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Skeletal extension, density and calcification rates of massive free-living coral *Porites lobata* Dana, 1846

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ABSTRACT

Hermatypic corals are an important sessile group in the benthic structure of tropical coral reef communities. Many organisms, in response to the environmental conditions, have developed different strategies of growth by modifying their morphologies and reproduction mode, as is the case of free-living colonies called coralliths. So far, important parameters such as calcification, growth rates and their relation with biotic and abiotic factors on coralliths have not been described. This study represents the first record of a corallith form of *Porites lobata* and provides information on its sclerochronology. Coral growth parameters of different coralliths were compared by measuring extension rate (cm y^{-1}), skeletal density (g cm^{-3}), calcification rate (g cm^{-2} y^{-1}), average age (yr) and sphericity (S). The influence of the environment on corallith growth was assessed using water temperature as an abiotic factor and bioturbation by fish as a biotic factor. Analysis of annual density bands using X-ray densitometry provided a mean extension rate of 0.47 ± 0.23 cm y^{-1}, skeletal density of 1.08 ± 0.14 g cm^{-3}, and calcification rate of 0.51 ± 0.26 g cm^{-2} y^{-1}. The results reveal differences in growth parameters between coralliths including a strong relationship of calcification rate with seawater temperature. In addition, direct and indirect bioturbations promoted the colony rotation resulting in a hemispherical form. Hence, the evidence suggests that scleractinian corals have developed an important growth strategy that allows the species to form new colonies and maintain successful coral reef communities through free-living corallith growth.

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1. Introduction

Scleractinian corals grow as hard structured colonies with different forms and shapes depending on species and the environment (Grigg, 2006; Sheppard et al., 2009). At the community level, they determine the benthic substrata and complexity of the coral ecosystem. Factors such as environmental conditions, substrate availability, competition between groups and other local characteristics determine the different growth strategies which help the organism to survive successfully (Rodríguez-Martínez and Jordán-Dahlgren, 1999; Smith et al., 2007; Sheppard et al., 2009; Sorauf, 2010).

Coral growth (=Shape) is represented by branched, massive, encrusting, columnar, laminar, foliaceous and free-living forms or "coralliths" (Veron, 2000). Free-living (i.e., unattached) corals are less common, characterized by low diversity and abundance, and have been infrequently studied to date. Consequently their importance and contribution to coral reef communities is poorly known (Latypov, 2007). Free-living corals can disperse over small scales and, in turn, can colonize new spaces close to the main coral reef framework (Glynn, 1974; Scoffin et al., 1985; Roff, 2008).

Coralliths result from asexual fragmentation produced by fish erosion (Cortés, 1997), and "gemmae" fragmentation, a reproduction mode where single or groups of polyps detach from the parent colony, known as polyp bail out (Sammarco, 1982; Weil et al., 2000). The small fragments and polyps settle on small, unstable substrates such as coralline algae, shells, dead corals, and rocks and then form a new colony that develops into spherical, radial or globular shapes; such corals are commonly called "rolling stones" (Glynn, 1974; Harrison, 2011). This spherical shape results in the colonies being unattached and consequently, the colonies are subject to constant movement, stress and partial tissue death which are not optimal conditions. Thus they are relatively inconspicuous and uncommon in benthic communities (Fig. 1) (Kissling, 1973; Glynn, 1974; Scoffin et al., 1985; Sorauf and Harries, 2009). As a consequence of their instability, local environmental conditions such as currents, tides, waves and bioturbation produces and intensifies a direct factor that may have a positive effect on promoting their hemispheric growth, or it may have a negative effect of causing partial or total mortality (Glynn, 1974; Lewis, 1989; Sorauf and Harries, 2009).

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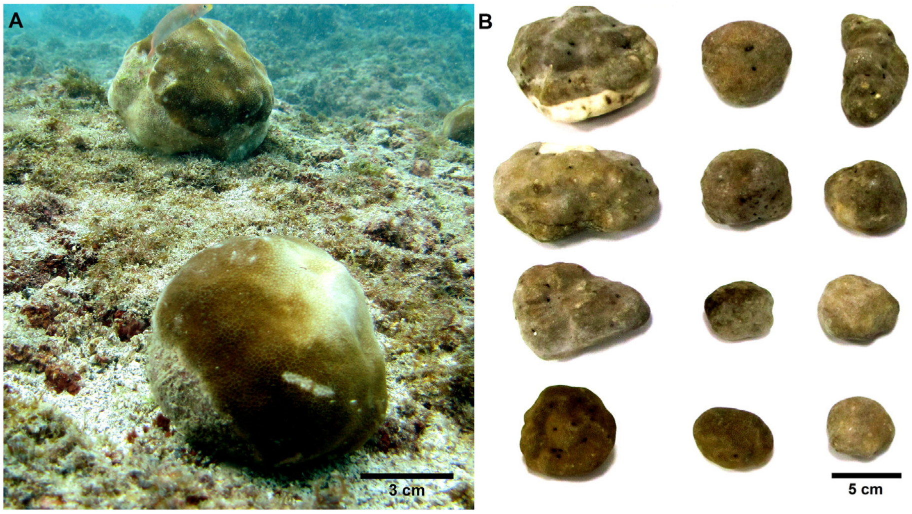

Fig. 1. *Porites lobata* free-living colonies. A) Coralliths *in situ* at Isla Isabel from the Central Mexican Pacific. B) Morphology of the colonies collected.

Coralliths have been reported in both Atlantic and Pacific regions for different coral genera including: *Acropora*, *Agariciella*, *Pavona*, *Pocillopora*, *Siderastrea*, *Solanastrea*, *Psammocora* and *Porites* (Glynn, 1974; Pichon, 1974; Scoffin et al., 1985; Lewis, 1989; Rielg et al., 1996; Reyes-Bonilla et al., 1997; Rodríguez-Martínez and Jordán-Dahlgren, 1999; Roff, 2008; Sorauf and Harries, 2009; Capel et al., 2011). In the eastern tropical Pacific (ETP), mobile coralliths represented by the genera *Agariciella*, *Porites* and *Pavona* were reported in the Gulf of Panamá (Glynn, 1974) and uncommon free-living colonies associated with rhodolith beds have been recorded in the Gulf of California (Reyes-Bonilla et al., 1997). Despite the presence of coralliths in reef ecosystems, important parameters such as calcification and growth rates have not been previously reported.

Coral growth and calcification assessment studies in massive coralliths are necessary to understand their ecological contributions and permanence in any region. It is well known that massive corals contain annual band pairs of high and low skeletal density (Knutson et al., 1972), commonly used to determinate the growth and environmental characteristics of their life history (Barnes and Lough, 1996; Lough and Barnes, 1997; Carricart-Ganivet and Barnes, 2007; Lough and Cooper, 2011). To date, annual growth parameters from density bands have been described only for massive attached corals such as *Porites* spp. and such information is lacking for the corallith forms. As far as we are aware, there have been limited reports of coralliths in the ETP (Glynn, 1974). Moreover, there are no reports of calcification rates for corallith forms of any species worldwide.

In the central Mexican Pacific (CMP), *Porites* spp. have been reported as the predominant massive corals, and they are always observed in attached massive form (Reyes-Bonilla et al., 2005; Reyes-Bonilla et al., 2012; López-Pérez, 2013) and never as in free-living form (Fig. 1). This study provides new data demonstrating the ability of *Porites lobata* Dana, 1846 to settle on unstable substrata and initially grow in corallithic form. The effect of the environment on the morphology and growth rates of these free-living coral colonies was specifically addressed via three approaches: (1) comparing the sphericity (S), extension rate (cm y^{-1}), skeletal density (g cm^{-3}), and calcification rate (g cm^{-2} y^{-1}) between different coralliths, (2) evaluating the relationship between calcification rates and density banding patterns with variation in the sea surface temperature (SST) and (3) describing the influence of bioturbation on the development of the coralliths. The results of this study provide an indication of the life history of this species in the area, and may serve as a basis for future research of calcification rate and growth in corallith forms.

2. Materials and methods

2.1. Study area

The Isla Isabel National Park (IINP) is located in the Mexican Pacific Ocean (21° 51′ 21.84″ — 21° 50′ 23.44″ N, 105° 53′ 31.84″ — 105° 52′ 43.52″ W) at 28 km off the coast (Fig. 2). It is characterized as a volcanic island with a surface area of 82.164 ha (CONANP, 2005). The adjacent coastal topography consists of flat-limestone substrata at shallower depths (1–5 m) and rocky-sandy substrate at greater depths (3–11 m). The island is composed of fringing reefs of scleractinian corals mainly of the genera *Pocillopora, Porites, Pavona* and *Psammocora*; distributed within a depth range of 1–11 m in different patches around the Island (Rodríguez-Zaragoza et al., 2011). Sea surface temperatures (SST) range from 20 °C to 26 °C and are influenced by the California Current (CC) and the coastal Costa Rica Current (CCR) (Pennington et al., 2006; Palacios-Hernández et al., 2010; Pantoja et al., 2012). During El Niño–Southern Oscillation (ENSO) events, the El Niño phase causes an abnormal increase of the SST >3 °C and during La Niña phase SST may decrease ≤4 °C (Wang and Fiedler, 2006; Reyes-Bonilla et al., 2002) below normal. The two ENSO phases result in either positive or negative thermal stress on corals, and thereby affecting the growth and survivorship of the coral communities of the region (Glynn, 2000; Carriquiry et al., 2001; Reyes-Bonilla et al., 2002; Cupul-Magaña and Calderón-Aguilera, 2008; Rodríguez-Troncoso et al., 2014).

2.2. Coral samples

Surveys were conducted from April 2012 to February 2013. Coralliths *P. lobata* densities were evaluated *in situ* using SCUBA; total colony counts were determined on a flat reef and rocky–sandy sea platform within an area of 399.71 m^{-2} and a depth rage of 3–6 m. Twelve *P. lobata* coralliths (6.40–14.50 cm diameter) were collected and transported to the laboratory. In order to eliminate any organic matter, all colonies were air dried and exposed to sun light for 72 h and afterward placed in a convection oven at 70 °C for 3 h. Morphology and hemispherical measurements were evaluated as described by Glynn (1974) measuring maximum, intermediate and minimum diameters (cm), dry mass (g) of the entire corallith (using an Ohaus Explorer®, analytical balance with precision 0.001 g), and the total superficial tissue area was determined by using the methods of Marsh (1970).

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