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Growth, Mortality and Reproductive Biology of Narrow-bared Spanish mackerel *Scomberomorus commerson* (Lecepede, 1800) Along the Northern Tanzanian Coastal Waters

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ABSTRACT

Scomberomorus commerson samples were collected monthly from April 2012 to August 2013 in the coastal waters of Dar es Salaam (DSM) and Pangani (PN), Tanzania. Growth parameters which included, mortality and spawning patterns were investigated. The estimated growth parameters of the von Bertalanffy function at DSM site was $L\infty$ = 122.59 cm; K = 0.68. The corresponding parameters for the PN site were $L\infty$ = 122.85 cm; K = 0.3. The total mortality estimates were Z = 2.7 yr^{-1} at DSM and 1.44 yr^{-1} at PN while natural mortality M was 0.74 and 0.43 yr-1, respectively. Fishing mortality (F) at DSM (1.77 yr-1) and PN (0.9 yr-1) was higher than F_{opt} and F_{limit} BRP; indicating that *S. commerson* along the northern coastal waters of Tanzania is being overexpled. Regional investigation of a number of biological population parameters and ichthyoplankton study is needed for a comprehensive stock assessment of *S. commerson*.

Key words: *Scomberomorus commerson*, growth parameters, mortality, biological reference points, Tanzania

1.0 INTRODUCTION

Globally, Narrow bared Spanish mackerel *Scomberomorus commerson* is one of the most important to fish being harvested by fishers both for local and commercial needs (FAO 1999). Due to its socio-economic importance and the need for the future management of marine resources, the biological aspects of *Scomberomorus commerson* such as as growth, mortality and reproduction have been the focus of many past studies (Mehdi et al. 2007; Kaymaram et al. 2010). Many important wild fisheries around the world are severely depleted or have collapsed in recent time due to overfishing and poor stock management (FAO, 2004 and Worm et al. 2006). The Western Indian Ocean (WIO) region has rich diversity of marine fish resources which are to be explored and exploited on sustainable basis taking into consideration that elsewhere world-wide marine ecosystem is under greatest threat caused by human (Worm et al. 2006) and/or natural factors.

Scomberomorus commerson which contributes significantly to the commercial and artisanal fisheries needs in the WIO region (Kimaro, 1993) is reported to be highly threatened by anthropogenic activities, which include: habitat destruction, pollution, over-fishing and bad fishing practices. Studies conducted in Tanzania, revealed that S. *commerson* is the second most significant group of large pelagic fish in Tanzania marine waters (Kimaro (1993). Due to the above anthropogenic threats its catch have been declining over the years from 2730.4 tones in 1990 to 593.6 tones in 1993, with a low catches of 100.5 tones in 1992 (Kimaro, 1993). The demand for *S. commerson* is particularly increasing in Tanzania and in the WIO region, resulting in an increase in its fishing activities. High economic value caused by development of tourism industry and population increase has increased pressure to the exploited stock consequently leading to the decline in numbers and biomass landed. Elsewhere in Queensland waters, the combined commercial and recreation take of *S. commerson* has put significant pressure on stocks, leading to a possible decline in the spawning stock abundance (McPherson and Williams, 2002). While the stock status of *S. commerson* is not known in the WIO region, important biological information such reproductive characteristics, growth and mortality parameters are crucial for sound management of important fishery resources. Description of growth parameter, mortality rate and reproductive biology was a key focus of this study, since this information is required for stock assessment models and for management controls.

2.0 MATERIAL AND METHODS

2.1 Growth Parameters

Length and weight fish data was collected randomly from two landing sites: Dar es Salaam (DSM) and Pangani (PN), from April 2012 to September 2013 (Fig. 1). The total length and weight were measured to the nearest cm and gram, respectively. The length frequencies were grouped in 2 cm intervals. The length-frequency data was used to calculate the von Bertalanffy growth function (*K*) and the asymptotic length ($L\infty$) by model progression analysis using the program ELEFAN 1 within the FiSAT II program. Total mortality (Z) was estimated from the length-converted catch curve using FiSAT II software. Natural mortality (*M*) was calculated according to Pauly (1980) formula: $\text{Log } M = 0.0066 - 0.279 \text{ Log } L\infty + 0.6543 \text{ Log } K + 0.4634 \text{ Log } T$; where *T* is the mean sea surface temperature of water, which was considered to be 27.50^0C. Since *Scomberomorus* species are considered schooling migratory fish, some researches (e.g. Pillai et al. 1993) have multiplied the *M* values by 0.8 to reduce bias: 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 0.5 (L_{50}), 0.75 (L_{75}), and the size at which fish were fully recruited to the fishery (L_{100}). 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} = 0.5 M and F_{limit} = 2/3 M, following Patterson (1992).

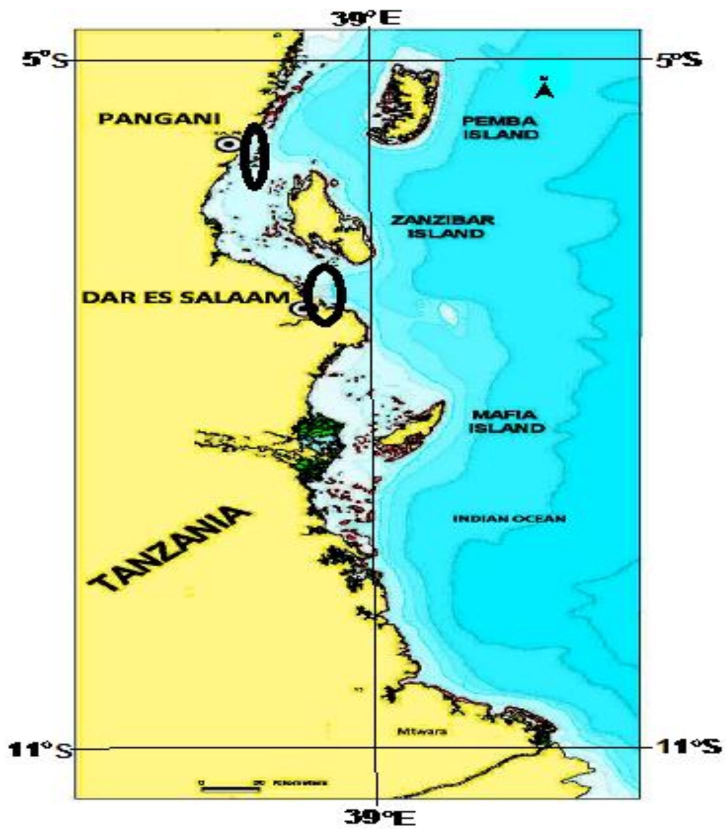

Fig 1: The map of coastal Tanzania showing the location of the sampling sites

2.2 Reproductive Characteristics

The maturity development stages were assessed according to the criteria modified from West (1992). The mean size at first maturity (L_{50}) was estimated for both sex by fitting the logistic function to the proportion of mature fish in 20 cm (FL) size categories and determined as the size at which 50% of individuals were mature (King, 2005): P =1/ (1+exp (-r (L-LM50)), where: *P* is the proportion of sexually mature individuals by length *L* and r the slope of the curve. Monthly gonad somatic index means (GSI) were calculated according to Claereboudt et al. (2005) formula: GSI = Mass of gonad (g)/gutted fish mass (kg). The timing and frequency of spawning were established by plotting GSI against the sample period.

RESULTS

Growth Parameters

The length frequency data was analyzed to determine the growth parameters using the von Bertalanffy equation (Fig. 2). The growth parameters estimated were as follow: $L\infty$ = 122.59 cm, k = 0.68 yr-1, t_0 = 0.17 in DSM and $L\infty$ = 122.85 cm, K = 0.3 y-1, t_0 = 0.15 in PN. The value of $L\infty$ was higher than the maximum observed total length of 119 cm (Fig. 2) in both sites. The results indicated that the growth patterns of *S.commerson* along the northern parts of Tanzania coastal waters are similar.

Mortality and Fishery Assessment

The length-converted catch curve of *S. commerson* population sampled from PN and DSM is shown in Fig. 3. The estimated annual instantaneous rate of natural mortality (*M*) and total mortality (*Z*) was 0.93 and 2.7 in DSM and 0.54 and 1.44 yr-1 in PN. The black circles calculated the *Z* through the least square linear regression while blank circles represent the points either not fully recruited or very close to $L\infty$. The value of *M* was multiplied by 0.8 which is the annual natural mortality as recommended by Pauly (1983) for pelagic species and a coefficient value of 0.74 yr^{-1} in DSM and 0.43 yr^{-1} in PN were estimated. Furthermore, the fishing mortality (*F*) and exploitation ratio (*E*) were estimated at 1.77 yr-1 and 0.66 for DSM and 0.90 yr-1 and 0.62 for PN. The ratios of M/K were 1.8 at PN and 1.37 at DSM which are consistent with the

Beverton and Holt (1957) range of 1.12 to 2.50. The mean size at first capture (L_c) was 51 cm *TL* while the size at capture at a probability of 0.75 (L_{75}) was 76 cm *TL*. Fishes were fully recruited to the fishery at a size that was considerably higher (L_{100} = 82 cm *TL*) than the mean size at first sexual maturity for females (75 cm *TL*). Yield per recruit (Y'/R), biomass per recruit (B'/R), and exploitation ratio at E-50 and maximum exploitation ratio at DSM was 0.06, 0.13, 0.36 and 0.66, 0.59 while at PN the estimated value was 0.042, 0.11, 0.28 and 0.62, respectively.

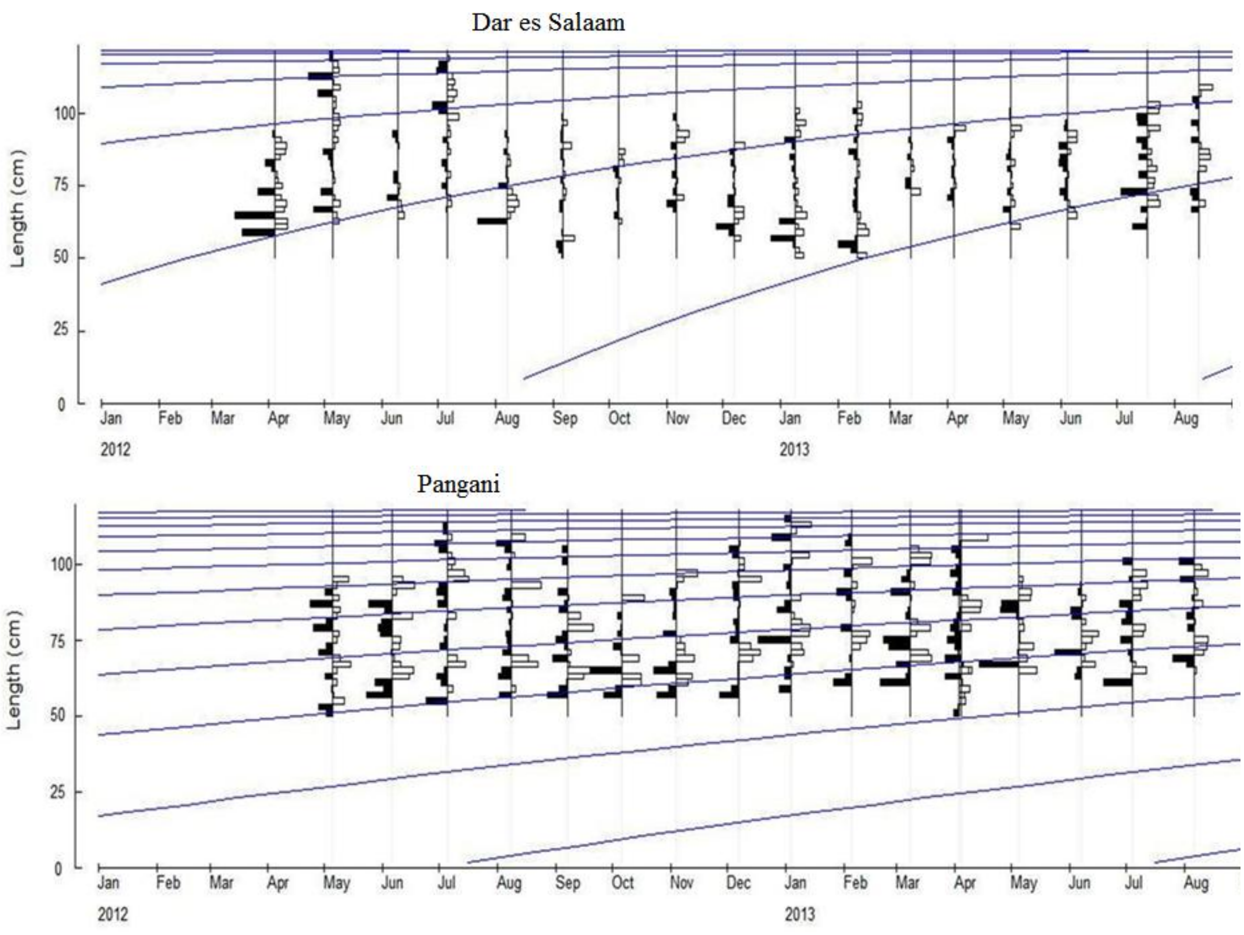

Fig 2: The von Bertalanffy growth curves of *Scomberomorus commerson* from DSM (top) and PN (bottom), Tanzania as superimposed on the length-frequency histograms

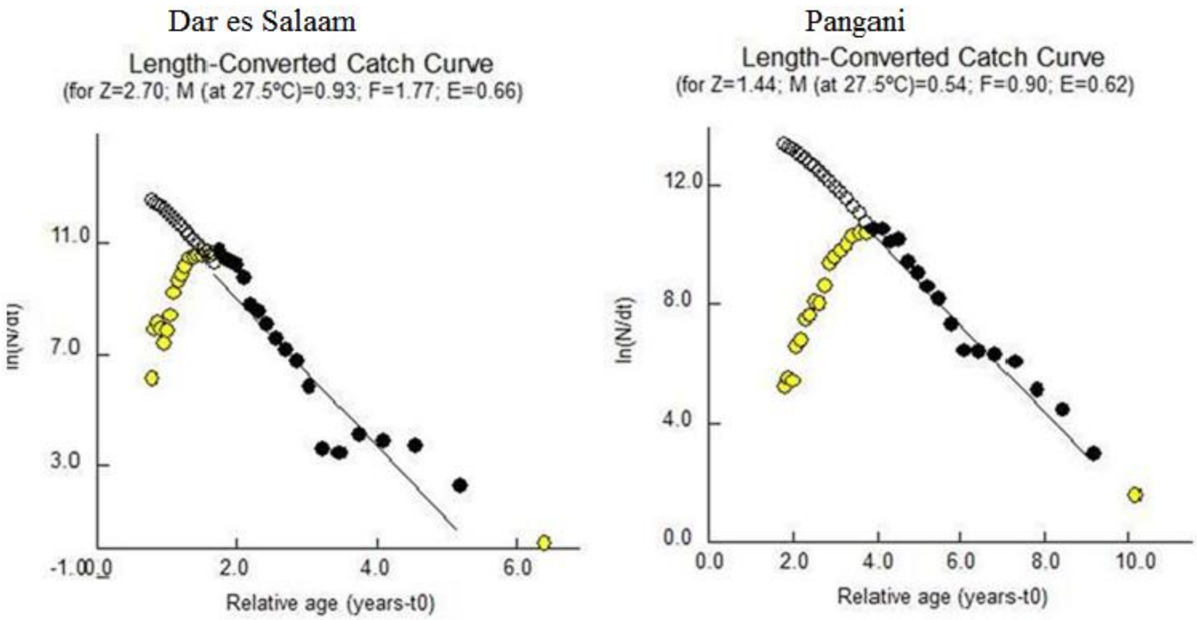

Fig 3: Length converted catch curve of *S. commerson* in northern Tanzania coastal waters (yellow circles refer to length classes not fully recruit to the fishery)

The estimated precautionary F_{opt} and F_{limit} biological reference points (BRP) was 0.37 and 0.49 yr^{-1} in DSM and 0.25 and 0.29 yr^{-1} in PN. Fishing mortality (*F*) in DSM (1.77 yr-1) and PN (0.9 yr-1) was higher than F_{opt} and F_{limit} BRP in both study areas; indicating that *S. commerson* in the coastal waters of Tanzania is overexploitation.

Spawning Patterns and Fish Condition

Analysis of gonads showed that females and males of 51 to 53 cm *TL* at immature stage I were recorded in April and May, while individuals at maturing stage II appeared in April, May, September and October. Individual females and males at mature stage III and at spawning condition *i.e*. stage IV were dominant in June to August and November to March. Only few individuals were caught in the period spanning from February to April. Analysis of the gonads maturity revealed that females at DSM reached maturity at 74 cm *TL* as compared to males which obtained maturity at 77 cm *TL*. Females and males in PN attained maturity at 75 and 79 cm TL, respectively. Thus, the present study indicated that females attained maturity earlier than males at both sites. Analysis of the fish conditions (*K*) at both sites indicated that fish were in better condition during the period spanning from June to August and December to March for both male and female individuals (Fig. 4 and 5). Similar trends were shown by the gonado-somatic index (GSI); indicating that the health conditions of fish improved with increasing values of GSI (Fig. 4). Analysis of the spawning pattern along the northern Tanzania coastal waters revealed two breeding spawning cycles of *S. commerson* with two different trends.

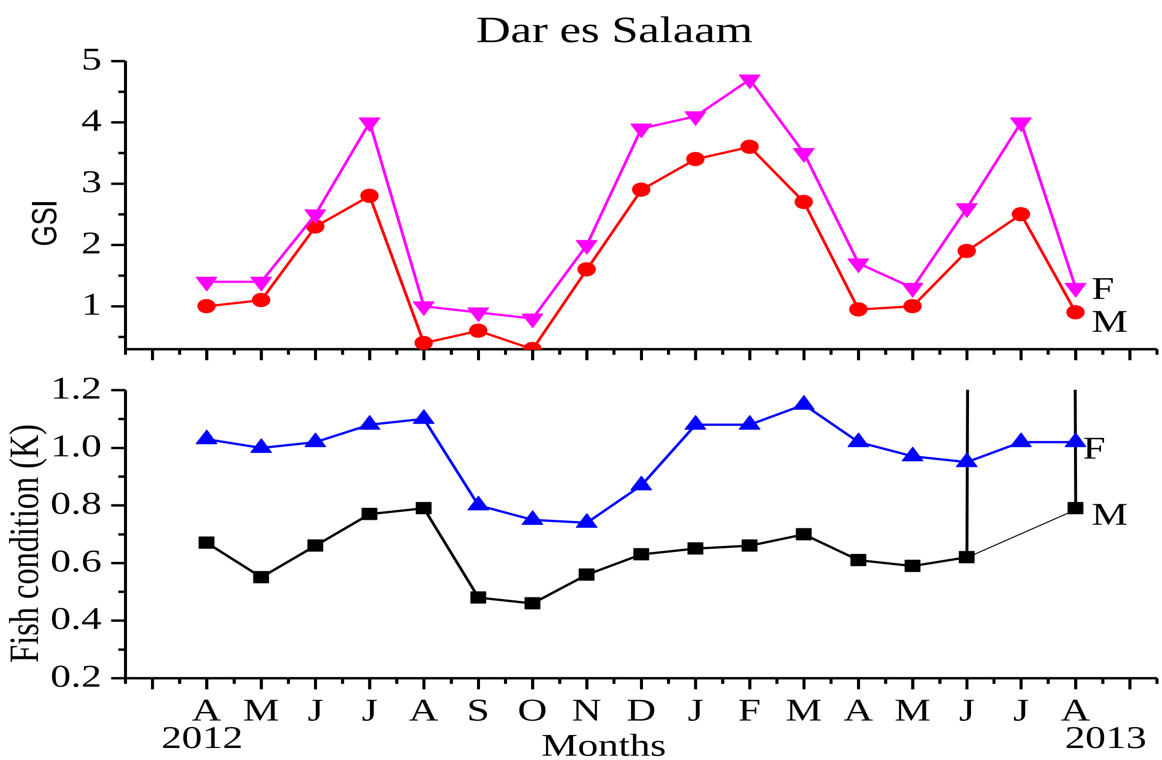

Fig 4: Variations in the spawning patterns of *S. commerson* with body condition (*K*)

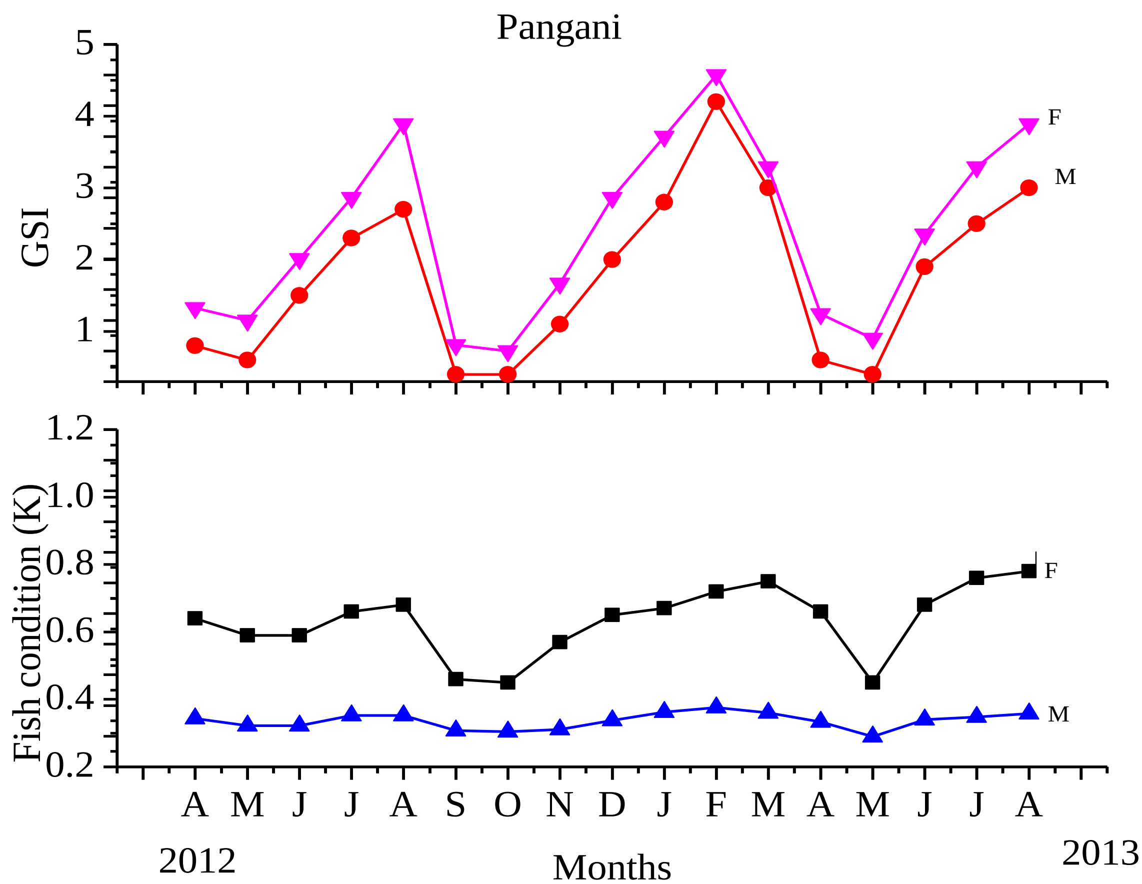

Fig 5: Variations in the spawning patterns of *S. commerson* with body condition (*K*)

The PN population was characterized by a short spawning period, spanning from June to August (with a peak in August), followed by a long spawning period, spanning from December to March (with a peak in February). On the other hand, the spawning cycle in DSM was noticed from June to July (with peak in July) and from December to March with peak in February (Fig. 5).

DISCUSSION

Growth Parameters and Stock Status: Understanding the stock status can provide guidance for management of the growing fisheries of *S. commerson* in the WIO region. During the present study, the Electronic Length Frequency Analysis (ELEFAN) program was used to fit the von Bertalanffy growth curve to estimate the growth constants (L_∞, K and t_o) (Devaraj, 1981; Dayaratne, 1989b; Dudley et al. 1992). The estimated value of L∞ varied from 122.59 cm TL in DSM and 122.85 cm TL in PN coastal waters, Tanzania were not comparable to calculated values of the same species in India, Saudi Arabia Red Sea, Gulf of Eden Yemen and Djibout (Table 1). However, our results (for L∞) were consistent with the published range derived from von Bertalanffy growth equation in Oman (Table 1). The estimated value of *K* (growth rate) which varied from 0.3 to 0.68 in DSM and PN were consistent with those for *S. commerson* reported in other studies (Table 1). Age at zero length (t_0) was found to be negative indicating that; juveniles grew more quickly than the predicted growth curve for adults (King, 1995). However, taking into consideration that S. *commerson* is a pelagic migratory fish with a schooling behavior, the factor which could affect the representativity of the samples as reported for the same species by Kedidi et al. (1993).

The values of the growth parameter *M* for *S.commerson* in the present study (Table 1), was consistent with that estimated by Pillai et al. (1993) and Dayaratne (1989) in Southwest India and Sri Lanka. The population of *S. commerson* at DSM had higher mortality as compared to the population of *S. commerson* PN since *M* of a fish is directly correlated with the growth coefficient '*K*' but inversely related with L∞ and the life span (Beverton and Holt, 1957). The value of *E* and *F* of S. *S. commerson* at DSM were comparable to those reported elsewhere in the world Oceans (Table 1).

Table 1: Summary of the growth parameters, mortality, fishing and exploitation rates of *S. commerson*

Author	Region	L∞	K	t_o	Z	M	F	E
Present study	Pangani Tanzania	122.59	0.68	-0.28	2.7	0.74	1.77	0.66
	Dar es Salaam Tanzania	122.85	0.3	-0.34	1.44	0.43	0.9	0.62
McIlwain et al. 2004	Oman	140.44 (FL-♂)	0.309	-1.501				
	Oman	118.80 (FL-♀)	0.595	-0.73				
Grandcourt et al. 2005	Oman	138.6 (FL)	0.21	-1.9				
Devaraj, 1981	South and west India	208.1 TL	0.18	-0.16				
Pillai et al., 1993	Southwest India	146 TL	0.78		3.288	0.78	2.508	0.76
Thiagarajan, 1989	South east India	177.5 FL	0.38	-0.23				
Dudley et al. 1992	Oman	226 FL	0.21	-0.85				
Kedidi and Abushusha, 1987	Saudi Arabian Red Sea,	153.3 TL	0.38	-0.26	1.04	0.46	0.58	0.56
Bouhlel, 1985	Djibouti, Ford Watford pl	151 TL	0.21					
Edwards et al., 1985	Gulf of Aden, Yemen	230.3 FL	0.12	0.01				
Dudley and Aghanashinikar, 19	Oman				1.151	0.526	0.625	0.543
Kedidi et al. 1993	Saudi Arabian Gulf	183.6 TL	0.26		0.758	0.36	0.398	0.525
Dayaratne, 1989b	Sri Lanka	146 FL	0.37		1.63	0.605	1.03	0.63

Fishing mortality (*F*) in DSM (1.77 yr-1) and PN (0.9 yr-1) was substantially greater than both F_{opt} and F_{limit} BRP in the study areas; indicating that *S. commerson* in the coastal waters of Tanzania is heavily overexploited. The present findings are important to fisheries management authorities in Tanzania as they suggest that in addition to a revision of mesh size regulations, a substantial reduction in fishing effort is required if sustainable utilization are to be achieved.

Reproduction

The present study observed that fish obtained maturity at a length ranged from 74 to 79 cm TL. The results are comparable to that of Devaraj (1983) which estimated the size at first sexual maturity 75 cm in the northern Indian Ocean as well as 75-80 cm *FL* given by Dudley et al. (1992) for males and females combined off Oman. Claereboudt et al. (2004) estimated the size at first sexual maturity (also off Oman) at 80.4 cm FL for females. Also *Scomberomorus commerson* has been found to mature between 70 – 80 cm FL off Madagascar, Papua New Guinea, Fiji and north eastern Australia (McPherson, 1993). Studies by Begg (2005) revealed that maturation like other life history traits tends to express the interaction between the genetic settings and environmental influences, and thus provide evidence of geographic or reproductive isolation of fish population. Also Rose et al. (2001) reported that temporal trends in maturation could be caused by density dependent effect that arises from food limitation, thus regulates fish population growth.

The study observed two reproductive cycles; short spawning from June to July with peak in July and the long spawning cycle, spanning from December to March (with a peak in February) in DSM site. Similarly, two spawning periods were noted at PN; the short spawning running from June to August (with a peak in August) and a long spawning period running from December to March (with a peak in February). Our observed spawning period in Tanzania is not similar to that reported by Claereboudt et al. (2004) who noted single though earlier spawning season in May and June for king fish off Oman. Devaraj (1983) established three distinct spawning periods between January and September in the waters off the southern coast of India. Also Nzioka (1991) reported reproductive activity during year with two peaks in May and October in coastal water in Kenya. Differences in spawning cycle may be attributed to seasonal changes in water temperature and food availability as reported in other marine teleosts by Bye (1990). The body condition of fish correlated with the gonad somatic index; which is an indication that environmental variables such as water temperature, currents, winds and nutrients during the spawning months of June to July and December to March at DSM and June to August and December to March in PN are highly favorable for the fish to spawn. Wind patterns analysis along the coast of Tanzania by Mahongo et al. (2011) indicated that highest wind speeds during northeast monsoon are experienced during December to February (with peak wind speeds in

January/February) and for southeast monsoon, May to October (with peak wind speeds in June/July). Strong winds tend to enhance the vertical mixing of the water column, thereby allowing for the nutrients far deep along the water column to come to the surface and vice versa.

Recommendation

Apart from limited length, genetic, otolith, and catch-and effort data analyses, nothing concrete is known about the life history of *Scomberomorus commerson* in many countries. Spawning areas, larval and juvenile distribution, and adult migration are largely not investigated in many countries in the WIO region. Regional investigations of a number of biological population parameters are needed for a comprehensive stock assessment. Ichthyoplankton study is crucial for the identification of spawning areas, spawning intensity and frequency, and egg and larval distribution in space and time. This calls for a systematic gonad sampling for monitoring of seasonal growth, mortality and reproduction trends.

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