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UV light and vertical distribution of the marine planktonic copepod *Acartia hudsonica* Pinhey

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Abstract: Of the many hypotheses put forth to explain the possible adaptive value of daytime residence in subsurface waters and diel vertical migration behavior of zooplankton, avoidance of potentially harmful UV radiation has only recently been proposed. We undertook a manipulative field experiment to test the effect of UV-B (290–315 nm) solar radiation on the daytime vertical distribution of the marine planktonic copepod *Acartia hudsonica* Pinhey. Since no statistically significant difference in the daytime depth distributions of adult *A. hudsonica* in control and UV-B-filtered treatments was found, we conclude that some other factor(s) must determine the daytime vertical distribution of this copepod.

Key words: *Acartia hudsonica*; Diel vertical migration; UV light; Vertical distribution; Zooplankton

INTRODUCTION

Diel vertical migration behavior (DVM), whereby aquatic organisms inhabit surface waters during the night and migrate downward to spend the daylight hours at depth, is widespread among pelagic animals. While many hypotheses have been put forth to explain the possible adaptive value of DVM in zooplankton (see Kerfoot, 1985, for a recent review), avoidance of potentially harmful UV solar radiation by daytime residence in deeper, subsurface water has only recently been proposed (Damkaer, 1982; Pennington & Emlet, 1986).

UV-B radiation (290–315 nm) has been shown to be effective in inducing photochemical reactions in plants and animals generally (Caldwell, 1971; Giese, 1976), and to affect the activity, development and survival of marine zooplankton (Karanas et al., 1979; Damkaer et al., 1980, 1981; Damkaer & Dey, 1982; Pennington & Emlet, 1986). Since substantial UV-B light can, depending on the organic content of the water, penetrate up to several meters in marine waters (Calkins, 1975; Smith & Baker, 1979), such radiation might play a role in determining the daytime vertical distribution and DVM behavior of surface-dwelling plankton. Indeed, Pennington & Emlet (1986) suggested that the daytime vertical distribution and DVM of planktonic echinoderm larvae effected avoidance of UV-B radiation.

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We recently reported (Bollens & Frost, 1989) a manipulative field experiment done on enclosed populations of the marine planktonic copepod *Acartia hudsonica* Pinhey to test the hypothesis that DVM exhibited by this species is induced by its predator, the three-spined stickleback *Gasterosteus aculeatus*. In the shallow (3.3 m) experimental enclosures, copepods were nearly always least abundant (though never absent) in the surface layer in the daytime, even in the absence of predation. Subsequently we undertook a second manipulative field experiment to test whether UV light caused *A. hudsonica* to avoid the surface layer in the daytime.

Materials and Methods

The field site was Jakles Lagoon, a small (2.6 ha) marine lagoon on San Juan Island, Washington, USA. It was chosen for two reasons: (1) previous sampling indicated that *A. hudsonica* consistently exhibited diel vertical migration, residing at depth during the day and entering the surface layer only at night (Landry, 1978; Bollens & Frost, 1989), and (2) the lagoon is shallow (maximum depth 3.9 m), facilitating use of enclosures that span the depth range of the copepods.

We deployed six 2600-l cylindrical (1.0 m diameter × 3.3 m depth) enclosures constructed of 10 mil (0.25 mm) woven polyethylene in a linear array along the south side of a raft moored in the center of the lagoon. The enclosures were presoaked in seawater for ≈3 wk, then filled with filtered (73 μm) seawater. On the night of 19 June 1988, vertical plankton hauls (0.5 m diameter net, 110 μm mesh, closed cod end) were made in the lagoon from within 15 cm of the bottom to the surface on the north side of the raft. The contents of three vertical hauls were placed in each enclosure, giving an expected initial density of *A. hudsonica* equal to ≈3/4 natural density. The tops of three of the enclosures were immediately covered with 0.25 mm thick mylar plastic. Mylar removes wavelengths below 315 nm (Damkaer et al., 1981), thus acting as a filter of UV-B radiation, while transmitting >90% of incident visible radiation (Bjorksten Research Laboratories, 1956). The three remaining enclosures were left uncovered and served as controls.

Near midday (1305–1333) on 20 June 1988, we determined the vertical distribution of *A. hudsonica* in each enclosure using the multiple water bottle sampler described by Bollens & Frost (1989). A single vertical series of samples was taken from each enclosure. The sun was directly overhead and the sky was clear. Samples were concentrated on a 73-μm sieve and preserved in 10% buffered formalin–seawater solution. We counted all adult female and male *A. hudsonica* in each sample.

Results and Discussion

Adult female and male *A. hudsonica* were aggregated at depth in all six experimental enclosures (Fig. 1), although a small proportion of the copepod populations (both sexes)

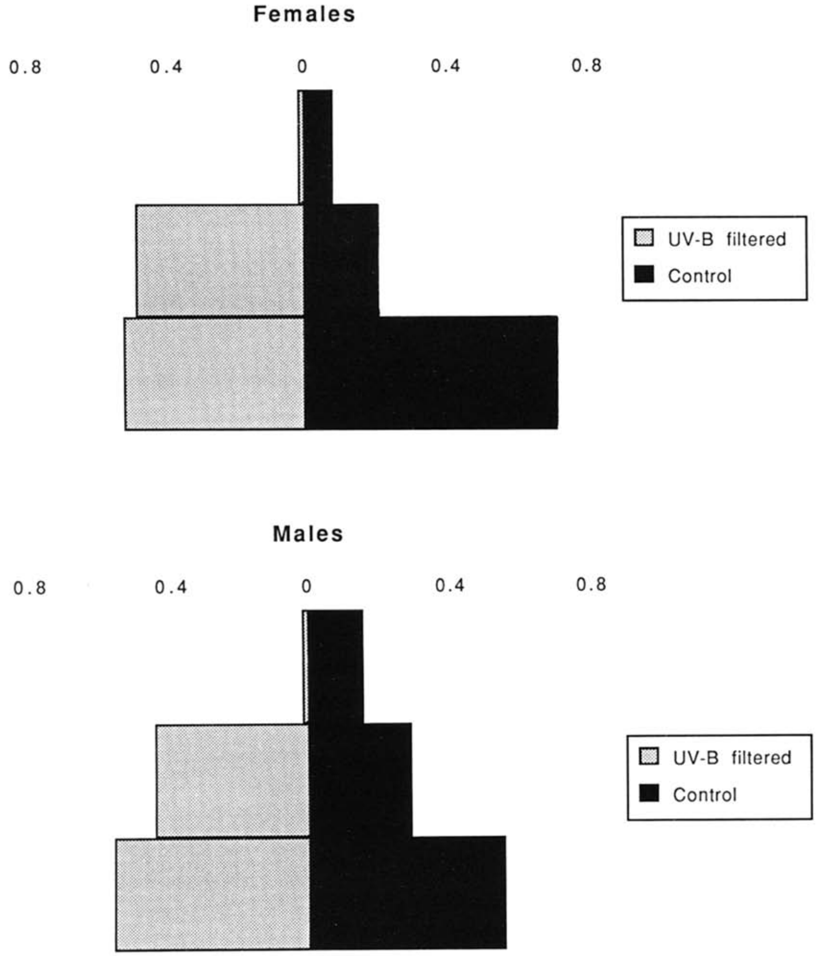

Fig. 1. Vertical distribution of adult *A. hudsonica* in experimental enclosures. Each vertical distribution is mean of three enclosures for each treatment (control and UV-B-filtered). Variability among triplicates within treatments is indicated by weighted mean depths (WMD) in Table I. Depth range of each histogram is 0.15–3.15 m. Scales are proportions of copepod populations in sampled layers.

occurred in the surface layer in both control and UV-B-filtered enclosures. The mean depths of the copepods in the two types of enclosures were not statistically significantly different (Table I), although the statistical power of the test is low for distinguishing such slight differences ("effect size" as in Rotenberry & Wiens, 1985). We conclude that UV-B solar radiation had a negligible proximate effect on the daytime depth distribution of adult *A. hudsonica*.

Our conclusions are in contrast to those of Pennington & Emlet (1986) who observed DVM in planktonic plutei of the echinoid *Dendraster excentricus* in a floating enclosure

TABLE I

Daytime mean depths (m) of adult *A. hudsonica* in each of six experimental enclosures. Weighted mean depth, WMD = $(\sum n_i d_i)/\sum n_i$, where n_i is abundance (no. $\cdot$ 3.5 l^{-1}) at depth d_i (d_1 = 0.65, d_2 = 1.65, d_3 = 2.65 m) in each of three replicate enclosures. Mean depth (MD) is mean of three WMD values. Mean depths were compared between control and UV-B-filtered treatments by t test (one-tailed, 4 df). For both sexes, differences between treatments were not statistically significant ($P > 0.10$).

	Treatment	WMD			MD
Females	Control	2.23	2.29	2.43	2.32
	UV-filtered	1.94	2.27	2.36	2.19
Males	Control	1.65	1.96	2.13	1.91
	UV-filtered	1.93	2.23	2.39	2.18

and outdoor aquarium. They concluded that DVM "apparently removes plutei from harmful effects of ultraviolet light" (Pennington & Emlet, 1986, p. 69). While this may be so, a direct causal relationship between UV-B light and the observed daytime vertical distribution and DVM of plutei was not established experimentally by Pennington & Emlet (1986). Their conclusion was based on rapid avoidance responses induced in plutei by exposure to UV-B light in very small containers with very shallow water columns ($\approx$3–30 cm deep). Such induced avoidance behavior may not have been relevant to the larger-scale daytime vertical distribution and DVM behavior of plutei observed by Pennington & Emlet (1986) in the deeper water columns (1.8–3.2 m) of the floating enclosure and outdoor aquarium. Alternatively, the echinoid plutei and copepods may have different sensitivities and responses to UV-B radiation. For example, Damkaer & Dey (1982) also detected no effect of UV-B radiation on vertical distribution of healthy specimens of two species of planktonic crustaceans, whereas some adult echinoderms have high UV sensitivity (Pennington & Emlet, 1986).

In this and our earlier experiment (Bollens & Frost, 1989), adult *A. hudsonica* avoided the surface layer in the daytime. Since we could detect no effect of UV light, some other factor(s), such as visible light (Damkaer, 1982), must determine the daytime vertical distribution of this copepod in the absence of predation.

These contrasting results (Pennington & Emlet, 1986 vs. Damkaer & Dey, 1982 and this paper) point to the need for studying a wider range of species if we are to understand the role of UV light in determining the vertical distribution and DVM of planktonic animals. This need is all the more pressing given the expected increases in UV radiation accompanying the possible deterioration of the stratospheric ozone layer.

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