SUBMARINE ILLUMINATION AND THE TWILIGHT MOVEMENTS OF A SONIC SCATTERING LAYER

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It has long been recognized that many zooplankton organisms exist in distinct strata during the day and that they may undergo extensive diurnal vertical migrations. The similarity of their behavour to that of certain sonic-scattering layers in the sea, observable with echo-sounding equipment, led Johnson (1) to suggest that the origin of these layers is biological. Collections by various methods have shown that concentrations of both zooplankton and fishes are associated with these layers. Although much thought has been devoted to the composition of the layers and to the acoustic properties of the animals probably comprising them, attention to the causes of their vertical migrations has been restricted to speculation and to laboratory experiments with individuals.

As a first step in determining these causes, the change of depth of a certain level of submarine illumination during twilight is compared by the authors in this article with the depths of a certain scattering layer during its vertical migration.

Intensity of illumination at depth was measured with a submarine photometer designed expressly for this purpose by James M. Snodgrass, of the Special Developments Division at the Scripps Institution of Oceanography. This instrument has already been described by Kampa and Boden (2). The tube is protected against pressure at depth by an oil-filled glass riding-light cover which makes water-tight contact with the brass cylinder containing the submerged portion of the photometer circuit, the latter calibrated with a Weston illumination meter using a 100-watt *G.E.* projection bulb at 115 volts.

During the observations reported here, the submerged unit was rigged in such a way that the sensitive surface of the photomultiplier tube was vertical, favouring measurement of horizontal illumination.

When a curve of equal illumination was to be determined for comparison with scattering layer position during vertical migration, the submerged unit was lowered to the depth of the top of the layer, and the light intensity and time were recorded. This time was noted on the fathogram as well. The photometer was

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(1) Anonymous. Stratification of Sound Scatterers in the Ocean. University of California, Division of War Research. Report N° M397 (1946).

(2) Kampa, E. M. and Boden, B. P., Bermuda Biological Station. Report 1 (1954).

then either raised (sunset) or lowered (sunrise) 10 m. and held at the new position until meter readings showed that the illumination intensity was the same as that previously observed. The time was again recorded. This process was repeated until the fathogram showed that the scattering layer position had become relatively constant, either at the surface or at depth.

Scattering layers were observed with an *NMC-1* fathometer operating at 17.5 kc./s. The wide-band sound source in this analysis was a block of TNT detonated at the surface about 30 m. from the receiver. The receiver was a directional Rochelle salt hydrophone directed vertically downward just below the surface at the side of the ship. Sounds received by hydrophone were recorded with a « Magnecord » 63 *AH* tape-winder with *PT7-P* « Magnecord » amplifier adapted to operate at 30 in. per sec. The record of echoes from each explosion was filtered through an H.H. Scott Type 420-*A* sound analyser, and an oscillographic record was made of the reverberation at various frequencies using a triggered single-sweep oscillograph fitted with a « Polaroid » Land camera.

Biological collections were made from each layer under observation with a plankton net which could be opened and closed at depth by means of the Leavitt (3) opening and closing device. A time-depth recorder was incorporated in the collecting gear to give a record of the fishing depth of the net.

The authors recorded graphically the twilight ascent of a scattering layer in the San Diego Trough on June 30, as well as the ascent of the level of illumination with which this scattering layer had been associated during the afternoon.

During its migration, this layer was observed to split into two components, the upper scattering relatively high frequencies, the lower scattering lower frequencies. These components were also noted in the oscillograms which registered the reverberations from the explosions and on the fathogram made in the San Diego Trough. A record was made of the descent of the scattering layer with the isolume superimposed.

The extremely close correlation between the vertical movements of a scattering layer and those of a constant level of illumination argues strongly that the migrations of these layers are simple responses to variations in environmental light intensity. It seems that during moonless nights, in layers of similar composition, the animals become dark-adapted and consequently more sensitive to lower light intensities. The authors plan to investigate the extent to which various degrees of dark- and light-adaptation influence the position of the scatterers relative to illumination-level as this bears out previous observations which indicate that in the heterogenous layer, a certain illumination intensity is found to be connected with the presence of certain animals and with their ascending movements.

Plans are under way to study the vertical migration of a layer in order to determine which organisms respond to light and which merely follow a migrating food source.

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(3) Leavitt, B. B., *Biol. Bull.* 69 (1), 111 (1939).