POSSIBLE INFLUENCES OF SOLAR UV RADIATION IN THE EVOLUTION OF MARINE ZOOPLANKTON

by

David M. Damkaer[1,2]

[1]University of Washington WB-10, Seattle, WA 98195 U.S.A.

[2]National Marine Fisheries Service/National Oceanic and Atmospheric Administration, Manchester, WA 98353 U.S.A.

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ABSTRACT

Evolution is understood to be a species' total response to a large number of environmental factors. One of these factors, even in the sea, may be solar UV radiation. If so, one might relate a number of unique features of marine zooplankton to the selective pressures of this near-surface stress. Some characteristics of marine zooplankton that may have been influenced or even determined by UV radiation are the diel vertical migration, certain seasonal migrations and the seasonal occurrence of near-surface larvae, UV-absorbent cuticles, zooplankton coloration, zooplankton associations, and zooplankton shapes.

The environment has always changed and presumably it will continue to change. Change is also a fundamental aspect of living matter. Morphological and behavioral variability are the raw materials which allow better adapted organisms to survive environmental changes. Recent discussions of the development of life have pointed to UV radiation as a major limiting factor on the early earth (Sagan, 1973; Caldwell, 1979). That solar ultraviolet radiation has played some subsequent part in the evolutionary selection process on land is evident in the protective coverings and avoidance behavior of many terrestrial organisms. Organisms have also responded in an evolutionary sense to infrared radiation (heat), and in many cases it would be difficult to separate the effects of these two spectral extremes.

UV radiation has not until recently been believed to be of consequence in the oceans, so that studies on morphology, behavior, and horizontal, vertical, and seasonal distributions of marine organisms have not generally explored possible relationships to solar UV. That UV radiation enters the sea to a depth and with an intensity that it can potentially affect marine organisms has now been demonstrated (NAS, 1979). If solar UV radiation has exerted a Life-long influence over the development of marine organisms, one would find its imprint in the most ordinary characteristics of marine plants and animals.

The most striking general phenomenon exhibited by zooplankton is the diel vertical migration (Banse, 1964). This daily migration has been regarded by many as the normal behavior pattern of pelagic animals, even though many species do not respond in this way or do so only under some conditions. Certainly the majority of pelagic animals show diel vertical migration. There are vertically migrating representatives in all zooplankton groups, in freshwater as well as in the oceans. The migrations may cover less than a meter for some species, to more than 1,000 m for others. In general, the diel vertical migration is most marked at the very surface, and less noticeable in deeper water. It is also less pronounced in neritic areas, where light attenuation as well as salinity and temperature gradients are stronger. There has never been a completely satisfactory explanation for the universality of the diel vertical migration, but it is generally agreed that these migrations are reactions to changing light conditions, and an attempt of the zooplankton to keep at some optimum illumination. It is possible that these responses are basically the simple avoidance of damaging UV radiation, although not necessarily from a direct sensing of UV. Since UV is coupled to visible radiation, organisms not avoiding light might be selected against. Vertical migrations of deep-living zooplankton may be instinctive, primal responses, or indirect responses in following prey organisms.

Besides diel vertical migrations, which would enable many species to avoid UV, some seasonal vertical migrations might also lessen harmful solar effects. Most seasonal migrations of holopelagic animals seem to indicate the opposite trend, since over-wintering at depth is the rule. However, the seasonal occurrences of surface-living larvae of bottom-living adults might have evolved to optimize the larval feeding and dispersion possibilities while at the same time minimizing harmful effects of solar UV. If this were true, one might see suggestions of UV-regulation near the extremes of surface-seasons, and also one would find increasing UV tolerance in larvae found naturally under higher UV levels. Both of these conditions have been observed. The periods of surface occurrence ended for shrimp, crab, and euphausid larvae shortly after solar UV exceeded the laboratory-determined UV tolerance limits (Damkaer et al., 1980). Northern anchovy larvae have their maximum abundance in the near-surface layer during periods of low and increasing solar UV, and are less abundant during late spring and summer, when solar UV exceeds laboratory-determined tolerances (Hunter et al., in press). Hunter et al. have also reviewed literature on other clupeoid fishes worldwide, and this indicates that maximum spawning in many major stocks does not coincide with the period of maximum UV radiation. An exception seems to be with species spawning nearshore or in bays where UV attenuation is generally greater. Hunter et al. (1979) have shown that Pacific mackerel, which spawn intensively in June, are much more UV resistant than anchovy. The resistance of mackerel may lie in superior repair mechanisms. Hunter et al. (in press) mention also that some fish larvae found at the surface during peak months of UV radiation are heavily pigmented, and thereby obtain some protection against harmful UV.

Finally, one could expect that some of the geographical variability in vertical and seasonal distributions of widely distributed species might be related to UV trends. This has not yet been investigated.

In quasi-static vertical distributions, there are marked changes in abundance with depth over very short distances near the surface, even in water that is homogeneous with respect to temperature and salinity. The concentrations of holopelagic animals, particularly copepods, may vary 300% in tenths of meters (Della Croce, 1962), while the abundance of photopositive larvae of bottom-living adults might vary 1,000% within 1-2 m (Banse, 1964). Since UV radiation is attenuated rapidly in natural waters, this vertical partitioning of abundance may simply be a response to detrimental UV.

Regardless of the typical vertical distribution or vertical migration patterns observed for given species, there are always individuals that do not conform. Presumably present selection pressures would be against these aberrant specimens, but within a significantly changed environment, new selection pressures could change the relative advantages. In the long term, it is the variability within species that will ensure that Life goes on.

There are very few organisms that cannot escape UV radiation. One group is the tropical open-ocean water-striders *(Halobates).* Cheng et al. (1978) have shown that the cuticle of species of three genera of water striders is progressively more absorbant of UV (and hence more UV-protective) as the habitat is more exposed to solar UV. The least UV-absorbant cuticle was found in water-striders from shaded river habitats. Cuticles of water striders from mangrove lagoons are of intermediate UV-absorbancy, while the greatest protection was given by the cuticle of *Halobates.* The actual solar-UV tolerance of *Halobates* is unknown, but specimens remained active for 24 h in the laboratory under a germicidal UV lamp (254 nm) which killed the fruit fly *Drosophila* in 30 min.

An extraordinary community of zooplankton is found just beneath the surface film in the tropical open ocean (David, 1965). With regard to solar UV, their situation appears to be not much different than *Halobates.* Many of these forms could increase their depth at times, but others certainly remain exposed. The most striking and unifying characteristic of these diverse surface animals is the intense blue color of many of them. In some cases this is due to pigments, as in the common pontellid copepods; in other cases the blue is caused by optical refraction and interference, as with some cyclopoid copepods *(Sapphirina).* Previously, this blue coloration has been said to afford concealment, but it might also be tied to protection against UV radiation (Herring, 1965). Perhaps significant harmful UV is reflected from such pigmented or refractile bodies.

One would tend to think of the near-surface tropical ocean as shadeless. Unless protective means have been acquired, there may be high potential for UV damage. Yet shade exists under the floating gelatinous umbrellas of *Physalia, Porpita,* and *Velella.* This may be particularly significant in the latter two, whose chitinous floats continue to drift about on the surface long after the rest of the animal has died or been eaten away. Besides providing substrate for the eggs of many species, such gelatinous floats are centers of complex communities of amphipods, copepods, and fishes. Usually these relationships are thought to be based on feeding, but the avoidance of UV by association with these floats could be a great advantage.

No one could be unimpressed by the bizarre structures encountered in the plankton. Many of these forms seem to have evolved as responses to predation or water viscosity. If UV radiation is an important environmental stress, some plankton shapes could be attempts to mitigate that stress. In particular, the leaf-like phyllosoma larva of the spiny lobsters might offer a minimum UV-absorbing target if aligned parallel to solar radiation. Unfortunately, there is no information on the orientation of these interesting paper-thin larvae.

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