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Range extension of the non-indigenous alga *Mastocarpus* sp. along the Southeastern Pacific coast

Extensión del rango geográfico del alga foránea *Mastocarpus* sp.
a lo largo de la costa del Pacífico Sudeste

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Abstract.- The red macroalga *Mastocarpus* sp. (Rhodophyta, Gigartinales) has been reported as a non-indigenous species in central Chile. In this area the geographic range described for the species encompasses approximately 200 km, from Cobquecura (36°08'S, 72°48'W) up to Punta Lavapié (37°08'S, 73°35'W). Observations carried out at 22 localities along the central-southern Chilean coast allow us to extend the known range of this species approximately 300 km to the north and 600 km to the south. Additional analysis indicated high percentage cover on areas described as the introduction point of the species.

Key words: *Mastocarpus*, geographic range, non-indigenous species, South-eastern Pacific coast

INTRODUCTION

The arrival of a non-indigenous species to an ecosystem might change the structure of the recipient communities (Schaffelke *et al.* 2006). In particular, non-indigenous algal species are a major concern because when they become established can impact both the ecosystem structure and function, *i.e.*, altering food webs, monopolizing space and spreading beyond their introduction point (Thresher 2000). Examples include the green alga *Caulerpa taxifolia* in the Mediterranean (Meinesz *et al.* 2001), and *Codium fragile* ssp. *tomentosoides* in northern Chile which has had negative impacts on the aquaculture of the red alga *Gracilaria*, affecting farming operations (Neill *et al.* 2006). This alga has been documented at different sites in Chile from 26°S to 55°S with faster spread expected towards northern Chile because of its affinity with high temperatures (Neill *et al.* 2006). The spread of introduced algal species seems to be rapid and characterized by long distance dispersal events (Lyons & Scheibling 2009).

In Chile, 15 non-indigenous algal species have been described (Castilla & Neill 2009), and of these, only 2 species are considered invasive: *C. fragile* ssp. *tomentosoides* (Neill *et al.* 2006) and *Asparagopsis armata* (Ramírez *et al.* 2007). Only *C. fragile* ssp. *tomentosoides* has been studied in detail: *e.g.*, taxonomic identity (González & Santelices 2004), origin (Provan *et al.* 2005), distributional range and abundance (Neill *et al.* 2006),

biology and ecology (*i.e.*, reproduction and epiphytes: Villaseñor-Parada & Neill 2011, Villaseñor-Parada *et al.* 2013). We have a limited understanding of the ecology, biology and distribution in Chilean coastal waters for the remaining species. *Mastocarpus* sp. (known locally as 'luga gallo' or 'luga-luga') is a red alga from the order Gigartinales, and is a non-indigenous algal species in Chile (Castilla *et al.* 2005, Castilla & Neill 2009). The genus' natural distribution is restricted to Pacific coast of North America, the North Atlantic and Japan (Guiry *et al.* 1984). The first published references of the species in the Southern Hemisphere account from early 1980s by several authors (Alveal & Romo 1980, Ruiz & Giampaoli 1981 - sampling during 1976, Guiry *et al.* 1984, Avila & Alveal 1987). The species was initially reported as *M. papillatus*, but recent molecular analysis has confirmed it as *M. latissimus* (Lindstrom *et al.* 2011). The genetic analysis also revealed the closest relationship with samples from California, therefore Lindstrom *et al.* (2011) suggests a recent anthropogenic dispersal. According to Castilla *et al.* (2005), the species first arrived during early 1980s on the hulls of ships associated with coal transport. This species is found from the low to mid intertidal (as a foliose gametophyte) to the subtidal (as a tetrasporophytic crust) on rocks at protected and semi-protected habitats, and is occasionally harvested for carrageenan extraction (Hoffmann & Santelices 1997).

The species distribution in Chile has been recorded as restricted only to the Biobío Region in Central Chile along 200 km approximately, between Cobquecura ($36^{\circ}10'S$ - $72^{\circ}49'W$) and Punta Lavapié ($37^{\circ}08'S$ - $73^{\circ}35'W$) (Guiry *et al.* 1984, Avila & Alveal 1987, Ramírez & Santelices 1991, Hoffmann & Santelices 1997). Little is known about the species' present geographic distribution, abundance and effects on local flora and fauna. Recently, Oróstica *et al.* (2012) reported that detached blades and papillae provide an alternative dispersal mechanism that might facilitate the establishment of individuals at new places. This alternative dispersal mechanism and formation of cistocarpic plants in the absence of male gametophytes (Avila & Alveal 1987) could facilitate geographic expansion and invasion of new territory. The aim of this paper is to provide new information about the distribution of the non-indigenous species *Mastocarpus* sp. in Chilean coastal waters, and about its abundance relative to other species in the intertidal.

MATERIALS AND METHODS

This study was carried out along the central-southern Chilean coast between Valparaíso ($32^{\circ}57'S$, $71^{\circ}32'W$) and Melinka ($43^{\circ}53'S$, $73^{\circ}44'W$). Twenty-two sites were sampled (Fig. 1) in January/February 2011 and January 2012 and 2013. In order to assess the presence of *Mastocarpus* sp. in the intertidal, visual surveys were carried out carefully at each site during low tide at rocky platforms and intertidal pools. In addition, percentage cover of *Mastocarpus* sp. and other algae (Rhodophyta, Chlorophyta and Phaeophyceae) and animals (Cirripedia) was measured using digital photos from 10 quadrats (25x25 cm) at each site. The positioning of the quadrats was random but limited to the mid and low intertidal where *Mastocarpus* sp. typically occurs. Such measurement was restricted at 6 sites of the center species distribution (Curanipe to Lebu), since the sampled sites represent the actual geographic range and the potential introduction point. Percentage cover analyses were carried out using

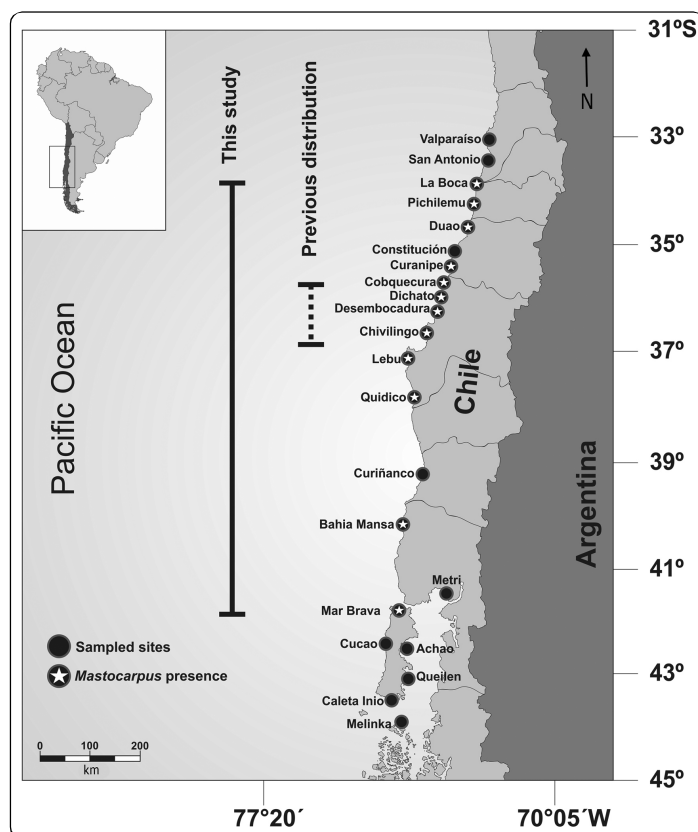


Figure 1. Survey sites at Central-Southern Chile. Circles with stars indicate presence of *Mastocarpus* sp. The dashed lines represents the previous geographic range, whereas continuous line represents the current distribution / Sitios de observación en Chile Centro-Sur. Círculos con estrellas indican la presencia de *Mastocarpus* sp. Línea punteada representa la distribución descrita, mientras que la línea continua representa la distribución luego de este estudio

the Coral Point Count with Excel extensions (CPCe) program Version 4.1 (Kohler & Gill 2006). A one-way ANOVA was carried out to detect differences in *Mastocarpus* sp. cover among sites. Significant differences detected by the analysis were explored with Tukey's HSD *a posteriori* test. The assumption of normality of the data was checked with the Kolmogorov-Smirnov test and homogeneity of variances with Levene's test. Percentage cover data were arcsine-square root-transformed to achieve normality.

RESULTS AND DISCUSSION

Mastocarpus sp. was found in 10 of the 22 sites surveyed, and its geographic range increased approximately 300 km northward, to La Boca (33°54'31.49"S; 71°50'32.25"W) and 600 km southward, to Mar Brava in Chiloé Island (41°52'5.72"S; 74°1'15.30"W) from previous descriptions (Avila & Alveal 1987, Ramírez & Santelices 1991, Hoffmann & Santelices 1997). Similarly, Ramírez *et al.* (2007) have reported a range extension of 300-400 km for another non-indigenous species along the Chilean coast, the red alga *Asparagopsis armata*, which is considered invasive (Chualain *et al.* 2004). Results from our study revealed that in the central area of the distributional range of *Mastocarpus* sp. (Dichato 36°32'26.78"S; 72°56'04.84"W) percentage cover was highest (~60% *Mastocarpus* sp.: ANOVA $F=16.37$, $P < 0.0001$, Tukey post-hoc). From this central region, percentage cover declined in both directions with other algal groups (mainly Gigartinales and Chlorophyta) becoming more dominant. At most sites

algal groups and barnacles (Cirripedia) were evenly distributed (Fig. 2). Lebu (37°35'35.8"S; 73°40'03.57"W) displayed the lowest *Mastocarpus* sp. cover with ~2%, whereas the green algae (*Ulva* spp.) were more abundant (~90%), however this site experienced a co-seismic uplift of approximately 1.7 m after the 27 February 2010 earthquake (Vargas *et al.* 2011) and at the time of the surveys (one year after earthquake) the distribution of intertidal species might still reflect the changes produced by this major disturbance; *Ulva* commonly appears in the rocky intertidal zone after disturbances (*e.g.*, Sousa 1979a, b, Dawson & Foster 1982, Kim & DeWreede 1996).

The highest cover of *Mastocarpus* sp. at the center of its distributional range might be confirmation of the suggested introduction point, particularly as major ports are nearby (*e.g.*, Lirquén, San Vicente, Talcahuano) and the area experiences intense shipping activity (Muñoz & Salamanca 2001); as mentioned above, arrival was most likely associated with hulls of coal ships (Castilla *et al.* 2005). Williams & Smith (2007) have suggested boat traffic as one of the major causes of marine algal introduction. Similarly, invasion of the brown alga *Undaria pinnatifida* in several places probably originated from transport on ship hulls (Chapman *et al.* 2006). Another introduction mechanism such aquaculture activity can't be ruled out, but are less likely since the area lacks dispersal vectors (*e.g.*, imported species from the northeast Pacific).

Our data suggest that, since the first reports in the early 1980s of *Mastocarpus* sp. in Chilean waters, an

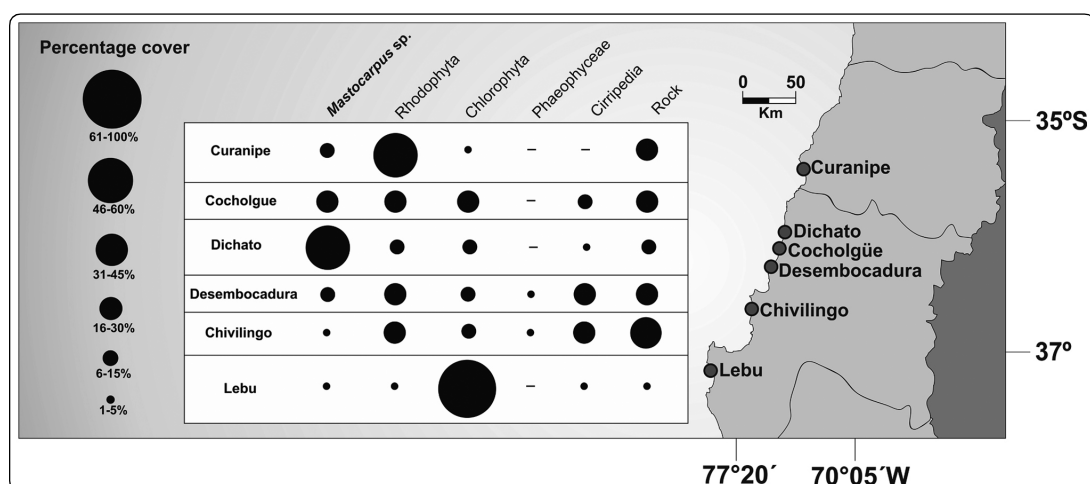


Figure 2. Percentage cover of *Mastocarpus* sp., other algal groups (red - *Mastocarpus* sp. excluded, green and brown algae), Cirripedia, and rocky substrate of each site at the centre of the alga's distributional range / Porcentaje de cobertura de *Mastocarpus* sp., otros grupos algales (algas rojas -no incluye *Mastocarpus* sp., verdes y pardas), Cirripedia y sustrato rocoso en cada sitio, al centro del rango de distribución del alga

expansion of an average of 10 and 20 km year⁻¹ has occurred towards north and south respectively (assuming a constant rate of spread over the intervening years, and no previous record of the species in Chilean waters, for such reason the results must to be taken in account with caution). However, expansion rates are variable and depend on several biotic and abiotic factors, such as life history traits and interactions with other species, etc., (see Lyons & Scheibling 2009 for details), and can be unpredictable even within the same species at different times and geographic regions. The expansion of *Mastocarpus* sp. is slower in comparison with other invasive species such as *Codium fragile* ssp. *tomentosoides* and *Undaria pinnatifida*, but similar to that of the red alga *Grateloupia turuturu* in North America (21 ± 4 km year⁻¹) (Lyons & Scheibling 2009). Cover values of *Mastocarpus* sp. along the Chilean coast indicates that although the alga has become established, it has not competitively displaced native species in most places. For example, in both extremes of its geographic range individuals of *Mastocarpus* sp. are scarce, with approximately 1-2 individuals per m² (Macaya E, pers. observ.). Although the species seems to disperse naturally (Oróstica *et al.* 2012), biotic and abiotic factors might also restrict the rapid growth and colonization and additional studies need to be carried out. Temperature is unlikely to represent a barrier along the Chilean coast since the genus is distributed in seawater ranging from 3 to 23°C (Bell 1993). The species is also extracted by local fishermen, possibly hindering its growth and distribution.

Our understanding of environmental impacts caused by non-indigenous algal species in Chilean waters is still limited; harmful effects might vary over time and geographically as introduced species expand their ranges from their initial introduction points (Chapman *et al.* 2006). Future studies should examine the ecological interactions of a range of invasive algal species with native flora/fauna. Patches of *Mastocarpus* sp. appear to have, for example, a high diversity of associated fauna (Macaya *et al.* unpublished data). Additionally, future approaches could also include genetic analysis of the species along the geographic range in Chile, therefore identifying the possibility of a single or multiple introductions from its native range in the North Pacific. The value of the molecular techniques in such assignment has been successfully studied in several algae (Voisin *et al.* 2005, Uwai *et al.* 2006, Cheang *et al.* 2010). Finally this article highlights the importance of distributional survey studies in providing baseline information on changes in native and non-native communities.

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