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## Cirripedia of Madeira

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**Abstract** We give a list of Cirripedia from Madeira Island and nearby deep water, based on specimens in the collection of the Museu Municipal do Funchal (História Natural) (MMF), records mentioned in the literature, and recent collections. *Tesseropora atlantica* Newman and Ross, 1976 is recorded from Madeira for the first time. The *Megabalanus* of Madeira is *M. azoricus*. There are 20 genera containing 27 species, of which 22 occur in depths less than 200 m. Of these shallow water species, eight are wide-ranging oceanic forms that attach to other organisms or to floating objects, leaving just 13 truly benthic shallow water barnacles. This low diversity is probably a consequence of the distance from the continental coasts and the small area of the available habitat. No endemic species have been found.

**Keywords** Cirripedia · Barnacles · Biogeography · Island faunas

### Introduction

Madeira and its associated islands is the smallest among the three groups of islands in the warm temperate region of the NE Atlantic (Fig. 1), and its terrestrial fauna and flora have attracted much attention from biogeogra-

phers. The marine invertebrates have been less studied and there has been no compilation of cirripede records for Madeira, comparable to those for the Azores archipelago (Young 1998a; Southward 1999). We here summarize records from Madeira and nearby deep water and discuss their biogeographical implications.

### Methods

The records are based on (1) the work of R.T. Lowe, who sent specimens to Charles Darwin; (2) material in the Museu Municipal do Funchal (História Natural) (MMF); (3) casual collecting carried out by residents or visitors to the island; (4) several hundred SCUBA dives in a depth range of 1–60 m, from 1992–2005 (Fig. 2) and (5) ad hoc surveys in spring 2005 (Fig. 2). The species listed include those noted by Darwin (1851, 1854) and Gruvel (1905). For each species, we note whether a specimen is present in the collection of the Museum (MMF). The classification follows Newman and Ross (1976), Newman (1996), Young (1998b) and Pitombo (2004).

### Results

#### Suborder Heteralepadomorpha

##### Family Heteralepadidae

*Heteralepas cornuta* (Darwin, 1854)

MMF: no

Several specimens attached to whip coral at Seine Seamount, 170–180 m depth, approximately 250 km north-east of Madeira Island. This species is common off the Azores and the Canaries (Young 1998a; Southward 1999; Buhl-Mortensen and Newman 2004; A.J. Southward, personal records). Reported by Darwin (1851) as *Alepas cornuta*, but only from the West Indies.

*Heteralepas microstoma* Gruvel, 1902

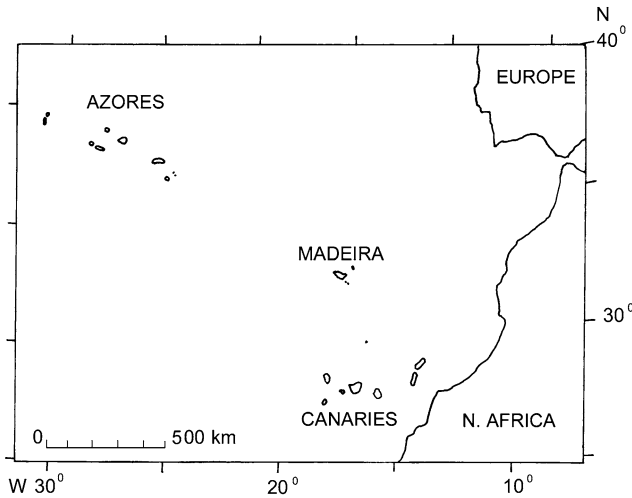
MMF: no

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**Fig. 1** The position of Madeira relative to the continental coasts and to the other NE Atlantic islands with warm-temperate climates

On octocorals in several hundred metres depth; see Young (1998a).

#### Suborder Lepadomorpha

##### Family Oxynaspidae

*Oxynaspis celata* Darwin, 1851

MMF: yes

Described by Darwin (1851, p. 134) as “attached in numbers to an *Antipathes*; Rev. R.T. Lowe”. Presently common on bushes of black coral, *Antipathella wollastoni*, from 35 m downwards; colour photo in Wirtz and Debelius (2003); see also Wirtz (2001).

##### Family Poecilasmatidae

*Poecilasma aurantia* Darwin, 1851

MMF: yes

The original description by Darwin (1851, p. 105) is based on material from Madeira, collected by R.T. Lowe (“attached to the rare *Homola cuvieri*”). Presently common on the deep-water crab *Chaceon affinis*.

*Poecilasma crassa* Gray, 1848

MMF: yes

Recorded by Darwin (1851, p. 107) as “attached to *Homola cuvieri*, Rev. R.T. Lowe”. Common on the deep-water crab *C. affinis*; see Young (1998a) and Southward (1999).

*Octolasmis lowei* (Darwin, 1851)

MMF: no

Described by Darwin (1851, p. 128, as *Dichelaspis lowei*), “attached to a rare Brachyurous crab”. No recent records.

##### Family Lepadidae

*Lepas anatifera* Linnaeus, 1758

MMF: yes

The commonest pedunculate barnacle on buoys and floating objects; colour photo in Wirtz and Debelius (2003).

*Lepas hilli* Leach, 1818

MMF: yes. The specimen in the collection of the Madeira Natural History Museum (registration number MMF 27213 from 02 Oct 1963) has no location data. It is thus not entirely certain (but most probable) that it comes from Madeiran waters.

*Lepas pectinata* Spengler, 1793

MMF: yes. The specimen in the museum collection comes from a buoy washed ashore at Selvagem Grande Island.

*Dosima fascicularis* (Ellis et Solander, 1786)

MMF: no

This species forms its own float. Juvenile specimens were encountered floating at the surface near Seine Seamount.

*Conchoderma aurita* (Linnaeus, 1758)

MMF: yes

From a floating buoy near Garajau, south coast of Madeira Island.

*Conchoderma virgata* Spengler, 1789

MMF: yes

Frequent on *Caretta caretta* caught near Madeira Island, occasionally on floating buoys.

#### Suborder Scalpellomorpha

##### Family Calanticidae

*Smilium acutum* (Hoek, 1883)

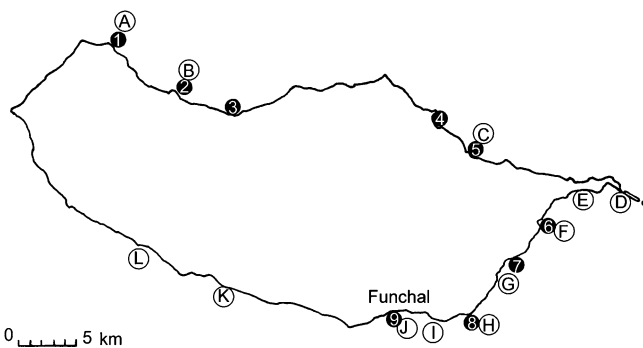
MMF: no

Occurs deeper than 1500 m. See Young (1998a).

#### Suborder Verrucomorpha

##### Family Verrucidae

*Verruca spengleri* Darwin, 1854



**Fig. 2** The locations investigated in Madeira. Intertidal stations shown as numbers on filled circles: 1 Porto Moniz; 2 Seixal; 3 São Vicente; 4 Faial, beach; 5 Porto da Cruz; 6 Machico; 7 Santa Cruz; 8 Caniço de Baixo, Reis Magos; 9 Funchal, harbour and marina. Sub-littoral SCUBA-diving stations, worked by the first author, shown as letters on open circles: A Porto Moniz; B Seixal; C Porto da Cruz; D Baía d’Abra; E 1 km east of Caniçal; F Machico bay and small sea mount in front of bay; G Porto Novo; H Caniço de Baixo; I Garajau; J Lido do Funchal; K Ribeira Brava; L Calheta

MMF: yes

The original description by Darwin (1854, p. 521) is based on specimens from Madeira (“Museum Lowe”). See also Young et al. (2003). Common in dark places from low water level downwards, e.g. under stones and on the walls of caves.

#### Suborder Balanomorpha

##### Family Chthamalidae

[*Chthamalus montagui* Southward, 1976

MMF: no

This species is figured by Morton et al. (1998; pp. 39, 40) in a diagram of the intertidal fauna at Caniço de Baixo, south coast of Madeira. The record appears to be a confusion of its occurrence somewhere else, perhaps on Lanzarote in the Canary Islands (Crisp et al. 1981). We have intensively searched for this species on the shores of Madeira but did not encounter it.]

*Chthamalus stellatus* (Poli, 1795)

MMF: yes

*Chthamalus stellatus* is the common intertidal barnacle of Madeira Island, present on all rocky shores and in harbours.

##### Family Chelonibiidae

*Chelonibia caretta* Spengler, 1790

MMF: yes

Common on *C. caretta*. Southward (1999) identified specimens of *Chelonibia* from the Azores as being this species; the *C. caretta* from Madeira belong to the same population of turtles (Bolten et al. 1998).

##### Family Coronulidae

*Coronula diadema* Linnaeus, 1758

MMF: yes

Dry shells without tissues in the Museum; records state that they are from a fin whale.

##### Family Platylepadidae

*Stomatolepas elegans* (Costa, 1838)

MMF: yes; specimens taken from a leatherback turtle, *Dermochelys coriacea*.

A worldwide distributed species.

##### Family Tetraclitidae

*Tesseropora atlantica* Newman and Ross, 1976

MMF: yes

This species was the first record of living *Tesseropora* in the Atlantic, other extant species being restricted to the Indo-Pacific. The original description by Newman and Ross (1977) was based on specimens from Bermuda, but also included material from the Azores. Later the species was recorded from St. Paul’s Rocks in the South Atlantic (Edwards and Lubbock 1983). It has never been found on the continents on the eastern side of the Atlantic. It has been regarded as a relict species belonging to a genus more widely distributed in previous epochs (Carriol 1993). In 1997, Paulo Young visited Madeira and collected Cirripedia. In a letter of 5 Nov 1997 to the first author, he wrote that he had collected “*Tesseropora* sp. (provavelmente uma espécie que desc-

revi para os Açores)”, i.e. he believed he had collected *Tesseropora arnoldi* Young, 1998. This was a species he had erected to cover the Azores specimens of the genus, which he thought differed morphologically from the Bermudan form, as described by Newman and Ross (1977). Southward (1999) examined new material from both the Azores and Bermuda and found the supposed morphological differences were not apparent when large numbers of specimens were examined. Paulo Young died in a traffic accident in 2004; his Madeiran specimens are probably in the collection of the Natural History Museum in Rio de Janeiro. We have now collected specimens of *Tesseropora* from under stones at low tide level, Reis Magos, Caniço de Baixo, south coast of Madeira, and at Seixal on the north coast. We are classifying these as *T. atlantica* pending investigations of the DNA of the specimens. There is a current project to examine within island and between island genetic variation in this species in the Azores and Madeira. *T. atlantica* is interesting because it retains the developing larvae to the cyprid stage before release, and hence might be regarded as having poor larval dispersal capabilities (Newman and Ross 1977; Southward 1999).

##### Family Archaeobalanidae

*Elminius modestus* Darwin, 1854

MMF: yes

*Elminius modestus* colonized NW Europe from New Zealand during World War II, carried by shipping (Bishop 1947; Crisp 1958). A single specimen was found in the marina at Funchal in May 2005.

*Acasta cyathus* Darwin, 1854

MMF: yes

By an oversight, this species was not listed in the Cirripedia section of the European Register of Marine Species (Southward 2001). The original description is from Madeira (Darwin 1854, p. 312, “Museum Lowe”). The species lives embedded in sponges such as *Petrosia ficiformis*. Collected at Madeira by the late P. Young (personal communication). Recently found at Caniço de Baixo, in 12 m depth.

##### Family Pyrgomatidae

*Megatrema anglicum* (Sowerby, 1823)

MMF: yes

Commensal on solitary, azooxanthellate scleractinian corals; recorded by Darwin (1854, p. 360) from Madeira, but no details given. Common in a cave off Caniço, 9 m depth on *Polycyathus pulchellus*. Colour photo in Wirtz and Debelius (2003).

##### Family Balanidae

Subfamily Amphibalaninae (cf. Pitombo, 2004)

*Amphibalanus amphitrite* (Darwin, 1854)

MMF: yes

Now of worldwide occurrence, this species was thought to have been carried by shipping from the Indo-Pacific to the Atlantic in the late nineteenth century. However, archaeological investigations show that it was abundant in the naval harbour at Carthage in the second century BC, so it was established in the Mediterranean over 2,000 years ago (A.J. Southward, personal

identification). Discovered in May 2005 in the harbour at Funchal, both in the marina and on the outer mole near the berth for the ferry to Porto Santo, but not very abundant, less than 1 individual/dm<sup>2</sup>. May well be periodically reintroduced from ships. It was not found in the Azores in 1997 though previously recorded there (Southward 1999).

Subfamily Balaninae

*Balanus spongicola* Brown, 1844

MMF: yes

Recorded by Darwin (1854) “with *B. tulipiformis*, Museum Lowe”. Recently collected on dead branches of *A. wollastoni* off south-east Madeira, in about 30 m depth, near Caniçal in 27 m and in Baía d’Abra at 25 m. It often occurs mixed with *Megabalanus tulipiformis*.

*Balanus trigonus* Darwin 1854

MMF: yes

Darwin (1854) recorded this species only from the Pacific Ocean and the East Indian archipelago. It has since been spread by ships to the Atlantic (Zullo 1992), and was recorded at Madeira by Pilsbry (1916). It is the commonest shallow subtidal barnacle in Madeira, covering bare rocks in great numbers. It occurs at low tide level in Funchal Harbour and Marina and in the harbour at Machico. It was also collected from a dead branch of *A. wollastoni* in about 30 m depth. Colour photo from Madeira in Wirtz (1995).

Subfamily Megabalaninae

*Megabalanus azoricus* Pilsbry, 1916

MMF: yes

Recorded by Darwin (1854, p 196 “on rocks”) as *Megabalanus timtinnabulum*; probably this was material sent by Lowe. Examination of this common species by the authors has now shown it to be *M. azoricus* Pilsbry, (Pilsbry 1916, p. 62), which is also present in St Helena and the Canaries (Henry and McLaughlin 1986; A.J. Southward, personal identification). As in the Azores (Southward 1999), the species forms bands just below low tide on exposed rocky shores. Photo from Madeira in Wirtz and Debelius (2003).

*Megabalanus tulipiformis* (Ellis, 1758)

MMF: yes

Recorded from Madeira by Darwin (1854, p. 205, “Museum Lowe”). Recently found on dead branches of *A. wollastoni* off south-east Madeira, in about 30 m depth near Caniçal and in 27 m off Ponta da Saõ Lourenço. It often occurs mixed with *B. spongicola*.

## Discussion

The total number of barnacle species so far recorded for Madeira (27) is less than for the Azores Islands (52), which are, nevertheless, farther away from the mainland coasts. However, much of the difference is made up of species that occur below 200 m (5 for Madeira, 33 for the Azores), and thus appears to be a result of the small amount of deep water dredging carried out off Madeira compared with the Azores. If we take the species

occurring in less than 200 m, 22 were recorded here for Madeira and 19 for the Azores. The small difference is related to the slightly larger number of pelagic species noticed at Madeira, i. e. species attached to other organisms and floating objects. Of the truly benthic shallow water barnacles, Madeira has 13 and the Azores 12. There are no endemic species; all but one of the records are of species present on the neighbouring coasts of mainland Europe and North Africa. The exception is *T. atlantica*, known from other Atlantic islands, including Bermuda.

The low diversity of barnacles in Madeira and the Azores is in contrast to the abundance of seaweed species, especially the Rhodophyta (Neto et al. 2001; Titley 2002). It is not clear how much time has been available for colonization of Madeira by the present warm-temperate fauna. Geological evidence places the underwater origin of the island over a hot spot as far back as 75–130 Ma, but the first shallow water communities seem to have been tropical coral reefs in the late Miocene (Da Silva Mata 1997; Geldmacher and Hoernle 2000; Sziemer 2000).

It should be noted that cirripedes have a number of ‘bottlenecks’ to their ability to colonize new habitats. First, the majority 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. Exceptionally, a few species such as *C. stellatus* and other species of the genus can self-fertilize, while others, mostly pedunculate forms but including some balanomorphs, have dwarf or complementary males that settle on hermaphrodites or females and can impregnate them. A second bottleneck is the length of larval life. Species with full planktotrophic development through six naupliar stages (the majority) may live from several days to a few weeks in the plankton, depending on temperature, but this still limits their dispersal. The absence of *Balanus perforatus* from both Madeira and the Azores confirms that this species is unable to cross sea barriers (Crisp and Southward 1953), in spite of its capacity to occur sub-littorally to 40 m depth and settle on floating objects (Herbert et al. 2003; E.I.S. Rees, personal communication). A final bottleneck concerns species such as *T. atlantica*, which incubate their lecithotrophic larvae to the cyprid stage before release, thus restricting larval dispersal to a few days or else requiring some unknown vector. Thus, the majority of barnacles would have difficulty reaching the Atlantic islands from the European or African continents. It is necessary to postulate ‘rafting’ on floating objects, transport by larger animals, or former island ‘stepping stones’. There is also the possibility that remote dispersal by fouling of ships has taken place since human occupation of the Atlantic islands began, 600 years ago.

The record of *T. atlantica* for Madeira increases the known range of this species, which can still be regarded as a probable insular relict (Newman and Ross 1976; Southward 1999). The genus was more widespread in the

European Oligocene and Middle Miocene, being recorded from formations in the Mediterranean and the Atlantic region of France (Carriol 1993, 2005).

A barnacle that can be a common fouler of ships, *Balanus eburneus*, would have been expected to occur in estuaries and other areas of reduced salinity in Madeira, as it does in the Azores, but examination of several ribeiras failed to disclose any. Most of the lower parts of the ribeiras in Madeira have recently been canalized with concrete revetments and their fresh water input reduced by abstraction higher up the mountains, probably making the habitat unsuitable for this barnacle.

Summing up, the shallow water barnacles of Madeira can be said to have low diversity, like those of the Azores (Southward 1999). Madeira is closer to the mainland of North Africa, 620 km measured from the Desertas, and might have been expected to have greater barnacle biodiversity than the Azores, which are over 1,200 km away from continental Portugal. However, we have to take area as well as distance into account when studying island faunas, as stressed by MacArthur and Wilson (2001). The area of shallow water habitat, from 0 to 200 m depth, provided by Madeira, Porto Santo and the Desertas taken together (1,040 km<sup>2</sup>), is only half that available around the Azores (2,130 km<sup>2</sup>). We could speculate that the smaller size of Madeira counterbalances its position closer to the mainland coast. The Canary Islands, which are only 100 km from N Africa, provide much more habitat for shallow water barnacles (4,980 km<sup>2</sup>) so that by both distance and area they should have a potential for higher diversity. The Canaries have not yet been fully surveyed for Cirripedia, but we know that they are inhabited by at least two species, *Chthamalus montagui* and *Pollicipes pollicipes*, which are not found in Madeira or the Azores.

An alternative hypothesis (disregarding area and considering only distance) would be that only a subset of the continental barnacle species reaches Madeira and a still smaller subset reaches the more distant Azores.

*Tesseropora atlantica* has a wider distribution than might be expected from its short dispersal phase. In theory this would lead to greater local genetic diversity than expected in a co-occurring species such as *Chthamalus stellatus*, which has the typical barnacle set of six free-swimming nauplius stages. There is evidence from other habitats that species with a short larval phase may indeed show more genetic diversity than those with a long larval phase, but it is not possible to generalize (Arndt and Smith 1998, and references therein; Luttkhuizen et al. 2003; Nishikawa et al. 2003)

In apparent contrast with the barnacles, the common limpets (*Patella*) of the Atlantic islands appear to have diverged from those on the continental mainland, some becoming distinct species (Hawkins et al. 2000; Weber and Hawkins 2005). The most abundant intertidal barnacle of Madeira and the Azores, *Chthamalus stellatus*, shows no genetic differences from the mainland populations (Hawkins et al. 2000), and it has been suggested

that either there is panmixia related to wide dispersion of larvae or else the species is a relative newcomer to the islands.

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