Bacterial-Algal Interactions in Antarctic Coastal Ecosystems

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Summary

The coastal zone of the Antarctic Peninsula is characterized by an intense seasonal bloom of phytoplankton. These populations have dramatic effects on ambient nutrient and dissolved gas concentrations and on the cycling of carbon and associated bioelements. During the RACER program, we had an opportunity to test several hypotheses regarding bacterial-algal interactions in this perennially cold, seasonally-phased oceanic habitat. Our results indicate that bacterial population dynamics are uncoupled from photoautotrophic processes. Possible causes for the observed temporal uncoupling of bacterial and algal populations include differential effects of temperature, organic substrate limitation, chemical antagonism and direct competition between algae and bacteria.

1. Introduction

The Southern Ocean, defined here as that body of water south of the Antarctic Convergence, covers an area of 35×10^6 km^2, nearly 10% of the World Ocean. The Southern Ocean is an important site for deep ocean ventilation and bottom water formation and for the exchange of gases and heat between the ocean and atmosphere. It is also the major surface ocean repository of plant nutrients.

Despite the fact that the Southern Ocean is perennially cold and in some locations permanently ice-covered, there is a diversity of microbial habitats and, therefore, microbial assemblages. Superimposed on these spatially diverse marine habitats is an intense temporal variability, perhaps the most extreme seasonality observed anywhere in the world ocean. This is especially true for coastal ecosystems which experience an annual cycle of sea-ice formation and ablation, as well as large variations in phytoplankton biomass and rates of primary production due to fluctuations in mixed-layer depth and solar radiation.

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Our current models of the trophic organization of antarctic marine ecosystems have evolved considerably during the past decade. Prior to 1980, energy flow in Southern Ocean habitats was believed to be relatively short and, therefore, highly efficient transfer from large phytoplankton cells to krill to higher trophic levels. This classical view of a linear antarctic food chain model has recently been expanded to reflect the roles of other herbivorous and carnivorous macrozooplankton including copepods, ostracods and gelatinous predators, benthic secondary productivity and plankton-benthos coupling and energy flow through microheterotroph (bacteria) and protozooplankton (flagellates and ciliates) assemblages. Nevertheless, it is important to emphasize that comprehensive, quantitative ecosystem studies of energy and carbon flow through the antarctic food web do not exist. At best only order of magnitude estimates for a few selected study areas are available. Consequently we must view food web models as hypotheses that require and deserve a thorough, quantitative field evaluation.

2. The Research on Antarctic Coastal Ecosystem Rates (RACER) Program

The interdisciplinary RACER field program had as its principal objective the study of physical and biological interactions leading to high levels of productivity in antarctic coastal marine ecosystems. Our subcomponent was focused on the role of the microbial loop in carbon and energy flux.

One of the more interesting, and unexpected, results of these analyses was the relationship between phytoplankton and bacterioplankton biomasses. Contrary to highly positive correlations often observed between their standing crops for aquatic environments worldwide (1,3), the RACER study failed to support this ecological prediction. These data revealed a deficiency, by up to an order of magnitude, in bacterial cells at chl *a* concentrations ≥ 2.5 *ug* chl *a* l^{-1}, relative to aquatic ecosystems previously studied (5). Several independent studies in high latitudes have revealed similar results suggesting that depauperate bacterial populations may be a fundamental difference between polar and non-polar habitats (4,6).

Since the initial 1986-87 RACER expedition we have confirmed these initial results by making independent determinations of bacterial biomass by epifluorescence microscopy, flow cytometry and lipopolysaccharide (LPS) concentrations during RACER cruises in Oct-Nov 1989, Dec 1991-Jan 1992 and July-Aug 1992. Using these independent measurements and best estimates of extrapolation to cell carbon, bacterial biomass was typically <2% and never exceeded 5% of phytoplankton cell carbon. Bacterial production rates, based on the uptake of ^{3}H-leucine, also indicate that microheterotrophic growth processes contribute only minimally to total ecosystem production. Furthermore, bacterial

cell removal as a result of microzooplankton grazing cannot be invoked to reconcile these steady-state biomass distributions (2). Based on these results we must conclude that the microbial loop is not active in the antarctic coastal marine ecosystem, at least not during the spring-summer bloom periods.

3. Future Prospectus

This apparent uncoupling of algal and bacterial processes suggests that the microbial loop consumes a negligible amount of the total carbon production. The reason(s) for this uncoupling are not well understood at present. At least four processes may be important: (1) organic substrate limitation, (2) differential temperature effects, (3) direct competition by mixotrophic algae and (4) chemical antagonism.

Experiments are currently underway to evaluate these mechanisms and in particular to field test the interesting hypothesis of low temperature-induced enhanced substrate requirements for heterotrophic bacteria (7).

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