DEEP OBSERVATIONS OF ANCHOVY AND BLUE SHARKS FROM *DEEPSTAR 4000*

Visual observations from manned deep-submersibles have recently contributed to the knowledge of the vertical distribution of marine organisms. Prior to the introduction of these craft, vertical distribution patterns were established using sampling gear such as nets. This was generally sufficient in the case of the smaller, easily captured forms since many of the nets used in these studies could be opened and closed at predetermined depths so that selected strata would be sampled exclusively. In the case of the larger, more active fishes, however, knowledge of their depth ranges has been mostly speculative. Sampling of these animals has normally been accomplished using commercial fishing gear which is generally indiscriminate with respect to the depth of capture. This has been true of the two species in question, the northern anchovy, *Engraulis mordax* Girard, and the blue shark, *Prionace glauca* (Linnaeus).

One method used to establish the depth of anchovy schools has been to locate them with echo sounders during the day when they are deep, then remain over them until they rise to the surface at night. Once the schools are at the surface, identification can be made with midwater trawls. Common daytime depths of these schools are between 140 and 220 m (personal communication with K. F. Mais, California Department of Fish and Game). Information on vertical distribution of blue sharks has been reported by Strasburg (1958). Analysis of longline fishing data from the central Pacific showed that these sharks were often captured on the deepest hooks. Although the exact depth of the hooks at the time of capture was not known, the approximate depths were in the 110-150 m range. This report, then, should serve as a visual verification of this previous information.

Dive 502 of the submersible *Deepstar 4000* was made on 9 November 1968 at lat 32°26'N, long 117°23'W, west of the Coronado Islands. On the way to the dive site from San Diego aboard the mothership *Searchtide*, a continuous echogram was made on a Gifft GDR-T depth recorder[1] driving a hull-mounted UQN-1 transducer at 12 kHz. Shortly after cresting the Coronado Escarpment, where the bottom dropped off to the deeper water of the San Diego Trough, hyperbolic targets appeared in the 160 to 270 m region of the recording. Underway at 12 knots, the largest of these had dimensions of 600 m horizontally, and 70 m vertically. As *Searchtide* hove-to at the dive site, these targets appeared as in Figure 1. Interspersed with the large targets were several discrete targets which appear on the record as lines, rather than large masses. The bottom depth at the site was approximately 1,200 m and its trace was programmed out of the recording.

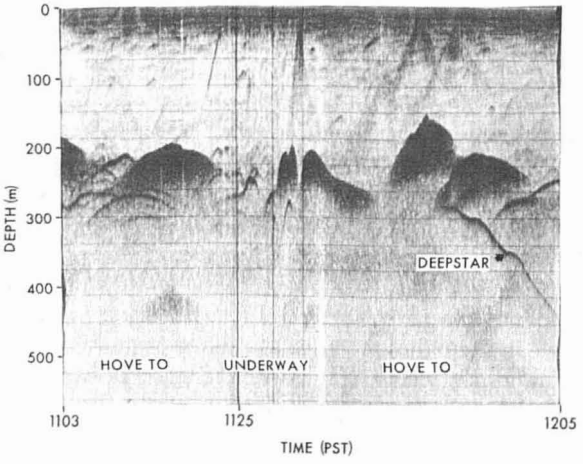

FIGURE 1.—Echogram recorded during *Deepstar* dive 502. The large targets between 150 and 250 m were observed to be schools of anchovy. The discrete traces may have been blue sharks. During the underway portion, the ship was repositioning over the submersible for tracking purposes. The acoustic return from *Deepstar*, a 2-m-diameter sphere, is labeled to provide a qualitative comparison of acoustic reflection strength.

The dive began at 1103 (PST), and a slow descent (13 m/min) was made to 100 m where two blue sharks were observed. This shark is a common species which is easily identified vis-

[1] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

ually. They swam actively out of the gloom, then veered away and circled for a short time before disappearing.

Continuing the descent, at approximately 180 m we became aware of the presence of a large concentration of fish at the periphery of the light field. The descent was stopped and we maneuvered in an attempt to obtain visual and photographic data. Each time the propulsion motors were activated, the fish would hurriedly retreat from view. Their movements were as a disciplined school. Several times we approached the school with the lights out, a technique which enabled the submersible *Alvin* to penetrate schools of myctophids in the Atlantic (Backus et al., 1968). Although we were never able to penetrate the school, the darkened submersible apparently attracted a few individuals who remained near the windows when the lights were switched on. Stunned by the sudden illumination, they remained transfixed long enough for good visual identification. The northern anchovy, with its projecting snout and thin body, is sufficiently distinct from other local clupeoids to give us confidence in our identification. Unfortunately, the photographs taken were blurred.

Three more blue sharks were observed at the same depth as the anchovy school. The deepest sighting was at 275 m. Because these were observed individually, the sightings could all have been of the same individual. Possibly, one of the same sharks sighted at 100 m may have followed *Deepstar* during the descent. We also observed a few squid, presumed to be *Loligo opalescens*, at the depth of the school. The spatial proximity of the sharks, squid, and anchovy suggests a predator-prey relationship, although no predation was observed.

The lower limit of the anchovy school was at 310 m and after dropping below it we descended to 590 m. There we released the descent weight and rose rapidly to the surface. The school was observed between 300 and 200 m during the ascent. The dive ended at 1407.

There is little doubt of the relationship between the anchovies and the large targets on the recording. It is difficult, however, to be sure that there is a correlation between the sharks and the discrete targets. Whatever is responsible for these traces has a high acoustic target strength at 12 kHz. This can be seen by comparison on the figure with the trace made by *Deepstar*, a 2-m-diameter air-filled sphere.

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THE USE OF CONCENTRATION INDICES IN FISHERIES [1, 2]

The temporal-spatial distribution of organisms has generated considerable interest among biologists. This interest has generated many studies which deal primarily with the distribution of a single organism in space. In this note we consider the relationship between two organisms in space or time. We are interested, in particular, in an index of the relation between a predator (a fishing fleet) and a prey (the population to be harvested). We begin by writing

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[2] Portions of this study were undertaken while B. J. Rothschild was affiliated with the Center for Quantitative Science in Forestry, Fisheries, and Wildlife, University of Washington, Seattle.