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Length–Weight Relationship of some Discarded Fish Species with Emphasis on Length at Maturity from the Central Aegean Sea, Turkey

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Abstract

In this study, length–weight relationships were estimated for discarded trawl fish species and mean size at capture was compared with reported mean length at first maturity (L_m). Sampling was conducted in Sığacık Bay, on the Turkish coast of the central Aegean Sea, between October 2008 and April 2010 onboard a commercial trawler fishing over a depth range of 88–450 m. A total of 14,120 individuals from 15 fish species belonging to 13 families were examined: 9 species were elasmobranchs and 6 were teleosts. Length-weight relationship (LWR) values of b parameter varied between 2.55 and 3.37, with five species having isometric growth, five negative and six positive allometric growth. LWR was not determined for one species due to insufficient sample size. Average size at capture for 14 fish species was found to be below the reported L_m. Our results could be useful in stock assessments and serve as a reference for future comparison of similar parameters estimated in other parts of the Aegean Sea or Mediterranean. Furthermore, information on the discard species in the trawl fishery, their mean size at capture and conservation status is important when considering sustainable ecosystem based fishery management.

Keywords Discard · Length weight relation · Length at maturity · Conservation

Introduction

With the implementation of ecosystem-based fisheries management in recent years, attention on the protection of resources which have little or no economic significance including bycatch and discards in bottom trawling has increased (Jørgensen et al. 2016). Discards are generally composed of non-commercial species and undersized individuals of commercial species (Demestre et al. 2018; Soykan et al. 2019). It is well-known that bottom trawls are one of the least selective fishing gears and produce a high amount of discards (Kelleher 2005; Demestre et al. 2018; Roda et al. 2019). Nowadays, there is an increasing scientific interest with regard to impact of bottom trawling on benthic habitats, communities and demersal species. These impacts have potential to create changes in the ecological functioning of benthic components which may result in serious repercussions on the exploited populations (de Juan et al. 2007; Frid 2011). Therefore, the link between benthic communities, especially the discards, and commercial resources must be taken into consideration, because a huge number of ecological interactions may be adversely affected by fishery practices (Demestre et al. 2018). It is also important to address fundamental biological features such as reproduction and feeding of discarded species for ecosystem-based fishery management (EBFM) in order to protect the marine ecosystems and their sustainability (Browman and Stergiou 2004; Gullestad et al. 2014). Reproductive characteristics of many discarded species are generally omitted from scientific papers because they have no commercial value in the fishing industry. Even so, a number of studies (Yapıcı and Filiz 2014; Bradai et al. 2012; D'Onghia et al. 1998; Bottari et al. 2010) do provide information on reproduction of some discarded species of the bottom trawl fishery in the Mediterranean Sea. As is well-known, length at maturity (L_m) is a key population parameter that is extremely important in the fisheries management of exploited stocks (Jennings et al. 2001). L_m for a population is often expressed as the value at which 50% of the sample has reached sexual maturity (King 1996).

Length–weight relationships (LWR) are important tools in fisheries science for estimating the weight for a certain length of an individual fish, assessing the biomass when the length–

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frequency distribution is known, and calculating the condition indices of fish (Anderson and Gutreuter 1983; Froese 2006; Froese et al. 2011; Yapıcı et al. 2015). LWR is also used to compare life histories of fishes inhabiting different locations (Yapıcı et al. 2015). Previous studies reporting the LWR of some species inhabiting the Turkish coast of the Aegean Sea were conducted by many researchers (Table 1).

In this study, length–weight relationships were estimated for 14 discarded trawl fish species captured from Sığacık Bay, representing the first information available on length–weight relationships for 2 of these species (*Nezumia sclerorhynchus, Dalatias licha*) for the Turkish coast of the central Aegean Sea. Size at capture of those were compared with reported mean lengths at first maturity for each species. Therefore, our results are important for the fisheries assessment of the area and can be used as a reference for future comparison of similar parameters estimated in other parts of the Aegean Sea or Mediterranean.

Materials and Methods

The Sığacık and Kuşadası Bays are located along the Turkish coast of central Aegean Sea (Fig. 1). Fish samples were taken from a commercial trawler (27 m length, 550 hp. engine), using a commercial bottom trawl net which had 1200 mesh around the mouth of the net. Codend of the trawl net was 5 m in length (400 mesh circumference at the codend) and made of braided polyethylene material with 44 mm mesh size netting. A total of 40 trawl hauls were made between October 2008 and April 2010. During winter; in 2009, number of hauls (n) = 4 and in 2010 $n = 6$. In spring of both 2009 and 2010 $n = 5$; and in summer 2009, $n = 10$. In autumn 2008, n = 6; in 2009, $n = 4$. Depth was 88–450 m and duration of trawl operation varied from 192 to 415 min at a towing speed of 2.4 to 2.6 knots.

The discarded samples were taken from the discards of each haul after the commercially valuable fraction of the catch had been sorted and retained by the fishermen. The discarded portion of the catch from each haul was first mixed by a paddle on deck in order to maintain a homogenous distribution of species. Then subsamples were taken randomly according to the amount of discarded yield in the sampling ratios of 1/3, 1/5, etc. and put in hard plastics sacks. Discard subsamples in the plastic sacks of each operation were kept in the cold storage room of the vessel and brought to the laboratory fresh after each fishing trial without any chemical application. Fishes were identified to the species level in the laboratory according to Whitehead et al. (1986) and scientific names for each species were checked with the FishBase (Froese and Pauly 2019). Individual samples were measured for total length (TL) to the nearest 1 mm using a measuring board, and weighed to the nearest 0.01 g using an electronic scale in the laboratory.

Length–weight relationship parameters (a and b) were estimated by linear regression analysis on log-transformed data ($W = aL^b$) where “a” is the intercept (coefficient related to body form), and “b” is the slope of the linear regression (exponent indicating the growth type). The degree of association between variables was calculated by the determination coefficient (r^2). One of the most important results of the length-weight relationship function is to determine the growth type. It was reported that length weight relationship, hence the type of growth, may significantly change in different life stages of a species and it also depends on size range of the samples (Froese 2006; Ilkyaz et al. 2008). Therefore, growth types of species were given in the results and compared to other studies. In cases where b-values are equal to 3, then the growth of fish is isometric, whereas when b is less or greater than 3, the

Table 1 Studies reporting the LWR of discarded species in trawl fisheries along the Turkish coast of the Aegean Sea. N - number of species reported on, Sampling - type of fishery sampled, Year - time of data collection

	N	Sampling	Year	Location
Filiz and Bilge (2004)	24	Trawl	2003	Northern Aegean Sea
Karakulak et al. (2006)	47	Trawl	2004–2005	Gökceada Island, northern Aegean Sea
Özaydin and Taskavak (2006)	47	Trawl	1998–2001	İzmir Bay, central Aegean Sea
Akyol et al. (2007)	8	Longline	2002–2003	Gökova Bay, nouthern Aegean Sea
İşmen et al. (2007)	63	Trawl	2005–2006	Saros Bay, northern Agean Sea
Özaydin et al. (2007)	60	Trawl	2005	İzmir Bay, central Aegean Sea
Ilkyaz et al. (2008)	62	Trawl	2005–2006	Central Aegean Sea
Ceyhan et al. (2009)	17	Trammel nets and longline	2006	Gökova Bay, southeastern Aegean Sea
Gurkan et al. (2010)	22	Beach seine	2006–2008	Candarli Bay, northern Aegean Sea
Bilge et al. (2014)	103	Trawl	2009–2010	Southern Aegean Sea
Eronat and Özaydın (2014)	16	Trawl	2008–2009	Central Aegean Sea
Yapıcı et al. (2015)	11	Trawl	2011	SE Aegean Sea

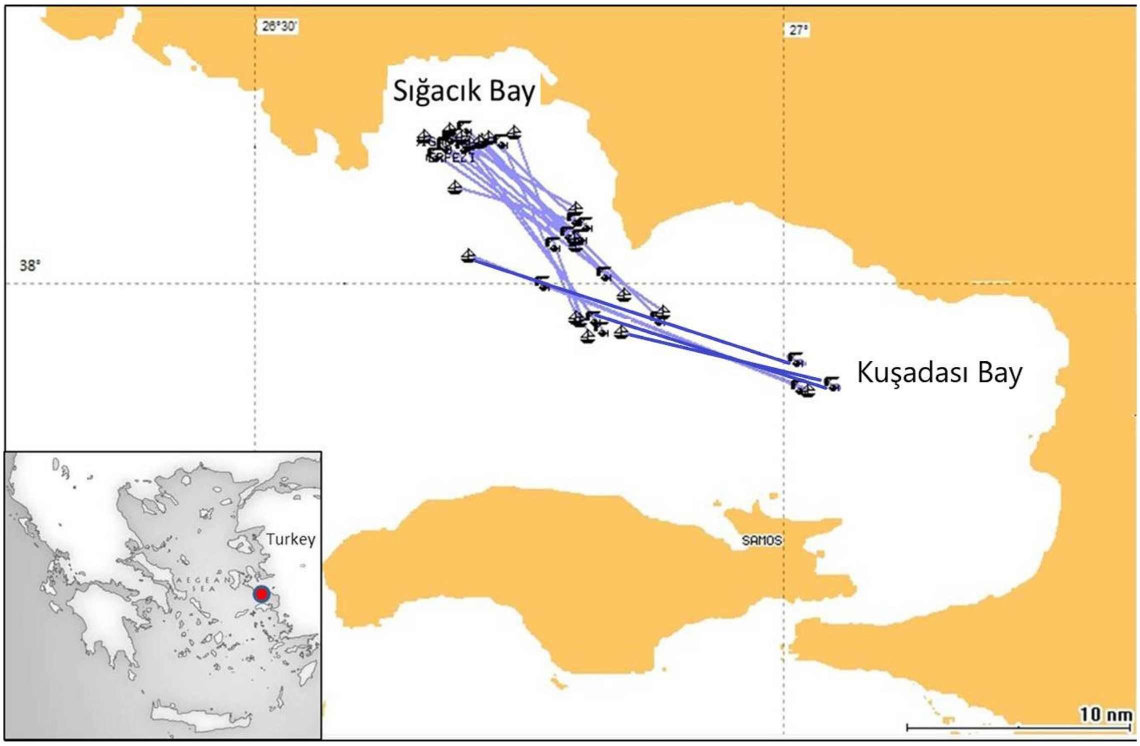

Fig. 1 Sığacık and Kuşadası Bays, the study area where discarded fish samples were collected by a commercial trawler between October 2008 and April 2010 (Black ship and fish symbols indicate the beginning and end of trawl hauls, respectively and blue stretched lines designate the distance hauled)

growth is considered to be negative or positive allometric (Froese 2006). Growth type identification (whether the value of the regression slope (b) was significantly different from 3.0) was based on Student's t test (Ilkyaz et al. 2008).

Global conservation status of the species was based on the International Union for Conservation of Nature's Red List of Threatened Species (IUCN 2020). Average size at capture of species were compared with their L_m values which were given in previous studies conducted in the Mediterranean basin,to avoid regional differences. Percentages of individuals caught below the mean length at first maturity were also calculated.

Results

A total of 14,120 individuals from 15 fish species belonging to 13 families were examined: 9 species were elasmobranchs and 6 were teleosts (Table 2). According to the International Union for Conservation of Nature's Red List of Threatened Species: 11 species are listed to be in the least concern category; 1 is vulnerable (*Dalatias licha*); 2 are near threatened (*Raja clavata*, *Dipturus oxyrinchus*); and 1 is endangered (*Squalus acanthias*). Sample size; length and weight range; length–weight relationship parameters (95% confidence limits of b, and coefficient of determination); and other relevant parameters for each fish species are given in Table 2. All regressions were highly significant ($P < 0.001$). Furthermore, sample size ranged from 1 individual for *Hexanchus griseus*, to 2940 for *Scyliorhinus canicula* and due to insufficient sample size, LWR for *H. griseus* could not be determined.

Concerning the type of growth, 5 species (*Coelorinchus caelorhincus, Dalatias licha, Galeus melastomus, Nezumia sclerorhynchus, Peristedion cataphractum*) showed isometric growth ($b = 3$); 5 species (*Dipturus oxyrinchus, Hoplostethus mediterraneus, Raja clavata, Scyliorhinus canicula, Squalus acanthias*) positive allometry ($b > 3$); and 4 species (*Capros aper, Etmopterus spinax, Macroramphosus scolopax, Torpedo marmorata*) negative allometry ($b < 3$) (Table 2).

It was found that TL ranged from 3.4 (*Capros aper*) to 59.1 cm (*Raja clavata*). The values of the slope b ranged from 2.55 (*Macroramphosus scolopax*) to 3.37 (*Dipturus oxyrinchus*). The a values varied from 0.0007 (*Dipturus oxyrinchus*) to 0.041 (*Torpedo marmorata*).

Comparison of average size at capture and L_m are presented in Table 3 indicating that vast majority of discard species caught were below the L_m. Average size at capture of only one teleost species (*Nezumia sclerorhynchus*) was found to be above the L_m. Regarding the proportion of individuals below L_m, elasmobranch species had the highest percentages. All individuals of elasmobranch fishes (except *S. canicula*) and *P. cataphractum* were captured before they reached L_m. The difference between the average size at capture and L_m is particularly large in elasmobranches ranging from 15.7 (*S. canicula*) to 332.5 cm (*H. griseus*).

Table 2 Descriptive statistics for 15 and length–weight relationship parameters for 14 discarded fish species from bottom trawl fishery of the Central Aegean Sea

Species	Sampling charecteristics					Relationship parameters				
	RLS	Sn	N	LR	WR	a	b	95% CL of b	SE(b)	r^2
Elasmobranchii										
Dalatias licha (Bonnaterre, 1788), Kitefin shark	VU	Su	42	32.9–46.1	416.6–1050	0.018	2.87	2.41–3.31	0.02	0.98
Etmopterus spinax (Linnaeus, 1758), Velvet belly	LC	Su	1057	9.3–19.2	3.54–29.56	0.006	2.9	2.88–2,93	0.01	0.99
Galeus melastomus (Rafinesque, 1810), Blackmouth catshark	LC	All	1722	9.1–51.0	1.86–345	0.0025	3	2.97–3.03	0.04	0.98
Hexanchus griseus (Bonnaterre, 1788), Bluntnose sixgill shark	LC	Sp	1	61.5	599.9	–	–	–	–	–
Raja clavata (Linnaeus, 1758), Thornback ray	NT	Wn,Sp,Aut	294	8.8–59.1	1.59–1150	0.0012	3.366	3.30–3.43	0.03	0.98
Dipturus oxyrhinchus (Linnaeus, 1758), Longnosed skate	NT	Wn, Sp	63	17.1–34.5	10.68–112.75	0.0007	3.374	3.23–3.50	0.05	0.99
Scyliorhinus canicula (Linnaeus, 1758), Lesser spotted dogfish	LC	Sp,Su,Aut	2940	8.1–49.4	1.24–399	0.0015	3.199	3.18–3.21	0.008	0.99
Squalus acanthias (Linnaeus, 1758), Picked dogfish	EN	Wn	133	19.0–34.0	24.25–176.82	0.002	3.226	2.97–3.48	0.12	0.97
Torpedo marmorata (Risso, 1810), marbled electic ray	LC	Aut,Wn,Sp	70	10.0–16.9	24.57–80.79	0.041	2.705	2.35–3.06	0.15	0.97
Teleostei										
Capros aper (Linnaeus, 1758), Boar fish	LC	All	2569	3.4–10.0	0.74–15.69	0.025	2.79	2.76–2.82	0.03	0.98
Coelorinchus caelorhincus (Risso, 1810), Hollowsnout grenadier	LC	Sp,Su	266	7.7–24.5	1.5–58.4	0.003	2.99	2.77–3.22	0.08	0.95
Hoplostethus mediterraneus (Cuvier, 1829), Mediterranean slimehead	LC	Sp,Su,Wn	1757	4.3–16.6	1.1–66.0	0.001	3.13	3.11–3.15	0.02	0.99
Macroramphosus scolopax (Linnaeus, 1758), Longspine snipefish	LC	Aut,Wn,Sp	1372	4.1–13.4	0.60–9.94	0.014	2.55	2.51–2.60	0.021	0.98
Nezumia sclerorhynchus (Valenciennes, 1838), Roughtip grenadier	LC	Su	525	7.5–25.5	2.05–66.44	0.005	2.86	2.69–3.04	0.09	0.93
Peristedion cataphractum (Linnaeus, 1758), African armoured searobin	LC	Sp,Su,Wn	1309	6.8–18.7	2.0–25.67	0.005	2.92	2.82–3.03	0.005	0.94

Species listed in alphabetical order. RLS: Red list status (LC, least concern, VU, vulnerable, NT, near threatened, EN, endangered); Sn: season (C, all seasons combined; Sp, spring; Su, summer; Au, autumn; Wi, winter); n, sample size; LR, total length range in cm; WR, weight range in g; a, intercept of the relationship; b, slope of the relationship (different from 3 in bold); CL, confidence limits; SE(b); standart error of b; r^2 , coefficient of determination

Species listed in alphabetical order. TL, total length (with standard error values); L_m, length at maturity; Per bel Lm, percentage of individuals below maturity length.

Discussion

This study provides length–weight relationships for 15 discarded fish species from the Turkish coast of the central Aegean Sea which was stated to be one of the most suitable trawling areas within the waters surrounding Turkey (Soykan et al. 2019). Average sizes at capture of each species were also compared with reported L_m in order to determine the impact of fishing on reproduction ability.

Froese (2006) has recommended separation of the LWR for males, females and both sexes, when the sex ratio is significantly different from 1:1. Sex of the specimen couldn't be determined in the present study. Therefore, LWR was calculated for both sexes without making sex determination. Fish samples in this study were intermittently collected throughout the year. Estimated LWR parameters should be considered to be mean annual values for each species of this study since the data were obtained over an extensive period of time (Dulčić and Glamuzina 2006). Furthermore, LWR relationship parameters of *Nezumia sclerorhynchus* and *Dalatias licha* are reported for the first time for Turkish coast of the Aegean Sea with the present study.

Length and weight data were reported to provide useful information for estimating growth rates of fish populations (Froese 2006) and they are also useful for many of the fisheries assessment models. Many LWR studies (Ilkyaz et al. 2008; Kapiris and Klaoudatos 2011; Bilge et al. 2014; Yapıcı et al. 2015) include results on growth types of other species. All of the b-values presented in this study ranged from 2.5 to 3.5,

Table 3 Comparison of average size at capture and reported mean length at first sexual maturity for 15 discarded fish species from bottom trawl fishery of the central Aegean Sea

Species	Mean length	Lm	Ref	Per bel Lm
Elasmobranchii				
Dalatias licha (Bonnaterre, 1788)	37.9±1.98	98.0	Bottaro et al. 2003	100%
Etmopterus spinax (Linnaeus, 1758)	13.9±2.18	36.9(♀), 33.0(♂)	Porcu et al. 2014	100%
Galeus melastomus (Rafinesque, 1810)	16.1±0.43	69.7(♀), 49.4(♂)	Costa et al. 2005	100%
Hexanchus griseus (Bonnaterre, 1788)	61.5	394(♀), 300(♂)	Bradai et al. 2012	100%
Raja clavata (Linnaeus, 1758)	24.1±1.74	72.4(♀), 55.0(♂)	Kadri et al. 2014	100%
Dipturus oxyrhinchus (Linnaeus, 1758)	26.7±2.25	82.0(♀), 64.0(♂)	Yığın and İşmen 2010	100%
Scyliorhinus canicula (Linnaeus, 1758)	19.3±0.52	35.0(♀), 40.0(♂)	Bradai et al. 2012	88.4%
Squalus acanthias (Linnaeus, 1758)	23.0±0.87	51.5(♀), 47.0(♂)	Bradai et al. 2012	100%
Torpedo marmorata (Risso, 1810)	12.7±0.86	31.2(♀), 25.1(♂)	Consalvo et al. 2007	100%
Teleostei				
Capros aper (Linnaeus, 1758)	6.3±0.09	6.7	Yapıcı and Filiz 2014	62%
Coelorinchus caelorhincus (Risso, 1810)	14.0±0.67	17.2	Paramo et al. 2017	72%
Hoplostethus mediterraneus (Cuvier, 1829)	10.6±0.18	16.5(♀), 15.5(♂)	D'Onghia et al. 1998	99.7%
Macroramphosus scolopax (Linnaeus, 1758)	7.7±0.14	12.3	Froese and Pauly 2019	99%
Nezumia sclerorhynchus (Valenciennes, 1838)	13.1±0.41	5.5	Cohen et al. 1990	0%
Peristedion cataphractum (Linnaeus, 1758)	10.3±0.14	19.1(♀), 21.2(♂)	Bottari et al. 2010	100%

similar to the findings of Froese (2006). Most of the b values of the present study are in accordance with those of İşmen et al. (2007) and Bilge et al. (2014). Six of the elasmobranch species of this study match with those of Eronat and Özaydın (2014) who conducted their research in the same area. However, growth types of only two species (*G. melastomus* and *R. clavata*) are similar. Discrepancies on growth type for the other 4 species are considered due to sampling strategy (operation depth, hauling time, the type of the net and etc) and length distribution differences between the two studies. At this point, the differences in b-values and growth types between reported results may generally be attributed to changes in the water temperature, maturity stage, habitat, degree of stomach fullness, etc. (Weatherley and Gill 1987) but they were not considered in this study.

According to global conservation status of animals, 4 species sampled in this study are listed in more serious categories than least concern (LC) and among them *Squalus acanthias* was considered to be facing a very high risk of extinction in the wild (Ellis et al. 2016). *R. clavata* and *S. acanthias* are under conservation management and their capture is prohibited. As such if these species are found onboard by inspectors, both the captain and owner of the boat could be fined under Turkish fisheries legislation.

Soykan et al. (2019) reported that discards of bottom trawling in the Aegean Sea constitute an important fraction of the total catch and that the number of affected species is very high. Relatively large number of discarded species and specimens belonging to those were included in the present work. Morphological traits were reported to be useful for assessing the impact of trawling to benthic resources (Jørgensen et al. 2016). While morphological traits like "body size" and "shape" are currently available in the scientific literature, crucial information on "lifespan", "larval development strategy", "fecundity" (Tyler et al. 2012) or "reproduction" are rudimentary for many discarded species. Concerning this, all species in the present study were found to be caught at sizes smaller than reported L_m values indicating negative impact on reproduction and sustainability of mentioned species. Although the difference between average size at capture and L_m is relatively small for some bony fish (*C. aper*, *C. caelorhincus*), big gaps are noteworthy for cartilaginous fish species.

Understanding the life history or population dynamics of discarded species is important due to interspecific relations. Discarded fish populations may have influences on the abundance of target species (Yapıcı and Filiz 2014). Furthermore, discarded fish species within the demersal trawl catch composition are important for biodiversity and sustainability of future commercial harvests (Yapıcı and Filiz 2014). Therefore, comprehensive studies focusing on discarded fish populations are required in order to understand their biological aspects on the marine food web (Alverson et al. 1994; Yapıcı and Filiz 2014). Discard information such as species composition, discarded amount and discard ratios of the Aegean Sea trawl fishery must be addressed in the further legislative actions for sustainable fisheries management.

Our results could be useful in stock assessments of the area and as a reference for future comparison of similar parameters estimated in other parts of the Aegean Sea or Mediterranean. Long-term monitoring of demersal living resources is essential for sustainability of fish stocks and the conservation of biodiversity. Parameters such as length at first sexual maturity, reproduction period and global conservation status of discarded species should be considered during decision making for continuity of the species and providing the sustainability of the ecosystem.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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