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Population dynamics parameters of narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacèpéde, 1800), from commercial catch in the northern Persian Gulf

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ABSTRACT

Population dynamics parameters of *Scomberomorus commerson* in Bushehr area waters of Iran were analyzed between October 2011 and September 2012. Fork length frequencies were collected from the gill net commercial catch. Von Bertalanffy growth function was used to estimate growth parameters K and L_∞. Instantaneous total mortality rate (Z), instantaneous natural mortality rate (M) and the instantaneous fishing mortality rate (F) were also calculated. Resource status was evaluated by comparing estimates of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points. FiSAT program was used to assess growth and mortality parameters. Based on the growth curve analysis, growth parameters were: $K = 0.5$ year^{-1} and $L_\infty = 148$ cm. Instantaneous total mortality was $Z = 0.97$ year^{-1}. The estimate of $M = 0.56$ year^{-1} and $F = 0.41$ year^{-1}, resulting in an exploitation rate (F/Z) of $E = 0.42$ year^{-1}. Target and limit biological reference points were: $F_{opt} = 0.28$ year^{-1} and $F_{limit} = 0.37$ year^{-1}. Size at capture at probabilities of 0.25 (L_{25}), 0.5 ($L_{0.5}$) and 0.75 ($L_{0.75}$), were 46.3 cm, 55 cm and 60.2 cm respectively. Longevity (T_{max}) was calculated as $3/K$ equal to 6 years. The exploitation rate (E) did not indicate overfishing; however, F_{opt} and F_{limit} rates were lower than fishing mortality (F), suggesting that overexploitation occurred. Growth parameters in the present study showed that the gillnet fishery catches of *S. commerson* that are of ages 1 or 2, which may not have reached maturity. Gillnet mesh size can be a factor why the catch is composed of mostly small, immature fish. Therefore, changes in mesh size and net size should be considered.

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1. Introduction

The narrow-barred Spanish mackerel *Scomberomorus commerson* is the most commercially important pelagic species in the northern Persian Gulf, where it inhabits shallow coastal waters less than 100 m deep and often associates itself with reefs and shoals (Collette and Nauen, 1983). Generally comprised of small schools, *S. commerson* undertake long-shore migrations, although permanent resident populations have also been reported (Collette, 2001).

S. commerson is most abundant in the northern Gulf from September to May where it is captured using 9 and 14 cm mesh gillnets and, to a lesser extent, with trolling gears. The 9 cm mesh is not used specifically to target *S. commerson*, but instead smaller *Scomberomorus guttatus* and *otolithes ruber*. In the southern Persian Gulf, *S. commerson* is mainly caught using encircling gillnets and trolling lines that are targeted by the recreational fishery (Grandcourt et al., 2005). In Oman, *S. commerson* is a target species of artisanal fishermen. A dramatic decrease of this species in landings over the past decade, exacerbated by a lack of regulations, has raised concerns about the sustainability of this fishery (Al-Hosni and Siddeek, 1999).

In the northern Persian Gulf although the fishery status of *S. commerson* has been an issue for some time, it has not been ascertained to date. Therefore, information on population dynamics and biology of this species is required for management purposes in this area.

The present study objectives were to use gillnets catch data from the northern Persian Gulf to: (i) estimate growth, mortality and longevity, and (ii) investigate yield-per-recruit analyses to provide a preliminary assessment of the stock status.

2. Materials and methods

Monthly sampling[5] at Bushehr landing sites was undertaken using various methods to obtain fish with the widest possible range of sizes. These included fish captured by commercial vessels using 9 and 14 cm mesh gillnets. A total of 2093 fish were randomly selected from six landing sites (Abadan, Bandar Ganaveh, Bandar Bushehr, Ameri port, Dayer and Kangan) encompassing the entire coastline of Bushehr and Khuzestan Provinces in the northern Persian Gulf (Fig. 1).

Fork length (FL) was recorded to the nearest cm and fish were grouped into 3 cm length intervals. Growth curves were estimated using ELEFAN1 in FiSAT program (Gayanilo et al., 1995) for combined sexes. It was assumed that *S. commerson* was a single stock and ignored spatial differences in growth. The von Bertalanffy growth function (VBGF) was used to estimate growth parameters L_∞ and K:

$$Lt = L_\infty[1 - e^{-K\,(t-t_0)}]$$

where: Lt is the fork length of the fish at age t, L_∞ the theoretical length at age infinity, K the intrinsic growth rate and t_0 is the theoretical age at length zero.

The annual natural mortality rate (M) was estimated using empirical equations (Pauly, 1980):

$$\ln M = 0.8 * \exp[-0.0152 - 0.279 * \ln L_\infty + 0.6543 * \ln K + 0.463 * \ln T]$$

where: K and L_∞ are derived from the VBGF and T is the annual mean water temperature estimated at 26 °C. The annual instantaneous rate of total mortality coefficient (Z) was estimated from age-based catch curves (Beverton and Holt, 1957). The instantaneous fishing mortality coefficient (F) was calculated as:

$$F = Z - M.$$

Fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points (BRP's) was estimated using the formula described by Patterson (1992), defined as:

$$F_{\text{opt}} = 0.5M$$
$$F_{\text{limit}} = 2/3M.$$

The exploitation rate (E) was estimated as the proportion of fishing mortality relative to total mortality ($E = F/Z$).

Backwards extrapolation of the descending limb was used to estimate probability of capture data. A selectivity curve was generated by fitting the logistic function to probability of capture and size data, which was used to derive values of the sizes at capture at probabilities of 0.25 (L_{25}), 0.5 (L_{50}) and 0.75 (L_{75}).

Longevity estimates ($T_{\max}$) were calculated by using the inverse of the VBGF (King, 2006).

$$T_{\max} = t_0 - (l/k)\ln[1 - (Li/L\infty)]$$

where: Li is arbitrarily considered equal to 99% of the asymptotic length.

$$T_{\max} = t_0 - (3/K).$$

[5] -In August due to opening of shrimp season in the studied area gill net fishery is closed and no samples were taken in this period.

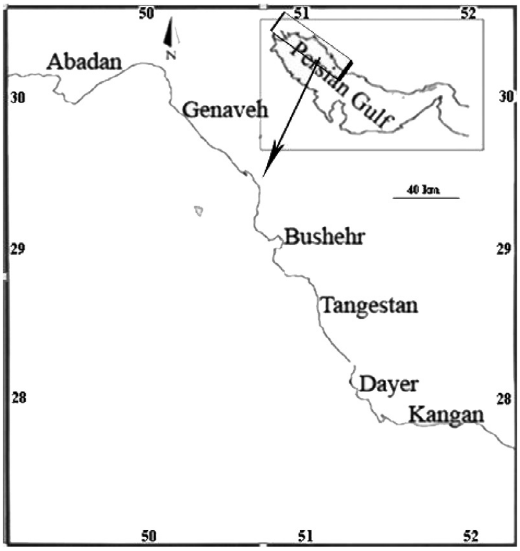

Fig. 1. Locations of the six regions where *S. commerson* were sampled.

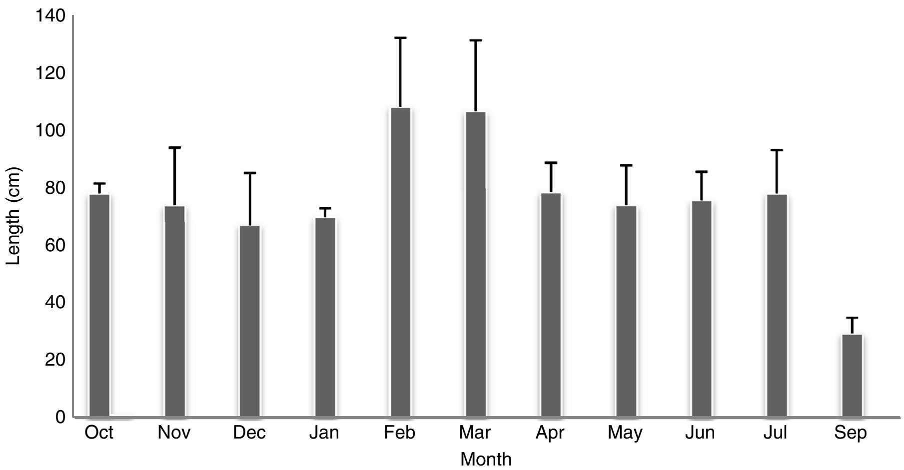

Fig. 2. Monthly length frequency (FL) of *S. commerson* in northern Persian Gulf (2011–2012).

3. Results

3.1. Growth

Fish ranged in size from 17 to 152 cm FL. The mean size of frequency ranged from 29.4 cm FL (SD = 5.5) in September to 108 cm FL (SD = 24) in February (Fig. 2).

Growth parameters L_∞ and K were obtained by VBGF in the ELEFAN1 program. The best estimates of $L_\infty = 148$ cm FL and $K = 0.5$ year^{-1} (Fig. 3).

3.2. Mortality

Using Pauly's (1980) empirical formula, a value of $M = 0.56$ year^{-1} was obtained for the instantaneous rate of natural mortality, with an average temperature of 26 °C.

A length-converted catch curve (Fig. 4) showed the growth parameters obtained by ELEFAN 1 ($L_\infty = 148$ cm and $K = 0.5$ year^{-1}), and allowed the calculation of the instantaneous total mortality at $Z = 0.97$ $(0.6 - 1.33)$ year^{-1}.

$$Z = 0.97(0.6 - 1.33); \qquad r^2 = 91.$$

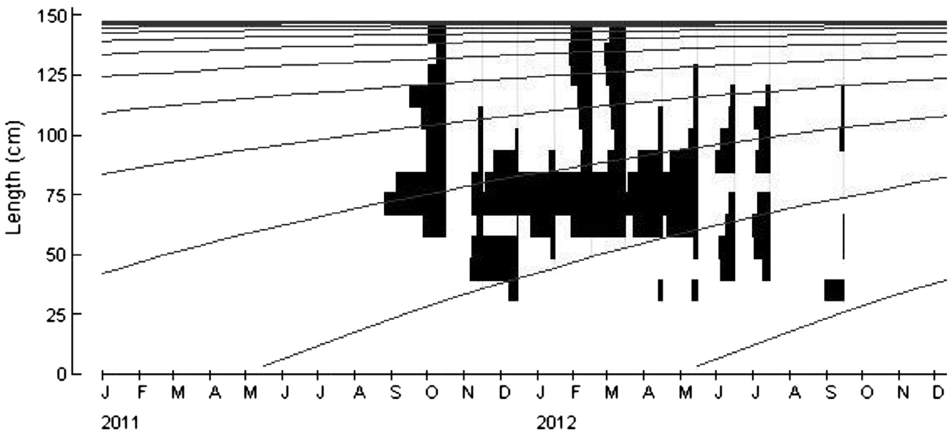

Fig. 3. Growth parameter estimates ($L_\infty = 148$ cm, $K = 0.5$ year^{-1}, ESP/ASP $= 0.72$) for *S. commerson* in northern Persian Gulf (2011–2012).

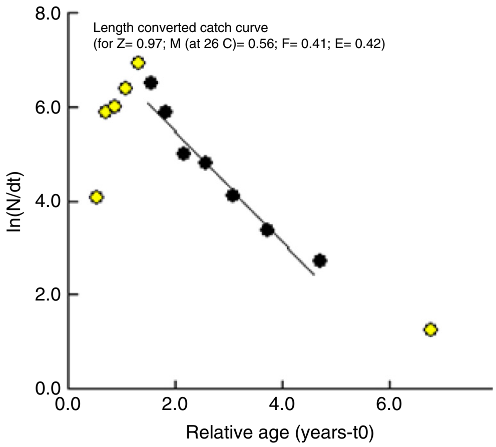

Fig. 4. Catch curve analysis of *S. commerson* in northern Persian Gulf (2011–2012).

Table 1
Length cohort analysis of pooled data of *S. commerson* in northern Persian Gulf (2011–2012).

Midlength (cm)	Catches (in tons)	Population	Fishing mortality	Biomass (t)
35	43	7669	0.03	4.1
44	92	6819	0.08	7.3
53	106	5954	0.1	11.7
62	245	5114	0.25	16.7
71	504	4190	0.59	21.22
80	372	3094	0.53	24.44
89	194	2232	0.33	27.47
98	98	1628	0.19	30.80
107	101	1179	0.23	33.31
116	95	780	0.28	33.18
125	72	448	0.29	29.59
124	127	204	1.16	36.33
143	000	…	1.16	000

3.3. Fishery assessment

The input and output of cohort analysis are represented in Fig. 5 and Table 1. The calculated fishing mortalities at length are depicted for both 9 and 14 cm gillnets. Fishing mortality ranged from 0.03 to 1.16 per year. Maximum catches consisted of lengths ranging from 62 to 80 cm FL, while fishing mortality for these sizes ranged from 0.25 to 0.53. Size at highest catch was 71 cm FL, corresponding to $F = 0.59$.

The ratio of actual number caught by length class estimated using ELEFAN II, correcting each length class for mesh selectivity. Values of $L_{25\%}$, $L_{50\%}$ and $L_{75\%}$ were 46.3, 55 and 60.2 cm FL, respectively (Fig. 6).

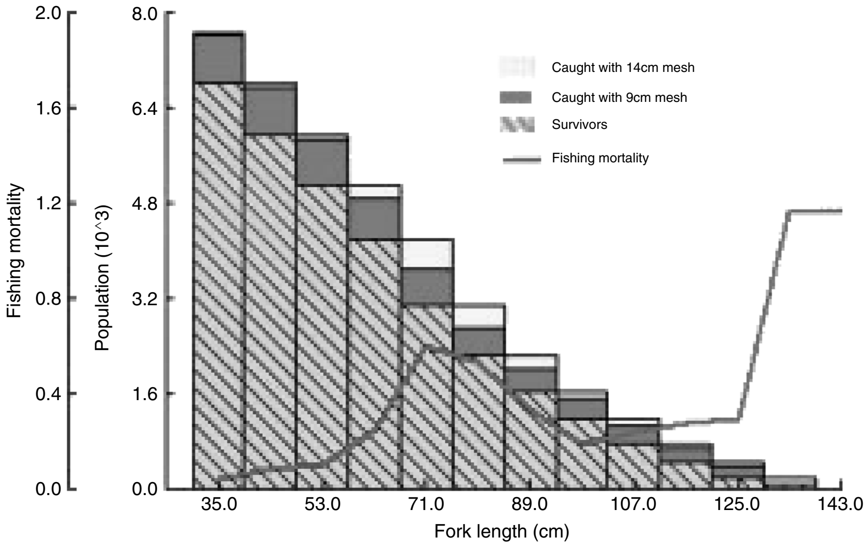

Fig. 5. Length cohort analysis of *S. commerson* in northern Persian Gulf (2011–2012).

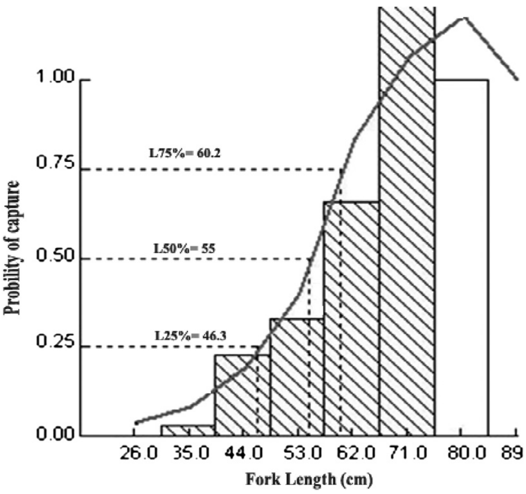

Fig. 6. Estimated probability of capture by length of *S. commerson* caught by the commercial fishery in northern Persian Gulf (2011–2012).

4. Discussion

The 9 and 14 cm mesh gillnets used in our study captured sizes of narrow-barred Spanish mackerel from 17 to 152 cm FL. Specimens less than 17 cm FL are reportedly caught with shrimp trawl gears in the study area, suggesting mesh sizes in our study are selective for size. A lack of the larger sized individuals landing places and local markets may be due to the migration into neighboring areas. Although details of movement and spawning patterns are not well understood, Al-Oufi et al. (2004) reported *S. commerson* migratory movement in and out of the Persian Gulf. This is further supported by genetic analyses that indicate mixing of *S. commerson* populations inside and outside the Persian Gulf (Hoolihan et al., 2006). In the neighboring area of the Persian Gulf, Begg et al. (1999) reported *S. commerson* in the northwest Indian Ocean which probably migrate across several international boundaries. The biological study of this species indicated that adults undertake extensive seasonal migrations along the shore (Collette and Russo, 1984).

In the present study $K = 0.5$ year^{-1} and $L_\infty = 148$ cm. The lack of smaller sizes from gillnet catches has been effected to the growth parameters estimation. The growth parameters of L_∞ and K in the Hormozgan waters (Persian Gulf area) were computed as $L_\infty = 175.26$ cm and $K = 0.45$ year^{-1} (Darvishi et al., 2011). In the United Arab Emirate combined sexes were estimated as $K = 0.21$ year^{-1} and $L_\infty = 138.6$ cm (Grandcourt et al., 2005). These estimates are lower than in the present study. In Kuwait, *S. commerson* reached sizes of 44.5–52 cm FL in five months of age (Brothers and Mathews, 1987), and in neighboring area (Oman Sea) 50 to 60 cm FL in six months (Dudley et al., 1992).

Growth estimates using VBGF models for *S. commerson* from Australia, South Africa and Oman suggest rapid growth in juveniles, reaching 60 cm FL and 75–80 cm FL for fish 18 months and two years old, respectively (Dudley and Arundhati, 1989; Dudley et al., 1992; McPherson, 1992; Govender, 1994). These estimates were reassessed in Dudley et al. (1992) from Oman Sea who examined sectioned otoliths and found that growth of *S. commerson* was extremely rapid up until 2 years of age. Recalculated length was 70–80 cm and 100–110 cm for fish 1 and 2 years old, respectively. Maximum length (FL) and weight of the species were recorded 240 cm and 70 kg respectively in Australian waters (McPherson, 1992). In the southern part of the Persian Gulf (United Arab Emirate waters) maximum fork length has been reported at 220 cm (Carpenter et al., 1997). In the Oman Sea, the minimum and the maximum FL recorded were 37.9 cm and 166.0 cm, respectively. In this area, the minimum and maximum total weight reported were 0.49 kg and 40.40 kg, respectively. Using annual increments on the sagittal otolith revealed that Oman's Spanish mackerel are relatively long-lived, with individuals recorded up to 21 years (McIlwain et al., 2005). Females live longer and grow larger than males.

Dudley et al. (1992) estimated size at spawning of 75–80 cm FL for sex combined of Oman. Claereboudt et al. (2004) later estimated the size at first sexual maturity (also off Oman) at 84.7 cm FL for males and 80.4 cm FL for females. *S. commerson* has been found to mature between 70–80 cm FL off Madagascar, Papua New Guinea and Fiji (Collette and Russo, 1984), and in the northern Indian Ocean the mean size at first sexual maturity was estimated at 75 cm FL by Devaraj (1983).

Comparing age–length relationships from other areas with the estimated growth parameters in the present study, it appears the commercial gillnet fishery for *S. commerson* in the northern Persian Gulf mostly catches age-1 and age-2 fish, which may not have reached sexual maturity. Gillnet mesh size and over exploitation are factors why the catch is composed of mostly small, immature fish.

Exploitation rates above F_{limit} have been associated with stock declines whilst below this level the tendency has been towards stock recovery. Exploitation below F_{opt} allows stock to increase in size (Patterson, 1992). Grandcourt et al. (2005) reported overexploitation of *S. commerson* in the southern Persian Gulf, based on estimates of $F = 0.62$ year^{-1}, $F_{\text{opt}} = 0.13$ year^{-1}, and $F_{\text{limit}} = 0.17$ year^{-1}. In the southern Persian Gulf, many fish populations have been heavily exploited and fishing effort may be above optimum levels for some species (Samuel et al., 1987; Siddeek et al., 1999). In the neighboring Gulf of Oman, because of high fishing pressure on this species, Siddeek and Al-Hosni (1998) estimated various biological reference points in Oman Sea and concluded that there was a need to reduce fishing mortality. Also in this area, De Rodellec et al. (2001) described the dynamics of the large pelagic fishery that included of Spanish kingfish and found that its fishery displayed all the "symptoms" of an overfished stock.

Comparatively, in our study the annual instantaneous rate of fishing mortality ($F = 0.42$ year^{-1}) was considerably greater than the target ($F_{\text{opt}} = 0.28$ year^{-1}) and limit ($F_{\text{limit}} = 0.37$ year^{-1}) biological reference points, suggesting that the *S. commerson* is also over-exploited in the northern Persian Gulf.

5. Conclusion

In comparison, our study estimated the annual instantaneous rate of fishing mortality to be considerably greater than the target and limit biological reference points, although the 9 cm mesh size was not specifically used to target *S. commerson* in the study area, it still is responsible for a significant amount of juvenile catches. Management measures that require an increase in gillnet mesh size, and a reduction in fishing effort are considered necessary for resource conservation and rebuilding of the *S. commerson* stock in the northern Persian Gulf. Further research to determine differential growth and mortality rates between male and females, with regard to different mesh sized gillnets, would benefit our understanding of this fish stock.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2015.10.012.

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