Acoustic Measurement of Micronekton Distribution over Southeast Hancock Seamount, Central Pacific Ocean

Christopher D. Wilson and George W. Boehlert
Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service,
NOAA; and Department of Oceanography, Joint Institute of Marine and Atmospheric
Research, University of Hawaii, Honolulu, Hawaii 96822-2396, U.S.A.

ABSTRACT

Acoustic detection of scattering layers over certain seamounts demonstrates significant diel variations that suggest changes in biological activity. We describe the behavior of these acoustic scattering layers over the Southeast Hancock Seamount in the central Pacific Ocean in 1985-88. Ground truth provided by sampling with midwater trawls provides a description of the organisms responsible for this scattering, but avoidance of the trawls by larger organisms may bias these results in certain circumstances. The spatial distribution of micronekton, as revealed by analysis of acoustic data, may differ from night to night; preliminary acoustic Doppler current profiler data indicate that ocean currents affect these distributions. The high density of the scattering layers may also bias acoustic measurements of ocean currents.

INTRODUCTION

Current-topography interactions result in complexities in physical oceanography [1] that can have important biological implications [2]. Increased biological abundance in regions near seamounts and islands is evident as increased acoustic scattering intensity as compared with open ocean waters [3]. Analysis of the temporal and spatial distributions of these scattering layers may depend upon geographic region, depth of seamount, and ocean current conditions. Acoustic scattering over certain seamounts may be characterized by diel variations of immense magnitude; many of these organisms are specific to these seamounts [4, 5, 6]. On shallower banks, however, the main acoustic scattering layers may be derived from oceanic regions and can be depleted by predators on the banks [7, 8]. Because seamounts represent a major geological feature of most ocean basins [9], these acoustic signatures may be widespread. Further, the variation in ocean currents and local oceanography induced by current-topography interactions [1] may result in corresponding variations in the characteristics of acoustic scattering at a particular seamount. In this paper, we describe diel variation in acoustic scattering over the Southeast Hancock Seamount, the abundance of micronekton organisms as determined by net sampling and acoustic signals, and briefly examine the relationship between the acoustic signature and the ocean currents.

EXPERIMENTAL DESIGN

The study was conducted aboard the NOAA ship Townsend Cromwell, July 1985 to January 1988, at the Southeast Hancock Seamount (lat. 29°48'N, long. 179°04'E), an open ocean seamount in the central North Pacific. Its summit depth is about 265 m; the bottom depth of the surrounding ocean is nearly 5 km. All times are reported as local standard time.

Observations of acoustic scattering were made with a 38 kHz Simrad[1] echo sounder (model EQ-38) operating with a pulse length of 0.3 ms and a time varied gain (TVG) of about 40 log(R) + 2αR [10]. A Raytheon-JRC chromoscope was configured to display the signal of the Simrad by assigning the echo voltage to one of several bins (1985, N = 12; 1988, N = 8) on the basis of signal strength. Each bin was represented by a unique color, which was displayed on a monitor as a function of depth and ship position. The composite chromoscope screen images were photographed with color slide film (35 mm) for later data analysis. Diel behavior of seamount-associated scattering layers was observed in 1985 by periodically running transects along an east to west line intersecting the center of the summit along lat. 29°48.0'N.

Relative biomass of the sonic scattering layer (SSL) at the Southeast Hancock Seamount was estimated from acoustic data collected in 1988 while the vessel ran at a nominal speed of 2.5 m/s along 6 km long transects over the summit and flanks and oriented at 45 degrees to one another. Transects began and ended about 1.9 km beyond the summit edge (transect end depths, ca. 700-1000 m). Identical instrument and camera settings were used during relative biomass assessment transects. The instrument settings on the chromoscope-echo sounder system were quantified by a Simrad echo probe, which provided a constant, continuous wave test signal to the input of the echo sounder receiver to determine the specific echo voltage level represented by each "color bin" for calibration purposes.

To determine relative estimates of biomass of sonic scatterers (which are proportional to the echo voltage squared) [11], the echo voltage level for each data cell was first calculated by visual "echo integration" of all colors comprising each chromoscope image. Data cells were constructed by dividing the transect into eight contiguous regions (each about 0.75 km long), which were subdivided into either five or seven depth strata of 50 m, each between depths of 10-260 m or 10-360 m over the summit and flanks, respectively. The relative cell area covered by each color was determined visually by projecting the 35 mm color slide image on a projector display screen overlaid with a grid of 2 mm squares. Heavy lines were drawn over the plastic grid to delineate each depth cell. About 60 grid squares were included in a cell; the reader made an assessment of the relative area that each of the eight colors occupied within a cell by determining the number of grid squares for each color. Each cell area was thus characterized by eight values corresponding to percentages of each color. The total echo voltage for each cell was calculated as the sum of each specific color voltage, after weighting each value by the relative cell area covered for each respective color. Before the total echo voltage for each cell was calculated, however, color-specific voltages were adjusted to represent voltage levels equivalent to those that would have resulted under a 20 log(R) + 2αR TVG function. This correction was necessary because, under a 20 log(R) + 2αR TVG function, the sum of the squared echo voltage over the depth of interest is

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

proportional to the relative biomass of the SSL over the same depth range [10]. The 40 log(R) + 2αR TVG function used in the Simrad (model EQ-38) echo sounder reaches a maximum at about the 150 m depth (R. Brede, Simrad Corp., pers. commun.); thus, raw echo voltage values beyond this depth needed to be adjusted to values that would have resulted if taken under a 20 log(R) + 2αR TVG function over the full depth range.

To adjust the echo voltages, first the TVG function of the instrument was quantified by recording voltage levels as a function of time (depth) for a given input test voltage level from the echo probe. From these values, the instrument TVG curve was constructed. For depths at which the TVG function of the instrument operated ($\leq$150 m), the differences between the observed voltage levels and the voltage levels subjected to a 20 log(R) + 2αR function were used to calculate correction factors to correct observed voltages to values appropriate for relative biomass estimation (20 log(R) + 2αR). These corrections were then used to correct observed voltages from the SSL to values that would have been derived with a 20 log(R) + 2αR TVG function. For depths beyond the operating range of the TVG function of the instrument, the observed voltage for each color was amplified with a 20 log(R) + 2αR function.

Biological sampling to confirm acoustic targets used midwater trawls. A 1.8 m Isaacs-Kidd midwater trawl (IKMT) sampled the micronekton, a calibrated flowmeter estimated the volume of seawater filtered, and time-depth recorders registered the depth profile of each tow. Two larger midwater trawls were also used: The first was a Marinovich herring trawl with a mouth opening of 60 m^2 and body mesh of 19 mm; the second was a 264 rope wing trawl with a mouth opening of 400 m^2 and graduated mesh to as small as 100 mm. A Furuno net sonde system targeted specific components of the scattering layer to capture larger organisms not sampled by the IKMT.

Mean current velocity was estimated over the seamount summit using data collected from a vessel-mounted 150 kHz acoustic Doppler current profiler (ADCP) manufactured by RD Instruments. The ADCP data were collected with an 8 m pulse length and bin width and were initially averaged over 45 s intervals. Water velocity estimates relative to the vessel were referenced to absolute ship velocity estimates based on ADCP bottom tracking [12]. Usable data were collected and averaged between 40 and 210 m depths. The ADCP calibration runs similar to those conducted with other vessels [13] were conducted in 1988 to determine the transducer misalignment angle and amplitude bias [14]. Absolute ship velocities were determined with a NAVSTAR Global Positioning System (GPS) and by ADCP bottom tracking. The calibration coefficients were applied to ADCP velocity estimates.

The ADCP data from the summit center were collected while the vessel ran transects (described earlier) to estimate relative SSL abundance. Because all transects intersected at the center of the summit, we assumed velocity estimates averaged over 15- to 20-min intervals from the central portion of any transect profiled the same area. Velocity profiles from the central portions of the two transects immediately preceding the one presented in Figure 2 were averaged together with the latter transect to generate the estimate of mean current velocity.

RESULTS AND DISCUSSION

Acoustic observations on 12-13 July 1985 on the behavior of seamount-associated scattering layers showed a characteristic diel behavior (Fig. 1). The scatterers could often be distinguished acoustically during the day on the flanks of the seamount at about the 400 m depth. As dusk approached, the scatterers began moving upward, but the distribution of this movement was not uniform across the seamount summit (Fig. 1A). Just after sunset, the acoustic targets intensified and moved to shallower (ca. 50 m) water (Fig. 1B); the scattering layer later moved to deeper water and dispersed over a broader area around the seamount (Fig. 1C). The layer remained relatively stationary and uniform throughout the night but began dispersing in the early morning (Fig. 1D). In association with the increase in light intensity about 50 min before sunrise, some scatterers dispersed upwards, reaching shallower water (Fig. 1E). This was followed by consolidation of the layer, which moved rapidly downward as the sun rose above the horizon. Some scatterers remained in the water column above the seamount flanks later in the morning (Fig. 1F). No deep scattering layers in surrounding oceanic waters displayed this type of behavior.

Midwater trawl samples from the scattering layers in 1985-88 showed the sternoptychid fish Maurolicus muelleri and the mysid Gnathophausia longispina to be dominant components of the micronekton, with the sepiolid squid Iridoteuthis iris relatively common in the deeper portions of the scattering layer [5]. Oceanic micronekton, such as euphausiids and midwater fishes, were also present. Comparison tows taken in waters distant from the seamount lacked the three seamount-associated species but were characterized by greater abundance of certain open ocean taxa, such as the photichthyid fish Vinciguerria attenuata and V. nimbaria, and crustacean groups, such as euphausiids and caridean and penaeid shrimps [5].

Samples from large midwater trawls demonstrate the potentially high density of selected taxa and also the presence of larger fishes not sampled by the IKMT. In 1985, for example, a deployment of the Marinovich trawl in the scattering layer corresponding to Figure 1B took approximately 4400 M. muelleri in a short tow. This same species has been seen at densities as high as 147 metric tons/km^2 over seamounts in the South Atlantic [15]. One haul from the larger mesh rope trawl sampling a scattering layer in September 1986 produced 563 specimens of the gempylid fish Promethichthys prometheus (34.2-54.2 cm fork length). Based on these samples, the scattering layer may be much more dense locally than indicated by the smaller IKMT samples and may also be composed of organisms larger than micronekton.

Based on the acoustic data, relatively greater densities of scatterers were located on the southern side of the seamount at or slightly below summit depth when compared with the north summit region (Fig. 2). In addition, scatterers were relatively rare in water shallower than 50 m or in deep water to the north of the seamount. The mean current estimate during this period (2330-0150 h) demonstrates that the high relative biomass was on the downstream side of the seamount during this transect, suggesting the general morphology and location of the scattering layer over the seamount were probably functions of the current pattern at that time. However, the vertical component of the scattering distribution may be more a function of the swimming behavior of the organisms. These

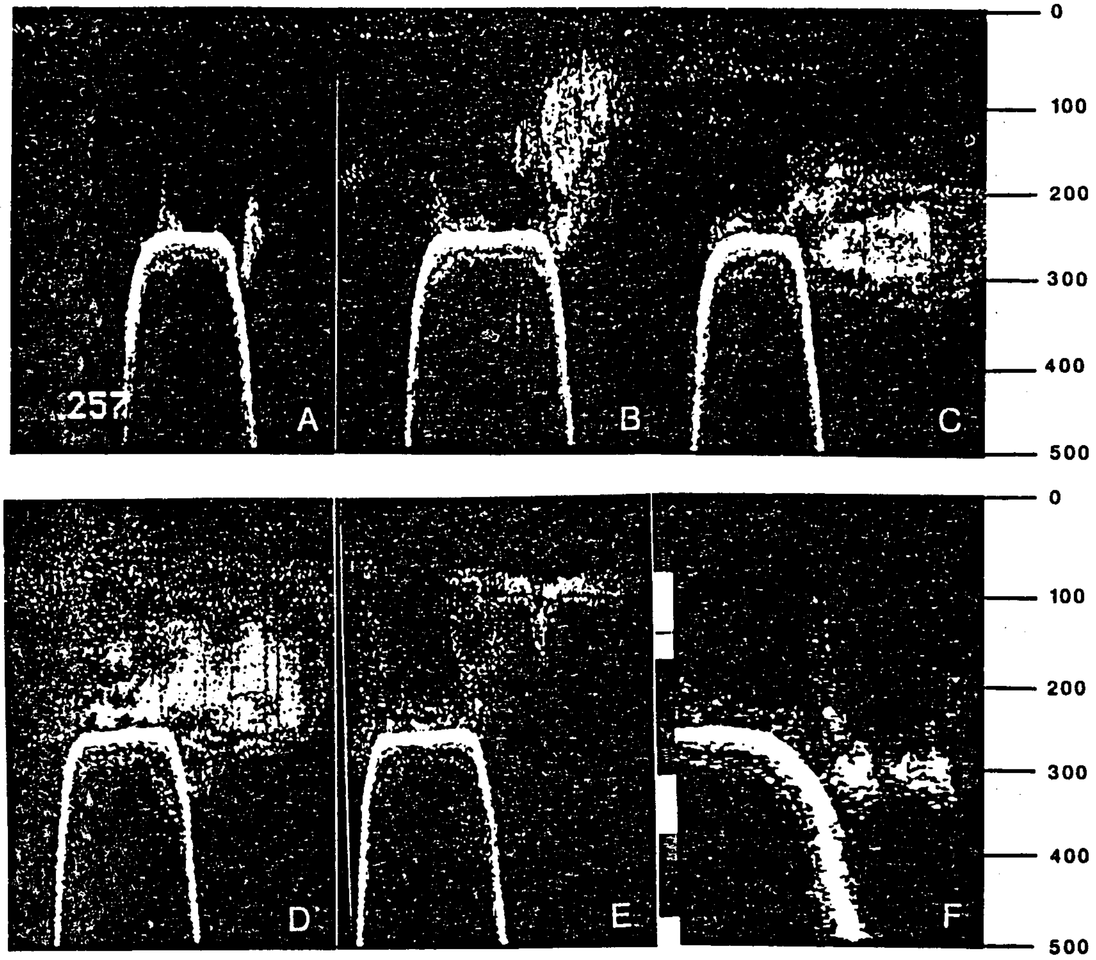

FIGURE 1. Acoustic transects over the Southeast Hancock Seamount on 12-13 July 1985 showing distribution of the scattering organisms over time. Depths are in meters. Each transect, from east to west (left to right), took approximately 25 min. The distance across the flat portion of the seamount is approximately 2.6 km. A. 1824 local standard time. The scattering organisms begin the initial ascent from the summit and western flank. Sunset was at 2003. B. 2015. The targets have moved to shallower water, and the scattering signal has intensified. C. 0027. The layer has dispersed slightly but at depths below 200 m (change near right side is due to inadvertent change in gain setting). D. 0355. Dispersion and some ascent is noted. E. 0514. The scattering layer consolidates in shallower water near sunrise at 0608. F. 0654. Large, discrete scattering targets remain below summit depth (horizontal scale differs on this figure).

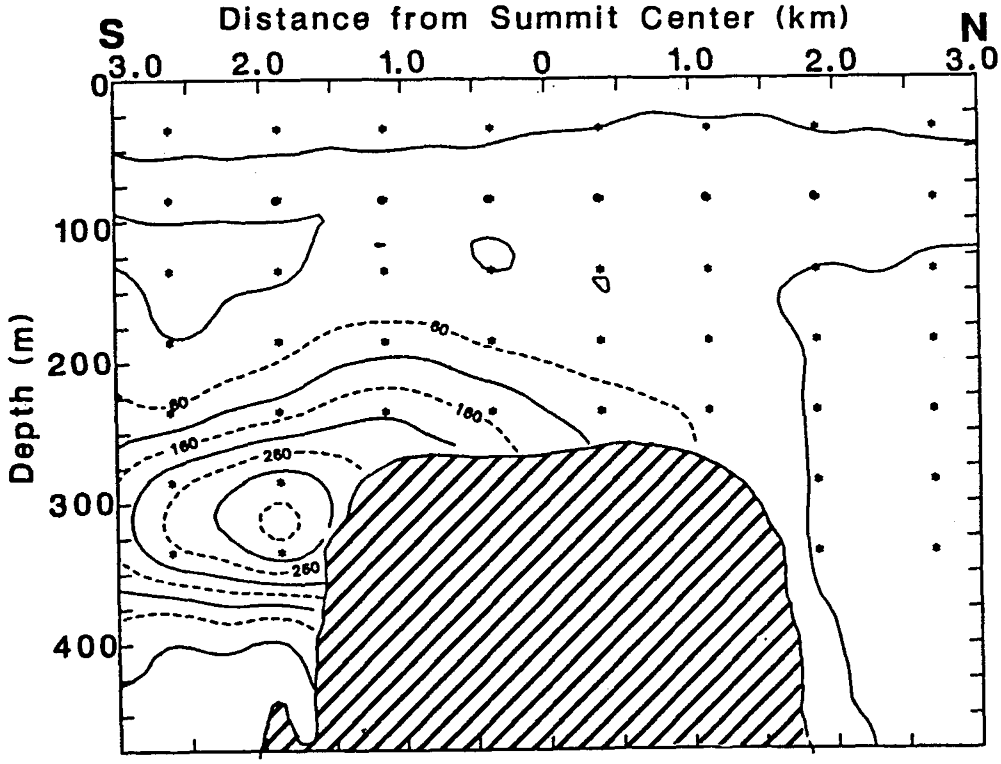

FIGURE 2. Acoustic section run from south to north (left to right) showing the contours of relative biomass of acoustic scatterers; the profile of the seamount is indicated by cross-hatching. This transect was made on 16 January 1988 at 0120 local standard time. Asterisks indicate the center of the 750 by 50 m bins where relative biomass was estimated and used as data points for contouring. Contour values represent an arbitrary scale of relative density units (see text for explanation). Estimated current velocity during this period was to the south (185°) at a speed of 17 cm/s.

results suggest that current speed during the transects in 1985 (when current was not measured) was probably from east to west (Fig. 1 B, C, D). Further research is needed to discern the relationship between the form of the acoustic scattering layer and the current speed and direction.

Variability of acoustic scattering due to biological activity around topography may interfere with ADCP-derived current estimates. For example, the high relative densities of organisms comprising the SSL associated with the seamount summit (Figs. 1, 2) may potentially bias estimates of velocity based on ADCP data. When ship velocity estimates are derived from ADCP instrument acoustic returns from the summit itself (i.e. bottom tracking [12]), it is critical that the instrument can distinguish between echoes reflected from the substrate versus those from the SSL. If the instrument is unable to resolve bottom and SSL echo signals, absolute velocity estimates will be in error. Although RDI instrument settings may be adjusted to optimize criteria used in identifying signals reflected from the substrate, we have found that variable, but high, densities of SSL at the Southeast Hancock Seamount have required careful post-cruise editing of the data to remove SSL echo signals that had been incorrectly labeled as valid bottom signals. Using factory default settings during the transect presented in Figure 2, for example, the instrument identified a false bottom at 275-350 m depths while approaching the south side of the summit (bottom depth, >500 m) over a dense SSL, whereas no false bottom was detected north of the summit, an area characterized by relatively few scatterers. Additional work is being conducted to determine suitable settings to optimize performance of the instrument when bottom tracking under conditions when dense SSLs occur. In the presence of such scattering layers, however, caution must be exercised in the interpretation of ADCP measurements. Vertical velocities (Fig. 1 A, B) on the order of 16 cm/s can be expected for vertically migrating micronekton [16]. The extent of directed horizontal movements within the seamount scattering layers is unknown, but similar swimming speeds could bias acoustically measured currents since the ADCP measures the speed of the scatterers, not the water.

CONCLUSIONS

The behavior of micronekton and nekton near the Southeast Hancock Seamount has a characteristic diel pattern that differs from scattering layers in surrounding oceanic waters. From night to night, the horizontal distribution of scatterers appears to be modified by the direction and magnitude of impinging currents. More detailed study with multibeam acoustic technology, net sampling, and time series of current measurements will be necessary to identify the behavior of individual species comprising these SSL.

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