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A provisional classification of algal-characterised rocky shore biotopes in the Azores

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Abstract

Recent studies of the rocky shores of the Azores archipelago have provided information on community structure allowing provisional identification of plant-characterised biotopes (habitats and their associated communities). Although the Azores share some littoral and sublittoral biotopes with the Atlantic coast of mainland Europe, shores in the archipelago mostly lack the functionally important 'leathery macrophyte' communities of fucoids and laminarians widespread in the North Atlantic. Intertidal biotopes are mainly turfs typical of warm-temperate and tropical regions, and characterised by articulated Corallinaceae or by non-coralline algae such as *Cladophora* spp., *Gelidium* spp., *Pterocladiella capillacea*, *Stypocaulon scoparia*, and *Valonia utricularis*. Subtidal algal biotopes are characterised by *Dictyota* spp., *Halopteris filicina*, *Sphaerococcus coronopifolius* and, most commonly, *Zonaria tournefortii*.

Introduction

Until the 1990s, ecological investigations that described marine algal community structure in the Azores were few (Schmidt, 1931; Pryor, 1967; Castro & Viegas, 1983; Marques, 1984; Castro & Viegas, 1987). The most thorough study was that of Schmidt (1931) who defined the algal associations (Table 1). In the past decade, detailed surveys have been undertaken throughout the archipelago and, as a result, there is now a more comprehensive body of information on community structure (Neto, 1992; Neto & Tittley, 1996; Morton et al., 1998; Tittley et al., 1998; Neto et al., 2000). Tittley et al. (1998) provisionally identified some algal-characterised biotopes of the island of Flores following Hiscock (1995). The present paper provides, for the first time, a provisional classification of algal-characterised biotopes drawn from field studies on the islands of Flores, Faial and São Miguel.

A biotope is defined as 'a seashore or sea-bed habitat (i.e. the environment's physical and chemical characteristics, and the particular conditions of wave exposure, salinity, tidal streams and other factors which contribute to the overall nature of the location) and its associated community of species, operating together' (Connor et al., 1997a, b). In this paper, Azorean littoral and sublittoral biotopes characterised by algae are defined provisionally following the methods of the Marine Nature Conservation Review (MNCR) (Connor et al., 1997a, b). The MNCR classification aims to be comprehensive, and includes biotopes for artificial, polluted or barren areas and is intended to complement other marine classifications (e.g. in France, Dauvin, 1995). This paper focuses on rocky shores (as opposed to sedimentary shores), the primary division of the biotope classification. Generally, rocky shores provide the stable substratum required for algal growth.

Materials and methods

Schmidt (1931) applied the phytosociological methodology of Braun-Blanquet used also by other workers to classify marine vegetation on continental European coasts [e.g. Den Hartog (1959) for the Netherlands]. There are similarities between the phytosociological

Table 1. Azores algal associations of Schmidt (1931) and biotope equivalents as defined in this paper

Association	Biotope
Open Littoral	
Bangia-Cyanophyta	Cyanobacteria-*Bangia*
Lichina pygmaea	*Lichina pygmaea*
Polysiphonia	?
Nemalion-Grateloupia-Bryopsis-Cladophora	Soft algal turf complex
Enteromorpha	*Enteromorpha*
Fucus spiralis	*Fucus spiralis*
Gelidium microdon	*Gelidium microdon*
Laurencia obtusa	Soft algal turf complex
Haliptylon virgatum	Coralline algal turf complex
Caulacanthus-Chondracanthus-Ceramiaceae	Soft algal turf complex
Gelidium-Codium adhaerens	*Codium adhaerens*
Corallina elongata	Coralline algal turf
Cystoseira	*Cystoseira*
Osmundea pinnatifida	Soft algal turf complex
Shaded littoral	
Gymnogongrus-Lomentaria-Rhodymenia	Shade turf
Catenella	Shade turf-*Catenella*
Griffithsia phyllamphora	?
Haliptylon squamatum	?
Crustose algae	Shade crustose spp.
Sublittoral	
Corallina officinalis	*Corallina* turf complex
Asparagopsis	*Asparagopsis* turf
Sargassum-Cladostephus-Nitophyllum-Plocamium	?
Crustose algae	Crustose algae

and biotope methods in defining marine algal communities. Schmidt's (1931) sublittoral observations were limited as SCUBA diving had not been developed at that time and sublittoral areas were sampled by dredging, an inexact method of surveying the vegetation of such habitats. Although many of the transect and quadrat studies recorded in recent surveys have provided data that support Schmidt's (1931) observations, the MNCR biotope classification was taken as a starting point for this paper.

The MNCR biotope classification is hierarchical and based on a matrix of environmental features including substratum type, wave exposure conditions, and shore level (Connor et al., 1997a, b). Within each of the major divisions of substratum, 'biotope complexes' (a broad feature often comprising several biotopes) were identified for each of the main shore zones (littoral, infralittoral, circalittoral) and four points on a scale of wave exposure conditions from very exposed to sheltered. Other biotope complexes (rock pools, overhangs, caves) were classified separately. For each biotope, a name is given together with a coded classification representing substratum type, wave exposure conditions and the characterising species. A description is provided also for each biotope, the characterising and other associated species are listed. For this provisional assessment of Azorean biotopes, we provide only a name.

The present study used both descriptive and quantitative data (obtained from quadrats along transect lines) to define provisionally algal-characterised biotopes. Field studies were undertaken at littoral and sublittoral levels (to 30 m depth) in a range of wave exposure conditions from sheltered to exposed.

Results

As the focus of this paper is on algal biotopes, some animal-characterised biotopes have been omitted from the classification. Table 1 presents the 24 algal associations defined by Schmidt (1931) with, where possible, a modern biotope or biotope complex equivalent. Of the associations identified by Schmidt (1931), two were restricted to supralittoral levels, 12 occurred in the littoral in full light conditions, a further five occupied shaded littoral situations and five were recorded from sublittoral areas.

Tables 2a, b present the biotope complexes in the Azores using the matrix structure of the MNCR biotope classification (cf. Table 5.2 in Connor et al., 1997a, b). At both littoral and sublittoral levels, these complexes in the Azores are similar irrespective of wave action. An important caveat is the definition of the scale of wave action in the Azores; there are probably no truly sheltered habitats in the archipelago comparable to those of sea lochs and inlets in Britain.

Tables 2a, b also present actual biotopes within the complexes (cf. Table 5.5 'Littoral rock habitat matrix' in Connor et al. 1997a, b). On wave exposed shores at supralittoral levels, the principal biotopes are characterised by various yellow lichens; at supralittoral fringe levels, black lichens (*Verrucaria* spp.) and Cyanobacteria crusts characterise a set of biotopes. Littorinids [*Melarhaphe neritoides* Linnaeus (1758) and *Littorina* spp.] often form a distinct animal biotope at upper midlittoral levels overlapping at lower levels with patches of the marine lichen *Lichina pygmaea* (Lightfoot) C. Agardh which may also form a distinct biotope. A feature of most Azorean shores (from very wave exposed to more sheltered situations) is an eulittoral 'barnacle-limpet' biotope complex. This may be interrupted by green algal (*Blidingia* spp., *Enteromorpha* spp.) biotopes according to season, wave action, presence of pools and draining water. The crustose coralline alga *Tenarea tortuosa* (Esper) Me Lemoine also forms a biotope in the 'barnacle-limpet' complex. On less wave exposed, more sheltered shores, the biotopes are broadly similar. In spring, the Cyanobacteria biotope may contain noticeable amounts of the filamentous red alga *Bangia atropurpurea* (Roth) C.Agardh and *Porphyra umbilicalis* (Linnaeus) Kützing. The only fucoid in the Azores, *Fucus spiralis* Linnaeus, occurs patchily as small plants and locally defines a biotope.

On both wave exposed and more sheltered shores, lower littoral levels commonly support algal 'turfs'. A turf is a convenience term to describe compact, sometimes densely intertwined mats of algae (Neto & Tittley, 1996). We have identified two broad types of turf biotope complex, those characterised by soft (mainly non-calcified) algae [e.g. *Gelidium* spp., *Pterocladiella capillacea* (S.G.Gmelin) Santelices & Hommersand, *Stypocaulon scoparia* (Linnaeus) Kützing, *Cladophora* spp., *Valonia utricularis* (Roth) C. Agardh], and those by calcified, articulated Corallinaceae (e.g. *Corallina* spp., *Jania* spp., *Haliptylon* spp.). Coralline turfs are a distinct feature of many rocky shores in the Azores, comprise several biotopes and extend to deep sublittoral levels. The soft algal turf is often species rich and comprises a complex of biotopes. The prostrate *Codium adhaerens* C. Agardh characterises a distinct biotope at low-water level on many shores. Crustose coralline algae are the dominant life forms and form a biotope on strongly wave washed rocky shores in the surge zone at shallow sublittoral levels. At sublittoral fringe levels, prolific growths of *Asparagopsis armata* Harvey often define a distinct summer biotope.

Occasionally, large brown algae may form biotopes at lower littoral or sublittoral levels. Morton et al. (1998) reported a carpet of *Cystoseira tamariscifolia* (Hudson) Papenfuss on the island of Santa Maria.

Intertidal areas are often modified to form rock pools, overhangs and caves and distinct algal communities are associated with these. Shaded habitat biotopes may have *Lomentaria articulata* (Hudson) Lyngbye or *Catenella caespitosa* (Withering) L. Irvine as the dominant species, or the crustose red alga *Hildenbrandia* sp. Pool biotopes are often characterised by the large brown algae *Cystoseira* spp. and *Sargassum* spp.

At subtidal levels, foliose algae are more prominent; the green alga *Ulva rigida* C. Agardh, and the brown alga *Padina pavonica* (Linnaeus) Thivy, are locally, seasonally, predominant at São Vicente on the island of São Miguel. Another brown alga, *Zonaria tournefortii* (Lamouroux) Montagne, forms extensive stands throughout the archipelago often to considerable depths. The red algae *Sphaerococcus coronopifolius* Stackhouse and *Plocamium cartilagineum* (Linnaeus) P.S. Dixon characterise biotopes in deep water. On the island of Faial, the *Corallina* turf extended to 30 m depth. The Formigas islets are unique in the Azores in the occurrence there of the leathery macrophyte kelp, *Laminaria ochroleuca* De La Pylaie; this single recorded example of a kelp-characterised

Table 2a. Habitat matrix in the Azores. Biotope complexes and (indented) species characterising probable biotopes

	Very exposed	Exposed
Supra-		
littoral	Yellow & grey lichens	Yellow & grey lichens
Upper		
Littoral Fringe	Cyanobacteria-*Verrucaria*	Cyanobacteria-*Verrucaria*
Lower		
Littoral Fringe	Littorinids	Littorinids
	Lichina pygmaea	*Lichina pygmaea*
Upper		
Eulittoral	Barnacles-limpets	Barnacles-limpets
	Enteromorpha spp.	*Enteromorpha* spp.
Mid	Barnacles-limpets	*Fucus spiralis*
Eulittoral		*Gelidium microdon*
	Tenarea tortuosa	*Tenarea tortuosa*
Lower	Soft algal turf	Soft algal turf
Eulittoral	*Gelidium latifolium*	*Gelidium latifolium*
	Cladophora prolifera	*Osmundea pinnatifida*
	Chondracanthus acicularis	*Rhodymenia pseudopalmata*
		Codium adhaerens
Rockpool	Rockpool	Rockpool
	Corallina spp.	*Corallina* spp.
	Sargassum spp.	*Sargassum* spp.
	Cystoseira spp.	*Cystoseira* spp.
Sublittoral	Coralline turf	Coralline turf
Fringe		
	Crustose Corallinaceae	Crustose Corallinaceae
		Asparagopsis armata
Sublittoral		Soft algal turf
		Stypocaulon scoparium
	Foliose algae	Foliose algae
	Ulva rigida	*Ulva rigida*
	Zonaria tournefortii	*Zonaria tournefortii*
	Dictyota spp.	*Dictyota* spp.
Deep	Red algae	Red algae
Sublittoral	*Sphaerococcus coronopifolius*	*Sphaerococcus coronopifolius*
	Plocamium cartilagineum	*Plocamium cartilagineum*
	Kelp stand	
	Laminaria ochroleuca	

Table 2b. Habitat matrix in the Azores (biotope complexes and (indented) keystone species characterising probable biotopes)

	Moderately exposed	Less exposed
Supra-littoral	Yellow & grey lichens	Yellow & grey lichens
Upper Littoral Fringe	Cyanobacteria-*Verrucaria*	Cyanobacteria-*Verrucaria* *Bangia*-Cyanophyta
Lower Littoral Fringe	Littorinids *Lichina pygmaea*	Littorinids *Lichina pygmaea*
Upper Eulittoral	Barnacles-limpets *Enteromorpha* spp.	Barnacles-limpets *Enteromorpha* spp.
Mid Eulittoral	*Fucus spiralis* *Gelidium microdon*	*Fucus spiralis* *Gelidium microdon*
Lower Eulittoral	Soft algal turf *Gelidium latifolium* *Rhodymenia pseudoplamata* *Pterocladiella capillacea*	Soft algal turf *Valonia utricularis* *Chondracanthus acicularis* *Rhodymenia pseudopalmata* *Pterocladiella capillacea* *Stypocaulon scoparium* *Codium fragile*
Rockpool	Rockpool *Corallina* spp. *Sargassum* spp. *Cystoseira* spp.	Rockpool *Codium fragile* *Corallina* spp. *Sargassum* spp. *Cystoseira* spp.
Sublittoral fringe	Coralline turf	Coralline turf *Asparagopsis armata*
Sublittoral	Soft algal turf *Stypocaulon scoparium* Foliose algae *Ulva rigida* *Zonaria tournefortii* *Dictyota* spp.	Soft algal turf *Stypocaulon scoparium* Foliose algae *Ulva rigida* *Zonaria tournefortii* *Dictyota* spp.
Deep sublittoral	Red algae *Sphaerococcus coronopifolius* *Plocamium cartilagineum*	Red algae *Sphaerococcus cornonopifolius* *Plocamium cartilagineum*

biotope occurs only in deep waters (30–40 m and below).

Discussion

A major distinction between the algal-characterised biotopes of the Azores and those of the northern North Atlantic in both Europe and America is the near absence of the leathery macrophyte communities of fucoids and laminarians. Where algae predominate in the Azores, they are often turf forming. Algal turf biotopes also occur in the northern North Atlantic Ocean. For example, an *Osmundea pinnatifida* (Hudson) Stackhouse and *Gelidium pusillum* (Stackhouse) Le Jolis turf occurs on moderately exposed mid-littoral rock in Britain where the fucoid canopy is reduced or absent (Connor et al., 1997a, b); both species are turf-forming constituents in the Azores but such turfs in Britain are less common and less species rich. The non-coralline algal turf biotope is typical of other Macronesian islands and also tropical West Africa where Lawson & John (1987) described a red algal turf as a principal feature of intertidal shores. A biotope defined by '*Corallina officinalis* on very exposed eulittoral rock' (Connor et al., 1997a, b) occurs widely in the northern North Atlantic and also in the Azores, usually as pure stands of *C. officinalis* Linnaeus in its typical form. A second *Corallina* turf biotope also occurs in the Azores and comprises a compact and tightly entangled species-rich mat in which *Corallina* is less recognisable and mixed with other articulated Corallinaceae, this biotope closely resembles *Corallina* turfs described from the Canary Islands (Lawson & Norton, 1971), West Africa (Lawson & John, 1977), Mexico (Stewart, 1989) and Brazil (Oliveira & Mayral, 1976). The predominance at sublittoral levels of the foliose *Zonaria tournefortii* biotope contrasts with the predominance of leathery macrophyte kelp biotope complexes of the North Atlantic but is a feature of Madeira (Levring, 1974) and the Mediterranean (Garcia & Carrascosa, 1987, Drago et al., 1997).

Although sea urchins graze areas clear of non-calcified algae to reveal a biotope characterised by crustose Corallinaceae, such cleared areas are restricted in extent in the Azores and contrast with localities on Madeira where this 'urchin barren' biotope is widespread and extends into deep waters (pers. obs). In the Azores, the littoral limpets have been removed by human predation (and thus the biotope destroyed) allowing algal assemblages to develop in areas that would otherwise lack such growth (Martins et al., 1987).

Conclusions

The improving body of knowledge of algal community structure and its dynamics has encouraged the application of the MNCR biotope method to marine community classification in the Azores. Although the biotope method was developed in Britain as a tool to aid management and conservation of marine habitats, its general principles can be applied to other geographical areas. In the present study, the method has helped identify differences in algal community structure between Britain and the Azores. It will also provide a useful monitoring tool to assess change in marine communities in the Azores whether natural or anthropogenic.

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