Length-Weight Relationships of 52 Species from the South of Sicily (Central Mediterranean Sea)

Fabio Falsone 1, Michele Luca Geraci 1,2,*, Danilo Scannella 1, Vita Gancitano 1, Federico Di Maio 1,2, Giacomo Sardo 1, Federico Quattrocchi 1 and Sergio Vitale 1

1 Institute for Biological Resources and Marine Biotechnology (IRBIM), National Research Council CNR, Via Luigi Vaccara 61, 91026 Mazara del Vallo (TP), Italy; fabio.falsone@irbim.cnr.it (F.F.); danilo.scannella@irbim.cnr.it (D.S.); vita.gancitano@cnr.it (V.G.); federico.dimaio2@unibo.it (F.D.M.); giacomo.sardo@irbim.cnr.it (G.S.); federico.quattrocchi@irbim.cnr.it (F.Q.); sergio.vitale@cnr.it (S.V.)
2 Marine Biology and Fisheries Laboratory of Fano, Department of Biological, Geological and Environmental Sciences, University of Bologna, Viale Adriatico 1/n, 61032 Fano (PU), Italy
* Correspondence: Micheleluca.geraci2@unibo.it

Abstract: The Length-Weight relationships (LWRs) of 52 species (14 never reported before) of fishes, crustaceans and cephalopods living on the shelf and upper slope off Southern Sicily are provided. Data were collected in the framework of the International bottom trawl survey in the Mediterranean (MEDITS) in the South of Sicily (Central Mediterranean), covering a time frame ranging from 2012 to 2019. Linear regressions were significant for all species \((p < 0.05)\) with \(R^2\) values ranging from 0.86 to 0.99. The intercept (a) of LWRs ranged from 0.0003 to 0.4677, while the slope (b) ranged from 2.1281 to 3.306. The Welch t-test, used to evaluate differences between the obtained LWRs with those reported in the literature, revealed that most of the LWRs (about 55%) reported in this study are in disagreement with those obtained previously by other authors from the Strait of Sicily. It is expected that the results obtained from this study will contribute to filling the knowledge gap of fish populations in this area and also assist fisheries scientists in future stock assessment studies.

Keywords: LWR; bony fishes; cartilaginous fishes; cephalopods; crustaceans

1. Introduction

A historical review of the Length-Weight relationship shows that the relationship between length (L) and weight (W) of fish was formally expressed by Keys \([1]\) in the equation: \(W = aL^b\). Many authors published on the cube law of the weight–length relationship, e.g., \([2]\), and several interpretations of the exponent \(b\) were presented. Ricker, in the year 1958, used the term “isometric growth”, for the value of \(b = 3\), and Tesch, in the year 1968, used the term “allometric growth” for values other than \(b = 3\) \([3,4]\). The importance of determining LWRs in fish was emphasized by many studies \([2,5,6]\). Length and weight relationships provide important information for stock assessment as well as population dynamics \([7,8]\). Indeed, they provide information about the growth pattern, general health, habitat conditions, life history, fish condition as well as morphological characteristics of the fish \([2,4,9–11]\). In addition, LWRs information is necessary to estimate the biomass from length-frequency data \([12–14]\) and is useful for between-region comparisons of life histories of certain species \([15,16]\). Despite their importance, LWRs are frequently incomplete and limited to the most common or commercial species. In the Eastern and Western Mediterranean basins, there are more studies focused on LWRs of fishes \([17–23]\) than in the Central Mediterranean \([24,25]\). Considering the paucity of data about LWRs in the published literature (many LWRs are reported in the grey literature), at least in the Strait of Sicily \([11,26–28]\), the present note aims to fill this knowledge gap by reporting the first references of LWRs of 14 species and updating the LWRs of the most studied species.
2. Materials and Methods

The study area was located off the south-western coast of Sicily within the Geographical Sub Area 16 (GSA16, according to the General Fisheries Commission for the Mediterranean—GFCM—classification; GFCM, 2007), namely the northern sector of the Strait of Sicily (Figure 1). This area covers about 31,000 km$^2$, and it is characterized by the presence of two wide and shallow banks (<100 m), one in the west (Adventure Bank) and one in the east (Malta Bank), and by a wide portion of water generally with depth higher than 200 m [29,30].

Figure 1. The sampling area covered by the MEDITS survey in the Strait of Sicily.

Samples were collected during the international bottom trawl survey in the Mediterranean (MEDITS) in a time frame ranging from 2012 to 2019. The MEDITS survey was carried out during the summer and fall seasons using a GOC 73 trawl net characterized by a vertical opening ranging between 2.4 and 2.9 m and a 20 mm stretched mesh-size at the cod end [31,32].

All samples were frozen on board and subsequently processed in the laboratory for biometric measurements. All species were measured and weighed according to MEDITS protocol [33–35]. In particular, the cephalopods were measured as mantle length (ML) at the lower 0.5 cm and weighted to the nearest 0.1 gr, crustaceans as carapace length (CL) at the lower 1 mm while the weight was recorded to the nearest 0.01 gr and fishes as total length (TL) at the lower 0.5 and weight to the nearest 1 gr.

The relationship between length and weight was calculated using the following classical Equation (1):

$$W = aL^b$$

(1)

Being TW total weight (g), L is TL (cm) for fish, ML for cephalopods (cm), CL for crustaceans (mm), a and b are the equation parameters calculated applying a linear regression model using the logarithmic form of Equation (2) as:

$$\log TW = \log a + b \log L$$

(2)
All species with less than 10 specimens were excluded from the analysis. Furthermore, according to the recommendations of Froese et al. [14] and Evangelopoulos et al. [36], the outliers (data points whose response values did not follow the general trend of the remaining data) were removed from the initial database. In addition, the analysis of covariance (ANCOVA) was performed to determine eventual significant differences between the sexes. The LWRs were shown by sex only when significant differences emerged by ANCOVA analysis; otherwise, they were provided as combined. The growth types (allometric or isometric) were tested using the \( t \)-test that investigates whether the slope \( b \) was significantly different from the theoretical value 3 (i.e., isometric growth), with a confidence level of 95\% [37]. For both \( a \) and \( b \), the confidence interval was provided. In addition, the differences between the prediction LWRs values of the present study with those reported in the literature in the Strait of Sicily were assessed through Welch \( t \)-test. All analyses were performed using R 4.0.3 [38].

3. Results

A total of 52 species belonging to 37 families were analyzed in this study. The best-represented family was Sparidae with six species, while the most abundant species was Parapenaeus longirostris Lucas, 1846 with about 47,128 specimens, followed by Merluccius merluccius (Linnaeus, 1758) and Illex coindetii (Verany, 1837) with 16,933 and 8754 specimens, respectively. The statistical descriptions of parameters obtained for each species are shown in Table 1, whereas a comparison with other studies from the Strait of Sicily and the outcomes of the \( t \)-test is provided in Table S1 [24,26,27,39–59].

### Table 1. Length-Weight relationships of 52 species from the South of Sicily. The species in bold type are those firstly reported in the Strait of Sicily. Length is reported in mm for crustaceans and in cm for cephalopods, bony and cartilaginous fishes. Weight is reported at 0.1 grams’ accuracies for crustaceans and cephalopods and at grams for bony and cartilaginous fishes. N: sample size; sd: standard deviation; \( a \): the intercept of the regression curve with the confidence interval; \( b \): the regression slope with the confidence interval, T: student \( t \)-test; \( P \): \( p \)-value of \( t \)-test; \( R^2 \): the coefficient of determination; T.G: type of growth: A\(^+\), positive allometric growth; A\(^-\), negative allometric growth; I, Isometric growth.

| Specie                | SEX | N   | Length (Min–Max) | Weight (0.1 g, Min–Max) | a  | 2.50% | 97.50% | b  | 2.50% | 97.50% | T.G. | T  | P     | \( R^2 \) |
|-----------------------|-----|-----|------------------|-------------------------|----|-------|--------|----|-------|--------|------|-----|-------|----------|
| **Crustaceans**       |     |     |                  |                         |    |       |        |    |       |        |      |     |       |          |
| Aristaeomorpha foliacea | F   | 4290 | 15–68            | 1.6–85.2                | 0.0017 | 0.0017 | 0.0018 | 2.5663 | 2.5587 | 2.574 | A\(^-\) | −111.05 | s     | 0.99 |
|                       | M   | 3226 | 19–52            | 3.2–45.9                | 0.0013 | 0.0012 | 0.0014 | 2.671 | 2.65 | 2.692 | A\(^-\) | −30.7 | s     | 0.95 |
| Aristeus antennatus   | F   | 710  | 18–59            | 3.7–59.2                | 0.0056 | 0.0052 | 0.0062 | 2.2591 | 2.2357 | 2.2826 | A\(^-\) | −62.14 | s     | 0.98 |
|                       | M   | 85   | 19–35            | 3.7–16.9                | 0.0083 | 0.0054 | 0.0128 | 2.1281 | 1.9945 | 2.2617 | A\(^-\) | −12.98 | s     | 0.92 |
| Nephrops norvegicus   | F   | 2313 | 17–49            | 3.3–93.9                | 0.0006 | 0.0006 | 0.0006 | 3.0578 | 3.0411 | 3.0744 | A\(^+\) | 6.81 | s     | 0.98 |
|                       | M   | 3271 | 18–68            | 3.8–224.0               | 0.0005 | 0.0005 | 0.0005 | 3.115 | 3.1034 | 3.1267 | A\(^+\) | 19.43 | s     | 0.99 |
| Parapenaeus longirostris | F   | 25,674 ago–43 | 0.6–28.4             | 0.035 | 0.035 | 0.036 | 2.4325 | 2.4272 | 2.4378 | A\(^-\) | −208.3 | s     | 0.97 |
|                       | M   | 21,454 ago–35 | 0.6–17.9             | 0.052 | 0.051 | 0.053 | 2.2822 | 2.2739 | 2.2905 | A\(^+\) | −169.63 | s     | 0.93 |
| Squilla mantis        | C   | 127  | 78–182           | 5.5–66.6                | 0.0017 | 0.0115 | 0.0262 | 2.8296 | 2.6705 | 2.9886 | A\(^-\) | −2.12 | s     | 0.91 |
| **Cephalopods**       |     |     |                  |                         |    |       |        |    |       |        |      |     |       |          |
| Eledone cirrhosa      | C   | 307  | 3.5–15.0         | 6.8–674.5               | 0.3141 | 0.2596 | 0.3801 | 2.859 | 2.7718 | 2.9464 | A\(^-\) | −3.17 | s     | 0.93 |
| Eledone moschata      | C   | 659  | 4.0–13.0         | 20.0–516.9              | 0.4677 | 0.3952 | 0.5535 | 2.6492 | 2.5672 | 2.7311 | A\(^-\) | −8.4 | s     | 0.86 |
| Illex coindettii      | F   | 4652 | 3.5–21.5         | 2.9–272.2               | 0.0512 | 0.0503 | 0.0537 | 2.7959 | 2.745 | 2.7733 | A\(^-\) | −33.38 | s     | 0.97 |
|                       | M   | 4102 | 4.0–19.0         | 2.9–228.2               | 0.0286 | 0.0273 | 0.03 | 3.0797 | 3.0581 | 3.1014 | A\(^+\) | 7.2 | s     | 0.95 |
| Loligo vulgaris       | C   | 2625 | 4.0–45.0         | 2.6–1600.5              | 0.107 | 0.1029 | 0.1113 | 2.5527 | 2.5342 | 2.5711 | A\(^-\) | −47.6 | s     | 0.97 |
| Octopus vulgaris      | C   | 398  | 4.0–19.5         | 31.9–3250.0             | 0.3996 | 0.3376 | 0.4279 | 2.9715 | 2.8909 | 3.0501 | I | −0.69 | ns     | 0.93 |
| Sepia officinalis     | F   | 150  | 4.0–19.0         | 12.3–750.0              | 0.3048 | 0.2742 | 0.3388 | 2.6848 | 2.5986 | 2.6983 | A\(^-\) | −13.94 | s     | 0.99 |
|                       | M   | 134  | 5.0–17.5         | 18.5–571.9              | 0.2474 | 0.214 | 0.2659 | 2.7219 | 2.6534 | 2.7904 | A\(^-\) | −8.03 | s     | 0.98 |
| Specie                  | SEX | N   | Length (Min–Max) | Weight (0.1 g, Min–Max) | a   | 2.50%  | 97.50%  | b   | 2.50%  | 97.50%  | T.G. | T  | P   | R²  |
|------------------------|-----|-----|------------------|-------------------------|-----|--------|---------|-----|--------|---------|------|----|-----|-----|
| *Todarodes sagittatus* | C   | 199 | 8.5–38.5         | 23.6–2048.5             | 0.0174 | 0.0133 | 0.0226  | 3.1427 | 3.0584  | 3.227  | A*  | 3.35 | s   | 0.98 |
| *Boops boops*          | C   | 312 | 10.0–25.5        | 9–169                   | 0.0064 | 0.0052 | 0.0078  | 3.1709 | 3.0988  | 3.2429 | A*  | 4.67 | s   | 0.96 |
| *Chelidonichthys cuclus* | F   | 2412 | 10.0–31.5        | 10–337                  | 0.0078 | 0.0073 | 0.0083  | 3.0937 | 3.0714  | 3.1161 | A*  | 8.2178 | s | 0.97 |
| *Chelidonichthys lastoviza* | C   | 682  | 5.5–21.5         | 2–117                   | 0.0139 | 0.0122 | 0.0158  | 2.9326 | 2.8866  | 2.9787 | A–  | −2.87 | s   | 0.97 |
| *Bony fishes*          | C   | 450  | 5.0–71.0         | 2–45                    | 0.0121 | 0.0111 | 0.0132  | 2.9219 | 2.8899  | 2.9539 | A–  | −4.79 | s   | 0.99 |
| *Citharus linguatula*  | C   | 1250 | 9.5–24.5         | 7–132                   | 0.0064 | 0.0059 | 0.0070  | 3.0859 | 3.0525  | 3.1192 | A*  | 5.0573 | s | 0.96 |
| *Boops boops*          | C   | 312  | 10.0–25.5        | 9–169                   | 0.0064 | 0.0052 | 0.0078  | 3.1709 | 3.0988  | 3.2429 | A*  | 4.67 | s   | 0.96 |
| *Boops boops*          | F   | 907  | 9.0–26.0         | 6–170                   | 0.0075 | 0.0067 | 0.0083  | 3.0226 | 2.9798  | 3.0654 | I   | 1.0367 | ns | 0.96 |
| *Boops boops*          | M   | 366  | 11.0–60.5        | 20–2882                 | 0.0241 | 0.0202 | 0.0288  | 2.8249 | 2.7719  | 2.8778 | A–  | −6.5  | s   | 0.97 |
| *Engraulis encrasicolus* | C   | 2313 | 8.5–16.5         | 4–32                    | 0.0036 | 0.0032 | 0.0041  | 3.2233 | 3.1728  | 3.2738 | A*  | 8.67  | s   | 0.87 |
| *Chelidonichthys lucerna* | C   | 5069 | 2.0–34.0         | 14–102                  | 0.0384 | 0.0258 | 0.0571  | 2.728  | 2.5804  | 2.8747 | A–  | −3.7417 | s | 0.97 |
| *Lepidopus caudatus*   | C   | 232  | 6.0–24.5         | 2–125                   | 0.0099 | 0.008  | 0.0124  | 2.9741 | 2.8914  | 3.0568 | I   | −0.616 | ns | 0.97 |
| *Lepidopus caudatus*   | C   | 2587 | 17.0–185.0       | 3–86                    | 0.0003 | 0.0003 | 0.0004  | 3.1417 | 3.1268  | 3.1567 | A*  | 18.6381 | s | 0.99 |
| *Lepidopterus guttatus* | C   | 3606 | 9.0–20.0         | 8–100                   | 0.013 | 0.0122 | 0.0138  | 2.9537 | 2.9292  | 2.9783 | A–  | −3.6947 | s | 0.94 |
| *Lepidopterus guttatus* | M   | 1178 | 10.0–21.0        | 9–175                   | 0.0106 | 0.0097 | 0.0116  | 3.0357 | 3.0014  | 3.0701 | A*  | 2.042  | s   | 0.96 |
Table 1. Cont.

| Specie                        | SEX | N    | Length (Min–Max) | Weight (0.1 g, Min–Max) | a    | 2.50% | 97.50% | b    | 2.50% | 97.50% | T.G. T | P   | R²   |
|-------------------------------|-----|------|------------------|-------------------------|------|-------|-------|------|-------|-------|-------|-----|------|
| Spicara Smaris               | C   | 170  | 5.5–19.0         | 1–70                    | 0.0159 | 0.007 | 0.0361 | 2.7723 | 2.4623 | 3.0824 | I   | −1.14 | ns  | 0.91 |
| Trachurus mediterraneus       | F   | 649  | 10.5–26.5        | 10–166                  | 0.0162 | 0.0141 | 0.0185 | 2.7467 | 2.6968 | 2.7965 | A−  | −9.98 | s   | 0.95 |
|                              | M   | 464  | 11.0–28.0        | 10–185                  | 0.0129 | 0.0108 | 0.0153 | 2.8333 | 2.769 | 2.8976 | A−  | −5.09 | s   | 0.94 |
| Trachurus trachurus           | C   | 5175 | 8.5–45.0         | 5–688                   | 0.0076 | 0.0074 | 0.0079 | 3.0382 | 3.0253 | 3.0512 | A+  | 5.79  | s   | 0.98 |
| Trachurus capelanus           | F   | 95   | 10.0–20.5        | 10–100                  | 0.0084 | 0.0054 | 0.0129 | 3.0961 | 2.9291 | 3.2631 | I   | 1.1429 | ns  | 0.93 |
|                              | M   | 64   | 10.5–18.0        | 9–61                    | 0.0108 | 0.0052 | 0.0222 | 3.0114 | 2.73  | 3.2928 | I   | 0.0809 | s   | 0.88 |
| Zeux faber                   | F   | 372  | 9.0–58.0         | 9–2000                  | 0.0177 | 0.0164 | 0.0192 | 2.9366 | 2.9124 | 2.9608 | A−  | −5.1497 | s   | 0.99 |
|                              | M   | 289  | 10.0–49.0        | 16–1536                 | 0.0232 | 0.0214 | 0.0251 | 2.8434 | 2.8185 | 2.8683 | A−  | −12.395 | s   | 0.99 |
| Centrophorus granulosus       | C   | 98   | 37.0–105.0       | 255–5482                | 0.002 | 0.0013 | 0.0032 | 3.2312 | 3.1317 | 3.3308 | A+  | 4.6116 | s   | 0.98 |
| Chimaera monstrosa            | C   | 310  | 5.0–79.5         | 8–1304                  | 0.078 | 0.0686 | 0.0878 | 2.9566 | 2.911 | 3.002 | I   | −1.8924 | ns  | 0.98 |
| Dalatias licha               | C   | 81   | 30.5–104.0       | 124–5444                | 0.003 | 0.0023 | 0.0049 | 3.0795 | 2.9906 | 3.1685 | I   | 1.7793 | ns  | 0.98 |
| Etmopterus spinax             | F   | 1174 | 8.0–52.5         | 2–390                   | 0.004 | 0.0041 | 0.0048 | 3.0076 | 2.9828 | 3.0223 | I   | 0.6013 | s   | 0.98 |
|                              | M   | 475  | 8.5–44.0         | 3–275                   | 0.006 | 0.0048 | 0.0063 | 2.9255 | 2.8837 | 2.9672 | A−  | −3.5115 | s   | 0.98 |
| Galeus melastomus            | F   | 3668 | 9.0–55.0         | 2–569                   | 0.003 | 0.0031 | 0.0033 | 2.9835 | 2.9742 | 2.9929 | A−  | −3.455 | s   | 0.99 |
|                              | M   | 4039 | 9.0–51.0         | 2–452                   | 0.004 | 0.0039 | 0.0042 | 2.9095 | 2.919 | 2.919 | A−  | −18.661 | s   | 0.99 |
| Heptanchias perlo             | C   | 38   | 37.0–105.0       | 188–3047                | 0.005 | 0.0022 | 0.0106 | 2.9044 | 2.714 | 3.0948 | I   | −1.0477 | ns  | 0.98 |
| Mustelus mustelus             | C   | 208  | 27.5–135.0       | 58–8000                 | 0.003 | 0.0024 | 0.0032 | 3.0269 | 2.989 | 3.0647 | I   | 1.4 | ns  | 0.99 |
| Mustelus punctulatus          | C   | 42   | 45.5–98.0        | 303–2700                | 0.007 | 0.0035 | 0.0136 | 2.7969 | 2.6338 | 2.96  | A−  | −2.5601 | s   | 0.63 |
| Scyliorhinus canicula         | F   | 1537 | 10.5–48.0        | 30–394                  | 0.001 | 0.0013 | 0.0015 | 3.2472 | 3.228 | 3.2663 | A+  | 25.26  | s   | 0.99 |
|                              | M   | 1774 | 10.0–51.5        | 30–431                  | 0.002 | 0.0018 | 0.002 | 3.1375 | 3.1216 | 3.1534 | A+  | 16.98  | s   | 0.99 |
| Squalus blainville           | F   | 1282 | 17.5–75.0        | 24–2451                 | 0.003 | 0.0032 | 0.0036 | 3.0816 | 3.0646 | 3.0986 | A−  | 9.4098 | s   | 0.99 |
|                              | M   | 970  | 16.5–77.0        | 22–2924                 | 0.005 | 0.0045 | 0.0051 | 2.9834 | 2.9652 | 3.016 | A−  | −1.7932 | s   | 0.99 |

Linear regressions were significant for all species (p < 0.05), with R² values ranging from 0.86 to 0.99, except for Mustelus punctulatus (Risso, 1826), for which a value of 0.63 was estimated. The intercept (a) of LWR ranged between 0.0003 for Lepidopus caudatus Euphrasen, 1788 (both male and combined LWR) and 0.4677 for combined LWR of Eledone moschata (Lamarck, 1798). On the other hand, the slope (b) ranged from 2.1281 for the female specimens of Aristeus antennatus (Risso, 1816) to 3.306 for Sardina pilchardus (Walbaum, 1792) (sex combined). Overall the results of the growth pattern showed that 45.8% of LWRs exhibited negative allometric, 33.4% positive and 20.8% isometric. As for cephalopods and crustaceans concern, the most represented growth type was the negative allometry, with values of 67% and 78%, respectively. Concerning the fishes (bony and cartilaginous combined), it was observed the same percentage for positive and negative allometry, namely 37%, whereas the isometric growth represents 26% of the total.

4. Discussion

The comparison of the LWRs parameters estimated in the present study with others carried out in the Strait of Sicily highlighted that 14 LWRs represent the first references in the area. For the other 38 species, a comparison is provided in Table S1. However, for Zeux faber (Linnaeus, 1758), M. punctulatus, and Squalus blainville (Risso, 1827), this comparison was not carried out due to the lack of available literature. The growth types herein provided were in disagreement with Froese [2], who reported that most of the fishes showed isometric growth.
The outcomes of the t-test revealed that most of the LWRs (about 55%) reported in this study are in disagreement with those obtained previously by other authors from the Strait of Sicily [24,26,27,40,49,53,55–60].

The main differences were due to the estimations of the b parameter, which in some cases resulted lower than those reported in the literature. This might be linked to the sampling methodology; indeed, in the present study, the data from the MEDITS survey (fisheries independent) were analyzed, while most of the compared studies used samples coming from trawling and/or small scale commercial fisheries (fisheries dependent). As a matter of fact, the low selectivity of the gear used during the MEDITS survey allowed to sample representative size distribution of the population where the bulk of the catch is constituted by the juvenile fraction. In addition, since the MEDITS survey investigates a wide and heterogeneous area, from inshore to offshore waters, another plausible source of bias may be due to the habitat type sampled: for example, younger individuals may be more prevalent at shallower depths than in deeper waters. In this regard, it is important to point out that for comparison purposes, LWRs should be of similar size classes, the same units (e.g., grams and centimeters) [13,61] or measurement type (e.g., TL and SL-standard length or TW and eviscerated weight). In addition, LWRs are not constant throughout the year, varying seasonally in relation to many factors such as temperature, salinity, food (quantity, quality and size), habitat, gonad development, sex, fishing time, fishing gear, and area [2,49,62,63] Moreover, for cephalopods, the differences might also be related to the conservation modality. Indeed, as suggested by Massi [64], the freezing process leads to an elongation of muscular tissue that may affect the measurement of ML. This could explain the different growth types found between sexes of the I. coindetii, where the females and males showed negative and positive allometry, respectively.

To the best of our knowledge, many studies compare the LWRs parameters without any statistical approach (i.e., through “visual inspection”), which often results in no reliability to detect the differences. Therefore, the methodology adopted in this study should be desirable in order to identify differences in a and b parameters between LWRs objectively. An evident example of the possible bias introduced by the absence of a statistical approach is provided by the comparison of the growth parameters between the present study and Di Maio et al. [27]. Indeed, although Di Maio et al. [27], analyzing the size structure of spawning aggregation of Pagellus acarne (Risso, 1827), reports a value of b much higher than that reported in the present study, the t-test does not detect significant differences. This methodology is very important in the shared stocks because it would allow obtaining unique and more accurate LWRs (calculated as the geometric mean of a and b) for the purpose of stock assessment.

5. Conclusions

The results obtained from this study will contribute to filling the knowledge gap of fish populations in this area and also assist fisheries scientists in future stock assessment studies, with particular attention to heavily exploited populations, as well as those under stock recovery plans or other management and conservation programs.

In addition, the statistical approach proposed here could represent a useful tool to compare LWRs estimated from specimens of different size classes, seasons, or areas.

Finally, to obtain a more accurate estimation of LWRs parameters, especially in shared stock, it would be desirable that in the future, other authors use a similar statistical approach to that reported in the present study.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes7020092/s1, Table S1: Comparison of available Length-Weight relationships from the South of Sicily. SEX: F—female, M—male and C—combined; N: the sample size; a: the intercept of the regression curve; b: the regression slope; R²: the coefficient of determination, n.a.: not available, T.G.: Type of growth, A− negative allometry, A+ positive allometry and I isometric. Trawl: c-commercial, s—survey. In bold are reported the significant difference
(t-test \( p < 0.05 \)) LWRs compared to the present study. In italic is the species for which the literature comparison was not available.

**Author Contributions:** F.F.: Conceptualization, Statistical analysis, Visualization, Writing—review and editing; M.L.G.: Conceptualization, Statistical analysis, Visualization, Writing—review and editing; D.S.: Data acquisition, Validation, Editing; F.D.M.: Data acquisition, Validation, Editing; G.S.: Data acquisition, Validation, Editing; F.Q.: Data acquisition, Validation, Editing; V.G.: Writing—review and editing; S.V.: Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The Ethical review and approval were waived for this study due to the manuscript deals with specimens captured during the demersal trawl survey (MEDIT) funded under the data collection framework (EC-DCF). Furthermore, the animals arrive already dead on board.

**Data Availability Statement:** The dataset analyzed during the current study is available from the corresponding author on reasonable request.

**Acknowledgments:** This work is conducted thanks to the European Data Collection Framework (DCF)—Medit survey module—funded by the European Union and the Italian Ministry for Agricultural, Food and Forestry Policies. We are grateful to all the technical staff of SS CNR-IRBIM of Mazara del Vallo, who collected the data and processed samples from the trawl surveys, and to Fabio Fiorentino and Gioacchino Bono for their useful comments that improved the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

**References**

1. Keys, A.B. The weight-length relation in fishes. *Proc. Natl. Acad. Sci. USA* **1928**, *14*, 922. [CrossRef] [PubMed]
2. Froese, R. Cube law, condition factor and weight-length relation-ships: History, meta-analysis and recommendations. *J. Appl. Ichthyol.* **2006**, *22*, 241–253. [CrossRef]
3. Ricker, W.E. Handbook of computations for biological statistics of fish populations. *Bull.-Fish. Res. Board Can.* **1958**, *119*, 300.
4. Tesch, F.W. Age and growth. In *Methods for Assessment of Fish Production in Freshwaters*; Ricker, W.E., Ed.; Blackwell Scientific Publications: Oxford, UK, 1968; pp. 93–123.
5. Cabbar, K.; Yigin, C.C. Length-Weight relationships of elasmobranch species from Gökçeada Island in the northern Aegean Sea. *Thalassas* **2021**, *37*, 497–504. [CrossRef]
6. Tsikliras, A.C.; Dimarchopoulou, D. Filling in knowledge gaps: Length-weight relations of 46 uncommon sharks and rays (Elasmobranchii) in the Mediterranean Sea. *Acta Ichthyol. Piscat.* **2021**, *51*, 249. [CrossRef]
7. Kampouris, T.E.; Kouroupakis, E.; Batjakas, I.E. Morphometric Relationships of the Global Invader *Callinectes sapidus* Rathbun, 1896 (Decapoda, Brachyura, Portunidae) from Papapouli Lagoon, NW Aegean Sea, Greece. With notes on its ecological preferences. *Fishes* **2020**, *5*, 5. [CrossRef]
8. Erzini, K. An empirical study of variability in length-at age of marine fishes. *J. Appl. Ichthyol.* **1994**, *10*, 17–41. [CrossRef]
9. Ricker, W.E. Computation and interpretation of biological statistics of fish populations. *Bull.-Fish. Res. Board Can.* **1975**, *191*, 382.
10. Schneider, J.C.; Laarman, P.W.; Howard Gowing, J.C.; Laarman, P.W.; Gowing, H. Length-weight relationships. In *Manual of Fisheries Survey Methods II*; Schneider, J.C., Ed.; Department of Natural Resources: Ann Arbor, MI, USA, 2000; Volume 17, pp. 1–16.
11. Geraci, M.L.; Scannella, D.; Falsone, F.; Colloca, F.; Vitale, S.; Rizzo, P.; Fiorentino, F. Preliminary study on the biological traits of the Por’s goatfish *Upeneus pori* (Chordata: Actinopterygii) off the southern coast of Lampedusa Island (Central Mediterranean). *Eur. Zool. J.* **2018**, *85*, 231–241. [CrossRef]
12. Anderson, R.; Gutreuter, S. Length, weight, and associated structural indices. In *Fisheries Techniques*; Nielsen, L., Johnson, D., Eds.; American Fisheries Society: Bethesda, MD, USA, 1983; pp. 283–300.
13. Petakis, G.; Stergiou, K.I. Weight-length relationships for 33 fish species in Greek waters. *Fish. Res.* **1995**, *21*, 465–469. [CrossRef]
14. Froese, R.; Tsikliras, A.C.; Stergiou, K.I. Editorial note on weight-length relations of fishes. *Acta Ichthyol. Piscat.* **2011**, *41*, 261–263. [CrossRef]
15. Gonçalves, J.M.S.; Bentes, L.; Lino, P.G.; Ribeiro, J.; Canario, A.V.; Erzini, K. Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. *Fish. Res.* **1997**, *30*, 253–256. [CrossRef]
16. Moutopoulos, D.K.; Stergiou, K.L. Weight-length and length-length relationships for 40 fish species of the Angene Sea (Hellas). *J. Appl. Ichthyol.* **2002**, *18*, 200–203.
17. Cicek, E.; Avsar, D.; Yeldan, H.; Ozutok, M. Length-weight relationships for 31 teleost fishes caught by bottom trawl net in the Babadillimani Bight (northeastern Mediterranean). *J. Appl. Ichthyol.* **2006**, *22*, 290–292. [CrossRef]
18. Yeldan, H.; Avsar, D. Length-weight relationship for five elasmobranch species from the Cilician Basin shelf waters (Northeastern Mediterranean). J. Appl. Ichthyol. 2007, 23, 713–714. [CrossRef]

19. Bayhan, B.; Sever, T.M.; Taşkavak, E.R.T.A.N. Age, length-weight relationships and diet composition of scadfish Arnoglossus laterna (Walbaum, 1792) (Pisces: Bothidae) in Izmir Bay (Aegean Sea). J. Anim. Vet. Adv. 2008, 7, 924–929.

20. Ceyhan, T.; Akyol, O.; Erdem, M. Length-weight relationships of fishes from Gökova Bay, Turkey (Aegean Sea). Turk. J. Zool. 2009, 33, 69–72.

21. Kapiris, K.; Klaoudatos, D. Length-weight relationships for 21 fish species caught in the Argolikos Gulf (central Aegean Sea, eastern Mediterranean). Turk. J. Zool. 2011, 35, 717–723. [CrossRef]

22. Deval, M.C.; Güven, O.; Saygu, I.; Kabapçioğlu, T. Length-weight relationships of 10 fish species found off Antalya Bay, eastern Mediterranean. J. Appl. Ichthyol. 2014, 30, 567–568. [CrossRef]

23. Özvarol, Y. Length-weight relationships of 14 fish species from the Gulf of Antalya (northeastern Mediterranean Sea, Turkey). Turk. J. Zool. 2014, 38, 342–346.

24. Ghailen, H.; Abdallah, H.; Hassan, A.; Mourad, C.; Abderrahman, B.; Othman, J. Length-weight relationships for 13 fish species from the Gulf of Gabes (Southern Tunisia, Central Mediterranean). Afr. J. Biotechnol. 2010, 9, 6177–6181.

25. Dimarchopoulou, D.; Stergiou, K.I.; Tsikliras, A.C. Gap analysis on the biology of Mediterranean marine fishes. PLoS ONE 2017, 12, e0175949. [CrossRef]

26. Miled-Fathalli, N.; Hamed, O.; Chakroun-Marzouk, N. Length-weight relationships of 22 commercial fish species from the Gulf of Tunis (Central Mediterranean Sea). Cah. Biol. Mar. 2019, 60, 541–546.

27. Di Maio, F.; Geraci, M.L.; Scannella, D.; Falsone, F.; Colloca, F.; Vitale, S.; Fiorentino, F. Age structure of spawners of the axillary seabream, Pagellus acarne (Risso, 1827), in the central Mediterranean Sea (Strait of Sicily). Reg. Stud. Mar. Sci. 2020, 34, 101082. [CrossRef]

28. Geraci, M.L.; Ragonese, S.; Scannella, D.; Falsone, F.; Gancitano, V.; Mifsud, J.; Gambin, M.; Said, A.; Vitale, S. Batoid abundances, spatial distribution, and life history traits in the Strait of Sicily (Central Mediterranean Sea): Bridging a knowledge gap through three decades of survey. Animals 2021, 11, 2189. [CrossRef] [PubMed]

29. Di Lorenzo, M.; Sinerchia, M.; Colloca, F. The North sector of the Strait of Sicily: A priority area for conservation in the Mediterranean Sea. Hydrobiologia 2018, 821, 235–253. [CrossRef]

30. Garofalo, G.; Quattrocchi, F.; Bono, G.; Di Lorenzo, M.; Di Maio, F.; Falsone, F.; Gancitano, V.; Geraci, M.L.; Lauria, V.; Massi, D.; et al. What is in our seas? Assessing anthropogenic litter on the seafloor of the central Mediterranean Sea. Environ. Pollut. 2020, 266, 115213. [CrossRef]

31. Falsone, F.; Scannella, D.; Geraci, M.L.; Gancitano, V.; Vitale, S.; Fiorentino, F. How Fishery Collapses: The Case of Lepidopus caudatus (Pisces: Trichiuridae) in the Strait of Sicily (Central Mediterranean Sea). Front. Mar. Sci. 2021, 7, 1188. [CrossRef]

32. Geraci, M.L.; Falsone, F.; Gancitano, V.; Scannella, D.; Fiorentino, F.; Vitale, S. Assessing Cephalopods Fisheries in the Strait of Sicily. Reg. Stud. Mar. Sci. 2021, 8, 584657. [CrossRef]

33. Bertrand, J.A.; Gil de Sola, L.; Papaconstantinou, C.; Relini, G.; Souplet, A. The general specifications of the MEDITS surveys. Sci. Mar. 2002, 66, 9. [CrossRef]

34. Anonymous. International Bottom Trawl Survey in the Mediterranean, Instruction Manual; Version 9; [MEDITS–hand-book. 2017, Version n. 9.]; MEDITS Working Group: San Jose, CA, USA, 2017; p. 106.

35. Spedicato, M.T.; Massuti, E.; Mérigot, B.; Tserpes, G.; Jadaud, A.; Relini, G. The MEDITS trawl survey specifications in an eco-system approach to fishery management. Sci. Mar. 2019, 83, 9–20. [CrossRef] [PubMed]

36. Evagelopoulos, A.; Batjakas, I.; Koutsoubas, D. Length-weight relationships of 9 commercial fish species from the North Aegean Sea. Acta Adriat. 2017, 58, 187–191. [CrossRef]

37. Zar, J.H. Biostatistical Analysis; Prentice Hall: Upper Saddle River, NJ, USA, 2010; p. 760.

38. R Core Team. R: A Language and Environment for Statistical Computing; Version 3.6.3; R Foundation for Statistical Computing: Vienna, Austria, 2020; Available online: https://www.R-project.org/ (accessed on 7 September 2021).

39. Gancitano, V.; Colloca, F.; Garofalo, G.; Grisitina, M.; Ragonese, S.; Badalucco, C.; Basilone, G.; Campanella, N.; Cusumano, S.; De Luca, B.; Di Maria, A.; et al. Programma Nazionale Italiano per la Raccolta di Dati Alieutici 2011–2013. Campionamento Biologico delle Catture Commerciali Metier Related (Sezione C) e Stock Related (Sezione E) Nel 2012 Programma Nazionale Italiano per la Raccolta di Dati Alieutici 2011–2013. Campionamento Biologico delle Catture Commerciali Metier Related (Sezione C) e Stock Related (Sezione E) Nel 2012; Final Report; Project Ref. FISH/2004/03-32; MedSudMed Technical Documents; FAO: Rome, Italy, 2013; Volume 32, p. 118.

40. Gancitano, V.; Garofalo, G.; Grisitina, M.; Ragonese, S.; Badalucco, C.; Basilone, G.; Campanella, N.; Cusumano, S.; De Luca, B.; Di Maria, A.; et al. Programma Nazionale Italiano per la Raccolta di Dati Alieutici 2011–2013. Campionamento Biologico delle Catture Commerciali Metier Related (Sezione C) e Stock Related (Sezione E) Nel 2012; MedSudMed Technical Documents; FAO: Rome, Italy, 2013; Volume 32, p. 118.

41. MRRA. Estimate based on an analysis of Maltese survey data from GSA 15. In Synthesis of Information on Some Demersal Crustaceans Relevant for Fisheries Target Species in the South-Central Mediterranean Sea; Fiorentino, F., Ben Hadj Hamida, O., Ben Meriem, S., Gaumour, A., Grisitina, M., Jardou, O., Knittweis, L., Rjeibi, O., Ceriola, L., Eds.; GCP/GER/010/ITA/MSM-TD-32; MedSudMed Technical Documents; FAO: Rome, Italy, 2013; Volume 32, p. 118.

42. A.A.V.V. Status of Deep-Sea Red Shrimps in the Central and Eastern Mediterranean Sea; Final Report; Project Ref. FISH/2004/03-32; Available online: https://imbrw.hcmr.gr/deep-sea-red-shrimps/ (accessed on 14 March 2022).

43. Gancitano, V.; Garofalo, G.; Grisitina, M.; Ragonese, S.; Badalucco, C.; Basilone, G.; Campanella, N.; Cusumano, S.; De Luca, B.; Di Maria, A.; et al. Programma Nazionale Italiano per la Raccolta di Dati Alieutici 2011–2013. Campionamento Biologico delle Catture Commerciali Metier Related (Sezione C) e Stock Related (Sezione E) Nel 2012; Final Report; Project Ref. FISH/2004/03-32; Available online: https://imbrw.hcmr.gr/deep-sea-red-shrimps/ (accessed on 14 March 2022).

44. Gancitano, V.; Garofalo, G.; Grisitina, M.; Ragonese, S.; Badalucco, C.; Basilone, G.; Campanella, N.; Cusumano, S.; De Luca, B.; Di Maria, A.; et al. Programma Nazionale Italiano per la Raccolta di Dati Alieutici 2011–2013. Campionamento Biologico delle Catture Commerciali Metier Related (Sezione C) e Stock Related (Sezione E) Nel 2012; Final Report; Project Ref. FISH/2004/03-32; Available online: https://imbrw.hcmr.gr/deep-sea-red-shrimps/ (accessed on 14 March 2022).
Commerciali Metier Related (Sezione C) and Stock Related (Sezione E) Nel 2011; Rapporto Finale; IAMC-CNR: Mazara del Vallo, Italy, 2012; p. 288.

44. Ben Meriem, S.; Fiorentino, F.; Dimech, M.; Gancitano, V.; Jarboui, O.; Knittweis, L.; Arneri, E.; Ceriola, L. Assessement of Deep Water Pink Shrimp, Parapenaeus Longirostris (Lucas, 1846), in the MedSudMed Area; Report of Working Group on Demersal Species (WGSAD): Istanbul, Turkey, 2014; pp. 18–23.

45. Rjeibi, M.; Ezzedine-Najai, S.; Chemmam, B.; Missaoui, H. Reproductive biology of Eledone cirrhosa (Cephalopoda: Octopodidae) in the northern and eastern Tunisian Sea (Western and Central Mediterranean). Malacologia 2013, 56, 69–84. [CrossRef]

46. Ragonesi, S.; Jereb, P. Length-weight relationships of illex coindetii Verany, 1837 (Mollusca: Cephalopoda) in the Sicilian Channel. Oebalia 1992, 28, 17–24.

47. Jabeur, C.; Nouira, T.; Khoufi, W.; Mosbah, D.S.; Ezzeddine-Najai, S. Age and growth of Bluemouth Chimaera monstrosa (Chondrichthyes: Chimaeridae) in the Gulf of Gabès (Central Mediterranean Sea). Cah. Biol. Mar. Mediterr. 2009, 20, 184–185. [CrossRef]

48. Cherif, M.; Zarrad, R.; Gharbi, H.; Missaoui, H.; Jarboui, O. Length-weight relationships for 11 fish species from the Gulf of Tunis (SW Mediterranean Sea, Tunisia). Pan-Am. J. Aquat. Sci. 2008, 3, 1–5.

49. Cannizzaro, L.; Alagna, A.; Andreoli, M.G.; Gianformaggio, N. Relazione Taglia-Peso per Alcuni Pesci del Canale di Sicilia; NTR-ITPP: Mazara del Vallo, Italy, 1991; Volume 39, p. 33.

50. Rimel, B.; Mourad, C.; Koched, W. Length-Weight relationships of 15 ground fish species caught in Tunisian deep water (SW Mediterranean Sea). Int. J. Recent Sci. Res. 2015, 6, 6386–6388.

51. Basilone, G.; Guisande, C.; Patti, B.; Mazzola, S.; Cuttitta, A.; Bonanno, A.; Kallianiotis, A. Linking habitat conditions and growth performance of the longnose spurdog, Squalus blainvillei (Chondrichthyes: Squalidae), in the Gulf of Gabès (Central Mediterranean Sea). J. Appl. Ichthyol. 2008, 24, 581–588. [CrossRef]

52. Gancitano, V.; Garofalo, G.; Gristina, M.; Ragonese, S.; Giusto, G.B.; Ingrande, G.; Cusumano, S.; Rizzo, P.; Gancitano, S.; Badalucco, C.; et al. Programma Nazionale Italiano per la Raccolta di Dati Alieutici. Modulo H “Campionamento Biologico Delle Catture Commerciali Metier Related (Sezione C) and Stock Related (Sezione E) Nel 2009; Rapporto Finale; IAMC-CNR: Mazara del Vallo, Italy, 2010; p. 262.

53. Mili, S.; Ennouri, R.; Amdouni, F.; Chamnam, B.; Missaoui, H. Age and Growth of Bluemouth Helicolenus dactylopterus (Delaroche, 1809) in the Northern Waters of Tunisia (Central Mediterranean Sea). Greener J. Life Sci. 2016, 3, 1–12. [CrossRef]

54. Gancitano, V.; Badalucco, C.; Cusumano, S.; Gancitano, S.; Ingrande, G.; Knittweis, L.; Rizzo, P. Exploitation state of black-bellied angler, Lophius budegassa, (Spinola, 1807) (Pisces: Lophiidae) in the Strait of Sicily (GSA 15&16). Biol. Mar. Mediterr. 2013, 20, 184–185. [CrossRef]

55. CNR-IAMC. Programma Nazionale Italiano per la Raccolta di Dati Alieutici. Modulo H “Campionamento Biologico Delle Catture Commerciali Metier Related (Sezione C) and Stock Related (Sezione E) Nel 2009; Rapporto Finale; IAMC-CNR: Mazara del Vallo, Italy, 2006; p. 72.

56. Malagola, S. Studio Della Biologia di due Specie di Condroitti Dello Stretto di Sicilia, Chimaera monstrosa (Linnaeus, 1758) e Squalus blainvillei (Risso, 1827). Master Degree Thesis, Università degli Studi di Padova, Padova, Italy, 2016. Available online: http://tesi.cab.unipd.it/53621/1/Malagola_Silvia.pdf (accessed on 7 September 2021).

57. Boudaya, L.; Neifar, L.; Rizzo, P.; Badalucco, C.; Bouain, A.; Fiorentino, F. Growth and reproduction of Chelidonichthys lucerna (Linnaeus) (Pisces: Triglidae) in the gulf of Gabès, Tunisia. J. Appl. Ichthyol. 2008, 24, 581–588. [CrossRef]

58. Baggenal, T.B.; Tesch, F.W. Age and growth. In Methods of Assessment of FISH production in Fresh Waters, 3rd ed.; Bagenal, Ed.; Blackwell Scientific Publications: Oxford, UK, 1978; Volume 3, pp. 101–136.

59. Pauly, D. Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators; International Center for Living Aquatic Resources Management: Manila, Philippines, 1984; p. 325.

60. Safran, P. Theoretical analysis of the weight-length relationships in the juveniles. Mar. Biol. 1992, 112, 545–551. [CrossRef]

61. Massi, D. Effetti del congelamento sull’accuratezza delle misure in Eledone cirrhosa (Lamarck, 1798). Biol. Mar. 1993, 1, 379–380.