EFFECTS OF A TOTAL SOLAR ECLIPSE ON THE VERTICAL DISTRIBUTION OF CERTAIN OCEANIC ZOOPLANKTERS

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ABSTRACT

The effect of the total solar eclipse of 7 March 1970 on some oceanic Copepoda and Euphausiacea in the Gulf of Mexico was studied by taking 10-min tows with Clarke-Bumpus nets on the days before, during, and after the eclipse. Illumination was continuously recorded. Most organisms that responded to the eclipse did so by migrating to the surface during totality. The magnitude of this response appeared to exceed that to the decrease in light intensity at night.

Most marine zooplankters exhibit some pattern of diel vertical migration which is presumably controlled or cued by daily fluctuations in light intensity. In most cases the pattern is one of ascent at night and descent during the day.

Studies of the migratory responses of pelagic marine organisms to a total solar eclipse are few. In waters 322 km south of Woods Hole, Massachusetts, Baekus et al. (1965) observed three scattering layers ascending vertically in apparent response to the solar eclipse of June 1963. At the entrance to Eel Pond off Great Harbor near Woods Hole, they also detected an increase in bioluminescence to nearly nighttime levels during the eclipse. In response to the same eclipse, copepods, especially the females of *Pseudocalanus minutus* and *Acartia longiremis*, collected from Bar Harbor and Boothbay Harbor, Maine, migrated upward; other species were less responsive (Skud 1967).

Petipa (1955), as noted by Skud (1967),
detected an upward movement of zooplankton in the Black Sea in response to the solar eclipse of 1954. The solar eclipse of March 1970 elicited a similar response, this time more rapid in the males, from *P. minutus* in the near surface coastal waters of Boothbay Harbor, Maine (Sherman and Honey 1970); *Calanus finmarchicus*, also abundant in the area, did not respond significantly.

We have attempted to investigate such reactions in oceanic zooplankton on dates (6, 7, and 8 March 1970) and a position (24°N, 89.5°W) selected to provide observations before, during, and after the eclipse at a location where totality would occur at about local solar noon. This we felt would allow us to make observations during the period of greatest fluctuations in light intensity. A preliminary report has already been published (Franceschini et al. 1970).

**MEASUREMENTS**

We made 10-min tows at a constant wire angle using an array consisting of one 30-cm nonclosing surface net and three 30-cm Clarke-Bumpus opening-closing plankton
samplers (mesh aperture, 0.569 mm) placed at 25, 50, and 75 m on the wire. About 42 m³ of water were filtered per tow by each net. Due to the paucity of organisms captured at the two deepest levels, we present here only the information from analyses of samples taken at the surface and 25 m.

Periodic bathythermograph observations showed insignificant variations in temperature (21.5–22.1°C) over the depth range considered here. Therefore, possible effects of temperature on the results presented below are disregarded.

Short-wave solar and sky radiation was measured with a silicon photovoltaic cell pyranometer and continuously recorded by potentiometric strip-chart recorder. Data for the day of the eclipse and for 8 March, a typical subtropical day at sea, are shown in Fig. 1. On 7 March light intensity dropped dramatically with the onset of the eclipse and during totality fell below the range of sensitivity of the instrument. After totality, cloudiness influenced the data considerably.

RESULTS

Figure 2 shows the biological results of our sampling at the surface and 25 m; average light conditions for each tow are depicted at the base of the figure. The frequency of tows was greatest on 7 March, especially during the 2 hr directly following the eclipse.

Male and female copepods displayed no significant differences in distribution and apparent response to the eclipse. According to Moore and O'Berry (1957), the common epipelagic copepod *Nannocalanus minor* has a small diel vertical migratory range. Individuals of this species were collected frequently in our 25-m nets the day before the eclipse but appeared in greater abundance that night, both at the surface and 25 m. The species disappeared from the surface during the morning before the eclipse. They apparently underwent a dramatic change in vertical distribution and were captured almost exclusively at the surface during totality, at which time their numbers exceeded those of any species in any other surface sample. Two tows later (30 min) they were again captured at 25 m. At 1430 hours, they seemed to have resumed their customary daytime distribution. Their sparsity in the three tows between 1252 and 1334 hours is notable but difficult to explain. The other species exhibited a similar sparse pattern of capture during the same interval. The fact that this species was collected only at the surface on the night following the eclipse is in interesting contrast to the preceding night when it was taken in significant numbers at both the surface and 25 m. Daytime distributions of *N. minor* were similar on the days before and after the day of the eclipse.

The same basic pattern of distribution and response apply to *Scolecithrix danae* and *Undinula vulgaris*. *Scolecithrix danae* was collected only in the 25-m nets during the day. On the night before the eclipse a few individuals were also collected in the surface nets. The species showed a dramatic change at totality and was captured exclusively and abundantly at the surface. On the following evening the few individuals collected came only from the surface nets.

*Undinula vulgaris* is reported by Moore and O'Berry (1957) to exhibit a moderate diurnal vertical migration. It was poorly represented in our samples taken during daylight hours at both depths. Elements of the population must have been shallow enough to migrate quickly to the surface in response to the decreased light intensity during the eclipse. This species was also collected exclusively in the surface samples on the night following the eclipse.

*Pleuromamma gracilis*, reported by Roehr and Moore (1965) as capable of perform-

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Fig. 2. Numbers of copepods and euphausiaceans captured during concurrent 10-min tows at the surface and 25 m.
ing vertical migrations of over 150 m, did not appear in any of our samples taken during daylight; at night the species was well represented at both the surface and 25 m. It is possible that this deep-living species did react to the eclipse but did not have time to swim into our sampling range before the response was negated by increasing light intensity.

The distribution of *Pleuromamma piseki* was similar to that of *P. gracilis*. Again, the dearth of individuals of these species at 25 m on the night after the eclipse should be noted.

During daylight hours of the days before and after the eclipse, and on the morning and afternoon of the eclipse, *Paracandacia bispinosa* was well represented at 25 m. The sparse nighttime occurrence of this species seems to suggest either that its distribution becomes more diffuse in the upper layers under low light levels or that the animals undergo a reversed vertical migration. In view of the previously discussed apparent patterns of response, it is significant to note that during totality, as during nighttime hours, the number of individuals of *P. bispinosa* captured at both depths was quite low compared to most other daytime catches.

Like the copepods, male and female euphausiaceans exhibited no significant distributional differences. Four deep-living species were captured during this study (*Euphausia tenera*, *Euphausia brevis*, *Euphausia mutica*, *Euphausia americana*). According to Lewis (1954) and Brinton (1962), all of these have centers of distribution at the surface at night and from 300–500 m or more during the day. The first three exhibited similar patterns of capture. They were totally missing from our samples during daylight hours, with the exception of one late descending specimen of *E. mutica* taken at the surface at 0840 on 7 March. At night these euphausiaceans were all present either at the surface or both the surface and 25 m. *Euphausia americana* varied from the above pattern in that one individual was captured at the surface during totality and several at 25 m in the hours thereafter.

If the first three species responded to the eclipse, they presumably did not have time to ascend into our sampling range from their deep position. Some individuals of *E. americana* were apparently distributed high enough in the water column to allow them time to ascend above 25 m during the eclipse. *Euphausia americana* may have a migration rate faster than that of the other three species, or it may have responded to a higher light intensity and thus started migrating upward earlier.

*Stylocheiron carinatum* has a generally shallower daytime center of distribution, 90–270 m. At night it may be found from the surface to 270 m but was not taken from the surface during the day by Lewis (1954). The species occurred in all of our 25-m samples but appeared in the surface samples only at night, during totality and, interestingly, at noon on the day following the eclipse. Of this species, the greatest number of individuals in any one sample occurred in the surface tow made during totality, suggesting a fairly strong response to the eclipse. If the appearance of seven individuals at the surface 24 hr afterwards is significant, it certainly cannot be explained on the basis of a drop in light intensity.

**CONCLUSIONS**

The evidence suggests that certain species of epipelagic oceanic copepods and euphausiaceans in the Gulf of Mexico responded to the noontime total solar eclipse of March 1970 by migrating to the surface. Where a response to the eclipse was noted, its magnitude, as reflected in the number of organisms captured at the surface, appeared to exceed to some extent the magnitude of the response to a decrease in light intensity at night.

The distributions of these organisms during totality were not identical to the nighttime distributions before or after the eclipse. Fewer organisms were captured at 25 m on the succeeding night than on the preceding one.

In one case, a euphausiacean, the data suggest a 24-hr carryover of its eclipse response, resulting in a repetition of the
upward migration at noon the following day in the absence of any drop in light intensity. In view of the small number of specimens involved, however, this last conclusion must be viewed as highly speculative.

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REFERENCES


