

Small marine Achnanthes (Bacillariophyceae) from coral reefs off Polynesia (South Pacific)

Catherine Riaux-Gobin, Andrzej Witkowski,
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**Small marine Achnanthes
(Bacillariophyceae) from coral
reefs off Polynesia (South Pacific)
Specificities and biogeography**

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Cover: Napuka lagoon land scape, with SEM illustration of *Cocconeis napukensis*.

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1. Abstract

A 2010–2020 survey of small-sized marine Achnanthes (Bacillariophyceae) undertaken in Central Polynesia (South Pacific) was largely focused on ultra-structure using the scanning electron microscope (SEM). The degree of colonization, species richness and emergence of new diatom taxa appeared to vary according to the geologic past, presence of coral reefs and degree of insularity (insulation) of each island. The Tuamotu atolls, active coral structures formed during the ancient geologic past, are characterized by low diatom colonization, with a relatively high species richness. High volcanic islands (younger geologic structures with more or less restricted coral reefs, e.g. Society and Austral Archipelagos) are enriched with numerous pantropical and cosmopolitan taxa, and a variable number of newly described taxa. Among the Marquesas Islands, characterized by flooded fossil reefs and water masses enriched with particulate matter, Nuku Hiva was found to be poorly colonized, with a low Achnanthes diversity. Several recently published taxa from French Polynesia are here presented, with in part unpublished observations and new illustrations. Several taxa first described from the Indian Ocean are also present in French Polynesia and can be considered as pantropical, whereas some of the others are presently listed from only one oceanic basin. A Venn diagram permitted the first comparison between assemblages studied with the same methodologies from French Polynesia (Central Polynesia), New Caledonia (Melanesia) and Mascarenes (Indian Ocean). The assemblages from the tropical West Atlantic are briefly discussed. Some taxa with slight morphological differences from their original description may signal morphotypes or *formae* as possible ‘cryptic taxa’. ‘Potential endemism’ is briefly discussed with 11 taxa pertaining to the genera *Amphicoconeis*, *Astartiella*, *Cocconeis* and *Xenococconeis*, yet only listed from the Pacific, and here briefly described. In addition, new details are added to the description of some rare pantropical taxa.

2. Introduction

Coral reef environments are generally recognized as highly diversified habitats through their high turn-over and complex food webs (Goreau et al. 1979, Pandolfi et al. 2003). The diatom floras are particularly diversified in tropical environments, especially among benthic diatoms (i.e. Riaux-Gobin et al. 2011b, Lobban et al. 2012). A survey from the Florida Keys (Tropical West-Atlantic) by Montgomery (1978) exemplifies this with SEM illustrations of numerous Achnanthes (ca. 60) demonstrating an impressive marine diatom diversity in tropical environments.

The Pacific Ocean is composed of three major ‘cultural areas’: Melanesia, Micronesia and Polynesia (Fig. 1), with Easter Island located in the most south-eastern part of Polynesia and islands such as the Galápagos in the most eastward part of the Pacific Basin. Diatom monographs mainly concerned 1) Micronesia (Central West Pacific, i.e. Guam & Yap Islands and Moen Island: Navarro & Lobban 2009, Lobban et al. 2012, Lobban 2015; Park et al. 2018), 2) Polynesia

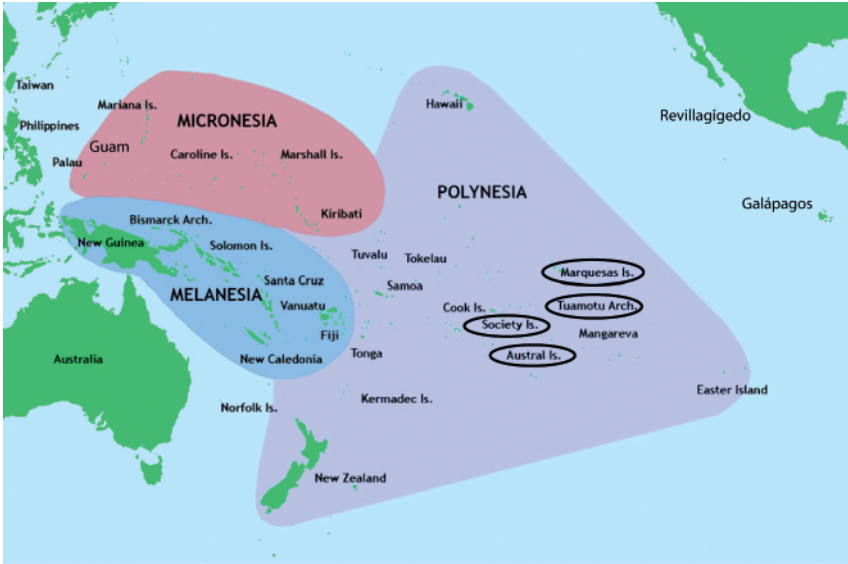


Fig. 1. Pacific Ocean culture areas: Melanesia (South-West Pacific), Polynesia (Central Pacific) and Micronesia (North-West Pacific). With position of Galápagos (Equatorial Eastern Pacific) and Revillagigedo (Mexico). Modified from: https://upload.wikimedia.org/wikipedia/commons/thumb/a/aa/Pacific_Culture_Areas.png/800px-Pacific_Culture_Areas.png; no copyrights.

(Central Polynesia-French Polynesia: Ricard 1975, Ricard 1977, Coste & Ricard 1990, Riaux-Gobin et al. 2021c; Easter Island: Navarro 2002; South Polynesia: New Zealand, from temperate to subtropical: Foged 1979), 3) Melanesia (Fiji Island: Foged 1987; New Caledonia, freshwater diatoms: e.g. Maillard 1978, Le Cohu 1985, Moser et al. 1998, and marine: Witkowski 1998 *in* Moser et al. 1998, Riaux-Gobin et al. 2022), and 4) Equatorial East Pacific (i.e. Galápagos Island: Hendey 1971, Stidolph et al. 2012, Łopato 2016; Revillagigedo Island: Siqueiros Beltrones et al. 2021). This relative scarcity of marine studies in such a large area (Figs 1–2) offers a wide range for further investigations, particularly concerning small and rare taxa.

French Polynesia extends over ca. 4167 km² (Fig. 2), with five archipelagos originating from several distinct hot spots lasting from 50 My BP (My BP = million years before present; e.g. atolls from the north-west Tuamotu Archipelago) to sub-actual (i.e. 300 000 y BP, Tahiti-Iti from the Society Archipelago – the smaller Tahiti volcano), even to actual (e.g. Mehetia Island, an active Society volcano). Depending on their age and geology, some islands are composed of volcanic high structures surrounded by more or less extended coral reefs, where-

as older structures evolved into atolls, such as the Tuamotu Islands. Depending on complex geological events, some atolls are also present on younger archipelagos, such as the Gambier. All these atolls are doomed over the course of geological time to become drowned guyots.

A special focus can be shed on the Marquesas Archipelago [geologic age from 5.5–4.9 My BP to 2.5–1.2 My BP along a north-west to south-east alignment (cf. Chauvel et al. 2012, fig. 1), with an intricate origin for these islands and also for the Marquesas Plateau itself]. The high Marquesas Islands (e.g. Nuku Hiva) experienced deep flooded coral reefs, ca. 80–95 m deep (Rougerie et al. 1992). Some other coral structures from this archipelago are less deeply flooded, such as several submerged atolls (e.g. Lawson Bank with a coral reef more or less 5m deep), and quasi-atolls (e.g. Fatu'Uku). This contrasted evolution of islands within the Marquesas gave rise to various hypotheses (see arguments about complex isostatic movements, according to assumptions by S. Jourdan* and Bouniot & Jourdan 2009). The complex geology of Marquesas, in conjunction with sub-actual eustatic movements [sea level rise due to deglaciation, around 14 000 y BP, with water mass cooling unfavorable to coral growth, particularly in the north of the Pacific Basin (Guille et al. 2002, Legendre 2003)], resulted in the above cited contrasted geomorphology among islands.

Rapa Island, a high volcanic island from Austral, has no associated coral reef, while the geologic past and hydrologic conditions of this island do not seem incompatible with their establishment (Montagioni 2015). The latter remark highlights the complexity of the geologic events in the South Pacific and their implication on coral reef building.

The complex geologic past (age and origin) of the South Pacific Islands, particularly from French Polynesia (Brousse et al. 1990, Diraison 1991, Le Dez et al. 1996, Guille et al. 2002), lead to contrasted geomorphology from one archipelago to another, or even from one island to another. For example, Tetiaroa as well as Tupai (Society) are atolls while other islands of this archipelago are high islands or semi-atolls, with Mehetia being an active volcano with, up to now, no associated reef.

Benthic diatoms are eukaryotes e.g. micrometric primary producers with a siliceous frustule, requiring a substratum to establish colonies. Their behavior can be driven by the chemical and physical environment: silica concentrations, photic zone light levels, nutrients, salinity, suitable hydrodynamic exposure and substrate, insularity. Thus, it is interesting to think about the existence of these micro-organisms as a possible function of their environment linked to the geologic past and degree of insulation of each island. The South Equatorial Current (SEC) with a westward drive (Rougerie et al. 1997, Martinez et al. 2009) may prevent isolated islands from directly influencing other islands, thereby reinforcing their geographic isolation.

*see <https://kn01.wordpress.com/nos-collections/collection9-geographie/les-atolls-et-presquatolls-des-marquises-un-pave-dans-le-lagon/>

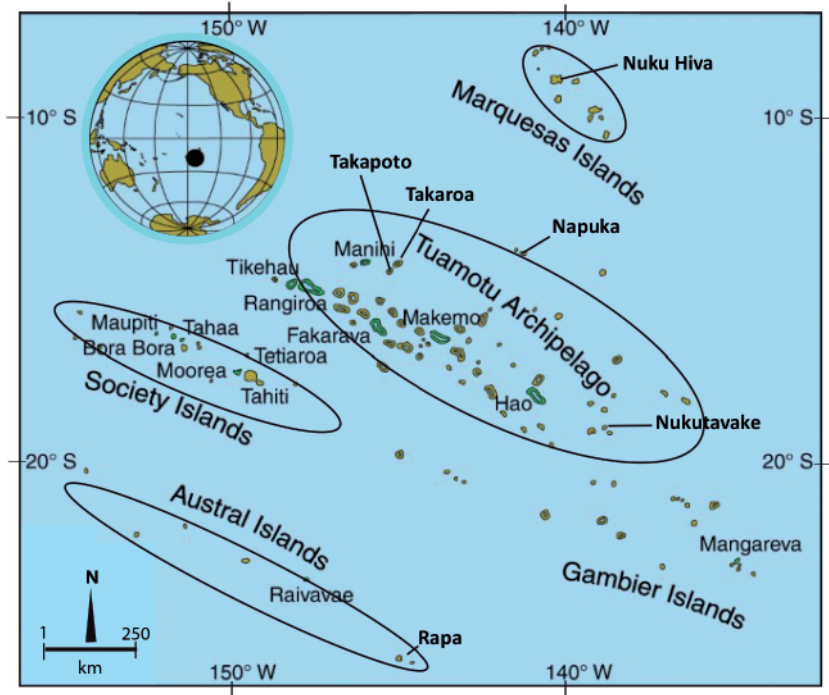


Fig. 2. French Polynesia position, with Marquesas, Tuamotu, Society, Gambier and Austral Archipelagos, and position of each sampled island during the 2010–2020 survey: Nuku Hiva, Takaroa, Takapoto, Napuka, Nukutavake, Tahiti, Moorea, Tetiaroa, Raivavae, Rapa. Modified version of: https://www.google.com/search?client=firefox-b-d&q=41467_2017_2695_Fig1_HTML+; no copyrights.

The CORDIA project (Coral Reef DIatoms, Labex, 2010–2012) was focused on the diatom diversity from Society and Tuamotu. One goal of CORDIA was to study the order Achnanthes Silva 1962 through a geomorphologic reef gradient (from high volcanic islands of the Society, to atolls from Tuamotu). Further samplings (2013–2020) permitted the investigation of several other South Pacific islands, from Marquesas to Austral, and led to the description of several new taxa.

Eleven small and marine Achnantheaceae, to our knowledge only present in Polynesia, are herein illustrated using the SEM, with comments on their similarities to other taxa. A short description is given for each taxon, with some new illustrations (however, if necessary, it is recommended that the reader consults

the full original description). New morphological details are also given for some rare pantropical taxa, along with a revision of their biogeography.

A Venn diagram allows the comparison of the taxonomic assemblages reported herein from French Polynesia, New Caledonia and Mascarenes (data obtained using the same methodologies, and with a similar effort -concerning sampling and SEM observation- on each sector). Finally, the Pacific assemblages are briefly compared with those detailed from the tropical West Atlantic through historical surveys.

Biogeography and ‘potential endemism’ are also briefly discussed.

3. Material and methods

During 2010–2020, ten French Polynesian islands, pertaining to four Archipelagos, were sampled: Tahiti-Nui – the larger Tahiti volcano –, Moorea, Tetiaroa (Society); Napuka, Takaroa, Takapoto, Nukutavake (Tuamotu); Nuku Hiva (Marquesas) and Raivavae, Rapa (Austral) (Fig. 2). Mangareva, pertaining to Gambier, a wide semi-atoll with volcanic islands still merging, was sampled in late 2021 and will be presented later on. Interestingly, Mangareva has an easterly position in the SEC.

All samples collection from Polynesia and Melanesia (2010–2020) took place in September–December, whereas the samplings in the Mascarenes (2005–2009) were all performed in May–June (Table 1). As a consequence, these Indo-Pacific samplings were performed during the dry season.

Diverse habitats, mostly marine intertidal, were sampled on each island, representing in total ca. 150 marine samples, which were observed during 240 SEM sessions. The investigated substrates were diverse, from mineral to plant and animal: coral sands, dead corals, intertidal marine sediments (i.e. surficial muds from mangroves), diverse macroalgae and short turfs, but also invertebrate scrapings, such as scrapings of *Holothuria atra* Jaeger and bivalve mollusks, particularly *Pinctada margaritifera* Linnaeus. Note that the sampled mangroves from French Polynesia (e.g. from Moorea Island) are not natural units, but settlements of human origin (*Rhizophora stylosa* Griffith was introduced in Moorea in 1930–1935; Cavaloc 1988). Scrapings of numerous marine turtles [ca. 120 specimens pertaining to four species, from French Polynesia, Martinique (Caribbean arc) and Guyana] were also studied, in collaboration with Damien Chevallier (turtle ethology, Institut Pluridisciplinaire Hubert Curien, UMR 7178, CNRS-Unistra) as part of his ANTIDOT project. The latter studies mainly focused on gomphonemoid genera and possible ‘commensalism’ (Riaux-Gobin et al. 2017a,b; Riaux-Gobin et al. 2021a).

Raw material (RM) was preserved with formalin (10% final dilution) or absolute ethanol. Due to the small size of the taxa, the descriptions of new monoraphids were based on very fine structures, e.g. the valvocopulae and areola hymenate structure, which are difficult or impossible to observe in the light microscope (LM). The scanning electron microscope (SEM) was systematically used and commented here (LM illustrations of several taxa are available in the