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# Day/night differences in the grazing impact of marine copepods

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**Abstract**

Day/night differences in the removal rate of phytoplankton can occur as a result of increased copepod grazing rates at certain times of the day and diel vertical migration of animals. We conducted shipboard grazing experiments and fine-scale vertical zooplankton sampling to resolve these behaviors. Day/night feeding differences were compared in the center of several warm-core Gulf Stream rings, under conditions of no lateral water mass exchange, in the mesohaline portion of Chesapeake Bay and when following drogues in the Chesapeake Bay plume. Day/night variations in copepod biomass in the surface mixed layer were greater in neritic waters as compared to the open ocean stations. Day/night differences in weight-specific copepod filtration rates varied less than biomass. At the neritic stations copepod grazing was often higher at night, whereas at the oceanic stations day/night grazing rates were similar or daytime grazing rates were highest. The night/day ratio of zooplankton grazing impact on the phytoplankton community (the product of zooplankton biomass and their weight-specific grazing rate) averaged 4.8 in the Chesapeake Bay plume and 1.6 in warm-core Gulf Stream rings. Our results suggest that at lower food levels, there often are less day/night differences in the removal rate of phytoplankton by the copepod community.

## Introduction

Diel differences in the removal rate of phytoplankton can occur as a result of higher grazing rates of zooplankton at certain times of the day and/or diel changes in the abundance of zooplankton in surface waters. These phenomena may be mutually exclusive or interactive. Investigators studying zooplankton grazing need to be aware of diel behavior patterns to ensure that their measurements represent the range of values that occur over 24 h.

Using a variety of techniques (i.e. gut fullness, gut fluorescence, shipboard and *in situ* feeding experiments, fecal pellet flux rates) scientists have studied day/night differences in marine copepod feeding for over 50 years. Early work by Gauld (1953) with *Calanus finmarchicus* in the Clyde Sea demonstrated that copepods in the surface waters had full guts at all hours of the day. Diel changes in the grazing impact on the phytoplankton community were attributed to animals migrating into surface waters at night (although nighttime copepod densities in surface waters exceeded daytime concentrations on only 7 of 13 sampling days). Petipa (1958) conducted a similar type of study in the Black Sea with *Acartia clausi* and found that although the copepods remained in the surface waters throughout the day, there often (but not always) was a higher percentage of

copepods with full guts at night. Thus the day/night grazing impact of the copepods varied as a consequence of changes in feeding activity rather than abundance. Since these two papers were published there have been numerous reports supporting their results. In addition, both migration into surface waters at night and higher feeding rates at night have been found to occur simultaneously (e.g. Boyd *et al.*, 1980; Daro, 1980; Hayward, 1980) as well as an absence of vertical migration occurring with no diel changes in feeding rate (e.g. Boyd *et al.*, 1980; Nicolajsen *et al.*, 1983; Kiørboe *et al.*, 1985).

The same copepod species have been shown to vary in their day/night feeding behavior: migrating to surface waters at night or remaining there all day; sometimes feeding more at night or during the day, or with no diel differences. This 'plasticity' in behavior suggests that both physical (light, temperature) and biological (food, predators) factors may influence the diel grazing behavior of copepods (e.g. Boyd *et al.*, 1980; Huntley & Brooks, 1982; Dagg, 1985; Kiørboe *et al.*, 1985).

We measured day/night abundances and grazing rates of the natural copepod community in the surface mixed layer in a variety of marine environments (estuarine, neritic, oceanic). Synoptic data were also collected on the abundance and size distribution of phytoplankton and composition of the copepod community. Our objective in these analyses was to elucidate the factors responsible for day/night differences in the removal rate of phytoplankton from the surface mixed layer.

## Methods

*Study areas*

Warm-core Gulf Stream rings (WCRs) are formed in the northwest Atlantic Slope Water when anticyclonic meanders of the Gulf Stream separate from the main current. These WCRs have a central core derived from the Sargasso Sea which is surrounded by a clockwise-rotating remnant of the Gulf Stream. A sharp frontal boundary derived from the cold wall of the Gulf Stream exists between this high velocity region and the surrounding Slope Water. Newly formed WCRs are 100 to 200 km in diameter, average 1000 m in depth, and migrate southwest at 3 to 5 km $d^{-1}$ (Joyce & Wiebe, 1983). Surface temperature inferred from satellite infrared (IR) observations have shown that WCRs are distinguishable for several months and may cover up to 50% of the surface area of the Slope Waters between the Gulf Stream and shelf/slope boundary (Mizenko & Chamberlin, 1979). Studies of short-term variations in zooplankton biomass and grazing are facilitated in WCRs because their hydrographic features are distinct from the surrounding water and because they can be tracked by both satellite imagery and buoys. We selected station positions near the center of WCRs (Fig. 1) from the depth of the 10 °C isotherm and surface temperature distributions (Roman *et al.*, 1985). Day/night differences in zooplankton grazing are presented for WCRs (1982) 82-B in June (4 months old), 82-B in August (6 months old), 82-E in August (1 month old) and 82-H in October (formed during the cruise).

Day/night grazing studies were also conducted in the Chesapeake Bay plume (Fig. 1). Coastal plumes are characterized by a distinct salinity structure and high biological production relative to ambient shelf water. The coastal plume of Chesapeake Bay has a horizonal scale of 10 to 100 km, a vertical scale of 5 to 20 m and a time scale of 1 to 10 days (Boicourt *et al.*, 1987). Our sampling protocol consisted of mapping physical (temperature, salinity) and biological parameters (nutrients, chlorophyll-a, bacteria, flagellates and zooplankton) in the shelf and plume waters. Upon completion of a map, a surface drogue was deployed near the mouth of the Bay and a time series was initiated (1–3 days) in which zooplankton were sampled at 2–4 hour intervals. Day/night differences in zooplankton grazing in the Chesapeake Bay plume were studied in February, June and August 1985 and April 1986.

Day/night grazing studies in the mesohaline portion of Chesapeake Bay (38° 33.5′ N, 76° 25.7′ W, Fig. 1) were conducted in May and