Length-weight relationship of the most landed pelagic fish species European pilchard (*Sardina pilchardus* Walbaum, 1792) and European anchovy (*Engraulis encrasicolus* Linnaeus, 1758) in the Izmir Bay (Aegean Sea, Turkey) purse seine fishery

Ahmet Mert Şenbahar1* • Özlem Güleç 2 • Zafer Tosunoğlu 2 • Okan Özaydın 1

1 Ege University, Faculty of Fisheries, Department of Marine-Inland Waters Sciences and Technology, 35100, Bornova, Izmir, Turkey
2 Ege University, Faculty of Fisheries, Department of Fishing and Processing Technology, 35100, Bornova, Izmir, Turkey

**ABSTRACT**

Length-weight relationships (LWR) of the most landed pelagic fish species *Sardina pilchardus* Walbaum, 1792 and *Engraulis encrasicolus* Linnaeus, 1758 in the Izmir Bay purse seine fishery were determined to reveal latest situation. Purse seine is a non-selective fishing gear compare to the other fishing gear such as gillnet or trammel net. For this reason, sampling all size individuals is very important to calculate mean length and other LWR parameters. In this study, seasonal LWR coefficient and minimum-maximum lengths were established as monthly basis. LWR of *S. pilchardus* and *E. encrasicolus* were $W = 0.0059L^{2.7930}$ ($r^2 = 0.94$) and $W = 0.0019L^{3.4207}$, ($r^2 = 0.87$), respectively. Growth type of the *S. pilchardus* was found negative allometric whereas *E. encrasicolus* was positive allometric. A decrease of the mean total length of *S. pilchardus* has been considerable variable from 1994 to 2014 in Izmir Bay but with this study, it is observed that mean length of the sardine found near of 2006 value related to seasonal fishing pressure.
Introduction

The length-weight relationship (LWR) is an important tool in fish biology, physiology, ecology and fisheries assessment (Oscoz et al., 2005) and also provide invaluable information on stock assessment studies (Moutopoulos and Stergiou, 2002; Gonzalez Acosta et al., 2004) for conversion of length observations into weight estimates to provide some measurements of biomass (Froese, 1998; Gonzalez Acosta et al., 2004).

Purse seine fishery is especially important for the Turkish fishery since it is the most important gear that targets small pelagic species especially anchovy and sardines as well as big pelagic species such as tunas. Once a fish school has been detected and surrounded by the purse seine net, there is no selectivity for individual size, species or catch quantity (Handegard et al., 2017). The catch quantity of a purse seiner is too much to compare with other fishing gears (e.g. trawls, seines). However, scientific studies on this fishing gear and method are quite limited in Turkey (Özbilgin et al., 2015).

Landing coming from purse seine accounts for about 30% of the world’s total catch (Watson et al., 2006). Vast majority marine fish landing (approximately 60-70%) achieved by purse seine in 2018 fishing season (TurkStat, 2019). According to the official catch records, anchovy is the most landed fish species in Turkey with 96452 tons (43%). Although sardine landing is only 8.5% in Turkey, this value is substantially higher for the Aegean Sea (67%). Anchovy (12969 tons) and sardine (12654 tons) are the most landed pelagic fish species in the Aegean Sea (TurkStat, 2019). However, anchovy landing was the first time recorded higher than the sardine’s in 2018 in the Aegean Sea.

So far, a few studies conducted to determine the LWR of S. pilchardus and E. encrasicolus with 10-year intervals (Hoşsucu et al., 1994; Özaydin and Taskavak, 2006; Acarli et al., 2014). For this reason, the purpose of the study is to reveal the current LWR parameters and compare it with the previous studies.

Material and Methods

During the study, a total of 567 of S. pilchardus and 212 of E. encrasicolus individual sampled in seven months. All the materials obtained from the monthly purse seine operations between September 28, 2017 and March 21, 2018 from Izmir Bay (Fig. 1) in depths between 26 and 60 m. The purse seine net used by the commercial purse seiner Afala 24 m LOA is overall 750 m in length, 164 m net in height and 14 mm mesh size. Purse seine is a non-selective fishing gear compare to the other fishing gear such as gillnet or trammel net. For this reason, sampling all size individuals is very important to calculate mean length and other LWR parameters.

In this study sampling was made only for seven months (three seasons) due to the 4/1 notification regulates commercial fishery by the Ministry of Agriculture and Forestry of Turkey. According to the regulation, there was a closed season for purse seine fisheries between 15th April and 31st August in Turkish waters. In the analysis of LWR, monthly data was converted to seasons and seasons converted to the total value. Final estimations made on the total values.

Total length (TL) of all individuals were measured to the nearest centimeter (cm), and wet weight (W) was recorded to the nearest gram (g). The functional relationship between the size and weight of the samples were fitted to the equation: \( W = a L^b \), where \( W \) is the wet weight in grams, \( L \) the size in centimeters, \( a \) and \( b \) are the parameters to be estimated, with \( b \) being the coefficient of allometry (Ricker, 1975). The basic statistical data of the measured values were calculated and the relationships between them were determined (Sokal and Rohlf, 1973). Additionally, \( t \)-test was used for carried out to determine if the \( b \) coefficient was different from “3” (Sokal and Rohlf, 1969).

Results

The overall mean length of the S. pilchardus was found 12.1 cm. However, vast majority of the sardine individuals (91%) accumulated between 11.0 and 14.0 cm (Fig. 2). It was found that there was no significant allometry coefficients of LWR among seasons (Table 1) and also, the LWR curve of the S. pilchardus has shown in Fig. 3. The estimated total value of \( b \) coefficient indicating negative allometric growth (\( b=2.79; \ t \)-test, \( t<0.05, n>500 =1.65 \) (Table 1). Furthermore, the \( r^2 \) values of S. pilchardus indicated a strong relationship between length and weight as 0.94.
Figure 2. Length-frequency distribution of *S. pilchardus*

![Length-frequency distribution of *S. pilchardus*](image)

Figure 3. Length – weight relationship of *S. pilchardus*

![Length – weight relationship of *S. pilchardus*](image)

Table 1. Overall estimated LWR values of *S. pilchardus*

| Seasons | N  | \( L_{\text{min}} \) | \( L_{\text{max}} \) | \( L_{\text{mean}} \) | \( W_{\text{min}} \) | \( W_{\text{max}} \) | \( W_{\text{mean}} \) | a   | b   | SE(b) | \( r^2 \) | \( t \)-test |
|---------|----|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|-----|-----|-------|---------|-------------|
| Spring  | 56 | 11.5                 | 15.0                 | 12.7                 | 9.1                 | 21.3                | 13.4                | 0.0077 | 2.7981 | 0.0097 | 0.9405  | -20.7      |
| Autumn  | 303 | 9.5                  | 15.3                 | 11.6                 | 5.2                 | 23.5                | 9.8                  | 0.0049 | 2.9256 | 0.0054 | 0.9289  | -13.6      |
| Winter  | 209 | 10.5                 | 14.8                 | 11.9                 | 8.3                 | 20.8                | 11.7                | 0.0227 | 2.5182 | 0.0089 | 0.8460  | -54.1      |
| Total   | 567 | 9.5                  | 15.3                 | 12.1                 | 5.2                 | 20.8                | 3.0                  | 0.0059 | 2.7930 | 0.0058 | 0.9376  | -35.3      |

Note: SE is the standard error.

Table 2. Overall estimated LWR values of *E. encrasicolus*.

| Seasons | N  | \( L_{\text{min}} \) | \( L_{\text{max}} \) | \( L_{\text{mean}} \) | \( W_{\text{min}} \) | \( W_{\text{max}} \) | \( W_{\text{mean}} \) | a   | b   | SE(b) | \( r^2 \) | \( t \)-test |
|---------|----|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|-----|-----|-------|---------|-------------|
| Spring  | 33 | 11.4                 | 13.9                 | 12.7                 | 8.6                 | 16.5                | 12.0                | 0.0040 | 3.1460 | 0.0144 | 0.9485  | 10.1       |
| Autumn  | 31 | 9.2                  | 11.4                 | 10.2                 | 3.6                 | 8.0                 | 4.7                  | 0.0024 | 3.2584 | 0.0557 | 0.7196  | 4.6        |
| Winter  | 148| 9.7                  | 13.8                 | 11.3                 | 4.1                 | 15.5                | 8.1                  | 0.0019 | 3.4370 | 0.0087 | 0.9142  | 49.8       |
| Total   | 212| 9.2                  | 13.9                 | 11.4                 | 3.6                 | 16.5                | 8.3                  | 0.0019 | 3.4207 | 0.0059 | 0.8687  | 70.8       |

Note: SE is the standard error.
According to length-frequency distribution, mean length of the *E. encrasicolus* was found as 11.4 cm and vast majority (87%) accumulated between 10.5 and 14.0 cm (Fig. 4). Allometry coefficient of the seasonal LWR parameters estimated and have been found for every season (Table 2). In detail, *b* value of the *E. encrasicolus* was found for months as 3.1460, 3.2584, 3.4370 and total as 3.4207, respectively (Table 2) and these values are indicating positive allometric growth (b=3.42; *t*-test, *t*<0.05, *n*<200=1.65) (Fig. 5). Also, *r*² values of *E. encrasicolus* shown a strong relationship between length and weight as 0.87.

**Discussion**

Overall results of *S. pilchardus* and *E. encrasicolus* showed dissimilarities in total length (TL) and mean length based on sampling sites (Table 3 and Table 4). So far, TL of *S. pilchardus* has been shown a great variety in the Aegean Sea. However, maximum total length value of *S. pilchardus* reported from Izmir Bay by Hoşsucu et al. (1994) as 17.0 cm and it is still maintaining validity. In Izmir Bay, prior records indicating that the mean length of European pilchard has been reported as 14.2 cm by Hoşsucu et al. (1994), 11.82 cm by Özaydin and Taskavak (2006) and 9.39 cm by Acarli et al. (2014). In the results of this study, total length distribution of *S. pilchardus* between 9.5-15.3 cm. For the estimation of the mean length values of *E. encrasicolus* distribution range has been reported as 9.95 cm by Acarli et al. (2014) and 12.09 cm by Özaydin and Taskavak (2006). In this study, the mean length found as 11.4 cm and it has been shown similarity and also, it has been found as a medium value of these results.

Furthermore, the reported results of the *b* coefficient, which show different types of growth, such as isometric and allometric growth depending on different sampling areas are notable. As a short note, the *b* value is useful in explaining the body shape (growth type) according to the conditions in which the fish is present. If this value is equal to “3” it is called isometric but if it is a different value than “3”, then it is called allometric growth (Ricker, 1975; Sparre et al., 1989; Sparre and Venema, 1992; Avsar, 2016).

Table 3. Comparative results of LWR parameters of *S. pilchardus*

| Author                     | Location                  | Sex | n   | a    | b    | *r*²  | Growth          |
|----------------------------|---------------------------|-----|-----|------|------|-------|-----------------|
| Present study              | Aegean Sea- Izmir Bay     | ♀♀  | 567 | 0.0059 | 2.793 | 0.94  | allometric      |
| Petrakis and Stergiou, 1995| South Euboikos Gulf       | ♀♀  | 82  | 0.0003 | 2.754 | 0.82  | allometric      |
| Sinović et al., 2004       | Adriatic Sea              | ♀♀  | 4441| 0.0038 | 3.230 | 0.98  | allometric      |
| Mendes et al., 2004        | Portuguese west coast     | ♀♀  | 113 | 0.0017 | 2.772 | 0.77  | allometric      |
| Tarkan et al., 2006        | Marmara Region -Turkey    | ♀♀  | 11  | 0.0021 | 3.540 | 0.98  | allometric      |
| Pešić et al., 2006         | Boka Kotoraska Bay        | ♀♀  | 2489| -0.0047 | 3.167 | 0.99  | allometric      |
| Özaydin and Taskavak, 2006 | Aegean Sea- Izmir Bay     | ♀♀  | 388 | 0.0076 | 3.190 | 0.89  | allometric      |
| Karachle et al., 2008      | North Aegean Sea          | ♀♀  | 752 | 0.0053 | 3.144 | 0.90  | allometric      |
| Veiga et al., 2009         | Southern Portugal         | ♀♀  | 676 | 0.0051 | 3.140 | 0.95  | allometric      |
| Mustac et al., 2010        | Middle Adriatic Sea       | ♀♀  | 668 | 0.0425 | 2.371 | 0.58  | allometric      |
| Torres et al., 2012        | Gulf of Cadiz             | ♀♀  | 1656| 0.0082 | 3.016 | 0.87  | isometric       |
| Acarli et al., 2014        | Izmir Bay – Homa Lagoon   | ♀♀  | 77  | 0.0070 | 3.053 | 0.99  | allometric      |

Table 4. Comparative results of LWR parameters of *E. encrasicolus*

| Author                     | Location                  | Sex | n   | a    | b    | *r*²  | Growth          |
|----------------------------|---------------------------|-----|-----|------|------|-------|-----------------|
| Present study              | Aegean Sea- Izmir Bay     | ♀♀  | 212 | 0.0019 | 3.421 | 0.87  | +allometric     |
| Sinović et al., 2004       | Adriatic Sea              | ♀♀  | 4234| 0.0039 | 3.160 | 0.99  | +allometric     |
| Özaydin and Taskavak, 2006 | Aegean Sea- Izmir Bay     | ♀♀  | 513 | 0.0116 | 2.840 | 0.94  | -allometric     |
| Ismen et al., 2007         | Saros Bay                 | ♀♀  | 212 | 0.0050 | 2.970 | 0.87  | -allometric     |
| Karachle et al., 2008      | North Aegean Sea          | ♀♀  | 759 | 0.0008 | 3.822 | 0.95  | +allometric     |
| Veiga et al., 2009         | Southern Portugal         | ♀♀  | 278 | 0.0039 | 3.190 | 0.98  | +allometric     |
| Torres et al., 2012        | Gulf of Cadiz             | ♀♀  | 2293| 0.0049 | 3.125 | 0.97  | +allometric     |
| Acarli et al., 2014        | Izmir Bay – Homa Lagoon   | ♀♀  | 68  | 0.0070 | 2.917 | 0.99  | -allometric     |
So far, many studies of *S. pilchardus* indicating allometric growth and only one study reported as isometric growth such as Torres et al. (2012). As it seems in Table 3, there were differences between allometric growth. So that, Mendes et al. (2004), Petrakis and Stergiou (1995) and this present study results has been shown negative allometric growth. Otherwise, the rest of them has been indicated positive allometric growth. Comparison of the reported values of *E. encrasicolus* shown that all researchers have been agreed on the allometric growth of this species. However, growth type of depending on b value have a variety among conducted studies. Such that, Sinovčić et al. (2004), Karachle et al. (2008), Veiga et al. (2009), Torres et al. (2012) and this present studies b value indicating positive allometric growth. On the contrary, other studies has been shown negative allometric growth (Table 4). Length-frequency distributions and b value is directly associated to the fishing gear and method. While gillnets/trammel nets are shown higher caught is also an important variable to establish the fishing pressure. 

### Conflict of Interest

The authors declare that there is no conflict of interest.

### References

Acarli, D., Kara, A. & Bayhan, B. (2014). Length-weight relations for 29 fish species from Homa Lagoon, Aegean Sea, Turkey. *Acta Ichthyologica et Piscatoria*, 44(3): 249-257. https://doi.org/10.3750/AIP2014.44.3.09

Aysar, D. (2016). Fisheries Biology and Population Dynamics (in Turkish). Ankara, Turkey: Akademisyen Publishing. 148 p.

Floese, R. & Pauly, D. (1998). FishBase 98: Concepts, Design and Data sources. 293 p

González Acosta, A. F., De La Cruz Agüero, G. & De La Cruz Agüero, J. (2004). Length-weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). *Journal of Applied Ichthyology*, 20(2): 154-155. https://doi.org/10.1046/j.1439-0426.2003.00518.x

Handegard, N. O., Tenningen, M., Howarth, K., Anders, N., Rieucu, G. & Breen, M. (2017). Effects on schooling function in mackerel of sub-lethal capture related stressors: crowding and hypoxia. *PLoS ONE*, 12(12): e0190259. https://doi.org/10.1371/journal.pone.0190259

Hoşsuçu, H., Kara, A., Metin, C., Tosunoğlu, Z. & Ulaş, A. (1994). Purse seine fisheries in Aegean Region and catch effort of the purse seine vessels (in Turkish with English abstract). *Ege Journal of Fisheries and Aquatic Sciences*, 11: 17-32.

Ismen, A., Ozen, O., Altinagac, U., Ozekinci, U. & Ayaz, A. (2007). Weight-length relationships of 63 fish species in Saros Bay, Turkey. *Journal of Applied Ichthyology*, 23(6): 707-708. https://doi.org/10.1111/j.1439-0426.2007.00872.x

Karachle, P. K. & Stergiou, K. I. (2008). Length–length and length–weight relationships of several fish species from the North Aegean Sea (Greece). *Journal of Biological Research-Thessaloniki*, 10: 149-157.

Mendes, B., Fonseca, P. & Campos, A. (2004). Weight-length relationships for 46 fish species of the Portuguese west coast. *Journal of Applied Ichthyology*, 20(5): 355-361. https://doi.org/10.1111/j.1439-0426.2004.00559.x
Moutopoulos, D. K. & Stergiou, K. I. (2002). Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). *Journal of Applied Ichthyology, 18*(3): 200-203. [https://doi.org/10.1046/j.1439-0426.2002.00281.x](https://doi.org/10.1046/j.1439-0426.2002.00281.x)

Mustač, B. & Sinovčić, G. (2010). Reproduction, length–weight relationship and condition of sardine, *Sardina pilchardus* (Walbaum, 1792), in the eastern Middle Adriatic Sea (Croatia). *Periodicum Biologorum, 112*(2): 133-138.

Oscoz, J., Campos, F. & Escala, M. C. (2005). Weight–length relationships of some fish species of the Iberian Peninsula. *Journal of Applied Ichthyology, 21*(1): 73-74. [https://doi.org/10.1046/j.1439-0426.2004.00587.x](https://doi.org/10.1046/j.1439-0426.2004.00587.x)

Özaydın, O. & Taskavak, E. (2006). Length-weight relationships for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). *Acta Adriatica, 47*(2): 211-216.

Pešić, A., Đurović, M., Regner, S., Joksimović, A. & Simić, V. (2006). Length-weight relationship of juvenile sardine *Sardina pilchardus* (Walbaum, 1792) from Boka Kotor Bay. *Kragujevac Journal of Science, 28*: 91-95.

Petakis, G. & Stergiou, K. I. (1995). Weight-length relationships for 33 fish species in Greek waters. *Fisheries Research, 21*(3-4): 465-469. [https://doi.org/10.1016/0165-7836(94)00294-7](https://doi.org/10.1016/0165-7836(94)00294-7)

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*. Bulletin No. 191, Ottawa, Canada. 382p.

Sokal, R. R. & Rohlf, F. J. (1969). Biometry: The principles and practice of statistics in biological research. 3rd ed. San Francisco, CA, USA: W. H. Freeman and Company. 776p.

Sokal, R. R. & Rohlf, F. J. (1973). Introduction to Biostatistics. San Francisco, CA, USA: W. H. Freeman & Company Ltd. 368 p.

Sparre, P., Ursin, E. & Venema, S. C. (1989). Introduction to tropical fish stock assessment: Part I. Manual FAO Fisheries Technical Paper. No. 306. 1. Rev. 1 Rome, Italy: FAO. 376 p.

Tarkan, A. S., Gaygusuz, Ö., Acpinar, H., Gürsöy, Ç. & Özuluğ, M. (2006). Length-weight relationship of fishes from the Marmara region (NW-Turkey). *Journal of Applied Ichthyology, 22*(4): 271-273. [https://doi.org/10.1111/j.1439-0426.2006.00711.x](https://doi.org/10.1111/j.1439-0426.2006.00711.x)

Veiga, P., Machado, D., Almeida, C., Bentes, L., Monteiro, P., Oliveira, F. & Gonçalves, J. M. S. (2009). Weight-length relationships for 54 species of the Arade estuary, southern Portugal. *Journal of Applied Ichthyology, 25*(4): 493-496. [https://doi.org/10.1111/j.1439-0426.2009.01230.x](https://doi.org/10.1111/j.1439-0426.2009.01230.x)

Watson, R., Revenga, C. & Kura, Y. (2006). Fishing gear associated with global marine catches: I. Database development. *Fisheries Research, 79*(1-2): 97-102. [https://doi.org/10.1016/j.fishres.2006.01.010](https://doi.org/10.1016/j.fishres.2006.01.010)