数理モデルによる南極湖沼における湖底藻類群集マットの群集構造とカラーパターンの解明

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Mathematical model for color pattern and community structure of mat-forming phytobenthos in shallow Antarctic lakes

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Under low nutrient levels, low temperature, and seasonally limited solar radiation in freshwater shallow lakes in continental Antarctica, phytobenthos dominated by cyanobacteria and green algae form very productive ecosystem of thick mat on the lake beds. The suface of mat was bright orange in color and was constructed carotenoids rich algae, but the subsurface was black green and was constructed from algae having more photosynthetic pigments (Fig 1. Tanabe et al. 2010). The mat-forming phytobenthos in shallow Antarctic lakes experienced strong UVR and PAR light conditions in the ice-free summer. It was suggested that algae in mat surface have photo-protective pigments to resist the strong UVR and PAR light, for example carotenoids.

We here propose a mathematical model for ecological community formation that takes into account physiological process of both photosynthesis and photoinhibition of an algal cell. A series of light-absorbing pigments for photosynthesis and protection are subject to selection in the photobenthic community, and evolved vertical distribution of color spectra and photosunthesis/protection functions are compared with the observed patterns of algal mat in Antarctic fresh water lakes. More specifically, if we denote by $U_i(\lambda)$ and $V_i(\lambda)$ the light-absorption rate of wavelength λ for photosynthesis and photoprotection, respectively, of species i, the net growth rate of species i at the depth z from the mat-surface is defined as

$$\phi_i(z) = P(J_i(z), E_i(z)) - c\left(\int_{300}^{700} U_i(\lambda)d\lambda + \int_{300}^{700} V_i(\lambda)d\lambda\right)$$

where $P(J,E)$ is the net photosynthetic rate of a mirobe with total photon capture J and total energy exposure E ($J = J_i(z) = \int_{300}^{700} I(z,\lambda)e^{-V_i(\lambda)}\left\{1-e^{-U_i(\lambda)}\right\}d\lambda$ for species i at depth z where $I(z,\lambda)$ is the transmissive light spectrum at the layer of depth z, and $E = E_i(\lambda) = \int_{300}^{700}\left[I(z,\lambda)\left\{1-e^{V_i(\lambda)}\right\}h/\lambda\right]d\lambda$ is the light energy exposure that deteriorates the photosynthesis). c denotes the constructive cost of light absorption for a microbe. The transmissive light spectrum of a deeper layer is attenuated by the physical and biotic absorptions (as explained above) according to the Lambert law.
As a results, the model expected pigments concentration gradient from surface to subsurface (Fig. 2). Photosynthetic pigments ware expected any amount at surface, and photo-protective pigments that is consistently demonstrated in mat-forming phytobenthos in Antarctic lakes.

Reference

Tanabe, Y., Ohtani, S., Kasamatsu, N., Fukuchi, M., Kudoh, S., (2010) Photophysiological responses of phytobenthic communities to the strong light and UV in Antarctic shallow lakes. Pol. Biol.,

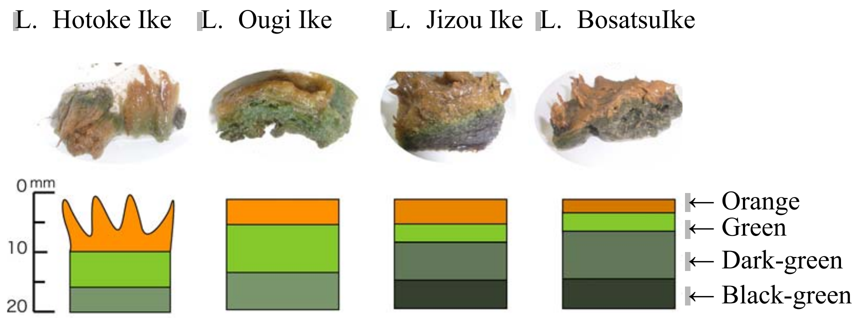

Fig. 1. Photographs phytobenthic mat from four antarctic lakes and pattern diagram for the colors. (modified from Tanabe et al. 2010)

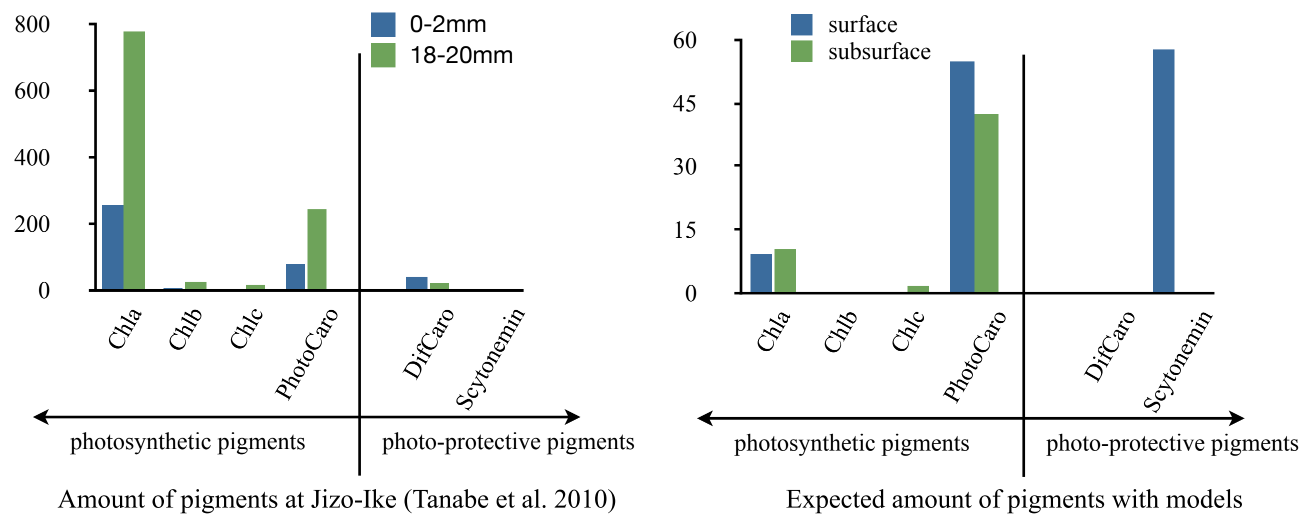

Fig.2. Expected and actual amount of pigments in surface and subsurface. Left pannel is amount of photosynthetic and photo-protective pigments at Jizo-Ike and Right pannel is expected amount of pigments.