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Hyposalinity stress compromises the fertilization of gametes more than the survival of coral larvae

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ABSTRACT

The life cycle of coral is affected by natural and anthropogenic perturbations occurring in the marine environment. In the context of global changes, it is likely that rainfall events will be more intense and that coastal reefs will be exposed to sudden drops in salinity. Therefore, a better understanding of how corals—especially during the pelagic life stages—are able to deal with declines in salinity is crucial. To fill this knowledge gap, this work investigated how gametes and larva stages of two species of *Acropora* (*Acropora cytherea* and *Acropora pulchra*) from French Polynesia cope with drops in salinity. An analysis of collected results highlights that both *Acropora* coral gametes displayed the same resistance to salinity changes, with 4h30-ES_{50} (effective salinity that decrease by 50% the fertilization success after 4h30 exposure) of 26.6 ± 0.1 and 27.5 ± 0.3‰ for *A. cytherea* and *A. pulchra*, respectively. This study also revealed that coral gametes were more sensitive to decreases in salinity than larvae, for which significant changes are only observed at 26‰ for *A. cytherea* after 14 d of exposure. Although rising seawater temperatures and ocean acidification are often perceived as the main threat for the survival of coral reefs, our work indicates that 70% of the gametes could be killed during a single night of spawning by a rainfall event that decreases salinity to 26‰. This suggests that changes in the frequency and intensity of rainfall events associated with climate changes should be taken seriously in efforts to both preserve coral gametes and ensure the persistence and renewal of coral populations.

1. Introduction

Coral reef ecosystems host an extremely high diversity of organisms (Reaka-Kudla, 1997). Unfortunately during the last few decades, coral reefs have been jeopardized by the unprecedented natural and anthropogenic changes occurring on Earth (Carpenter et al., 2008; Hoegh-Guldberg, 1999; Veron et al., 2009). Among the variety of stressors that alter the life cycle of corals, scientists draw attention to threats of global warming and ocean acidification (Gattuso and Hansson, 2011; Hoegh-Guldberg et al., 2007). Global warming and the associated rise in seawater temperatures endangers the obligate symbiosis between coral hosts and the zooxanthellae *Symbiodinium* (Douglas, 2003). Currently, the effects of changing temperature on corals have received the most interest (e.g., Loya et al., 2001; Negri et al., 2007), mainly due to its dramatic visual impact on adult colonies and its reported negative effects worldwide (e.g., Kenya, McClanahan et al., 2004; Australia, Marshall and Baird, 2000; South Africa, Celliers and Schleyer, 2002; Bahamas, Manzello et al., 2009). Moreover, the impact of ocean acidification during the last decade and its consequences on coral health have raised major concerns within the scientific community (e.g., Veron et al., 2009), and a large body of work evaluating the effects of ocean acidification on corals has emerged (e.g., Kleypas et al., 1999; Marubini et al., 2008; Nakamura et al., 2011).

Unfortunately, rising seawater temperatures and ocean acidification are only two of the many consequences of global changes. Increases in extreme rainfall events around the world are also expected in response to global warming (e.g., Westra et al., 2013; Trenberth, 2011). Moreover, recent findings of O'Gorman (2012) and of the IPCC (2013) highlighted that for tropical areas, an increase in frequency of rainfall events and in the intensity of extreme precipitation is also expected. These changes in tropical areas could result in more frequent and heavier flooding, causing extreme runoff discharges and changes in salinity. Although the response of corals to global stressors (mainly temperature and ocean

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acidification) has been extensively researched, very few studies have examined the response of various life stages of corals to salinity changes.

Indeed, studies assessing the effects of salinity on corals have primarily focused on adult life stages (e.g., Berkelmans et al., 2012; Kerswell and Jones, 2003; Loya et al., 2001; Seveso et al., 2013), and our understanding of how the pelagic life stages of corals are able to face salinity changes needs to be expanded. Supplemental research in this area is required considering that for the majority of coral species, gametes released in the water column are buoyant and float towards the surface, where fertilization occurs (Babcock et al., 1986). Coral gametes and embryos remain at the surface of seawater during the whole embryonic and larval development (two to three days), leaving them more vulnerable than other benthic stages of corals (recruits, adults) to salinity changes during heavy rains. Few studies have been aimed at assessing the effects of salinity on coral pelagic life stages (Humphrey et al., 2008; Richmond, 1993; Scott et al., 2013; True, 2012; Vermeij et al., 2006). These studies noted a sharp decline in the success of fertilization of coral gametes and larva settlement to decreases in salinity, as well as an increased pre- and post-settlement mortality in relation to salinity decrease.

Currently, corals living in coastal reefs experience large changes in salinity during severe rainfall events, which can lead to salinity levels decreasing to 10‰ (e.g., Jokiel et al., 1993; Moberg et al., 1997). The intensification of rainfall events in tropical areas and their associated freshwater runoff may have severe impacts on coral health. For example, the freshwater event in Kaneohe Bay (Hawaii) in 1987 dropped the salinity to 15‰ in surface waters and killed all corals present at a depth of 1–2 m (Jokiel et al., 1993). The rain associated with cyclone “Joy” in Central Queensland (Australia) decreased the salinity around Keppel Islands down to 7‰ at the surface, leading to extreme damage and loss of corals in shallow-water communities (Van Woesik et al., 1995). In French Polynesia, the volcanic islands (e.g., Moorea, Tahiti) are characterized by narrow lagoons which lead to coral reef ecosystems that are strongly influenced by environmental gradients. In these reefs, heavy rains and runoff may have drastic impacts on corals by reducing the benthic species richness, as was observed by Adjeroud and Salvat (1996) in Opunohu Bay. These rapid drops in salinity in coastal waters may have drastic effects not only for coral communities but also for the early life stages of corals. Moreover, the work of Mendes and Woodley (2002) highlighted that coral spawning generally occurs during periods of low rainfall and/or prior to the peak of heavy rains to ensure success of fertilization and increase larval survival rates. In Moorea (French Polynesia), *Acropora* corals spawn from September to November (Carroll et al., 2006; Hédouin, *personal communication*), which coincides with months of rising rainfall (from 40.4 to 70.9 mm per month, Fig. 1). Despite the recognized deleterious effects of salinity on early life stages of corals (Humphrey et al., 2008; Richmond, 1993; Scott et al., 2013); it could be hypothesized that *Acropora* coral gametes from Moorea (French Polynesia) display an enhanced tolerance to salinity drop to ensure fertilization success during that critical period of the year. It has already been observed that the history of salinity exposure plays a significant role in coral population tolerance (Chartrand et al., 2009), and it is plausible that such tolerance may be transmitted to the offspring. Currently, there are, to the best of our knowledge, only two published works on the sensitivity of early life stages of corals in French Polynesia to stress (ocean acidification and temperature, Rivest and Hofmann, 2014; copper pollution, Puisay et al., 2015), but none have assessed the effect of salinity on early life stages.

In an effort to bridge this knowledge gap, the goal of this study was to assess the sensibility of two critical pelagic life history stages (gamete *vs* larva) of two coral species (*Acropora cytherea* and *Acropora pulchra*) from French Polynesia in response to decreases in salinity and to determine whether the vulnerability of pelagic life stages from French Polynesia is similar to those from other regions.

2. Materials and methods

2.1. Study site

This work was performed on Moorea island (17° 30′ S, 149° 50′ W), French Polynesia (Fig. 2). Corals were collected from two fringing reef sites in Moorea, Te'avaro 1 (17° 30′ 50″S, 149° 46′ 02″ W) and Te'avaro 2 (17° 30′ 20″S, 149° 45′ 55″ W). These sites were selected for their high abundance of *A. cytherea* and *A. pulchra*.

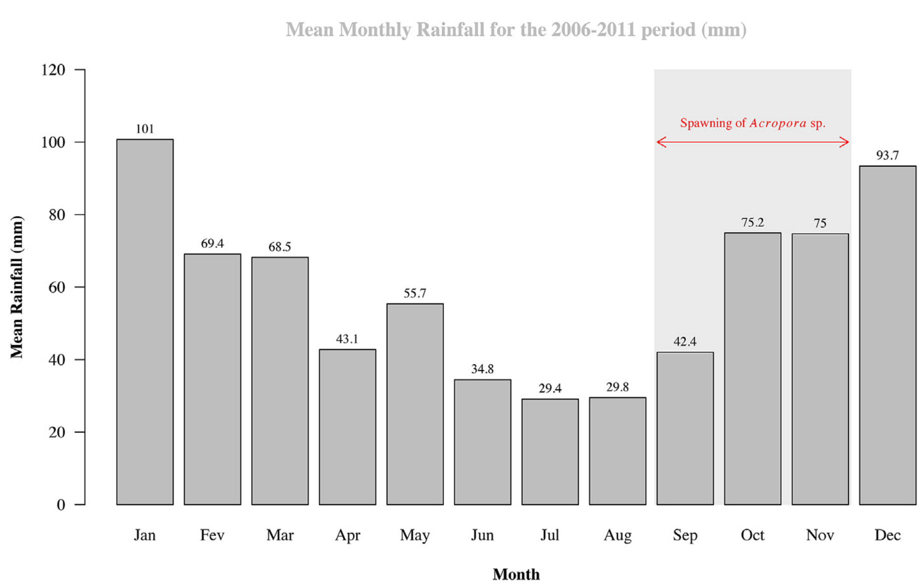

Fig. 1. Mean monthly rainfall data (mm) of Moorea for the 2006–2011 period from a weather station located in Papetoai, Moorea (17°31′11.9994”; 149°50′53.988″). Data were obtained from Meteo France.