



An assessment of shared stock fishery of the kingfish *Scomberomorus commerson* (Lacepède, 1800) in the GCC waters

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Abstract

Length-frequency data of the shared stock of kingfish *Scomberomorus commerson* (Lacepède, 1800) collected during the years 2004-2006 from the GCC waters (Saudi Arabia, Bahrain, Qatar, UAE, Oman and Kuwait) were analysed for evaluation of the fishery and stock parameters. The drift and set gillnets performed growth overfishing. Large quantities of immature fish (< 80 cm FL) were landed by the UAE (3,767 t), Saudi Arabia (2,548 t), Qatar (1,543 t) and Oman (1,336 t). The VBG parameters for *S. commerson* were: $L_{\infty} = 176$ cm; $K = 0.4y^{-1}$ and $t_0 = -0.45y$. The instantaneous total mortality (Z), natural mortality (M) and fishing mortality (F) were $1.59y^{-1}$, $0.5y^{-1}$ and $1.09y^{-1}$ respectively. The growth performance index ($\phi' = 4.09$) indicated fast growth of the fish in the GCC waters. The life span is estimated to be around 9 years. The high exploitation rate ($E = 0.69$) indicated excess effort in the fishery. The estimated biomass was 28,185 t and the maximum sustainable yield (MSY) was 14,825 t. The length at capture (L_c) was 63 cm fork length which was much lower than the length at first maturity ($L_m \approx 80$ cm FL). The estimates of yield-per-recruit (Yw/R) and stock spawning biomass-per-recruit (%SSB/R) indicated overexploitation of the resource. The study suggests the need for urgent management interventions to sustain the fishery of kingfish in the GCC waters.

Keywords: *Scomberomorus commerson*, GCC waters, growth, mortality, MSY, yield-per-recruit, overfishing

Introduction

The kingfish *Scomberomorus commerson* (Lacepède, 1800) belongs to the family Scombridae under the order Perciformes. It is an epipelagic predator distributed widely in the Indo-Pacific waters from the Red Sea and South Africa to the southeast Asia, in the north to China and Japan and south to Australia (Randall, 1995). The kingfish forms high economically important fishery in its ranges of distribution including the Arabian Gulf, Oman Sea and Arabian Sea (Carpenter *et al.*, 1997). The kingfish performs a lengthy long-shore migration up to 1000 n. miles (McPherson, 1989; Randall, 1995) and can reach a maximum size of 240 cm of fork length and a maximum weight of 70 kg (McPherson, 1992).

In the GCC region, kingfish fishery is an open-access fishery without any input or output control and hence, the resource is heavily harvested by the fishers using a variety of gears such as drift and set gillnets, handlines and trolling lines and rarely by beach seines. Due to high demand and unregulated fishing practice in the GCC waters, overexploitation of the kingfish stock has led to decline in the catches in recent years. For example, from Oman, the catch that peaked at 27,834 t in 1988 had a dramatic tenfold decrease to 2,559 t in 2001 (GoSO, 2001). The situation is no better in other GCC countries and growth over-fishing and recruitment failure associated with intense harvest of immature fish (Dudley *et al.*, 1992) are the common concerns of the GCC countries (Kingfish Task Force, 1996).

Based on fishermen's experiences and seasonal variation in size of fish in the commercial catches, long coastal migration of *S. commerson* has been proposed (Al-Mamry, 1989). The recent genetic analysis of the kingfish in the ROPME sea area (Arabian Gulf, Oman Sea and Arabian Sea) has indicated the existence of a unit stock of kingfish in the entire ROPME sea area (Hoolihan *et al.*, 2006).

To help develop appropriate strategies for management of kingfish resource on regional basis in the GCC waters, knowledge on stock characteristics from various locations is needed. However, the available information on the stock assessment of *S. commerson* from the GCC waters is scanty and mostly location specific *i.e.*, from Oman (Dudley and Aghanashinikar, 1989; Dudley *et al.*, 1992; Al-Hosni and Siddeek, 1999; Al-Oufi *et al.*, 2002, 2004; Claereboudt *et al.*, 2005; McIlwain *et al.*, 2005; Govender *et al.*, 2006; Ben Meriem *et al.*, 2007), from Saudi Arabia (Kedidi *et al.*, 1993) and from Abu Dhabi Emirate (Grandcourt *et al.*, 2005). Hence, there is need to assess the status of the stock of kingfish for the entire GCC region.

As a first step, a regional monitoring program of kingfish was initiated to collect the length frequency data from the fishery as the length data of fish could be used to estimate growth and other stock parameters of the tropical fishes (Sparre and Venema, 1992). The aim of this paper is to assess the fishery, growth and population dynamics of *S. commerson* in the GCC waters using the length frequency data and provide biological reference points for co-management of the resource.

Material and Methods

Study area: Length-frequency data of *S. commerson* were collected every month continuously for five days between October 2004 and December 2006 under the GCC Kingfish Monitoring Programme concurrently from 15 landing sites located along the coastline of Arabian Gulf, Oman Sea and Arabian Sea bordering Kuwait, Saudi Arabia, Bahrain, Qatar, UAE and Oman (Fig. 1).

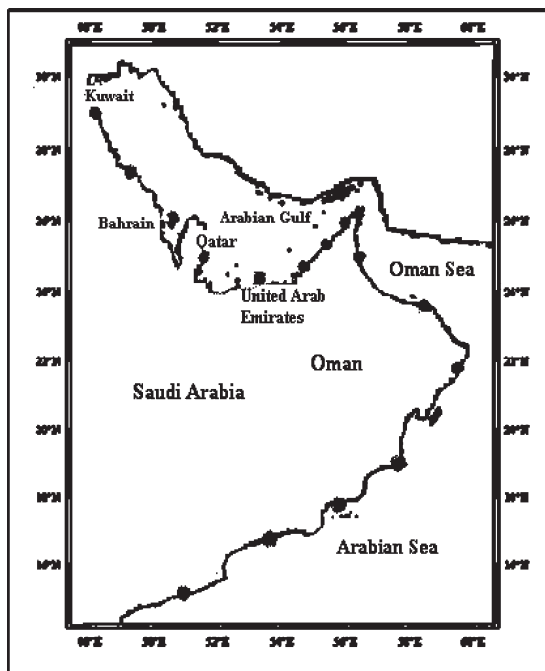


Fig. 1. Map showing kingfish landing sites along the coasts of the Arabian Gulf, Oman Sea and Arabian Sea

Length frequency data: A total of 33,232 kingfish caught from the Arabian Gulf, Oman Sea and Arabian Sea by drift gillnets (DGN), set gillnets (GN), handlines (HL) and trolling lines (TrL) were measured for the fork length (FL) to the nearest 1 cm. The pooled length data were grouped into 10 cm size groups to analyse the length data for evaluation of the fishery in the Arabian Gulf, Oman Sea and Arabian Sea. As the fish mature at around 80 cm FL in the region (Dudley *et al.*, 1992; Claereboudt *et al.*, 2004, Grandcourt *et al.*, 2005; Sadeghi *et al.*, 2009), fish measuring less than 80 cm FL were considered as immature and above 80 cm FL as mature.

Immature fish catch: From the total fish catch of the countries (IOTC, 2009) and the percentage contribution of fish in each size group, the midlength of each size group was converted into corresponding weight using the length-weight parameters ($a=0.0076$; $b=2.9826$) from an earlier study (Shojaei *et al.*, 2007).

Growth parameters: To estimate growth parameters (L_{∞} , K and t_0) of fish, the length frequency data were fitted to the von Bertalanffy growth (VBG) equation,

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

where L_t = length at age t ; L_{∞} = asymptotic length; K = growth coefficient; t = age of the fish and t_0 = hypothetical age at which fish would have zero length. Estimations were made using ELEFAN 1 technique available with the LFDA version 5.0 of FMSP-Fish Stock Assessment Software (Hoggarth et al., 2006).

The overall growth performance index (Φ') for *S. commerson* was calculated empirically (Munro and Pauly, 1983) using the formula,

$$\Phi' = \log_{10} K + 2 * \log_{10} L_{\infty}$$

where, K is expressed on annual basis and L_{∞} in cm.

Length at capture: Length at capture (L_c) was estimated from cumulative percentages of length against length classes. The optimum length for capture (L_{opt}) was calculated by the empirical method of Froese and Binohlan (2000) by the formula,

$$L_{opt} = 3 * L_{\infty} / (3 + M/K)$$

where, L_{opt} is the optimum length of exploitation; L_{∞} the asymptotic length; M , the natural mortality and K , the growth coefficient.

Mortality : To estimate the instantaneous total mortality rate (Z), Beverton-Holt method (Beverton and Holt, 1956) provided in the LFDA version 5.0 of FMSP software was used. The instantaneous natural mortality coefficient (M) of fish was estimated by the empirical method of Pauly (1980) assuming that the mean annual water temperature was 26°C. The instantaneous fishing mortality coefficient (F) was taken as the difference between the total and natural mortalities as, $F = Z - M$.

Exploitation: The exploitation rate (E) was derived from the estimates of Z and F as defined by the equation (Ricker, 1975; Sparre and Venema, 1992) as,

$$E = F/Z = F / (M+F)$$

The exploitation ratio *i.e.*, the fraction of the fish present at the start of a year that were caught during the year was estimated by the equation (Beverton and Holt, 1957; Ricker, 1975) as,

$$U = F / Z (1 - e^{-Z})$$

Estimation of yield (Y), biomass and maximum sustainable yield (MSY): The pooled annual average catch of fish by all the GCC countries (IOTC, 2009) was considered as yield (Y) for stock estimation purpose.

The biomass in weight was calculated using the relation between yield and exploitation ratio as,

$$\text{Biomass} = Y/U$$

where Y is the annual yield and U is the exploitation ratio. The maximum sustainable yield (MSY) of *S. commerson* was estimated by the Cadima's formula

$$\text{MSY} = 0.5 * (Y + \bar{M} * B)$$

The routine of the predictive Thompson and Bell model incorporated in the YIELD software (Hoggarth et al., 2006) was also used to estimate the MSY.

Per-recruit analysis: The biological reference points such as yield-per-recruit by weight (Yw/R) and spawning stock biomass-per-recruit ($\%SSB/R$) for a range of F -values were estimated using YIELD package available with the FMSP Software (Hoggarth et al., 2006).

Results

Length distribution in GCC waters: The pooled length measurements ($n=33,232$) of kingfish in the GCC waters (Arabian Gulf, Oman Sea and Arabian Sea) indicated that nearly 65.3% of the individuals landed were immature (Fig. 2A). The percentage frequency of fish showed that fish less than 80 cm was higher in the Arabian Gulf (68%; Fig. 2B) than in Oman Sea (43%; Fig. 2C) and Arabian Sea (39%; Fig. 2D).

Length distribution by country: Table 1 provides the details of the length of the fish landed by different types of gears in the GCC countries.

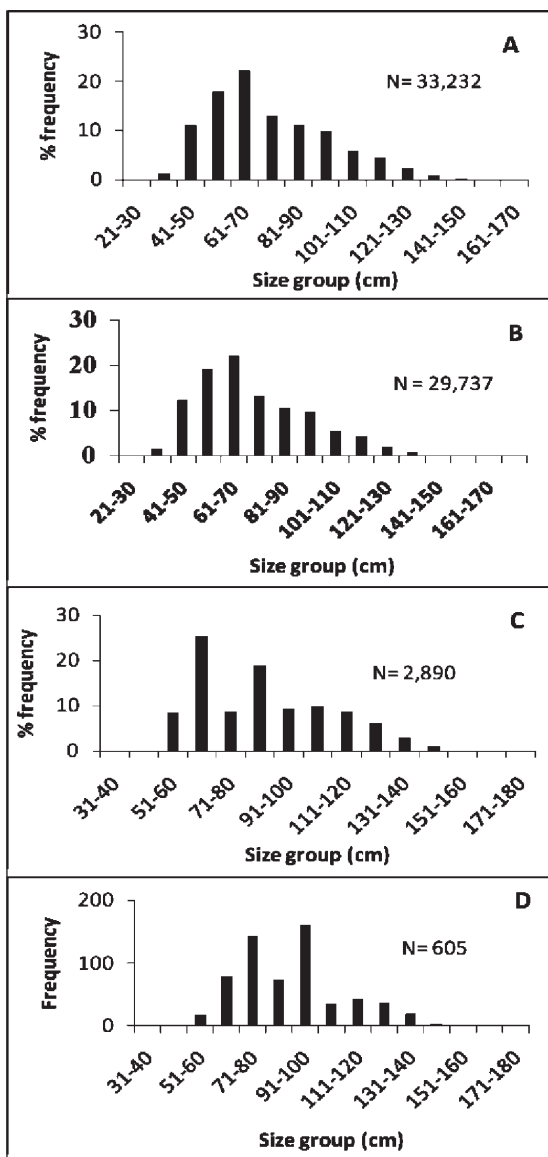


Fig. 2. Length frequency distribution of *S. commerson* in the GCC waters (A) pooled for all seas; (B) Arabian Gulf; (C) Oman Sea; (D) Arabian Sea

Saudi Arabia: In Saudi Arabia, which is a major kingfish producing country in the Arabian Gulf, the size of the fish ranged from 31 cm to 150 cm. About 47% of the fish were represented in the size range 31-80 cm. In the DGN landings, about 68.4% consisted of fish measuring less than 80 cm FL;

whereas, GN landed less number of fish. Compared to other gears, HL landed a large number of fish measuring >80 cm. The trolling line fishery consisted of about 58% of fish measuring up to 80 cm.

Bahrain: Of the 5,348 length measurements ranging in size of 31-170 cm, fish measuring less than 80 cm formed about 82%. The lengths from different gears showed that the gillnet (GN) and hand line (HL) captured about 89% immature fish.

Qatar: The size ranged from 31 to 140 cm and about 91% of the fish caught was below 80 cm. The length of fish was mostly < 80 cm in the DGN and GN and HL. Though, the TrL landed larger fish its contribution to the landings was small. All the gears except trolling line capture a large number of juveniles.

United Arab Emirates: In the UAE, while the overall sizes of the fish caught measured between 21 cm and 170 cm, nearly 79% of the fish caught were immature. Majority of the catches (92%) by gillnets measured less than 80 cm FL. Comparatively the hook and line caught larger fish.

Oman: Among the GCC states, Oman is the only country that catches kingfish from the Arabian Sea. It also lands considerable quantity of *S. commerson* from the Oman Sea. The overall length frequency of fish from the Oman Sea and Arabian Sea ranged from 41 cm to 160 cm and about 42% of the fish measured less than 80 cm. Compared to other gears, the drift gillnet captured large number of juveniles.

Kuwait: The kingfish collected in December 2004 from the drift gillnet fishery in Kuwait consisted of only two length groups *i.e.*, 101 to 120 cm and 131 to 140 cm fork length. The kingfish catches from Kuwait is < 100 t in recent years (IOTC, 2009). Thus the length was above the length at first maturity.

Estimates of immature fish landings: For the minimum and maximum size of the fish recorded (midlength: 25 to 165 cm FL) the computed weight was 0.11 kg and 31.24 kg. The weight contribution by different size groups of kingfish extrapolated for

Table 1. Length frequency distribution of *S. commerson* in various GCC countries

Country	Gear	Length range (cm)	No. of fish	% of immature fish
Saudi Arabia	All gears	31-140	11,475	47.0
	DGN	31-130	4,767	68.4
	GN	31-140	288	42.4
	HL	31-140	4,861	23.0
	TrL	41-140	1,559	57.5
Bahrain	All gears	31-170	5,348	81.7
	DGN	31-150	355	11.6
	GN	31-150	2,312	89.1
	HL	51-170	2,033	89.6
	TrL	61-130	648	69.4
Qatar	All gears	31-140	3,808	91.3
	DGN	31-130	696	96.0
	GN	41-70	2,374	100
	HL	61-90	534	81.8
	TrL	81-110	204	0
UAE	All gears	21-170	8,841	79.0
	DGN	21-150	6,954	91.5
	HL	21-170	1,887	33.0
Oman	All gears	31-160	3,495	42.2
	DGN	31-160	1,701	60.9
	GN	61-160	1,151	13.4
	HL	51-160	398	20.6
	TrL	71-170	245	5.7
Kuwait	DGN	101-140	265	0

the annual average catches (2004-2006) in various countries is given in Table 2 and all fish and immature fish which contributed to the catches in various countries are provided in Table 3. Large quantities of immature fish were landed by the UAE (3,767 t) followed by Saudi Arabia (2,548 t), Qatar (1,543 t) and Oman (1,336 t).

Growth parameters: The growth curves fitted by ELEFAN 1 for the monthly length frequency data (2004-2006) of *S. commerson* in the GCC waters are shown in Fig. 3. The VBG parameters for *S. commerson* were: $L_{\infty} = 176$ cm; $K = 0.4y^{-1}$ and $t_0 = -0.45y$. The estimated overall growth performance index for *S. commerson* in the GCC waters stood at 4.09 indicating a very high growth rate. The fish grow faster in the early part of their life. The length attained at the end of first and second years was 74.6 cm and 106.6 cm respectively. The length estimated for different ages of fish indicated that the life span

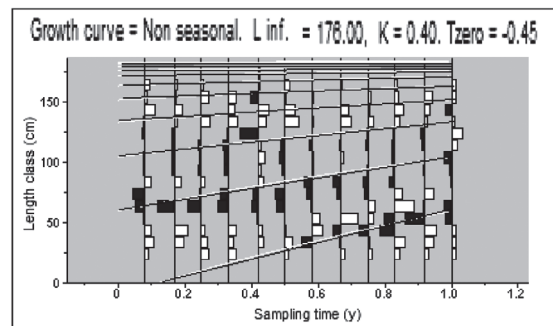


Fig. 3. Growth curves of *S. commerson* fitted by ELEFAN 1 technique

of fish may be around 8-9 years.

Length at capture: The age composition of *S. commerson* in the commercial catches from the GCC waters indicated that the fishery targeted individuals mainly in the age group of 0-2 years. Fish in the size group 21-30 cm were recruited to the fishery,

Table 2. Extrapolated catches (t) of kingfish from lengths based on production statistics in GCC countries (IOTC - average kingfish catch in various countries for 2004-2006 in parentheses; estimated catch from Kuwait was 105 t not included in Table)

Mid-length (cm)	Saudi Arabia (5,432 t)		Bahrain (107 t)		Qatar (1,810 t)		UAE (4,768 t)		Oman (3,167 t)	
	Length contribution (%)	Estimated wt. (t)	Length contribution (%)	Estimated wt. (t)	Length contribution (%)	Estimated wt. (t)	Length contribution (%)	Estimated wt. (t)	Length contribution (%)	Estimated wt. (t)
25	-	-	-	-	-	0.4	19.07	-	-	-
35	0.1	5.43	0.1	0.11	0.5	9.05	3.8	181.18	-	-
45	2.0	108.64	21.5	23.01	32.9	595.49	11.6	553.09	0.1	3.17
55	9.3	505.18	37.6	40.23	34.9	631.69	14.5	691.36	7.6	240.69
65	18.3	994.06	17.5	18.73	16.0	289.60	33.1	1578.21	23.3	737.91
75	17.2	934.30	4.9	5.24	7.0	126.70	15.6	743.81	11.2	354.70
85	16.6	901.71	3.8	4.06	4.4	79.64	9.1	433.89	17.8	563.73
95	16.7	907.14	4.5	4.82	3.2	57.92	3.7	176.42	12.4	392.71
105	10.3	559.49	2.4	2.57	0.7	12.67	3.1	147.81	9.2	291.36
115	7.0	380.24	3.7	3.96	0.3	5.43	2.7	128.74	8.4	266.03
125	2.3	124.94	2.3	2.46	0.1	1.81	1.8	85.82	6.0	190.02
135	0.2	10.86	1.3	1.39	-	-	0.4	19.07	2.9	91.84
145	-	-	0.2	0.21	-	-	0.1	4.77	0.9	28.50
155	-	-	0.1	0.11	-	-	0.05	2.38	0.2	6.33
165	-	-	0.1	0.11	-	-	0.05	2.38	-	-

but their contribution was <1% and in larger size groups the percentages increased. The length at which 50% of fish caught was 63 cm FL (Fig. 4). The optimum length of exploitation (L_{opt}) was estimated (Froese and Binohlan, 2000) at 111.7 cm (95% -range 100.6 cm – 124.1 cm) and the L_{opt}/L_{∞} value was 0.61.

Mortality rates: The instantaneous total mortality coefficient (Z) of *S. commerson* was 1.59 (SE=0.025). The natural mortality coefficient (M) was 0.63 which was subsequently multiplied by 0.8 as suggested by Pauly (1983) for the fast moving pelagic species like the kingfish that gave the coefficient value of $M=0.5$. The annual instantaneous fishing mortality (F) was 1.09.

Exploitation: The exploitation rate (E) was 0.69 and the estimated exploitation ratio (U) was 0.546.

Estimates of yield (Y), biomass and maximum sustainable yield (MSY): The average catch for the years 2004-2006 from all the GCC countries was estimated as 15,389 t (Table - 3). The biomass of kingfish was estimated as 28,185 t.

As the predictive Thompson and Bell model was not sensitive in the present study, the MSY estimated by Cadima's estimator was considered as the MSY level of kingfish resource. The maximum sustainable yield (MSY) of *S. commerson* estimated by the Cadima's estimator was 14,825 t.

Per-recruit analysis: At the current fishing mortality (F_{curr}), the Yw/R was estimated at 2.984 kg (Fig. 5). However, the highest Yw/R (Y_{msy}/R) was recorded at $F=0.5y^{-1}$. The spawning stock biomass (SSB) at the current fishing mortality (F_{curr})

Table 3. Extrapolated total and immature fish landings in GCC countries

Country	Total catch (t)	Immature fish catch (t)	% immature fish
Saudi Arabia	5,432	2,548	46.9
Bahrain	107	87	81.3
Qatar	1,810	1,543	85.2
UAE	4,768	3,767	79.0
Oman	3,167	1,336	42.2
Kuwait	105	-	-
Total	15,389	9,281	60.3

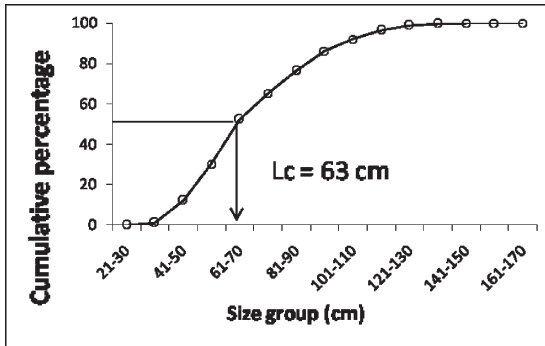


Fig. 4. Length at first capture of kingfish in GCC waters

was about 11.4% of the total biomass. By reducing the fishing mortality to $F=0.5$, the SSB can be increased to 27.8% (Fig. 5).

Discussion

Information on stock characteristics is an essential component for long term sustainable management of fisheries resources (Shaklee and Currens, 2003). Being an open access fishery, the kingfish resource of the GCC region is heavily exploited causing concern for the regional stakeholders of fisheries. The estimates of catches clearly indicate that the immature fish were landed in large quantities by the UAE, Saudi Arabia, Qatar and Oman. The set and drift gillnet fisheries in the above countries need mesh size regulation. The size range of fish in the commercial catches ranged between 21 cm and 170 cm of FL. The average length of capture (L_c) at 63 cm is well below the length at first maturity reported from earlier studies in the region (Dudley et al., 1992; Claereboudt et al., 2004; Grandcourt et al., 2005; Sadeghi et al., 2009). The predominance of 0, 1 and 2 year old fish in the commercial catches is similar to the observation of McIlwain et al. (2005) from the Oman Sea and Arabian Sea coasts of Oman.

In Oman, experiments on gillnet selectivity for kingfish indicated that the stretched mesh measuring 110 mm captured about 58% of fish below the length at first maturity. However, by increasing the mesh size to 120 mm, 130 mm and 140 mm, the capture of immature fish reduced to 41%, 27.5% and 15% respectively (Stengel and Salman, personal

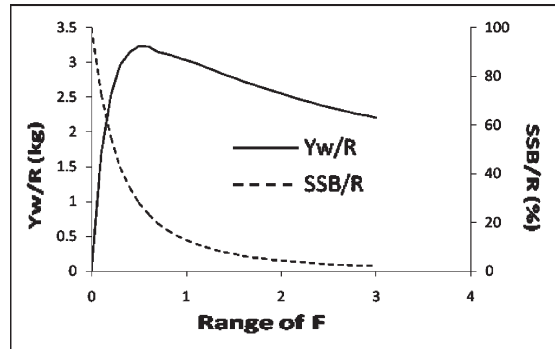


Fig. 5. Yield-per-recruit (kg) and spawning stock biomass per-recruit (%) in *S. commerson*

communication). While deciding the legal mesh size for gillnets, the above findings need due consideration.

The genetic study on stocks of *S. commerson* in the ROPME sea area has indicated that there is homogeneous distribution consistent with a single intermingling genetic stock (Hoolihan et al., 2006). Hence, the sub-stocks of *S. commerson* in the GCC waters and the neighbouring countries like Iran and Iraq should be considered as a unit stock for management purpose. Another important aspect to be considered is the migration of kingfish in the GCC waters. There is a popular belief among the fishermen of the region that the kingfish of Oman migrate to Arabian Gulf to spawn and the young fish return from the Arabian Gulf to the Oman Sea and to the Arabian Sea for further growth (Al-Mamry, 1989). However, this view has been contradicted and the young fish appear to migrate from the Arabian Sea to the Oman Sea for feeding and growth (Thangaraja and Al-Aisry, 2001). Migration is an important aspect to be considered for management of this shared resource in the GCC waters.

The estimations on the length at first maturity from Oman (Dudley et al., 1992), UAE (Claereboudt et al., 2004; Grandcourt et al., 2005) and Iran (Sadeghi et al., 2009), recruitment failure of kingfish (Dudley et al., 1992), the changed pattern of reproduction and spawning of the kingfish in the coastal waters of the Sultanate of Oman (Claereboudt et al., 2005) and the present length data indicate growth-overfishing and recruitment-overfishing

Table 4. Growth parameters of *S. commerson* in the Western Indian Ocean Region

Region/ Country	L_{∞} (cm)	K (y^{-1})	t_0 (y)	Reference	Technique/Remarks
GCC	183.0 FL	0.40	-0.76	Present study	Length frequency (LFDA)
Oman	226.0 FL	0.21	-0.85	Dudley <i>et al.</i> (1992)	Length frequency (ELEFAN & graphical method)
Oman	193.6 FL	0.29	-0.678	Dudley <i>et al.</i> (1992)	Bhattacharya method
Oman	138.3 FL	0.36	-1.16	Dudley <i>et al.</i> (1992)	Length at otolith age
Oman	131.2 FL	0.61	-0.438	Dudley <i>et al.</i> (1992)	Combined otolith age & length frequency
Oman	182.0 FL	0.30	-0.70	Bertignac & Yesaki (1993)	Length frequency (Bhattacharya method)
Oman	173.6 FL	0.28	-0.86	Al-Hosni & Siddeek (1999)	Length frequency
Oman	140.44 FL-	0.309	-1.509	McIlwain <i>et al.</i> (2005)	Length at otolith age
	118.80 FL-	0.595	-0.730	"	"
Oman	146.4 FL	0.216	-2.618	Govender <i>et al.</i> (2006)	Reassessment of data of McIlwain <i>et al.</i> (2005)
Abu Dhabi	138.6 FL	0.21	-1.94	Grandcourt <i>et al.</i> (2005)	Length at otolith age
S. Arabia (S.A. Gulf)	183.6 TL	0.26	-	Kedidi <i>et al.</i> (1993)	Length frequency (Bhattacharya method & ELEFAN)
Iran	140.0 FL	0.42	-0.26	Shojaei <i>et al.</i> (2007)	Length frequency (FiSAT Programme)
India	208.1 TL	0.18	-0.16	Devaraj (1981)	Petersen's technique & otolith
India	146.0 TL	0.78	-	Pillai <i>et al.</i> (1993)	Length frequency (Modal progression analysis)
India	177.5 FL	0.38	- 0.23	Thiagarajan (1989)	Length frequency (Ford-Walford plot)
India	137.6 FL	1.27	-	Kasim <i>et al.</i> (2002)	Length frequency (ELEFAN)

inviting effective regional regulatory measures at the earliest.

Table 4 provides the VBG parameters of *S. commerson* from earlier studies from the northern Indian Ocean. The estimated L_{∞} , K and t_0 in the present study are comparable with the earlier studies in the region. The high value of growth performance index ($\phi' = 4.09$) in the present study and in earlier reports from Oman (4.01) (Al-Hosni and Siddeek, 1999); Saudi Arabia (3.94) (Kedidi *et al.*, 1993) and Iran (3.92) (Shojaei *et al.*, 2007) indicated faster growth for the species in the GCC waters. It has been reported that *S. commerson* spawns only once annually in the Omani waters (Claereboudt *et al.*, 2004); Abu Dhabi (Grandcourt *et al.*, 2005) and Iran (Sadeghi *et al.*, 2009). However, three spawning periods have been established for *S. commerson* in the southern coast of India (Devaraj, 1983). Hence, the energy expenditure for spawning in GCC kingfish might be comparatively lower than in the waters where the kingfish spawns more than once and such energy conservation might trigger faster growth rate in the fish.

A comparison of Z, M, F and the exploitation rate of *S. commerson* from various countries is given in Table. 5. Since M is linked with the longevity and the latter to the growth coefficient K, the M/K ratio is found to be constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959). The M/K ratio usually ranges between 1 and 2.5 (Beverton and Holt, 1959). In the present study, the M/K ratio for *S. commerson* was calculated at 1.25.

The estimated higher fishing mortality ($F = 1.09$) than the value of M (0.50) in the study and the higher exploitation rate (E) of 0.69 indicate overexploitation of the resource. It has been recommended that the E should be ≈ 0.4 for pelagic migratory species like the kingfish. The MSY estimated at 14,825 t is lower than the average yield of 15,389 t for the period 2004-2006. It is suggested to cap the yield limit to the MSY level to sustain the fishery. The yield-per-recruit (Y_w/R) and SSB per-recruit have also indicated the need for reduction in fishing mortality through management strategies.

Table 5. Mortality (Z, M and F) and exploitation ratio (E) of *S. commerson* in various countries

Country/ Region	Z	M	F	E	Reference	Remarks
GCC	1.59	0.5	1.09	0.69	Present study	-
Oman	1.151	0.526	0.625	0.543	Dudley and Aghanashinikar (1989)	1987-1989 length data
Oman	1.78	0.384	1.369	0.784	Dudley and Aghanashinikar (1989)	Same data as above; but with different growth parameters
Oman (Male)	0.892	0.49	0.42	-	Govender <i>et al.</i> (2006)	-
(Female)	0.901	0.376	0.534	-	"	-
Saudi Arabia (S.A. Gulf)	1.592	0.36	1.23	0.77	Kedidi <i>et al.</i> (1993)	Length data considered- 95-160 cm
Saudi Arabia (S.A. Gulf)	0.758	0.36	0.398	0.525	Kedidi <i>et al.</i> (1993)	Length data considered- 45-160 cm
Abu Dhabi	0.88	0.26	0.62	0.7	Grandcourt <i>et al.</i> (2005)	-
Iran	1.47	0.49	0.98	0.64	Shojaei <i>et al.</i> (2007)	-
India	3.288	0.78	2.508	0.76	Pillai <i>et al.</i> (1993)	-
India	5.39	1.37	4.01	0.75	Kasim <i>et al.</i> (2002)	-

As the kingfish fishery is supported by a unit stock in the GCC and other countries in the region, a workable multilateral agreement for management is needed to sustain the fishery. To develop and implement a suitable management plan, the following may be considered: (i) Since the fish is highly migratory and not much is known about the migratory route and spawning ground, tagging programme needs to be undertaken. (ii) As the gillnet lands large quantities of young fish, the mesh size has to be increased. To decide on the mesh size of the net, the results of the study on gillnet selectivity conducted in Oman, may be considered. If needed, additional studies may be initiated on urgent basis. (iii) As the biological information available on this migratory fish is fragmentary from specific locations, a broader study for the entire GCC waters on the biology and stock assessment should be undertaken for a better understanding on the spawning season in the GCC waters which would help in suggesting seasonal and/or area closure for fishing in the entire GCC region.

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