PANAMJAS
Pan-American Journal of Aquatic Sciences

Scientific Note

Length - Weight Relationships for Nine Deep Sea Fish Species off the Kenyan Coast

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Abstract. Length-weight relationships for nine species of deep sea fishes were analyzed, totalizing 1012 individuals. Most regression coefficients calculated were indicative of positive allometric growths. The condition factor values higher than 1 suggests that the specimens were healthy.

Key words: Length-weight relationships, deep sea fish species, Kenyan coast

Resumen. Relación Longitud-Peso de nueve especies de peces de profundidad de la costa de Kenia. Las relaciones longitud-peso fueron analizadas para nueve especies de peces de profundidad totalizando 1012 individuos. La mayoría de los coeficientes de regresión obtenidos son indicativos de crecimiento alométrico positivos. Los valores del factor de condición superiores a 1 sugieren que los ejemplares estaban sanos.

Palabras clave: relación talla-peso, peces de aguas profundas, costas de Kenia

Studies on length-weight relationships of many fish species in the Western Indian Ocean (WIO) region have been carried out with the exception of the deep sea fishes. Length-weight relationship provides useful information for fish species in a given geographic region (Morato *et al*. 2001). In fish, size is generally more biologically relevant than age, mainly because several ecological and physiological factors are more size-dependent than age-dependent. Therefore, variability in size has important implications for diverse aspects of fisheries science and population dynamics, for instance the functional regression "b" value represents the body form and is directly related to the weight affected by ecological factors such as food supply, gonadal development, spawning conditions and other factors that may include sex, age, fishing time, area and fishing vessels (Erzini 1994).

In addition, length-weight regressions have been used frequently to estimate weight from length because direct weight measurements can be timeconsuming in the field (Sinovcic *et al*. 2004). One of the most commonly used analyses of fisheries data is length-weight relationship (Mendes *et al*. 2004). Length-weight relationships for fish were originally used to provide information on the condition of fish and to determine whether somatic growth was isometric or allometric (Le Cren 1951, Ricker 1973). Condition factor studies take into consideration the health and general well-being of a fish as related to its environment; hence it represents how fairly deep-bodied or robust fishes are (Reynold 1968). The present study presents the estimates of the length-weight relationships for nine deep sea fish species off the Kenyan coast.

The study was conducted in the deeper waters of Malindi-Ungwana bay (Fig. 1) at depths between 120 m and 180 m, from November 29th to December 20th 2009 using a beam trawler, on board the *MV Vega*. Malindi-Ungwana bay lies between latitudes 3°30”S and 2°30”S and longitudes 40°00”N and 41° 00”N covering the Malindi and Ungwana Bay Complex. The bay is within Malindi and Tana River Districts in the central part of the Coast Province of Kenya. The bay is under the influence of the dominant offshore wind regimes that include the South-East (SE) monsoon, which occurs between April and October, and the North-East (NE) monsoon, between November and March (McClanahan 1988). This region is the leading zone in prawn fishing and little has been done for the deep sea fishing by the local fishers despite the increased fishing ventures by the distant fleets (Kimani *et al.* 2002).

For this study, 10 hauls were conducted in the deep water. Trawling for each site was done twice using a 2 inch trawl net to maximize on the use of fuel by the sweeping method at a distance of 10 km. For each haul, all fish were collected, identified at the species level according to Smiths and Heemstra (1993) and FAO guide books (1985, 1993, 1996), and sexed. Total lengths (TL) and weight (W) for each fish of each species caught were recorded to the nearest cm and 0.1 g respectively. Samples of unidentified fish were taken and preserved for further identification in the laboratory.

Data was recorded in spreadsheets and analyzed using STATISTICA software package (Statsoft Inc., 2010, version 8.0). The least square method based on Type I linear regression model was used for the expression: log(W) = log (*a*) + *b**log(TL) where: W = weight (g), TL = total length (cm), *a* = regression intercept, *b* = regression slope from the expression; $W = aLT^b$ (Ricker 1973; Beverton and Holt 1996); using W as the dependent variable and LT as the independent variable. The data analysis has been given that for each specie, the number of outliers is far less than 10 % of total data and thus the least square model is satisfactory for each set of data (Chen & Jackson 2000). In the validation of the regression model, the degree of adjustment of the model studied was assessed by the correlation coefficient (r). Student’s t-test was applied to verify whether the declivity of regression (constant “b”) presented a significant difference of b = 3, indicating the type of growth: isometric (b = 3), positive allometric (b>3.0) or negative allometric (b<3.0) (Spiegel 1991) at a statistic significance of 5 %. An analysis of covariance (ANCOVA) was used to determine if there was a significant difference in the length-weight relationship between sexes. Condition factor (K) was calculated for each species according to $K = 100W/TL^b$ where: W = weight (g), TL = Total length (cm) and b = estimated regression coefficient (Tudorancea 1988).

A total of 1012 individual length and weight data were recorded for nine selected fish species that belonged to 8 families and 8 orders (Table I). For the nine fish species, ANCOVA indicated no significant differences (P > 0.05) for length-weight relationships between sexes (Table I).

Table I. Deep-sea fish species in their respective families, orders with their common English names and ANCOVA tests for Length (L) and Weight (W) between sexes (p< 0.05) sampled in Malindi-Ungwana Bay Fishery, Kenya, between 29th November to 20th December 2009 and between 120 m to 180 m of depth.

Order/family	Species	Common name	ANCOVA: L	ANCOVA: W
Aulopiformes/Synodontidae	*Saurida undosquamis*	Lizardfishes (Richardson 1848)	F =7.25, p=0.07	F=22.85, p=0.06
Beloniformes/Bempropsidae	*Bembrops caudimacula*	Duckbills (Steindachner 1876)	F=7.85, p =0.08	F=17.95, p=0.10
Carcharhinifromes/Scyliorhinidae	*Chiloscyllium indicum*	Cat sharks (Bennett 1830)	F=6.75, p=0.11	F=18.45, p=0.07
Perciformes/Triglidae	*Trigloporus africanus*	Gurnards fishes (Richards & Saksena 1978)	F=6.25, p=0.10	F=16.25, p=0.13
	Arnoglossus dalgleishi	Lefteye flounders (von Bonde 1922)	F=6.53, p=0.06	F=23.75, p=0.09
Rajiformes/Rajidae	*Raja alba*	Guitarfishes & Skates (Lacepede 1804)	F=7.05, p=0.12	F=34.75, p=0.07
Scorpaeniformes/Peristediidae	*Peristedion adeni*	Armoured gurnards (Lloyd 1907)	F=7.15, p=0.07	F=14.75, p=0.12
Squaliformes/Squalidae	*Squalis asper*	Dog fish sharks (Smith & Radcliff 1912)	F=7.35, p=0.11	F=19.25, p=0.13
Squatiniformes/Squalinidae	*Squatina africana*	Angel sharks (Regan 1901)	F=7.28, p=0.06	F=26.15, p=0.08

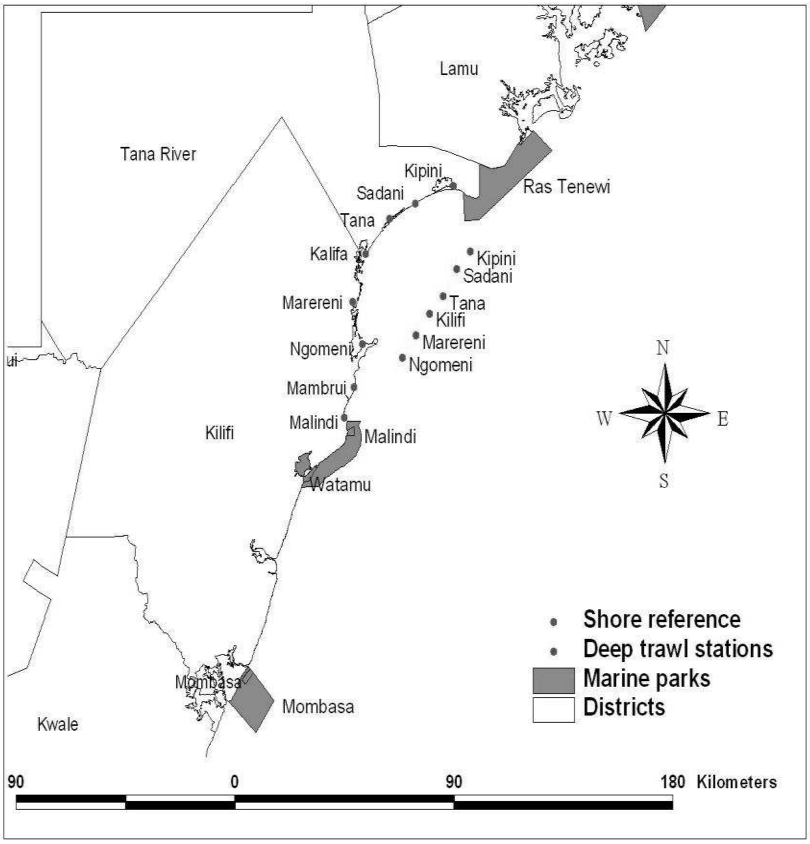

Figure 1. Study sites of the deep sea survey of Malindi-Ungwana bay, Kenya. The sites included Kipini, Sadani, Tana, Kilifi, Marereni and Ngomeni deep waters of the Western Indian Ocean (WIO) region.

The species studied ranged from 9 to 88 cm (Table II). There were no significant differences ($p > 0.05$) for regression slope *b* between sexes for each of the nine species. The non-significant differences in slope of length-weight relationship between females and males could be due to no sexual dimorphism in the species analyzed. The estimates for the *b* values were generally within the range 2.5 to 3.5 for fishes (Carlander 1969). The highest *b* value ($b = 3.41 \pm 0.043$) was recorded for *Peristedion adeni* and the lowest for *Squalis asper* ($b = 2.96$). Except *S. asper* ($b = 2.96 \pm 0.027$), which recorded negative allometric growth ($b < 3$; $p = 0.07$), the rest of the species had positive allometric growth ($b > 3$; $p < 0.05$). The *b* value reflects the pattern of change in body form and condition with increase in size, but the value of *b* may also be affected by the size range catcher in the area during the sampling period (Kimmerer *et al*. 2005, Kulbicki *et al*. 2005, Froese 2006). The coefficient of determination (r^2) for the nine species was very high (Table II). The deep-sea fishes included in the present study seem to be more elongated (Orlov & Binohlan 2009).

Regression coefficient values of the 9 fish species studied were found to be in line when compared to other but not similar deep-sea species counterparts located in other oceans like the Western Bering sea (Orlov & Binohlan 2009), Atlantic Ocean (Diaz *et al*. 2000, Haimovici & Velasco 2000) and in the western coast of India (Thomas *et al*. 2003).

The specimens in the study were found to be in good condition as the values were higher than 1 (Table III). Gayanilo and Pauly (1997) reported that certain factors often affect the well-being of a fish which include data pulling, sorting into classes, sex, stages of maturity and state of the stomach. The condition factor (K) reflects, through its variations, information on the physiological state of the fish in relation to its welfare. From a nutritional point of view, there is the accumulation of fat and gonadal development (Le Cren 1951). Braga (1986) through other authors, showed that values of the condition factor vary according to seasons and are influenced by environmental conditions but more studies are necessary for confirm this hypothesis in the area.

Table II. Descriptive characteristics for 9 selected deep sea species sampled in Malindi-Ungwana Bay deep waters during the study period. Use of * indicates significant difference at p<0.05.

Family	Species	Mean ± SE (cm)	*n*	Min	Max	*a*	*b* ± SE	*r*	t-test
Bempropsidae	*Bembrops caudimacula*	16.55±0.62	111	14.0	21.0	0.0038	3.02±0.015	0.94	2.94*(p=0.04)
	Arnoglossus dalgleishi	14.79±0.32	124	9.0	20.0	0.00049	3.16±0.031	0.95	3.59*(p=0.02)
Peristediidae	*Peristedion adeni*	14.11±1.03	106	12.0	20.0	0.0031	3.41±0.043	0.84	4.31*(p=0.01)
Rajidae	*Raja alba*	45.00±2.58	109	30.0	49.0	0.0042	3.06±0.023	0.93	3.56*(p=0.04)
Scyliorhinidae	*Chiloscyllium indicum*	30.40±0.87	115	22.0	34.0	0.0016	3.43±0.033	0.98	5.03*(p=0.03)
Squalidae	*Squalis asper*	28.50±6.50	108	22.0	35.0	0.012	2.96±0.027	0.97	0.29(p=0.07)
Squatinidae	*Squatina africana*	71.50±16.50	107	55.0	88.0	0.0032	3.12±0.065	0.93	3.41*(p=0.03)
Synodontidae	*Saurida undosquamis*	23.46±0.89	120	15.0	35.0	0.0043	3.06±0.024	0.94	3.42*(p=0.01)
Triglidae	*Trigloporus africanus*	12.29±0.30	112	10.0	16.0	0.0027	3.30±0.034	0.94	4.07*(p=0.04)

Table III. Condition factor (K) ± standard deviations and range values for nine deep sea species sampled in Malindi-Ungwana Bay deep waters during the study period

Family	Species	Mean ± SE	Range
Bempropsidae	*Bembrops caudimacula*	1.23±0.03	0.76-1.54
	Arnoglossus dalgleishi	1.08±0.01	0.94-1.20
Peristediidae	*Peristedion adeni*	1.12±0.03	0.86-1.27
Rajidae	*Raja alba*	1.05±0.01	0.91-1.13
Scyliorhinidae	*Chiloscyllium indicum*	1.06±0.02	0.78-1.17
Squalidae	*Squalis asper*	1.16±0.07	0.92-1.40
Squatinidae	*Squatina africana*	1.20±0.06	0.78-1.56
Synodontidae	*Saurida undosquamis*	1.14±0.04	0.96-1.50
Triglidae	*Trigloporus africanus*	1.11±0.03	0.88-1.38

The length-weight relationships in this study could be useful in modeling the biomass dynamics of deep-sea fishes which have increasingly become targets of fishing activities and whose population dynamics is unknown or little studied especially in the WIO region. However, for more precise weight estimations, the application of these length-weight relationships should be limited to the observed length ranges; otherwise it may be erroneous (Froese 2006). Although they were not considered in this study, the diet, gonadal development and stomach fullness (Tesch 1971) may influence the length-weight relationships of these deep sea fishes, but seasonal or annual data are necessary to verify this hypothesis.

Acknowledgements

This survey was financed by the Government of Kenya, through the Kenya Coast Development Project. We extend gratitude to all members of the crew who gave full cooperation during the survey.

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Received September 2010
Accepted August 2011
Published online November 2011