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Polychaete (*Marphysa mosambica*) Morphometrics, and their use in the Estimation of Whole Polychaete Size and Breeding Values of Bait Exploited by Artisanal Fishers at the Kenyan Coastline

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Abstract: Polychaetes, such as *Marphysa mosambica*, are extensively used as bait in tropical artisanal fisheries, while, cultured polychaetes are exploited as fishfeed in mariculture. In order to monitor exploited wild and cultured polychaetes populations, metrics that predict growth and reproductive condition, are needed. Adult polychaete specimen were collected from mudflats at three locations along the Kenyan coastline. Measurements of the head, trunk and tail length were obtained and correlated to whole polychaete dimension. Breeding values monitored were condition factor and gonadosomatic index. Regression between morphometrics and whole polychaete dimension, and also breeding values, were obtained and the best variable estimator identified. Results indicate, adult polychaete along the Kenyan coastline are 97 mm long, with 170 segments and weigh 2.36g, with an average egg load of 106 eggs. Polychaete morphometric and condition factor differed among the locations, but GSI were similar. Differences were attributed to habitat characteristics and bait exploitation patterns. Polychaete trunk length and width, were best estimators ($r^2<0.4$) of whole polychaete dimension, condition factor and GSI. Upon further validation, trunk dimensions may be used for rapid estimation of the total length, weight and reproductive condition of polychaetes.

Key words: Morphometrics, whole polychaete, Condition factor, Gonado Somatic Index

1. Introduction

Polychaetes are dioecious multi-segmented annelids that dominate marine benthic substrates, in both temperate and tropical intertidal zones, and are crucial to marine ecosystems (Fauchald & Jumars, 1979; Jumars et al, 2014). They are important trophic links in food webs, being major constituents in fish diet, but also linking sediment nutrients cycling, to overlying water mass food webs (Chatzigeorgiou et al., 2014;

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Jumars et al, 2014; Khan et al., 2014). Polychaetes also increase water clarity, sediment aeration, are intimately involved in the processing and sequestration of nutrients, and also enhance coral reef growth and formation (Kristensen, 2001; Mueller et al., 2013). Several polychaete taxa, are also directly utilized by man as fishing bait, food (e.g. Palolo, worms), in the management of pollution (e.g. multi-trophic aquaculture) and also as laboratory models (Palmer, 2001, Fidalgo et al., 2003; Rettob et al., 2013).

Accounts of the use polychaete as fishing bait, are widespread, for instance in Europe (Fowler, 1999), America (Spitkowski et al, 2000), Australia (Skilleter et al, 2006), South Africa (Mackenzie, 2005) and Kenya (Kihia et al, 2014). Annual polychaete bait harvest are estimated at over 300m$.yr^{-1}, 5-8m$.yr^{-1}, and 0.1 to 0.7 m$.yr^{-1} in Europe, America and South Africa respectively (Olive, 1999; Mackenzie, 2005). In the Northern hemisphere, lugworms (*Arenicola marina*), bloodworms (*Glycera* spp), ragworms (*Nereis diversicolor*) and sandworm (*Diopatra* spp), are the major exploited taxa (Fidalgo e Costa, 1999), while in Australia (Idris et al., 2013) and Kenya (Kihia et al, 2014), *Marphysa spp* are targeted.

Impacts of polychaete bait overexploitation range from displacement, to mortality of target and non-target biota, which culminates in changes of system structure and functioning (Fowler, 1999). In the northern hemisphere, and also in South Africa, such dangers are recognized and incorporated into polychaete harvesting management strategies (e.g. Olive, 1993; Fowler, 1999; Hodgson et al, 2000). Artificial culture of polychaete is recommended as an alternative to wild harvesting (Olive, 1999).

Bait fishing is frequently used by artisanal fishers, who form 90% of global fishers and also in Kenya (Cheunpagdee et al, 2006). Bait fishers attach a variety of bait types to hooks and monofilament line to haul the catch. Along the Kenyan coastline, polychaete worms (local name *choo*, Kisw), are commonly utilized (Kihia et al, 2014). Richmond (2011) describes two species in the region; *Marphysa mossambica* (Peters), and *M. macintoshi* (Crossland). *M. mossambica* is prevalent in mangrove fringed shores, while *M. macintoshi*, occurs in shallow sublittoral habitats. Artisanal fishers along the Kenyan coast use simple gears and vessels, to land about 90% of marine fish landing, from nearshore habitats (Fondo, 2004; Frame survey, 2012). These fishers, collect or excavate intertidal bait, such as *M. mossambica*, subsequently used to land a multispecies assemblage of fish, dominated by lethrinids and gerrids (Kihia et al., 2015).

Resource managers are confronted with two basic problems related to sustainable exploitation of these polychaetes; quantification and monitoring of harvested population, and stock selection for breeding. An ideal monitoring regime, would enumerate harvested polychaetes, however, breakage, either during excavation or handling, impairs accuracy of data obtained. Therefore identification of a suitable metric, that can predict the whole dimension of a polychaete section, is needed. Secondly, in order to artificially breed polychaetes, it is crucial to select parent stock, with superior body mass and/or reproductive potentials. Identification of metrics that are related to desired breeding traits, are thus critical. Polychaete morphometrics determine life history patterns, such as semelparity and iteroparity (Poulin, 2001). On the other hand, reproductive patterns are regulated by season, physicochemical cues, life history, among others (Olive, 1999; Rettob et al., 2013). This study therefore intends to evaluate the usefulness of a variety of polychaete external morphometrics, in the rapid estimation of whole body dimensions and breeding values.

2. Materials and Methods

2.1 Study area

The Kenyan coastline lies between longitudes 01^{o}41'S and 4^{o}40'E latitude, has a narrow continental shelf (GOK, 2009). The coastal weather is influenced mainly by the Northeastern and Southeastern Monsoon, that occur between December to March and May to October, respectively. Average temperature range from 24 to 30^{o}C, while annual rainfall ranges from 500 to 1600 mm. The coast is divided into two biogeographic zones; south and North coral coast monsoon sub-regions. The South Kenya coral coast subregion is contiguous to neighboring Tanzanian coast, and extends from Malindi to Vanga in the south (Figure 1). The Northern Kenya monsoon subregion extends from the Ungwana bay to Lamu and is contiguous to the cold upwelling Somali coastline (GOK, 2009). Adult polychaete samples were collected from Mida Creek, Kanamai and Gazi bay, all within the South Kenya corral sub-region.

Mida Creek (03^{o} 21'S; 39^{o} 59'E); a Marine National and Biosphere Reserve is situated 88km North of Mombasa town, has been in existence since 1968. The creek covers an area of 31.6 km^{2}, consisting of mangrove forests, seagrass beds, sandflats, rocky outcrops and subtidal habitats. Two sites at Mida Creek; Dabaso and Mayonda, were chosen for sampling due to the prevalence of polychaete bait excavations.

Dabaso: The Dabaso landing beach (S 15°03 20.53´: E 039°59.23´), situated approximately 1km off the Watamu-Malindi road. Mature mangrove trees are visible as well as residential houses close (~50m) to the beach. A 150-200*50m clearing through the mangrove forest allows access to boats and persons at the beach. The landing beach is muddy and has a coral rock terrain. At Dabaso, harvesting of gastropods (basket trap fishers) and also hermit crabs and polychaetes (hook and line fishers) is common (e.g. Kihia et al, 2014).

Mayonda: Lies (S03°19.274': E039°59.098') due North of Dabaso village and within the remnants of the biodiversity rich Arabuko-Sokoke forest. There is no village adjacent to the beach, unlike Dabaso. A band of mangrove forest (>50m) has to be crossed to access the beach. A number of boats and sometimes presence of fish traders, particularly women at the beach, is evidence of fishing activity. The nearest village to Mayonda forest is Gede, which is more than 2km away. The beach is sandy with limited coral substrate. At Mayonda, there is extensive harvesting of polychaete in the sandy-muddy shore.

Kanamai beach (3.91°S, 39.78 E); located 20 km due north of Mombasa, is within Kilifi County. It is characterized by extensive sandy beaches and is a favored tourist destination at the coast. A fringing reef occurs 0.7 to 1.2 km from the shoreline. The shoreline apart from beach consolidating flora (eg *Ipomea*) lacks Mangrove forest. These sandy beaches are favored nesting grounds for turtles.

Gazi bay; (4^0 25’ S, 39^0 30’ E); located in Kwale county, lies approximately 50 km south of Mombasa city, along the Kenyan coastline. Chale peninsula and a fringing coral reef, shelter the bay from incoming oceanic waves. The bay occupies an area of about 1,500 ha, consisting of mangrove forest (615 ha), creek (25 ha), intertidal mud and sandflats (300 ha) and 500 ha of subtidal seagrass beds. Freshwater input into the forest and bay is from two tidally influenced seasonal rivers and ground water seepage.

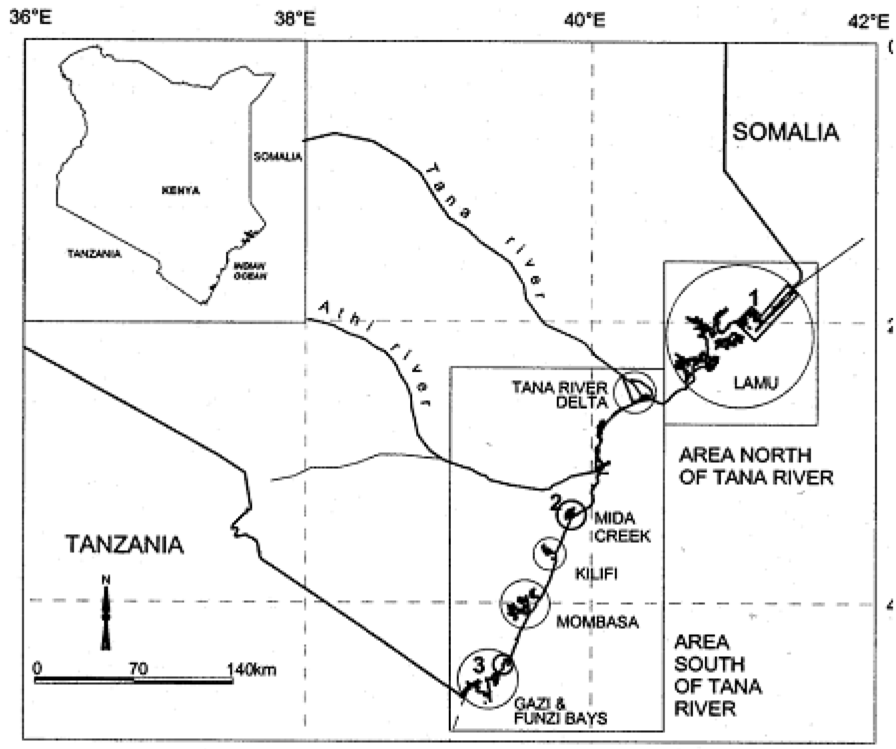

Figure 1. Sketch of the Kenyan coastline with study locations at Mida, Kilifi and Gazi marked (Inset map of Kenya)

2.2 Polychaete specimen collection

Local fishers were used in identifying excavation sites, commonly used by polychaete bait (locally known as *choo*) harvesters. These sites were characterized by extensive sandy-muddy intertidal flats, with evidence of previous excavations (abandoned excavation sites) and also harvesters encountered, actively excavating for the polychaetes.

A 1m by 1m plot was demarcated on the intertidal zone substrate at low tide; Dabaso, Kanamai, Mayonda, and at Gazi from 10th to 17th April 2014. The polychaetes were excavated within the plot using a digging stick, locally used by the local fishers, to a depth of about 30 cm. Polychaetes revealed during excavation, were slowly and carefully extracted from their burrows, to reduce breakage. Whole polychaete specimen from each plot were placed in labelled containers. At least 3 plots were excavated from each site. Ocean water and 5% formalin was added and samples transported to the laboratory. The adult polychaete specimen were subsequently identified as *Marphysa mosambica*, Peters (Polychaeta; Eunicidae) (*sensu* Richmond, 2011).

2.3 Determination of polychaete morphometrics

In the laboratory, samples were washed in water to remove excess debris. The length of the entire polychaete (TL), length of the prostomium (head), middle section (Trunk), pygidium (Tail), number of chaeta in all complete polychaetes, was determined and recorded. The polychaetes were dissected and the gonad bearing segments observed under a microscope. The total number of eggs in egg bearing segments was determined.

Data on polychaete morphometrics obtained above were compared among the sites. Data on whole polychaete (length, weight and egg load) were correlated to metrics of body segments (i.e. head, trunk and tail) and the best estimator of whole polychaete dimension identified.

2.4 Determination of breeding values

Breeding values monitored, were condition factor and gonadosomatic index (GSI). Data on specimen Body weight (W) and length (L) were obtained and used to compute condition factor using the following equation;

$$W = aL^b$$

Equivalent to;

$$log_{10}W = log_{10}a + blog_{10}L$$

And;

$$K_n = \frac{W_o}{W_p}$$

Where W- weight of polychaete, L-Length of polychaete, a- regression constant, b- power function, K_n- condition factor, W_o- observed weight, W_p - predicted weight.

The weight of the gonads (W_g) exposed after dissection, together with the total body weight (W_o), were also obtained and used to calculate gonadosomatic index using the following formulae:

$$GSI = \frac{w_g}{w_o}$$

Where GSI- Gonadosomatic index, W_g-weight of gonads, W_o -weight of whole polychaete.

Condition factor and GSI data were thereafter compared among the sites. Data on condition factor and GSI (length, weight and fecundity) were correlated to metrics of body segments (i.e. head, trunk and tail) and the best estimator identified.

3. Results

113 whole *Marphysa mossambica* specimen were examined from the four sites (Mida-Dabaso, Mayonda, Kanamai & Gazi). The average dimensions of the polychaetes were; 96.71 mm (length), 170 segments, 2.36g (weight), and 106 eggs. Polychaete specimen from Dabaso were significantly longer (F=2.81, P<0.05), and heavier (F=3.41, P<0.05), than from other sites (Table 1). Number of segments and eggs, were however similar among the sites.

Table 1. Variation in metrics of *M. mosambica* specimen obtained from sites along the Kenyan coastline

Site	N	Total length (mm)	Number of Chetae	Body Weight (g)	Number of eggs
Dabaso	15	$100.67\pm10.88_a$	186.53±17.46	$3.04\pm0.36_a$	67.60±26.02
Mayonda	50	$110.30\pm5.96_a$	172.96±+9.56	$1.79\pm0.20_b$	131.78±14.25
Gazi	25	$88.28\pm8.40_b$	168.88±13.52	$2.42\pm0.28_{ab}$	105.24±20.15
Kanamai	22	$82.91\pm8.98_b$	152.36±14.42	$2.20\pm0.30_{ab}$	119.36±21.48
Total	113	98.71±4.08	170.18±7.01	2.36±0.15	106.00±10.45

Values followed by the same letter a, or b are not significantly different (P<0.05)

Among the parameters tested, trunk length was the best predictor of whole polychaete length (0.99), total number of segments (0.66), Total weight (0.72) and egg load (0.33) (Table 2). Trunk width, was also significantly correlated to total length and weight. All other parameters were poorly correlated to polychaete total length, number of chetae and egg load. Polychaete weight was also correlated to carapace and pygdium width. Thus trunk length and width are the most reliable estimator of whole polychaete dimensions.

Table 2. Correlation coefficients between body part metrics to whole *Marphysa mossambica* dimensions at the Kenyan coastline

Body part metric	Total length	Number segments	Total weight	Number eggs
Head length	0.03^{ns}	-0.08^{ns}	-0.11^{ns}	0.07^{ns}
Head width	0.09^{ns}	-0.02^{ns}	0.46***	0.01^{ns}
Trunk Length	0.99***	0.66***	0.72***	0.35***
Trunk Width	0.23*	0.15^{ns}	0.76***	0.03^{ns}
Tail Length	-0.05^{ns}	0.09^{ns}	-0.18^{ns}	0.01^{ns}
Tail Width	0.03^{ns}	0.05^{ns}	0.44***	0.05^{ns}

Coefficient values are ns- not significant (P<0.05), *- significant (P<0.05), ***- Significant (P<0.001)

Regression between trunk width and length against polychaete weight were significant (F=102.19, 73.90, P<0.001) and positively correlated with regression coefficient of 0.46 and 0.40, respectively (Figure 2). Corresponding regression equations of the form:

$$Polychaete\ weight = 2.45\ Trunk\ Width - 0.60$$

$$Polychaete\ Weight = 0.21\ Trunk\ length + 0.02$$

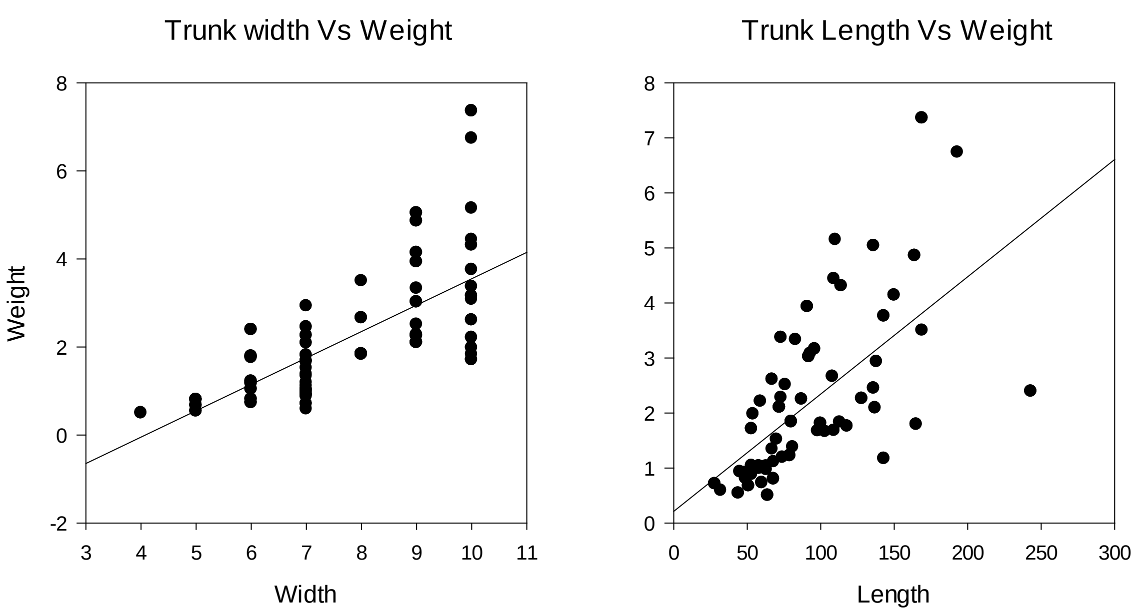

Figure 2. Scatter and regression lines for trunk dimension against whole polychaete weight of bait used by fishermen along the Kenyan coastline.

Evaluation of condition factor revealed that the power function for the regression between weight and length was 1.11±0.10 corresponding to significant positive regression coefficient of 0.52 (F=117.63). The relationship between weight and length could be described by the equation;

$W = 6.41L^{1.11}$.

Z test of departure of b values from isometric growth revealed the values were significantly lower than 3 (t=18.9, df=111, P<0.001), indicating negative allometric growth.

Breeding values

The average condition factor for *M. mosambica* examined was 0.12±0.005. Comparison of condition factor among the sites revealed that specimen from Mayonda (Mida) had significantly lower condition factor (0.08), compared with other sites, which had similar but higher values of above 0.11 (Figure 3).

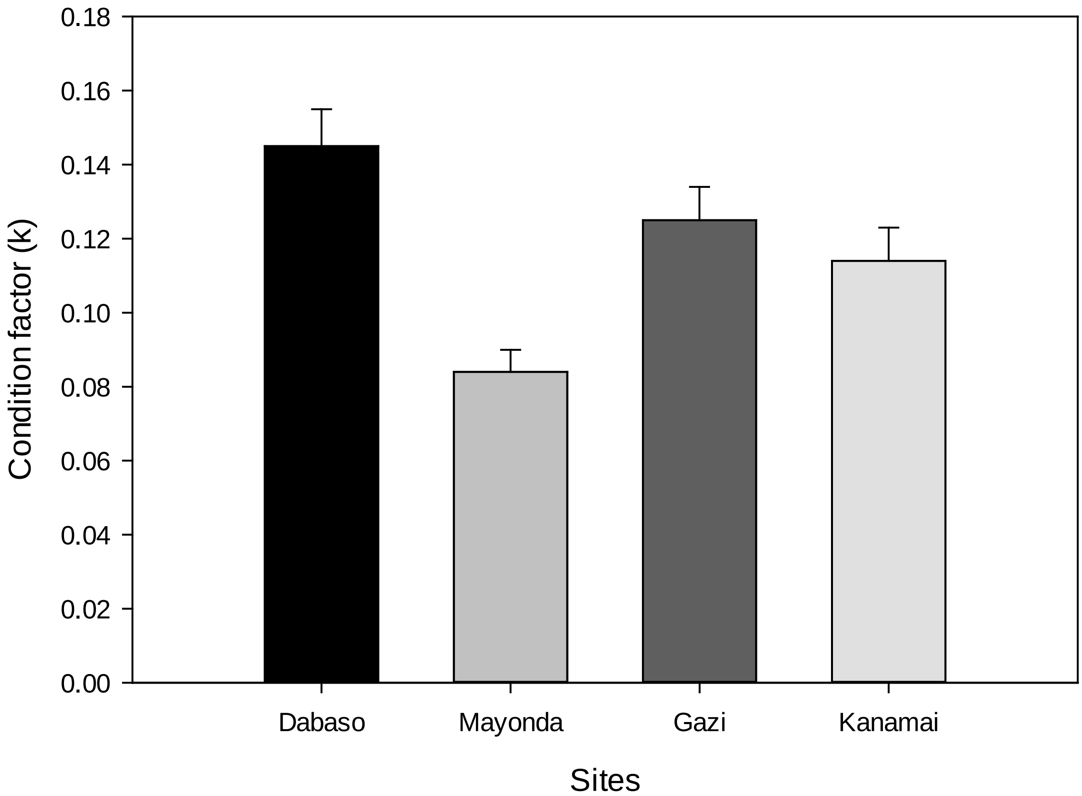

Figure 3. Variation in condition factor of *M. mosambica* at sites along the Kenyan coastline

Number of segments was not correlated to condition factor (χ^2=0.15, P=0.1), but other parameters were significant. Generally width of head, trunk, and tail were positively and highly correlated to condition factor.

Length of head, trunk had low or negatively correlation to condition factor. The highest correlation (0.91) were observed between condition factor and trunk width.

Regression between trunk width and condition factor had a highly significant regression coefficient (r=0.78; F=385.93). The corresponding regression equation derived was of the form; $Condition\ Factor = 0.026\ Trunk\ Width - 0.09$ (Figure 4).

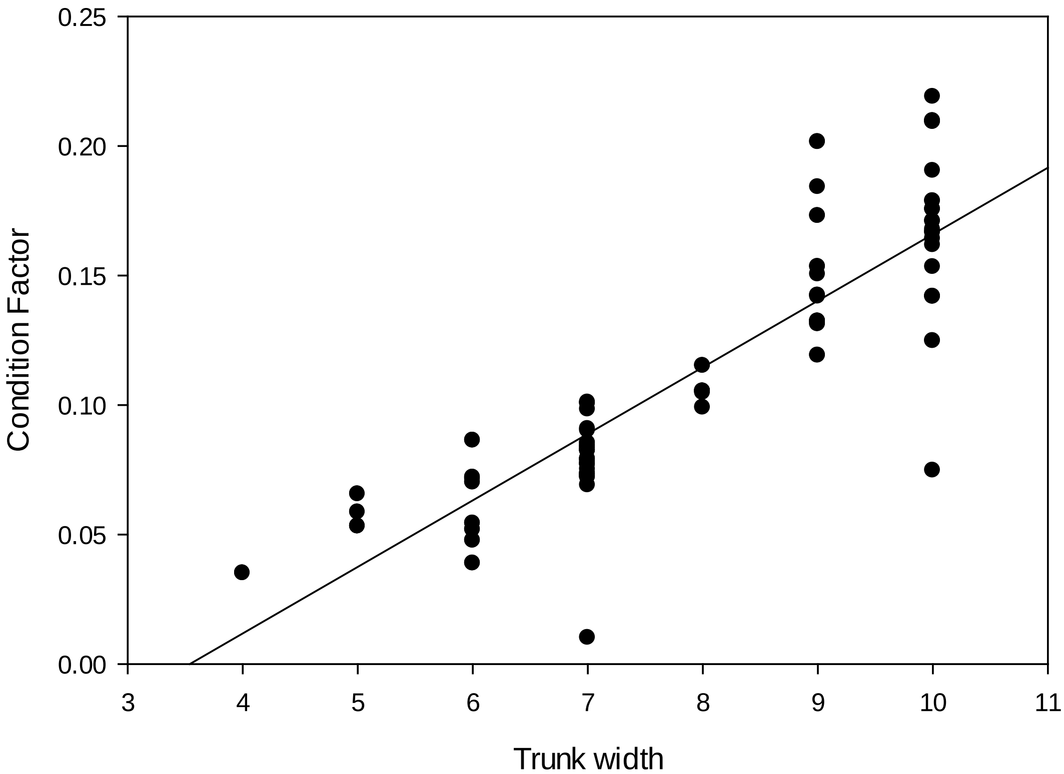

Figure 4. Scatterplot of trunk width against condition factor of polychaete bait used by fishers along the Kenyan coastline

The average gonad weight of *M. mosambica* specimen examined was 2.71g, however these differed among the sites, with Specimen from Mida creek such as Dabaso registering significantly (F=7.95, P<0.001) higher gonad weight (4.74g) similar to Mayonda, but higher than both Kanamai and Gazi (Table 3). Average gonadosomatic index (GSI) for the polychaetes encountered along the coastline was 0.76. There were no significant differences in GSI among the sites (Table 3).

Table 3: Variation in reproductive condition of *M. mosambica* among sites at the Kenyan coastline

Site	N	Gonad weight (g)	GonadoSomatic Index
Dabaso	7	4.74±0.58$_a$	0.81±0.04
Mayonda	10	3.04±0.49$_{ab}$	0.74±0..03
Gazi	7	1.47±0.58$_b$	0.78±0.04
Kanamai	7	1.58±0.43b	0.71±0.04

Values followed by the same letter a, or b are not significantly different (P<0.05)

4. Discussion

The *Marphysa mossambica* obtained from intertidal excavation along the Kenyan coastline have an average of 170 chaetae, length of 97mm and weight of about 2.4g and harbor about 106 eggs. The number of chaetigers reported here, is lower than the 200 to 345 chaetigers and 22 to 33 cm length reported for the related, but pantropical species; *Marphysa sanguinea*, from Australia (Hutchings & Karageorgopoulus, 2003), but in the same order of magnitude (128 chaetigers, 84 cm long) of specimen from the Netherlands (Wijnhoven & Dekkar, 2010). This may indicate that size in the genus may be influenced by local environmental conditions.

Although number of chetae and fecundity were similar among the sites, body mass and length of the polychaete varied, with specimen from Mida Creek, being larger than from other sites. This may be attributed to local variation in sediment characteristics, nutrient status and human disturbance. Poulin (2001), working on a variety of temperate polychaete taxa, attributed the higher body segment abundance and size of oenid polychaetes to parasitic life history, compared to the free living strategy of eunicid polychaetes. It is postulated variation in substrate quality and local environmental conditions, may precipitate plasticity in life history strategies within *Marphysa* taxa. Similar sentiments are expressed by Olive (1999) that relate changes in Nereid polychaete biology (e.g. growth, reproduction) to variation in ecological conditions.

This study has shown that trunk length and width are the most reliable estimators of whole polychaete dimensions. However, while the trunk length is the most reliable all-round estimator, its value in estimating polychaete dimension of cut worm pieces, is weaker than trunk width. However in order to be useful, cut specimen monitoring protocol must clearly and consistently indicate the section used, for instance reference to either the head or tail, in order to reduce double counting. Polychaete weight was the most sensitive to variation in segment metrics, since it was correlated to 5 metrics (especially with trunk metrics<70%), compared to polychaete length (2 metrics) or number of chaetae (1 metric). Although most polychaete metrics in literature report length data, more effort should be put into reporting weights. Unfortunately, sensitive weighing scales are needed, and this reduces suitability of weight monitoring in rapid evaluation of such metrics under field conditions.

Regression between trunk width and length against polychaete weight revealed significant regression coefficient that explained 46 and 40, respectively, of the variation. The corresponding regression equations were of the form: $Polychaete\ weight = 2.45\ Trunk\ Width - 0.60$, can be used in estimating the weight of cut polychaete segments.

Average condition factor for the polychaetes was less than 0.1, this reflects a negative allometric growth, with condition rapidly declining with increase in size. While condition factor were above 0.03 at most sites, Mayonda reported significantly lower condition factor. This may be related to the higher levels of polychaete exploitation at the site (Kihia et al., 2015).

Although there were significant variation in gonad weight among the sites, this was not reflected in the GSI, which were similar. Specimen from Mida creek, had higher gonad weight than those from either Kanamai or Gazi bay, but since their average body weight were larger (e.g. above 3g for Mayonda), this corresponded to lowering of their computed GSI. This suggests that Polychaetes from Mida creek due to their superior body size and mass, may be ideal for breeding as growers, while the smaller, but higher reproductive potential of worms from other site, as breeders. This study has reported low correlation between most polychaete morphometrics with fecundity, apart from trunk length. Similar results were reported by Rettob (2012), showing low correlation between polychaete length and fecundity. However, it is not clear whether reported differences in cultivable values is reflected on a genetic level and subsequently on performance under cultivation, more detailed studies are needed.

5. Conclusion

Polychaete trunk measurements, such as width, are the most reliable estimator of whole *Marphysa mosambica* dimension (e.g. length and weight), as well as breeding value (e.g. condition and gonadosomatic index). The predictive accuracy of trunk measurements, lie between 40 and 90% depending on the parameter. Field validation is however required prior to adoption as a rapid assessment tool.

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