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Original article

Benthic cyanobacterial diversity of Iles Eparses (Scattered Islands) in the Mozambique Channel

Mayalen Zubia [a, *], Jean Turquet [b], Stjepko Golubic [c]

[a] Université de Polynésie Française, UMR-EIO, LabEx-CORAIL, BP 6570, 98702 Faa'a, Tahiti, French Polynesia
[b] Agence pour la Recherche et la Valorisation Marines (ARVAM), CYROI, La Technopole, 2 rue Maxime Rivière, 97490 Sainte Clotilde, La Réunion, France
[c] Biological Science Center, Boston University, 5 Cummington Street, Boston, MA 02215, USA

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ABSTRACT

The marine benthic cyanobacteria of the Iles Eparses, Mozambique Channel, were surveyed for the first time. A total of 39 species are reported: 29 from Europa, 17 from Glorioso and 23 from Juan de Nova Islands. The higher biodiversity in Europa is explained by greater habitat diversity on this Island with unique ecosystems (mangroves, fossil reefs, pools). Average species richness varied between the geomorphological habitat types with higher diversity in shallow environments (fossil reef pools, mangroves, reef flats), which are characterized by high temperatures and high irradiances. The most common species observed on the three islands were *Hydrocoleum coccineum*, *Hydrocoleum glutinosum*, *Hydrocoleum lyngbyaceum*, *Phormidium laysanense*, *Lyngbya sordida*, and *Symploca hydnoides*; which are also the dominant species observed in the Southwest Indian Ocean region. The most frequent species was *Phormidium laysanense* with extensive cover observed in the northwest of Juan de Nova Island. Our study provided a comparison between the cyanobacterial flora of Iles Eparses and the recorded surveys in the Southwest Indian Ocean region. The low similarity observed between these species lists could be explained by differences in sampling strategies and efforts, as well as by different taxonomic approaches employed in past regional studies.

1. Introduction

Cyanobacteria are common constituents of coral reef ecosystems, where they contribute today, as they did in the geological past, to reef construction, forming microbial mats and microbialites (Krumbein et al., 2003; Riding and Awramik, 2000; Seckbach and Oren, 2010) and to reef degradation by participating in biocorrosion and promoting bioerosion of sedimentary structures (Tribollet and Golubic, 2011; Tribollet et al., 2011a,b; Wisshak and Tapanila, 2008). Cyanobacteria in tropical seas occur in the water column as well as in euphotic and disphotic benthos (Chazottes et al., 2009). They occupy a variety of reef habitats, covering hard and soft substrata and interacting with sponges, corals, other invertebrates and fungi (Charpy et al., 2012b; Le Campion-Alsumard et al., 1995a,b). Marine cyanobacteria play an important ecological role as primary producers, because they fix carbon as well as nitrogen (diazotrophy), helping to support numerous planktonic and benthic heterotrophs (Charpy et al., 2012a; Schneider and Torunski, 1983). Cyanobacteria are also recognized as important agents in marine bioerosion, including on coral reefs (Tribollet and Golubic, 2011; Tribollet et al., 2011a,b). Under normal oligotrophic conditions, diverse cyanobacterial populations occupy dispersed denuded surfaces on the reef, forming colonies and local benthic mini–blooms (Abed et al., 2003a,b; 2006). However, in recent years, massive benthic blooms of cyanobacteria have occurred with increasing frequency in coral reefs and tropical lagoons in response to natural and man–made environmental disturbances (Laurent et al., 2008; Littler et al., 2006; Paul et al., 2005). Studies have shown that blooms of cyanobacteria can inhibit recruitment of corals (Birrell et al., 2008; Kuffner and Paul, 2004; Kuffner et al., 2006). The excessive growth of cyanobacteria poses serious ecological, economic and health problems to marine animals (O'Neil et al., 2012; Roué et al., 2014). Some cyanobacteria (*Geitlerinema*, *Leptolyngbya*, *Phormidium*, *Pseudoscillatoria*) were identified as pathogens in coral "Black Band Disease" (Frias-Lopez et al., 2003; Kramarsky-Winter et al., 2013; Myers et al., 2007). Marine cyanobacteria, like their freshwater counterparts, produce potent neurotoxins, which are transferred along the food chain and

* Corresponding author.
E-mail address: mayalen.zubia@upf.pf (M. Zubia).

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present a health hazard to human populations on tropical coasts (Catherine et al., 2013; Golubic et al., 2009; Laurent et al., 2008; Roué et al., 2014).

In this context, studies have increasingly focused on benthic mat-forming cyanobacteria in tropical lagoons and coral reefs. Several studies on the diversity and ecology of marine cyanobacteria were conducted in coral reefs and atolls of the Pacific, in French Polynesia (Abed et al., 2003a,b; 2006; Bonnard et al., 2007; Charpy et al., 2012a; Charpy-Robaud et al., 1999; Laurent et al., 2012; Palinska et al., 2012; Richert et al., 2005, 2006; Villeneuve et al., 2012), in Guam (Thacker and Paul, 2004), in New Caledonia (Abed et al., 2006; Charpy et al., 2007a), in Okinawa (Charpy et al., 2010) and in the Atlantic, in Florida and the Caribbean area (Foster et al., 2009; Engene et al., 2013a,b; Paul et al., 2005). However, few studies have been done in the Southwest Indian Ocean (Bauer et al., 2008; Charpy et al., 2007b, 2010; 2012a,b; Echenique-Subiabre et al., 2015), and there is limited information, mostly from sporadic studies, on marine cyanobacteria from the Mozambique Channel, despite the many oceanographic expeditions that have passed through that region.

Our study presents the first inventory of the benthic cyanobacteria of three Iles Eparses: Europa, Glorioso and Juan de Nova. Knowledge of the coral reefs of Iles Eparses is sparse or lacking because of their limited accessibility. The islands are about to be declared marine protected areas (MPAs) and for this purpose, a management plan has to be established, which requires fundamental knowledge of the habitats and the communities associated with the surrounding coral reef ecosystems. Faced with gaps in our knowledge and to meet the needs for management, a research program called BIORECIE ("Biodiversité Ressources et Conservation des Récifs Coralliens des Iles Eparses") was designed. This program aims to update the inventories of the fauna and flora of these islands. Because these are uninhabited, pristine reef environments, the information is expected to provide an ecological yardstick for assessing environmental changes.

The present study is a part of this BIORECIE program, and focuses on the results obtained for the marine benthic cyanobacteria during the BIORECIE Expeditions in 2011, 2012 and 2013. The aim in the present paper is to provide a baseline species checklist for future biogeographical studies and management purposes, and to conduct a preliminary investigation of the distribution of species in relation to habitat and regional diversity.

2. Materials and methods

2.1. Area of study

Iles Eparses are a group of five coral islands distant from each other, which are administrated by the program French Southern Lands and Antarctica "Terres Australes et Antarctiques Françaises" (TAAF). The present study refers to three of these islands, situated in the Mozambique Channel from North to South: Glorioso, Juan de Nova and Europa (Fig. 1). The fourth island, Bassas, which is closest to Europa and the fifth, Tromelin, located northeast of Madagascar, are not included in the present study.

The Glorioso archipelago represents the northernmost islands of the Mozambique Channel. It is about 140 km Northwest of the northern tip of Madagascar and about 170 and 500 km Northeast of Mayotte (Comoros) and Juan de Nova, respectively, and 460 km East of the northern tip of Mozambique (11°35′S; 47°18′E, Fig. 1). The archipelago is composed of two main islands: Grande Glorieuse, the largest, which is sub-circular and has a maximum diameter of 2.3 km and Ile du Lys which is only 600 m long. The two islands are separated by 10 km of shallow reefs and surrounded by a lagoon. The total reef area of Glorioso Island is approximately 197 km^2

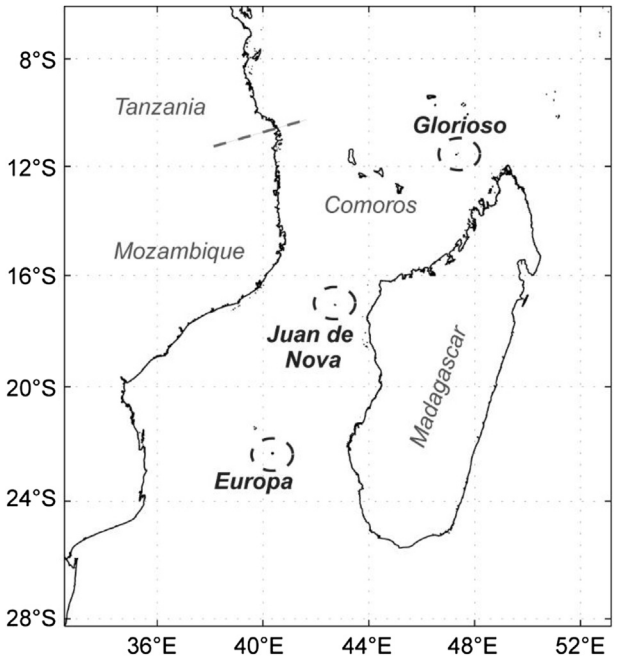

Fig. 1. Geographical position of Europa, Glorioso and Juan de Nova Islands in the Mozambique Channel.

(Andréfouët et al., 2008).

The Island of Juan de Nova is about 400 km North of Europa, about 175 km West of Madagascar and 280 km East of Mozambique (17°03′S; 42°43′E, Fig. 1). It is a small island with a surface area of only 5 km^2; it is 6 km at its longest and 1.6 km at its widest points, with sand dunes that can reach up to 12 m high, and it is surrounded by a large lagoon (163 km^2) and fringing reefs. The total reef surface of Juan de Nova Island is approximately 207 km^2 (Andréfouët et al., 2008).

Europa is the southernmost Island in the Mozambique Channel, located 550 km East of southern Mozambique and 300 km West of southern Madagascar (22°21′S; 40°21′E, Fig. 1). It is the largest of the Iles Eparses; it has a roughly circular shape, about 6–7 km in diameter, with a surface area of approximately 30 km^2. Its maximum elevation is 6–7 m above the sea level and it is surrounded by sand dunes and fringing reefs. The lagoon is almost empty at low tide and half of its 8 km^2 surface is occupied by mangrove trees (Battistini, 1966). The total reef surface of Europa Island is approximatively of 47 km^2 (Grellier, 2012).

A complete account of Iles Eparses, including geopolitical importance, geomorphology, and natural history is given by Caceres (2003).

2.2. The sampling strategy

The present study is a part of a wider objective to produce a complete inventory of the organisms inhabiting pristine and unspoiled coral reefs and to assess their diversity as well as their distribution and roles in different habitats of a complex environmental setting such as a coral reef. It was, therefore, important to design a consistent sampling method to use in surveys of different groups of organisms, so that the results can be integrated and interrelated. Cyanobacteria and algae are important because they are primary producers that support various animal taxa (hydroids, corals, echinoderms, decapods and fishes), which live in different habitats of the coral reef ecosystem. The habitat will be characterized first by its physical characteristics (geomorphology,