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ORIGINAL PAPER

Extraordinary abundance of hydrocorals (Cnidaria, Hydrozoa, Stylasteridae) in shallow water of the Patagonian fjord region

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Abstract During two scuba-diving expeditions in 2005 and 2006, stylasterids were documented and sampled from fjords and channels in the Central Patagonian Zone, Chile. At 15 of a total of 33 sampling sites we found colonies of *Errina antarctica*. We discuss the observed distribution patterns and the variability of colony shapes. In some regions we found *E. antarctica* to occur in extraordinary high densities on primary and secondary hard substratum below 10 m. In the archipelago Madre de Dios we discovered large colonies of *E. antarctica* covering areas of more than 10,000 m² with coverage exceeding 80%. The dense accumulations of *E. antarctica* have reef-like structure and form complex habitats. At one site we observed extensive mechanical damage to the corals that may result from coral extraction by divers and/or from boat anchors. Slow growth, fragility, scarceness and the lack of knowledge on their ecology make these spectacular and unique biocenoses very susceptible for damages and require protection and further studies.

Keywords Stylasteridae · Southern Chile · Patagonia · Shallow water · Benthos · Fjords

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Introduction

After the scleractinians, stylasterinae (Cnidaria, Hydrozoa) are the next large group of calcified cnidarians in number of species (Cairns 1999). They can be found in all oceans, in shallow water as well as in the deep sea, but most of the approximately 250 described species worldwide, live between 200 and 500 m depth (Cairns 1983b, 1984, 1992). Nevertheless, comparably few publications deal with stylasterids.

Of the 13 stylasterid species recorded for Chile, 10 were exclusively found south of Cape Horn in depths between 87 and 2,355 m depth, with only some records of *Errina labiata* shallower than 200 m; only two species are recorded from the Chilean coast proper, *Errina antarctica* form *moseleyi* from 18 to 119 m in the southern Chilean fjords (50–55°S) and *Allopora profunda* from 631 m in the Golfo de Penas (48°S) (Cairns 1983a). *Errina antarctica* is also known from the Falkland Islands and the Burdwood Bank in the Scotia Arc (approx. 54°S; 57–62°W) down to 771 m, but occurs rarely deeper than 300 m. *Errina antarctica* form *moseleyi*, originally described as *Labiopora moseleyi* by Ridley (1881), is characterized by having larger, more erect colonies with thick, flattened branches and distinguishable anterior and posterior sides. It is recorded from shallow water between Punta Rosario, Madre de Dios Arquipelago and Tierra del Fuego.

The Central Patagonian Zone between Golfo de Penas and the Straits of Magellan (Pickard 1973; Viviani 1979; Stuardo and Valdovinos 1992) is one of the least studied marine regions in the world (Arntz 1999; Escribano et al. 2003), mainly due to its remote location, difficult accessibility and harsh weather conditions. The hard bottom benthos is largely unknown and the shallow water, steep wall habitats that form an important portion of the sea bottom in the channels and fjords have never been sampled before. As part of an ongoing initiative to describe and map the benthic invertebrate communities of the Chilean fjord region, two scuba-diving expeditions were carried out in the region between 48 and 52°S in the Central Patagonian Zone. Here we found large colonies of *E. antarctica* in channels from 10 m downward that can locally form dense, three-dimensional reef-like aggregations. Although similar in appearance to stylasterid accumulations in New Zealand fjords (Miller et al. 2004) and from the Southern Californian Channel Islands (Gibson 1893; Ostarello 1973), extension and densities of the accumulations and maximum colony sizes of Patagonian stylasterids appear to be exceptionally high. The following is the first description of these dense stylasterid accumulations.

Materials and methods

Between 1997 and 2005, scuba diving surveys were undertaken by the authors along the Chilean coast between Arica (15°S) and Punta Arenas (55°S) with a focus on the Chilean fjord region between 42 and 45°S. During four expeditions to the Northern Patagonian Zone and an ongoing research project in the fjord Comau (since 2003), numerous dives were made at more than 100 sites, mainly on rocky substrate, down to 35 m (occasionally to 40 m) depth. During two expeditions in 2005 and 2006 to the Central Patagonian Zone between the Golfo de Penas (48°S) and Puerto Natales (approx. 52°S), 35 dives were made at 33 sites down to 40 m depth (Fig. 1). The study sites were chosen to best represent hard substrata habitats of the channels in the area. For fjord habitats, we selected several sites along the fjords Bernardo and Tempano (approx. 48° 30′S, 48°45′S; Fig. 1). Due to poor benthic life in sediment deposit areas within the continental fjords, a phenomenon that can also be observed in other fjord regions (Carney et al. 1999), we concentrated on dive sites with steep, preferably vertical rock walls where sediment stress for epibenthic organisms is less. Temperature data was taken from the dive computers; salinity of water samples from different depths was measured with a density gauge. More than 300 (2005) and more than 800 (2006) samples of macro-epibenthic organisms were photographed in situ, collected, preserved and sent to taxonomic specialists for identification. Structure- and habitat-forming species were given special attention. At some sites with exceptional high densities of stylasterids conservative approximations for coverage and densities were estimated from photos. This was done by scaling photos of stylasterid aggregations through measured sizes of single stylasterid colonies on these photos or through conservative size estimations of other known invertebrate species on the photos. The extent of areas dominated by stylasterids was estimated based on the maximum area observed during dives and therefore constitutes minimum values. Sampled colonies or fragments of colonies were preserved in 96% ethanol or dried. Stephen Cairns, Smithsonian Institution, identified all stylasterids.

Abbreviations used in the text include: IZUA—Instituto de Zoología de la Universidad Austral de Chile; NMNH—Nacional Museum of Natural History, Smithsonian, Washington, DC.

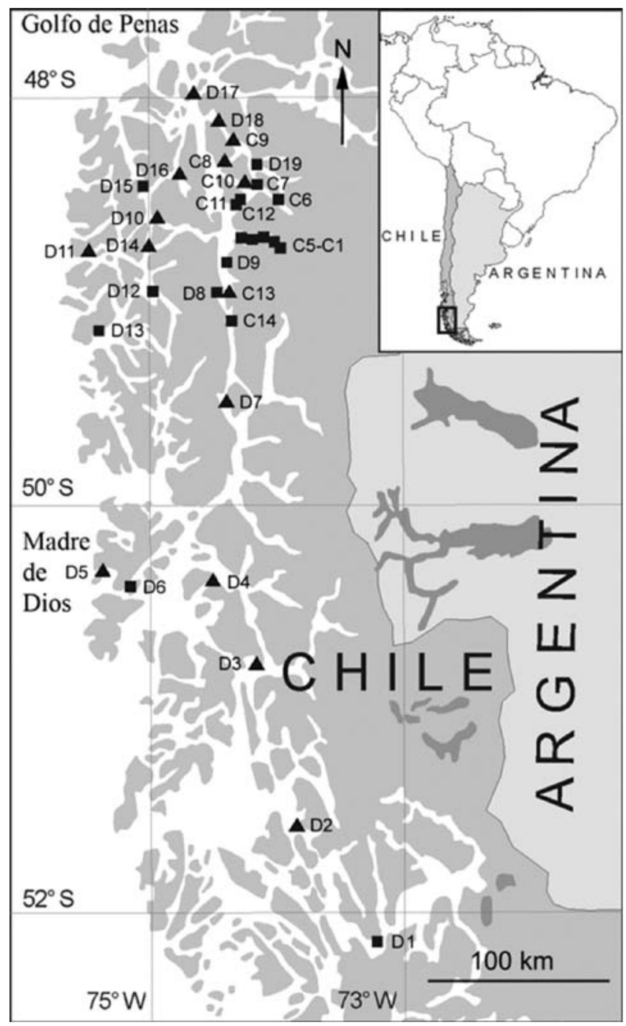

Fig. 1 Map of study sites in the Central Patagonian Zone. Study sites: C1-C14 (2005) and D1-D19 (2006). *Quadrates*: study sites without stylasterids; *triangles*: study sites where *Errina antarctica* was found

Collected and deposited material

If not stated otherwise, collected by the authors.

Errina antarctica

SE of Isla van der Meulen, 48°17′13.0′′S; 74°20′10.0′′ W, 25 m, 28.3.2005 (nr HF2-125) (NMNH 1092842); Canal Caldcleugh, 48°21′37′′S; 74°26′13′′W, 32 m, 28.3.2005 (nr HF2-144[1]) (NMNH 1092846); Isla Guarella, Arquiepelago Madre de Dios, approx. 50°20′S, approx. 20 m, May 2003, leg. Marcos Gonzalez (NMNH 1092843); Grupo Dacres, 51°36′20.8′′S, 73°55′33.8′′W, 20 m, 7.3.2006 (nr. HF3-0027); Canal Pitt Chico, 50°50′07.1′′S, 74°08′20.9′′W, 7.3.2006, 22 m (nr. HF3-0037); Canal Adalberto, 48°36′28.7′′S, 74°53′55.7′′W, 18 m, 12.3.2006 (nr. HF3-0163); Canal Copihue, 50°20′23.1′′S, 75°22′39.2′′W, 20 m, 9.3.2006, leg. Philippe Willenz (IZUA-CNI-0136); Canal Magdalena, Magellan area, 30 m, approx. 53°S, leg. Claudio Barría (NMNH 1092857 = piece of IZUA-CNI-0024).

Errina sp.

Golfo de Ancud, approx. 42°S, 80 m, leg. Germán Pequeño (NMNH 1092859 = piece of IZUA-CNI-0025).

Results

Study sites where *E. antarctica* was found by the authors:

Expedition 2005: Isla van der Meulen SE, 48°17′30′′S, 74°20′10′′W, 28.3.2005; (close to) Canal Messier, Isla Caldcleugh W, 48°21′37′′S, 74°26′13′′W, 28.3.2005; Estero Caldcleugh, N shore, Canal Caldcleugh, 48°24′46.4′′S, 74°18′23.6′′W, 29.3.2005; Angostura Inglesa, Canal Messier, 48°58′29′′S, 74°25′16.9′′ W, 1.4.2005.

Expedition 2006: Grupo Dacres, 51°36′20.8′′S, 73°55′33.8′′W, 7.3.2006; Canal Pitt Chico, 50°50′07.1′′S, 74°08′20.9′′W, 7.3.2006; Canal Artilleria, 50°24′52.4′′S, 74°33′33.1′′W, 8.3.2006; Canal Copihue, 50°20′23.1′′S, 75°22′39.2′′W, 9.3.2006; Paso del Abismo, 49°34′38.7′′S, 74°26′49.3′′W, 10.3.2006; Canal Adalberto, 48°36′28.7′′ S, 74°53′55.7′′W, 12.3.2006; Canal Castillo, 48°44′11.4′′S, 75°24′53.1′′W, 12.3.2006; Canal Cochrane, Boca west, 48°49′33.5′′S, 75°03′06.5′′W, 14.3.2006; Seno Waldemar, 48°23′48.5′′S, 74°43′48.8′′W, 15.3.2006; Isla Millar, 47°58′45.4′′S, 74°40′47.0′′W, 15.3.2006; Canal Ofhidro, 48°09′52.1′′S, 74°23′48.4′′W, 16.3.2006.

[1] Form uncertain

In fjords and channels of the Central Patagonian Zone between the Golfo de Penas (approx. 48°S) and Puerto Natales (approx. 52°S) specimens of *E. antarctica* were present at 15 of 33 study sites between 10 and 40 m depths: of the 20 study sites in the channels, *E. antarctica* was present at 11 sites; within the fjords Tempano and Bernardo, *E. antarctica* was present at four of 13 study sites (see Fig. 1), but only at those closest to the mouths of the fjords. Despite more sampling effort in the Northern Patagonian Zone, we could not find the species in the fjords or channels between Puerto Montt (41°30′S) and Puerto Chacabuco (45°30′S). Colonies grow on rock as well as on secondary hard substratum such as barnacles or stems of dead gorgonians and vary in diameter from a few centimetres to over 40 cm. The colonies inhabit mainly steep walls, but at some sites also horizontal portions of steps or the bottom of flat U-shaped channels. On vertical walls that are exposed to moderate and strong currents, *E. antarctica* tends to form mainly two-dimensionally branched, fan-like colonies (here called form A) with flattened branches. The "fans" are orientated vertically on the rock wall and thus perpendicular to a horizontal current (Fig. 2 c, d). On a horizontal substrate specimens grow in bushy colonies (here called form B) (Fig. 1 a, g). The branches of these colonies have a round cross section, pointed tips and the branches are distributed and oriented approximately equal in all directions, very much resembling the colony form of the scleractinian *Seriatopora* from tropical reefs. Transitional forms between form A and B are common, with form A being more similar to what is described as *Errina antarctica* form *moseleyi* than form B. Population densities of form A were observed to vary between sites from a few scattered small colonies to up to 20 colonies/m² on vertical walls in the Canal Pitt Chico (Fig. 2c). Where morphology tended towards form B, densities were generally high with highest densities observed on the bottom of a flat channel in the Archipiélago Madre de Dios with estimated coverage of up to 80% (Fig. 2a, f). Here, the species was found to dominate the benthos on a surface of at least 50 × 200 m (10,000 m²). While living portions of the colonies are used as substrate by many sedentary organisms such as the crinoid *Antedon rosacea*, the ophiurids *Gorgonocephalus chilensis* and *Ophiacantha rosea* and the sea anemone *Metridium senile lobatum*, dead portions of the colonies are colonized by a multitude of sessile, sedentary, mobile and boring organisms (Fig. 2b) among which the polychaetes *Chaetopterus* sp., the crustaceans *Pagurus comptus* and *Paralomis* aff. *granulosa*, the sea urchin *Arbacia dufresnei* and the starfish *Lophaster stellans* and various not yet identified sponges and bryozoans belong to the most eye-catching representatives.

Discussion and conclusions

Growth form

The robustness and shallow-water occurrence of *Errina antarctica* form *moseleyi* was explained by its inclusion in nutrient-rich upwelling waters of the Chilean fjords Cairns (1982; 1983a). Although Chilean fjords are not under the influence of upwelling of the Humboldt system (Barber and Smith 1981) they may indeed be rich in nutrients due to local factors and phenomena (Pizarro et al. 2000). A similar phenomenon with a large growing shallow-water form is known from the deep-water scleractinian coral *Desmophyllum dianthus*. Large pseudo-colonies can be found in high densities in shallow water of the northern Chilean fjords (Försterra and Häussermann 2003). A connection between nutrient supply and colony morphology has never been tested. But as in *Desmophyllum dianthus*, physical factors like currents and sedimentation may determine colony form in *E. antarctica* more than nutrient-richness.

The fan-like two-dimensional colonies of *Errina antarctica* on steep walls (form A) are always oriented vertically and perpendicular to a horizontal current. This colony shape and orientation minimizes surface that can be affected by sediment running off the slopes or originating from the water column while it maximizes colony surface facing the current. The three-dimensional bushy colony type (form B) was found on moderate slopes and horizontal portions of channels with moderate to strong currents, closer to the open

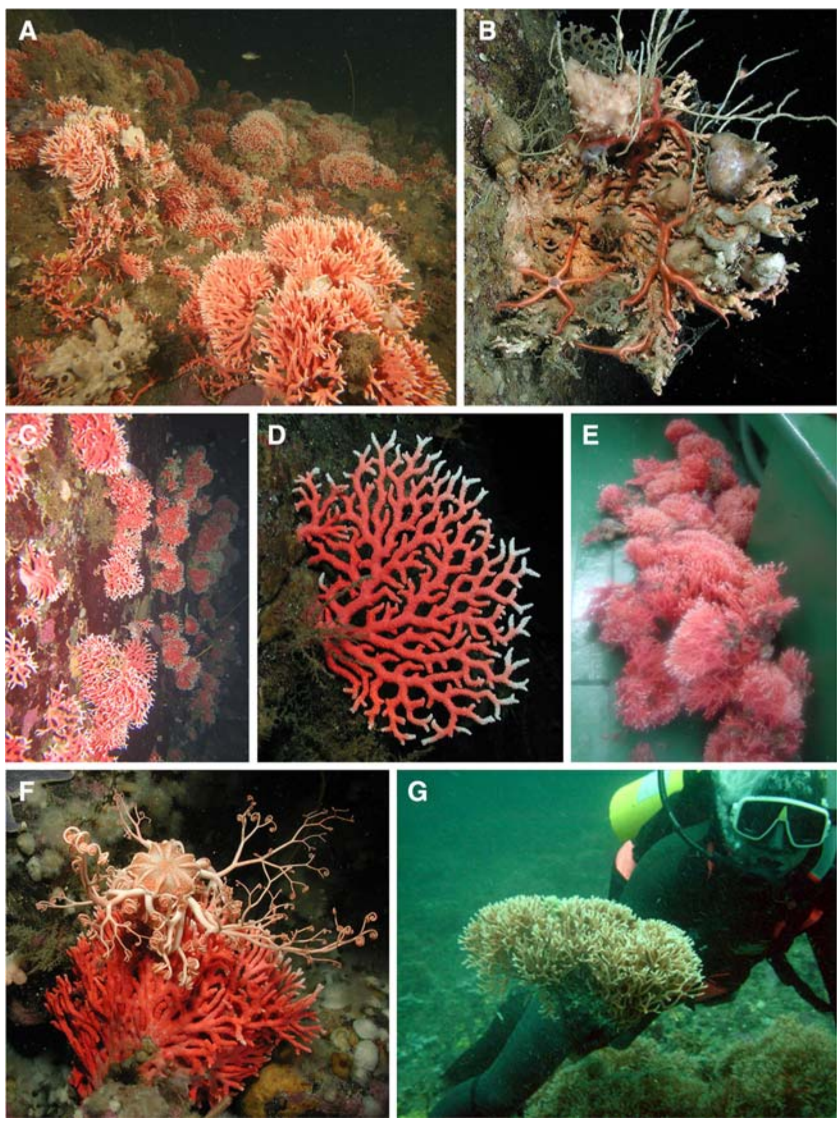

Fig. 2 *Errina antarctica* from the Chilean fjord region. **a** Reef-like structures in a U-shaped channel in the Madre de Dios Arquipélago, 20 m. **b** Dead stylasterid with diverse epifauna, 20 cm Ø, 25 m. **c** *Errina antarctica* growing on a vertical wall in Canal Pitt Chico, 20 m, heights of foreground ~0.8 m. **d** Two-dimensionally branched, fan-like colony form (form A), 15 cm Ø, 20 m. **e** A dive's harvest of stylasterids, Madre de Dios Arquipélago. **f** *Gorgonocephalus chilensis* is commonly encountered on *E. antarctica*, 28 cm Ø, Messier Channel, 18 m. **g** Divers extracting big colonies of *E. antarctica* and producing damages on surrounding colonies; note the bushy growth of form B, Madre de Dios Arquipélago, 15 m. **e**, **g** Photos from anonymous

Pacific where sedimentation stress was apparently low. These observations suggest an influence of either current or sediment stress or both on colony morphology but this hypothesis remains to be tested.

Growth rate

No data on growth rates are available for *E. antarctica*. Studies of the most similar sister species *E. novaezelandiae* suggested a growth rate of 1 mm/year (Stratford et al. 2001). More recent studies calculated a growth of up to 7 mm/year, but stressed the fact that colonies also suffer partial death and thus were diminishing in size in some years (Miller et al. 2004) so that conclusions for size to age ratio cannot be made easily and refer to minimum age estimations. If the Chilean species grows at similar rates as the New Zealand species and ignoring years with less or negative growth, a colony diameter of 40 cm implies a minimum age between 30 and 200 years.

Depth distribution

From shallow temperate waters of New Zealand fjords two species of the genus *Errina* are described, *E. novaezelandiae* and *E. dendyi* (Stratford et al. 2001; Miller et al. 2004). It is assumed that the existence of these species in waters as shallow as 20 m or sometimes even 10 m can be explained by deep-water emergence, a phenomenon described for several species of the New Zealand fjords (Miller et al. 2004). With a depth distribution between 10 and 771 m, *E. antarctica* can also be seen as an eurybathic species emerging into shallow waters in the central and southern Chilean fjords.

Geographic distribution

The distribution of *E. antarctica* in South Chile, the Burdwood Bank and around the Malvinas Islands is described for several other cnidarians such as sea anemones and a benthic siphonophore (Riemann-Zürneck 1986; Riemann-Zürneck 1991) and can be explained by the oceanographic conditions: the Cape Horn current, surrounding South America from west to east meets the Circum Antarctic current at the southern tip of South America, turns north or northeast and partly sweeps over the Burdwood Bank and Falkland Shelf (Riemann-Zürneck 1991).

Within Chile, *E. antarctica* was found only in the Central and Southern Patagonian Zone of the Magellan province. Despite intense sampling we did not find this species in the shallow water in the Northern Zone between Puerto Montt (41°30′S) and the Golfo de Penas (approx. 47–48°S) (for sampling sited north of the Golfo de Penas, see Häussermann and Försterra (accepted)). This supports the idea that the Golfo de Penas and the Peninsula Taitao (approx. 46–47°S) (Fig. 1) represents a zoogeographic barrier (Lancellotti and Vásquez 1999; Häussermann and Försterra 2005). However, one specimen of *Errina*, due to its poor condition could not be identified to species status, has been collected in 80 m depth in the Golfo de Ancud (approx. 42°S) and is deposited in the museum of the Universidad Austral de Chile (IZUA-CNI-0025). If this specimen constituted *E. antarctica*, the distribution of this stylasterid fits into another observed pattern: the deep-water emergence of several species is stronger south of the Golfo de Penas than to the north of it. For example the bivalve *Acesta patagonica* was found as shallow as 15 m in the Central Patagonian Zone but north of it only below 80 m depths (Häussermann in press).

Threats and state of protection

Remoteness and difficult accessibility of channels in the Central Patagonian Zone and a scarcity of studies can explain the lateness of the discovery of such large accumulations of *E. antarctica*. Unfortunately the remoteness does not protect these habitats any longer. Although hydrocorals are on the list of CITES species, which restricts international trade, stylasterids in Chile have no special protection. In the Madre de Dios Arquipélago stylasterids are harvested by fisherman for the national souvenir market (Fig. 2e, g). Although the market still seems to be comparably small, this activity apparently causes substantial damage not only through the extraction of colonies but also through considerable mechanical damages to other colonies by the divers and boat anchors. The sea floor of one channel in the Madre de Dios Arquipélago where coral extraction is practiced (Fig. 2e, g) was found to be covered with pieces and fragments of stylasterids. In New Zealand, scuba diving sport was found to be a threat to stylasterids in marine protected areas that were created for the protection of these very same corals (Miller et al. 2004).

In 2006, Chile is expected to surpass Norway as world leader in the production of marine farmed salmonids (SalmonChile 2004) and prognoses predict further massive expansions mainly to the Central Patagonian Zone in the next few years. The effects of fish farming on the marine ecosystems in this region and in particular on the stylasterids are completely unknown but should be considered as potentially detrimental or destructive. Regulations that control and inhibit the extraction of stylasterids and other potentially harmful activities need to be introduced urgently. Larger mapping projects should be launched to assess the distribution patterns on several scales and the ecological prerequisite for stylasterid reefs in temperate waters. Highly protected marine reserves have to be established to prevent fast degradation, decline or even the disappearance of these spectacular and unique benthic communities.

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