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A review of the fisheries, biology, status and management of the narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Gulf Cooperation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates)

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Abstract

The Gulf Cooperation Council (GCC) is a political and economic union of six littoral states (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates) located at the northern extremity of the western Indian Ocean on the Arabian peninsula. The Narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacépède, 1800), forms a large component of catches in these countries and in some cases it is the most important commercially exploited species. It is mainly caught with gillnets set around schools from outboard powered fiberglass dories and traditional wooden dhows, hand lines and trolling lines are also used and it is targeted by the recreational fishery. Nets may also be set in a trap configuration and the extensive use of drifting gillnets has also been reported. Landings of *S. commerson* in the GCC countries increased to 35,000 mt in 1988. Subsequently, there was a precipitous decline associated with a collapse in the fishery and the total annual catch dropped to 10,662 mt by 1991. During the same period, the numbers of fishermen and size of the fishing fleet had increased dramatically. Stock assessments have indicated growth and recruitment over-fishing associated with the intensive differential harvesting of young immature fish. Management strategy simulations suggest that reductions in fishing effort are required along with closed seasons and mesh size regulations to modify the selectivity characteristics of nets. Fisheries management efforts in the region are limited and undermined by a lack of synergy in planning and regulation between the GCC States. Given the highly migratory nature of this species, and considering that the stock is homogenous throughout the Arabian Gulf and Gulf of Oman, it is unlikely that the initiatives of any one of the littoral states alone would be sufficient to achieve resource management objectives. Clearly, a strategic regional approach to the assessment and management of *S. commerson* is imperative in this context.

Introduction

The Narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepède, 1800) is a member of the family Scombridae (Mackerels, tunas, bonitos), subfamily: Scombridae. It is distributed in the Indo-Pacific from the Red Sea and South Africa to southeast Asia, north to China and Japan and south to Australia (Randall, 1995), being an immigrant to the eastern Mediterranean Sea by way of the Suez Canal (Ben-Tuvia, 1978).

S. commerson occurs from the edge of the continental shelf to shallow coastal waters where it is found along drop-offs, gently sloping reefs and lagoon waters from depths of 10 to 70 m. (McPherson 1985, Myers 1991). In north Queensland Australia, small juveniles up to 10 cm fork length live in creeks, estuaries and sheltered mud flats during the early wet season (McPherson, 1981). Large adults may be solitary, whereas juveniles and young fish occur in small schools (Collette, 2001). The diet mainly consists of small fishes like anchovies, clupeids and carangids, though squids and shrimps are also consumed (Blaber *et al*., 1990). It reaches a maximum size of 240 cm fork length and maximum weight of 70.0 kg (McPherson, 1992).

Whilst *S. commerson* is an inshore pelagic species, it is known to undertake lengthy long-shore migrations (Randall, 1995). In Australia, migrations extend along the entire east coast of Queensland, however, permanently resident populations also seem to exist. The resident fish disperse from reefs after spawning, while migrating fish move up to 1000 nautical miles to the south (McPherson, 1989). In the waters of the southern Arabian Gulf, *S. commerson* is most abundant between September and May, with fish generally moving in an east to west direction during this period (Grandcourt *et al*., 2005).

The Gulf Cooperation Council (GCC) is a political and economic union of six littoral states of the Arabian Gulf (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates). *S. commerson* is an important component of catches to these countries and in some cases it is the most important commercially exploited species. Consequently, there have been many studies on its biology, associated fisheries and stock assessment. However, to date, there hasn’t been an attempt to collate and synthesize this information for the region. This review presents a synopsis of the fisheries, biology, status and management of *S. commerson* in the GCC. It is warranted, particularly given that the majority of the GCC countries (all except Oman) are not members of the IOTC, so this work may fill a critical technical information gap for the most important neritic species at the northern extremity of the western Indian Ocean.

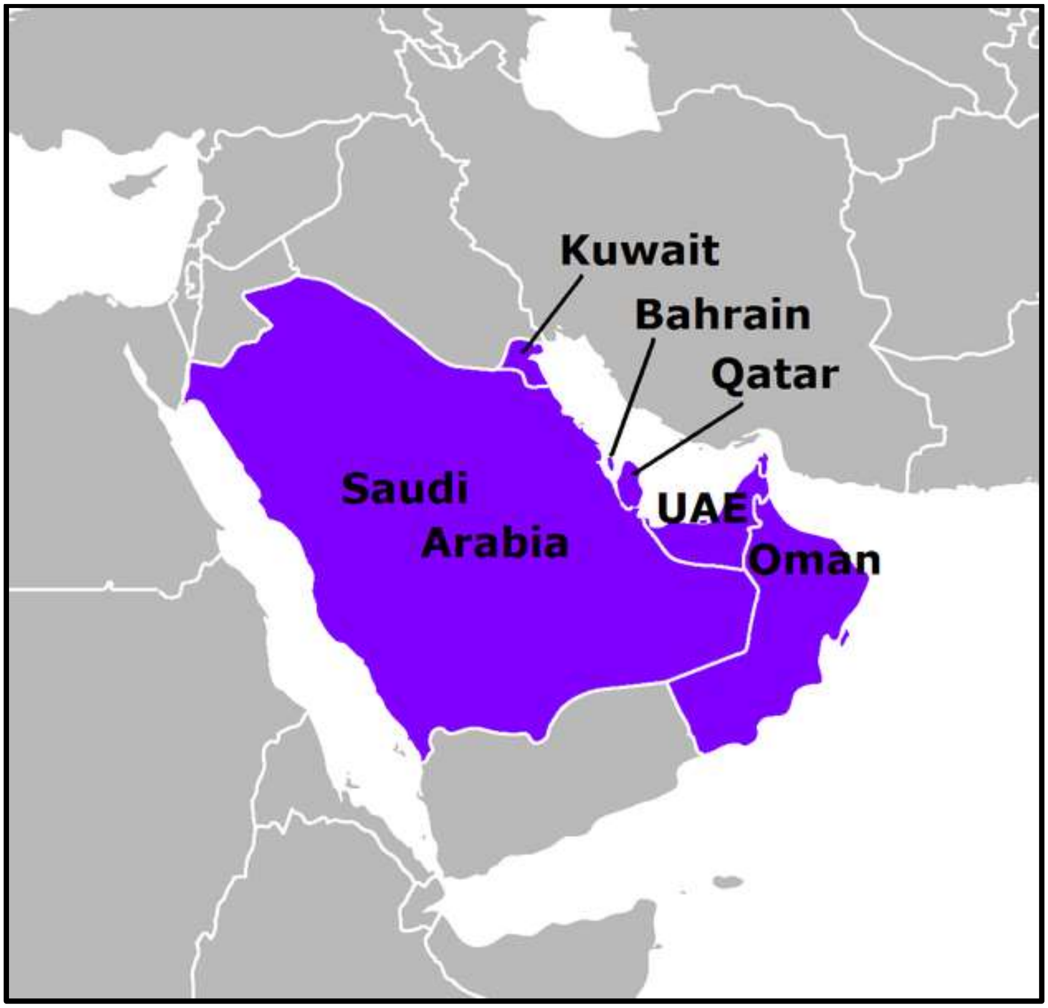

Figure 1 **The Arabian Peninsula showing member States of the Gulf Cooperation Council (GCC)**

Fisheries

Catch & Effort

In the GCC, *S. commerson* is mainly caught with gillnets set around schools from outboard powered fiberglass dories and traditional wooden dhows, hand lines and trolling lines are also used and it is targeted by the recreational fishery. Nets may be set in a trap configuration and the extensive use of drifting gillnets at night has also been reported (Ben Meriem *et al*., 2006). In terms of consumption, it is the most important highly migratory species occurring in the region (Hoolihan, 2004).

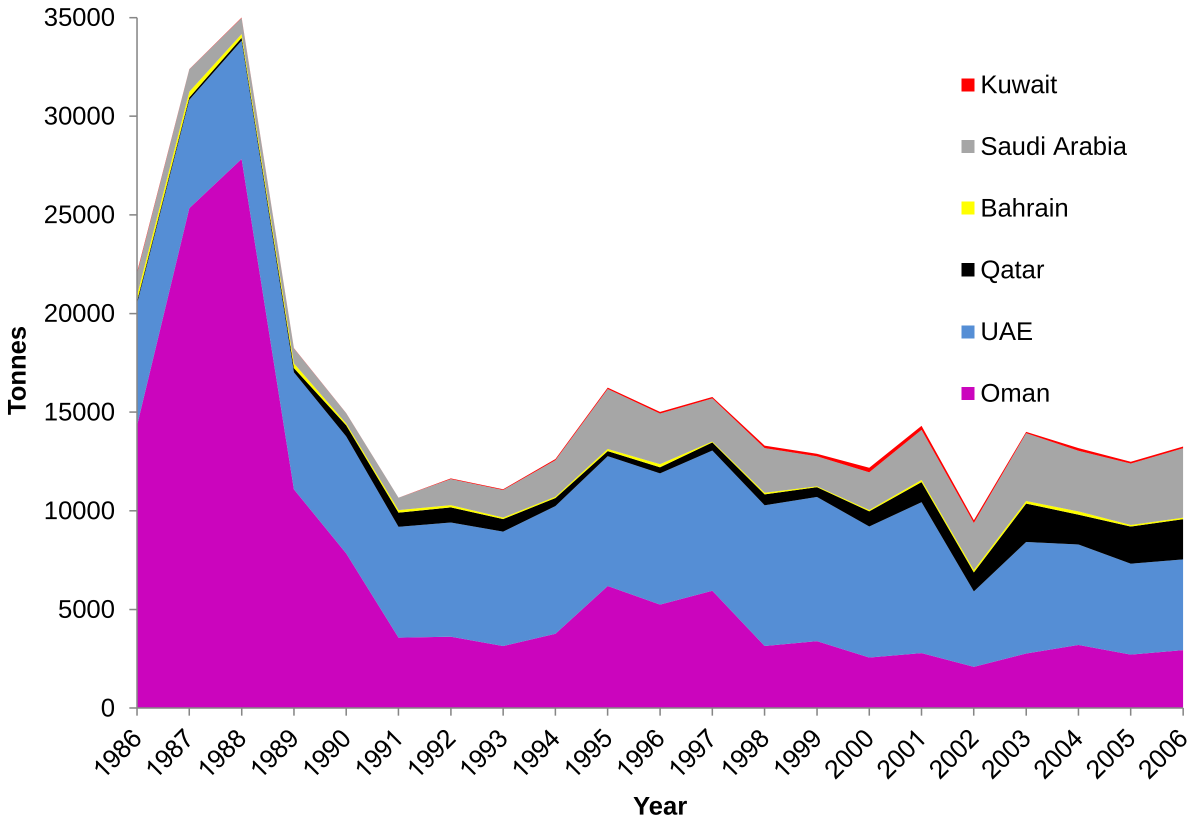

Figure 2 **Annual catches of *S. commerson* between 1986 and 2006 by member States of the Gulf Cooperation Council (GCC)**
(Source: Trends and patterns of RECOFI capture fisheries production (1986-2006) FAO, UN)

Landings of *S. commerson* in the GCC countries increased to 35,000 mt in 1988. Subsequently, there was a precipitous decline associated with a collapse in the fishery and the total annual catch dropped to 10,662 mt by 1991. Since then, annual landings have varied between 9,521 mt in 2001 to 16,242 mt in 1995 (Figure 2). Effort data indicates that the total number of boats (fiberglass and launch) in the narrow-barred Spanish mackerel fishery in Oman had increased from 7,442 in 1987 to 13 248 in 2000 (Ben Meriem *et al*., 2006).

The majority of the catch is landed in Oman (43.4%), the UAE (38.1%) and Saudi Arabia (12.4%) with Qatar (4.8%), Bahrain (0.8%) and Kuwait (0.5%) contributing much smaller proportions. Dudley *et al*. (1992) have shown substantial seasonal variations in landings and fishing mortality in Oman, the largest catches being made between September and March. During this period, fleets target different age classes, depending on the fishing area and gear (Ben Meriem et al., 2006). Similar seasonal variations in catches have also been recorded in the southern Arabian Gulf (Figure 3).

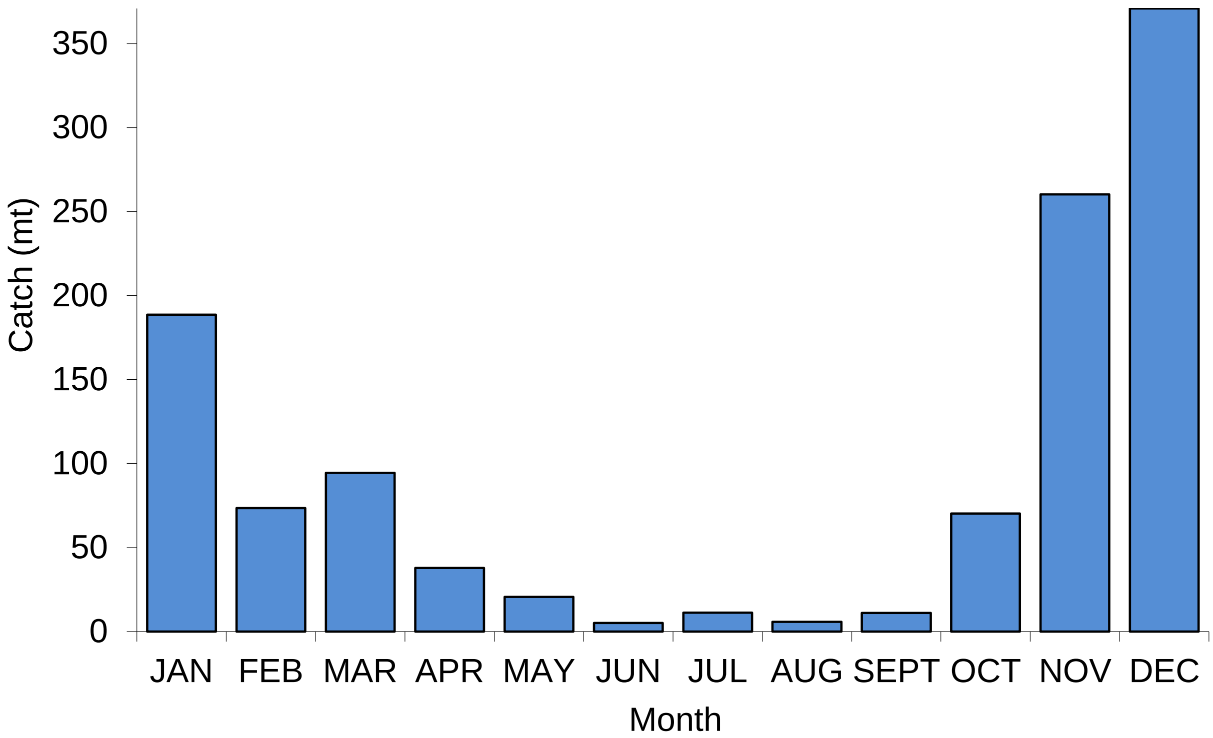

Figure 3 Mean monthly landings of *S. commerson* during 2012 in the southern Arabian Gulf (Source: EAD, 2012)

Selectivity

One of the key management issues of the *S. commerson* fishery is the selectivity characteristics of the nets which are the principal gear type used to target this species in the GCC Region. This is highlighted in the assessment of Grandcourt *et al*. (2005) which established the mean size at first capture (29.7 cm L_F) and size at which fish were fully recruited to the fishery (L_{100} = 62.6 cm L_F) to be considerably smaller than the size at first sexual maturity for females (86.3 cm L_T) and the size at which yield per recruit would be maximized (95.6 cm L_F) (see Figure 4). Consequently, 94.7 % of the yield consisted of fish that were below the mean size at first sexual maturity.

The small mesh sizes of nets combined with the differential targeting of young schooling fish explains the high levels of juvenile retention throughout the region. Dudley *et al*. (1992) estimated the size at first capture to be between 40 and 60 cm, corresponding to an age at first capture of 4-6 months for *S. commerson* off Oman. In addition, up to 90% of the fish captured there are immature with very few reaching their third year of life (Claereboudt *et al*., 2004; McIlwain *et al*., 2005). The selectivity characteristics of the fishery for *S. commerson* off Oman are therefore remarkably similar to those in the Arabian Gulf.

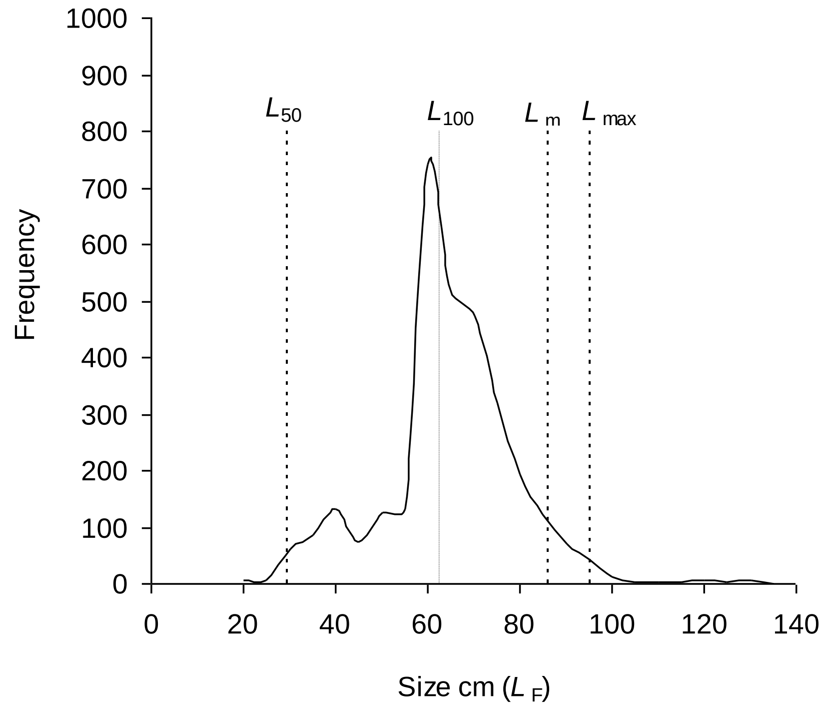

Figure 4 **Aggregated length frequency distribution for *S. commerson* showing the mean size at first capture (L_{50}), the size at which fish are fully recruited (L_{100}), the mean size at first sexual maturity (L_m) and the size at maximum yield per recruit (L_{max}).** (Source: Grandcourt *et al*. 2005).

Stock Structure

Hoolihan *et al*. (2006) studied the genetic stock structure of *S. commerson* using restriction fragment length polymorphism (RFLP) and direct sequencing analyses of mtDNA samples from seven locations within the ROPME sea area (Arabian Gulf, Gulf of Oman, and Arabian Sea). The results indicated a homogeneous distribution consistent with a single intermingling genetic stock. Considering that a few migrating fish could reduce heterogeneity to where genetic drift is undetectable, panmixia could not be conclusively established. The results suggested that adopting a single-stock model and regional shared management were appropriate for sustainable long-term use of the stock. However, more rigorous genetic testing, and mark-recapture experiments to detect spatial movement patterns were recommended to further elucidate any stock substructure.

van Herwerden *et al*. (2006) also developed microsatellite markers for *S. commerson*, and used them in a population genetic study of this species from the Arabian Peninsula. Samples were taken from six sites within four geographic regions: Iran (Arabian Gulf), two sites in northern Oman (Gulf of Oman), two sites in southern Oman (Arabian Sea) and Yemen (Gulf of Aden). The results identified two genetic stocks, one restricted to one locality (Dhofar) in the Arabian Sea, the other widespread with sufficient gene flow between all four regions to prevent regional genetic differentiation from occurring. It was, however, considered advisable to use additional, conventional stock structure assessment methods to determine management strategies as conventional measures of stock structure operate at ecological rather than evolutionary time scales, unlike genetic methods based on neutral markers and genetic drift.

Biology

Age and growth

As a result of the importance of *S. commerson* to fisheries in the GCC, there have been a number of studies relating to the age and growth of this species. These have confirmed the utility of seasonally deposited increments in sagittal otoliths (Figure 5) for demographic investigations in the Arabian Gulf (Grandcourt *et al*., 2005, Brothers and Mathews, 1987) and Gulf of Oman/Arabian Sea (Dudley *et al*., 1992, McIlwain *et al*., 2005).

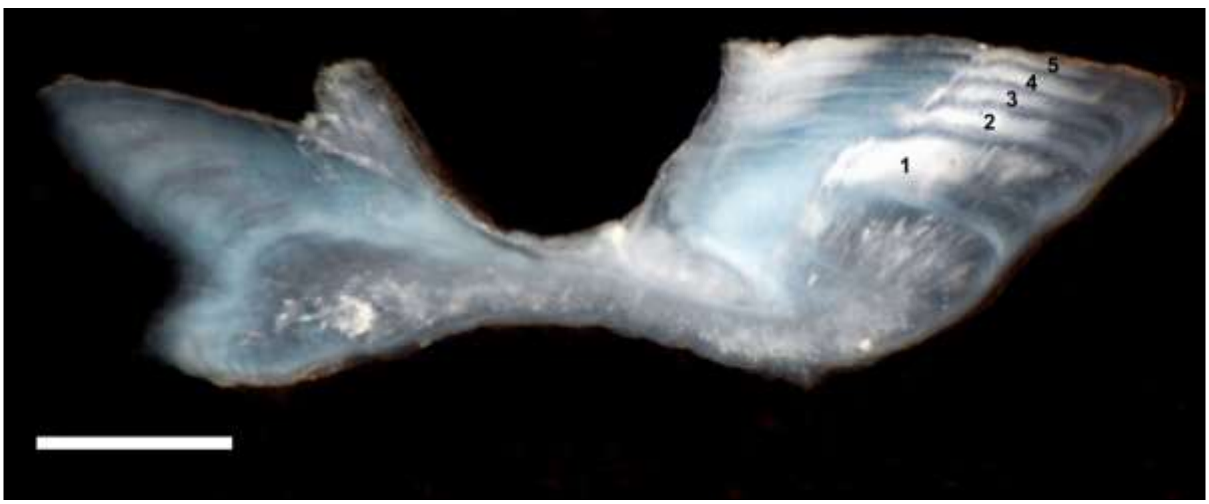

Figure 5 **Photomicrograph of a transverse section through the sagittal otolith of *S. commerson* (128.7 cm LF). Numbers show the position of opaque bands. (Scale bar = 1 mm).** (Source: Grandcourt *et al*. 2005).

The growth of *S. commerson* in the Gulf of Oman was characterized by a very rapid initial increase in size with fish achieving between 100 and 110 cm during the first two years of life (Dudley *et al*., 1992; McIlwain *et al*., 2005). Initial growth was also reported to be rapid in the southern part of the Arabian Gulf with 2 year old fish reaching a mean size of 82.8 cm L_F (±12.7 cm SD) (Figure 5) (Grandcourt et al., 2005). This pattern has also been described for young *S. commerson* from Australia (McPherson, 1992) Kuwait (Brothers and Mathews, 1987) and South Africa (Govender, 1994).

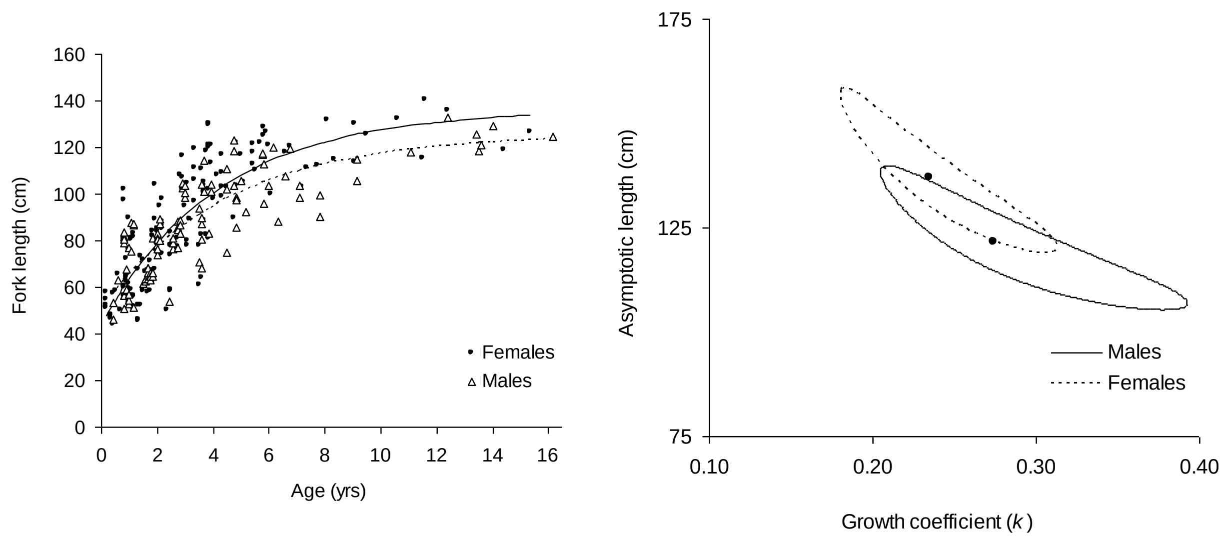

Figure 6 **The von Bertalanffy growth function fit to size at age relationships for *S. commerson* (left) and associated confidence regions (95%) for growth parameter estimates (*k* and *L*∞) (right).** (Source: Grandcourt *et al*. 2005).

Analyses of sex specific growth characteristics in the Arabian Gulf have shown that whilst female *S. commerson* approached their asymptotic size at a faster rate than males, as well as growing to a greater mean length at age, the differences observed were not significant (Figure 6) (Grandcourt *et al*., 2005). In the Gulf of Oman and Arabian Sea, female kingfish have been shown to grow at a slower rate but reach a greater asymptotic length than males (McIlwain *et al*., 2005). Parameters of the von Bertalanffy growth function for *S. commerson* from the GCC are given in Table 1.

The maximum age reported from the Arabian Gulf for *S. commerson* is 16.2 years (Grandcourt *et al*., 2005) and a maximum age of 20 years has been reported by McIlwain *et al*. (2005) from the Gulf of Oman. These values are of the right order compared with that of 17 years for this species in Queensland (Tobin and Mapleston, 2003).

Table 1 Parameters of the von Bertalanffy growth function (*k* and L_∞) for *S. commerson* derived from size-at-age data in the GCC region

VBGF parameter		Sex	Source
k	L_∞ cm (L_F)		
0.24	136.1	Females	Grandcourt *et al*., 2005
0.22	125.6	Males	Grandcourt *et al*., 2005
0.21	138.6	Combined	Grandcourt *et al*., 2005
0.36	138.3	Combined	Dudley *et al*. (1992)
0.22	146.4	Combined	Govender *et al*. (2005)
0.19	151.3	Females	Govender *et al*. (2005)
0.28	134.7	Males	Govender *et al*. (2005)
0.31	140.4	Females	McIlwain *et al*. (2005)
0.60	118.8	Males	McIlwain *et al*. (2005)

Reproduction

Reproductive studies suggest a single spawning period from April to August in the southern Arabian Gulf (Grandcourt *et al*. 2005). The results of Claereboudt *et al*. (2004; 2005), also revealed a single though earlier spawning season in May and June off Oman.

Mean sizes at first sexual maturity for *S. commerson* in the GCC region are given in Table 2. In Oman, females were found to mature at a significantly smaller length and about 2 months earlier than males, spatial variations in maturation were also observed with fish from the Arabian Sea maturing at a smaller and younger size than those in the Gulf of Oman (Al-Oufi *et al*. 2004).

Table 2 The mean size at first sexual maturity (L_m) for *S. commerson* in the GCC region

L_m (cm L_F)	Sex	Source
86.3	Females	Grandcourt *et al*., 2005
72.8	Males	Grandcourt *et al*., 2005
75-80	Combined	Dudley *et al*. (1992)
80.4	Females	Claereboudt *et al*. (2004)
84.7	Males	Claereboudt *et al*. (2004)

Mortality

Total mortality rate (*Z*) estimates for *S. commerson* may be inherently biased upwards due to the differential targeting of younger schooling fish in the region. Estimates of *Z* and the size/age compositions may also have been biased by ontogenetic and/or seasonal migrations (Grandcourt *et al*., 2005). McPherson and Williams (2002) considered that certain gear types resulted in the larger older fish being proportionately higher on fishing grounds than their representation in catches would suggest. Size specific selectivity would explain the small proportion of larger and older fish in the size and age frequency distributions. However, the impact of fishing cannot be discounted, especially given the limited regulation and intensity of fisheries targeting *S. commerson* throughout the region. Particularly given that the high total mortality rate (Z = 0.88 yr^{-1}) derived from the age based catch curve for the southern Arabian Gulf (Grandcourt *et al*., 2005) compares well to the estimates of 0.90 yr^{-1} and 0.89 yr^{-1} for females and males respectively in the waters off Oman (McIlwain *et al*., 2005).

Natural mortality rate (*M*) Estimates of the natural mortality rate by Govender (1995) ranged from 0.45 to 0.55 yr^{-1}. Dudley et al. (1992) estimated the natural mortality rate of *S. commerson* as 0.44 yr^{-1} in the Gulf of Oman and Edwards *et al*. (1985) estimated a rate of 0.38 yr^{-1} for this species in the Gulf of Aden. However, these were derived from the empirical equation of Pauly (1980), which has been shown to overestimate *M* (Newman *et al*., 2000). Al-Hosni and Siddeek (1999) estimated *M* for *S. commerson* in Oman as 0.35 yr^{-1}, 0.64 yr^{-1} and 0.77 yr^{-1} using 3 independent methods based on life history parameters. Estimates of M using the Hoenig (1983) model (0.26 yr^{-1}) (Grandcourt et al., 2005), were considerably lower than other estimates for this species in the GCC region.

Fisheries Oceanography & Ecology

The oceanography of the Arabian Gulf is characterized by extreme conditions, with high seasonal variations in water temperature and salinity. Maximum summer water temperatures exceed 34^{o}C during August and September and surface salinity is high at over 40 ppt. Surface temperatures drop to 17^{o}C during January, giving a seasonal range of some 19^{o}C (Fig. 7). The oceanographic conditions in the Gulf of Oman are less extreme than those in the Arabian Gulf and more oceanic in nature. However, there are large seasonal fluctuations in the temperatures and salinities of inshore surface waters.

The concentration of chlorophyll-*a* declines from March onwards in coastal waters and the waters in the Gulf of Oman have a similar trend of decreasing primary production which reaches extremely low levels by May and June. The abundance of zooplankton in the Arabian Gulf is low in the summer months and increases as waters cool during the autumn. The abundance and distribution of fisheries resources, in particular the small pelagic species, have been shown to be closely associated with the seasonal change in secondary productivity. Consequently, there are large changes in the relative abundance of *S. commerson* in the region in association with seasonal changes in productivity and the associated abundance of prey (Figure 7). Stomach content analysis reveals that the diet is primarily composed of clupeids (sardines and anchovies) (56%) and carangids (10%) (Al Oufi et al., 2004).

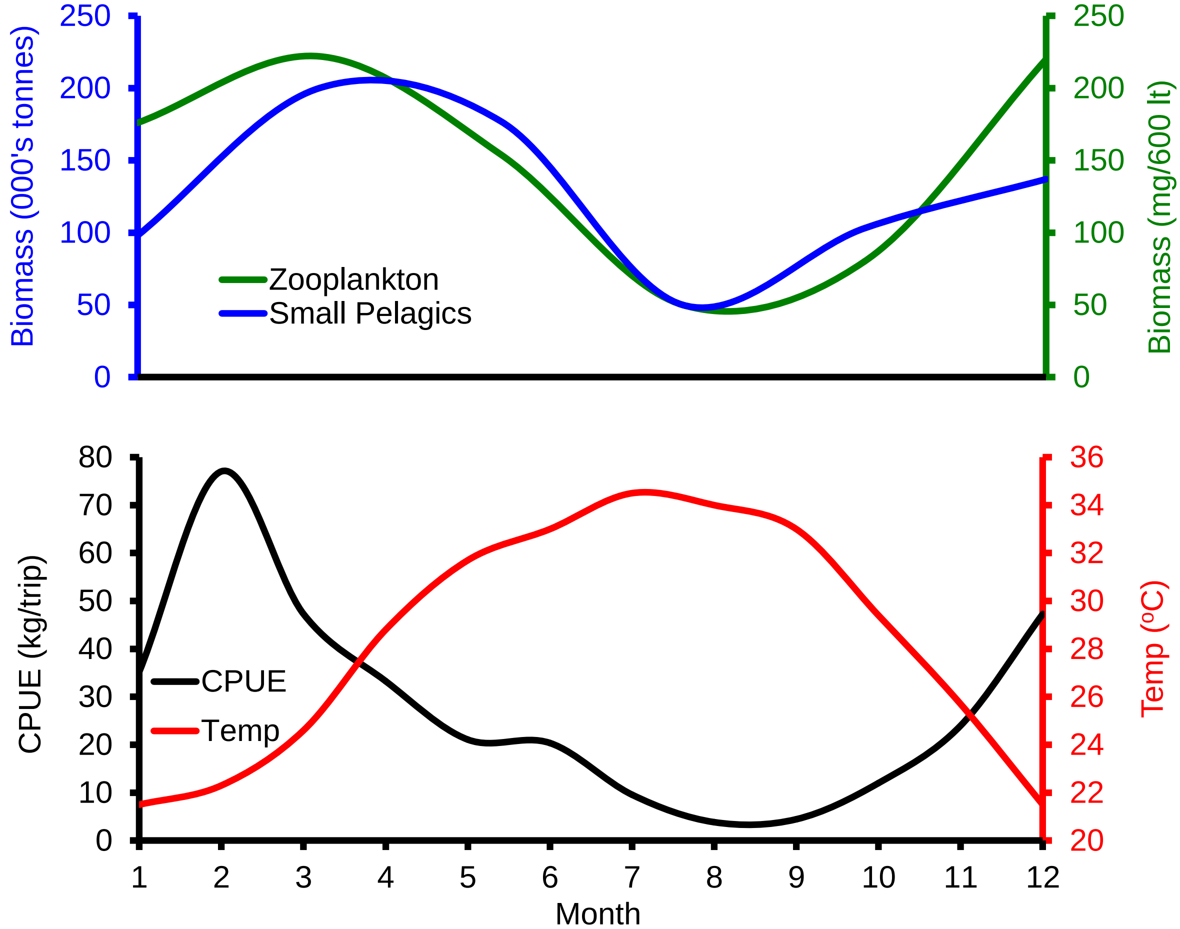

Figure 7 The seasonal abundance of zooplankton and small pelagic species (top) and CPUE of *S. commerson* and surface water temperatures (bottom) in in the Arabian Gulf. (Source: EAD unpublished data)

Stock Assessments & Status

The threat of growth over-fishing and potential of recruitment failure associated with the intensive harvest of immature fish has been of particular concern for *S. commerson* in the GCC region (Al-Kiyumi 2010; Dudley *et al*. 1992; King Fish Task Force 1996). In the Gulf of Oman, there has been a progressive tenfold decrease in yields during recent years (Al-Oufi et al., 2002). The length based assessments conducted by Siddeek and Al-Hosni (1998) and Al-Hosni and Siddeek (1999) indicated that this was a direct result of overfishing.

The yield model for the *S. commerson* fishery in Oman (Dudley *et al*., 1992) revealed that increases in the weight of the total catch (30%) could be obtained by protecting young *S. commerson* and that the necessary protection could be accomplished by regulating stretched mesh sizes to 14 cm. Such a strategy was also considered prudent in terms of enhancing reproductive capacity, predicting a 40% increase in egg production to be associated with the protection of 0-2 year old fish. A more recent age based per recruit assessment (Govender *et al.,* 2005) determined that the Oman fishery is overexploited, with a high chance of recruitment failure in the future. Simulations suggested that closed seasons and minimum size limits may be the most effective means of increasing spawning biomass per recruit. Siddeek and Al-Hosni (1998) also estimated various biological reference points for this fishery based on length–frequency data for the period 1987–1995 and concluded that there was a need to reduce fishing mortality by 17–40%. DeRodellec *et al*. (2001) using a multi-species surplus production model described the dynamics of the large pelagic fishery (kingfish, longfin and Yellowfin tunas) and found that fishing effort needed to be reduced by 60% from its current level and that the kingfish fishery displayed all the "symptoms" of an overfished stock.

Length based cohort analyses and YPR have been conducted for different fleet components in order to develop management options for the *S. commerson* fishery in Oman (Ben Meriem, 2006). The sharp decrease in the number of survivors (only 18% of the recruit numbers reach L_{50}) emphasizes a heavy exploitation of the juvenile fraction of the population and indicates a growth overfishing of the stock (Ben Meriem, 2006).

The results of stock assessments within the Arabian Gulf corroborate findings from the Gulf of Oman. In the southern Arabian Gulf, the annual instantaneous fishing mortality rate of 0.62 year^{-1} was by far in excess of the precautionary target (F_{opt} = 0.13 year^{-1}) and limit (F_{limit} = 0.17 year^{-1}) biological reference points, indicating that the resource is heavily over-exploited. The results suggest that an increase in mesh size regulations for gillnets in combination with a substantial reduction in fishing effort will be required if resource conservation and stock rebuilding objectives are to be achieved (Grandcourt *et al*., 2005).

The regional assessment of Al-Kiyumi (2010) based on the analysis of data from all GCC countries concluded that:

- The kingfish stock in the Arabian Gulf is showing severe stress.
- The drift/set gillnet fishery requires regulation and appropriate management measures to stop growth-overfishing are required.
- Large quantities of immature fish are landed.
- The average length of fish caught is lower than the length at first maturity.
- Fishing mortality (F = 1.09 per year) is much higher than natural mortality (M = 0.5 per year) indicating heavy overexploitation.
- The average annual yield is greater than the MSY estimate for GCC countries.
- Biological reference points indicate the need to reduce fishing mortality.

Management

The kingfish fishery is not currently managed properly in the GCC region where there is growth-overfishing and recruitment failure as a consequence of the intensive harvest of immature fish (Al-Kiyumi, 2010). The level of intervention and management regulations for the *S. commerson* fisheries in the Arabian Gulf, Gulf of Oman and Arabian Sea vary widely among GCC States and even within States at local levels. Some fisheries can be described as 'laisser-faire' with no or extremely limited regulation and monitoring control and surveillance and drift nets are still used in many countries (Claereboudt 2004, Govender, 2005, Hoolihan 2004). In addition, during the same period over which the stock decline has occurred, the numbers of fishermen and size of the fishing fleet has increased dramatically as a direct result of government subsidies (Claereboudt 2004).

Conversely, some jurisdictions have a suite of regulations, in the Emirate of Abu Dhabi in the UAE for example, both drift and set gillnets have been banned as is the use of monofilament and the length of gillnets is constrained to 700 m. There is a seasonal fishery closure between the 30th of April and the 1st of October, which coincides with the spawning season. Fishers may use a maximum of two nets per licensed vessel and there is limited entry to the fishery. Nevertheless, where management initiatives have been implemented, there is no evidence of how effective these have been.

Local and national efforts are undermined by a lack of synergy in management planning and regulation between the GCC States. Given the highly migratory nature of this species, and that the stock is homogenous throughout the Arabian Gulf and Gulf of Oman, it is unlikely that the initiatives of any one of the littoral states alone would be sufficient to achieve resource management objectives. Clearly, a strategic regional approach to the assessment and management of *S. commerson* is imperative in this context (Grandcourt *et al*., 2005).

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