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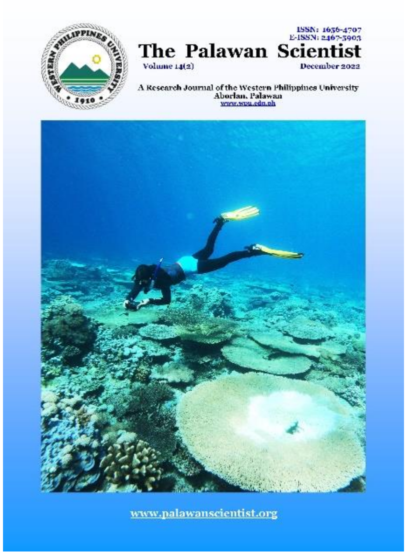

Length-weight relationships of eight discarded flatfish species from Gallipoli Peninsula (Northern Aegean Sea, Türkiye): An evaluation for ecosystem-based fisheries management

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ABSTRACT

The fishing management authorities are in need of some biometric throughput and analysis with a view to the administration and protection of fishery stocks. The inputs regarding the lengths and weights of fish species have frequently been taken into account in order to divulge biological information. In the present research, length-weight relationships were extrapolated for discarded eight flatfishes off Gallipoli Peninsula (Northern Aegean Sea, Türkiye). From January 2017 to December 2017, a total of 142 individuals of eight species (*Arnoglossus imperialis*, *Arnoglossus laterna*, *Arnoglossus rueppelii*, *Arnoglossus thori*, *Symphurus nigrescens*, *Microchirus ocellatus*, *Microchirus varieagatus*, *Monochirus hispidus*) belonging to three families (Bothidae, Cynoglossidae, Soleidae) were collected from commercial fishermen's catches. The length-weight relationships' slopes (b) varied from 2.64 to 3.41. Every length-weight relationships was statistically significant ($P < 0.0001$). This paper embodies preliminary data on the LWRs of discarded eight flatfishes for the Gallipoli Peninsula (Northern Aegean Sea, Türkiye). Hence, data on the discarded fish species is of importance when keeping in view sustainable ecosystem-based fisheries management and, in the continuation of the long-dated investigations of the length-weight relationships of the fish species in question. This must be performed on an ongoing basis so as to monitor the current state of fish stocks. The stakeholders could utilize the results of the present research in the coming times.

Keywords: Fish biology, Gallipoli Peninsula, Northern Aegean Sea, Türkiye

INTRODUCTION

Since the late 1800s, researchers have been studying the length-weight relationships (LWRs) of fish species, and the method in question has been regarded as a valuable tool for characterizing numerous biological characteristics (Le Cren 1951; Froese 2006; Freitas et al. 2017) and to understand the management and sustainable exploitation of fish communities (Anene 2005; Al Kamel et al. 2020), up to the present. When estimating population increase in fish stocks, the length-weight relationship is frequently the initial step (Hercos et al. 2021) and because regional or temporal differences may have occurred, it should be examined and reviewed on a regular basis. As a result, information regarding the length-weight relationship is critical for the conservation of fish stocks and the implementation of fisheries management plans (Acarli et al. 2022). They are helpful for (1) figuring out weights from smoother length measurements (Santos et al. 2002), (2) deciding if either somatic growth is allometric or isometric (Ricker 1975), (3) estimating weight-at-age, (4) conjecturing fish condition, and (5) figuring out morphologic analogies of species from various areas (Ricker 1975; Petrakis and Stergiou 1995; Stergiou and Moutopoulos 2001). Additionally, the studies of the length-weight relationships become important because of the requirement to understand the fish life cycle, particularly in areas where fishing is one of the most significant sectors and fish populations are the primary food supply for many traditional people (Freitas et al. 2014).

The number of studies regarding fisheries has traditionally focused on commercially important fish stocks, whereas the attention towards less economically significant fishery sources has decreased in recent years (Jørgensen et al. 2016). Most low-value fishes have an environmentally vital function in the marine ecosystem, and several of these animals are used as fish food in many coastal nations (FAO 2019; Han et al. 2021). For ecosystem-based fisheries management, it is critical to conceive the biological data of these animals (Pikitch et al. 2004; Zhang et al. 2016).

The order Pleuronectiformes were first named in 1758 by Linnaeus; “pleuro” meaning “on side” and “necto” meaning “swim”. The flatfishes are easy to recognize since this is the only group of fishes that is not bilaterally symmetrical. The ventral side of the body is eyeless and white, while the dorsal is dark and has both eyes. They swim by the undulation of the body, and usually remain close to the bottom of the continental shelf (Aung et al. 2019). It encapsulates 793 species in 16 families, worldwide (Froese and Pauly 2022). As far as it is known, 26 species in six families (Bothidae, Citharidae, Pleuronectidae, Scopthalmidae, Soleidae, Cynoglossidae) from Turkish territorial waters were reported (Bilecenoğlu et al. 2014).

Although Gallipoli Peninsula (Northern Aegean Sea, Türkiye) exhibits the diversity in terms of the species’composition, information concerning the length-weight relations (LWRs) of the fish species in the area is still inadequate, especially for discarded fish species. This study included preliminary data on the LWRs of eight flatfishes [*Arnoglossus imperialis* (Rafinesque, 1810); *Arnoglossus laterna* (Walbaum, 1792); *Arnoglossus rueppelii* (Cocco, 1844); *Arnoglossus thori* (Kyle, 1913); *Symphurus nigrescens* (Rafinesque, 1810); *Microchirus ocellatus* (Linnaeus, 1758); *Microchirus varieagatus* (Donovan, 1808); *Monochirus hispidus* (Rafinesque, 1814)], which are discarded fish species in the Gallipoli Peninsula (Northern Sea, Türkiye) commercial fisheries and compares these results with the previous studies in different areas of Mediterranean Basin. The studies on the LWRs of the species at issue have been carried out in different regions of the Mediterranean Basin (Lamprakis et al. 2003; Karakulak et al. 2006; Özaydın and Taskavak 2006; Özaydın et al. 2007; Bayhan et al. 2008; Çakır et al. 2008; Ilkyaz et al. 2008; Karachile and Stergiou 2008; Özekinci et al. 2009; Giacalone et al. 2010; Bilge et al. 2014; Altın et al. 2015; Yapıcı et al. 2015). Hence, the data on these species are vastly needed to have a better understanding of the functioning of any marine ecosystem and will make a significant contribution to the scientific literature for fisheries managers.

METHODS

The Mediterranean Basin has an oligotrophic feature, whereas the eastern Mediterranean exists its highest oligotrophic part (Psarra et al. 2000). Along the North-South line of the Aegean Sea, there is a tendency parallel to declining basic production values (Antoine et al. 1995; Gönülal and Dalyan 2017). That's why, the northern Aegean territories are qualified by a long oceanic crust, flat sandy/muddy land, and high nutrient contents (Maravelias and Papaconstantinou 2006) and when compared with the southern Aegean territories, these areas are higher for zooplankton and phytoplankton abundance (Theocharis et al. 1999). The northern Aegean coasts of Türkiye are separated into sub-regions to be the Edremit and Saros Bays, the Bozcaada and Gökceada Islands and the Gallipoli Peninsula (Cengiz 2021; Cengiz and Paruğ 2021). For the reasons stated above, the Gallipoli Peninsula exhibits diversity in terms of the species’ composition and is also considered an important fishing area (Cengiz et al. 2012) (Figure 1).

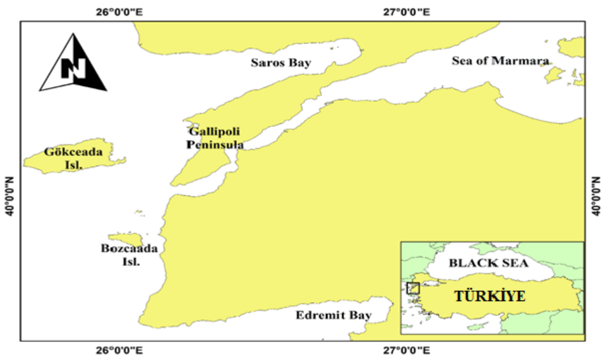

Figure 1. Gallipoli Peninsula and the northern Aegean coasts of Türkiye.

Samples were obtained from commercial fishermen’s catches around Gallipoli Peninsula during the period of January 2017 - December 2017. The criteria of Mater et al. (2011) were used to identify the fish. In agreement with Froese and Pauly (2022), the scientific names for each species were checked. The individuals were measured to the nearest centimeter (total length) and weighed to the nearest 0.01 g (total weight). Length-weight relationships were calculated by applying an exponential pattern, $W = aL^b$ (Le Cren 1951). The exponential curve's parameters *a* and *b* were calculated using the least-squares method over log-transformed data log W = log$a$ + $b$log L, where W is total weight (g), where *b* is the slope of the linear regression (exponent indicating the growth type), *a* is the intercept (coefficient related to body form), and *W* is the total weight (g), *L* is the total length (cm), using the least-squares method. The determination coefficient, R^2, was used to calculate the degree of correlation between the variables. Excel 2010 for Windows was used to calculate the variables of linear relationships. Student's t-test was used to determine fish growth types using the equation of Sokal and Rohlf (1987): ts = (b – 3) / SE(b), where SE(b) is the standard error of the slope, *b* is the slope, and ts is the t-test value. The growing style of fish is determined by the *b* value. Hereby, $b > 3$ denotes positive allometric growth, whereas $b < 3$ denotes negative allometric growth. When the value of *b* equals 3, the growth is isometric (Bagenal and Tesch 1978). SPSS 19 was used to assess all statistical analyses at a 5% significance level.

RESULTS

During the research period, 142 individuals of eight species (*Arnoglossus imperialis*, *Arnoglossus laterna*, *Arnoglossus rueppelii*, *Arnoglossus thori*, *Symphurus nigrescens*, *Microchirus ocellatus*, *Microchirus varieagatus*, *Monochirus hispidus*) belonging to three families (Bothidae, Cynoglossidae, Soleidae) was evaluated. For each species, the sample size, length and weight ranges, estimated parameters of LWR (*a* and *b*), 95% confidence intervals and standard error of *b* value and coefficient (R^2) are shown in Table 1, respectively. Length values of the catch varied from 8.2 cm (*Arnoglossus rueppelii*) to 18.0 cm (*Arnoglossus laterna*) whereas values of weight observed between 8.78 g (*Arnoglossus rueppelii*) to 234.82 g (*Arnoglossus laterna*). The coefficients of determination (R^2) ranged from 0.95 to 0.98, and all regressions were highly significant ($P <$ 0.0001). While three species (*Arnoglossus imperialis*, *Arnoglossus laterna*, *Arnoglossus thori*) showed positive allometry growth regarding the growth type, four species (*Arnoglossus rueppelii*, *Microchirus ocellatus*, *Microchirus varieagatus*, *Monochirus hispidus*) displayed negative allometry growth. One species (*Symphurus nigrescens*) presented isometric growth. The values of *b* were observed from 2.64 to 3.41, while values of *a* varied between 0.0037 to 0.0681 (Figure 2).

Table 1. Length-weight relationships for discarded eight flatfish species from Gallipoli Peninsula (Northern Aegean Sea, Türkiye). N: Sample size; *a* and *b*: intercept and slope of length-weight relations; CI: confidence interval; SE: standard error; R^2: the coefficient of determination

Family	Species	N	Length range (cm)	Weight range (g)	*a*	*b*	95% *CI* of *b*	*SE*(*b*)	R^2
Bothidae	*Arnoglossus imperialis*	23	8.4-14.8	5.00-27.77	0.0045	3.26	2.88-3.64	0.1809	0.95
	Arnoglossus laterna	30	8.8-18.0	4.59-42.79	0.0044	3.18	3.03-3.34	0.0742	0.98
	Arnoglossus rueppelii	10	8.2-15.1	4.00-25.00	0.0078	2.92	2.56-3.29	0.1575	0.97
	Arnoglossus thori	16	8.3-13.4	4.85-25.00	0.0037	3.41	3.01-3.80	0.1826	0.96
Cynoglossidae	*Symphurus nigrescens*	10	9.1-12.1	9.00-19.00	0.0112	3.00	2.42-3.55	0.2449	0.95
Soleidae	*Microchirus ocellatus*	11	10.2-13.5	17.78-39.00	0.0321	2.70	2.34-3.05	0.1581	0.97
	Microchirus variegatus	25	9.8-15.2	12.20-37.00	0.0226	2.74	2.35-3.12	0.1877	0.95
	Monochirus hispidus	17	9.6-14.0	13.55-33.01	0.0681	2.64	2.25-3.02	0.1153	0.96

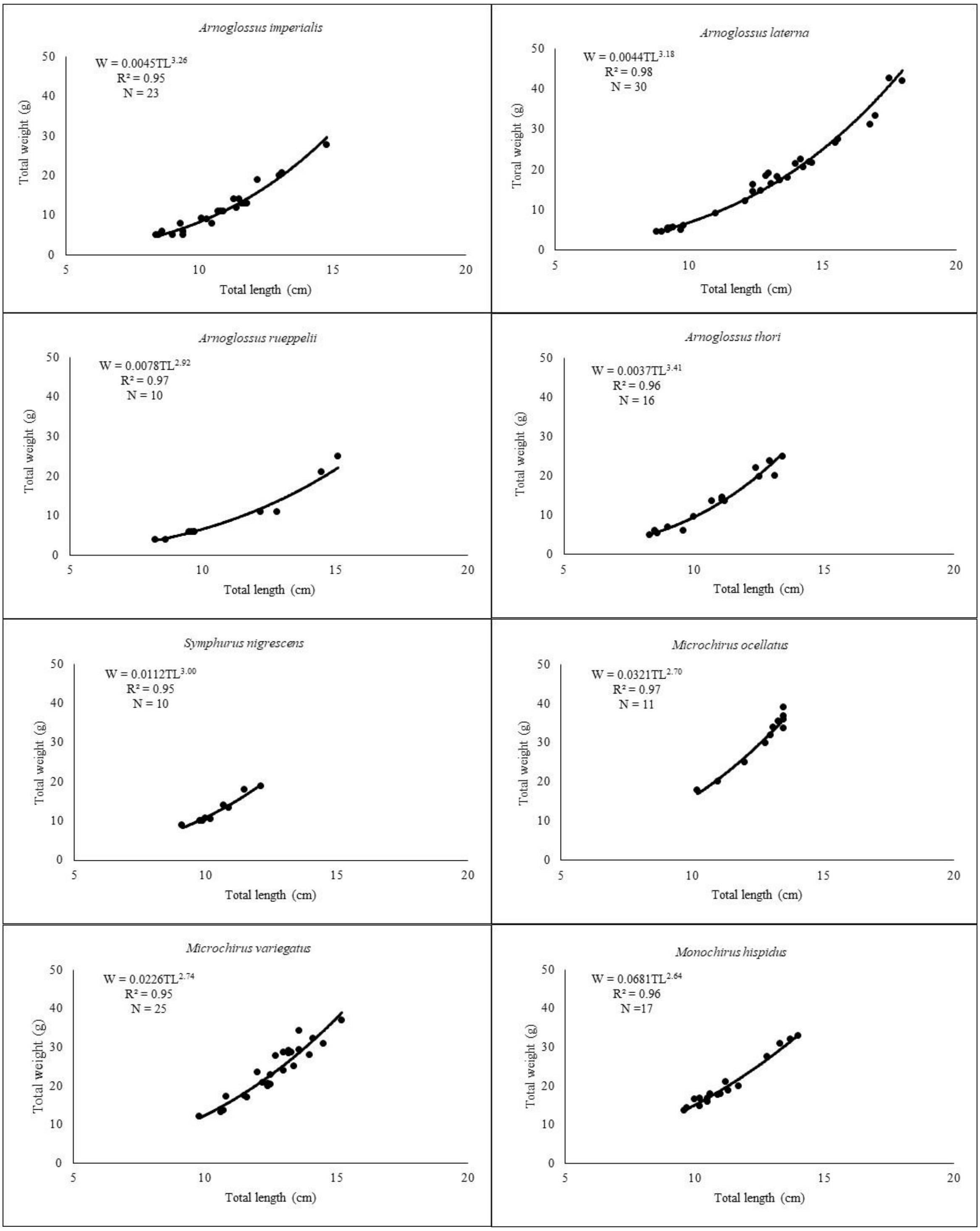

Figure 2. The curves of length-weight relationships of discarded eight flatfish species from Gallipoli Peninsula (Northern Aegean Sea, Türkiye).

DISCUSSION

Table 2 displays the comparison of the present study with the previous ones. In LWRs, the values of *b* ranged from 2.5 to 3.5 (Carlander 1969) or between 2 and 4 (Tesch 1971). The values of *b* ranged between 2.64 (*Monochirus hispidus*) and 3.41 (*Arnoglossus thori*) in this research. The tested fish species' *b* values were within these predicted limits. Although Jellyman et al. (2013) and Valle et al. (2021) accentuated that numerous reasons like season, location, fishing gear, and sex can affect length-weight relationships, Ricker

(1975) and Cengiz et al. (2019) explained that differences in *b* values can be influenced by ecological factors such as species-specific biological properties, environmental factors, and survey period. Likewise, Moutopoulos and Stergiou (2002) explained that variances in *b* values might be connected to sample size, seasonal circumstances, and sampling area, but Cabbar and Yigin (2021) justified that fishing gears' selectivity and depth of sampling have also influenced the results. The coefficient of determination (R^2) ranged between 0.95 and 0.98. While Silva-Junior et al. (2011) noted that small determination coefficients (under 0.95) might appear when a population has a small range of size, Cabbar and Yigin (2021) pointed out that a large determination coefficient indicates a wide range of sizes and a large number of individuals.

Jørgensen et al. (2016) emphasized that in recent years, with the exercise of ecosystem-based fisheries management (EBFM), interest in the conservation of resources with little or no economic importance has grown. Discards are commonly consist of undersized individuals of commercial species and non-commercial species (Demestre et al. 2018; Soykan et al. 2019). Because discarded fish species are important for biodiversity and also could influence the abundance of target species, the understanding of their population dynamics and/or life history is significant both due to interspecific relationships (Yapıcı and Filiz 2014) and for ecosystem-based fisheries management to conserve the marine ecosystems and their continuation (Browman and Stergiou 2004; Gullestad et al. 2014). As a result, extensive research on discarded fish species is both keystone for sustainable fisheries management and essential for uncovering their ecological features on the marine food chain (Alverson et al. 1994).

The present study extrapolated, for the first time, the length-weight relationships of discarded eight flatfishes in the gillnet fishery for the Gallipoli Peninsula. These values own major significance since they specify fish growth patterns, which in turn are requisite for improving of ecosystem-based fisheries management and could be used as a reference for further biological investigations and management of species in question in different regions of the Mediterranean, Aegean Sea, or worldwide. Moreover, further legislative efforts for ecosystem-based fisheries management in Gallipoli Peninsula must reveal essential biological parameters such as growth, age, feeding, and reproduction of these species, as well as discard data such as discarded ratios and discarded amount. In addition, more researches need to be performed to figure out the intraspecific/interspecific relations of discarded species. Lastly, the information obtained from the present study should be disseminated to stakeholders (fisheries scientists, fishing management authorities, etc.).

Table 2. The length-weight relationships of discarded flatfishes from previous studies in different areas. N: Sample size; *a* and *b*: intercept and slope of length-weight relationships. [1] first L-W relationships reference for the Gallipoli Peninsula, Northern Aegean Sea, Türkiye.

Species	References	Area	Sampling gear	Sampling period	N	Length range (cm)	Weight range (g)	*a*	*b*
Arnoglossus imperialis[1]	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	36	7.6-15.2	3.00-28.64	0.0039	3.29
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	23	8.4-14.8	5.00-27.77	0.0045	3.26
Arnoglossus laterna[1]	Karakulak et al. (2006)	Gökceada Island (Türkiye)	Gill net	March 2004 - February 2005	8	7.6-18.3	-	0.0150	2.74
	Özaydın & Taşkavak (2006)	Izmir Bay (Türkiye)	Beach seine, Gill net, Bottom trawl	1998 - 2001	721	6.8-21.9	2.30-79.40	0.0052	3.16
	Özaydın et al. (2007)	Izmir Bay (Türkiye)	Bottom trawl	February 2005 - December 2005	1078	4.5-14.9	-	0.0097	2.90
	Bayhan et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	January 2002 - December 2002	796	5.6-17.1	1.20-37.83	0.0073	3.00
	Çakır et al. (2008)	Edremit Bay (Türkiye)	Bottom trawl	September 1997 - September 2000	328	5.5-20.5	8.40-392.41	0.00002	3.24
	İlkyaz et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	June 2005 - May 2006	1629	5.5-19.8	-	0.0071	3.05

Species	References	Area	Sampling gear	Sampling period	N	Length range (cm)	Weight range (g)	*a*	*b*
	Karachle & Stergiou (2008)	Thermaikos Gulf (Grecee)	Gill net, Purse seine, Trawl	June 2001 - January 2006	212	4.5-16.9	-	0.0032	3.32
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	57	8.8-20.2	4.31-62.42	0.0046	3.18
	Giacalone et al. (2010)	Gulf of Castellammare (Italy)	Bottom trawl	Summer 2004 - Spring 2005	1455	4.0-16.0	-	0.0093	2.97
	Bilge et al. (2014)	Southern Aegean Sea (Türkiye)	Bottom trawl	December 2009 - November 2010	1305	4.5-14.9	-	0.0092	2.92
	Altın (2015)	Gökceada Island (Türkiye)	Beach seine, Beam trawl	June 2013 - June 2014	11	4.3-10.7	0.49-11.21	0.0050	3.23
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	30	8.8-18.0	4.59-42.79	0.0044	3.18
Arnoglossus rueppelii[1]	Lamprakis et al. (2003)	Thracian Sea (Grecee)	Bottom trawl	1996 - 1998	72	5.5-15.7	-	0.0077	2.88
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	13	7.5-16.2	3.00-33.00	0.0081	2.91
	Giacalone et al. (2010)	Gulf of Castellammare (Italy)	Bottom trawl	Summer 2004 - Spring 2005	26	5.0-10.0	-	0.0049	3.08
	Bilge et al. (2014)	Southern Aegean Sea (Türkiye)	Bottom trawl	December 2009 - November 2010	126	4.7-11.9	-	0.0037	3.17
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	10	8.2-15.1	4.00-25.00	0.0078	2.92
Arnoglossus thori[1]	Lamprakis et al. (2003)	Thracian Sea (Grecee)	Bottom trawl	1996 - 1998	572	3.8-12.6	-	0.0060	3.15
	Karakulak et al. (2006)	Gökceada Island (Türkiye)	Gill net	March 2004 - February 2005	8	8.5-11.2	-	0.0068	3.12
	Özaydın et al. (2007)	Izmir Bay (Türkiye)	Bottom trawl	February 2005 - December 2005	20	6.17.9	-	0.0288	2.47
	Bayhan et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	January 2002 - December 2002	6	6.7-9.0	2.52-5.04	0.0442	2.16
	Çakır et al. (2008)	Edremit Bay (Türkiye)	Bottom trawl	September 1997 - September 2000	170	6.5-22.5	1.59-83.87	0.00001	2.94
	İlkyaz et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	June 2005 - May 2006	371	4.4-12.5	-	0.0054	3.26
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	15	8.0-13.1	3.84-23.80	0.0026	3.56
	Giacalone et al. (2010)	Gulf of Castellammare (Italy)	Bottom trawl	Summer 2004 - Spring 2005	73	6.5-10.5	-	0.0108	2.98
	Bilge et al. (2014)	Southern Aegean Sea (Türkiye)	Bottom trawl	December 2009 - November 2010	121	6.8-9.9	-	0.0328	2.39
	Altın (2015)	Gökceada Island (Türkiye)	Beach seine, Beam trawl	June 2013 - June 2014	71	3.9-12.4	0.45-18.15	0.0060	3.14
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	16	8.3-13.4	4.85-25.00	0.0037	3.41
Symphurus nigrescens[1]	Lamprakis et al. (2003)	Thracian Sea (Grecee)	Bottom trawl	1996 - 1998	406	4.7-13.0	-	0.0029	3.45

Species	References	Area	Sampling gear	Sampling period	N	Length range (cm)	Weight range (g)	*a*	*b*
	İlkyaz et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	June 2005 - May 2006	182	7.3-12.2	-	0.0088	2.98
	Karachle & Stergiou (2008)	Thermaikos Gulf (Grecee)	Gill net, Purse seine, Trawl	June 2001 - January 2006	10	6.4-11.9	-	0.0024	3.41
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	7	9.8-10.09	10.09-14.02	0.0075	3.15
	Yapıcı et al. (2015)	Southern Aegean Sea (Türkiye)	Bottom trawl	October 2011 - December 2011	10	7.8-10.6	-	0.0027	3.49
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	10	9.1-12.1	9.00-19.00	0.0112	3.00
Microchirus ocellatus[1]	İlkyaz et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	June 2005 - May 2006	6	7.7-12.7	-	0.0079	3.25
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	8	10.3-13,7	18.81-42.43	0.0326	2.72
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	11	10.2-13.5	17.78-39.00	0.0321	2.70
Microchirus variegatus[1]	Karakulak et al. (2006)	Gökceada Island (Türkiye)	Gill net	March 2004 - February 2005	10	10.1-14.6	-	0.0137	3.02
	İlkyaz et al. (2008)	Izmir Bay (Türkiye)	Bottom trawl	June 2005 - May 2006	36	8.1-14.1	-	0.0044	3.31
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	29	10.1-15.5	12.20-39.40	0.0162	2.87
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017- December 2017	25	9.8-15.2	11.98-37.00	0.0226	2.74
Monochirus hispidus[1]	Karachle & Stergiou (2008)	Thermaikos Gulf (Grecee)	Gill net, Purse seine, Trawl	June 2001 - January 2006	24	9.2-12.8	-	0.0537	2.45
	Özekinci et al. (2009)	Saros Bay (Türkiye)	Bottom trawl	September 2006 - September 2008	15	9.7-13.7	14.40-32.01	0.0565	2.43
	This study	Gallipoli Peninsula (Türkiye)	Gill net	January 2017 - December 2017	17	9.6-14.0	13.55-33.01	0.0681	2.64

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