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Morphometric Relationship and Condition Factor of *Siganus stellatus, S. canaliculatus and S. sutor* (Pisces: Siganidae) from the Western Indian Ocean Waters

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Abstract

The rabbitfishes (Pisces: Siganidae) have long been considered good candidates for aquaculture. Some biological attributes including morphometric relationships (length-length, length-weight) and condition factors of three siganids of the Western Indian Ocean were estimated over peak April-August monsoon season in Southcoast Kenya. Specimens were caught using basket traps "malema", one of the main gears in the traditional fishery. A total of 64, 260 and 736 specimens of *Siganus stellatus, S. canaliculatus* and *S. sutor* were recorded, with mean±standard error for total length (TL) as 16.0±0.6cm, 22.5±0.3cm and 26.5±0.2cm with corresponding wet body weights (BWs) of 71.28±8.53g, 158.58±6.45g and 258.80±4.30g respectively. TL-BW relationships were best expressed by $\log_{10}BW=2.597\log_{10}TL-1.356$ for *S. stellatus,* $\log_{10}BW=2.800\log_{10}TL-1.635$ for *S. canaliculatus* and $\log_{10}BW=2.716\log_{10}TL-1.484$ for *S. sutor* with relative condition factors expressed by $Kn = BW/ [(4.41x10^{-2}) (TL^{2.597})]$, $Kn = BW/ [(2.32x10^{-2}) (TL^{2.800})]$ and $Kn = BW/ [(3.28x10^{-2}) (TL^{2.716})]$ for the three species respectively. TL and BW were significantly correlated with *K*n and *K*. To the best knowledge of the authors, this study provides the first L-W relationship and *K*n data for *S. stellatus* within the species geographical distribution. The overall results and equations provide useful simple tools for *in-situ* gauging of overall health of wild siganid populations in Southcoast Kenya for fisheries management and assessment of potential aquaculture species.
Key words: condition factor, morphometric relationship, Siganidae, Southcoast Kenya, Western Indian Ocean,

Introduction

Morphometric relationships including length-length (L-L) and length-weight (L-W) relationships and relative *K*n and Fulton's K condition factors are important biological parameters for fishes, from which the condition of stocks health of fish populations can be deduced (BAGENAL and TESCH 1978). These parameters are also invaluable in the selection of species for aquaculture.

The family siganidae, comprised of rabbit fishes and spinefoots inhabit tropical

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and subtropical Indo-Pacific regions mainly within sea grass beds at <15m water depths (JONES 1981). The members are almost all marine except *Siganus vermiculatus* which is brackish, and are widely distributed in the tropical Indo-Pacific and eastern Mediterranean (WOODLAND 1990). Ecologically, these diurnal herbivores are important in keeping filamentous and leafy algae from smothering corals (JOHNSON and GILL 1998) and form key target species for the artisanal fisheries of the East African coasts (GUARD 1999). Together with lethrinids, siganids constituted ~31% of the total reef fish landings along the Kenya coast over the last five years in the 1990's (FAO 1998).

The Kenya coast, part of the wider Western Indian Ocean (WIO) marine eco-region extends from Vanga (Tanzania border, at 4.663°S and 39.215°E) to Kiunga (Somalia border, at 1.663°S and 41.557°E), supporting an estimated coastal population of 2.49 million people ((HORRIL and KAMAU 2001). Five siganid fishes; *Siganus stellatus* (FORSSKÅL 1775), *S. luridus* (RUPELL 1928), *S. canaliculatus* (PARK 1797), *S. argenteus* (QUOY and GAIMARD 1885) and *S. sutor* (VALENCIENNES 1835) are common in the inshore waters with *S. sutor* ('tafi') being by far the most abundant in the artisanal catch (NTIBA Unpubl.).

The siganids of the WIO region are fairly well studied (GEORGE 1972, BRYAN *et al.* 1975, GUNDERMANN *et al.* 1983). Localized studies show two spawning seasons in January/February and May/June off the Kenyan and Tanzania waters respectively (De SOUZA 1988, NTIBA and JACCARINI 1990, KAMUKURU 2006). However, species-specific morphometric analysis (L-L and L-W relationships) and condition factor (relative *K*n and Fulton's *K*) studies for these siganids of the WIO waters have received little attention. Consequently, such information gaps have led to lack of clearly defined stock management strategies. Further, lack of significant sexual differences in siganids also makes interpretation of body condition factors difficult (THRESHER 1984). However, relative condition *K*n remains a practical tool that biologists and managers can use to gauge the overall health of fish stocks regardless of the underlying assumptions and limitations, providing an alternative to the expensive *in-vitro* proximate analyses of tissues (SUTTON *et al.* 2000). The present paper provides information on L-L and L-W relationship parameters and body condition factors of three common species; *Siganus stellatus, S. canaliculatus* and *S. sutor* from the artisanal fisheries of the WIO waters of Kenya, sampled during peak southeast monsoon (SEM) season, April through August, 2007.

Materials and Methods

Study sites

Three study sites; Diani, Msambweni and Shimoni were selected for this study on the Diani-Vanga coastal stretch (Fig. 1) based on annual fish landings with preference for fishing villages under the beach management program of the Fisheries Department, Kenya. The Diani site straddling at 4.296°S and 39.590°E had six fish designated landing beaches; Congo beach, Southern palms, Trade winds, Mwaepe, Mvuleni, and Mwanyaza. Sampling was conducted on the last three landing beaches. The Msambweni site, straddling at 4.472°S and 39.473°E with two designated landing beaches; Mwaembe and Mkunguni borders Diani site to the south. The site has a fringing reef 0.5-1.5 km offshore with shallow lagoons, and a reef flat that exposed in some places during low tide, sloping down to about 30m at 2km offshore. The last site, Shimoni, at 4.648°S and 39.380°E lies within the Funzi bay complex bordering Msambweni to the north and Vanga to the south. Four landing beaches were sampled in this stretch; Kibaoni, Kijiweni, Nyuli and Kibuyuni making a total of 9 landing beaches sampled along the Southcoast Kenya during the present study.

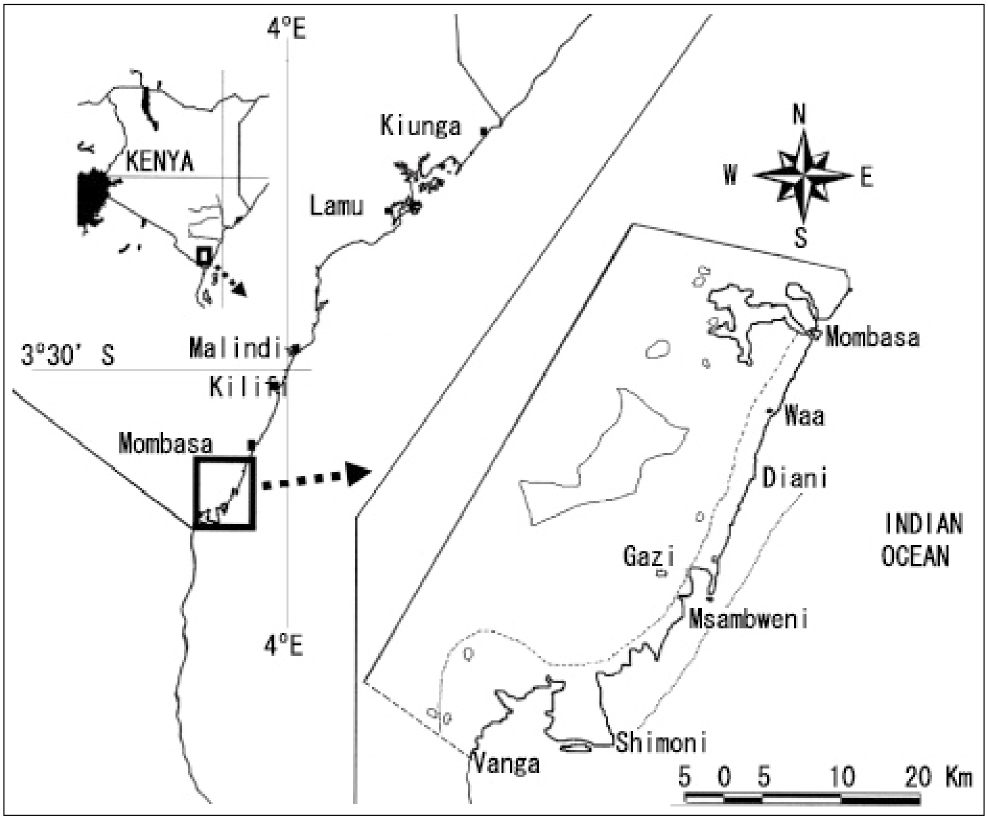

Fig. 1. A map of Diani, Msambweni and Shimoni sites of the Western Indian Ocean waters of Kenya in the present study of Siganus stellatus, S. canaliculatus and S. sutor (Pisces: Siganidae), April through August, 2007.

Sampling procedures and data analyses

Fish sampling was conducted using 10 baited traditional basket traps, "malema" common in the traditional artisanal fishery (Fig. 2). The traps, hexagonal in shape measuring 1.5m diagonally, 20cm height and 10cm at mouth opening, are fabricated out of sticks and reeds. The traps were baited with seaweeds before setting daily, for 5

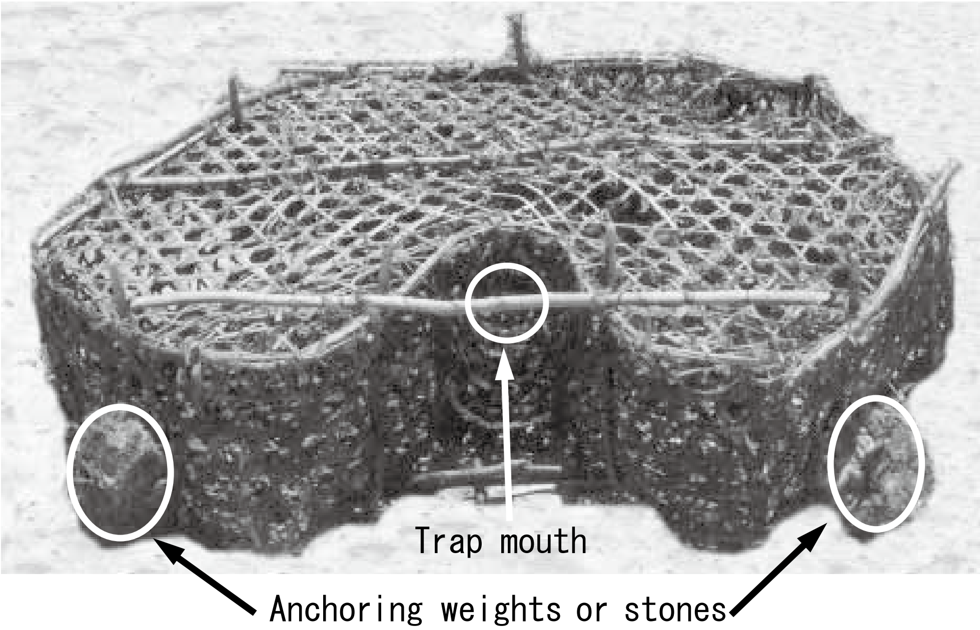

Fig. 2. Traditional basket valve traps “malema” of the traditional fishery used in the present study of Siganus stellatus, S. canaliculatus, and S. sutor (Pisces: Siganidae) in Diani, Msambweni and Shimoni sites of the Western Indian Ocean waters of Kenya in the present study, April through August, 2007. The traps measure 150cm diagonally, 20cm height and 10-15cm mouth diameter and are anchored by a single stone on each side.

days every month over a period of five months from April though August, 2007. The fish samples were sorted to family level and all siganids specimens selected and further identified to species level for morphometric measurements. Total length (TL), from tip of snout to tip of caudal fin and standard length (SL), from tip of snout to posterior end of last vertebra were measured to the nearest 0.1cm using a graduated measuring-board while wet body weight (BW) was measured to the nearest 0.01g using an electronic balance (VIBRA AJ4200CE, Gemini, BV).

In order to examine the morphometric changes occurring with increases in body size, the relationships between TL and SL were calculated using the linear relationship equation SL = $a + b$TL. A plot of $\log_{10}$TL against $\log_{10}$BW for each species by study site was used to determine the intercept and slope parameters a, and b (HAYES et al. 1995) of the equation. The relative condition factor *K*n for each individual (based on sample size *n*) was calculated according to Le CREN (1951) equation $K\text{n} = \text{BW}/a\text{TL}^b$, where BW and TL are the wet body weight and total length respectively. Fulton’s condition factor *K* was calculated using the equation $K = 100 \times (\text{BW}/\text{TL}^3)$. Pearson’s correlation coefficients (as coefficient of determination, r^2) were determined for analyses of the relationship between the morphometric indices (*K*n and *K*) with TL and BW.

Results

Species composition

In the present study, a total of 1060 siganids ranging from 11.2 to 44.8cm TL were caught using set traditional basket traps "malema" in the artisanal fisheries of the Western Indian waters of the Diani, Msambweni and Shimoni, Southcoast Kenya. Three species, *Siganus stellatus, S. canaliculatus* and *S. sutor* were encountered in the samples, accounting for 64, 260 and 736 of the fish caught respectively. *Siganus stellatus* recorded the lowest catch representing only 6% of the total siganid catch. No specimens were recorded from the Diani site. *S. canaliculatus* was the most widely distributed, recording specimens from all the study sites. There was unexplained absence of *S. sutor* specimens from Msambweni although this site lies centrally sandwiched between the other two sites. Moreover, the species accounted for >69% of the total catch, distributed in both Diani and Shimoni at 45.7% and 54.3% respectively.

Length-frequency distribution

The results of the morphometric measurements for the three species are shown in Table 1. In *S. stellatus*, 64 specimens pooled from Msambweni and Shimoni samples recorded 16.0±0.6cm TL. All the recorded specimens were mainly below the 18.0cm length class (Fig. 3). The Shimoni sites recorded 16.2±0.7cm TL compared to 14.0±0.4cm in Msambweni but the differences were statistically insignificant (P = 0.739, U-test).

In *S. canaliculatus*, a total of 260 specimens were recorded from all the three sites

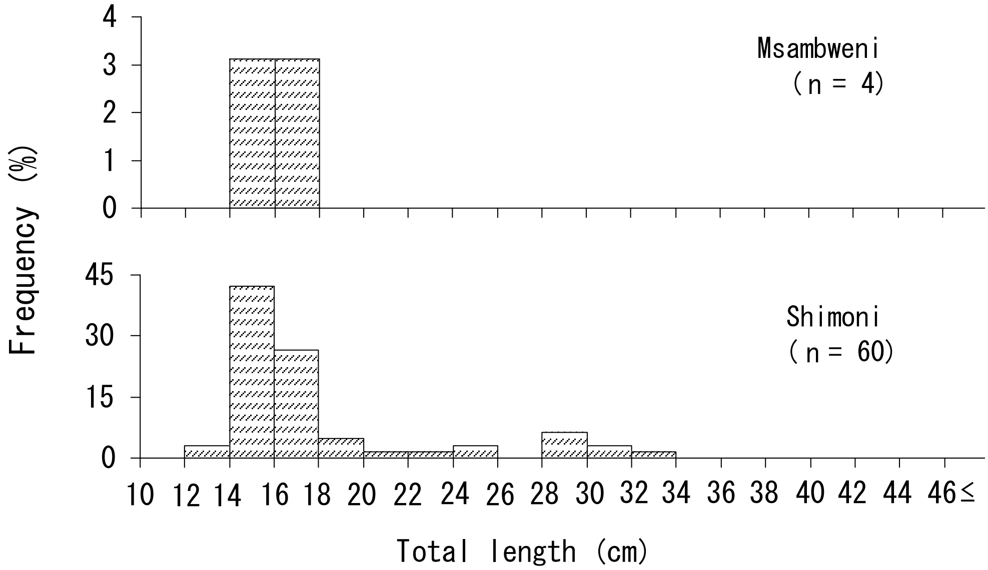

Fig. 3. Total length frequency distribution for Siganus stellatus in Msambweni and Shimoni sites of the Western Indian Ocean waters of Kenya in the present study, April through August, 2007. n = samples size.

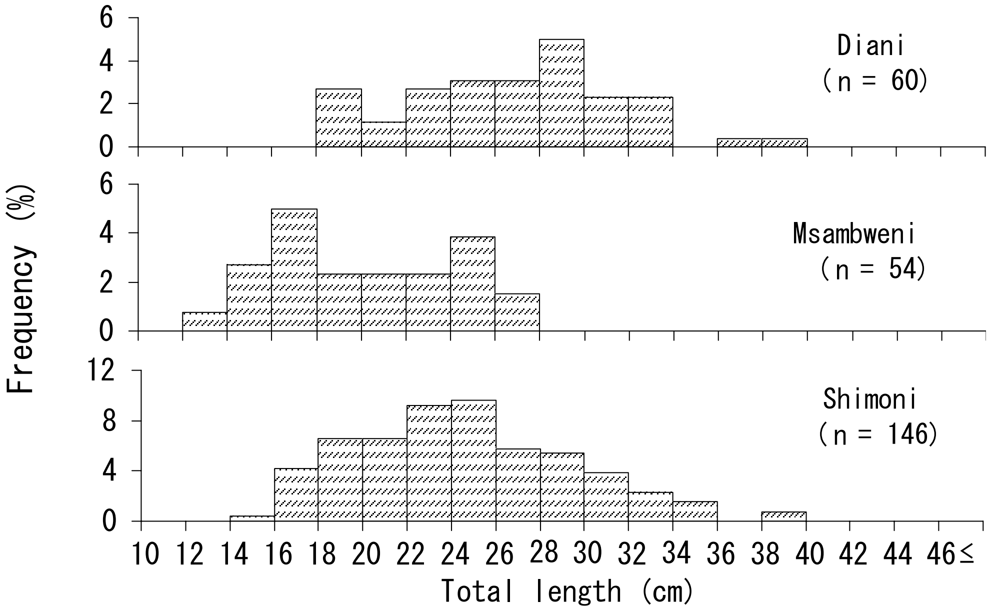

Fig. 4. Total length frequency distribution for Siganus canaliculatus in Diani, Msambweni and Shimoni sites of the Western Indian Ocean waters of Kenya in the present study, April through August, 2007. n = samples size.

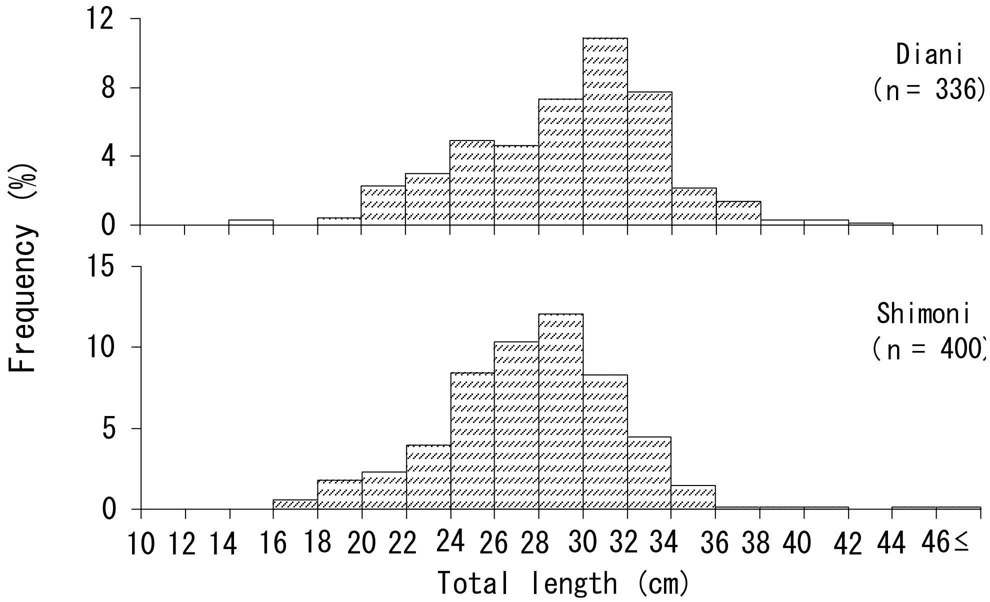

Fig. 5. Total length frequency distribution for Siganus sutor in Diani and Shimoni sites of the Western Indian Ocean waters of Kenya in the present study, April through August, 2007. (n = samples size).

with mean 22.5±0.3cm TL. A clear unimodal distribution was noted in *S. canaliculatus* at Shimoni site although the 34cm-35.9cm and 34cm– 37.9cm size classes were absent in both Diani and Shimoni (Fig. 4). Similarly, the 28.0cm+ TL size class was

Table 2. Overall length-length (SL-TL) and length-weight (TL-BW) relationships and relative condition factor (*K*n) equations, and coefficient of determination (r^2) for *K*n and *K* with total length (TL, cm) and wet body weight (BW, g) for *Siganus stellatus, S. canaliculatus* and *S. sutor* (Pisces: Siganidae) in Diani, Msambweni and Shimoni on the Western Indian Ocean waters of Kenya in the present study, April through August, 2007

Species	*n*	SL-TL relationship	TL-BW relationship	*K*n	r^2, for correlation between			
					*K*n-TL	*K*n-BW	*K* -TL	*K* -BW
Siganus stellatus	64	SL = 0.867 TL -1.544 (r^2 = 0.988)	BW = (4.41 x 10^{-2})($TL^{2.597}$) (r^2 = 0.989)	*Kn= BW/[(4.41x10^{-2})(TL$^{2.597}$)*	0.349*	0.345*	0.667*	0.648*
Siganus canaliculatus	260	SL = 0.849 TL -1.121 (r^2 = 0.982)	BW = (2.32 x 10^{-2})($TL^{2.800}$) (r^2 = 0.973)	*Kn= BW/[(2.32x10^{-2})(TL$^{2.80}$0)*	0.130*	0.205*	0.167*	0.069*
Siganus sutor	736	SL = 0.824 TL -0.220 (r^2 = 0.943)	BW = (3.28 x 10^{-2})($TL^{2.716}$) (r^2 = 0.909)	*K*n= BW/[(3.28x10^{-2})($TL^{2.716}$)	0.009*	0.141*	0.097*	0.001*

* shows significance (*P* 0.01), *n* = samples size

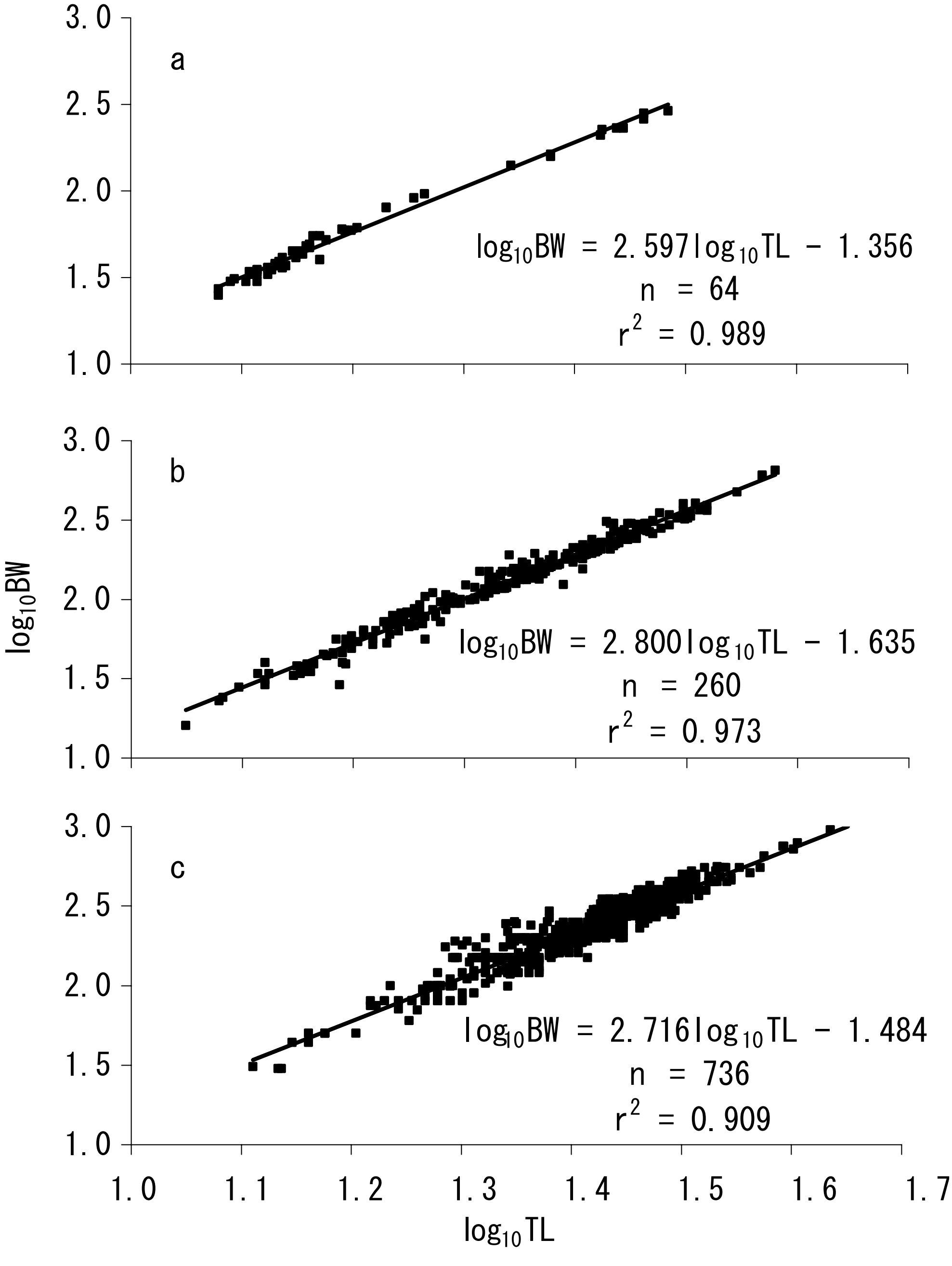

Fig. 6. Relationship between logarithm of body weight (g) (log10BW) and logarithm of total length (cm) (log10TL) for Siganus stellatus (a), S. canaliculatus (b) and S. sutor (c) (Pisces: Siganidae) in Diani, Msambweni and Shimoni of the Western Indian Ocean waters of Kenya in the present study, April through August, 2007.

not encountered in Msambweni samples. Site analyses showed highly significant differences observed in *S. canaliculatus* ($P < 0.001$, Kruskal-Wallis test) with Diani recording larger specimens at 25.1±0.6cm TL compared to 18.2±0.6cm in Msambweni and 22.7±0.4cm in Shimoni ($P < 0.01$ for all pairs, Steel-Dwass test).

In *S. sutor*, a total of 736 specimens caught in Diani and Shimoni recorded 26.5±0.2cm TL with near-normal distributions in both sites (Fig. 5). There was notable absence of *S. sutor* specimens in Msambweni site and like in *S. canaliculatus*, the Diani site recorded significantly larger specimens compared to Shimoni, at 27.2±0.2cm and 26.1±0.2cm TL respectively ($P < 0.001$, *U*-test).

The L-L changes occurring with growth in the three siganids of Southcoast Kenya were best described by equations SL = 0.867TL-1.544 for *S. stellatus*, SL = 0.849TL-1.121 for *S. canaliculatus* and SL = 0.824TL-0.220 for *S. sutor* (Table 2).

Length-weight relationships and condition factors

Wet BWs ranged from 25.27 to 289.20g in *S. stellatus,* 16.33 to 650.27g in *S. canaliculatus* and 30.10-1009.07g in *S. sutor* with mean±SE calculated as 71.28±8.53g, 158.58±6.45g and 258.80±4.30g for the three species respectively (Table 1).

Taking into account potential morphometric differences by species, L-W relationships for the three species were best expressed by the equations $\log_{10}BW = 2.597\log_{10}TL-1.356$, $\log_{10} BW = 2.800\log_{10}TL–1.635$ and $\log_{10}BW = 2.716\log_{10}TL-1.484$ for *S. stellatus, S. canaliculatus* and *S. sutor* respectively (Fig. 6). Using the slope *b* and intercept *a* from the power function of BL-TL relationship, the relative condition factor for each species was best expressed by the equations Kn =BW/ [(4.41x10-2) ($TL^{2.597}$)] for *S. stellatus*, *K*n =BW/ [(2.32x10^{-2}) ($TL^{2.800}$)] for *S. canaliculatus* and *K*n =BW/ [(3.28x10^{-2}) ($TL^{2.716}$)] for *S. sutor* (Table 2).

Siganus stellatus recorded similar fish conditions in both Msambweni and Shimoni, ($P = 0.620$ for *K*n and 0.659 for *K*, *U*-test). However, significantly better fish condition was recorded in Diani for *S. canaliculatus* and *S. sutor* ($P < 0.001$, *U*-test). In overall, *S. stellatus* and *S. sutor* recorded similar but significantly better relative condition factor *K*n than *S. canaliculatus.* In contrast, Fulton's condition factor *K* showed significant variation among all the three species, with best performance by *S. stellatus, S. sutor* and *S. canaliculatus* in that order, calculated as 1.471±0.021, 1.317±0.008 and 1.259±0.010 respectively ($P < 0.001$, Kruskal-Wallis test; $P < 0.01$ for all pairs, Steel-Dwass test) (Table 1). There was a positive correlation for *K*n and *K* with TL and BW for all the three species ($P < 0.01$ for all groups, Pearson's correlation test) (Table 2).

Discussion

The siganid fishes of the WIO waters of Diani, Msambweni and Shimoni fisheries in Southcoast Kenya were in the same range of morphometric parameters and body condition factors reported for fisheries within similar latitude ranges. In the present study, the largest *S. stellatus* specimen encountered at 30.5cm TL in Shimoni was near the upper end of growth ranges (40cm TL) reported for this species (WOODLAND

Table 1. Morphometric measurements (standard length, SL; total length, TL; body weight, BW) and, relative (Kn) and Fulton's (K) condition factors for Siganus stellatus, S. canaliculatus and S. sutor (Pisces: Siganidae) in Diani, Msambweni and Shimoni, on the Western Indian Ocean waters of Kenya in the present study, April through August, 2007

Species	Study site	*n*	Mean ± standard error (SE)				
			SL (cm)	TL (cm)	BW (g)	Relative *K*n	Fulton's *K*
Siganus stellatus	Diani	0	—	—	—	—	—
	Msambweni	4	11.3±0.4	14.0±0.4	42.25±4.01	1.120±0.414	1.530±0.053
	Shimoni	60	12.5±0.6	16.2±0.7	73.23±9.04	1.0933±.012	1.468±0.022
	Pooled	64	12.4±0.5^{a}	16.0±0.6^{a}	71.28±8.53^{a}	1.095±0.112^{a}	1.471±0.021^{a}
Siganus canaliculatus	Diani	60	20.3±0.5^{a*}	25.1±0.6^{a*}	211.85±14.11^{a*}	1.038±0.016^{a*}	1.259±0.023
	Msambweni	54	14.3±0.5^{b*}	18.2±0.6^{b*}	86.83±7.57^{b*}	0.909±0.018^{b*}	1.251±0.022
	Shimoni	146	18.2±0.3^{c*}	22.7±0.4^{c*}	163.22±8.36^{c*}	0.997±0.008^{a*}	1.261±0.012
	Pooled	260	17.8±0.3^{b}	22.5±0.3^{b}	158.58±6.45^{b}	0.988±0.007^{b}	1.259±0.010^{b}
Siganus sutor	Diani	336	22.1±0.2^{a*}	27.2±0.2^{a*}	292.55±6.45^{a*}	1.191±0.009^{a*}	1.397±0.012^{a*}
	Msambweni	0	—	—	—	—	—
	Shimoni	400	21.3±0.2^{b*}	26.1±0.2^{b*}	230.46±5.38^{b*}	1.047±0.008^{2b*}	1.249±0.010^{b*}
	Pooled	736	21.7±0.1^{c}	26.5±0.2^{c}	258.80±4.30^{c}	1.112±0.006^{a}	1.317±0.008^{c}

a, b, c indicate significant differences between species and a*, b*, c* study sites (P 0.01); same letters after mean denote lack of significant differences between sites within species or between species (pooled). n = sample size.

1986) and the TL size classes of 12.0-15.0cm comprising small individuals recorded in Shimoni suggest a continuous recruitment on this site. For S. canaliculatus, the largest recorded specimen was 38.0cm TL in Diani compared to 33cm TL reported in India (JEYASEELAN 1988), 23.0cm TL from the west coast of Malaysia (AHMAD *et al.* 2003) and 25.2cm TL in the Southern Negros islands of Philippines (PAULY 1978). These observations probably suggest a low fishing pressure on *S. canaliculatus* populations on this site owed to removal of modern gears such as beach seines and spear gun fishing under the fisheries beach management program. The species however was less abundant in catches compared to *S. stellatus* and *S. sutor*, attributed to its wider habitat preference, tolerating more turbid waters, invasion of river mouths especially around sea grass beds and reduced schooling in adults (Woodland 1990). On the Diani site, *S. sutor* recorded 44.8cm TL, comparable to 36.2cm SL reported from Gazi bay on the same coast (NTIBA and JACCARINI 1988), 25cm TL in the near-shore fisheries off Dares salaam coast, Tanzania (BENNO Unpubl.), 49.9cm TL in Mauritius (JEHANGEER 1988) and 52.1cm FL in Seychelles (GRANDCOURT 2002).

The L-L relationship parameters calculated for the three siganid species (slope *b* = 0.867, 0.849 and 0.824 for *S. stellatus, S. canaliculatus* and *S. sutor* respectively) were consistent with those reported in other populations, deviating little from WOODLAND (1990) (slope *b* = 0.784 for *S. stellatus*), WASSEF and ABDUL (1997) and WOODLAND (1990) (slope *b* = 0.704, 0.796, and 0.845 for *S. canaliculatus* in Arabian gulf) and WOODLAND (1990) (slope = 0.810-0.846 for *S. sutor*). Similarly, for the L-W relationship, the parameters (slope b = 0.0441, 0.0232 and 0.0328 for S. stellatus, *S. canaliculatus* and *S. sutor* respectively) were consistent, though slightly deviating from those reported elsewhere; YANAGAWA (1994) (slope *b* = 0.0120 for *S. canaliculatus* of Rayong gulf, Thailand) and, SAMBOO and MAUREE (1988) (slope *b* = 0.0596 / 0.0597 for male/female *S. sutor* from Mauritius).

In the present study, L-W relationships for the three siganids indicated negative allometric growth for pooled samples of each species (Table 2). MURPHY *et al.* (1991) noted for L-W relationships, the main controlling factors for *K*n and *K* are mainly age, spawning season, sex, food availability, stomach fullness and general fatness. The calculated *K*n ranged from 0.909±0.018 for *S. canaliculatus* in Msambweni to 1.191±0.009 for *S. sutor* in Diani. Fulton's condition *K* was lowest for *S. sutor* in Shimoni (1.249±0.010) and highest for *S. stellatus* in Diani (1.530±0.053). These results indicate better health in the Diani stocks compared Shimoni and Msambweni. However, literature on comparative studies on body condition from other siganid populations are lacking, making it difficult to gauge the health of the siganids of the WIO waters of Southcoast Kenya relative to other populations. Notwithstanding, the present results may be suggestive of better food availability in the Diani site owing to banning of destructive gears. Fewer records of 18cm-27.9cm TL size classes for *S. stellatus* in Msambweni may also point to higher fishing pressure on larger specimens, comparable to the absence of 26.0cm+ TL size-classes for *S. canaliculatus*, thus creating possible gaps in recruitment for these species.

Population age significantly influences L-L and L-W relationships and consequently the *K*n and *K* condition factors. The observed SL-TL and TL-BW relationships in the present study show that siganid populations of the WIO waters of Southcoast Kenya are still young. Sexes were not determined conclusively in the present study but literature indicates differential growth in sexes, though differences may not be observable until the females have matured and reproduced several times (JOHNSON and GILL 1998, NELSON and WILKINS 1993). Further, morphological differences exist between juveniles and adults, with early maturity in males through out the family (NELSON 1994, THRESHER 1984, WHEELER 1975). However, lack of observable differences between sexes (KUITER 1993, THRESHER 1984) made external sex determination difficult except hence this was only done by dissecting for gonads in a few specimens. Consequently, the L-L and L-W relationships and *K*n equations presented herein may be used to conclusively distinguish sexes in the siganids of WIO waters. Therefore, caution should be exercised when assessing sex differences by use of growth and condition factor equations except where sexes have been determined, refining the present equations into sex-specific SL-TL and TL-BW relationships and *K*n and *K* values. Notwithstanding, the broad spectrum of gonadal maturity stages for these species with all year-round spawning and with visible peaks only in spring and early summer, and a prominent lunar rhythm (THRESHER 1984) calls for caution when assessing the populations. Further, intermittent spawning with non uniform sexual activity and spawning within the adult population during any particular season also calls for caution THRESHER (1984). Moreover, ovarian and testicular development studies show that many species gain water weight during food scarcity therefore masking the effect of nutrition on body condition (BEAMISH *et al.* 1996). Independent variation between water weight and fat weight thus makes interpretation of body condition as a measure of nutritional reserves difficult (SUTTON *et al.* 2000). Notwithstanding, the equations developed from the present study for the SL-TL and TL-BW relationship, and conditions factors *K*n and *K for* the siganids of the WIO waters provide a useful *in-vitro* tool for assessing the individual species and general health of the siganids stocks.

Conclusion

The present study determined the SL-TL, TL-BW relationship for *S. stellatus, S. canaliculatus* and *S. sutor* of the WIO waters caught during the peak SEM April-August season and the TL-BW relationships were used to develop condition factor equations for the three species. The SL-TL and TL-BW relationships and condition Kn and K factor values obtained were comparable with siganid populations within the same geographical range. The Diani site recorded higher *K*n and *K* values compared to the other two sites, probably indicative of better food resources, signaling residual effects of the beach management program in supporting a relatively healthy population. The SL-TL and TL-BW relationships and *K*n and *K* equations developed are important in assessing population health within the fisheries of the WIO waters. Caution should however be exercised when interpreting and comparing results of body condition data for stock health assessment of individuals as shown by the wide distribution of *S. stellatus*, though with fewer samples compared to *S. canaliculatus* and *S. sutor.* To the best knowledge of the authors, this study provides the initial data on L-W relationship and *K*n for *S. stellatus* within the species geographical distribution. The results of the present study and equations developed herein provide useful simple tools for *in-situ* gauging of overall health of wild siganid populations in the WIO eco-region for sustainable fisheries. The equations would also provide useful comparisons between wild and cultured populations of the three siganid fishes.

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