

Carbon and Oxygen Budgets of Hypersaline Cyanobacterial Mats: Effects of Tidal Cycle and Temperature

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The hierarchical organization of microbial ecosystems determines the rates of processes that shape Earth's environment, define the stage upon which major evolutionary events occurred, and create biosignatures in sediments and atmospheres. In cyanobacterial mats, oxygenic photosynthesis provides energy, organic substrates and oxygen to the ecosystem. Incident light changes with depth in the mat, both in intensity and spectral composition, and counteracting gradients of oxygen and sulfide shape the chemical microenvironment. A combination of benefits and hazards of light, oxygen and sulfide promotes the allocation of the various essential mat processes between light and dark periods and to various depths in the mat. Microbiota produce hydrogen, small organic acids, and nitrogen and sulfur species. Such compounds fuel a flow of energy and electrons in these ecosystems and thus shape interactions between groups of microorganisms. Coordinated observations of population distribution, abundance, and activity for an entire community are making fundamental questions in ecology accessible. These questions address those factors that sustain the remarkable diversity of microorganisms that are now being revealed by molecular techniques. These questions

also target the processes that shape the various kinds of biosignatures that we will seek, both in ancient rocks from Earth and Mars, and in atmospheres of distant planets beyond our Solar System.

At Guerrero Negro, BCS, Mexico, we examined mats that are dominated by *Microcoleus* (subtidal) and *Lyngbya* (intertidal to supratidal) cyanobacteria. We observed the exchange of O₂ and dissolved inorganic C (DIC) between mats and the overlying water, during diel (24 hr.) cycles. *Microcoleus* mats assimilated near-equal amounts of DIC during the day as they released at night, but *Lyngbya* mats typically showed net uptake of DIC over the diel cycle. Patterns of O₂ daytime release and nighttime uptake mirrored these DIC trends in both mat types. Nighttime DIC effluxes from *Microcoleus* mats were equivalent in the presence versus absence of O₂, whereas nighttime DIC effluxes from *Lyngbya* mats dropped markedly in the absence of O₂. Thus, aerobic diagenesis was more important in *Lyngbya* mats than in *Microcoleus* mats, perhaps because trapped O₂ bubbles persist only in *Lyngbya* mats at night and thus sustain populations of aerobes. In both mat types, effluxes of H₂, CH₄ (Hoehler et al., 2001) and short-chain fatty acids were much greater at night in the absence of O₂ (Albert et al., 2000), emphasizing the importance of fermentation. Differences observed between *Microcoleus* versus *Lyngbya* mats forecast differences in their microbiota and in their patterns of gene expression.

Subtidal *Microcoleus*-dominated mats were examined in seawater concentrating ponds (S ~70 to 90 permil) at Exportadora de Sal, S.A., Guerrero Negro, BCS, Mexico. Between May and October (diel temperatures ranged between 15 and 27°C), mats exhibited high gross rates of production and consumption of oxygen (O₂) and dissolved inorganic carbon (DIC), but only a slight net O₂ release and DIC uptake over a full diel cycle. Fermentation became relatively more important at night and maintained fluxes of reduced products into the water column at low O₂ levels. At higher temperatures, higher irradiance levels were required to initiate detectable O₂ production. Net/gross O₂ production was always <0.7 and decreased at higher temperatures. As temperature increased by 10°C, rates increased approximately as follows: gross O₂ production: 1.5X; net daytime O₂ flux to water column: 1X; net nighttime O₂ uptake from water column: 2X; net nighttime DIC flux to water column: 2X; net daytime DIC uptake from water column: 1.1X. At higher temperatures, the downward O₂ flux below the photic zone increased and O₂ penetration shallowed. Temperature markedly affects gross versus net gas fluxes.

References

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