ABSTRACT

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Title	Ecophysiology of carrageenophytes (Gigartinales) and kelps (Laminariales) in the western Pacific Ocean （太平洋西部におけるカラギーナン原藻（スギノリ目）およびコンブ類（コンブ目）の生理生態）
Keywords	(Algae) (Photosynthesis)

Knowledge concerning the effects of abiotic factors on the physiology of carrageenophytes and kelps is essential from the perspective of massive expansion of seaweed-based industries, as well as the conservation of natural communities in the face of climate change. Photosynthetic measurements are good tools to assess the effects of numerous stressors in macroalgae, which could provide insights into the causes and consequences of shifts in macroalgal productivity. The study presents the photosynthetic characteristics of economically important carrageenophytes (*Eucheuma denticulatum* and *Kappaphycus* spp.) and kelps (*Costaria costata* and *Alaria crassifolia*) distributed in the western Pacific Ocean, as determined by examining their photosynthetic response to a gradient of temperature and photosynthetically active radiation (PAR) using dissolved oxygen measurements and the pulse amplitude modulated (PAM)-chlorophyll fluorometer. Information such as these in the present study are considerably important as researches in carrageenophyte or kelp cultivation are directed towards the development of effective management protocols, as well as production of improved seaweed species and/ or strains with respect to growth, product yield/ quality, abiotic stress tolerance and disease resistance.

Photosynthesis–PAR (*P*–*E*) experiments on *E. denticulatum*, *K. striatus*, and *K. alvarezii* from Indonesia at 26°C revealed that net photosynthetic rates of the three seaweeds increased until the estimated saturation PAR (E_k) of 130–157 μmol photons m^{-2} s^{-1}; and that no photoinhibition was observed at the highest PAR of 1000 μmol photons m^{-2} s^{-1}. *K. alvarezii* also exhibited photosynthetic tolerance to high PAR as shown by their recovery in maximum quantum yields (F_v/F_m) following chronic exposures. Temperature responses of all carrageenophyte samples revealed their tolerance over a broad range of temperature, which is from 18.2 to 31.0°C for *E.*

denticulatum, 15.7–31.6°C for *K. striatus*, 19.7–28.5°C for brown *K. alvarezii*, and 17.4–32.4°C for green *K. alvarezii*. These characteristics indicate that they are well-adapted to the annual seawater temperatures observed at the cultivation site; however, they are also likely close to threshold levels for thermal inhibition, given the decline in F_v/F_m above 30°C. Higher photosynthetic parameter values of *E. denticulatum* also suggest that this species will probably be more superior in productivity under optimal conditions in commercial seaweed cultures.

The *P–E* curve of the Japanese *Kappaphycus* sp. (*K. striatus* auctorum japonicorum) from Okinawa, Japan at 24°C revealed that the compensation (E_c) and saturation (E_k) PAR were 26 μmol photons m^{-2} s^{-1} and 140 μmol photons m^{-2} s^{-1}, respectively. No inhibition in oxygenic evolution and quantum yield was observed at the highest PAR of 1000 μmol photons m^{-2} s^{-1}. However, the ability of the seaweed to recover from photoinhibition was complicated following 6-h PAR exposures at 18°C but not at 28°C. The native alga showed temperature tolerance for photosynthesis at 17.4–29.1°C. These characteristic results were closely related to the depth of its habitat and its northern limit of distribution in Okinawa, as influenced primarily by seawater temperature. Mariculture of this native carrageenophyte in subtropical waters of Okinawa, Japan is feasible, and may be conducted throughout the year under natural seawater temperatures.

P–E curves of the two life history stages of *C. costata* and *A. crassifolia* revealed the higher E_c (4–9 μmol photons m^{-2} s^{-1}) and E_k (53–243 μmol photons m^{-2} s^{-1}) of the sporophyte as compared to the gametophyte (E_c = 0–7 μmol photons m^{-2} s^{-1}; E_k = 7–44 μmol photons m^{-2} s^{-1}). This reflects the low-PAR adaptation of the microscopic stage that is commonly found on the underside of rocks or in crevices where light exposure is limited. Both stages exhibited chronic photoinhibition, as shown by the failure of recovery in their F_v/F_m following high PAR stress, with greater possibility of photodamage at low temperature. As for the temperature response, gross photosynthesis (*GP*) and F_v/F_m characteristics were similar for both developmental stages; their temperature optima range from 14 to 23°C, which correspond to the growth and maturation periods of these kelp species in Japan. They are also likely to suffer from thermal inhibition as both *GP* rates and F_v/F_m declined above 24°C. These physiological performances provide a basis for understanding the persistence of these kelp species near its southern boundary in the western Pacific.