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RESEARCH ARTICLE

Thoracic cirripeds (Thoracica: Cirripedia) from Antalya Bay (Eastern Mediterranean)

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Abstract

The present paper deals with thoracic cirripeds collected in the supralittoral, mediolittoral, and upper infralittoral zones of Antalya Bay (eastern Mediterranean, Turkey) between August 2009 and January 2010. A total 13477 specimens belonging to 7 species and 6 genera were found in the area. Among these, *Chthamalus montagui* and *Lepas anatifera* are new records for the Mediterranean coast of Turkey. *Chthamalus stellatus* is the dominant species in the supralittoral and mediolittoral zones, reaching a maximum density of 69600 ind.m^{-2} and a biomass of 3100 g.m^{-2}. *Perforatus perforatus* was the dominant species in the infrallitoral zone, comprising 71% of the total number of individuals and 85% of the total biomass in this zone. Biometrical features of the shells of the dominant species were analysed and their length-weight relationships were estimated. In addition, a check-list of the thoracic cirripeds that have been reported from the coasts of Turkey up to date is provided.

Keywords: Thoracica, Cirripedia, Antalya Bay, Mediterranean

Introduction

Thoracic cirripeds inhabit a variety of natural and artifical hard substrates from littoral zones to great depths (Relini, 1980; Young 2001; Southward 2008) and some live in the extreme conditions such as hydrothermal vents (Watanabe 2004). In addition, some species prefer to attach to living organisms such as whales, dolphins, turtles, crabs, lobsters, or sponges (Relini 1980; Scarff 1986; ERC 2007). Due to their hard calcareous shell plates, they also play a crucial role in the fouling phenomenon and thus create several economic problems for marine operators (Maguire 1956; Wahl 1989; Railkin 2004). They also constitute excellent foods for many organisms in their larval and mature stages (Connell 1970; Luckens 1975; Buschbaum 2002). Besides their ecological importance, some species [for example *Pollicipes pollicipes* (Gmelin, 1790),

Megabalanus azoricus (Pilsbry, 1916) and *Austromegabalanus psittacus* (Molina, 1788)] are being consumed by humans in some regions (especially Portugal, Spain and Chili) (Thorpe *et al*. 2000; Molares and Freire 2003; Wirtz and Debelius 2003).

Cirripeds include 3 superordines (Thoracica, Acrothoracica and Rhizocephala), 203 genera and almost 1220 species worldwide (Southward 2008; Walters and Johnson 2007). A total of 61 species of Cirripedia belonging to 30 genera and 3 superordines have been reported from the Mediterranean until now (Turquier 1985; Koukouras and Matsa 1998; Oeksnebjerg 2000; Kolbasov and Newman 2005). The order Thoracica that has non-parasitic forms is represented by 23 genera and 34 species in the Mediterranean (Koukouras and Matsa 1998). On the coasts of Turkey, 9 thoracic cirriped genera (*Chthamalus*, *Euraphia*, *Balanus*, *Amphibalanus*, *Perforatus*, *Lepas*, *Chelonibia*, *Verruca* ve *Scalpellum*) with 12 species have been found to date (see Table 2).

The present study aims to determine which thoracic cirriped species are inhabiting the supralittoral, mediolittoral, and upper infralittoral zones of Antalya Bay, and to assess some of their biometric and ecological features.

Materials and Methods

Specimens of the thoracic cirripeds were collected at 12 stations located in Antalya Bay (between Anamur and Adrasan) between 19.8.2009 and 04.01.2010 (Figure 1). Samples were collected by a quadrate of 20x20 cm. Three replicates were taken in the supra-mediolittoral and infralittoral zones of each station. SCUBA diving and snorkelling were used to collect specimens in the upper infralittoral zone, using the same quadrate.

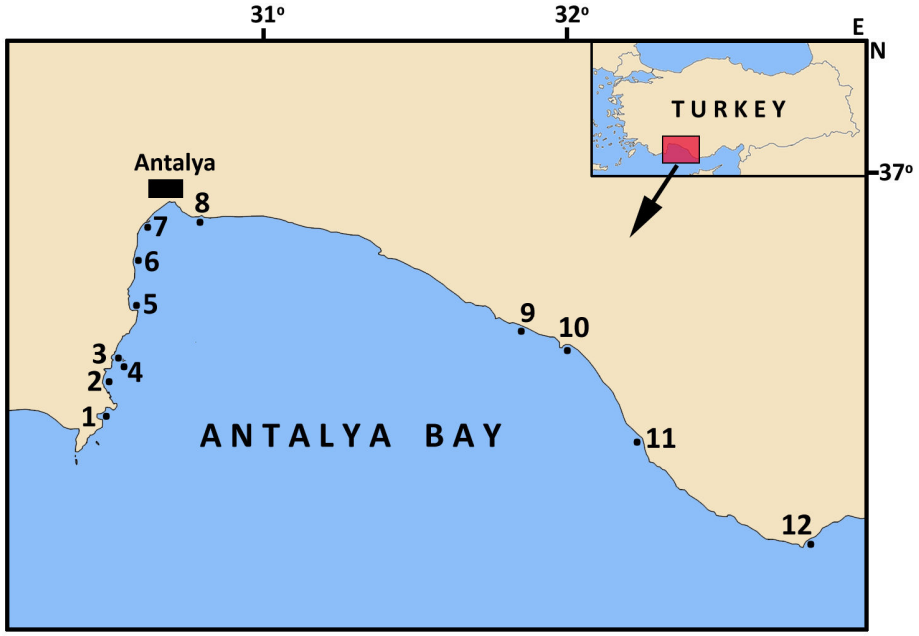

Figure 1. Map of the investigated area with the locations of sampling sites.

At each station, an area of 400 cm^2 was scraped off using a spatula. All specimens collected were put into a jar containing 10% formalin solution. In the laboratory, the material was washed under tap water and then preserved in 70% ethanol. The specimens were identified using stereo- and compound microscopes, and counted. The wet weights of specimens were estimated by using a balance of 0.0001 g sensitivity.

To determine biometric characteristics of the dominant species, the length of the basis along the carino-rostral axis (LB), the width of the basis (WB), the length of the orifice along the carino-rostral axis (LO), the width of the orifice (WO), and the height of the carina (H) were measured using an ocular micrometer (Figure 2). Pearson-moment correlation and regression analyses were applied to the biometrical data.

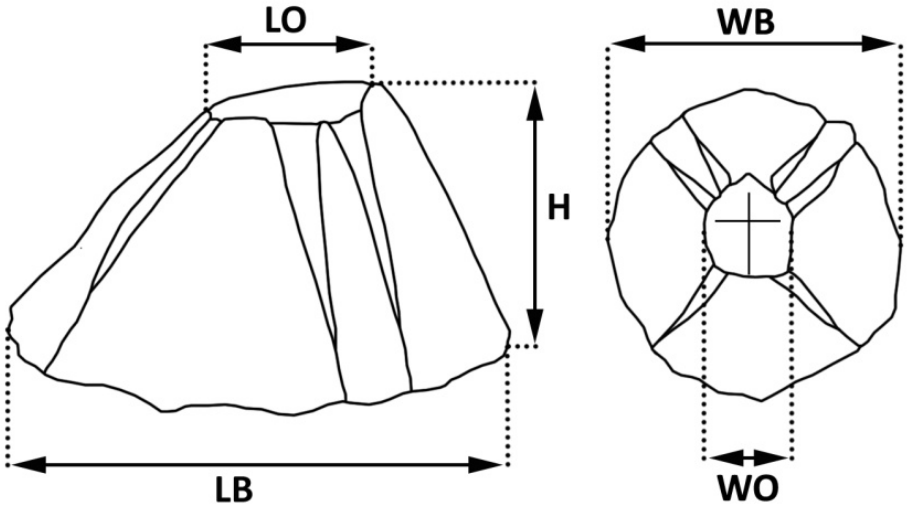

Figure 2. Diagram of the shell in sessile (unstalked) thoracic cirripeds showing shell exterior, lateral view (left) and apical view (right). Abbreviations for measurements are: LB, basal length; WB, basal width; LO, orifice length; WO, orifice width; and H, carinal height.

The specimens identified were deposited at the Museum of the Faculty of Fisheries, Ege University (ESFM).

Results

Faunistic Analysis

A total of 13477 specimens belonging to 6 genera and 7 species were encountered in Antalya Bay (Table 1). Among these, *Chthamalus montagui* (Figure 3A, C) and *Lepas anatifera* (Figure 3G) are new records for the southern coast of Turkey.

Table 1. List of thoracic cirripeds found in the study area and their total abundance.

	STATIONS										
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**
PEDUNCULATA Lamarck, 1818											
Lepadidae Darwin, 1851											
Lepas anatifera Linnaeus, 1758	-	4	-	9	-	-	-	-	-	-	-
SESSILIA Lamarck, 1818											
Chthamalidae Darwin, 1854											
Chthamalus montagui Southward, 1976	-	-	36	46	214	2625	-	256	54	2	148
Chthamalus stellatus (Poli, 1795)	61	-	63	101	3174	4317	45	442	327	152	706
Euraphia depressa (Poli, 1795)	-	89	-	-	-	-	-	-	-	-	-
Chelonibiidae Pilsbry, 1916											
Chelonibia patula (Ranzani, 1818)	-	-	-	1	-	-	-	-	-	-	-
Balanidae Leach, 1817											
Perforatus perforatus (Bruguière, 1789)	161	-	9	21	-	6	135	-	-	-	-
Amphibalanus amphitrite (Darwin, 1854)	2	23	-	3	88	-	157	-	-	-	-

The chthamalid species *Chthamalus montagui*, *C. stellatus* (Figure 3B, C) and *Euraphia depressa* (Figure 3D) were found only in the supralittoral and mediolittoral zones of stations, whereas *Lepas anatifera* and *Chelonibia patula* (Figure 3H) were only collected in the infralittoral zones of stations 2 and 4. *Perforatus perforatus* (Figure 3F) seemed to prefer the upper infralittoral zone of stations, but the majority of specimens of *Amphibalanus amphitrite* (Figure 3E) (58% of total specimens) were encountered in the mediolittoral zone of station 7 (on a plastic platform).

Chthamalus stellatus is accounted for 70% of the total number of individuals and 50% of the total biomass in the area, followed by *C. montagui* and (25% and 26%, respectively) and *Perforatus perforatus* (2% and 15%, respectively).

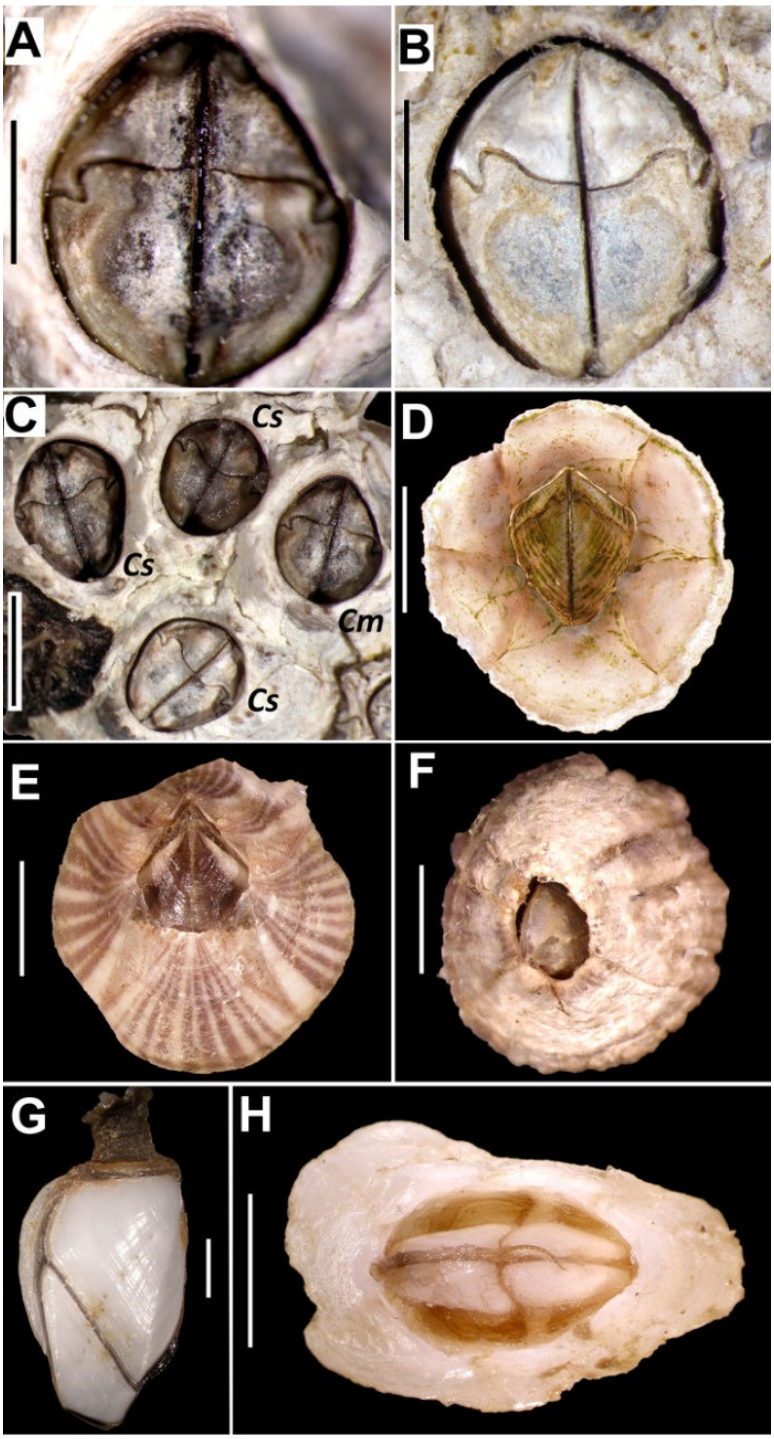

Figure 3. A. Apical view of *Chthamalus montagui*, B. Apical view of *C. stellatus*, C. Mixed populations of *C. montagui* (Cm) and *C. stellatus* (Cs), D. Apical view of *Euraphia depressa*, E. Apical view of *Amphibalanus amphitrite*, F. Apical view of *Perforatus perforatus*, G. Lateral view of *Lepas anatifera*, and H. Apical view of *Chelonibia patula*. Scale bars: A=1.25 mm, B= 1.6 mm, C=2.5 mm, D=3.2 mm, E=3.8 mm, F=3.2 mm, G=3.8 mm, H=5 mm.

In the supralittoral and mediolittoral zones, *C. stellatus* comprised 72% of the total number of individuals and 59% of the total biomass, followed by *C. montagui* and *Amphibalanus amphitrite* (Figure 4A, B, left). The chthamalid species were present in the majority of samples (more than 60%) and accounted for 98% of the total number of individuals and 91% of the total biomass in these zones. *C. stellatus* attained its highest density (69600 ind.m^{-2}) and biomass (3100 g.m^{-2}) at station 5. This species also formed a dense population (55000 ind.m^{-2}) at station 6. The highest density (29600 ind.m^{-2}) of *C. montagui* was estimated at station 5. The other chthamalid, *Euraphia depressa*, was found only at station 2, where its maximum density reached up to 875 ind.m^{-2}. In the mediolittoral zone of station 7, *A. amphitrite* had a maximum density of 1650 ind.m^{-2}.

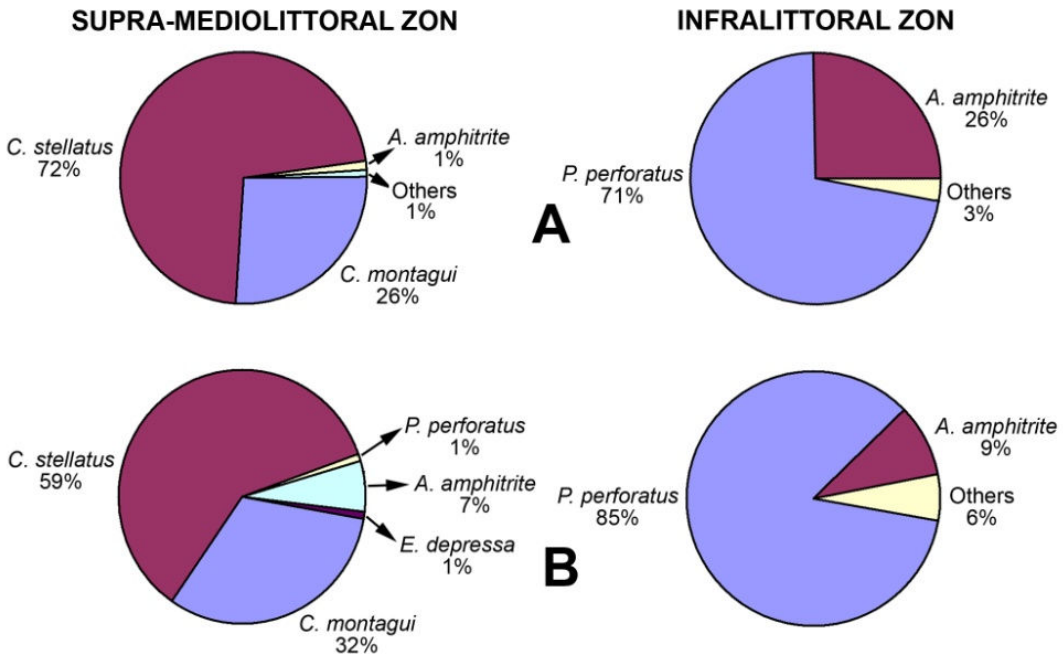

Figure 4. *Left*. Relative dominance of the species collected in the supralittoral and mediolittoral zones by the number of individuals (A) and biomass (B). *Right*. Relative dominance of the species collected in the upper infralittoral zone by the number of individuals (A) and biomass (B).

In the infralittoral zones of six stations (stations 1, 2, 4-6, 8), a total of four species were found. Of these, *Lepas anatifera* was found only on artificial substrates such as ship's keels or ropes, whereas *Chelonibia patula* was only encountered on the upper valve of the large bivalve *Spondylus gaederopus* Linnaeus, 1758 at station 4. *A. amphitrite* was found on a ship's keel and rocks, and *Perforatus perforatus* occurred solely on rocks. The dominant species in the infralittoral zone was *Perforatus perforatus*, which comprised 71% of the total number of individuals and 85% of the total biomass (Figure 4A,B, right). This species was found in 80% of samples and formed a dense population (max. 1600 ind.m^{-2}, 383 g.m^{-2}) at station 1. The other dominant species in this zone

was *A. amphitrite* that possessed its maximum density (2200 ind.m^{-2}) and biomass (337 g.m^{-2}) at station 5.

Among stations, the highest mean cirriped populations (57950 ind.m^{-2}) and biomass (1757 g.m^{-2}) were encountered at station 6, the lowest mean values (508 ind.m^{-2}, 13,96 g.m^{-2}) at station 1. Samples taken from Kemer Marina also possessed the highest mean density and biomass (28233 ind.m^{-2}, 1301 g.m^{-2}).

Biometric Features of Species

The relationships among the basal length (LB) and other biometrical features [the basal width (WB), the orifice length (LO), the orifice width (WO) and the carinal height (H)] of shells of 5 species (*C. stellatus*, *C. montagui*, *Euraphia depressa*, *A. amphitrite* and *P. perforatus*) are depicted in Figure 5. The highest correlation coefficients were estimated between the basal length and width. Among the chthamalids, the lowest carinal height was measured in *E. depressa*. The carinal length of *C. stellatus* were higher than that of *C. montagui*. The ratio between the orifice length and width in *E. depressa* was higher that those estimated in the other chthamalids.

Among the balanids, *P. perforatus* had the highest carinal length but smaller orifice dimension. The correlations between the basal length and other measurements in *A. amphitrite* were significantly high, but that (r=0.58) between the basal length and the orifice width was relatively low in *P. perforatus*.

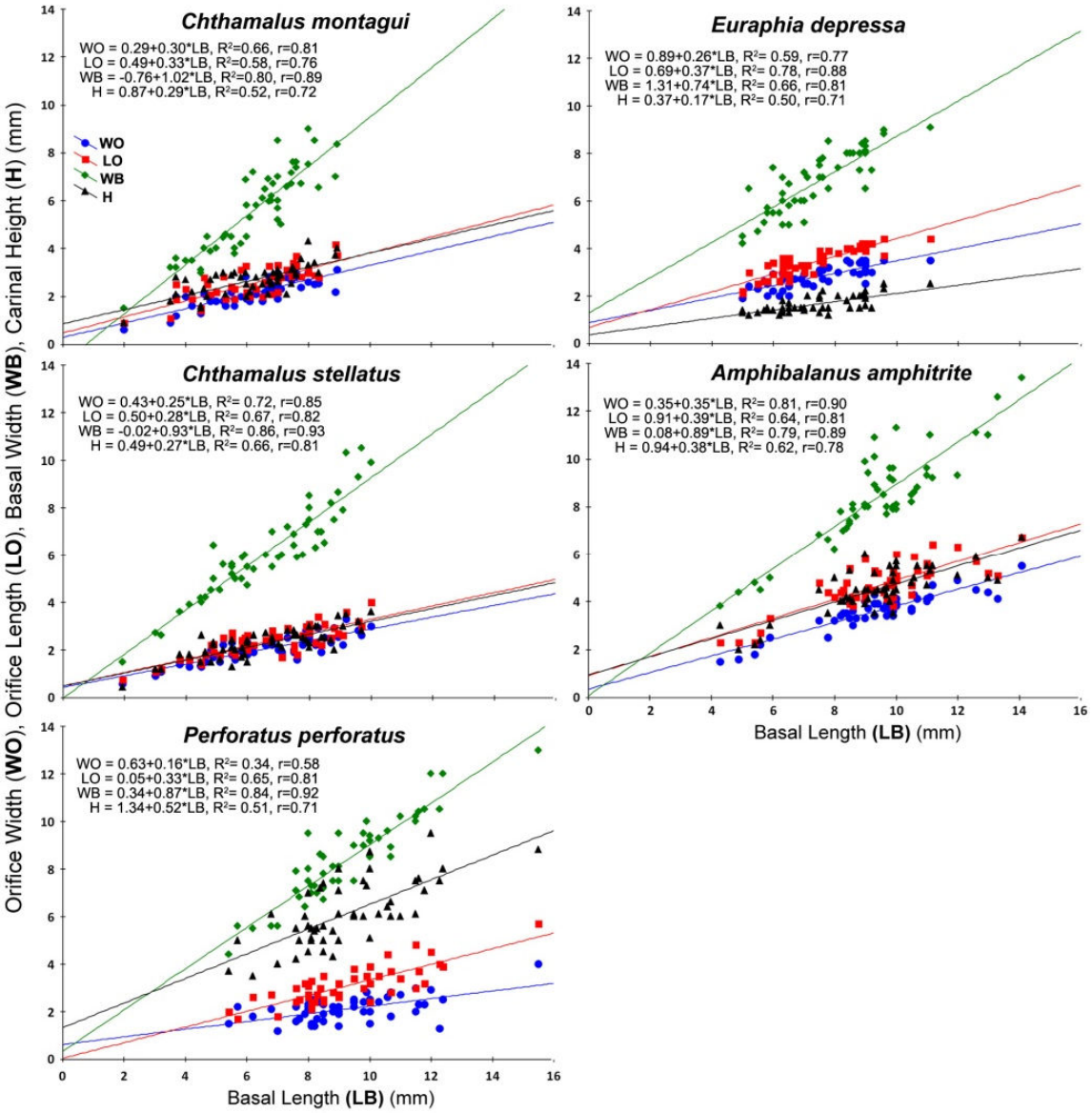

Figure 5. The relationships among the basal length (LB), and the basal width (WB), the orifice length (LO), the orifice width (WO) and the carinal height (H) of the dominant species.

Length-weight relationships

The relationships of body sizes of the dominant species to their shapes were analyzed using the basal length and the individual wet weight (Figure 6). The regression equations indicated that all barnacle species examined have allometrical growth patterns. The allometric coefficient for the wet weight with respect to the basal length is positive (b=3.13) for *P. perforatus*, which indicates that the weight increases rapidly with respect to the basal length, due to the shape of the species (conical). The allometric coefficients estimated for other species are negative.

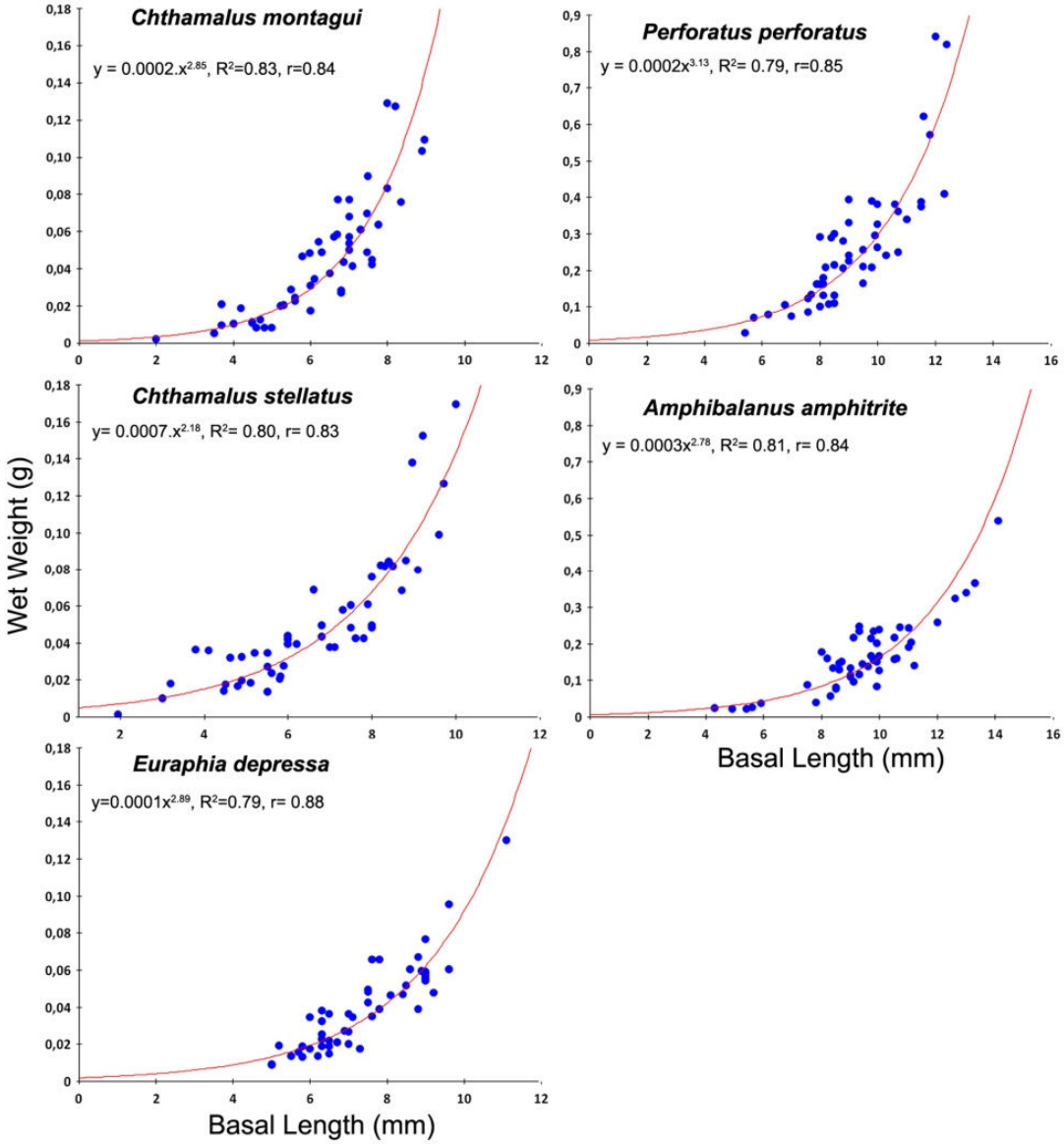

Figure 6. The length-weight relations of the dominant species in the area.

Discussion

In the present study, seven thoracic cirripeds were found in Antalya Bay, of which *Chthamalus montagui* and *Lepas anatifera* are new records for the Levantine coast of Turkey. Prior to this study, a total of 15 thoracic cirripeds were reported along the coasts of Turkey (Table 2). However, the occurrences of the species *Balanus crenatus* and *Verruca stroemia*, which were reported by Demir (1952) and Geldiay and Kocatas (1972), were considered to be questionable in the Mediterranean (Newman and Ross 1976; Young *et al*. 2003). In this case, the number of species known from the area decreased to 13. Only one species (*Amphibalanus eburneus*) was reported from the Black Sea coast of Turkey (Pinar 1974), while eight-nine species are known on the other coasts of Turkey.

Table 2. A checklist of thoracic cirripeds reported from the coasts of Turkey (BS: Black Sea, SM: Sea of Marmara, AS: Aegean Sea, L: Levantine Sea). The occurrence of the species marked with asterix is questionable in the area. (1. Ostroumoff 1896; 2. Neu 1939; 3. Demir 1952; 4. Geldiay and Kocatas 1972; 5. Pinar 1974; 6. Tek 1975; 7. Kocatas 1978; 8. Cirik 1979; 9. Geldiay *et al*. 1982; 10. Balkis 1994; 11. Ergen *et al*. 1994; 12. Pannacciulli *et al*. 1997; 13. Koçak *et al*. 1998; 14. Koçak *et al*. 1999; 15. Koçak and Kucuksezgin 2000; 16. Koçak and Tekogul 2003; 17. Bakir *et al*. 2004; 18. Dogan *et al*. 2005; 19. Çinar *et al*. 2006; 20. Kalkan *et al*. 2006; 21. Dagli *et al*. 2008; 22. Çinar *et al*. 2008; 23. Dogan *et al*. 2008; 24. Shemesh *et al*. 2009; 25. Bakir *et al*. 2010; 26. Topaloğlu and Gönülal 2012; 27. Present study).

	SEAS			
Species	**BS**	**SM**	**AS**	**L**
PEDUNCULATA				
Lepas anatifera (Linnaeus1767)	-	-	17,21	27
Scalpellum scalpellum (Linnaeus 1767)	-	3	26	-
SESSILIA				
Chthamalus montagui (Southward, 1976)	-	24	-	27
Chthamalus stellatus (Poli 1791)	-	3,5,10,24	4,7,8,11,24	12,24,27
Euraphia depressa (Poli 1791)	-	24	4,6,7,24	24,27
Amphibalanus amphitrite (Darwin 1854)	-	2*	2,4-7,13-16,19,22	5,27
Amphibalanus eburneus (Gould, 1841)	5	2,5	5-7,14-16,18,19, 22,23	5
Amphibalanus improvisus (Darwin, 1854)	-	2,5,20	4,15,22	-
**Balanus crenatus* Bruguiére, 1789	-	3	4	-
Balanus trigonus (Darwin, 1854)	-	-	14	-
Chelonibia patula (Ranzani, 1818)	-	-	-	25,27
Chelonibia testudinaria (Linnaeus,1758)	-	-	-	9
Perforatus perforatus (Bruguiere 1789)	-	5	4,5,6,7,11,22,23	5,27
Verruca spengleri Darwin, 1854	-	1	-	-
***Verruca stroemia* (O.F.Muller 1776)	-	3	-	-

*Newman and Ross (1976) postulated that the records of *Balanus crenatus* in the Mediterranean are questionable.

**Young *et al.* (2003) reported that only *Verruca spengleri* exists in the Mediterranean.

In the Mediterranean Sea, 34 thoracic cirripeds were reported up to date (Koukouras and Matsa 1998). Among the basins of the Mediterranean, 34 species were known from the eastern Mediterranean, 17 species from the Adriatic Sea, 18 species from the Aegean Sea and 13 species from the Levantine Sea. In the Black Sea, 7 species were reported. The species that were previously reported from the Levantine Sea but not found during the present study are *Lepas pectinata* Spengler, 1793, *L. anserifera* Linnaeus, 1767, *Amphibalanus eburneus*, *A. improvisus*, *Balanus trigonus*, *C. testudinaria* and *Megabalanus tintinnarium*. Among these species, *L. pectinata* and *L. anserifera* were reported

from the Israeli coast on hard substrata (Carmin 1955); *M. tintinnabulum* from the Israeli coast on a sunken wood (Bodenheimer 1935); *A. eburneus*, *A. improvisus* and *B. trigonus* from the coasts of Egypt and Turkey on algae, bivalves and experimental panels (Broch 1935; Pinar 1974); and *C. testudinaria* from the coast of Turkey (Dalyanköy) on the carapace of turtles (Geldiay *et al*. 1982).

Thoracic cirriped species that can easily settle on submerged parts of ships have been transferred from one area to another via ships (Bishop 1951; Carlton 1996; Anil *et al*. 2002). It is obvious that the spread rates of alien species have been accelarated nowadays as a result of the increase in maritime transport among continents (Kerckhof 2002; Çinar *et al*. 2011). In addition, global warming enabled thermophilic species to advance their distributional ranges to the northern regions (Occhipinti-Ambrogi 2007). In the Mediterranean Sea, a total of 6 thoracic cirripeds [*Amphibalanus eburneus*, *A. reticulatus* (Utinomi, 1967), *Balanus trigonus*, *Austrominius modestus* (Darwin, 1854), *Megabalanus titinnabulum* and *Tetraclita squamosa* Pilsbry, 1916) were considered as aliens (Zenetos *et al*. 2010). Except for *A. modestus* and *T. squamosa*, these species were also reported from the eastern Mediterranean and formed dense populations in harbour or estuarine environments. However, the reports of *M. tintinnabulum* in the area were tought to be questionable (Galil and Zenetos 2002) as it was only found on a ship's keel in Pireus Harbour (Greece) and on a sunken wood washed up on an Israeli beach (Bodenheimer 1935). *Amphibalanus reticulatus* was first noticed on a ship's keel sailed from the Indian Ocean to Toulon Harbour (France) through the Red Sea (Zibrowius 1991) and then in Hadera Harbour (Israel) (Galil 2007). It is not clear at the moment if this species has become established in the western Mediterranean, but it seems to be a new resident of the eastern Mediterranean now. *Tetraclita squamosa,* which is an Indo-Pacific species, was only reported from the coast of Tripoli (Libya) (Zaouali *et al*. 2007). Along the coasts of Turkey, only two alien thoracic cirripeds (*A. eburneus* and *B. trigonus*) were reported (see Çinar *et al*. 2011).

The dominant species in the supralittoral and mediolittoral zones of Antalya Bay was *Chthamalus stellatus*. Lipkin and Safriel (1971) also reported this species as a dominant component of the upper mediolittoral zone along the Israeli coast and postulated that it was totally absent on surfaces where *Lyngbya aestuarii* (Mertens) Liebman ex Gomont, 1892 formed a cover. In addition, it was also observed that high settlements of *Patella* spp. on rocks greatly diminished the recruitment of this species (Lipkin and Safriel 1971). Crisp *et al*. (1981) reported that *C. stellatus* formed dense populations on rocks exposed to waves, whereas *C. montagui* was the dominant component of rocks in enclosed bays or harbours. For example, *C. montagui* comprised 81-97% of the total chthamalid individuals in a harbour in Spain (Crisp *et al*. 1981). In the present study, the maximum density of *C. stellatus* was estimated as 69600 ind.m^{-2}, but it had

lower population sizes along the coasts of Spain (27000 ind.m^{-2}) and France (30200 ind.m^{-2}) (Crisp *et al*. 1981). It generally prefers the lower mediolittoral zone (Southward, 1976). As egg sizes of *C. stellatus* are larger than those of *C. montagui*, *C. stellatus* stays longer in the pelagic and can spread distant areas (Burrows *et al*. 1992). Due to this strategy, *C. stellatus* can settle on islands far from mainlands, but *C. montagui* cannot (Crisp *et al*. 1981).

Chthamalus montagui attained a maximum density of 29600 ind.m^{-2} in Antalya Bay, whereas this species was less abundant along the coasts of Spain (15200 ind.m^{-2}) and France (4400 ind.m^{-2}) (Crips *et al*. 1981). This species was reported to be the dominant chthamalid species in the Adriatic (Battelli and Dolenc-Orbanić 2009). Along the southern coast of Portugal, *C. montagui* reached a maximum density of 322800 ind.m^{-2}, whereas *C. stellatus* had a maximum density of 2000 ind.m^{-2} (Sousa *et al*. 2000). *Chthamalus montagui* was the dominant species (*C. montagui*: 40000 ind.m^{-2}, *C. stellatus*: 2500 ind.m^{-2}) on rocky shores of Trieste, which is less exposed to hydrodinamism and has high tide level (almost 1 m), whereas *C. stellatus* was the dominant species (*C. stellatus*: 35000 ind.m^{-2}, *C. montagui*: 15000 ind.m^{-2}) on rocky shores of Genova, which is more exposed to waves and has low tide level (30 cm) (Pannacciulli and Relini 2000).

Euraphia depressa was only found on the mediolittoral zone of station 1. This species was known to prefer the supralittoral zone of rocks that are gradually extending into the sea (Southward 1964; 2008). It was rarely found on steep rocks and in areas open to waves (Lipkin and Safriel 1971). It generally settles within crevices of rocks (Southward 1964; Lipkin and Safriel 1971). It was previously considered as a species endemic to the Mediterranean Sea. However, Achituv and Safriel (1980) found large and semi-transparent specimens of it along the Suez Canal and considered it as an anti-Lessepsian species (i.e., species migrated from the Mediterranean to the Red Sea via the Suez Canal). The specimens we found at station 1 are closely related to those found in the Suez Canal. Our observation reveals that the Aegean Sea specimens of *E. depressa* seem to differ from the those in the Levantine Sea in terms of body shape (not transparent in the Aegean Sea) and size (smaller in the Aegean Sea). Therefore, a genetic analysis should be performed to discover if the specimens from these areas are identical or not.

The highest population density (2200 ind.m^{-2}) and biomass (337 g.m^{-2}) of *Amphibalanus amphitrite* were found at station 5. This species was previously reported to have a maximum population size up to 400 ind.m^{-2} along the Argentina coast (López Gappa *et al*. 1997), up to 12300 ind.m^{-2} in the Aegean Sea (Koçak and Tekoğul 2003) and up to 10250 ind.m^{-2} in Alsancak Harbour (Aegean Sea) (Çinar *et al*. 2008).

Perforatus perforatus was known to be a thermophilic species and its expansion to the northern coast of the England was considered as a result of the global warming (Herbert *et al*. 2003). Therefore, *P. perforatus* can be used as an indicator species of global warming. This species abundantly occurs along the Levantine coast of Turkey and its population density drastically decreases from the southern to the northern part of the Aegean Sea. For example, its density was calculated as 1600 ind.m^{-2} in the present study, whereas it attained a maximum density of 675 ind.m^{-2} in the polluted part of Izmir Bay (mid-Aegean Sea) (Çinar *et al*. 2008).

Spivey (1989) postulated that there is a high correlation between the basal length and the weight in *Balanus* species. The present study supported this finding; the correlation coefficient was estimated as 0.84 for *Amphibalanus amphitrite* and 0.85 for *Perforatus perforatus*.

The present study is the first attempt to make a study on barnacles along the Levantine coast of Turkey. In future studies to be performed in the area, more habitats and depth should be sampled to elucidate the real diversity of this group and their distributional patterns in the area.

Antalya Körfezi'nin (Doğu Akdeniz) Thorasik Sirripedleri (Thoracica: Cirripedia)

Özet

Bu çalışmada Antalya Körfezi'nin (Doğu Akdeniz, Türkiye) supralittoral, mediolittoral ve üst infralittoral zonlarında Ağustos 2009 ve Ocak 2010 tarihleri arasında toplanmış torasik sirripedler ele alınmıştır. Bölgede 6 genusa ait 7 tür ve 13477 birey bulunmuştur. Türler arasında, *Chthamalus montagui* ve *Lepas anatifera* Türkiye'nin Akdeniz sahilleri için yeni kayıtlardır. *Chthamalus stallatus* supralittoral ve mediolittoral zonlarda dominant tür olup, azami 69600 birey.m^{-2}'lik bir populasyon yoğunluğuna ve 3100 g.m^{-2}'lık bir biyokütleye sahiptir. *Perforatus perforatus* infralittoral zonun en dominant türü olup, bu zondaki toplam birey sayısının %71'ini, toplam biyokütlenin ise %85'ini içermektedir. Dominant türlere ait kabukların biyometrik özellikleri analiz edilmiş ve türlerin boy-ağırlık ilişkileri hesaplanmıştır. Ayrıca, Türkiye kıyılarında şu ana kadar rapor edilen torasik sirripedlerin bir kontrol-listesi verilmiştir.

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