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Author(s)	Baria, Maria Vanessa Bunda
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The impacts of elevated temperature and ocean acidification on spawning and early life stages of corals

Abstract

The increase in atmospheric carbon dioxide causes ocean to warm (ocean warming) and pH to decrease, also known as ocean acidification (OA). Both are considered as a major threat in the early stages of corals. However, there are few studies that looked into its individual and combined effects from the timing of reproduction to juvenile stage that are important in structuring coral populations on the reef. This study aims to conduct comparative studies on the effects of elevated temperature and OA on early stages of corals (fertilization to settlement) using the same species and experimental setup with a hypothesis that subtropical corals that are more exposed to a wider range of temperature are more acclimatized to the increase in temperature than tropical corals. Also, this study would like to evaluate the effects of OW and or OA at multiple stages of early life history of *Acropora digitifera* in Okinawa, Japan. Chapter 2 examined the effect of OW on the fecundity and reproductive timing of *A. digitifera.* Colonies exposed to +2°C one month prior to expected spawning showed that timing of spawning is 1 day advanced while volume and sperm density were reduced. Chapter 3 evaluated the optimum tolerance of early stages of corals to OW and OA in tropical (Philippines) and subtropical reefs (Okinawa), *Acropora tenuis* and *A. digitifera,* commonly found in both sites. Effects of OW (-3 to +6°C from ambient) and OA (pH: Control= 8.1-2, medium = 7.8, high= 7.6) on fertilization, embryonic development, survival and settlement were employed. Development of embryo is slower in colder (-3°C) and faster at OW (+3°C). OW reduced fertilization, survival and settlement in both species and sites, while OA had minimal effect. Fertilization, survival and settlement were lowest at +6°C for both sites. Chapter 4 examined the effects of OW and OA on post-settlement survival and growth of one-month old *A. digitifera* in Okinawa. One-month old coral juveniles were exposed to OW (control = 29±1 and high = 33±1°C) and OA treatment (pH: Control= 8.1-2, medium = 7.8, high= 7.6) combinations for 1 month. Survival was highly reduced by OW but not by OA while growth was reduced by OA. In addition to *Acropora* species, chapter 5 used fungiid larvae (solitary corals) in Okinawan reef. Larvae of *Fungia fungites* and *Lithophyllon repanda* were exposed to OW (Control, +3°C, +6°C) and OA treatment (pH: Control= 8.1-2, medium = 7.8, high= 7.6) combinations for 8 days. *F. fungites* was neither affected by OA, OW nor its combination. Similarly, survival of *L. repanda* was not affected by OA however; it was significantly affected by OW. Temperature tolerance varies between species; *L. repanda* (+3°C) has lower tolerance than *F. fungites* (+6°C). Generally, OW reduces the success of early stages of corals more than OA regardless of latitudinal stands with a tolerance of +3°C above ambient temperature. The negative effect of OA is more pronounced at post-settlement stage, when it started to calcify. In conclusion, subtropical corals are more acclimatized to higher temperature increase than tropical corals. Hence, corals in the tropics are at a greater risk than subtropics in the future climate change scenario. Among multiple stages of early life of corals, the negative effects of OW on gametogenesis will have cascading effects on the later stages of corals. Both OW and OA have negative impacts on early stages of corals which threatens successful coral recruitment on the reef.