D-4.1.2 Effects of environmental stresses on corals

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Total Budget for FY1994-FY1996 8,727,000Yen (FY1996; 2,757,000Yen)

Abstract The purpose of the present research is to find out suitable indices of coral health, to study effects of nutrient enrichment on coral growth rate, and to study the mechanism of bleaching of corals.
The rates of calcification and photosynthesis, density of zooxanthellae as well as sugar and lipid contents appeared to be good indices of coral health. High concentrations of ammonium affected coral growth rates even when zooxanthellae density was not changed. The morphology of zooxanthellae in the coral *Galaxea fascicularis* exposed to various stresses was compared with that of zooxanthellae expelled from the host. Isolated zooxanthellae exposed to the same stresses were also studied. The degradation process of zooxanthellae varied depending on the type of stresses. Degraded zooxanthellae were selectively expelled by the host when the coral was treated with high temperature or strong light.

Key Words: Bleaching, Coral, Zooxanthella, Environmental stress

1. Introduction

Changes in global climate and eutrophication of sea water are considered to be major factors that affect coral reefs. To monitor the condition of coral reefs, we need appropriate indices of coral health.

Hermatypic corals contain zooxanthellae in their gastrodermal cells. They lose their symbionts and become bleached when exposed to stress such as high or low temperature, low salinity, strong light, and UV[1) 2)]. Mechanism of bleaching in corals has not been fully understood. It is likely that mechanisms by which corals become bleached are different depending on the types of stresses. It is not known whether the stresses act on zooxanthellae or host tissue when they cause bleaching.

Enrichment of nutrients also affect corals by changing density of zooxanthellae. High concentrations of ammonium increases zooxanthella

density[3),4)], but decreases coral growth rate[5)]. It is suggested that if the density of zooxanthellae is too high, translocation of photosynthate to host corals will be reduced[5)].

2. Research Objectives

The purpose of the present research is to find out suitable indices of coral health, to study effects of nutrient enrichment on coral growth rate, and to study the mechanism of bleaching of corals.

3. Materials and Methods

To find out suitable indices of coral health, we measured several biomass and physiological parameters of the coral *Stylophora pistillata* kept in darkness for various lengths of time.

To test the hypothesis that bleaching occurs when cnidarian hosts fail to supply their symbiotic algae with enough amounts of inorganic nutrients, we examined whether enrichment of ammonium (100 mM) or phosphate (10 mM) prevents bleaching in the coral *Galaxea fascicularis* exposed to a high temperature.

Sensitivity to high temperature was compared among three species of corals, *Stylophora pistillata*, *Goniastrea aspera*, and *Psammocora contigua*.

To study whether corals expel damaged zooxanthellae selectively when they are exposed to stresses, isolated polyps of the coral *Galaxea fascicularis* were exposed to various stresses and the morphology of zooxanthellae remained in the host tissue and expelled zooxanthellae were observed. Isolated zooxanthellae exposed to the same stresses were also examined to investigate possible role of host cells in digestion of zooxanthellae.

4. Results

The rates of calcification and photosynthesis, and density of zooxanthellae all decreased after dark incubation. Sugar content also decreased while lipid content decreased only after prolonged incubation in darkness.

High concentrations (30-60 mM) of ammonium decreased the growth rate of the coral *Galaxea fascicularis* without affecting the density of zooxanthellae (Fig. 1). This suggests that ammonium acts directly on corals rather than indirectly by increasing the density of zooxanthellae.

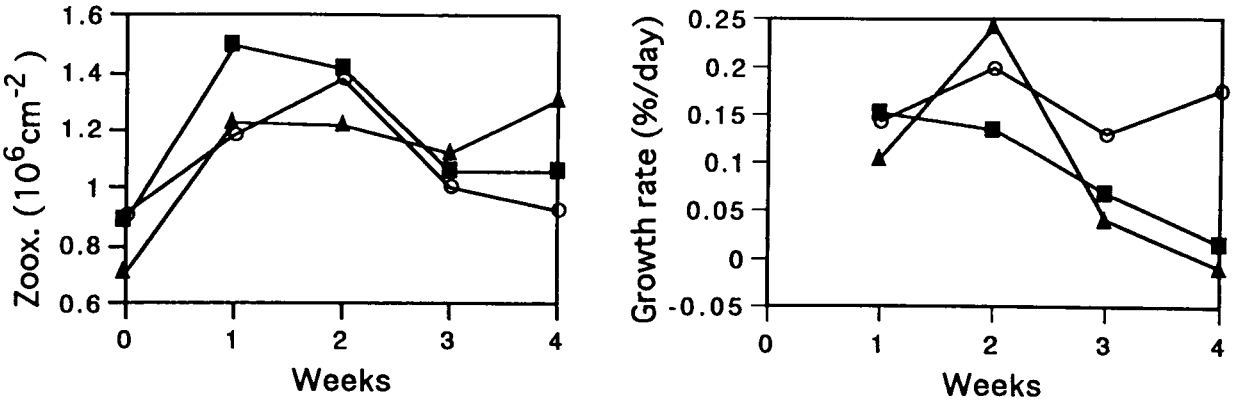

Fig. 1. Effects of ammonium enrichment on the density of zooxanthellae (A) and on growth rate (B) of the coral *Galaxea fascicularis*.

The addition of ammonium or phosphate to the incubation solution did not prevent decreases in the zooxanthella density or in chlorophyll a concentration of polyps of *G. fascicularis* exposed to an elevated temperature (Fig. 2).

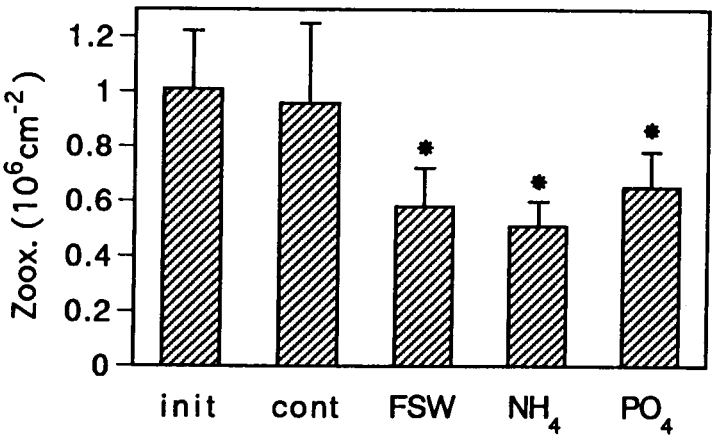

Fig. 2. Effects of ammonium (100 mM) and phosphate (10 mM) on zooxanthella density of polyps of *G. fascicularis* exposed to an elevated temperature, 32 0C, for 10 days. * indicates that the zooxanthella density decreased significantly from the initial value ($P<0.05$).

The rate of net photosynthesis of the coral *Montipora digitata* decreased at temperature above 34oC and became nearly zero at 36oC. Respiration rate increased at 36oC. The temperature dependence of photosynthetic rate of the coral is similar to that reported for cultured zooxanthellae6).

S. pistillata was most sensitive to high temperatures among three species studied.

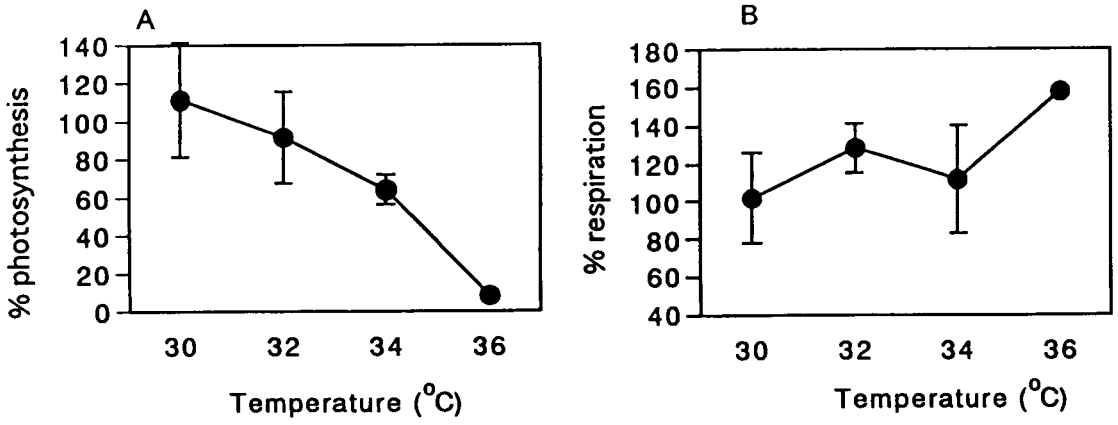

Fig. 3. Effects of temperature on the rates of photosynthesis (A) and respiration (B) of the coral *Montipora digitata*.

Zooxanthellae in polyps of *Galaxea fascicularis* exposed to various stresses were observed and classified into six types: NO, normal zooxanthellae; HO, zooxanthellae with an apprent hollow; DG1, degenerate zooxanthellae which have a small empty space; DG2, degenerate zooxanthellae which have a gap between cell wall and shrunk cytoplasm; RP, small red particle without cell wall; CL, colorless zooxanthellae.

The degradation process of zooxanthellae varied depending on the type of stresses. Strong light directly acts on zooxanthellae degrading their chlorophyll and produced colorless zooxanthellae (CL). Heat stress increases small red particles (RP) which might be produced by digestion of zooxanthellae by host7). Degraded zooxanthellae were selectively expelled by the host exposed to high temperature or strong light.

5. Discussion

The rates of calcification and photosynthesis, density of zooxanthellae as well as sugar and lipid contents appeared to be good indices of coral health.

The present results suggest that loss of zooxanthellae at high temperature is not due to decreased level of inorganic nitrogen supplied to zooxanthellae by their host. Other mechanisms have been proposed: Photosynthesis of zooxanthellae stops at a high temperature and corals expel those algae that fail to secrete photosynthate[6]. Heat shock causes endodermal cells containing zooxanthellae detach from mesogloea[8]. Lysosomes in the host cells become unstable at high temperature resulting in digestion of zooxanthellae[9].

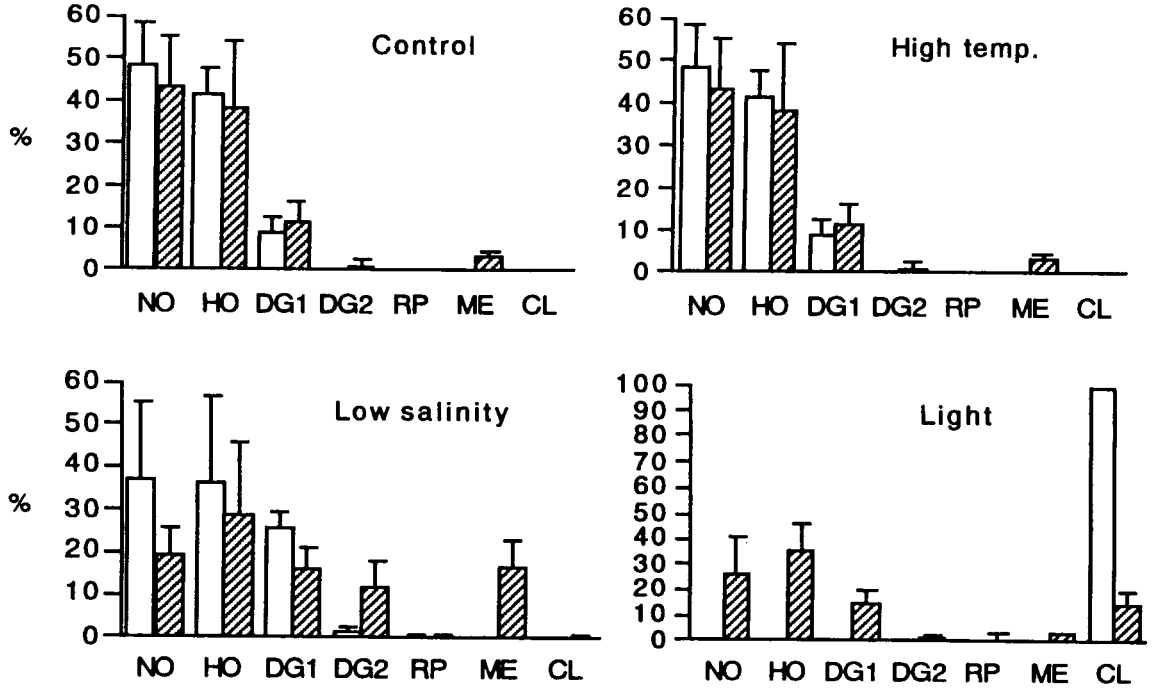

Fig. 4. Histograms of zooxanthellae of various degrees of degradation in polyps of *G. fascicularis* exposed to various stresses (open column) and isolated zooxanthellae exposed to the same stresses (hatched column). Refer to text for abbreviations.

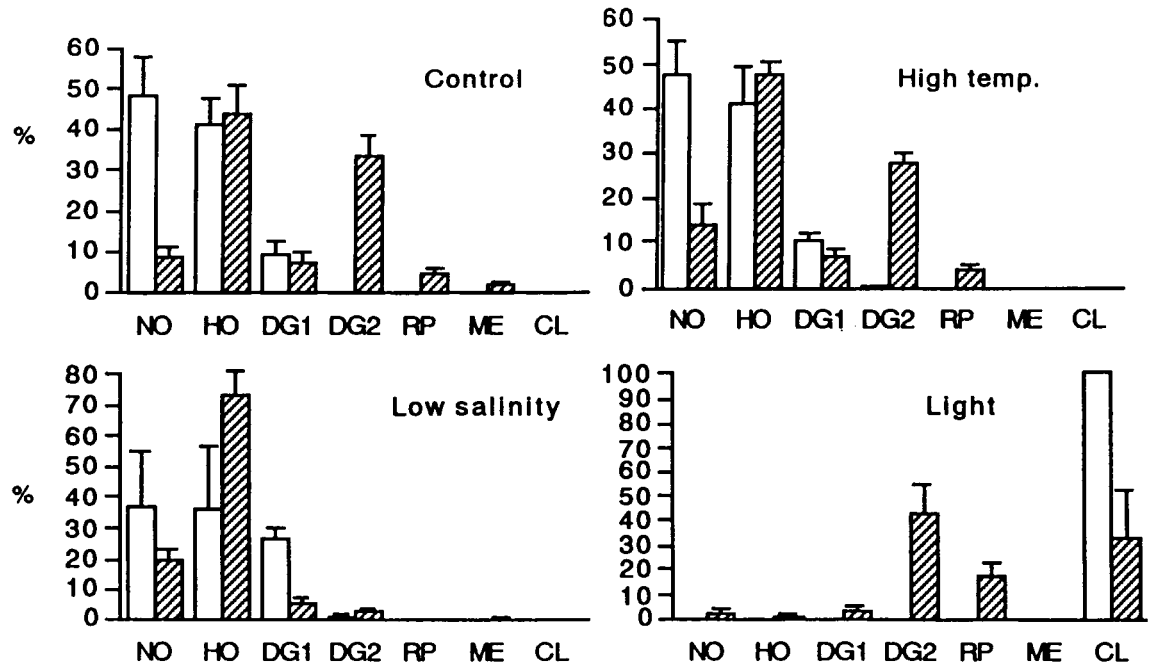

Fig. 5. Histograms of zooxanthellae of various degrees of degradation in polyps of *G. fascicularis* exposed to various stresses (open column) and in expelled zooxanthellae (hatched column). Refer to text for abbreviations.

The present results suggest that degradation process of zooxanthellae varies depending on the type of stresses and that degraded zooxanthellae are selectively expelled by the host when the coral is treated with high temperature or strong light.

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