ISSN: 2642-9020

Research Article

Journal of Marine Science Research and Oceanography

# Length-length Relationship, Weight-Length Relationship, Sex Ratio and factor of Condition of Sardinella maderensis (Lowe, 1838) in South-Eastern Coastal waters of Benin

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**Submitted**: 01 July 2020; **Accepted**: 06 July 2020; **Published**: 16 July 2020

## Abstract

*Face to decreasing of high-value commercial fishes' stocks particularly of small pelagic fish in the central part of FAO fishery area 34, the present study has been carried out. From November 2016 to June 2018, monthly 1041 specimens of Sardinella maderensis were collected from southeastern coastal water of Benin randomly. Standard and Total Length, and weight as well as, the sex data were collected.t-test, z-test and ANOVA one tail test were performed to determine whether there was a significant difference between data. With a ratio of 1:1.5 statistically different from 1:1 ($p<0.001$), female dominate S. maderensis population in Benin. Negative allometry both for the female (2.92) the male (2.88) and combined sexes (2.90) highly different from the consensus, "b=3" ($p<0.001$) is remarked. The relative condition factor computed from the allometry shows an average environmental condition for S. maderensis growth. Regarding the shared character of S. maderensis stock in CECAF's central area, these results are important for the next stock assessment..*

**Keys words:** S. Maderensis, llr, lwr, benin, cecaf, relative condition factor

## Introduction

Sardinella maderensis, flat sardinella is euryhaline and often found in abundance near river outlets. It prefers less turbid, and relatively warmer waters with temperatures above 24°C Similar to the round sardinella, the flat sardinella is less abundant in waters with no upwelling, and steady surface temperature and salinity. They spawn continuously throughout the year, with the maximum breeding occurring at the beginning of the warm season in countries like Senegal and Côte d'Ivoire, and during the cold season in Congo. Though concentrated in coastal waters at early stages of development, juveniles gradually move away as they reach sexual maturity, and the vast majority of adults remain confined to the shallow half of the continental shelf [1]. S. Maderensis is one of the small pelagic fish species of high commercial value commonly found in countries along the sub-Saharian coastline, from Mauritania to Angola [2]. Like all other pelagic fish stocks of high economic value, Sardinella maderensis is under the intense pressure of overexploitation in many countries including Côte d'Ivoire, Ghana, Togo and Benin where they serve as a vital source of nutrition and support livelihoods of many artisanal fishers. In Benin, S. maderensis is increasingly becoming rare in landings of artisanal fishers. Moreover, in the last 20 years, the total catch of small pelagic has fallen below 500 tons. The catch of S. maderensis has also declined from about 1200 tons to less than 300 tons [3]. This underscores the need for drastic management measures to conserve these important fishes and shift to sustainable fishing. For effective management of fish stocks, studies on important aspects of the biology that provides insights on the growth patterns, population dynamics and the effects of abiotic and biotic factors on fish are extremely crucial. Few studies on S. maderensis in Benin's territorial marine waters exist. Important aspects such as length-length relationship, length-weight relationships and the relative condition factor in S. maderensis remain absent in existing literature. Over the years, since Le Cren's work, Length-Length and Length-Weight relationships are useful for converting growth equations to length and weight for use in stock assessment models and for estimating stock biomass from limited sample data [4, 5]. Presently, only 9 and 4 studies have been identified in Fishbase (2019) on length-weight and length-length relationships respectively. The need of more studies on length-weight and length-length relationships of economically important fishes, and the response to the recommendations of the Food and Agriculture Organization/ Fishery Committee for the Eastern Central Atlantic (FAO/CECAF) working group on the assessment of small pelagic species, subgroup South underpinned this study. Against this background, we examine the length-length and length-weight relationships of S. maderensis; and then evaluate the relative condition factor to understand the effect of changes in environmental conditions on the growth of the species in the territorial waters of Benin for sustainable management of S. maderensis [3].

## Methodology

### Study area

The study was carried out at the Cotonou Artisanal Fishing Port (PoPAC) (6°21N; 2°25E) and at the Akpaka Dodomey landing camp (currently demolished) (6°21N; 2°26E).

### Sampling

Sampling was conducted monthly from November 2016 to June 2018 concurrently at the two landing sites. Specimens of S. maderensis were randomly sampled from the fisherfolks as soon as landings were made during the afternoon. These samples were taken randomly from catches by artisanal fisherfolks using gillnets "sovi" of mesh diameter 2.5cm.

### Data Collection

Once sampled, the specimens were transported immediately to the laboratory. Measurements of length (cm) and weights (g) were taken using an ichthyometer and a kitchen balance accurate to 1g the weighing was done without evisceration or any form of treatment.

### Length-to-length relationship

The length-to-length relationship between Standard Length and Total Length was evaluated using an Ordinary Least Squares (OLS) regression model to fit the linear regression model Y=a+bx, where Y is the Standard Length; X, the Total Length; a, the proportionality constant and b, the regression coefficient.

### Length-weight relationship

The parameters of the Length-Weight relationship were calculated separately for males, females and the whole population ( a combination of both sexes) using the linearized formula of the equation: ln(Wt) = log "a "+ "b" log (Lt), where (Wt) is the total weight (g), (Lt) is the Total length (cm), "a" is the intercept, and "b" is the slope of the relationship (which indicates the isometric growth of body proportions if b ~3) [6]. The parameters "a" and "b" were determined from the results of the regression model with a confidence interval of 0.95. Before the linear regression adjustment, the data were log-transformed and were plotted for outliers according to Froese et al., [7].

A t-test following Pauly's method was carried out to test the significant difference between the calculated b and 3 according to the formula below [8].

$$t = \frac{SD_{logTL}}{SD_{logTL}} * \frac{|b-3|}{\sqrt{(1-R^2)}} * \sqrt{(n-2)}$$

(Where $SD_{logTL}$ et $SD_{logTL}$ are the respective standard deviations of $\log_{10}$TL et de $\log_{10}$ w and, n is effective.

b is different from 3 if t is greater than the value calculated for a degree of freedom of n-2.

The different analyses of the Length-Length and Weight-Length Relationship were performed using Excel 2016.

### Sex Ratio

Sexes were identified by the observation of internal organs of fishes. The Sex Ratio was calculated using the formula SR= 100*M/F. The results obtained were statistically verified and compared to the expected value of 1:1 using a z-test using R function "prop.test".

### Relative Condition Factor Krel

The relative condition factor Krel was calculated according to

$$Krel = \frac{W}{al^b}$$

to avoid the influence of length on this indicator of fish environmental quality and feeding status [9, 10]. Krel = relative condition factor; W = actual weight of the fish and W'= $aL^b$ = weight calculated from the size-weight relationship. A one-tailed ANOVA statistical test (α=0.05) was performed to determine whether there was a significant difference between the Krel values obtained between the sexes during the months of the study.

### Data Analysis

The data were processed and analyzed using Excel version 2016. Descriptive statistics (means, minimum and maximum, and normality test) and inferential statistics (regression) were applied.

## Results

### Distribution of sample characteristic

A total of 1041 specimens of Sardinella maderensis were collected between November 2016 and June 2018 including 600 females, 384 males and 57 unidentified specimens at the Artisanal Fishing Port of Cotonou. Descriptive statistics of Total Length (TL) and Standard Length (SL) and Total Weight for each sex and sample are given in Table 1 below. Specimens whose sex could not be identified have been removed from the dataset; the same applies to "outliers", i.e. data that deviate from the regression line after log-transformation of the data.

**Table 1:** Descriptive statistics of S. maderensis measurements in Benin.

| | **Female** | | | | | **Male** | | | | | **Both Sexes** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Min | Moy | SD | Max | n | Min | Moy | SD | Max | n | Min | Moy | SD | Max |
| LT (cm) | 630 | 12 | 18.47 | 4.41 | 33 | 383 | 12 | 20.91 | 5.11 | 32 | 1013 | 12 | 19.38 | 4.83 | 33 |
| LS (cm) | 619 | 9 | 14.79 | 3.20 | 26 | 353 | 10 | 16.44 | 3.76 | 24 | 973 | 9 | 15.41 | 3.47 | 26 |
| WT (g) | 630 | 11 | 57.61 | 48.54 | 275 | 383 | 14 | 82.24 | 54.36 | 234 | 1031 | 11 | 66.97 | 52.18 | 275 |

### Length-length (L-L) Relationship

The equations developed for the relationship between lengths are presented below with the correlation coefficients and corresponding statistical parameters in Table 2.

**Males : (10<SL<24) TL= 1.3618SL - 1.9597 ($R^2$=0.96, N= 353, p<0.001)**

**Females: (9<SL<26) TL = 1.3167SL - 1.1618 ($R^2$= 0.91, N= 619, p<0.001)**

**Combined: (9<SL<26) TL = 1.3332SL - 1.4352 ($R^2$ = 0.96, N= 972, p<0.001)**

### Weight-Length (W-L) Relationship

The equations developed for the Length-Weight relationship are presented below with the corresponding correlation coefficients and, in Table 2 and Graph 1, the statistical relationship parameters for males, females and the whole sample. They are presented in a linearized form.

**Males: $\log_{10}W$= -1.9561+2.88$\log_{10}TL$ ($R^2$=0.97; p<0.001; t= 4.77)**

**Females : $\log_{10}W$= -2.0175+2.92$\log_{10}TL$ ($R^2$=0.98; p<0.001; t = 4.70)**

**Combined: $\log_{10}W$= -1.9912+2.90$\log_{10}TL$ ($R^2$=0.98; p<0.001; t = 5.24)**

**Table 2:** Length-Weight Relationships

| | L-L Relationship | | | W-L Relationship parameters | | | | |
|---|---|---|---|---|---|---|---|---|
| | a | b | $R^2$ | a | b | SD | $R^2$ | Allometry |
| Male | 1.9126 | 0.709 | 0.91 | -1.9561 | 2.88 | 0.19 | 0.97 | A- |
| Female | 1.4242 | 0.729 | 0.96 | -2.0175 | 2.92 | 0.32 | 0.98 | A- |
| Bothsexes | 1.5507 | 0.725 | 0.96 | -1.9912 | 2.90 | 0.65 | 0.98 | A- |

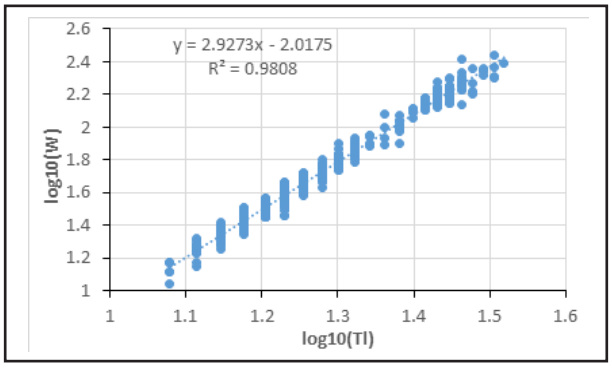



**Fig 1a:** Length-Weight relationship in females

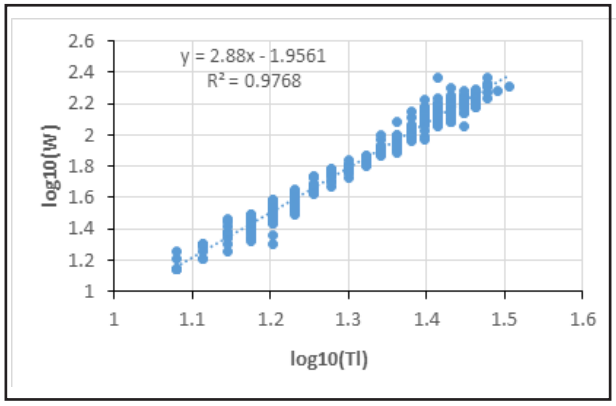



**Fig 1b:** Length-Weight relationship in male

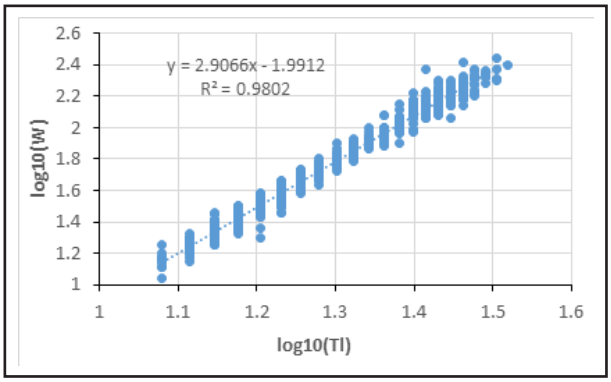
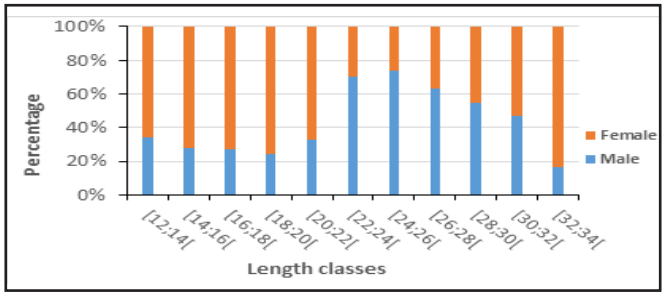



**Fig1c:** Length-Weight relationship in both sexes

### Sex-Ratio

Bar chart 1 below shows the evolution of the sex ratio during the study period.




**Bar chart 1:** S. maderensis sex ratio

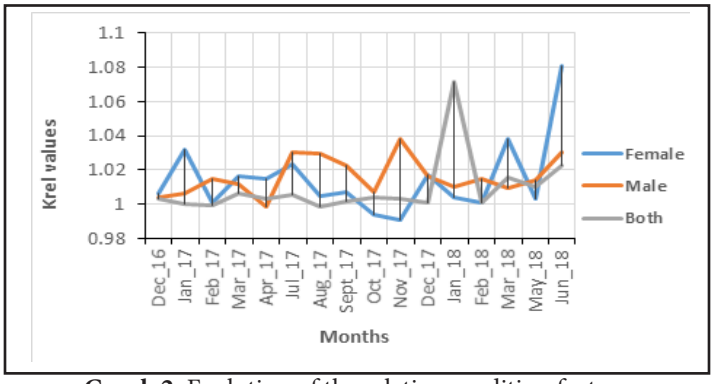
A majority of specimens 62% were females whiles males constituted the few 38%. The sex ratio for the total sample is 1:1.5 during the sampling. The sex ratio is in favor of males in size classes 22-24, 24-26, 26-28 and 28-30.

## Condition Factor

Table 3 and Graph 3 below present the estimated values of the relative condition factor K according to month and gender and its evolution. The mean values of the relative condition factor expressed for each sex and the whole sample give for females, males and both sexes combined: 1.01±0.02; 1.02±0.01 and 1.01±0.02 respectively. These values are not statistically different from each other ($p>0.05$) by month and by sex. In general, the relative condition factor varies between 0.99±0.06 and 1.07±0.39.

**Table 3:** Estimated values of the relative condition factor (Krel).

| Male | Female | Combined |
|---|---|---|
| 1.004±0.09 | 1.006±0.06 | 1.003±0.07 |
| 1.006±0.13 | 1.032±0.09 | 1.000±0.11 |
| 1.015±0.09 | 1.001±0.08 | 0.999±0.10 |
| 1.012±0.12 | 1.016±0.09 | 1.006±0.08 |
| 0.999±0.08 | 1.015±0.09 | 1.004±0.08 |
| 1.030±0.10 | 1.023±0.13 | 1.006±0.11 |
| 1.030±0.06 | 1.004±0.06 | 0.999±0.06 |
| 1.023±0.11 | 1.007±0.07 | 1.002±0.08 |
| 1.007±0.06 | 0.994±0.07 | 1.004±0.07 |
| 1.038±0.08 | 0.991±0.05 | 1.004±0.06 |
| 1.016±0.07 | 1.017±0.08 | 1.001±0.08 |
| 1.010±0.11 | 1.004±0.08 | 1.072±0.39 |
| 1.015±0.08 | 1.001±0.04 | 1.001±0.06 |
| 1.009±0.14 | 1.038±0.11 | 1.016±0.14 |
| 1.014±0.19 | 1.003±0.12 | 1.010±0.16 |
| 1.031±0.09 | 1.081±0.24 | 1.022±0.14 |




**Graph 2:** Evolution of the relative condition factor

## Discussion

The results obtained from this study will be compared with the work carried out in the southern zone of CECAF. Indeed, the FAO/CECAF sub-group of this zone agreed on the existence of four different stocks in the zone by delimiting it into North, Central, South and West zones [3]. This delimitation should be reconsidered given the latest work on the identification of Sardinella maderensis stocks using the genetic tools which concludes that there is a single stock in the central zone of FAO Area 34 [11].

## Length-length Relationship

For S. maderensis, the length-length relationship by sex is not available in Fishbase. Linear regressions between lengths (TL vs SL) were highly significant with $p<0.001$. The values obtained for "a" and "b" in the present study are lower than those obtained by Sossoukpe et al., This difference could be due to the number of specimens sampled and the clearance of our data set according to Rainer Froese et al., This present relationship for determining the total length, knowing the standard length has no precedent in FishBase for S. maderensis [7, 12].

## Weight-Length Relationship

Nine studies on the Total Length-Total Weight relationship are available in Fishbase: three (03) concern the central (Nigeria) and northern (Sierra Leone) zones of the southern CECAF zone and one concerns the northern CECAF zone (Senegal), one concerns Cape Verde and the other three concern Tunisia. , Therefore, the results obtained in the present study will be compared with those obtained in the areas close to Benin based on the uniqueness of the stock proven by Takyi [11].

The values obtained for "b" in the present study are within the range of 2.5-3.5 suggested by Rainer Froese et al., and higher than those obtained by and in Nigeria for the combined sexes [7, 13, 14]. This may be due to the quality of the environment, the availability of the food and the size classes sampled. Those obtained in the southern and northern zones of CECAF respectively in Senegal and Sierra Leone and, outside CECAF (Tunisia) in Fishbase fall in the rang obtained in this study. It appears that the S. maderensis stock present along West Africa coast would seem to be the same.

## Sex Ratio

The sex ratio in S. maderensis is marked by a dominance of females in Benin. The present result is in agreement with those obtained in Benin and Senegal [1, 12]. This predominance is characteristic of Clupeidae according to Boely even though the sex ratio is not in the same proportions in these studies and statistically quite different from the 1:1 consensus ($p<0.001$) [1].

## Relative Condition Factor

According to Jisr et al., fish of relative condition factor Krel ≥1 is described as overweight, and this is attributable to good environmental conditions whereas fish of relative condition factor Krel<1

is underweight, potentially as a result of environmental conditions that inhibit growth [15, 16]. Our Krel's values (Table 3) are greater than or equal to 1, indicative of the relatively favourable conditions (biotic and abiotic) of coastal waters of Benin where S. maderensis is fished.

## Conclusion

The results of this study provide information on morphometric parameters of S. maderensis in Benin in the western CECAF zone, where his stock is facing intensive pressure. Thus, S. maderensis shows negative allometry despite, the known environmental conditions in the South Eastern coastal waters of Benin that allow him to have an average relative condition factor. A high significance was found for the LLR and LWR and the sex-ratio showing a female dominance along with the study.

They will serve as a reference for future work to be undertaken on the rest of the Beninese coastline. Also, they will allow coordinated management of the resource which seems to be a single stock between the countries of the northern and western parts of CECAF.


## Acknowledgements

The authors would like to thank the "Institut de Recherches Halieutiques et Océanologiques du Bénin" (IRHOB) and "JEAI-SAFUME" project for having made available the financial and technical resources for this study. They also thank all the fishermen and fish-mongers who helped in the collection of samples.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