Quantifying Phytoplankton Contributions to Export using ^{13}C.

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Many recent models for the ecosystem control of surface ocean carbon export have emphasized the role of direct export of large phytoplankton, which grow rapidly and thus “escape” grazing by their relatively long-lived predators [Boyd and Newton, 1999; Laws et al., 2000; Michaels and Silver, 1988]. This view has been promoted as a JGOFS paradigm [Ducklow et al., 2001, but the detailed mechanisms of this export pathway and its quantitative significance have yet to be fully explored. If grazing is not involved, then presumably physical aggregation is involved, because individual large algae appear to sink too slowly [Riebesell and Wolf-Gladrow, 1992; Waite and Nodder, 2001]. There have been few quantitative observations to document this pathway for export, either in the water column, or in sinking particles collected by sediment traps. Does this aggregation selectively remove only the large phytoplankton, or are all particles aggregated and removed? How can we quantitatively assess the relative contributions of small and large phytoplankton to carbon export over the full annual cycle of production and export? Stable carbon isotope mass balances offer some promise to address these questions. Recent observations of the organic-^{13}C of Southern Ocean phytoplankton found that large phytoplankton (70-200 µm size class dominated by the pennate diatom, *Fragillariopsis kerguelensis*) were enriched in ^{13}C in comparison to small phytoplankton (1-5 µm size class, comprised of a mix of small diatoms and other algae) by ~ 8 per mil [Trull and Armand, 2001]. This range is consistent with predictions from models and laboratory experiments on the moderation of isotopic fractionation by the limitation of CO_2 supply to larger algae as a function of the cellular surface to volume ratio [Popp et al., 1998], and thus is likely to be a general characteristic of phytoplankton communities. In the Southern Ocean study, comparison of phytoplankton organic-^{13}C compositions with the seasonal mixed layer increase in ^{13}C of dissolved inorganic carbon (^{13}C-DIC) suggests that large phytoplankton must have been responsible for the majority of seasonal export, and that this export appears to have occurred without co-export of small phytoplankton.
In principle, the ^{13}C mass balance approach can be applied to quantitatively assess export contributions from small and large phytoplankton at any site where seasonal surface water ^{13}C-DIC enrichments have been measured. This does require consideration of calcite export and air-sea gas exchange using other constraints such as seasonal alkalinity and pCO_2 estimates, although these terms are often small.

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