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ORIGINAL ARTICLE

Preliminary observations on the benthic marine algae of the Gorringe seabank (northeast Atlantic Ocean)

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Abstract Examination of marine samples collected in 2006 from the Gettysburg and Ormonde seamounts on the Gorringe seabank southwest of Portugal has revealed 29 benthic Chlorophyta, Phaeophyceae (Ochrophyta), and Rhodophyta that were identified provisionally to genus and to species. Combining lists for the present and a previous expedition brings the total of algae thus far recorded to 48. The brown alga *Zonaria tournefourtii* and the red alga *Cryptopleura ramosa* were the most abundant species in the present collections. The kelp *Laminaria ochroleuca* was present only in the Gettysburg samples while *Saccorhiza polyschides* was observed only on the Ormonde seamount. Comparisons with the benthic marine algae recorded on seamounts in the mid-Atlantic Azores archipelago show features in common, notably kelp forests of *L. ochroleuca* at depths below 30 m and *Z. tournefortii* dominance in shallower waters.

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Introduction

Seamounts are undersea mountains over that occur in all ocean basins but few of which have been sampled for their marine biota (Hall-Spencer et al. 2011). They rise steeply from the abyssal plain and may ascend to shallow depths within the photic zone and create suitable habitat for benthic algae. It has been suggested that seamounts may function as stepping stones for the transoceanic dispersal of benthic species and may also host endemic species. However, a recent review using mainly faunistic data (Rowden et al. 2010) drew attention to gaps in our knowledge of seamount biodiversity and ecology and questioned hitherto-held views on seamounts as unique and fragile environments, and hot spots of biodiversity and endemicity.

The Gorringe seabank (Fig. 1), part of the Horseshoe seamounts range and Paleo Madeira (Madeiran volcanic province, Fernández-Palacios et al. 2011), contains two prominent peaks, the Ormonde and Gettysburg seamounts (Anon 2005). The Gorringe seabank and Paleo Madeiran seamounts are on the African tectonic plate separated from Europe by the Azores-Gibraltar fracture zone. The Gorringe seabank is over 180 km long (Anon 2005) and lies southwest of Cape St Vincent, Portugal with the Gettysburg seamount approximately 240 km offshore and the Ormonde 200 km offshore. The seabank rises from 5,000 m depth to the photic zone with peaks <50 m below sea level. Its surface is composed of recent conglomerates and lava flows with some areas of exposed carbonate rock (Anon 2005). A previous investigation on the Gorringe seabank that employed SCUBA diving to record its marine

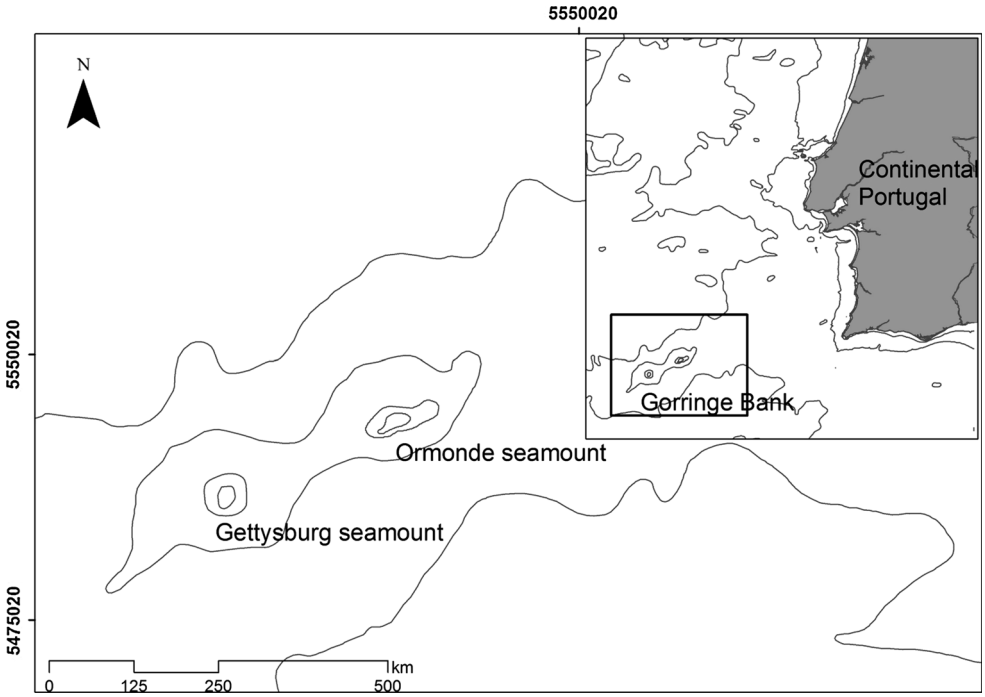

Fig. 1 Location of the Gorringe seabank and Gettysburg and Ormonde seamounts

life recorded 26 benthic marine algae (Anon 2005). There have been no investigations on the benthic marine algal flora of other seamounts in the region; the nearest comparable studies have been undertaken on seamounts in the mid-Atlantic Azores archipelago (latitude 37°–40°N; 1,100–1,600 km from mainland Europe) where similar surface and deep sea temperatures and water clarity prevail; algae have been recorded from the Dom João de Castro seabank, the Princess Alice seabank, the Formigas islets (2–3 m above sea level) and nearby Dollarbarat reef (Cardigos et al. 2005; Neto 1994; Santos et al. 2001).

The field study undertaken in 2006 gathered further biological and ecological data to support conservation designation (Anon 2013). This paper reports the benthic algae obtained during investigations of the Gettysburg and Ormonde seamounts.

Materials and methods

Qualitative collections of benthic algae were obtained during the Lusoexpedição 2006 (Lusófona University expedition) supported by the Portuguese navy. The Gettysburg and Ormonde seamounts are in clear oceanic water with visibility to 30 m depth; the aphotic zone is at >200 m depth (de Alteriis et al. 2003). Surface sea temperatures range annually from 15 to 24 °C (22–23 °C at the time of investigation) with a thermocline at depth 50 m below which temperature dropped by 4 °C (pers. comm. Coriolis Data Centre); the deep sea temperature profile for 37°N 11°W (near the Gorringe seabank, Peliz et al. 2005) shows little variation in the top 100 m of the water column when temperature was 17 °C in May 1998. Tidal amplitude does not exceed 2.2 m (de Alteriis et al. 2003) with a small surface current to 15 m depth at the diving sites.

SCUBA diving surveys for algae, part of a wider biological survey, were undertaken in July 2006 on six occasions on the Gettysburg (36°31′N, 11°34′W) and two occasions on the Ormonde (36°02′N, 11°09′W) seamounts at depths of, respectively, 35 and 39.6 m. Material collected was preserved in neutralized 4 % formaldehyde seawater and brought back to the laboratory for identification. Algae were identified to species with the aid of keys and floras, principally Afonso-Carillo and Sansón (2000); Lawson and John (1987); Maggs and Hommersand (1993); Taylor (1967); some were identified provisionally, others only to genus while notably the crustose Corallinaceae remained largely undetermined. Algal nomenclature follows Guiry and Guiry (2013). Specimens have been deposited in the herbarium Guy Telles Palhinha of the Department of Biology of the University of the Azores, Ponta Delgada (AZB).

Results

The present investigation revealed 29 algae (3 Chlorophyta, 7 Phaeophyceae, 19 Rhodophyta) that were identified provisionally to genus and in many cases to species. The total of algae listed for the Gorringe seabank including

Table 1 Marine algae recorded from the Gorringe seabank and their biogeographical occurrence

Species	Gb 06	Or 06	Gr pr	sb	ab	Pt	Az	Az sm	Md	Cn	Med	Atl en	Atl est	Atl wst	Ind	Pac
Rhodophyta																
Acrochaetium sp.	+	+	0	ep	r	−	−	−	−	−	−	−	−	−	−	−
Acrosorium ciliolatum (Harvey) Kylin	0	+	0	ep	r	+	+	+	+	+	+	+	+	+	+	+
Aglaothamnion cf. *sepositum* (Gunnerus) Maggs and Hommersand	0	0	+	u	u	0	0	0	0	0	+	+	0	0	0	0
Aglaothamnion sp.	0	+	−	ep	r	−	−	−	−	−	−	−	−	−	−	−
Botryocladia cf. *chiajeana* (Meneghini) Kylin	+	+	0	el	o	0	+	0	+	+	+	0	+	0	+	0
Callithamnion tetragonum (Withering) S·F.Gray	0	+	0	u	r	+	+	0	+	+	+	+	+	0	0	0
Callophyllis laciniata (Hudson) Kützing	0	0	+	u	u	+	0	0	0	0	+	+	+	0	0	+
Cryptopleura ramosa (Hudson) L.Newton	+	+	+	ep/ el	a	+	+	+	+	+	+	+	+	+	0	+
Cryptonemia seminervis (C.Agardh) J.Agardh	+	0	0	el	r	+	+	0	0	+	+	+	+	+	+	+
Dasya cf. *caraibica* Børgesen	+	+	0	el	f	0	0	0	0	+	+	+	+	+	+	+
Erythrotrichia carnea (Dillwyn) J.Agardh	+	+	0	ep	o	+	+	0	0	+	+	+	+	+	+	+
Gracilaria cf. *multipartita* (Clemente) Harvey	+	0	0	el	f/o	+	+	0	0	0	0	+	+	0	0	0
Halymenia floresii (Clemente) C.Agardh	0	0	+	u	u	+	0	0	0	0	+	0	+	+	+	+
Halymenia sp.	+	0	0	u	r	−	−	−	−	−	−	−	−	−	−	−
Hypoglossum hypoglossoides (Stackhouse) F.S.Collins and Hervey	0	+	0	u	o	+	+	0	+	+	+	+	+	+	+	+
Irvinea cf. *ardreana* (J.Brodie and Guiry) Guiry	0	0	+	u	u	+	0	0	0	0	0	+p	0	0	0	0
Kallymenia cf. *reniformis* (Turner) J.Agardh	0	0	+	el	u	+	+	0	+	+	+	+	+	0	+	+
Kallymenia cf. *requienii* (J.Agardh) J.Agardh	0	+	+	el	r	0	0	0	0	+	+	0	0	0	0	0
Laurencia cf. *obtusa* (Hudson) J.V.Lamouroux	0	0	+	u	u	+	+	0	+	+	+	+	+	+	+	+
Lithophyllum incrustans Philippi	0	0	+	el	u	+	+	+	0	+	+	+	+	+	+	+
Lithophyllum cf. *stictaeforme* (Areschoug) Hauck	0	0	+	u	u	0	0	0	+	+	+	0	+	+	0	+
Meiodiscus spetsbergensis (Kjellman) G.W.Saunders and McLachlan	+	0	0	ez	r	0	0	0	0	0	+	0	+	0	0	+
Mesophyllum alternans (Foslie) Cabioch and M.L.Mendoza	0	0	+	u	u	+	+	0	0	+	+	+	0	0	0	0
Mesophyllum sp.	+	0	0	el/ ep	o	−	−	−	−	−	−	−	−	−	−	−
Nitophyllum punctatum (Stackhouse) Greville	0	+	0	ep	r	+	+	0	+	+	+	+	+	+	+	+
Palmaria palmata (Linnaeus) Weber and Mohr	0	0	+	u	u	+	+	0	0	0	0	+	0	0	+	+
Peyssonnelia cf. *inamoena* Pilger	0	0	+	u	u	0	0	0	+	+	+	+	+	+	+	+
Plocamium cartilagineum sensu lato cf. Saunders and Lemkuhl (2005)	+	+	+	u	u	+	+	0	+	+	+	+	+	+	+	+
Pyropia leucosticta (Thuret) Neefus and J.Brodie	0	0	+	u	u	+	+	0	+	+	+	+	?	?	+	+
Rhodophyllis divaricata (Stackhouse) Papenfuss	+	+	+	ep/ el	a	+	+	+	+	+	+	+	+	0	0	0
Sebdenia monnardiana (Montagne) Berthold	0	0	+	u	u	0	0	0	0	0	+	0	0	0	0	0

Table 1 continued

Species	Gb 06	Or 06	Gr pr	sb	ab	Pt	Az	Az sm	Md	Cn	Med	Atl en	Atl est	Atl wst	Ind	Pac
Spermothamnion strictum (C.Agardh) Ardissone	0	+	0	ep	r	0	0	0	0	0	+	+	0	0	0	0
Titanoderma sp.	0	0	+	u	u	−	−	−	−	−	−	−	−	−	−	−
Ochrophyta–Phaeophyceae																
Arthrocladia villosa (Hudson) Duby	0	0	+	u	u	+	0	0	+	+	+	+	0	+	0	0
Desmarestia ligulata (Stackhouse) J.V.Lamouroux	+	+	0	el	c	+	0	0	0	0	+	+	0	+	0	+
Dictyopteris polypodioides (A.P.De Candolle) J.V.Lamouroux	0	0	+	u	f	+	+	+	+	+	+	+	+	+	+	+
Dictyota dichotoma (Hudson) J.V.Lamouroux	0	0	+	el	u	+	+	+	+	+	+	+	+	+	+	+
Ectocarpus siliculosus (Dillwyn) Lyngbye	0	+	0	u	u	+	+	0	+	+	+	+	+	+	+	+
Halopteris filicina (Grateloup) Kützing	+	0	+	u	u	+	+	0	+	+	+	+	0	+	+	+
Laminaria ochroleuca Bachelot de la Pylaie	+	0	+	el	f	+	+	+	0	+	+	+	?	+	0	0
Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira	+	0	0	el	o	0	0	+	+	+	+	0	+	+	+	+
Saccorhiza polyschides (Light-foot) Batters	0	+	0	el	f	+	0	0	0	0d	+	0	0	0	0	0
Sporochnus pedunculatus (Hudson) C.Agardh	0	0	+	el	u	+	+	0	+	+	+	+	0	+	+	+
Zonaria tournefortii (J.V.Lamouroux) Montagne	+	+	+	el	a	+	+	+	+	+	+	+p	+	+	0	0
Chlorophyta																
Bryopsis hypnoides J.V.Lamouroux	0	+	0	u	r	+	+	0	+	+	+	+	0	+	+	+
Valonia cf. *aegagropila* C.Agardh	0	0	+	el	u	0	0	0	0	?	+	0	0	+	+	+
Valonia macrophysa Kützing	0	+	0	el	o	0	+	0	+	+	+	0	0	+	+	+
Valonia utricularis (Roth) C.Agardh	0	+	0	el	o	+	+	+	+	+	+	+p	+	+	+	+
Total out of 42 algae identified to species						31	27	9	24	31	40	34	26	27	25	29

Gb Gettysburg, *Or* Ormonde, *Gr* previous Gorringe list (Anon 2005), *sb* substratum, *ab* abundance, *Pt* Portugal, *Az* Azores, *Az sm* Azores seamounts, *Md* Madeira, *Cn* Canaries, *Med* Mediterranean Sea, *Atl en* eastern North Atlantic, *Atl est* eastern subtropical and tropical Atlantic, *Atl wst* western subtropical and tropical Atlantic, *Ind* Indian Ocean, *Pac* Pacific Ocean; + = present, 0 = not recorded, − = no information, ? = uncertain record, a = abundant, cf. = resembles, d = drift, el = epilithic, ep = epiphytic, ez = epizoic, f = frequent, o = occasional, p = Portugal only, r = rare, u = unknown

those from the previous expedition is 48 comprising 4 Chlorophyta, 11 Phaeophyceae, and 33 Rhodophyta. These are listed in Table 1 together with the substrata upon which they grew, their relative abundance in the samples, their occurrence in adjacent Portugal, and the Azores, Madeira and Canaries archipelagos, and more widely in the Atlantic and other oceans.

Discussion

This study has increased the total of benthic marine algae known for the Gorringe seabank from 26 to 48 of which five were determined to genus only. Most species in the present samples were Rhodophyta; there were only a few species of Phaeophyceae and Chlorophyta although in both collections, the foliose *Zonaria tournefortii* was dominant and served as a host substratum for epiphytic algae. The list presented here (Table 1) is provisional as some of the species included are problematic; examples include *Bryopsis hypnoides* (Brodie et al. 2007), *Laurencia obtusa* (Cassano et al. 2012), *Lobophora variegata* (Sun et al. 2012), and *Plocamium cartilagineum* (Saunders and Lemkuhl 2005). Of the 43 algae identified to species, 40 occur in the Mediterranean Sea while 33 occur in the Macaronesian archipelagos (Azores, Madeira, Canaries). Thirty-one species occur on the relatively nearby coast of Portugal, 34 species more widely in the eastern and western subtropical and tropical regions of the Atlantic Ocean other than the Macaronesian islands, and 33 in the temperate northeast Atlantic. Thirty species found on the Gorringe seabank occur globally widely in the Indian and Pacific Oceans (with the caveat that some may prove to encompass several entities, e.g., *Lobophora*, Sun et al. 2012). The

major proportion of benthic algal species on the Gorringe seabank occur in the Mediterranean Sea and eastern and western subtropical and tropical Atlantic Ocean (Table 1), demonstrating a warm-water floristic affinity. Currently, no endemic algal species have been recorded for the Gettysburg and Ormond seamounts.

Differences were found in the collections from the two seamounts. Present only on the Gettysburg were *Cryptonemia seminervis, Gracilaria* cf. *multipartita*, *Halymenia* sp. *Meiodiscus spetsbergensis*, *Measophyllum* sp., *Halopteris filicina*, *Laminaria ochroleuca and Lobophora variegata* while on the Ormonde only were *Acrosorium ciliolatum*, *Aglaothamnion* sp., *Hypoglossum hypoglossoides*, *Kallymenia* cf. *requienii, Nitophyllum punctatum*, *Spermothamnion strictum*, *Ectocarpus siliculosus*, *Saccorhiza polyschides*, *Bryopsis hypnoides*, *Valonia macrophysa* and *V. utricularis.* Reasons for the differing algal assemblages and the separate occurrence of the kelps *L. ochroleuca* and *S. polyschides,* respectively, on these seamounts are unclear, but may reflect a gradient of changing algal species assemblages as noted by O'Hara et al. (2010) in the southwest Atlantic Ocean.

Of the 27 benthic algae (1 Chlorophyta, 8 Phaeophyceae and 18 Rhodophyta) previously recorded on the Gorringe seabank (Anon 2005), five (*Cryptopleura ramosa*, *Kallymenia reniformis*, *Plocamium cartilagineum, Rhodophyllis divaricata*, *Zonaria tournefortii*) were confirmed in the 2006 survey. By contrast, 14 Rhpdophyta, 4 Phaeophyceae, and 1 Chlorophyta were recorded previously but not in 2006 (Table 1); reasons for these differences are also unclear but may be due to different approaches to sampling, rare or sporadic occurrence, and to differences in taxonomic interpretation.

The combined total of 48 algae on the Gorringe seabank is small compared with the more thoroughly researched adjacent flora of southern Iberia with over 500 species (Tittley 2003). The species-poor flora of the seabank reflects the very limited geographical and seasonal scope of the study, the absence of an intertidal flora, the limitations in investigating a permanently immersed isolated offshore site where the shallow sublittoral flora is missing and the deep-water assemblage below 40 m depth requires different methods of sampling and recording (see Littler et al. 1986; Vadas and Steneck 1988).

Studies on seamounts in the Azores archipelago have revealed 53 benthic algae of which 36 occurred on the Dom João de Castro seabank where rocky habitats at 25–45 m depth were dominated by a mosaic of *Sargassum* sp., *Corallina* sp., and *Stypocaulon scoparium* with at greater depths, as on the Gorringe seabank, *Z. tournefortii* as the dominant species (Cardigos et al. 2005). Twenty-two species have been recorded on the Formigas islets (Neto 1994) where *Cystoseira* sp. occurred at shallow depths and *L. ochroleuca* (specimens in AZB) below 40 m depth; *L. ochroleuca* forests occur on the Gorringe seabank but *Cystoseira* has not been found there. Of 53 algae recorded on the Azores seamounts, only ten are currently known to occur on the Gorringe seabank. *Zonaria tournefortii* has been recorded on seamounts elsewhere in the tropical Atlantic Ocean (Littler et al. 1986) while *L. ochroleuca* has a more northern warm temperate distribution in the northeast Atlantic (Tittley 2003). The presence of foliose brown algae (*L. variegata*, *Z. tournefortii*) typical of the tropics and subtropics and kelps (*L. ochroleuca*, *S. polyschides*) more typical of temperate waters reflects the geographical position of the Gorringe seabank in a boundary area of the North Atlantic Ocean. However, Graham et al. (2007) predict the widespread occurrence of deep-water kelp habitats and forests in subtropical and tropical waters where, as on the Gorringe seabank and in the Azores, deep waters might have adequate sea temperatures and nutrient supply (cf. Coelho and Santos 2003 for the Gorringe seabank) to support kelp growth (see also Santelices 2007). On the Gorringe seabank, *L. ochroleuca* and *S. polyschides* were collected in the warmer waters above the thermocline at 50 m depth; the cooler waters at greater depths remain unexplored for algae. Graham et al. (2007) also discovered the temperate macroalga *Desmarestia ligulata* further south in the Pacific Ocean in deep waters around the Galápagos islands; these species were present in the 2006 samples from the Gettysburg and Ormonde seamounts.

Conclusions

Field studies confirm an extensive cover of benthic algae on the peaks of the submerged Gorringe seabank; its currently known flora of 48 benthic algae is small compared with mainland Portugal. The flora shows affinities with the warm-water floras of the Mediterranean Sea, southern Iberia, and the Macaronesian archipelagos. The geographically wide occurrence of most algal species on the Gorringe seabank suggests that its seamounts are not floristically isolated islands. Evidence for Gettysburg and Ormonde seamounts as hot spots of algal species richness is lacking despite the species richness of this geographical area but much more sampling remains to be done. These isolated sea mounts probably have served as stepping stones for algal dispersal in the region.

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