Fazli, H., Zhang, C.I., Hay, D.E., Lee, C.W., Janbaz, A.A. and Bourani, M.S., 2007.** Population dynamics and stock assessment of common kilka (*Clupeonella cultiventris caspia*) in Iranian waters of the Caspian Sea. *Iranian Journal of Fisheries Sciences*, **7(1)**:47-70.
- FAO, 1989.** Review of large pelagic resources in the Arabian Sea and Gulf areas. IOFC: DMG/89/inf. May 1989.
- Gayanilo, F.C. and Pauly, D., 1997.** FAO-ICLARM stock assessment tools, Reference manual. FAO, pp: 101-102.
- Govender, A., 1994.** Growth of king mackerel (*Scomberomorus commerson*) off the coast of Natal, South Africa from length and age data. *Fisheries Research*, **20**:63-79.
- Grandcourt, E.M., Al Abdessalaam, T.Z., Francis, F. and Al Shamsi, A.T., 2005.** Priliminary assessment of biology and fishery for the narrow-barred Spanish mackerel, *Scomberomorus commerson*, in the southern Persian Gulf. *Fisheries Research*, **76**:277-290.
- Hosseini, S.A., Daryanavard, G. and Kaymaram, F., 2003.** [Survey on the status of narrow-barred Spanish mackerel (*Scomberomorus commerson*) and Indo-Pacific king mackerel (*Scomberomorus guttatus*) stock using length-frequency data in Sistan and Baluchestan Province]. Iranian Fisheries Research Organization, 98P. (in Persian)
- Kedidi, S.M. and Abushusha, T.L. , 1987.** Stock assessment of the 'derak' *Scomberomorus commerson* caught off the southern Saudi Red Sea coast. *Saudi Fisheries Research*, Vol. 3, 36P.
- Kedidi, S.M., Fita N.I. and Abdulhadi, A., 1993.** Population dynamics of the king seerfish, *Scomberomorus commerson*, along the Saudi Arabian Gulf Coast, IPTP collective Volumes, NO. 8, pp.76-87.
- King, M., 1995.** Fisheries biology, assessment and management. Fishing News Book. 342P.
- McIlwain, J.L., Claereboudt, M.R., Al-Oufi, H.S. and Goddard, J.S., 2004.** Spatial pattern in age and growth of the king fish, *Scomberomorus commerson*, from coastal waters in the Sultanate of Oman. *Fisheries Research*, **73**:283-298.

- McPherson, G.R., 1992.** Age and growth of the narrow-barred Spanish mackerel (*Scomberomorus commerson* Lac'ep'ede 1800) in north-eastern Queensland Waters. Australian Journal of Marine and Freshwater Research, **43**:1269–1282.
- New Zealand Ministry of Fisheries. 2002.** <http://www.fish.govt.nz/sustainability/research/stock/1999-2000/guide>.
- Patterson, K., 1992.** Fisheries for small pelagic species: An empirical approach to management targets. Reviews in Fish Biology and Fisheries, **2(4)**:321-338.
- Pauly, D., 1980.** On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal Du Conseil International Pour L'Exploration De La Mer, **39(2)**:175-192.
- Pauly, D., 1983.** Some simple methods for the assessment of tropical fish stocks. FAO. Fisheries Technical Paper, 55P.
- Pauly, D., 1984.** Fish population dynamics in tropical waters: a manual for use with programmable calculators, ICLARM, 313P.
- Pauly D., and Munro J.I., 1984.** Once more on the comparisons of growth in fish and invertebrates, Fish byte, 21P.
- Pillai P.P., Pillai, N.G.K., Sathianandan, T.V. and Kesavan Elayathu, M.N., 1993.** Fishery biology and stock assessment of *Scomberomorus commerson*, from the south-west coast of India. IPTP Collective Volumes, No. 8, pp.56-61.
- Randall, J.E., 1995.** Coastal fishes of Oman. Crawford House Publishing, Bathurst, Australia. pp.39-40.
- Sparre, P. and Venema, S.C., 1998.** Introduction to tropical fish stock assessment. FAO Fisheries Technical Paper, 450P.
- Shojaei Ghodrati, M., Taghavi Motlagh, S.A., Seyfabadi, S.J., Abtahi, B. and Dehghani, R., 2007.** Age, growth and mortality rate of the narrow-barred Spanish mackerel (*Scomberomorus commerson* Lacepede, 1800) in coastal waters of Iran from length frequency data. Turkish Journal of Fisheries and Aquatic Sciences, **7(2)**:115-121.
- Welch, D.J., Hoyle, S.D., McPherson, G.R. and Gribble, N.A., 2002.** Preliminary assessment of the Queensland east coast Spanish mackerel fishery. Information Series QI02110, Queensland Government, Department of Primary Industries, Cairns, 32P.