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Cover image: *Macrophthalmus depressus* at Saco da Inhaca, Mozambique (© Jose Paula, 2014)

The biology of Goldsilk Sea Bream (family: Sparidae) from the inshore waters of north coast Kenya

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Abstract
The biology of the sparid, *Acanthopagrus berda* (goldsilk sea bream) was investigated using catch samples obtained from artisanal fishers at selected fish landing sites in the Marereni and Ngomeni fishing areas on the north coast of Kenya. This species has not previously been studied in Kenya although it forms significant proportions of artisanal fish landings and is also a promising aquaculture species. In order to contribute to knowledge of this species, the length-weight relationship, condition factor and feeding preference for prey items were studied in a total of 751 specimens sampled from July 2013 to July 2014. Length-weight relationships for male and female individuals from both fishing areas were strongly correlated (Males: Marereni - $R^2 = 0.920$, Ngomeni - $R^2 = 0.983$; Females: Marereni - $R^2 = 0.966$, Ngomeni - $R^2 = 0.941$). The condition factor of mixed sexes was not significantly different between the two fishing areas (Marereni 2.15 ± 0.08; Ngomeni 2.05 ± 0.02) at $p > 0.05$. Gut content analysis recorded a total of 5 taxa in the diet (gastropods, molluscs, detritus, crustaceans and fish). The overall sample was dominated by female individuals with an overall sex ratio of females (405 individuals) to males (338 individuals) of 1:0.8 being significantly different at $p < 0.05$. The species exhibited isometric and positive allometric growth patterns, indicative of the physiological well-being of this species on the north coast of Kenya. Gonadal maturation occurred throughout the year with peaks in July, August and September. However, more work is needed on the biology, distribution, spawning grounds, behavior, and migration patterns along the Kenyan coast.

Keywords: goldsilk sea bream, biology, north coast of Kenya

Introduction
The family Sparidae, commonly known as sea breams or porgies, inhabit both tropical and temperate coastal waters worldwide (Randall *et al*., 1997) where the genus *Acanthopagrus* prefers shallow waters, specifically estuarine environments. In southern Africa this fish family has been reported to comprise a total of 41 species, of which 25 are endemic (Smith and Heemstra, 1986). Many sparids have been shown to be hermaphroditic, with both male and female gonads developing simultaneously (Smale, 1988; Jakobsen, 2009). Some individuals change sex from male to female (protandrous) or from female to male (protogynous) (Randall, 1995). They typically consume a wide variety of benthic prey with substantial amounts of plant material (Sarre *et al.*, 2000; Mariani *et al.,* 2002; Tancioni *et al.,* 2003).

The Sparidae include many species of commercial, recreational and aquaculture importance (Mongile *et al*., 2014; Rahim *et al*., 2017). The goldsilk sea bream (*Acanthopagrus berda* Forsskål, 1775) is widely distributed in the tropical Indo-Pacific region; from South Africa to India, northern Australia and Japan. As with many species of seabreams, *Acanthopagrus* sp. is considered a commercially important food fish, with good potential for aquaculture and recreational fishing throughout several regions of the world, including China, south-east Asia, Africa, the United Kingdom and the United

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States of America (Rahim *et al.*, 2017). *A. berda* has the potential to change sex and is one of several protandrous sparids (Garratt, 1993). This species prefers habitats with a bottom characterized by gravel or rubble and water depths of between 20 and 500 m. Abundance of the species varies with water depth with juveniles being gregarious and adults solitary (FAO, 1981).

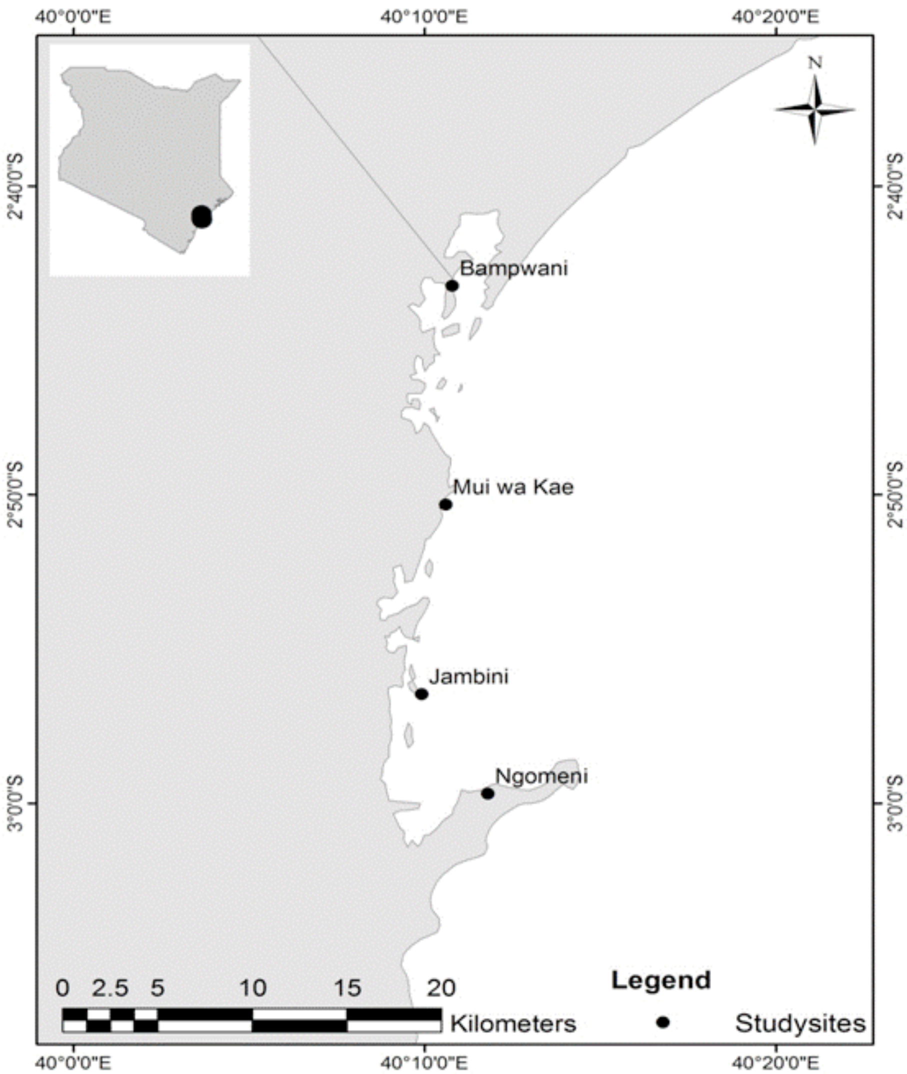

Figure 1. Map of part of the north coast of Kenya showing the sampling stations of Ngomeni and Jambini fish landing sites in the Ngomeni fishing area, and Mui-wa-kai and Bampwni fish landing sites in the Marereni fishing area.

A. berda is an important component of the artisanal fishery throughout the Western Indian Ocean region, and especially in Kenya, where its stock status and biology is poorly understood. This species comprises a significant proportion of demersal fish landings on the north coast of Kenya, while a few specimens have occasionally been reported on the south coast. Several species belonging to the genus *Acanthopagrus* are harvested throughout the Indo-Pacific region. In Kuwait, *Acanthopagrus* sp. are landed in large numbers by commercial fishers using stake nets, fish traps, fish pots and trawl nets. They are also targeted in the recreational fishery which is becoming increasingly common (Nicola, 2001). In South African estuaries, *A. berda* is targeted by a variety of fishing gears including hook and line, gill nets and traditional fish traps. Specifically, in Kwa Zulu Natal, *A. berda* is caught in both recreational and subsistence fisheries on large estuaries, comprising one of the five most abundant species caught (James *et al.*, 2001). In Kenya, *A. berda* is also associated with estuaries, both in the juvenile and adult phases of its life cycle. Adult individuals of this species have been rarely observed in the oceanic environment. Several studies on this species have been carried out in South Africa where reproductive and feeding biology has been well documented (Wallace, 1975; Wallace and van der Elst, 1975; Garratt, 1993; Eschmeyer et al., 2016). Similar studies are needed in Kenya, where this species is growing in commercial importance in the artisanal fishery, and is a promising candidate for aquaculture production.

Critical physiological functions of an organism such as growth and reproduction are dependent on energy derived from food. Therefore, food is the basic determinant of fish species distribution and abundance (Wootton, 1992; Anderson and Neumann, 1996). Research on food, feeding and ecology are fundamental in understanding the physiological functions of fish in relation to ecosystems (Hajisamaea *et al*., 2003). This helps in understanding competition and predation effects on fish community structure (Krebs, 1999). Food and feeding habit studies help in determining the nutritional requirements of a fish species, its interaction with other organisms, and its aquaculture potential (Santos and Borges, 2001). Further, food and feeding habits are a vital part of biological and taxonomic studies in fish. The present study therefore examined the length-weight relationship, condition factor, and feeding preference for prey items of *A. berda*, both to fill scientific knowledge gaps, and to lay a foundation for formulating species management recommendations in Kenya and the Western Indian Ocean region as a whole.

Materials and Methods

The Study Area

This study was conducted on the north coast Kenya in the fishing areas of Ngomeni (comprising the Ngomeni village and Jambini fish landing sites), and Marereni (comprising Mui-wa-kae and Bampwani fish landing sites), within Malindi-Ungwana Bay, the largest bay in Kenya (Fig. 1). The study area extends from 0.6462° S, 38.4061° E to 2° 58' 32" S, 40° 1' 29" E. Two large rivers, Sabaki River to the south and Tana River to the north, drain into the bay providing nutrient enrichment to the bay ecosystem. The common artisanal fishing gears in the study area are seine nets, gill nets, intertidal weirs, hand lines and spear guns, targeting both pelagic and demersal fisheries resources. Artisanal fishing activities are regulated by both river discharge and ocean tides, as well as the north east monsoon (NEM) and south east monsoon (SEM) seasons. Artisanal catches are generally observed to be higher during the dry NEM season as compared to the wet SEM season. Higher catches of *A. berda* are however, associated with the wet season.

Fish Sampling and Data Analysis

Fish specimens were sampled from artisanal fishers on a monthly basis for a period of 1 year from July 2013 to July 2014, covering both the NEM and SEM seasons. For each specimen, the total length (TL, cm) was measured to the nearest 0.1 cm using a fish measuring board. Measurements were taken from the snout tip (mouth closed) to the tip of the longest caudal fin (Anam and Mostarda, 2012). Body weight (BW, g) was measured to the nearest 0.1 g using a top loading balance (Ashton Meyers, model 7765). Sex of each specimen was determined by macroscopic examination of the gonads in the laboratory. Maturity stages of males and females were assigned macroscopically according to the descriptions of Owiti and Dadzie (1989) (Table 1), while spawning period was established by analyzing the composition and proportion of gonad maturity stages. The proportion of male and female individuals was used to calculate the sex ratio. Differences in sex ratio was analyzed using a non-parametric Chi-square (χ^2) test.

The length-weight relationship (LWR) was determined using the power curve: $W = aL^b$ (Le Cren, 1951) where: W = fish weight in grams; L = fish total length in cm; and a and b are regression constants. A straight line relationship was provided by the formula:

$$\text{Log } W = \log a + b\log L$$

Coefficient parameter of determination (R^2), a and b were calculated by least-squares regression.

The condition factor (K) was calculated according to Fulton (1904) and Wootton (1990) from the relationship:

$$K = \frac{100W}{L^3}$$

Where: K = condition factor; W = total body weight (g); L = total length (cm); 100 and 3 = constants. The difference in mean K between the years was analyzed using a non-parametric Kruskal Wallis test.

Finally, food items in the guts were identified to taxon level following Richmond (2011). The percentage composition of each (taxon) food item by season

Table 1. Identification of gonad maturity stages by description of macroscopic appearance of gonads in both male and female *Acanthopagrus berda* sampled on the north coast of Kenya.

Maturity Stage	Male	Female
I. Immature	Never reproduced before, gonads small and close to vertebral column, undiscernible to naked eye, testes threadlike, transparent and colourless or grey, occupy about 1/3 of body cavity.	Never reproduced before, gonads are small and undiscernible to naked eye, ovary contains no developed oocytes, transparent, colourless or grey, occupy about 1/3 of body cavity.
II. Maturing	Testis ribbon-like structures, slightly bigger than Stage I, greyish-white in colour, occupy about 1/2 of ventral cavity.	Firm and ribbon like with slight increase in size, pink in colour, Oocytes not discernible to naked eye, occupy about 1/2 of body cavity.
II b. Regenerating/Resting	After each spawning cycle, macroscopic aspects of testes in regenerating phase are very similar to those in immature phase, but transverse section tends to be larger and the gonad wall thicker, they tend to be more opaque than immature gonads, occupy about 1/2 of ventral cavity.	After each spawning circle, macroscopic aspects of regenerating ovaries are very similar to those in immature phase, but transverse section tends to be larger, gonad wall thicker, they tend to be more opaque than immature gonads, reddish with blood capillaries, occupy about 1/2 of ventral cavity.
III. Maturing	Broad and thick, dark white in colour, blood vessels visible externally to naked eye, milt oozes out from cut surfaces and occupying 3/4 of abdominal cavity.	Broad and thick, red or reddish brown, blood vessels visible externally, Oocytes visible through ovary wall, occupying 3/4 of abdominal cavity.
IV. Mature	Testes white, occupying almost 9/10 of abdominal cavity, sperm flows following application of slight pressure.	Ovary very large, occupying almost 9/10 of abdominal cavity, very thin ovarian membrane. Oocytes easily visible and expelled on application of slightest pressure.
V. Ripe/Running	Fully distended occupying almost entire abdominal cavity, exudes milt on slight pressure.	Fully distended with granular surface occupying almost entire abdominal cavity.
VI. Spent	Testes shrunken and flaccid, occupy about 1/2 of ventral cavity, walls are harder and wrinkled, no milt oozes out on pressure and blood vessels still visible externally.	Ovary not fully empty, occupy about 1/2 of ventral cavity, residual oocytes present. Flaccid and red in colour, ovary wall thick.

and fish length size class were calculated based on the number of occurences in all sampled fish guts.

Results

A total of 751 specimens were sampled with the highest number from Ngomeni (201), followed by Jambani (195), Mui wa kae (180) and Bampwani (175). More specimens were sampled in the NEM season (464) than the SEM season (287). More females (454) were sampled compared to male individuals (297). The majority of males were within the size range of between 14 and 22 cm, while the majority of female individuals ranged from 15 and 29 cm (Fig. 2). Results of 2-way ANOVA, however, indicated no significant difference in sizes between sexes (df = 1; f = 0.400; p = 0.527).

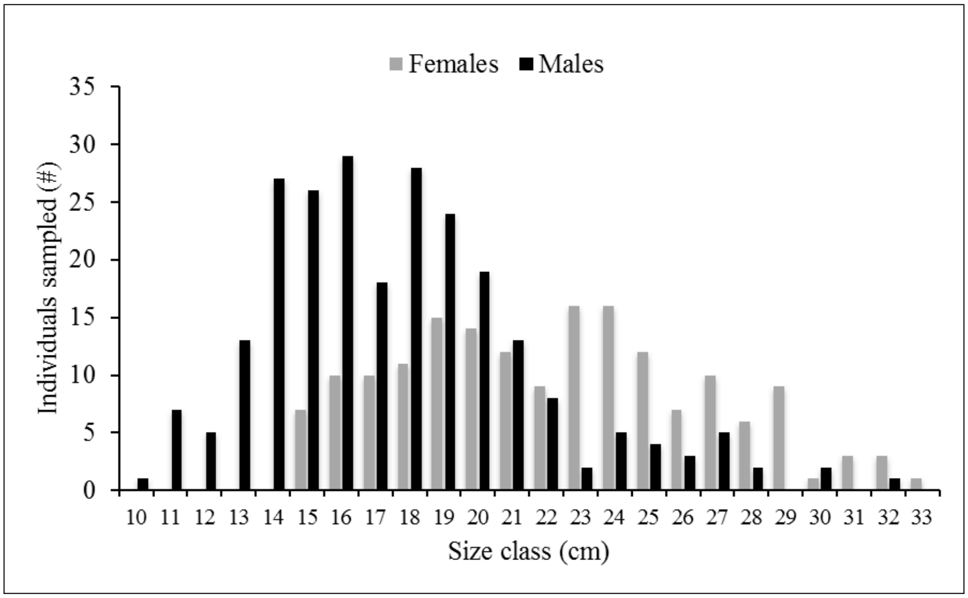

Figure 2. Length frequencies of *Acanthopagrus berda* individuals by sex, sampled on the north coast of Kenya during the study period.

The length-weight (LWR) parameters computed by sex resulted in *b* values of 2.9673 for male individuals, and 2.9941 for female individuals, with an overall *b* value of 2.988 for combined sexes. These *b* values are indicative of a positive allometric growth pattern. The LWR of both male and female individuals (Fig. 3) fitted the expected exponential growth curves (R^2 = 0.9571 for males; 0.9654 for females; and 0.9676 for combined sexes).

The condition factor (*K*) of both male and female individuals of *A. berda* was highest in the months of July and October 2013 (2.15 ± 0.08 each), compared to (2.05 ± 0.02) observed in the month of March 2014 (Fig. 4). However, there was no significant annual difference in *K* (Kruskal Wallis test: p = 0.052).

Both mature and immature gonads were observed throughout the year in different numbers (Table 2).

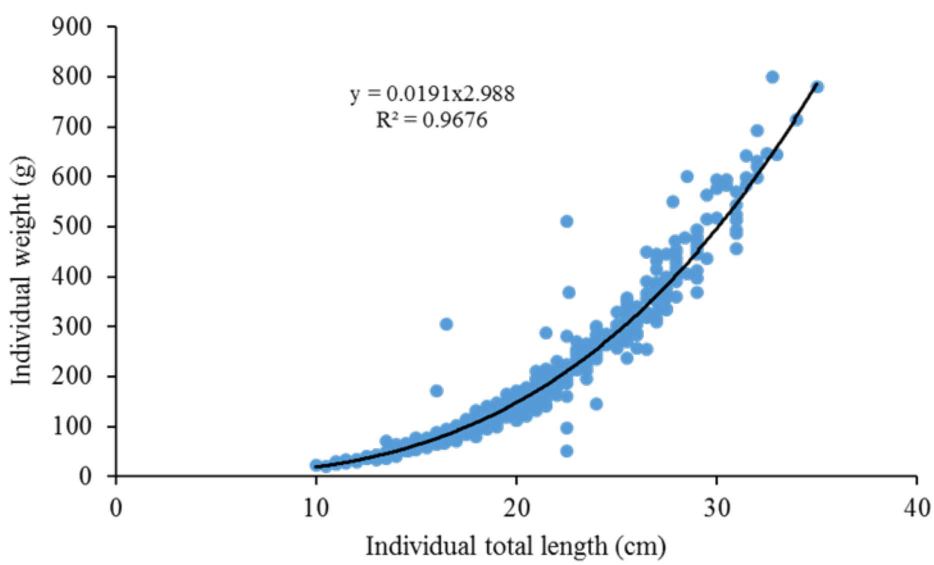

Figure 3. Length-weight relationship of combined sexes of *Acanthopagrus berda* individuals sampled on the north coast of Kenya during the study period.

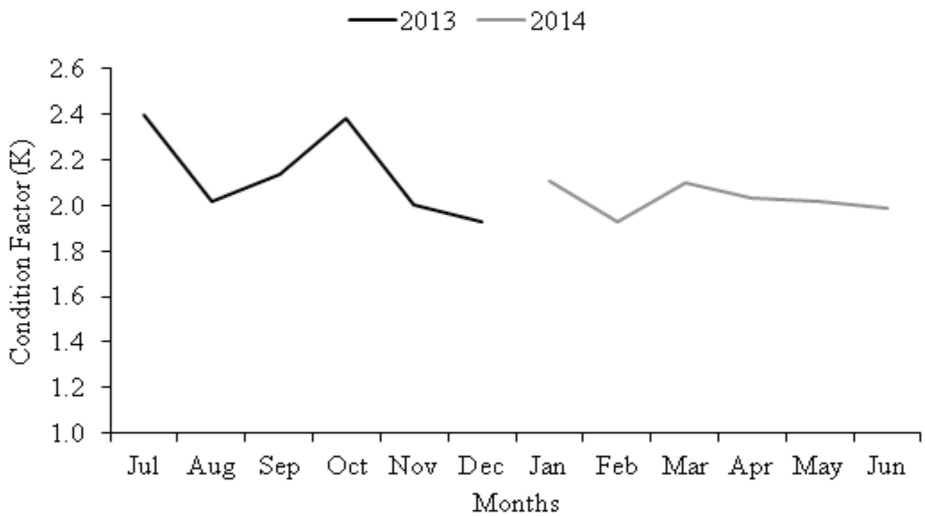

Figure 4. Condition factor (K) of male and female *Acanthopagrus berda* individuals observed during the study period on the north coast of Kenya.

Three peaks of mature gonads occurred in the months of July, August and September (Fig. 5). The majority of immature gonads were observed from October, November, December and January, with the month of December being the peak for immature gonads. The least mature and immature gonads were observed between February and June.

Male to female sex ratio was 1:1.1 for 2013 (n = 201 and 228, respectively). This was not significantly different from the expected 1:1 (χ^2 = 1.699; p = 0.192). The male to female sex ratio in 2014 was 1: 0.5 (n = 204 and 110, respectively). This differed significantly from the expected 1:1 (χ^2 = 28.140; p = 0.000). The overall male to female sex ratio of 0.8:1.0 (338 males and 405 females) was also significantly different (χ^2 = 6.042; p = 0.014).

A total of six food items (taxa) were identified, with a number of empty guts observed (Fig. 6). Seasonal differences in gut content was also observed, with more guts containing food items during the dry NEM season compared to the wet SEM season. The preference food (PF) index was highest for gastropods (25.2%),

Table 2. Monthly distribution of gonad maturity stages for both sexes of *Acanthopagrus berda* sampled on the north coast of Kenya over the study period.

Months	Maturity Stages						
	I	II	II b	III	IV	V	VI
January	28	25	1	21	4	1	2
February	4	10	2	13	2	2	1
March	6	6	0	21	2	1	1
April	4	11	2	15	2	1	0
May	2	8	3	11	2	8	3
June	5	10	1	1	1	12	9
July	4	5	1	22	7	16	23
August	1	1	0	12	7	12	8
September	19	37	0	22	5	19	15
October	20	14	0	8	0	0	13
November	22	34	0	0	0	0	27
December	48	32	25	0	0	0	3

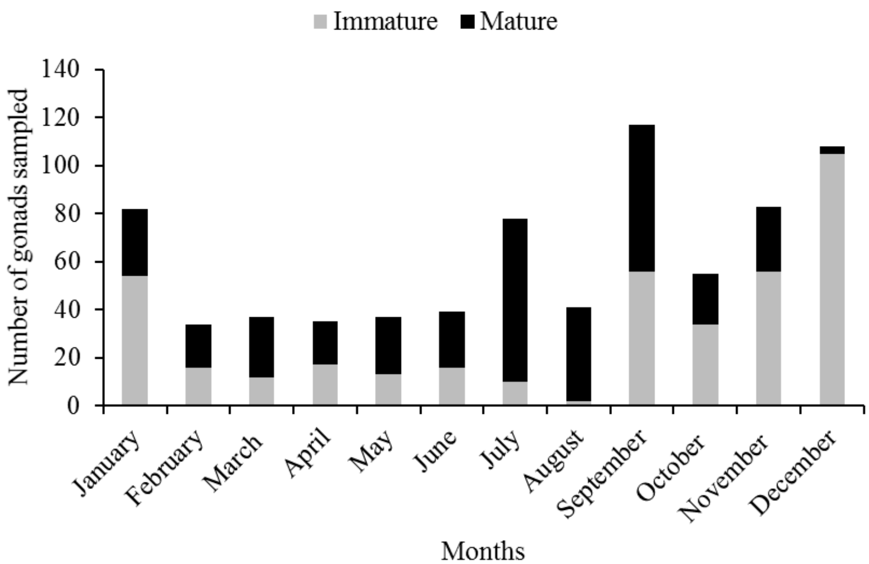

Figure 5. Monthly distribution of gonad maturity (immature and mature stages) of both sexes of *Acanthopagrus berda* sampled on the north coast of Kenya.

followed by crustaceans and fish at 22.8% and 16.2%, respectively. Relatively low values of FP index were recorded for detritus (13.5%), mollusks (13.1%), and mixed mollusk and gastropod prey (9.2%). Analysis of food items taken by different size classes of fish showed that the majority of the guts containing food items came from fish ranging between 16 to 21cm and between 22 to 27 cm. Most guts contained gastropods, mollusks and detritus (Fig. 5). Fewer guts contained food items such as crustaceans, fish and mixed mollusk-gastropods. Empty guts were recorded in some specimens from size classes that ranged between 10 and 15 cm, 16 and 21 cm, and 22 and 27 cm.

Discussion

The present study established key population parameters and biological characteristics of the sparid, *Acanthopagrus berda*, on the north coast of Kenya. It was found that the *b* exponents of the length-weight relationships (individual sexes and combined sexes) were all close to 3, indicative of an isometric growth pattern. Similar values of *b* were reported for other sparids in

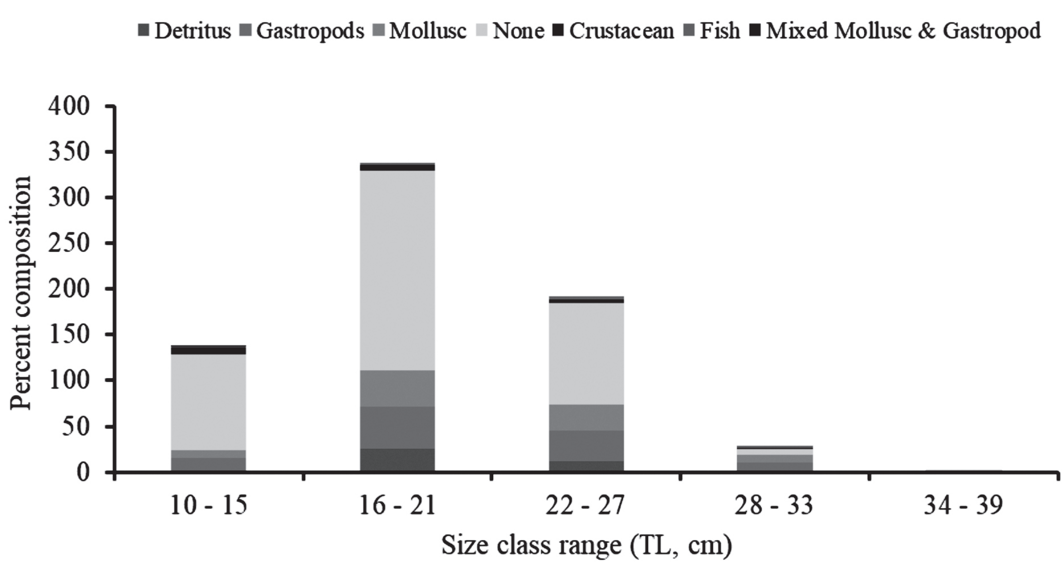

Figure 6. Composition of food items (taxa) in stomachs of *Acanthopagrus berda* sampled from the north coast of Kenya over the study period.

Kenya by Aura *et al.* (2013), and in Nigeria by Omogoriola *et al.* (2011), while b varied slightly from the same sparid species studied in Kuwait (Vahabnezhad *et al.*, 2017). Biological parameters in fishes, including length-weight relationships, are affected by factors such as prevailing environmental conditions, health condition, season, and population differences (Morey et al., 2003; Faroese, 2006). The condition factor (*K*) in *A. berda* indicated good physiological condition of the individuals sampled during the study period. Observed annual differences in *K* for this species may be attributed to variations in physico-chemical conditions.

The monthly occurrence of mature gonad stages (III and above) indicates that *A. berda* spawns throughout the year (Fig. 4). Previous studies by Wallace (1975), and Kyle (1986), documented that sparids mature between May and August in South Africa, with a peak spawning period observed in May and June. This compares favourably with the work of Garratt (1993) who reported differential maturity levels of ripe and running gonads between sexes of 8.8:1 (males to females) in Kosi Estuary, South Africa.

The presence of more mature males at the time when most females were immature may suggest that the males were caught before the end of the sex change process. Differences in sexual maturity between males and females indicates that females mature at stage III, at a time when males are in ripe and running condition. Several fish species have been reported to exhibit prolonged spawning periods lasting for between 7-9 months in the Western Indian Ocean region (Qasim, 1973). This scenario has also been confirmed to occur in other sparid species such as *Acanthopagrus latus* in the Persian Gulf, where spawning took place from February to June (Vahabnezhad *et al.*, 2017).

Sex composition of the sampled fish was characterized by more females than males (405 females against 338 males). This may be attributed to behavioral differences during sex change, or to one sex being more vulnerable to certain fishing gears. Hirpo, (2013) attributes the prevalence of female tilapia in catches to sexual segregation during spawning, activity differences, gear type and fishing sites.

This study established that gastropods, detritus, mollusks, crustaceans and fish displayed the highest FP index in the *A. berda* specimens sampled. This is in agreement with previous studies conducted along the west African coast that classified sparids as carnivorous feeding chiefly on crustaceans, fish and mollusks (FAO, 1981). Based on the wide range of food items observed, including detritus, *A. berda* may be referred to as “opportunistic feeder” (organisms that eat any available food item) in the absence of preferred food items. A seasonal difference in diet was observed with a greater variety of food items in the guts during the NEM compared to the SEM season. This may be attributed to higher water transparency in the NEM season that may improve visual location of prey items (Nyunja *et al.*, 2002).

Conclusion

The study established that *A. berda* occurring along the Kenyan coast exhibited positive allometric and isometric growth patterns, and were in good physiological condition. The species was found to spawn throughout the year with July, August and September being the peak spawning months. Males dominated the sample at immature stages, but overall females were more dominant. *A. berda* is a carnivorous bottom feeder that feeds mainly on gastropods and mollusks, but may also take detritus, crustaceans and fish in the absence of preferred food. It is recommended that longer term investigations of the life cycle and ecology of *A. berda* are carried out to confirm the spawning patterns found in this study. More work needs to be conducted on the biology, distribution, spawning grounds, behavior, and migration patterns of the species along the entire Kenyan coast. There is also a need for further research on the taxonomy of *A. berda*, including analysis of molecular genetic variation, to confirm relationships both within Kenya and in the western Indian Ocean region as a whole.

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