Controls on the ratio of mesozooplankton production to primary production in marine ecosystems

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Abstract

An ecosystem model was used to determine the extent to which global trends in the ratio of mesozooplankton production to primary production (referred to herein as the “z-ratio”) can be explained by nutrient enrichment, temperature, and euphotic zone depth. Equilibrium model solutions were first calibrated to global observed and empirically-derived patterns in phytoplankton biomass and growth rates, mesozooplankton biomass and growth rates, and the fraction of phytoplankton that are large (> 5 µm ESD). This constrained several otherwise highly uncertain parameters within the ecosystem model. Most notably, half saturation constants for zooplankton feeding were constrained by the biomass and growth rates of their prey populations, and low zooplankton basal metabolic rates were required to match observations from oligotrophic ecosystems. Calibrated model solutions had no major biases and produced median z-ratios and ranges consistent with global estimates. However, much of the variability around the median values in the calibration dataset (72 points) could not be explained. Model results were then compared with an extended global compilation of z-ratio estimates (> 10,000 points). This revealed a modest yet significant ($r = 0.40$) increasing trend in z-ratios from values ~0.01-0.04 to values of ~0.1-0.2 with increasing primary productivity, with the transition from low to high z-ratios occurring at lower primary productivity in cold-water ecosystems. Two mechanisms, both linked to increasing phytoplankton biomass, were responsible: 1) zooplankton gross growth efficiencies increased as their ingestion rates became much greater than basal metabolic rates, and 2) the trophic distance between primary producers and mesozooplankton shortened as primary production shifted toward large phytoplankton. Substantial regional z-ratio variability overlying these mean trends remained unexplained by the equilibrium model solution forced with basic nutrient enrichment, temperature, and euphotic zone depth scalings. Comparison of the modeled patterns and mechanisms revealed herein with those obtained using models of similar biological structure embedded in global circulation models will help elucidate the causes of this variation.

Key words: zooplankton, ecosystem modeling, energy flow, food webs, trophic levels, secondary production