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Cirripedia of the Canary Islands: distribution and ecological notes

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The present paper is the first annotated account listing all species of Cirripedia: Thoracica recorded from the Canary Islands (eastern Atlantic Ocean) together with notes on their distribution and ecology. Voucher specimens have been deposited as reference material in the collection of the Instituto Canario de Ciencias Marinas. Seventeen species are listed and seven of them are recorded for the first time for the Canaries: Lepas hilli, Conchoderma virgatum, Xenobalanus globicipitis, Chthamalus sp. (*cf.* C. proteus), Acasta cyathus, Balanus trigonus *and* Perforatus perforatus.

Keywords: checklist, Cirripedia, Thoracica, Canary Islands, eastern Atlantic

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INTRODUCTION

The archipelagos of the Azores, Madeira and the Canaries form the so-called Macaronesian region in the eastern Atlantic Ocean (Figure 1). They act as a bridge favouring faunistic exchange between the western and eastern Atlantic basins (e.g. González, 1995; Santos *et al.*, 1997; Brito *et al.*, 2002; Wirtz *et al.*, 2006).

Islands have featured strongly in the development of evolutionary and ecological ideas from the earliest formal studies (see Hawkins *et al.*, 2000). The sea is generally viewed as homogeneous areas, being interconnected via ocean currents and broad scale dispersal mechanisms of the biota. Isolated islands are playing an important role in allopatric speciation of many species of gastropods and barnacles (e.g. Kay & Palumbi, 1987; Hawkins *et al.*, 2000). Macaronesia is a superb natural laboratory to understand speciation in intertidal organisms. During glaciation, it is likely that many temperate species retreated to north-west Africa and the Canaries, from which refuge they may have subsequently expanded outwards and northwards, including into the Mediterranean Sea (Hawkins *et al.*, 2000; Brito *et al.*, 2002). The biological performance of species close to their biogeographical boundaries is of critical interest in a period of rapid climate change and can inform predictions of future patterns of distribution (Herbert *et al.*, 2009).

The volcanic characteristics of the Canary Islands are manifest by the absence of wide insular shelves, with a bottom depth of 180–200 m near the coast. The Canary archipelago is situated relatively close to the continents of Africa and Europe, but separated from them by great depths (Figure 1). The Canary Islands are also under the influence of the subtropical gyre of the eastern central Atlantic, which would facilitate the transport of marine organism larvae to the archipelago from the American, European and north-west African coasts (e.g. Aguilera *et al.*, 1994). The littoral biota of the Canaries is dominated by tropical/subtropical east Atlantic species, followed by Atlantic–Mediterranean and amphi-Atlantic species (González, 1995; Brito *et al.*, 1996). The poverty of Guinean (tropical and subtropical) species on the Canary coasts may be the result of the absence of a consistent current flow from the south, and the thermal barrier created by the Cape Blanc upwelling cell (e.g. Mittelstaedt, 1983).

Recent studies about the hydrography, composition and horizontal distribution of a larval fish community between the Canary Islands and the African coast have found a strong mesoscale oceanographic activity. This mesoscale distribution of larvae has been described in filaments of the upwelling system from the African coast reaching the south-east of this archipelago (Rodríguez *et al.*, 2004; Bécognée *et al.*, 2009), and suggests specific retention mechanisms for the larvae of neritic invertebrate populations (including barnacles) around the oceanic islands of the Canaries (Landeira *et al.*, 2009, 2010). These studies have proved that short-lived larvae from Africa are arriving to the Canary Islands transported by the currents or upwelling filaments, since a quasi-permanent flow of this type of organisms has been registered. Although some cypris larvae might be able to reach the Canaries and even to settle on their coast, a part of them might not be able to develop a stable reproductive population because of one or several adverse environmental conditions, like temperature of seawater, food availability, etc.

Also, the Canary Islands are geographically located on a very important maritime route and ships have long been

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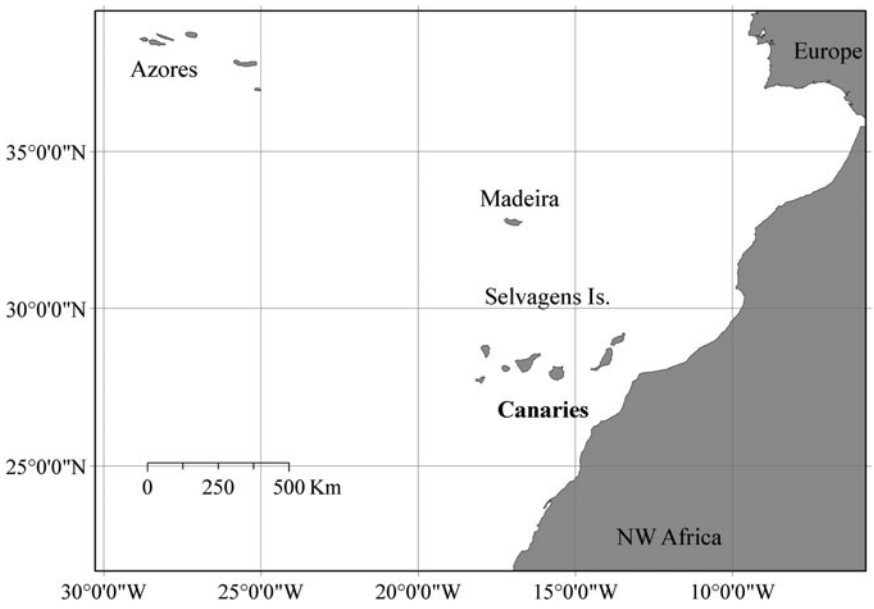

Fig. 1. The Macaronesian region—archipelagos of the Azores, Madeira and the Canaries.

recognized as a major vector for the introduction of non-native and encrusting organisms. Many yacht marinas are located at the Canary Islands, and some of them are frequently organizing races and cruises to Madeira and the Caribbean Sea with the participation of thousands of recreational boats.

Geomorphological, geographical and oceanographic particularities of the Canaries could explain the great diversity in the biogeographic patterns of the biota inhabiting this area. These physical and biodiversity characteristics, together with the climatic condition of the Canary Islands—a temperate–subtropical area—compared to the surrounding region highlight the uniqueness and oceanographic connectivity of the Canary Islands to the surrounding waters.

Professor A.J. Southward, being fascinated by the intrinsic interest of the islands and particularly interested in the bridging role of the Macaronesian islands in the distribution of marine species, first studied the Azorean barnacles (Southward, 1998) followed by the Madeiran barnacles (Wirtz *et al.*, 2006). He then started to identify some specimens of Cirripedia of the Canary Islands in the collections of the Instituto Canario de Ciencias Marinas, before his death in 2007.

The monographs on Cirripedia by Darwin (1851, 1854), and the account of barnacles of tropical West Africa by Stubbings (1967), do not include any record for the Canary Islands. The three most frequent species (*Chthamalus stellatus*, *Pollicipes cornucopia* and *Balanus* sp.) were included in the preliminary catalogue of the benthic fauna from the Canaries (Barquín-Diez *et al.*, 1983). Apart from several popular science books (Brito *et al.*, 1984; Pérez & Moreno, 1991; Franquet & Brito, 1995; Espino *et al.*, 2006) and one non-annotated preliminary check-list (Haroun *et al.*, 2003), there have been no scientific studies devoted to the Canarian Cirripedia to date.

This is the first account of the intertidal, shallow-water and oceanic thoracian barnacles from the Canaries. It includes notes on their distribution and ecology, based on the authors' collections and the invaluable identification work conducted by the late A.J. Southward.

MATERIALS AND METHODS

This report is based on material collected by hand, snorkel- and SCUBA-diving from shore, shallow depths and ship hulls by the authors and their collaborators, with material collected during cruises or project surveys. Additional preserved material has been included, whenever relevant for depth-range or ecological information. Species reported from all these sources are listed in Table 1, which also lists the shallow-water species found in Madeira and the Azores. A scale map of the Canary Islands with the localities of capture of the specimens studied is provided in Figure 2.

All reference samples and part of the additional material were identified by A.J. Southward at the Laboratory of the Marine Biological Association of the United Kingdom (MBA) in Plymouth. The remaining additional samples, mainly replicates of the reference material, were checked and identified at the Instituto Canario de Ciencias Marinas (ICCM) in Gran Canaria. The nomenclature and synonyms still in use follow Southward (2008). Voucher specimens have been deposited in the collections of the ICCM. All measurements (in mm $\pm$ 0.1) follow Young (2001) and Southward (2008). Abbreviations are as follows: cl, capitular length; tl, total length; and rc, rostro-carinal diameter.

RESULTS

See Southward (2008) for families, genera and species' descriptions.

SYSTEMATICS

Order PEDUNCULATA Lamarck, 1818
Suborder LEPADOMORPHA Pilsbry, 1916
Family LEPADIDAE Darwin, 1852
Genus *Lepas* Linnaeus, 1758
Lepas anatifera Linnaeus, 1758

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Table 1. Shallow-water/oceanic barnacle species (Cirripedia: Thoracica) occurring in the Canaries, Madeira and the Azores.

Group/family species	Deep range	Canaries depth-range (m)	Madeira depth-range (m)	Azores depth-range (m)	Geographical distribution
PEDUNCULATA					
HETERALEPADOMORPHA					
HETERALEPADIDAE					
Oxynaspis celata Darwin	35–1425	See Discussion	35 downwards Wirtz *et al.*, 2006	35–1425 Southward, 1998	Cosmopolitan, including Azores and Madeira
Oxynaspis patens Aurivillius	125–455			358–406 Southward, 1998; Young, 2001	North Atlantic (Great Meteor Bank and Great Meteor Seamount in the eastern sector)
LEPADOMORPHA					
POECILASMATIDAE					
Dichelaspis sessilis Hoek	Shallow water			? Southward, 1998	Azores
LEPADIDAE					
Lepas anatifera Linnaeus	0	0 Pérez & Moreno, 1991; this report	0 Wirtz *et al.*, 2006	0 Southward, 1998	Cosmopolitan, including Azores, Madeira and Canaries
Lepas anserifera Linnaeus	0			0 Southward, 1998	Cosmopolitan, including Azores and Great Meteor Bank
Lepas hillii Leach	0	0 This report	0 Wirtz *et al.*, 2006	0 Southward, 1998	Circumtropical, including Azores and Canaries
Lepas pectinata Spengler	0	0 Pérez & Moreno, 1991; this report	0 Wirtz *et al.*, 2006	0 Southward, 1998	Circumtropical, including Azores, Selvagens Islands and Canaries
Dosima fascicularis (Ellis & Solander)	0		0 Wirtz *et al.*, 2006	0 Southward, 1998	Cosmopolitan, including Azores and Seine Seamount
Conchoderma auritum (Linnaeus)	0		0 Wirtz *et al.*, 2006		Cosmopolitan, including Madeira
Conchoderma virgatum Spengler	0	0 This report	0 Wirtz *et al.*, 2006	0 Southward, 1998	Cosmopolitan, including Azores, Madeira and Canaries
SCALPELLOMORPHA					
POLLICIPEDIDAE					
Pollicipes pollicipes (Gmelin)	0–1	0–1 Barquín-Diez *et al.*, 1983; this report			North-east Atlantic, including Canaries
SESSILIA					
VERRUCOMORPHA					
VERRUCIDAE					
Verruca spengleri Darwin	0–130	10–38 Pérez & Moreno, 1991; this report	Low water level downwards Wirtz *et al.*, 2006	0 down to 130 Southward, 1998	Azores, Madeira, Canaries, Mediterranean
BALANOMORPHA					
CHTHAMALIDAE					
Chthamalus montagui Southward	0	0–3 Crisp *et al.*, 1981; Southward, 2008; this report			Eastern Atlantic
Chthamalus sp. (this paper)	10–15	10–15 This report			Canaries
Chthamalus stellatus (Poli)	0	0–3 Barquín-Diez *et al.*, 1983; Southward, 2008; this report	Intertidal Wirtz *et al.*, 2006; Southward, 2008	0 Southward, 1998, 2008	Eastern Atlantic

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Table 1. Continued

Group/family species	Deep range	Canaries depth-range (m)	Madeira depth-range (m)	Azores depth-range (m)	Geographical distribution
TETRACLITIDAE					
Tesseropora atlanticum Newman & Ross	0–40		Intertidal	Intertidal, shallow water	Bermuda, Azores, Madeira and St Paul's Rocks
		See Discussion	Wirtz *et al.*, 2006	Southward, 1998	
CHELONIBIIDAE					
Chelonibia testudinaria (Linnaeus)	0	0			Cosmopolitan in tropical and warm
		Pérez & Moreno, 1991; this report			temperate seas, on turtles (Southward, 2008)
Chelonibia caretta Spengler	0		0	0	Cosmopolitan in tropical and warm
			Wirtz *et al.*, 2006	Southward, 1998	temperate seas, on turtles (Southward, 2008)
PLATYLEPADIDAE					
Platylepas hexastylos (Fabricius)	0			0	Cosmopolitan in tropical and warm
				Southward, 2008	temperate seas, on turtles (Southward, 2008)
Stomatolepas elegans (da Costa, 1838)	0		0		Cosmopolitan, on turtles
			Wirtz *et al.*, 2006		
CORONULIDAE					
Coronula diadema (Linnaeus)	0		0	0	Pacific and northern Atlantic including Azores region and
			Wirtz *et al.*, 2006	Young, 2001	Madeira, on cetaceans
Xenobalanus globicipitis Steenstrup	0	0		0	Worldwide on cetaceans
		This report		Southward, 1998	(Southward, 2008)
Acasta cyathus Darwin	12	12	12		Circumtropical, including Madeira
		This report	Wirtz *et al.*, 2006; Southward, 2008		and Canaries, in sponges
Elminius modestus Darwin	0		0		North-west Europe and New Zealand, on
			Wirtz *et al.*, 2006		ships' hulls (Southward, 2008)
PYRGOMATIDAE					
Megatrema anglicum (Sowerby)	0–80		9		Eastern Atlantic and Mediterranean
		See Discussion	Wirtz *et al.*, 2006		On corals (Southward, 2008)
BALANIDAE					
Balanus spongicola Brown	15–100		25–30	15–100	Circumtropical, including Azores
			Wirtz *et al.*, 2006; Southward, 2008	Southward, 1998	and Madeira
Balanus trigonus Darwin	0–100	0–50	Shallow subtidal	0–54	Circumtropical in tropical/subtropical
		This report	Wirtz *et al.*, 2006	Southward, 1998, 2008	seas, including Azores, Madeira and Canaries
Amphibalanus amphitrite (Darwin)	0–10	0–2	0	10	Now cosmopolitan, including Azores,
		Pérez & Moreno, 1991; this report	Wirtz *et al.*, 2006	Southward, 1998	Madeira and Canaries
Amphibalanus eburneus (Gould)	0–40			0	Western and eastern Atlantic, including
				Southward, 1998, 2008	Azores
Perforatus perforatus (Bruguière)	0–40	0–1			Eastern Atlantic warm seas and
		This report			Mediterranean
Megabalanus azoricus (Pilsbry)	0–40	0–22	Just below low tide	Just below low tide	Azores, Madeira, Canaries and St Helena
		Henry & McLaughlin, 1986; this report	Wirtz *et al.*, 2006, Southward, 2008	Southward, 1998; Wirtz *et al.*, 2006	

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Table 1. Continued

Group/family species	Deep range	Canaries depth-range (m)	Madeira depth-range (m)	Azores depth-range (m)	Geographical distribution
Megabalanus tulipiformis (Ellis)	25–250	0–22 (new record) Pérez & Moreno, 1991; this report	27–30 Wirtz *et al.*, 2006; Southward, 2008		Eastern Atlantic and Mediterranean, including Madeira and Canaries

Depth-range and geographical distribution taken mainly from Southward (1998, 2008), Young (1998, 2001).

MATERIAL EXAMINED

Thirteen specimens found attached to a loggerhead turtle *Caretta caretta* (ICCM-345) and floating buoys (ICCM-326, 392) in Gran Canaria and La Palma islands. Size-range: tl (cl) 6.5 (4.0) to 55.9 (40.7) mm. Additional material from La Palma includes one extremely large barnacle measuring 108.8 (55.1) mm.

DISTRIBUTION

Cosmopolitan, including the Azores (Southward, 1998), Madeira (Wirtz *et al.*, 2006) and the Canaries (Pérez & Moreno, 1991).

REMARKS

This is the most common pedunculate on the Canary coasts, where it usually attains 8 cm in length, living attached to any floating object such as wood, ropes, buoys, ship hulls or sea turtles.

Lepas hilli Leach, 1818

MATERIAL EXAMINED

Two subadult specimens, tl (cl) 16.2 (11.8) to 23.7 (17.1) mm, and several juveniles, off Gran Canaria, surface, found on a loggerhead turtle *Caretta caretta* (ICCM-336).

DISTRIBUTION

Circumtropical, including the Azores (Southward, 1998).

REMARKS

This is the first record of the species for the Canary Islands. It does truly belong to the Canarian fauna. In the past *L. hilli* was misidentified as *L. anatifera*.

Lepas pectinata Spengler, 1793

MATERIAL EXAMINED

Many specimens, tl (cl) 1.8 (1.2) to 3.0 (2.0) mm, off La Palma, surface, hand-collected from a floating plastic bucket (ICCM-389). Additional material was collected on one dead *Spirula spirula* off Tenerife (Figure 3).

DISTRIBUTION

Circumtropical, including the Azores (Southward, 1998) and the Canaries (Pérez & Moreno, 1991).

REMARKS

This species is a winter breeder (Southward, 2008), which is confirmed by our observations of living recently settled individuals and cyprids in late February (Figure 3).

Genus *Conchoderma* Olfers, 1814
Conchoderma virgatum Spengler, 1789

MATERIAL EXAMINED

Seventeen specimens, tl (cl) 8.6 (6.3) to 13.0 (9.7) mm, plus three juveniles, Gran Canaria and El Hierro, found on loggerhead turtles *Caretta caretta*, and on a mooring at 20–25 m depth (ICCM-335, 398). One additional specimen was observed in Gran Canaria on a mooring at 5 m.

DISTRIBUTION

It is known worldwide, including the Azores, on ships, whales and other floating objects (Southward, 2008).

REMARKS

This is the first record of the species for the Canary Islands.

Suborder SCALPELLOMORPHA Newman, 1987
Family POLLICIPEDIDAE Leach, 1817
Genus *Pollicipes* Leach, 1817
Pollicipes pollicipes (Gmelin, 1789)

Synonyms: *Mitella pollicipes*, *Pollicipes pollicipes*.

MATERIAL EXAMINED

One specimen, tl (cl) 53.5 (28.1) mm, Fuerteventura, 0–1 m (ICCM-360). It was first reported from the Canary Islands by Barquín-Diez *et al.* (1983; as *Pollicipes cornucopia*).

DISTRIBUTION

A north-east Atlantic species, including the Canaries (Barquín-Diez *et al.*, 1983). Not found in the Azores (Southward, 1998) or Madeira (Wirtz *et al.*, 2006).

REMARKS

In the Canaries, this species occurs as scattered colonies in the north and west sectors of the islands, but is common in certain localities of the easternmost islands, Lanzarote and Fuerteventura, especially on the west coast of the latter (Franquet & Brito, 1995). It inhabits the low-water mark on rocky coasts in highly wave-exposed areas, mainly on vertical faces and in crevices. It usually occurs as a pinecone- or

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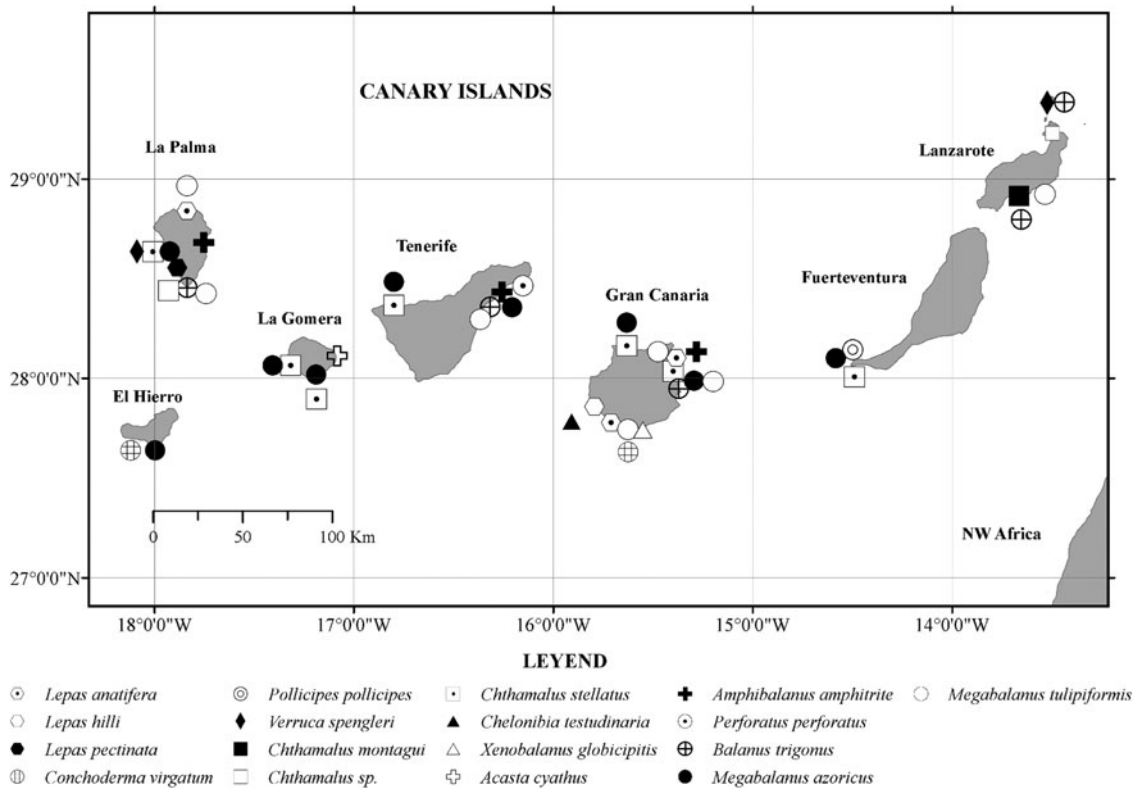

Fig. 2. Collection locations of barnacles studied around the Canary Islands.

raceme-shaped cluster of several barnacles, up to 100 mm in length.

Order SESSILIA Lamarck, 1818
Suborder VERRUCOMORPHA Pilsbry, 1916
Family VERRUCIDAE Darwin, 1854

Genus *Verruca* Schumacher, 1817
Verruca spengleri Darwin, 1854

MATERIAL EXAMINED

Four specimens, rc 0.4–0.6 mm, La Palma, 10 m, found on the walls of a cave (one of them on a specimen of

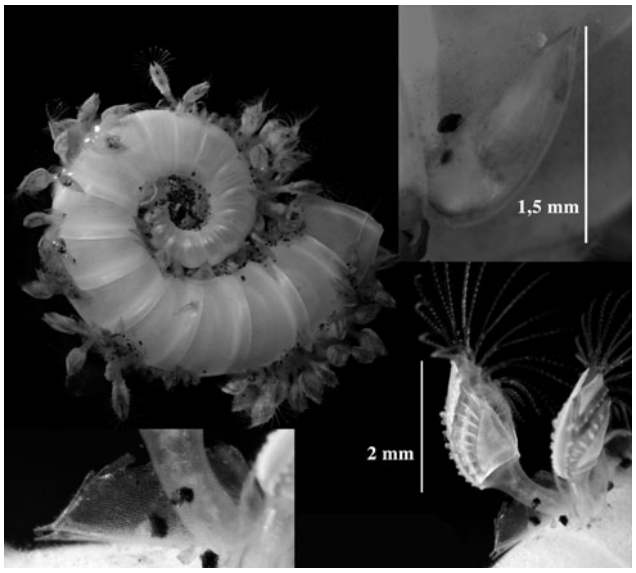

Fig. 3. Many *Lepas pectinata* attached to a *Spirula spirula* (top left); two living recently settled barnacles (bottom right); broken valves of a cypris larvae and of the peduncle of a newly metamorphosed (bottom left); cypris larvae just attached to *Spirula* (top right).

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Megabalanus tulipiformis) (ICCM-397). One additional specimen, Alegranza islet, Lanzarote, 38 m, attached to a *M. tulipiformis*, collected by SCUBA-diving, deposited at the Laboratory of the MBA.

DISTRIBUTION

A Mediterranean and north-east Atlantic species, including the Azores (Southward, 1998), Madeira (Wirtz *et al.*, 2006) and the Canaries (Pérez & Moreno, 1991).

REMARKS

The citation of *Verruca stroemia* (O.F. Müller, 1776) by Gruvel (1902, 1920) for the Azores was probably based on a mistaken identification, because this species has a boreo-Arctic distribution (the White Sea to the Algarve, Portugal) living from extreme low water to 500 m (Southward, 1998, 2008). In the Mediterranean, in southern Spain, the Azores and Madeira, the genus is represented by *V. spengleri* (depth-range: 0–130 m) (Southward, 1998, 2008). The original description of *V. spengleri* is based on specimens from Madeira (Museu Municipal do Funchal), where it is common in dark places from low-water level downwards, e.g. under stones and on the walls of caves (Wirtz *et al.*, 2006). The citation of *V. stroemia* for the Canaries by Pérez & Moreno (1991) is very probably erroneous and based on *V. spengleri* specimens.

Suborder BALANOMORPHA Pilsbry, 1916
Family CHTHAMALIDAE Darwin, 1854
Genus *Chthamalus* Ranzani, 1814
Chthamalus montagui Southward, 1976

MATERIAL EXAMINED

One colony, rc 3.0–6.0 mm, Lanzarote, 0–1 m. Two additional specimens ranging rc 2.1–4.3 mm (ICCM-331), attached to a *Pollicipes pollicipes* specimen from north-west Africa were used as comparative material.

DISTRIBUTION

A north-east Atlantic species. Known from British and Irish coasts to at least Senegal (Southward, 2008). This species is absent from the Azorean and Madeiran coasts (Southward, 1998, 2008; Wirtz *et al.*, 2006). For more details on its distribution-range, see Southward (2008).

REMARKS

Chthamalus montagui was first reported from the Canary Islands by Crisp *et al.* (1981) based on examples from the east coast of Puerto del Carmen, Lanzarote, one of the nearest islands to the African mainland, where the species is present. We have searched intensively for this species on the shores of the Canary Islands, but only encountered it at the previously cited locality at Lanzarote, where it apparently occurs in areas sheltered from wave action. The fact that it is an uncommon species in the Canaries suggests that it does not have a breeding population capable of extending its distribution at present.

Chthamalus stellatus (Poli, 1795)

MATERIAL EXAMINED

About one hundred specimens, rc 0.4–6.8 mm, Fuerteventura, Gran Canaria, La Palma, Tenerife, and La Gomera, 0–1 m, in general on rocks with or without algae but also on aquaculture sea cages (ICCM-343, 359, 361, 369, 384, 395-6). Twenty-nine additional specimens collected from La Gomera were identified by A.J. Southward and deposited in the MBA.

DISTRIBUTION

A north-east Atlantic species, known from the British Isles to north-west Africa and the Cape Verde Islands, including the Azores, Madeira and the Canaries; also reported from the Mediterranean Sea and the Black Sea (Southward, 2008; Pannacciulli *et al.*, 2009).

REMARKS

In the Canaries, this abundant species ('sacabocaos' or 'canutillos') forms a wide yellowish band on the rocky level just on the top of the intertidal zone. The density of *C. stellatus* in this level increases with the degree of wave exposure (Brito *et al.*, 1984). Individuals are small, and rarely attain more than 8 mm in diameter (Pérez & Moreno, 1991).

Chthamalus sp.

MATERIAL EXAMINED

Two entire specimens, rc 6.1–7.2 mm, and four disarticulated ones, rc 6.3–7.0 mm, La Palma (Fuencaliente), 10–15 m, on rocks, collected by SCUBA-diving in December of 2008 (ICCM-374). Additional material (2 specimens, rc 5.5–6.0 mm) from Lanzarote (El Salado, La Graciosa) has been collected in November of 2010 from the intertidal zone at 0 m.

REMARKS

The specimens examined have a low conical shell (altitude up to 2.6 mm), dull brown-white coloured, not corroded; five individuals have smooth shell plates with smooth rounded edges, the remaining one is moderately ribbed with crenulated edges; shell orifice kite-shaped; scuto-tergal articulation placed 1/4 to 1/3 the distance from carina to rostrum, and forming an oblique angle when the two occludent angles are added together; scutum with relative long occludent edge and a straight tergal margin; adductor muscle insertion not clearly visible; tergum wide with slightly prominent spur, the lateral margin only slightly indented; depressor muscle crests, 3–4 (Figure 4). These morphological features clearly separate these individuals from the *Chthamalus* species known to occur on the Mediterranean, European and north-west African coasts. *Chthamalus* sp. from the Canaries seems to be, based on shell morphology, closely related to *Chthamalus proteus* Dando & Southward, 1980, a western Atlantic and tropical eastern Pacific intertidal species (reaching about 1 cm diameter), which is arriving in Hawaiian harbours on the bottoms of ships (Dando & Southward, 1980; Southward *et al.*, 1998). *Chthamalus proteus*, a barnacle that arrived in the Hawaiian Islands ~30 years ago, is now the most abundant and widespread non-native barnacle in the intertidal zone on the island of Oahu; at an intertidal site on this island, the invasive barnacle settled in highest numbers on rough substrata, with a trend toward higher settlement on dark-coloured substrata (Zabin & Altieri, 2007; Zabin, 2009). However, the dissection of one specimen from La Palma and another from Lanzarote has made evident their arthropodal characters which can provide, according to Southward & Newman (2003) and Southward (2008), a sound taxonomic basis. As a result, *Chthamalus* sp. found on the Canary coast belongs to the Southward & Newman '*malayensis*' subgroup

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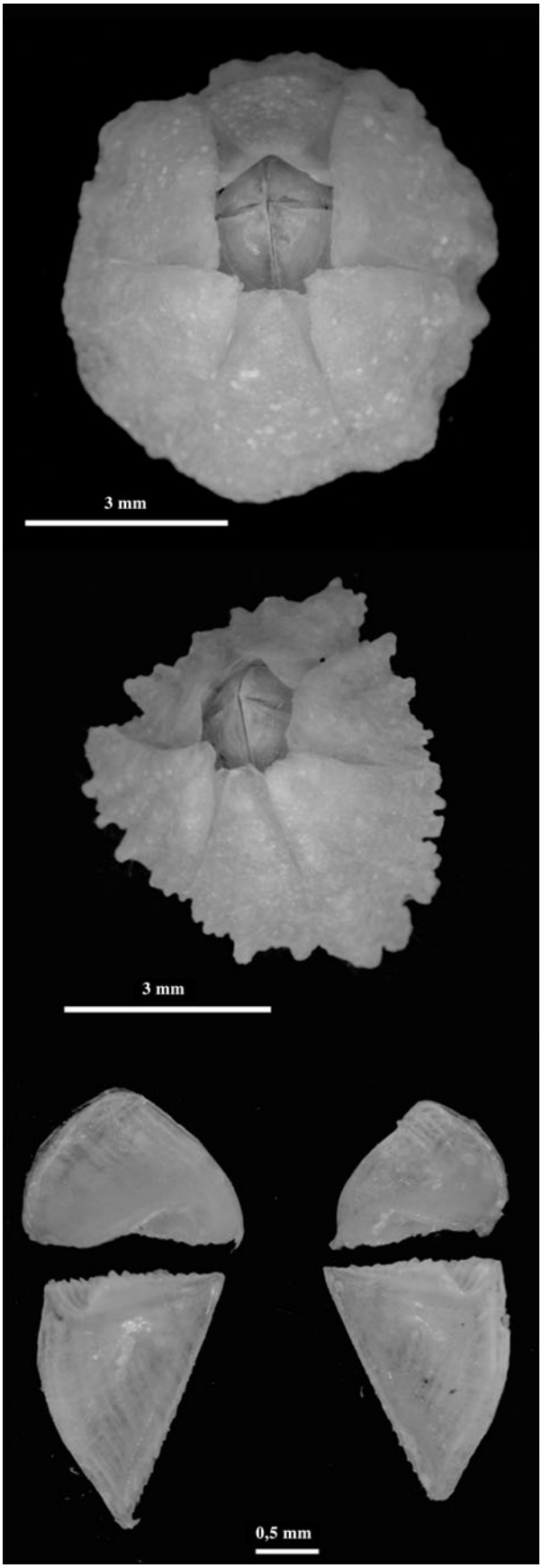

Fig. 4. *Chthamalus* sp. Specimen with smooth shell plates (top). Specimen moderately ribbed (middle). External appearance of terga and scuta (bottom).

of the genus. They have conical spines on the inner side of the outer ramus of the first cirri and with basal guards present on complex setae on cirrus II, and the pecten of mandible show small teeth.

Family CHELONIBIIDAE Pilsbry, 1916
Genus *Chelonibia* Leach, 1817
Chelonibia testudinaria (Linnaeus, 1758)

MATERIAL EXAMINED

Three specimens, rc 8.7–9.8 mm, Gran Canaria, on a loggerhead turtle *Caretta caretta* (ICCM-334).

DISTRIBUTION

Turtle barnacles are cosmopolitan in tropical and warm temperate seas, including now British and Irish waters (Southward, 2008). Reported from the Irish Sea found on a leatherback turtle *Dermochelys coriacea*; apparently recently-settled juveniles, clustered at the basis of the flippers (Southward, 2008).

REMARKS

According to Pérez & Moreno (1991), in the Canaries it is an occasional to rare species on sea turtles and other floating objects.

Family CORONULIDAE Leach, 1817
Genus *Xenobalanus* Steenstrup, 1851
Xenobalanus globicipitis Steenstrup, 1851

MATERIAL EXAMINED

Three specimens, tl 24.3–26.7 mm, Gran Canaria, on pectoral, dorsal and caudal fin of a short-finned pilot whale *Globicephala macrorhynchus* (ICCM-337).

DISTRIBUTION

Worldwide on cetaceans (Southward, 2008).

REMARKS

This is the first record of the species for the Canary Islands.

Family ARCHAEOBALANIDAE Newman & Ross, 1976
Genus *Acasta* Leach, 1817
Acasta cyathus Darwin, 1854

MATERIAL EXAMINED

Two dead shells in a sponge, *Petrosia ficiformis*, rc 6.9–7.6 mm, La Gomera, 12 m (ICCM-328).

DISTRIBUTION AND REMARKS

In the east Atlantic Ocean it was only known from Madeira, where it lives embedded in sponges in the sublittoral zone, around 12 m depth (Wirtz *et al.*, 2006). Around Madeira this species seems to replace *Acasta spongites* Polli, 1795 (Southward, 2008). This is the first record of the species for the Canary Islands.

Family BALANIDAE Leach, 1817
Genus *Balanus* da Costa, 1778
Balanus trigonus Darwin, 1854

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MATERIAL EXAMINED

Sixty-one specimens, rc 2.2–12.9 mm, Gran Canaria, Lanzarote, La Palma, and Tenerife, 0–50 m, on rocks, concrete modules, floating buoys and bottom traps, also as a fouling species and as overgrowth on other balanids (ICCM-327, 340, 347, 352, 355, 357, 362, 377, 382, 388, 391).

DISTRIBUTION

Widely distributed in all tropical/subtropical seas. In the eastern Atlantic it ranges from Belgium down to South Africa (Southward, 2008). It has been reported several times on the Azores coasts from 0 to 54 m depth (Southward, 1998), and as the most common shallow subtidal barnacle in Madeira (Wirtz *et al.*, 2006).

REMARKS

This species is sometimes recorded from intertidal situations, but is more common in the sublittoral down to 100 m depth and also it is well-known as a member of the fouling community on ships (Southward, 1998, 2008). Although it is now the most abundant *Balanus* on the Canary Islands, we have not found any documented record of this species for this archipelago, apart from the check-list by Haroun *et al.* (2003). In the Canaries, it settles on floating objects, on rocky bottoms covered by algae, and on the *Diadema* barren grounds, it is very common down to around 50 m depth. Therefore, our reference material, based on many samples collected from 0 to 23 m depth, should be considered as the first record for the Canaries. This species has the usual planktotrophic larva, and like *C. stellatus*, is evidently able to maintain an abundant population among the islands (Southward, 1998).

Genus *Amphibalanus* Pitombo, 2004
Amphibalanus amphitrite (Darwin, 1854)

Synonym: *Balanus amphitrite amphitrite*.

MATERIAL EXAMINED

Ten specimens, rc 7.9–16.7 mm, Gran Canaria, Tenerife, and La Palma, 0–2 m, in mixed colony (fouling) together with three other balanids, on a ship hull, and on dikes (ICCM-351, 379, 394).

DISTRIBUTION

It is a very common fouling species, now widely distributed intertidally and sublittorally in all tropical seas. In the eastern Atlantic it ranges from Britain and The Netherlands down to southern Portugal, and from many Mediterranean locations (Southward, 2008).

REMARKS

Several colonies of scattered individuals of different size-classes observed at Charca de Maspalomas, south of Gran Canaria, 0.5–2 m, which is a coastal brackish pool receiving freshwater.

Genus *Perforatus* Pitombo, 2004
Perforatus perforatus (Bruguière, 1789)

Synonym: *Balanus perforatus*.

MATERIAL EXAMINED

One specimen, rc 18.1 mm, port of Santa Cruz de Tenerife, 0–1 m, on a jetty from a yacht marina (ICCM-380). This is the first record of the species for the Canary Islands.

DISTRIBUTION

An eastern Atlantic warm water species, known from Britain and The Netherlands down to the Spanish Atlantic coast into the Mediterranean and southward down to Luanda. The species has not yet reached Ireland or Scotland (Southward, 2008).

REMARKS

Its distribution pattern seems to be similar to that of *C. montagui*, and the short distance between the Canaries and the African mainland may have permitted its penetration into the islands. It is normally intertidal and when abundant occupies the lower half of the intertidal zone, but sometimes extends into the sublittoral as deep as 40 m (Herbert *et al.*, 2003). Despite its capacity to occur sublittorally and settle on floating objects, this species is absent on both Madeira (Wirtz *et al.*, 2006) and the Azores (Southward, 1998).

Genus *Megabalanus* Hoek, 1913
Megabalanus azoricus (Pilsbry, 1916)

MATERIAL EXAMINED

About sixty specimens, rc 6.9–41.0 mm, Fuerteventura, Gran Canaria, La Gomera, Tenerife, El Hierro and La Palma, 0–22 m, on rocks, dead shells, concrete modules, jetties, floating buoys, aquaculture sea cages, bottom traps, and as a fouling species together with other balanids (ICCM-327, 342, 350, 354, 358, 364, 371–3, 375–6, 378, 383, 385, 390). Barnacle samples taken from an archaeological site ('conchero') were sent by the first author to A.J.S., who identified them as *M. azoricus* (ICCM-387). This dumping place for shells (mainly from *Patella*) and bones, probably dated from over 800 years ago, is located at Jinámar, Gran Canaria.

DISTRIBUTION

This is an eastern warm-temperate and tropical Atlantic species (Southward, 2008). Apart from the Canaries, it is now only known on the Azores, Madeira (Wirtz *et al.*, 2006; Southward, 2008) and St Helena, inhabiting from 0 to 40 m depth (Southward, 1998).

REMARKS

Both on the Azores and Madeira, it forms bands just below low tide on exposed rocky shores (Wirtz *et al.*, 2006). In the Canaries, it is a common species more abundant in the eastern islands, Lanzarote and Fuerteventura (Franquet & Brito, 1995, as *M. tintinabulum* [sic]), which are closer to the African coasts, living from the mid-water mark to 5 m depth on rocky coasts in highly wave-exposed areas. It usually occurs in aggregates of several barnacles, up to 70 mm in height.

Megabalanus tulipiformis (Ellis, 1758)

MATERIAL EXAMINED

Twenty-five specimens, rc 5.5–32.2 mm, Lanzarote, Gran Canaria, Tenerife, and La Palma, 0–22 m, on rocks, concrete

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modules, dead shells, bottom traps, as well as on a *L. anatifera* attached to a floating buoy, and as a fouling species together with other balanids (ICCM-325, 341, 346, 353, 356, 370, 386, 393).

DISTRIBUTION

A fouling species occurring in the eastern Atlantic, now known from the French Bay of Biscay down to the western Mediterranean, and southward down to Angola (Southward, 2008). Reported from the Canaries (Pérez & Moreno, 1991), Madeira (Wirtz *et al.*, 2006; Southward, 2008), but absent in the Azores (Southward, 1998).

REMARKS

In the Canary Islands, the species has been reported to inhabit closely associated with coralliferous bottoms between 10 and 100 m of depth, frequently attached to dead branches of the tree coral *Dendrophyllia ramea* (Pérez & Moreno, 1991). Previously reported at 25–250 m depth, our findings enlarge its bathymetric range to surface level.

DISCUSSION

The barnacles listed in the present paper constitute the first scientific account on the thoracic Cirripedia of the Canary Islands, including the intertidal, shallow-water and oceanic species on animals (commensal or epizoic barnacles) and other floating objects from surface to about 150 m depth. Seventeen species, belonging to 7 families, 4 suborders and 2 orders are listed in this annotated catalogue, and seven of them recorded for the first time for the Canaries herein: *Lepas hilli*, *Conchoderma virgatum*, *Xenobalanus globicipitis*, *Chthamalus* sp., *Acasta cyathus*, *Balanus trigonus* and *Perforatus perforatus*. However, the Canaries have not yet been fully surveyed for this ecologically important group. The Canarian deep-sea forms should be catalogued in the near future, in order to have a complete check-list of the Cirripedia for the area and to better understand their ecological role and the mechanisms of colonization.

The shallow-water/oceanic barnacle species known to occur in the Canaries, Madeira and the Azores are systematically listed in Table 1, with information on depth- ranges, first citations and recent references, and geographical distribution pattern.

Adult *Lepas hilli* and *Lepas pectinata* are pelagic forms; moreover, *L. hilli* is occasionally transported on ships' hulls and on sea turtles (this paper). *Balanus trigonus* can occur to considerable depths (100 m depth), so this species might not need so many emerged island stepping stones to spread as do the purely intertidal form on the Canary coasts. *Balanus trigonus* appears to be most abundant on *Diadema* barren grounds, probably due to the intensity of grazing activity of the herbivorous *Diadema* aff. *antillarum*.

There is some confusion over the species of barnacles occurring on turtles (Southward, 2008). *Chelonibia caretta* (Spengler, 1790) was reported for Madeira and the Azores (Southward, 1998; Wirtz *et al.*, 2006), meanwhile *Chelonibia testudinaria* was cited for the Canaries (Pérez & Moreno 1991; this paper). This fact may reflect a latitudinal substitution of this epizoic barnacle.

The species of *Megabalanus* can also be carried by ships, so caution is needed when they are classed as endemics; the reported occurrence of *Megabalanus azoricus* at St Helena and from ships suggests a wider distribution (Southward, 1998, 2008). In fact, *Megabalanus* is a group of related species that had evolved in different parts of the world, but have since been distributed on ships, even before Darwin (1854) looked at them, so their geographical entity has been confused. *Megabalanus azoricus* is the species that occurs along the South European/North African coasts including the island archipelagos, and is also found on ships in the region—especially research ships that spend lots of time travelling slowly. *Megabalanus azoricus* is different from the Caribbean species, *Megabalanus antillensis* Newman & Ross, 1976, while true *Megabalanus tintinnabulum* (Linnaeus, 1758) is a Far Eastern species. In the Canaries, the species occurring is certainly *M. azoricus*, in addition to *Megabalanus tulipiformis*, which is quite different morphologically and occurs as far north as the southern Bay of Biscay (observations by A.J.S.).

Since the 1980s, *Pollicipes pollicipes* ('percebe' or 'patacabra') and *M. azoricus* ('claca') are much appreciated as food and commercially collected by hand from the coasts of Lanzarote and Fuerteventura (Franquet & Brito, 1995). No information on this activity is currently available, but we suspect that these resources are over-exploited in these islands of the Canary archipelago due to an excessive uncontrolled harvesting.

A particular problem is: how did the warm-water European barnacles, *Chthamalus* group and *Perforatus perforatus*, reach the islands? Because the occurrence of other *Chthamalus* species are based on mistaken identifications (Southward, 2008), only *Chthamalus stellatus* is found on the Azores and Madeira. However, in the Canaries there is also a small population of *C. montagui* (far less abundant than *C. stellatus*) on the east coast of Lanzarote, one of the nearest islands to the African mainland (see Crisp *et al.*, 1981). Sousa *et al.* (2000) studied the patterns of distribution and abundance of these co-occurring *Chthamalus* barnacles on the south-west coast of Portugal. *Chthamalus montagui* was significantly more abundant than *C. stellatus* in both degrees of wave action (on headlands and not) and at all tidal levels (low, mid and upper). *Chthamalus montagui* was more abundant at mid tide-level, while *C. stellatus* was more abundant on headlands. Small-scale variability (between sites) of abundance of each species was detected, while differences on a larger scale (between shores) were not significant. O'Riordan *et al.* (2004) examined the spatial variation in the recruitment (cyprids and metamorphs) of *C. montagui* and *C. stellatus* over five locations at Ireland, Spain, Portugal and Italy. They found significant differences among shores in each location. The recruitment period of both species varied with location, with recruitment beginning earlier further south. In general, recruitment of *C. montagui* and *C. stellatus* was recorded in 8 months in north-west Spain and north-east Italy, while only in 7 months in south-west Ireland. Recruitment of *C. montagui* occurred in 10 months in south-west Portugal, but no recruits of *C. stellatus* were found. In all locations there was at least one distinct peak of recruitment.

Herbert *et al.* (2007) re-surveyed the influence of recruitment and temperature on distribution of *C. montagui* and *C. stellatus* in the central English Channel from 1994 to 2004, a decade of exceptionally high sea temperatures, and found range extensions on both sides of the Channel compared to the 1950s and 1970s. Highest recruitment occurred during the warmest years. A high degree of similarity of

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annual recruitment within coastal cells was found, suggesting that local processes (hydrographic barriers and substratum) are also important. Herbert *et al.* (2009) have recently proposed that reductions in larval supply of *C. montagui* on the south coast of England caused by complex regional hydrography and suboptimal habitat quality, not caused by any gradient in adult biological performance (reproduction, growth, survival), is most likely responsible for a steep gradient in recruitment as the border (geographical boundary) is approached, although possible limitations in larval performance cannot be totally discounted.

Within the context of this paper the point is that in Morocco and Western Sahara the dominant species is *C. montagui*, but its larvae hardly spread to the Canaries and when they do they obviously do not maintain an extensive population. It should be noted that cirripeds have a number of 'bottlenecks' in their ability to colonize new habitats. First, the majority of them are cross-fertilizing hermaphrodites, and individuals have to be fairly close together to breed. Thus, successful colonization by these species demands a dense initial settlement. A second bottleneck is the length of larval life. Exceptionally, a few species such as *Chthamalus* species can self-fertilize (Wirtz *et al.*, 2006). *Chthamalus stellatus* has the usual pelagic larval phases, has a comparatively long planktonic life and is evidently able to maintain an abundant population among the islands of the Macaronesian group (Southward, 1998). Species with full planktotrophic development through six naupliar stages may live from several days to a few weeks in the plankton, depending on temperature (Wirtz *et al.*, 2006). Pannacciulli *et al.* (2009) have found that the among-samples genetic diversity in the Azorean archipelago suggested extensive connectivity in *C. stellatus* (see *Tesseropora atlantica* in Discussion for further information).

Most *Chthamalus* species do not settle on ships and are not fouling organisms but *C. proteus* can settle and grow on ships, so this is why it might be able to reach the Canary Islands from Brazil or the Caribbean (E.C. Southward, personal communication). If this is *C. proteus* it must be a recent introduction and worth investigating, and looking for it around yacht marinas.

Perforatus perforatus has failed to reach Ireland, and is certainly not found on the Azores (Southward, 1998) or Madeira (Wirtz *et al.*, 2006). Despite its capacity to occur sublittorally to 40 m depth and settle on floating objects, this species is absent on both oceanic archipelagos confirming that it is unable to cross sea barriers (Crisp & Southward, 1953). Its distribution pattern, quite similar to that *C. montagui*, and the short distance (100 km) between the Canaries and the African mainland may have permitted its penetration into these islands, as far as Tenerife in the central group within this archipelago, but only one specimen has been found.

Oxynaspis celata Darwin, 1851 (Lepadomorpha: Oxynaspidae) was originally recorded for the Madeira archipelago and is presently reported from there on bushes of the black coral *Antipathella wollastoni* (Gray, 1857), from 35 m downwards (Wirtz *et al.*, 2006). However, no specimens have been found to date around the Canary Islands.

Megatrema anglicum (Sowerby, 1823) (synonyms: *Pyrgoma anglicum* and *Boscia anglicum*) (Balanomorpha: Pyrgomatidae) has been recorded for the Madeira archipelago (Darwin, 1854; Wirtz *et al.*, 2006). Its vertical distribution extends from low water mark to 80 m, and it lives singly or with several others, spaced around the rim of a living solitary coral. It has been reported from Brittany, the Mediterranean, Madeira and the Cape Verde Islands (Southward, 2008). However, apart from a non-documented citation of this species in the Canaries in the check-list by Haroun *et al.* (2003), no specimens have been found by us around the Canary Islands.

A particular problem is posed by the relict barnacle *Tesseropora atlantica* Newman & Ross, 1976 (Balanomorpha: Tetraclitidae) found so far only in Bermuda, the Azores (Southward, 1998), St Paul's Rocks and recently in Madeira where living individuals have been recorded (Wirtz *et al.*, 2006). According to Hawkins *et al.* (2000), the Mediterranean/Atlantic interface, which includes Macaronesia, has clearly generated considerable differentiation of populations leading to allopatric speciation, including the generation of some endemic species. Greater differentiation has occurred in limpets with their shorter length of larval life (*Patella* spp., 1–2 weeks) than in barnacles (*Chthamalus* spp., 3–6 weeks). The Azores (and possibly Madeira) is also a refuge for at least one Tethyan relict species (*T. atlantica*) which may also have endemic status (Hawkins *et al.*, 2000). It has never been found on the shores of the continents on the eastern side of the Atlantic (Wirtz *et al.*, 2006). In Madeira, as in the Azores, it grows very low down in the intertidal zone, where it is wetted by waves, but where it is also sheltered from sunlight; typically it is on the undersides of boulders or in crevices (Wirtz *et al.*, 2006; observations by A.J.S.). A final bottleneck in the spread of this species is that adults incubate their lecithotrophic larvae to the cypris stage before release, thus restricting larval dispersal to a few days or else requiring some unknown vector (Wirtz *et al.*, 2006). How does it reach isolated islands? Within this context, Pannacciulli *et al.* (2009) compared the genetic structure of *C. stellatus* and *T. atlantica* in the Azores; the two barnacles differ as regards life cycle: the former conducting pelagic life for about 22 days, the latter for only 24 hours. Their results were consistent with expectations based on species life history and corroborate the importance of pelagic stages in determining the degree of genetic structuring in benthic marine invertebrates. These authors have found that the among-samples genetic diversity in the Azorean archipelago suggested isolation.

Despite the apparent absence of *Oxynaspis celata*, *Megatrema anglicum* and *Tesseropora atlantica* on the Canary Islands coasts, we cannot dismiss the possibility of finding them on this archipelago in view of their current geographical distribution and ecological requirements.

Thus, it seems that the majority of barnacle species apparently have difficulty reaching the Atlantic islands from the European or African mainland. It is necessary to postulate 'rafting' on floating objects, transport on larger animals (sea turtles, marine mammals, etc.), or the existence of island 'stepping stones' now vanished. There is also the possibility that remote dispersal by fouling on ships has taken place since maritime trade with the Atlantic islands began ~600 years ago (Southward, 1998; Wirtz *et al.*, 2006). Another point is that, if global warming continues, some tropical species might arrive and colonize on the Canary coast, in particular some chthamalid and balanid species coming from the eastern tropical Atlantic, for instance from the Cape Verde Islands.

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