Carbon and the Antarctic Marine Food Web

M. Huntley et al. present (1) a model of an Antarctic marine food web and suggest that top predators in the Southern Ocean are responsible for a large efflux of carbon into the atmosphere, up to 20 to 25% of primary production. These values are probably an order of magnitude too large because Huntley et al. have used an oversimplified food web and invalid assumptions and parameter values.

In the model (1), phytoplankton respiration is not accounted for, and all calculations refer to net rather than total primary production, which elevates the estimated contribution of all heterotrophs to the carbon flux. Net primary production, or photosynthetically fixed carbon (P), is apportioned between macrozooplankton (P_m) and the microbial loop (P_i). Mean values of 0.875 (sensitivity range 0.8 to 0.95) and 0.125 (0.2 to 0.05) were assigned to P_m and P_i, respectively.

That is, in all situations, it is assumed that the majority (at least 80%) of net primary production is directly channeled to macrozooplankton, with at most 20% entering the microbial loop. It is further assumed (1) that all fecal material produced by the microbial loop is ingested by macrozooplankton, bringing the total proportion of net primary production reaching macrozooplankton to 95%. In general, however, much of the carbon fixed during primary production in marine pelagic systems is believed to enter the microbial food web (2), and studies in productive coastal regions indicate that macrozooplankton probably consume no more than 20% of primary production (3). The relative abundances of protozooplankton and the structure of Antarctic marine food webs are sufficiently similar to those of lower latitude regions (4) that the possibility of a grazing pathway dominated by microbes should be incorporated in the model.

The value of P_i in the model apparently was chosen because bacterial production has been measured as 7 to 14% of phytoplankton production near the ice edge in the austral spring (5) and because bacteria do not comprise a large fraction of total microbial biomass (6). However, this assumes that the only production that enters the microbial loop is that of bacterioplankton. Heterotrophic flagellates, other protozooplankton, and small microzooplankton feed directly on phytoplankton cells of the appropriate size (4). Because most chlorophyll in the Antarctic is contained in cells smaller than 20 μm and because krill generally eat particles larger than 30 μm (7), a considerable factor may be heterotrophic organisms within the microbial loop grazing on phytoplankton (4, 7, 8). Carbon flux through the microbial food web may be low, but it does not follow that carbon entering the microbial food web is also reduced, as assumed in the model.

Values of growth efficiencies and carbon assimilation efficiencies in the model appear to be inappropriate large. This is a result of treating aggregations of organisms as trophic levels, when it would be more appropriate to consider them as food webs. For example, the microbial loop is given a mean growth efficiency (K_g) of 0.35 and comprises bacterioplankton, heterotrophic flagellates, ciliates, and many other protozoa and small zooplankton. Carbon entering this compartment may undergo four or five trophic transfers before being packaged into a form that can be eaten by macrozooplankton. In such a scenario, growth efficiency of the compartment would be expected to be approximately 0.5 to 1.5% (9), rather than the 35% assumed by Huntley et al.

In all instances, the model overestimates the amount of carbon being transferred to macrozooplankton, which leads to invalid estimates of carbon fluxes in the food web. If revised estimates of parameters are substituted in the model (P_i = 0.20, K_g = 0.01), a different result is obtained, with birds respiring approximately 5% of net carbon fixed and the microbial component approximately 60%. Thus, marine birds and mammals probably play a minor role as producers of atmospheric CO2, especially when compared with microbial plankton.

C. L. Moloney* Zeology Department, University of Cape Town, Rondebosch 7700, South Africa

Response: C. L. Moloney suggests that we overestimated the potential of Southern Ocean birds and mammals to respire CO2 to the atmosphere (1). On the basis of estimates for the Benguela Current, she has found (2) that zooplankton probably use only 20% of the primary production. This would require that 80% of primary production enter the microbial loop. We have no disagreement with these results, which are characteristic of a subtropical environment. However, studies cited in our Science report (3, 4) and results from our ongoing Research on Coastal Antarctic Ecosystem Rates (RACER) program (5) indicate that less than 10% of primary production enters the microbial loop of South-
Carbon and the Antarctic Marine Food Web
Coleen L. Moloney

Science 257 (5067), 259.
DOI: 10.1126/science.257.5067.259