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研究課題名（和文）Potential of coral resilience in an acidifying ocean

研究課題名（英文）Potential of coral resilience in an acidifying ocean

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研究成果の概要（和文）：海洋酸性化はサンゴに負の影響をもたらすが、その程度は種によって異なる。本プロジェクトでは群体形状の異なるサンゴに対して、海洋酸性化や低温ストレスに対する応答を解析し、テーブル状サンゴ(エンタクミドリイシ)が相対的に脆弱であること、種間差はサンゴ表面のpHの不均一性に起因することを明らかにした。さらに、式根島とパプアニューギニアのCO2シープの調査によって、耐性種は石灰化に投じるエネルギーが脆弱種に対して相対的に大きいことが明らかとなった。これらの成果に加えて、二種のサンゴのプラヌラ幼生の呼吸量が海洋酸性化の進行に伴い増大し、サンゴの加入に関連する化学物質への応答阻害も引き起こすことが示された。

研究成果の学術的意義や社会的意義
サンゴの群集組成の将来予測が求められている中、海洋酸性化に対するその適応メカニズムを知ることが必要である。本プロジェクトでは、サンゴの群体形状および生理的特色が適応性の決定要因になることを明らかにした。その特色は種特異的であり、海洋酸性化が生じるタイムスケールでは、脆弱種が新たに適応性を獲得するとは考えにくい。更に海洋酸性化はサンゴの幼生にも負の影響を与えることが示された。これらの影響は、海洋酸性化がサンゴの群集組成の激変を引き起こすことを意味している。

研究成果の概要（英文）：Both laboratory experiments and field studies at natural analogues for ocean acidification (OA) have highlighted different responses among coral species, with some showing a stronger resistance than others. We showed that the fast growing tabular and branching corals Acropora solitaryensis was more sensitive to both temperature and OA stresses than the slow growing sub-massive coral Porites heronensis. In the case of the tabular species, mor strong variation in the pH at the surface of the coral. Using resistant and sensitive corals from CO2 seeps, we showed that resistant species have the potential to invest more energy in inorganic growth (calcification) compare to sensitive species that allocated more energy towards somatic growth. Finally, we showed for two sensitive species, that OA increase the respiration rates of the early life stage planula larvae, and that it could impair their capacity to respond to chemical cues required for their settlement.

研究分野：海洋生理生態学

キーワード：造礁サンゴ　海洋酸性化　適応

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

Title: Potential of coral resilience in an acidifying ocean

１．研究開始当初の背景

The recent increase in atmospheric carbon dioxide (CO_2) causes climate change and ocean acidification (OA) (the decrease of seawater pH due to dissolution of the excess of CO_2) . OA has been identified as a major threat to marine ecosystems (Aze et al., 2014). However, many uncertainties remain, and new approaches are required (Stocker et al., 2013). Scleractinian corals have been shown to be highly threaten by OA as the future environment will not be favorable to calcification and could limit their growth. Field survey at naturally acidified sites, like volcanic CO_2 seeps, and laboratory experiments showed the negative effects of OA on corals but also highlighted variations of the response among coral species (Doney et al., 2009). Why are some coral species more resistant to OA than other remain unknown? Is it due to physiological or morphological characteristics? Is it due to a difference in the effects at different life stages?

２．研究の目的

While ocean acidification is recognized as a major threat to scleractinian corals, their resistance is expected to differ among species. The aim of the study is to elucidate the mechanisms behind this resilience. Two hypotheses will be tested: 1) Do resistant corals have a morphology that mitigate the effect of ocean acidification 2) are resistant corals able to allocate a higher amount of energy to maintain calcification under ocean acidification? 3) does OA affect the respiration rates of the larval stages of sensitive corals?

３．研究の方法

1) Do resilient corals have a morphology that mitigate the effect of ocean acidification

We conducted a cross transplantation of two coral species, *Porites heronensis* which show an encrusting to submassive morphology and *Acropora solitaryensis* which show a table to branching morphology. The corals were transplanted at three sites on in the Shimoda, which represent present conditions of temperature and pCO_2, one the Shikine Island, representing an analogues of ocean warming (compared to Shimoda) and one at the CO_2 seep in Shikine Island representing an analogue for ocean warming and acidification (compare to Shimoda). Their growth rates and physiological characteristics were investigated on a 9 months periods. Finally, the pH in the diffusive boundary layer (DBL) of these two species under different pCO_2 were measured under different flow rates.

2) Are resilient corals able to allocate a higher amount of energy to maintain calcification under OA?

Resistant and sensitive coral species to OA were sampled from the Shikine Island CO_2 seeps and a CO_2 seeps in Papua New Guinea. Corals were sampled from both control and elevated pCO_2 zones. In addition, some species both resistant and sensitive, were transplanted from the control to the elevated pCO_2 sites at both locations. Mitochondrial activities (ie Mitochondrial Electron Transport System Activities: ETSA), protein contents and surface area were measured.

3) The effects of OA on the respiration rates of the larval stages of two high latitude corals

The respiration rates of coral planula freshly collected of the coral species , *Astroides calycularis,* from the Mediterranean Sea and *Alveopora japonica* from Japan were measured in 1 ml glass vials using oxygen microsensors. The rates under reference and elevated pCO_2 and in the presence of chemical cues favoring their settlement were measured.

４．研究成果

1) Do resilient corals have a morphology that mitigate the effect of ocean acidification

The table corals *Acropora solitaryensis* was more sensitive to both the cold stress experienced during the winter at Shimoda as shown by cold stress bleaching (reduced Fv/Fm, zooxanthellae density and photosynthesis) and ocean acidification experienced at the Shikine CO_2 seep (reduced calcification and growth compared to the Shikine control sites). In comparison, the sub massive coral *Porites heronensis* showed a higher resistance to both cold stress and ocean acidification. However, under all scenarios but especially under the optimal (for coral growth) ocean warming scenario (Shikine control site) the coral *P. heronensis* showed lower growth and calcification rates than *A. solitaryensis.* The pH in the DBL of these two species under different pCO_2 were measured under different flow rates. At all flow rates and especially at the lower flow rates, the thickness of the DBL and the pH within, was more

homogenous on the surface of the coral *P. heronensis*. In comparison, *A. solitaryensis* showed a heterogeneous DBL depending on the direction of the surface measured, whether it was facing or not the current.

2) Are resilient corals able to allocate a higher amount of energy to maintain calcification under OA?

Contrary to expected, sensitive species showed a higher amount of biomass (proteins) per surface areas compare to the resistant species. However, as the latter had similar ETSA per surface, this resulted in higher ETSA per biomass. This was interpreted as a potential in resistant species to allocate more energy towards inorganic growth (calcification) compare to organic growth (somatic). Moreover, this ability could not be acquired neither through a 6 months nor to a lifetime exposure to elevated pCO_2. These resulted in a decrease in biomass for the sensitive species.

3) The effects of OA on the respiration rates of the larval stages of two high latitude corals

Planula from both species showed elevated respiration rate under acidified conditions. Moreover, the planula reacted to the presence of chemical cues by either increasing or decreasing their respiration rates in the presence of cues for *A. calycularis* and *A. japonica*, respectively, but this change was not observed under acidified conditions. Increased respiration under ocean acidification scenario for the planula of these two coral species could limit the time they are able to spend in the water column before settling. In addition, ocean acidification could impair their ability to detect the presence of the chemical cues required for their settlemsent. Taken together, ocean acidification could limit the successful recruitment of these two corals.

５．主な発表論文等

<u>Peer reviewed article</u>

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Risa Takimoto, and Sylvain Agostini. 'Effects of Ocean Acidification **on the Temperate Coral** Porites Heronensis at Its Thermal Limit'. Poster presented at the 21st Japanese Coral **Reef Symposium, Nishihara-machi (Okinawa-ken), 24 November 2018.**

Yamazaki, Wataru. 'Thermal Limits of the High Latitude Coral Porites Heronensis'. Oral **presented at the Japanese Coral Reef Symposium 20th meeting, Tokyo, Japan, 24 November 2017.**

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〔雑誌論文〕　計2件（うち査読付論文　2件／うち国際共著　2件／うちオープンアクセス　2件）

１．著者名 Agostini Sylvain、Harvey Ben P.、Wada Shigeki、Kon Koetsu、Milazzo Marco、Inaba Kazuo、Hall-Spencer Jason M.	４．巻 8
２．論文標題 Ocean acidification drives community shifts towards simplified non-calcified habitats in a subtropical temperate transition zone	５．発行年 2018年
３．雑誌名 Scientific Reports	６．最初と最後の頁 s41598
掲載論文のDOI（デジタルオブジェクト識別子） 10.1038/s41598-018-29251-7	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Higuchi, T., Yuyama, I., Agostini, S.	４．巻 in press
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オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計7件（うち招待講演　1件／うち国際学会　1件）

１．発表者名 Sylvain Agostini, Ben Harvey, Risa Takimoto, Joshua Heitzman, Fanny Houlbreque, Riccardo Rodolpho-Metalapa
２．発表標題 Is mitochondrial activity a factor for resistance ocean acidification in corals?
３．学会等名 21st Japanese Coral Reef Symposium
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１．発表者名 Agostini, Sylvain.
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Agostini, Sylvain, Yohei Nakamura, Nugues Maggy, Natacha Roux, Hironobu Fukami, Yuko Kitano, Shoji Yamamoto, and David Lecchini

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３．学会等名
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２．発表標題
Is Mitochondrial Activity a Factor for Resistance Ocean Acidification in Corals?

３．学会等名
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Risa Takimoto, and Sylvain Agostini

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Effects of Ocean Acidification; on the Temperate Coral Porites Heronensis at Its Thermal Limit

３．学会等名
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３．学会等名 20th Japanese Coral Reef Symposium
４．発表年 2017年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

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