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Short communication

# Length–weight relationship of 39 selected reef fishes in the Kenyan coastal artisanal fishery

E.K. Mbaru [a,*], C.M. Mlewa [b], E.N. Kimani [a]

[a] Kenya Marine and Fisheries Research Institute, Fisheries Research Program, P.O. Box 81651-80100, Mombasa, Kenya
[b] Department of Biological Sciences, Pwani University College, P.O. Box 195 - 80108, Kilifi, Kenya

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ABSTRACT

Length–weight relationships (LWRs) are presented for 39 major fish species in the Kenyan artisanal marine fishery. Captures were made between the years 2001 and 2009. The parameters $a$ and $b$ of the equation $W = aL^b$ were estimated. The parameter $b$ ranged from 2.030 (*Nomorhamphus weberi*) to 3.987 (*Lutjanus fulviflamma*) with a mean of 3.08 (S.E. 0.02) and 72% of its estimates were between 2.6 and 3.2. Whenever possible, the $b$ values for the species obtained both in this study and some of the previously reported in other studies were compared. The estimated parameters should only be applied to the species analyzed.



## 1. Introduction

The marine fishery in Kenya is predominantly small-scale and artisanal (UNEP, 1998). About 8000 artisanal fishermen operate off the Kenyan coast and intensely fish nearshore reefs, with the majority (80%) of the catch consisting of 39 species (DoF, 2008; Table 1). These species also represent about 83% of the total catch from all artisanal fisheries (DoF, 2006), most of which is provided to local markets. Furthermore, recent socio-economic surveys suggest that at least 90,000 people along the Kenyan coast depend on catches dominated by these 39 species (DoF, 2009). However, despite their ecological and economic importance, most of these species lack basic biological data, and specifically length–weight relationships (LWRs; Petrakis and Stergiou, 1995; Goncalves et al., 1997; Froese and Pauly, 2004).

The LWR is useful in fishery assessments for predicting weights from the more easily measured lengths (Ricker, 1975), yield assessment (Garcia et al., 1998) and when calculating biomass (Martin-Smith, 1996). In addition, morphometric comparisons can be made among species and populations (King, 1996; Goncalves et al., 1997), and relative condition factors for individuals calculated (Maguire and Mace, 1993). The exponent $b$ provides information on growth (Morey et al., 2003); being isometric when $b = 3$ and allometric when this is not the case (positive if $b > 3$, negative if $b < 3$). This study provides the first published LWRs for 32 of the 39 species considered, while also offering a comparison of LWRs for the remaining 7 species.

## 2. Materials and methods

Data were collected between 2001 and 2009 from the Catch Assessment Survey (CAS) conducted by the Kenya Marine and Fisheries Research Institute (KMFRI). Fishes were collected from several fishing fleets and gears with different mesh sizes. Species inhabiting the near-shore reef (0–20 m) were sampled during the north-east monsoon (NEM, October–April) and the south east monsoon (SEM, May–September) seasons while those in deeper (>20 m) were sampled during the NEM season only due to rough sea conditions during the SEM season. Data on total length (TL, cm) to the nearest millimeter and total weight (TW, g) to the nearest gram were recorded for each fish. The parameters $a$ and $b$ of the LWR were estimated after the logarithmic transformation of the equation: $W = a \cdot L^b$ (Ricker, 1975). The Student's $t$-test was used to test whether $b$ was significantly different from 3 ($\alpha = 0.05$). Normality of the distribution of $b$ was tested using the Shapiro–Wilk normality test.

## 3. Results and discussion

The 39 sampled species belong to 15 families. Lethrinidae was represented by 15% of the species analyzed, serranidae by 11%, mullidae, scombroidae, lutjanidae, carangidae, clupeidae, scaridae and siganidae each by 8%, hemiraphidae and acanthuridae each by 5%, and 3% each for balistidae, plotosidae, sphyraenidae and haemulidae. Species represented by few individuals ($n < 100$) from nine families: albulidae, carcharnidae, casiodidae, coryphaenidae,

* Corresponding author. Tel.: +254 721156129.
*E-mail address:* ekam.mbaru@yahoo.com (E.K. Mbaru).

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**Table 1**
Length–weight relationships for the 39 major reef fish species along the Kenyan coast: *n* is sample size; min. and max. are the minimum and maximum total length (cm) and weight (g) recorded; all measurements are of total length (TL); *a* and *b* are the parameters of the length–weight relationship; S.E. is the standard error of *b*; G is the type of growth (I-isometry, P-positive allometry, N-negative allometry); $r^2$ is the coefficient of determination.

| Species | Length (cm) | | | Weight (g) | | Regression parameter | | | | Growth |
|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | Min | Max | Min | Max | *a* | *b* | S.E. (*b*) | $r^2$ | G |
| ***Acanthocybium solandri*** | 168 | 25.0 | 102.0 | 389.5 | 5387.0 | −53.58 | 3.423 | 0.415 | 0.957 | P |
| ***Acanthurus lineatus*** | 101 | 18.5 | 63.0 | 120.0 | 900.0 | −18.17 | 3.572 | 0.005 | 0.919 | P |
| *Balistapus undulatus* | 375 | 16.5 | 35.5 | 112.0 | 225.0 | −10.98 | 3.743 | 0.056 | 0.911 | P |
| ***Carangoides malabaricus*** | 132 | 19.5 | 89.0 | 189.0 | 4595.0 | −6.086 | 3.492 | 0.094 | 0.901 | P |
| ***Cephalopholis sexmaculata*** | 180 | 24.0 | 67.0 | 310.0 | 4100.0 | −13.89 | 2.718 | 0.395 | 0.929 | I |
| ***Decapterus macrosoma*** | 158 | 17.0 | 100.0 | 178.0 | 5190.0 | −14.53 | 3.930 | 0.125 | 0.928 | P |
| ***Dussumieria acuta*** | 641 | 9.5 | 19.5 | 92.0 | 200.0 | −4.093 | 3.228 | 0.065 | 0.903 | I |
| ***Epinephelus andersoni*** | 182 | 23.5 | 66.0 | 300.0 | 3650.0 | −7.139 | 3.111 | 0.360 | 0.908 | P |
| *Epinephelus marginatus* | 260 | 56.0 | 102.0 | 570.0 | 2800.0 | −0.212 | 3.444 | 0.0080 | 903 | I |
| ***Etrumeus micropus*** | 124 | 7.5 | 18.5 | 45.0 | 123.0 | −19.53 | 3.045 | 0.051 | 0.959 | I |
| ***Euthynnus affinis*** | 173 | 37.0 | 104.5 | 700.0 | 5032.0 | −20.56 | 3.853 | 0.480 | 0.911 | P |
| ***Gnathodon speciosus*** | 127 | 20.5 | 102.5 | 102.5 | 6632.0 | −4.964 | 2.362 | 0.119 | 0.905 | N |
| ***Leptoscarus vaigiensis*** | 131 | 32.0 | 65.5 | 320.0 | 950.0 | −7.151 | 3.541 | 0.041 | 0.903 | P |
| ***Lethrinus genivittatus*** | 960 | 36.5 | 78.0 | 300.0 | 1540.0 | −1.218 | 3.952 | 0.029 | 0.908 | P |
| ***Lethrinus harak*** | 1401 | 21.0 | 57.5 | 250.0 | 2600.0 | −1.537 | 3.082 | 0.043 | 0.903 | I |
| ***Lethrinus lentjan*** | 1066 | 22.5 | 52.5 | 300.0 | 2200.0 | −4.070 | 3.183 | 0.032 | 0.900 | I |
| *Lethrinus mahsena* | 119 | 12.0 | 21.5 | 30.0 | 119.5 | −3.257 | 2.562 | 0.421 | 0.937 | N |
| *Lethrinus miniatus* | 632 | 17.5 | 23.5 | 102.0 | 140.0 | −3.463 | 3.534 | 0.033 | 0.901 | P |
| *Lethrinus nebulosus* | 128 | 10.5 | 62.3 | 100.0 | 800.0 | −8.421 | 3.024 | 0.008 | 0.901 | I |
| ***Lutjanus agennes*** | 507 | 21.0 | 79.0 | 300.0 | 1420.0 | −10.47 | 3.872 | 0.108 | 0.908 | P |
| ***Lutjanus bohar*** | 688 | 38.5 | 98.5 | 480.0 | 1365.0 | −4.685 | 3.085 | 0.115 | 0.903 | I |
| ***Lutjanus fulviflamma*** | 1922 | 25.0 | 74.0 | 280.0 | 1200.0 | −15.68 | 3.987 | 0.103 | 0.949 | P |
| ***Mulloidichthys flavolineatus*** | 190 | 18.0 | 48.5 | 150.5 | 580.0 | −8.549 | 3.310 | 0.072 | 0.906 | P |
| ***Mycteroperca microlepis*** | 172 | 25.0 | 68.0 | 321.0 | 4750.0 | −0.048 | 3.048 | 0.401 | 0.908 | I |
| *Naso hexacanthus* | 199 | 20.5 | 64.0 | 138.0 | 950.0 | −7.101 | 3.127 | 0.010 | 0.910 | I |
| ***Nomorhamphus weberi*** | 126 | 45.5 | 98.0 | 450.0 | 2100.0 | −3.131 | 2.030 | 0.011 | 0.905 | N |
| ***Parupeneus cyclostomus*** | 281 | 15.5 | 45.5 | 130.0 | 600.0 | −1.396 | 3.963 | 0.066 | 0.915 | P |
| ***Parupeneus insulari*** | 155 | 12.5 | 54.0 | 120.0 | 650.5 | −0.757 | 3.790 | 0.057 | 0.907 | P |
| ***Plectorhinchus flavomaculatus*** | 110 | 23.5 | 56.0 | 260.0 | 740.0 | −4.117 | 3.501 | 0.039 | 0.904 | P |
| ***Plotosus lineatus*** | 154 | 34.5 | 63.0 | 350.0 | 800.0 | −17.10 | 3.158 | 0.030 | 0.909 | I |
| ***Sardinella longiceps*** | 193 | 10.5 | 20.5 | 87.0 | 205.0 | −48.65 | 3.505 | 0.077 | 0.984 | P |
| ***Scarus rivulatus*** | 505 | 16.0 | 36.0 | 110.0 | 230.0 | −7.454 | 3.971 | 0.030 | 0.903 | P |
| ***Scomberoides commersonnianus*** | 504 | 21.5 | 96.0 | 115.0 | 5185.0 | −6.722 | 3.633 | 0.141 | 0.918 | P |
| ***Scomberomorus plurilineatus*** | 171 | 39.0 | 113.5 | 394.5 | 5279.0 | −15.64 | 2.644 | 0.512 | 0.905 | N |
| ***Siganus javus*** | 1586 | 32.5 | 78.5 | 350.0 | 3580.0 | −3.354 | 3.675 | 0.054 | 0.902 | P |
| ***Siganus luridus*** | 1029 | 28.5 | 67.5 | 290.0 | 3578.0 | −10.49 | 3.587 | 0.019 | 0.903 | P |
| *Siganus sutor* | 2093 | 22.0 | 58.0 | 290.0 | 2820.5 | −5.504 | 3.290 | 0.043 | 0.912 | I |
| ***Sphyraena barracuda*** | 197 | 22.5 | 81.0 | 300.0 | 4780.0 | −0.085 | 3.513 | 0.176 | 0.908 | P |
| ***Tondanichthys kottelati*** | 233 | 65.0 | 104.5 | 602.0 | 3000.0 | −4.743 | 2.736 | 0.014 | 0.916 | I |

dasyantidae, lobotidae, priacanthidae, scianidae and tachysuridae were excluded from the analysis. Lengths ranged between 9.5 cm (*Dussumieria acuta*) and 113.5 cm (*Scomberomorus plurilineatus*).

The parameters of the length–weight relationships for the 39 fish species ($N = 18{,}073$) are shown in Table 1. Information on the kind of growth (isometric or allometric) of each species is provided in Table 1, box–whiskers plots of the estimates of *b* in Fig. 1 and the distribution of *b* in Fig. 2. The *b* values ranged from 2.030 (*Nomorhamphus weberi*) to 3.987 (*Lutjanus fulviflamma*) with a mean value of 3.08 (S.E. 0.02), and a median value of 3.1. 72% of the estimates of *b* were between 2.6 and 3.2 (Fig. 1). The coefficient of determination ($r^2$) ranged from 0.900 for *Lethrinus lentjan* to 0.984 for *Sardinella longiceps*. Twenty-two species had $r^2$ values between 0.90 and 0.92, nine $r^2$ values less than 0.91, while eight species had $r^2 > 0.92$. All regressions were highly significant ($p < 0.001$). Twenty-two species showed positive allometric growth, 4 negative allometric, and 13 isometric growth (Table 1 and Fig. 2). Normality of the *b* distribution was not rejected (*W*-statistic = 0.981;

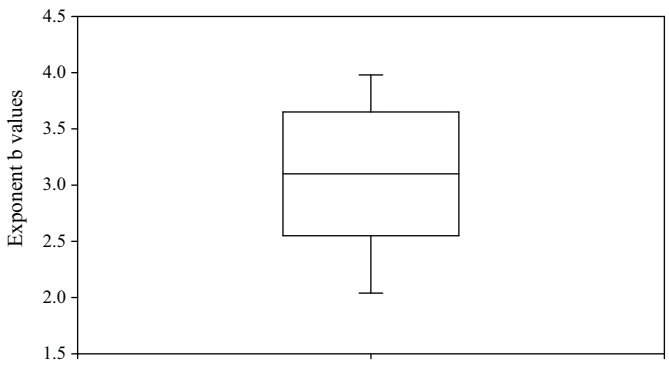


**Fig. 1.** Box–whiskers plots of the exponent *b* of the LWR for the 39 species analyzed. The central box covers 72% of data values, the horizontal line indicates the median, and the vertical line represents the range of the values.

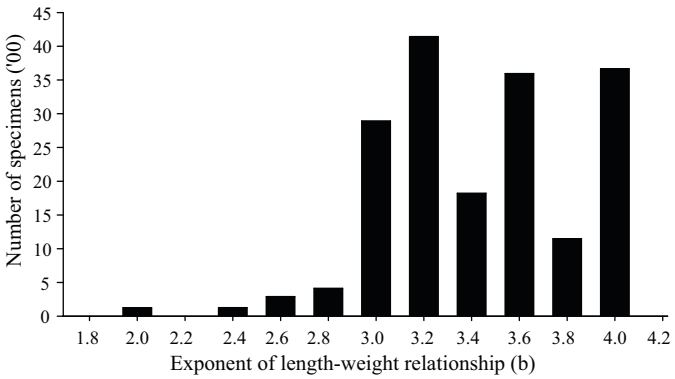


**Fig. 2.** Distribution of *b* values of the LWR.

**Table 2**
Number of specimens ($n$), total length ranges (TL range) and $b$ values for those species compared between this study and Western Mediterranean waters (Morey et al., 2003), Western Indian Ocean waters (Carpenter and Allen, 1989; Woodland, 1990; Kaunda-Arara and Rose, 2006) and Pacific Ocean waters (Masuda et al., 1984; Myers, 1991).

| Species | Western Mediterranean waters | | | Western Indian ocean waters | | | Pacific ocean waters | | |
|---|---|---|---|---|---|---|---|---|---|
| | *n* | TL range | *b* | *n* | TL range | *b* | *n* | TL range | *b* |
| *Balistapus undulatus* | | | | 6 | (11.2–30.0) | 2.640[a] | | | |
| *Epinephelus marginatus* | 222 | (13.4–105.6) | 3.121 | | | | | | |
| *Lethrinus mahsema* | | | | 16 | (26.1–65.0) | 2.600 | | | |
| *Lethrinus miniatus* | | | | | | | 6 | (12.4–44.0) | 3.130 |
| *Lethrinus nebulosus* | | | | | | | 6 | (14.6–86.0) | 3.410 |
| *Naso hexacanthus* | | | | 3 | (16.7 – 38.6) | 3.200 | | | |
| *Siganus Sutor* | | | | 32 | (16.2–45.0) | 3.060 | | | |

[a] $b$ values significantly different of those from this study.

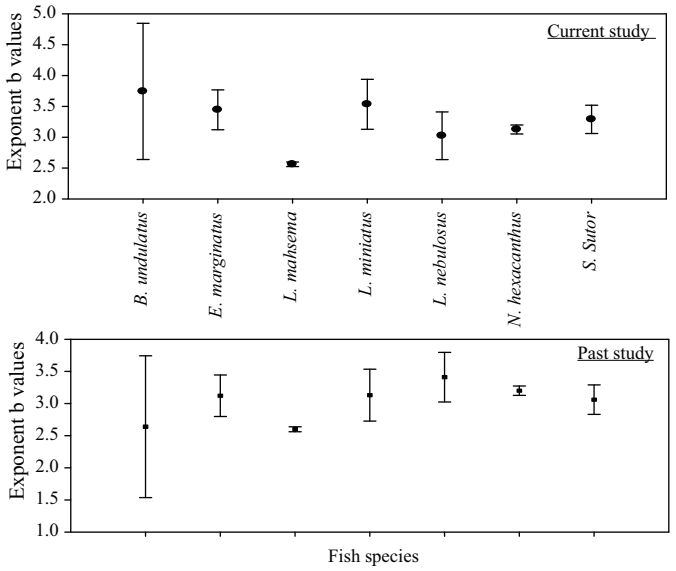


**Fig. 3.** Multiple scatter plots of the exponent $b$ values of the LWR for 7 species in this study compared to other past studies.

$p = 0.970$), indicating that the data match the expected pattern (Zar, 1996).

The parameters of weight–length relationships, particularly $a$, may vary daily, seasonally, and/or between habitats, unlike the parameter $b$, which does not vary significantly throughout the year (Bagenal and Tesch, 1978). Although sampling was not conducted seasonally in the present study, more fish were sampled during NEM than the SEM season. However, the estimated parameters in this study should be considered composites across the whole year rather than representing a particular season as the analysis was based on all data collected during the year. Of the 39 species, only seven have published LWRs (Table 2). Fig. 3 shows the scatter plots of $b$ for the seven species for which estimates of $b$ are available from other studies. Only the estimate of $b$ for *Balistapus undulatus* (3.743) was significantly different from the value based on a past study ($b = 2.640$; Kaunda-Arara and Rose, 2006). To the authors knowledge, this study provides the first information on length–weight relationships for 32 of the species (Table 1, species in bold). This is also the first record for *E. marginatus* species in North West Indian Ocean. Differences in LWR parameters may represent spatial variation (Sparre et al., 1989), due to the influence of water quality or food availability on fish growth (Mommsen, 1998). However, the observed differences in our comparisons could as well be related to the larger sample sizes (>100) compared to the fewer specimens ($n = 3$–16, Table 2) on which the LWRs of the previous studies were based. For more precise weight estimations through LWRs it is advisable to make use of local values, as well to limit their application to the length ranges used to calculate the regression parameters (Petrakis and Stergiou, 1995). Thus, the estimated parameters should only be applied to the species analyzed in the present study.

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## References

Bagenal, T.B., Tesch, P.W., 1978. Age and growth. In: Benegal, T. (Ed.), Methods for Assessment of Fish in Fresh Waters, 3rd ed. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, pp. 101–136.
Carpenter, K.E., Allen, G.R., 1989. FAO species catalogue, vol.9. Emperor fishes and large eye breams of the world (Family; Lethrinidae) FAO species synop. No. 125, 118 pp.
DoF, 2006. Annual Report: Ministry of Fisheries Development, Kenya. Provincial Headquarters, Mombasa, 98 pp.
DoF, 2008. Frame Survey Report. Ministry of Fisheries Development, Kenya. Provincial Headquarters, Mombasa, 143 pp.
DoF, 2009. Annual Report: Ministry of Fisheries Development, Kenya. Provincial Headquarters, Mombasa, 109 pp.
Froese, R., Pauly, D. (Eds.), 2004. Fishbase (www Database). World Wide Web Electronic Publications, URL: http://www.fishbase.org/ (accessed August 2010).
Garcia, C.B., Duarte, J.O., Sandoval, N., von Schiller, D., Melo, G., Navajas, P., 1998. Length–weight relationships of demersal fishes from the Gulf of Salamanca, Colombia, Naga. ICLARM Quart. 21 (3), 30–32.
Goncalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canario, A.V.M., Erzini, K., 1997. Weight–length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. Fish. Res. 30, 253–256.
Kaunda-Arara, B., Rose, G.A., 2006. Growth and survival rates of exploited coral reef fishes in Kenya marine parks derived from tagging and length frequency data. Western Indian Ocean J. Mar. Sci. 5 (1), 17–26.
King, R.P., 1996. Length–weight relationships of Nigerian freshwater fishes. Fishbyte 19 (4), 53–58.
Maguire, J.J., Mace, P.M., 1993. Biological reference points for Canadian Atlantic gadoid stocks. In: Smith, S.J., Hunt, J.J., Rivard, D. (Eds.), Risk Evaluation and Biological Reference Points for Fisheries Management, vol. 120, p. 350, Can. Spec. Publ. Fish. Aquat. Sci.
Martin-Smith, K.H., 1996. Length/weight relationships of fishes in a diverse tropical freshwater community, Sabah, Malaysia. J. Fish Biol. 49, 731–734.
Masuda, H., Amaoka, K., Araga, C.T., Yoshigo, T., 1984. The Fishes of the Japanese Archipalego. Tokad Univ. Press, Tokyo, Japan, 37 pp.
Mommsen, T.P., 1998. Growth and metabolism. In: Evans, D.H. (Ed.), The Physiology of Fishes. CRC Press, New York, pp. 65–97.
Morey, G., Moranta, J., Massutı, E., Grau, A., Linde, M., Riera, F., Morales-Nin, B., 2003. Weight–length relationships of littoral to lower slope fishes from the western Mediterranean. Fish. Res. 62, 89–96.
Myers, R.F., 1991. Micronesian reef fishes. In: Coral Graphics, 2nd ed. Barrigada, Guan, 298 pp.
Petrakis, G., Stergiou, K.I., 1995. Weight–length relationships for 33 fish species in Greek waters. Fish. Res. 21, 465–469.
Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191, 382.
Sparre, P., Ursin, E., Venema, S.C., 1989. Introduction to tropical fish stock assessment. Part I. Manual. In: FAO Fisheries Technical Paper No. 306.
UNEP, 1998. Eastern Africa Atlas of Coastal Resources: Kenya. United National Environment Programme, Nairobi, 119 pp.
Woodland, D.J., 1990. In: Fischer, W., Bianchi, G. (Eds.), Family Siganidae in FAO Species Identification Sheets for Fishery Purposes: Western Indian Ocean (Fishing Area 51), vol. iv. FAO, Rome.
Zar, J.H., 1996. Biostatistical Analysis, 3rd ed. Prentice-Hall Inc., New Jersey, 662 pp.