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Length–weight relationships of bivalve species in Italian razor clam *Ensis minor* (Chenu, 1843) (Mollusca: Bivalvia) fishery

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Abstract

Length–weight relationships of bivalve species collected during razor clam (*Ensis minor*) surveys along Italian coastal waters (Northern Adriatic and Tyrrhenian Sea) in the 3-year period 2016–2018 are reported. A total of 13,588 individuals, belonging to 12 bivalve species and 20 populations between the Adriatic and Tyrrhenian Seas, were sampled for this study. Analyzing growth parameters for each population, we found 11 allometries and nine isometries. About half of the species investigated showed different growth characteristics between the two areas.

Keywords: Bivalve species, length–weight relationship, razor clam fishery, Adriatic Sea, Tyrrhenian Sea

Introduction

The razor clam *Ensis minor* (Chenu, 1843), a bivalve species occurring in Italian coastal waters, lives buried in the sandy bottom between 2.5 and 4 m depth (Del Piero & Dacaprile 1998). The development of its gonads occurs in winter and the reproductive period is concentrated in early springtime. The minimum landing size of 8 cm in length is reached in about a year (Frogliia 1975; Del Piero & Dacaprile 1998). Frogliia (1975) found 6-cm individuals with mature gonads, demonstrating that the first reproduction event occurs within the first year of life. This species is an important fishery resource in the North Adriatic Sea and Central Tyrrhenian Sea, and it is actively exploited by hydraulic dredges. Landings for the year 2017 reported by fishermen's logbooks were 42,831.0 kg for the Central Tyrrhenian and 7228.6 kg for the North Adriatic. Annual surveys are carried out by the National Research Council, Institute for Biological Resources and Marine Biotechnologies (CNR-IRBIM), aiming to assess the exploitation status of populations in these two areas, and to propose fishery management measures. Fishing with hydraulic dredges leads to the catch

of other bivalve species occurring in the same habitat, and so allows collecting and analyzing a wide variety of bivalves of broad size ranges in different geographical areas. As information available on bivalve morphometric relationships is scarce and limited to specific areas (Gaspar et al. 2001, 2002; Charef et al. 2012; Vasconcelos et al. 2018), we here report the weight–length relationship of 12 bivalve species from the North Adriatic Sea and the Central Tyrrhenian Sea. Morphometric data could be used in fishery models and in improving the selectivity of hydraulic dredges (Gaspar et al. 2002), while comparison between populations from different habitats is useful to understand growth rates as a function of environmental and/or anthropogenic factors (Petракis & Stergiou 1995; Gonçalves et al. 1997).

Materials and methods

The specimens were collected during fishing surveys carried out along the Tyrrhenian and Adriatic coasts in the 3-year period 2016–2018 aboard fishing vessels. A commercial dredge 3 m wide was used to penetrate about 20 cm into the sediment and catch razor clams;

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the dredge was designed to catch specimens of legal size (from 8 cm upward), with a grating made of rods spaced 7 mm apart, following the Italian law (DM 22/12/2000). To collect juvenile specimens, a net sampler with fine meshes (14 mm) and dimensions 40 cm × 18 cm was fixed inside the dredge. Transects perpendicular to the coastline, spaced about 2 miles apart, were chosen (11 for the Adriatic, 40 for the Tyrrhenian Sea; Figure 1). For each transect, three random sampling stations were established at depths between 1 and 4 m. Each haul was carried out by towing the hydraulic dredge in sandy bottom for 100 m at a constant speed of 0.8 knots.

Identification of bivalve species was made to the lowest possible taxonomic level, and the nomenclature adopted was the most updated available in the World Register of Marine Species – WoRMS (<http://www.marinespecies.org>). Bivalve shell length (i.e. the maximum distance between anterior and posterior margins) was determined to the nearest 0.01 mm using a manual calliper; total wet weight was detected using a digital balance with a precision of 0.1 g. Damaged individuals were discarded and not considered in the analyses. The relationship $W = aL^b$, one of the most commonly used in any analysis of fishery data, allows the estimation of weight (W) from length (L) or vice versa for individuals (Le Cren 1951; Petrakis &

Stergiou 1995; Froese 2006). This relationship (1) is useful for comparison between populations of the same species living in different geographical areas (Gaspar et al. 2002); (2) is used in fishery models for stock monitoring and management (Robinson et al. 2010); and (3) can be used, in bivalve fishery, in improving dredge and onboard sorting sieve selectivity (Gaspar et al. 2002; Vasconcelos et al. 2018). The a parameter is the intercept, representing the initial growth coefficient. The exponent b is the slope, representing relative growth rates of the variables and so providing information on growth (Morey et al. 2003): when $b = 3$ growth is isometric, and when b is significantly different from 3 growth is allometric (positive if $b > 3$, negative if $b < 3$). The equation $W = aL^b$ and its linearized form $\log W = \log a + b \cdot \log L$ were determined for eight species in both sampling areas, and for four species only in one sampling area (one for the Adriatic Sea and three for the Tyrrhenian Sea). A t-test ($t_s = (b - 3)/s_b$) with a confidence level of 95% was applied to determine the significance of morphometric relationships using the coefficient b ($=$, $<$ or $>$ 3) and its standard error S_b (Huxley & Teissier 1936; Sokal & Rohlf 1987). An analysis of variance (ANOVA) was carried out to assess differences in growth between areas. All the analyses were performed with the free R-package FSA (Ogle et al. 2018, version 0.8.22).

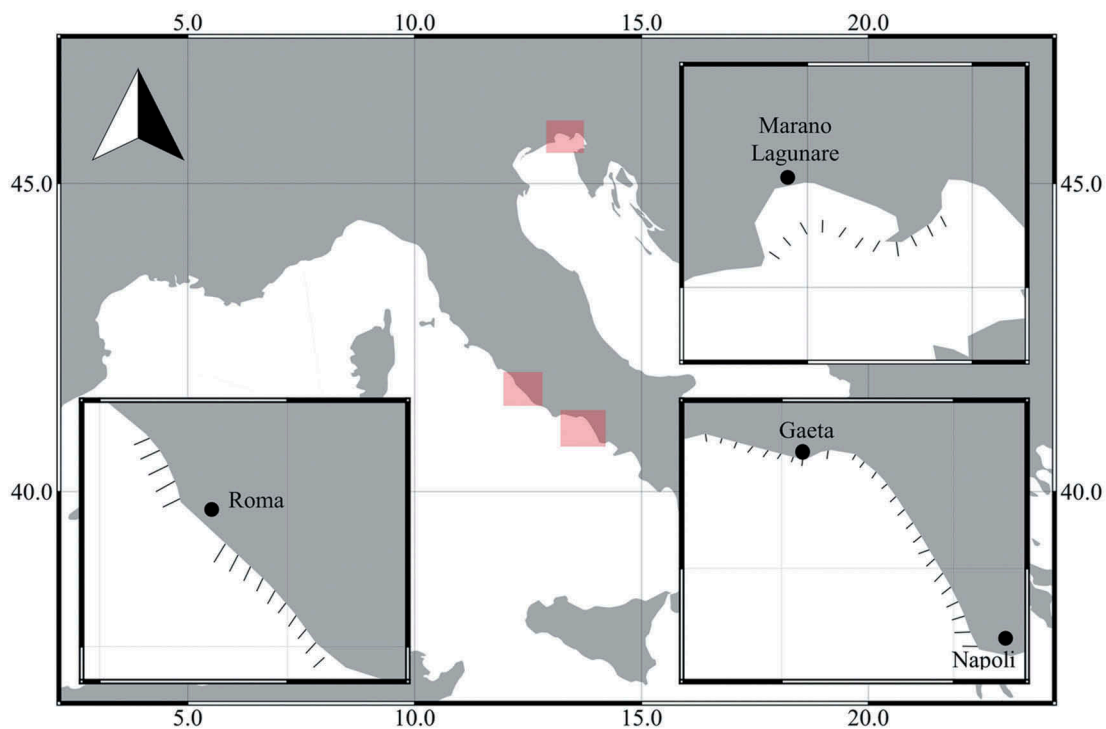


Figure 1. Map of the razor clam surveys carried out in the 3-year period 2016–2018 in Italian coastal waters.

Table I. Length–weight relationship and growth parameters of the bivalve species investigated.

Species	No. individuals	Area	log _a b	CI(b)	Standard error a	Standard error b	R ²	t	p	Relationship (t test)	Difference among areas
<i>Ensis minor</i>	5012	Tyrrhenian Sea	-5.49	3.28	3.26–3.29	0.016	0.008	33.209	<0.001	+ allometry	**
<i>Ensis minor</i>	1240	Adriatic Sea	-5.34	3.20	3.17–3.23	0.025	0.013	15.089	<0.001	+ allometry	**
<i>Chamelea gallina</i>	1066	Tyrrhenian Sea	-3.14	2.74	2.71–2.76	0.016	0.013	20.560	<0.001	- allometry	**
<i>Chamelea gallina</i>	2136	Adriatic Sea	-3.09	2.69	2.67–2.71	0.012	0.010	32.375	<0.001	- allometry	**
<i>Donax trunculus</i>	2392	Tyrrhenian Sea	-3.54	2.77	2.75–2.80	0.017	0.013	17.207	<0.001	- allometry	**
<i>Donax trunculus</i>	162	Adriatic Sea	-3.22	2.48	2.37–2.58	0.057	0.053	9.787	<0.001	- allometry	**
<i>Donax semistriatus</i>	368	Tyrrhenian Sea	-3.57	2.72	2.63–2.82	0.054	0.047	5.919	<0.001	- allometry	**
<i>Donax semistriatus</i>	114	Adriatic Sea	-3.85	3.00	2.86–3.14	0.088	0.073	0.004	0.997	Isometric	ns
<i>Macra stultorum</i>	264	Tyrrhenian Sea	-3.80	2.90	2.80–3.01	0.081	0.055	1.726	0.085	Isometric	ns
<i>Macra stultorum</i>	48	Adriatic Sea	-4.20	3.21	2.88–3.54	0.249	0.164	1.309	0.197	Isometric	ns
<i>Solen marginatus</i>	137	Tyrrhenian Sea	-4.89	3.03	2.89–3.17	0.121	0.071	0.447	0.656	Isometric	ns
<i>Solen marginatus</i>	58	Adriatic Sea	-5.01	3.16	3.12–3.21	0.038	0.023	7.225	<0.001	+ allometry	ns
<i>Dosinia lupinus</i>	103	Tyrrhenian Sea	-3.55	2.92	2.82–3.03	0.065	0.053	1.465	0.146	Isometric	ns
<i>Dosinia lupinus</i>	65	Adriatic Sea	-3.44	2.87	2.74–3.01	0.078	0.067	1.875	0.065	Isometric	ns
<i>Peronidia albicans</i>	35	Tyrrhenian Sea	-4.35	3.07	2.94–3.21	0.101	0.067	1.099	0.280	Isometric	ns
<i>Peronidia albicans</i>	41	Adriatic Sea	-4.42	3.15	3.03–3.28	0.090	0.063	2.457	0.019	+ allometry	ns
<i>Loripes orbiculatus</i>	129	Adriatic Sea	-3.10	2.51	2.34–2.69	0.082	0.089	5.463	<0.001	- allometry	ns
<i>Maccomopsis cumana</i>	102	Tyrrhenian Sea	-3.72	2.64	2.33–2.95	0.204	0.155	2.325	0.022	- allometry	ns
<i>Pharus legumen</i>	84	Tyrrhenian Sea	-5.18	3.16	2.98–3.34	0.152	0.091	1.812	0.074	Isometric	ns
<i>Peronaea planata</i>	32	Tyrrhenian Sea	-4.24	3.01	2.78–3.24	0.170	0.113	0.124	0.902	Isometric	ns

ns = not significant; **p < 0.001.

Results

A total of 13,588 individuals, belonging to 12 bivalve species and 20 populations between the Adriatic and Tyrrhenian Seas, were sampled for this study, and a summary of the statistics referring to their length–weight relationship is listed in Table I. It is important to specify that the gear used for sampling is not designed for all species of bivalves or all sizes within species. Nevertheless, the presence of the fine mesh sampler allowed us to sample individuals of these bivalve communities belonging to a wide range of size classes. The length–weight relationships estimated for each population were significant ($p < 0.001$) in some cases (Table I). In total, 11 allometries and nine isometries were found; for the North Adriatic Sea, allometry was observed in *E. minor*, *Chamelea gallina* (Linnaeus, 1758), *Donax trunculus* (Linnaeus, 1758), *Solen marginatus* (Pulteney, 1799), *Peronidia albicans* (Gmelin, 1791) and *Loripes orbiculatus* (Poli, 1795); for the Central Tyrrhenian Sea, allometry was observed in *E. minor*,

C. gallina, *D. trunculus*, *Donax semistriatus* (Poli, 1795) and *Maccomopsis cumana* (O.G. Costa, 1830).

For eight species out of 12 we obtained growth curves from both areas (Adriatic and Tyrrhenian Seas), which are summarized in Figure 2. Results from ANOVA between the two sampling areas gave significant differences in growth for *E. minor* ($F_{1, 63} = 9.41, p < 0.002$), *D. trunculus* ($F_{1, 26} = 65.35, p < 0.001$), *D. semistriatus* ($F_{1, 48} = 9.64, p < 0.002$) and *C. gallina* ($F_{1, 32} = 8.66, p < 0.003$). No statistical significance was observed for *Mactra stultorum* (Linnaeus, 1758) ($F_{1,31} = 3.01, p = 0.08$), *Dosinia lupines* (Linnaeus, 1758) ($F_{1,16} = 0.31, p = 0.58$), *S. marginatus* ($F_{1,19} = 1.39, p = 0.24$) or *P. albicans* ($F_{1, 72} = 0.63, p = 0.43$).

Discussion

About half of the species investigated in the two areas could present a significantly different growth. Populations of the same species living in different

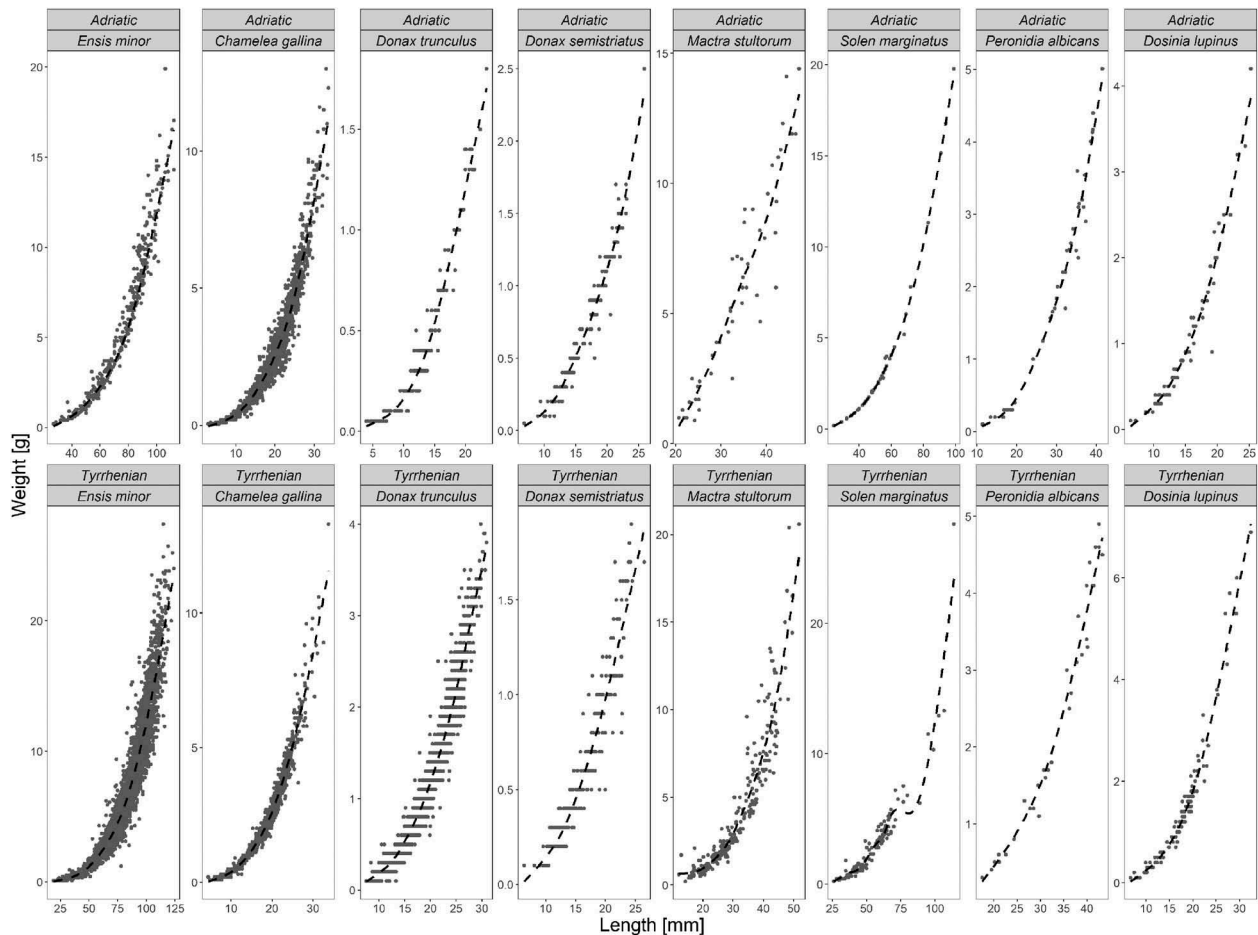


Figure 2. Growth curve of bivalve species compared by area; species whose data are not available for both areas are not included.

Table II. Morphometric growth patterns available in the literature.

Reference	Species	N	Area	a	b	R ²	Standard error (b)	Type of growth
Kasapoğlu & Duzgunes 2013	<i>Chamelea gallina</i>	628	Black Sea	0.45200	2.37	0.954	0.173	A–
Robinson et al. 2010	<i>Chamelea gallina</i>	55	North Sea	0.00035	2.87	0.933		A–
Rufino et al. 2006	<i>Chamelea gallina</i>	242	Algarve Coast (Southern Portugal)	0.00064	2.80	0.96	0.072	A–
Gaspar et al. 2001	<i>Chamelea gallina</i>	695	Algarve Coast (Southern Portugal)	0.00070	2.80	0.998	0.024	A–
Ramón 1993	<i>Chamelea gallina</i>	706	Gulf of Valencia (Western Mediterranean)	0.00066	2.78	0.99		A–
Tunçer & Erdemir 2002	<i>Chamelea gallina</i>	91	Marmara Sea (Karabiga-Çanakkale)	0.00040	2.97	0.95		
Çolakoğlu 2014	<i>Donax trunculus</i>	2376	West Marmara Sea	0.00030	2.69	0.914		A–
Gaspar et al. 2001	<i>Donax trunculus</i>	740	Algarve Coast (Southern Portugal)	0.00060	2.57	0.991	0.049	A–
Tirado & Salas 1998	<i>Donax trunculus</i>	80 (Fb)	Littoral of Malaga (Southern Spain)	0.02291	2.58	0.82		
		193 (Mr)		0.06180	2.29	0.67		
		85 (Ap)		0.00877	2.95	0.94		
		84 (My)		0.01413	2.79	0.91		
		84 (In)		0.01954	2.74	0.9		
		89 (Il)		0.01739	2.62	0.94		
		73 (Ag)		0.00589	2.89	0.91		
		49 (Sp)		0.01368	2.66	0.91		
		81 (Oc)		0.01552	2.67	0.92		
		81 (Nv)		0.02256	2.58	0.96		
		64 (Dc)		0.00228	3.24	0.96		
		85 (Jan)		0.00450	2.99	0.94		
Ansell & Lagardère 1980	<i>Donax trunculus</i>		Île d'Orleon (French Atlantic Coast)	0.00041	2.61			A–
Ramón 1993	<i>Donax trunculus</i>	664	Gulf of Valencia (Western Mediterranean)	0.00039	2.70	0.99		A–
Charef et al. 2012	<i>Donax semistriatus</i>	1115	Gulf of Tunis	0.00070	2.44	0.834	0.028	A–
Gaspar et al. 2001	<i>Donax semistriatus</i>	255	Algarve Coast (Southern Portugal)	0.00006	3.17	0.923	0.057	A+
Gaspar et al. 2001	<i>Mactra stultorum</i>	480	Algarve Coast (Southern Portugal)	0.00003	3.46	0.935	0.042	A+
Charef et al. 2012	<i>Mactra stultorum</i>	1128	Gulf of Tunis	0.94220	2.20	0.887	0.045	I
Vasconcelos et al. 2018	<i>Mactra stultorum</i>	55	Algarve Coast (Southern Portugal)	0.00010	2.87	0.941	0.141	I
Da Costa & Martínez-Patiño 2009	<i>Solen marginatus</i>	≈ 500	Cages (Galicia, NW Spain)	0.00003	2.96			
Remacha-Triviño & Anadon 2006	<i>Solen marginatus</i>	100	Asturias region (NW Spain)	0.00006	2.68		0.043	A–
Charef et al. 2012	<i>Solen marginatus</i>	1117	Gulf of Tunis	0.00020	2.45	0.869		A–
Robinson et al. 2010	<i>Dosinia lupinus</i>	6	North Sea	0.00018	3.19	0.99		A+
Gaspar et al. 2001	<i>Dosinia lupinus</i>	51	Algarve Coast (Southern Portugal)	0.00030	2.98	0.851	0.178	I
Vasconcelos et al. 2018	<i>Peronidia albicans</i>	45	Algarve Coast (Southern Portugal)	0.00004	3.07	0.984	0.084	I
Charef et al. 2012	<i>Peronaea planata</i>	58	Gulf of Tunis	0.77840	0.83	0.920	0.031	A–

A– = negative allometry; A+ = positive allometry; I = isometry.

areas are in fact conditioned by different variables, which can be abiotic (environmental) or biotic (physiological) (Gaspar et al. 2002), although in the present study these variables were not taken into account. Growth patterns also vary considering different life stages (Gaspar et al. 2002) and seem to vary even within the year, as demonstrated by different *b* values in monthly length–weight relationships (Tirado & Salas 1998; Ngor et al. 2018). Between the North Adriatic and the Central Tyrrhenian Sea, a possible hypothesis explaining this difference may be related to latitude (Beukema & Meehan 1985), depth, type of bottom (Claxton et al. 1998) and/or type of sediment (Newell & Hidu 1982). Our data included a wide size range for each species and area, so we can exclude differences due to sampling.

Interestingly, only the commercial species showed significantly different growth parameters between the two areas. In particular, for *E. minor*, *C. gallina* and *D. trunculus* we found that *b* values were significantly lower in the North Adriatic Sea than in the Central Tyrrhenian Sea; in contrast, *D. semistriatus* showed a *b* value higher in the Adriatic Sea than in the Tyrrhenian Sea.

Growth parameters observed in the literature review showed clear differences among the present study and previous observations made in the Mediterranean Sea and on the European Atlantic coasts for some of the species (Table II). A qualitative comparison between our findings on *C. gallina* and *D. trunculus* and those available in the literature revealed a common negative allometry, indicating that individuals of both species grow more in length than in weight. Other species such as *D. semistriatus*, *S. marginatus*, *D. lupinus* and *P. albicans* displayed different types of growth depending on the area where they were collected.

Our results improve the existing knowledge of growth parameters of some bivalve species that are very common along the Italian coasts, and point to the extreme variability of the length–weight relationship within the species in different areas. Further studies are required to better comprehend morphometric patterns especially of commercial species, in order to identify direct and/or indirect anthropogenic stressors to better manage these economic resources.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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