

Massive proliferation of *Grateloupia intestinalis* (Hooker fil. et Harvey) Setchell ex Parkinson (Rhodophyta, Halymeniaceae), a non-native species in Valparaíso Bay, central Chile

Proliferación masiva de *Grateloupia intestinalis* (Hooker fil. et Harvey) Setchell ex Parkinson (Rhodophyta, Halymeniaceae), especie no-nativa en la bahía de Valparaíso, Chile central

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Resumen.- Se informa la proliferación masiva de *Grateloupia intestinalis*, una especie no reportada previamente en la bahía de Valparaíso, Chile. Un total de 74 ejemplares fueron recolectados al azar en el intermareal bajo de Playa Cochoa (32°57'21,8''S-71°32'57,7''W) en octubre de 2006. El material fue herborizado y se realizaron cortes histológicos para su observación con microscopía óptica. Los especímenes recolectados se caracterizan por un talo de color rojo vinoso, linear, ligulado, con uno o dos ápices, ligeramente gelatinoso y ondulado. Los especímenes alcanzan aproximadamente 18 cm de largo y 1 cm de ancho. Los cortes transversales muestran una corteza con tres a cuatro cubiertas de células elípticas entre

las cuales se presentaron tetrasporangios cruciados esparcidos. La médula es laxa dejando en el centro un espacio lleno de mucílago. No se observaron plantas cistocárpicas. En la costa de Chile central no ha sido registrada otra proliferación de *G. intestinalis* como la observada en Playa Cochoa. Aunque se había encontrado en el sur del país, esta información no era explícita por encontrarse en una publicación sobre Gigartinales y Rhodymeniales, en la cual esta especie sólo se menciona entre el material de herbario trabajado. Se sugiere que *G. intestinalis* sería una especie no nativa para la costa de Chile.

Palabras clave: Tetrasporangios, distribución geográfica, algas

Introduction

Eight species of *Grateloupia* C. Agardh have been listed in the catalogue of the benthic seaweeds of the Pacific southern temperate coast of Chile: *G. denticulada*, *G. doryphora*, *G. filicina*, *G. rojassii*, *G. spathulata*, *G. subsimplex*, *G. versicolor* and *Grateloupia* sp. (Ramírez & Santelices 1991). Saunders *et al.* (2004) included *G. intestinalis* collected by A. Peters from Los Molinos, Valdivia, southern Chile, in a table that showed the collection data for the species included in their molecular analyses.

Due to their variable morphology, the species of the genus *Grateloupia* are difficult to determine (Ardré & Gayral 1961, Cabioch *et al.* 1997, Kraft 1977). The species *Grateloupia doryphora*, described from Chile and Peru (Ramírez & Santelices 1991) has long been viewed as introduced in the Atlantic Ocean as well in Western Europe (Farnham & Irving 1973, Cabioch *et al.* 1997, Maggs & Stegenga 1999), eastern North America (Villalard-Bohnsack & Harlin 1997), and in the Mediterranean Sea (De Masi & Gargiulo 1982, Tolomio 1993). Recently, on the basis of morphological and

molecular evidence, Gavio & Fredericq (2002) have clarified the taxonomic position of *G. turuturu*, the correct name species reported as *G. doryphora*. These last authors proposed a possible route of introduction of *G. turuturu* from its native Japan, while restricting the distribution of *G. doryphora* to Peru and Chile.

Understanding the mechanisms and impact of biological invasions is crucial to preserve marine biodiversity. The invading species can compete or hybridize with the native species, resulting in the loss of marine biodiversity and an altering of fundamental processes in the ecosystem (Vitousek *et al.* 1997). The invasion of coastal ecosystems by non-native species is a widely recognized phenomenon and it is expanding in scope (Grosholz & Ruiz 1996). Although most of the introduced species do not become invasive, those that do can cause an enormous ecological and economic impact (Preskitt 2006¹).

¹Preskitt L. 2006. Invasive Marine Algae of Hawaii. Department of Botany, University of Hawaii at Manoa. [on-line] <http://www.hawaii.edu/reefalgae/invasive_algae/index.htm>.



Figure 1

Grateloupia intestinalis. Habits of specimens used in this study (MHNV-al-0019R-2)

Grateloupia intestinalis. Hábitos de los especímenes utilizados en el presente estudio (MHNV-al-0019R-2)

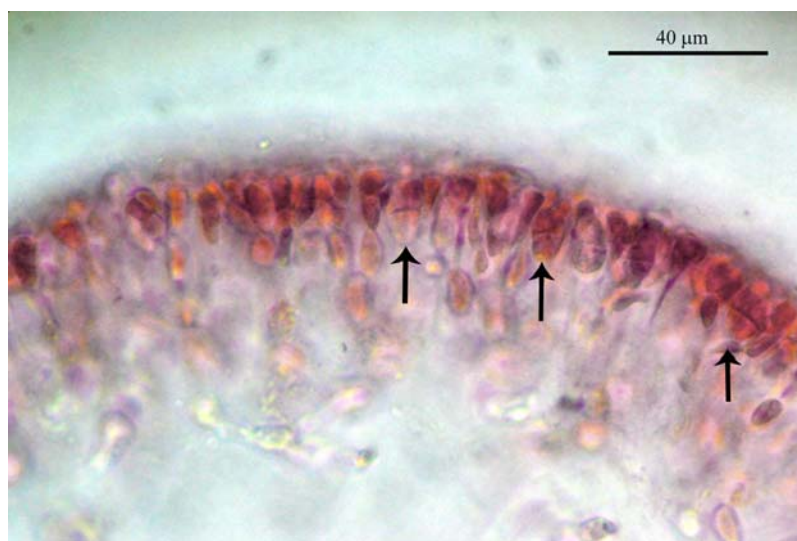


Figure 2

Grateloupia intestinalis from Playa Cochoa. Transverse section through a tetrasporophyte showing a lax medulla and three to four elliptical cortical cell layers. The arrows point to tetrasporangia

Grateloupia intestinalis de Playa Cochoa. Corte transversal a través de un tetrasporofito mostrando la médula laxa y tres a cuatro capas de células corticales elípticas. Las flechas apuntan a los tetrasporangios

Recent publications have demonstrated that invasive species can be successfully identified on the basis of morphological characters. Early detection and handling of the foreign species have been the best tools to stop their impact on the coast of Hawaii (Abbott 1999). Five species of non-native seaweed invaders have been recognized from Chile; each species has been documented in the literature at least twice or has been collected at different time intervals. Among these five species of algae, two of them are highlighted: *Mastocarpus papillatus* and *Codium fragile* var. *tomentosoides* (Castilla *et al.* 2005). Nevertheless, only the green alga *Codium fragile* is considered a pest (Neill *et al.* 2003², Neill *et al.* 2006).

Mastocarpus papillatus, native to Japan, was first reported in Chile by Avila & Alveal (1987). It is believed that this species most likely arrived in the area in the early 1980s on the hulls of ships associated with coal transport (Castilla *et al.* 2005). *Codium fragile* var. *tomentosoides* also native to Japan, was reported for the first time in Chile in 1998 by Neill *et al.* (2003²) as an invader in northern Chilean *Gracilaria chilensis* aquaculture facilities. Currently, *C. fragile* is found in 34 places between Antofagasta and Punta Arenas, with a discontinuous distribution and greater abundance in the north, in the region of Caldera, Calderilla and Bahía Inglesa. *C. fragile* alters the biodiversity and negatively affects the cultures of *Gracilaria*, with disastrous economic effects for the industry (Neill *et al.* 2003², Castilla *et al.* 2005, Neill *et al.* 2006). In this context the present work reports a non-native seaweed species of *Grateloupia* in Valparaíso Bay, Chile. It is improbable that this species was native to Valparaíso Bay because it has not been found before although the central coast of Chile has been the focus of enough seaweed collection efforts (Guiller 1952, Alveal 1970, Etcheverry 1986, Ramírez & Santelices 1991, Hoffman & Santelices 1997, González & Collantes 2001) including several thesis during the last two decades (González 1998, La Rosa 2003).

Material and methods

A total of 74 specimens were collected on October 10, 2006 in the rocky intertidal of Playa Cochoa (32°57'21,8''S-71°32'57,7''W) (GPS Garmin eTrex

Legend, datum WGS 84), Valparaíso, central Chile, and transferred wet to the laboratory. The material was vouchered according to traditional techniques and deposited in the Museo de Historia Natural de Valparaíso, voucher number MHNV-al-0019R-1, MHNV-al-0019R-2. Algae were cross sectioned by hand with a razor blade. Microscopic observations were done with Nikon Labophot microscope, equipped with a digital camera Canon Power Shot A85. The vouchered specimens were scanned and registered using a HP ScanSet 3400Cs scanner. Vouchers were also dried in the field with silica gel for future molecular analyses.

Provisional determination of the species was carried out by comparing the collected material with the species descriptions of *Grateloupia* by Kützting (1867), De Toni (1905) and Kraft (1977).

Results

The collected specimens are characterized by red-wine linear, ligulate, gelatinous-fleshy, slightly undulated thalli, reaching up to 18 cm in length, 1 cm in width. The thalli reflect the light irregularly and have one or two apical regions, and are born on a short stipe (Fig. 1). Cross sections reveal a cortex (60 µm) of 3-4 layers of elliptical cells between which cruciately divided tetrasporangia are interspersed (Fig. 2). The medulla is lax (100 µm), medullary filaments separate and break apart, leaving the centre of the plant mostly hollow and filled with mucilage. The transition between cortex and medulla is abrupt. Habits of cystocarpic thalli have not been found.

Discussion

The external morphology and the construction of the medulla of *Grateloupia* individuals from Playa Cochoa (Fig. 1) show the centre of the plant mostly hollow and filled with mucilage, and do not agree with the description of any of the *Grateloupia* species previously reported for the Chilean coasts which have the centre of the plant filled with medulla without hollow (Ramírez & Santelices 1991), but they display similar characteristics to those of *Grateloupia intestinalis* (Hooker fil. et Harvey) Setchell ex Parkinson, depicted in Figs. 1-21 by Kraft (1977).

The habits of *Grateloupia* collected in Playa Cochoa and *G. intestinalis* (Kraft 1977) differ in the range of the number of fronds that are simple in specimens from Playa Cochoa. These would correspond to specimens of a young population that became established no longer than four weeks earlier since during 2006 this beach was monthly monitored in search of *Porphyra* spp. and only few specimens of this species of *Grateloupia* had been previously observed.

²Neill P, O Alcalde & J Correa. 2003. Presencia de la especie invasora *Codium fragile* (Chlorophyta) en el norte de Chile: efectos potenciales sobre cultivos de *Gracilaria chilensis* (Rhodophyta). XLVI Reunión Anual de la Sociedad de Biología de Chile, Pucón, Chile. Biological Research 36: 56 [Abstract].



Figure 3

Lower rocky intertidal zone exposed to the surge in Playa Cochoa showing the population of *G. intestinalis*

Intermareal rocoso bajo de frente expuesto en Playa Cochoa mostrando la población de *G. intestinalis*

According to Guiry & Guiry (2008³), *G. intestinalis* has as basionym and synonym *Nemastoma intestinale* Hooker & Harvey 1855 ('*intestinalis*'). In the past, *G. intestinalis* had been confused with *Grateloupia prolifera* J. Agardh. Unfortunately specimens suitable for studies of cystocarp ontogeny have not been observed but Setchell (in herb. Lindauer) mentions that it has well developed pericarpia propria (*i.e.* Gonimocarps). The binomial *Grateloupia intestinalis* was never effectively published by Setchell (Chapman & Parkinson 1974); its listing by Adams (1972) does not constitute valid publication under Art. 33 of the International Code of Botanical Nomenclature (*vide* Chapman & Parkinson 1974).

The native distribution of *G. intestinalis* comprises New Zealand (Chapman & Parkinson 1974, Womersley 1994, Adams 1994, Nelson & Phillips 1996, Adams 1997, Miller 2005) and Tasmania (Womersley 1994).

A distance tree of results emphasizing Halymeniales (Saunders *et al.* 2004) showed that *G. intestinalis* collected by A. Peters on November 1996 from Los Molinos, Valdivia, Chile (voucher number: GWS000354; GenBank number: AY437702) solidly joined the two included species of *Polyopes* in all analyses and failed to join the generic type, *G. filicina*. Notwithstanding the Fig. 11 exhibited in Saunders *et al.* (2004) does not match the collection data, as the habit presented corresponds to *G. intestinalis* from New Zealand (Kraft 1977) and not to the specimen from Chile that they worked on.

In Playa Cochoa the population of *G. intestinalis* occurred in the semi - protected, lower rocky intertidal (Fig. 3), occupying almost completely the regular habitat of *Porphyra pseudolinearis* at the end of the winter and spring (González 1998, González & Collantes 2001, La Rosa 2003, Muñoz-Muga 2005⁴) and sharing rocks exposed to the surge with *Codium dimorphum*.

³Guiry MD & GM Guiry. 2008. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. [on-line] <<http://www.algaebase.org>>.

⁴Muñoz-Muga P. 2005. Fenología morfológica y reproductiva del lucheillo *Porphyra woolhousiae* Harvey (Rhodophyta, Bangiophyceae). Seminario de Investigación de Biología Marina, Facultad de Ciencias del Mar, Universidad de Valparaíso, Valparaíso, 25 pp.

In the central coast of Chile, such a proliferation of *Grateloupia* as the one seen in 2006 has not been registered in the subsequent years, only isolated specimens have been found in the area during winter, spring and the beginning of summer. *G. intestinalis* from Los Molinos, Valdivia, southern Chile, studied by Saunders *et al.* (2004), would be the first report of the species from Chilean coast.

The early and localized detection of the massive proliferation of *G. intestinalis* in Playa Cochoa represents a good model for the pursuit of the behavior of an introduced species in relation to the native species. The taxonomy of *G. intestinalis* from Playa Cochoa requires later confirmation of molecular and morphological evidence, as well as an interpretation of its possible routes of introduction.

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Literature cited

- Abbott IA. 1999.** Marine red algae of the Hawaiian Islands, 477 pp. Bishop Museum Press, Honolulu.
- Adams NM. 1994.** Seaweeds of New Zealand. An Illustrated guide, 360 pp. Canterbury University Press, Christchurch.
- Adams NM. 1997.** Common seaweeds of New Zealand, 48 pp. Canterbury University Press, Christchurch.
- Alveal K. 1970.** Estudios ficoecológicos en la región costera de Valparaíso. *Revista de Biología Marina* 14(1): 7-88.
- Ardré F & P Gayral. 1961.** Quelques *Grateloupia* de l'Atlantique et du Pacifique. *Revue Algologique* 6: 38-48.
- Ávila M & K Alveal. 1987.** Ciclo de vida de *Mastocarpus papillatus* en el área de Concepción, Chile (Petrocelidaceae, Rhodophyta). *Investigación Pesquera (Chile)* 34: 129-138.
- Cabioch J, A Castric-Fey, MT L'Hardy-Halos & A Rio. 1997.** *Grateloupia doryphora*, et *Grateloupia filicina* var. *luxurians* (Rhodophyta, Halymeniaceae) sur les côtes de la Bretagne. *Cryptogamie Algologie* 18: 117-137.
- Castilla JC, M Uribe, N Bahamonde, M Clarke, R Desqueyroux-Faúndez, I Kong, H Moyano, N Rozbaczylo, B Santelices, C Valdovinos & P Zavala. 2005.** Down under the southeastern Pacific: marine non-indigenous species in Chile. *Biological Invasions* 7: 213-232.
- Chapman VJ & PG Parkinson. 1974.** Cryptonemiales. In: Chapman VJ (ed). *The marine algae of New Zealand. Part III. Rhodophyceae*, pp. 155-278. J. Cramer, Lehre.
- De Masi F & GM Gargiulo. 1982.** '*Grateloupia doryphora*' (Mont.) Howe (Rhodophyta Cryptonemiales) en Méditerranée. *Allionia* 25: 105-108.
- De Toni GB. 1905.** *Sylloge algarum. Florideae. Sectio IV: 1523-1973.* Patavii, Padova.
- Farnham WF & LM Irving. 1973.** The addition of a foliose species of *Grateloupia* to the British marine flora. *British Phycology Journal* 8: 208-209.
- Gavio B & S Fredericq. 2002.** *Grateloupia turuturu* (Halymeniaceae, Rhodophyta) is the correct name of the non-native species in the Atlantic known as *Grateloupia doryphora*. *European Journal of Phycology* 37: 349-359.
- González A. 1998.** Caracterización de especies y/o morfotipos de *Porphyra* (Rhodophyta, Bangiales), 'luche' de las bahías Valparaíso y Laguna Verde, V Región, Chile. Tesis de Biología Marina, Instituto de Oceanología, Universidad de Valparaíso, Valparaíso, 150 pp.
- González A & G Collantes. 2001.** Taxonomía numérica en la estimación de la diversidad de *Porphyra* spp. In: Alveal K & T Antezana (eds). *Sustentabilidad de la biodiversidad*, pp. 125-138. Universidad de Concepción, Concepción.
- Grosholz ED & GM Ruiz. 1996.** Predicting the impact of introduced marine species: Lessons from the multiple invasions of the European green crab *Carcinus maenas*. *Biological Conservation* 78: 59-66.
- Guiller E. 1952.** The intertidal ecology of the Montemar Area, Chile. *Papers and Proceedings of the Royal Society of Tasmania* 93: 165-183.
- Hoffmann A & B Santelices. 1997.** Flora marina de Chile central, 434 pp. Ediciones Universidad Católica de Chile, Santiago.
- Kraft GT. 1977.** The morphology of *Grateloupia intestinalis* from New Zealand, with some thoughts on generic criteria within the family Cryptonemiaceae (Rhodophyta). *Phycologia* 16(1): 43-51.
- Kützing FT. 1867.** *Tabulae Phycologicae, oder Abbildungen der Tange.* Vol. XVII: 1-30, 100 pl. Gedruckt auf Kosten des Verfassers, Nordhausen.
- La Rosa A. 2003.** Monosporas en las historias de vida de especies de *Porphyra* de la bahía de Valparaíso. Tesis de Biología Marina, Facultad de Ciencias del Mar, Universidad de Valparaíso, Valparaíso, 83 pp.
- Maggs CA & H Stegenga. 1999.** Red algal exotics on North Sea coasts. *Helgoländer Meeresunters* 52: 243-258.
- Miller IJ. 2005.** The structure of the polysaccharide from *Grateloupia intestinalis* in New Zealand. *Botanica Marina* 48: 142-147.
- Neill PE, O Alcalde, S Faugeton, SA Navarrete, JA Correa. 2006.** Invasion of *Codium fragile* spp. *tomentosoides* in northern Chile: A new threat for *Gracilaria* farming. *Aquaculture* 259: 202-210.
- Nelson WA & L Phillips. 1996.** The Lindauer legacy: current names for the Algae Novae-Zelanicæ Exsiccatae. *New Zealand Journal of Botany* 34: 553-582.

- Ramírez ME & B Santelices. 1991.** Catálogo de las algas marinas bentónicas de la costa temperada del Pacífico de Sudamérica, 437 pp. Monografías Biológicas 5, Pontificia Universidad Católica de Chile, Santiago.
- Santelices B. 1989.** Algas marinas de Chile, 399 pp. Ediciones Universidad Católica de Chile, Santiago.
- Saunders GW, A Chiovitti & GT Kraft. 2004.** Small-subunit rDNA sequences from representatives of selected families of the Gigartinales and Rhodymeniales (Rhodophyta). 3. Delineating the Gigartinales *sensu stricto*. Canadian Journal of Botany 82(1): 43-74.
- Tolomio C. 1993.** Prima segnalazione di *Grateloupia doryphora* (Mont) Howe (Rhodophyceae) nella Laguna di Venezia. Lavori della Società Veneziana di Scienze Naturali 18: 215-220.
- Villalard-Bohnsack M & M Harlin. 1997.** The appearance of *Grateloupia doryphora* (Halymeniaceae, Rhodophyta) on the Northeast coast of North America. Phycologia 40: 324-328.
- Vitousek PM, CM D'Antonio, LL Loope, M Rejmanek & R Westbrooks. 1997.** Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21: 1-16.
- Womersley HBS. 1994.** The marine benthic flora of southern Australia - Part IIIA - Bangiophyceae and Florideophyceae (Acrochaetales, Nemaliales, Gelidiales, Hildenbrandiales and Gigartinales *sensu lato*), 508 pp. Australian Biological Resources Study, Canberra.

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