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Length–weight relationships of 14 fish species from the Gulf of Antalya (northeastern Mediterranean Sea, Turkey)

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Abstract: Length–weight relationships (LWRs) were determined for 14 fish species from the Gulf Antalya along the northeastern Mediterranean Sea coast of Turkey. Samples were collected using bottom trawl at depths varying from 25 to 150 m. The parameters *a* and *b* from the LWR formula $W = aL^b$ were estimated. The values of the exponent *b* of the length–weight relationships ranged from 2.513 to 3.465. Seven species (*Pagrus pagrus*, *Pagellus erythrinus*, *Nemipterus randalli*, *Merluccius merluccius*, *Citharus linguatula*, *Chelidonichthys lastoviza*, *Spicara flexuosa*) indicated negative allometries, 5 species (*Serranus cabrilla*, *Mullus surmuletus*, *Mullus barbatus barbatus*, *Upeneus moluccensis*, *Saurida undosquamis*) indicated positive allometries, and 2 species (*Boops boops*, *Serranus hepatus*) indicated isometries.

Key words: Fish growth, marine fish, Gulf of Antalya, northeastern Mediterranean Sea

1. Introduction

The relation between length (L) and weight (W) of fish is very important for estimating growth rates, age structures, and stock conditions; comparing life histories of fish species between regions; and assessing the condition of fish and other components of fish population dynamics (Petrakis and Stergiou, 1995; Binohlan and Pauly, 2000; King, 2007). This relationship is generally expressed by the equation $W = aL^b$. In this formula, coefficient *a* describes body shape and coefficient *b* gives information about the balance of the dimensions. Values of *b* can be smaller than 3 (negative allometry = the fish grows faster in weight than in length), bigger than 3 (positive allometry = the fish grows faster in length than in weight), or equal to 3 (isometry) (Froese, 2006).

There are many studies on the length–weight relationship (LWR) of fish along the coasts of Turkey, such as in the Marmara region (Tarkan et al., 2006; Keskin and Gaygusuz, 2010; Bök et al., 2011), the Black Sea (Demirhan and Can, 2007; Kalaycı et al., 2007; Ak et al., 2009; Yankova et al., 2011), the Aegean Sea (Moutopoulos and Stergiou, 2002; Koutrakis and Tsikliras, 2003; Filiz and Bilge, 2004; Karakulak et al., 2006; Özaydın and Taşkavak, 2006; Akyol et al., 2007; İşmen et al., 2007; Özaydın et al., 2007), and the Mediterranean Sea (Taşkavak and Bilecenoğlu, 2001; Çiçek et al., 2006; Sangun et al., 2007; Özcan, 2008), but there are no studies concerning the LWRs of the fish species of the Gulf of Antalya. In the present study, the LWRs of 14 fish species from the Gulf of Antalya were determined.

2. Materials and methods

The data from 14 species were collected monthly from the Gulf of Antalya (Figure) between September 2012 and June 2013. Samplings of fishes were made by a bottom trawl net having 44 mm mesh size (22 mm mesh size in the cod end). Trawl shots (1 haul per month) were performed at depths varying from 25 to 150 m for 2 h each time. Fish species were identified according to Whitehead et al. (1986) and Mater et al. (2003). All individuals were weighed (total wet weight) to the nearest 0.1 g and measured to the nearest cm in the laboratory of the research vessel.

The relationship between length and weight were calculated using the formula $W = aL^b$, in which W is the total weight (g) and L is the total length (cm). The parameters *a* and *b* were calculated by functional regression. The *b* value for each species was tested by t-test at the 0.05 significance level to verify that it was significantly different from isometric growth (Beverton and Holt, 1996; Çetinkaya et al., 2005; Froese, 2006).

3. Results and discussion

A total of 3090 individuals of 14 fish species belonging to 9 families were sampled. The main abundance of samples belonged to the families Mullidae (55.1%),

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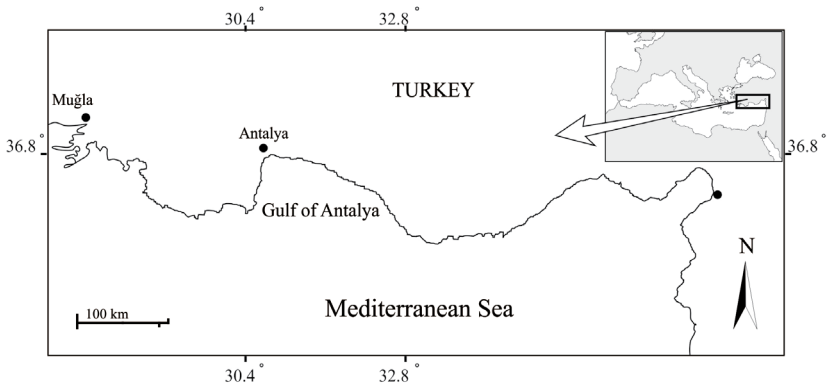

Figure. Map of the study area.

Centracanthidae (14.2%), Sparidae (10.9%), Synodontidae (6.8%), Serranidae (5%), Nemipteridae (4.7%), Citharidae (1.4%), Gadidae (1%), and Triglidae (1%). The best-represented families were Mullidae and Sparidae with 3 species; Nemipteridae, Gadidae, Citharidae, Triglidae, Synodontidae, and Centracanthidae were represented only by 1 species each.

The estimated parameters of LWR are given in Table 1. Values of the coefficient of determination (r^2) varied from 0.810 [*Upeneus moluccensis* (Bleeker, 1855)] to 0.973 [*Chelidonichthys lastoviza* (Bonnaterre, 1788)]. The values of the exponent *b* of the LWRs ranged from 2.513 [*Pagellus erythrinus* (Linnaeus, 1758)] to 3.465 (*Mullus surmuletus* Linnaeus, 1758). The sample size ranged from 28 individuals for *Chelidonichthys lastoviza* to 1565 for *Mullus barbatus barbatus* Linnaeus, 1758.

In this study, the growth type of 7 species [*Pagrus pagrus* (Linnaeus, 1758), *Pagellus erythrinus*, *Nemipterus randalli* (Russell, 1986), *Merluccius merluccius* (Linnaeus, 1758), *Citharus linguatula* (Linnaeus, 1758), *Chelidonichthys lastoviza*, *Spicara flexuosa* (Linnaeus, 1758)] indicated negative allometries ($b < 3$, $P < 0.05$), 5 species [*Serranus cabrilla* (Linnaeus, 1758), *Mullus surmuletus*, *Mullus barbatus barbatus*, *Upeneus moluccensis*, *Saurida undosquamis* (Richardson, 1848)] indicated positive allometries ($b > 3$, $P < 0.05$), and 2 species [*Boops boops* (Linnaeus, 1758), *Serranus hepatus* (Linnaeus, 1758)] indicated isometries ($b = 3$, $P > 0.05$).

Table 1. Length–weight relationship parameters for fish species from the Gulf of Antalya.

Family	Species	N	L range	a	b	SE(b)	r^2	P	GT
Sparidae	*Pagrus pagrus*	127	9.5–19	0.0186	2.922	4.936	0.943	P < 0.05	A-
	Pagellus erythrinus	87	11.6–21.5	0.0511	2.513	5.036	0.946	P < 0.05	A-
	Boops boops	124	10–20.2	0.0139	2.821	3.300	0.876	P > 0.05	I
Nemipteridae	*Nemipterus randalli*	143	9.5–22	0.0120	2.975	4.457	0.937	P < 0.05	A-
Gadidae	*Merluccius merluccius*	31	16–28.7	0.0096	2.899	7.012	0.946	P < 0.05	A-
Serranidae	*Serranus cabrilla*	52	9–18.5	0.0091	3.048	3.246	0.960	P < 0.05	A+
	Serranus hepatus	100	5.8-13.9	0.0288	2.732	2.272	0.728	P > 0.05	I
Citharidae	*Citharus linguatula*	44	8–19.2	0.0133	2.780	4.151	0.920	P < 0.05	A-
Triglidae	*Chelidonichthys lastoviza*	28	10.1–20.0	0.0272	2.638	3.521	0.973	P < 0.05	A-
Mullidae	*Mullus surmuletus*	45	13.7–24.5	0.0029	3.465	7.915	0.948	P < 0.05	A+
	Mullus barbatus barbatus	1565	8.7–21.5	0.0071	3.165	6.302	0.894	P < 0.05	A+
	Upeneus moluccensis	93	9.5–19.2	0.0053	3.231	3.913	0.810	P < 0.05	A+
Synodontidae	*Saurida undosquamis*	211	11.5–35.5	0.0037	3.190	22.71	0.968	P < 0.05	A+
Centracanthidae	*Spicara flexuosa*	440	9.0–17.3	0.0260	2.655	3.531	0.816	P < 0.05	A-

N: Number of specimens; L: total length (cm); *a* and *b*, relationship parameters; SD: standard deviation; SE(b): standard error of *b*; r^2: coefficient of determination; P: P-value for t-test comparing differences for isometric growth ($b = 3$); GT: growth type; I: isometric, A+: positive allometric, A-: negative allometric.

The functional regression *b* value represents the body form, and it is directly related to the weight, affected by ecological factors (temperature, food supply, and spawning conditions) and other factors (sex, age, fishing time, area, and fishing vessels) (Ricker, 1973). Other studies have conducted research on the LWRs of identical species in different localities (Table 2). Growth types were found to be different for *Pagrus pagrus*, *Pagellus erythrinus*, *Boops boops*, *Nemipterus randalli*, *Merluccius merluccius*, *Serranus cabrilla*, *Citharus linguatula*, *Chelidonichthys lastoviza*, *Mullus surmuletus*, *Mullus barbatus barbatus*, and *Spicara flexuosa*. The differences of growth type and *b* values for the same species from different areas may be attributed to one or more factors: the season and effects of different areas, changes in water temperature and salinity, sex, degree of stomach fullness, gonad maturity, health, habitat, nutrition, food reserves, environmental factors, pollution, and differences in the number of specimens

Table 2. Different growth types of the same fish species in other studies.

Family	Species	Growth type		
		A-	A+	I
Sparidae	*Pagrus pagrus*			Moutopoulos and Stergiou, 2002
	Pagellus erythrinus	Cherif et al., 2007 Ceyhan et al., 2009 Çakır et al., 2008 Moutopoulos and Stergiou, 2002 Cengiz, 2013		Sangun et al., 2007 Karakulak et al., 2006 Merella et al., 1997
	Boops boops	Moutopoulos and Stergiou, 2002	Karakulak et al., 2006	Sangun et al., 2007 Ceyhan et al., 2009 Merella et al., 1997 Cherif et al., 2007
Nemipteridae	*Nemipterus randalli*			Erguden et al., 2010
Gadidae	*Merluccius merluccius*	Sangun et al., 2007	Bök et al., 2011 Karakulak et al., 2006 Moutopoulos and Stergiou, 2002 Cherif et al., 2007	Ceyhan et al., 2009 Merella et al., 1997 Çakır et al., 2008
Serranidae	*Serranus cabrilla*	Çakır et al., 2008 Merella et al., 1997 Moutopoulos and Stergiou, 2002	Sangun et al., 2007	Bök et al., 2011 Karakulak et al., 2006 Cengiz, 2013
	Serranus hepatus	Çakır et al., 2008	Merella et al., 1997	Keskin and Gaygusuz, 2010 Sangun et al., 2007
Citharidae	*Citharus linguatula*	Sangun et al., 2007 Moutopoulos and Stergiou, 2002	Karakulak et al., 2006 Çakır et al., 2008 Merella et al., 1997	
Triglidae	*Chelidonichthys lastoviza*	Moutopoulos and Stergiou, 2002		Sangun et al., 2007
Mullidae	*Mullus surmuletus*	Bök et al., 2011	Maci et al., 2009 Karakulak et al., 2006	Keskin and Gaygusuz, 2010 Merella et al., 1997 Moutopoulos and Stergiou, 2002
	Mullus barbatus barbatus	Merella et al., 1997 Moutopoulos and Stergiou, 2002	Cherif et al., 2007 Çakır et al., 2008 Karakulak et al., 2006 Çakır et al., 2008 Cengiz, 2013	
	Upeneus moluccensis		Sangun et al., 2007	
Synodontidae	*Saurida undosquamis*		Sangun et al., 2007 Ceyhan et al., 2009	
Centracanthidae	*Spicara flexuosa*			Soykan et al., 2010

I: Isometric, A+: positive allometric, A-: negative allometric growth.

examined, as well as in the observed length ranges of the species caught (Tesch, 1971; Moutopoulos and Stergiou, 2002). Only the growth types of *Saurida undosquamis* and *Upeneus moluccensis* were similar to those of other studies.

Fish samples in this study were caught over the course of 10 months. Because of this, these species are represented across all seasons. In this study, maximum length of some species (*Boobs boops*, *Pagrus pagrus*, *Pagellus erythrinus*, *Merluccius merluccius*, *Mullus barbatus barbatus*, *Mullus surmuletus*, *Serranus cabrilla*) were smaller than in other studies along the Mediterranean coast of Turkey (Karakulak et al., 2006; İşmen et al., 2007; Ceyhan et al., 2009). This can be explained by the choice of fishing gear, nets, and intense fishing in the Gulf of Antalya. The information in this study could be used as a reference for fisheries and stock management of fish populations in the Gulf of Antalya.

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