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Acoustical Detection of High-Density Demersal Krill Layers in the Submarine Canyons off Georges Bank

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High-density demersal layers of krill have been detected in the submarine canyons off Georges Bank by means of a high-frequency, dual-beam bioacoustical technique. Krill densities in these demersal layers were observed to be two to three orders of magnitude greater than the highest densities observed in water-column scattering layers. Such abundances may help explain the unusually high squid and demersal fish production estimates attributed to the Georges Bank ecosystem.

EUPHAUSIIDS TYPICALLY PLAY A MAJOR role in the economy of pelagic marine ecosystems. In the productive waters of the North Atlantic, the species *Meganyctiphanes norvegica* provides an important link in the food chain between lower trophic level plankton and higher trophic level consumers, including decapod crustaceans, squids, fishes, marine mammals, and birds (*1, 2*). Early Norwegian whalers referred to *M. norvegica* as krill, a term that has now been expanded to encompass all species of euphausiids (*3*). A feature of krill ecology that makes them particularly vulnerable to successful exploitation by higher trophic level consumers is their tendency to form highly aggregated distributions (*1, 2, 4*). Krill aggregations have been categorized into four basic types: patches, shoals, swarms, and schools, with the last two types corresponding to high-density aggregations of more than 1000 animals per cubic meter (*2*). Such high-density aggregations of *M. norvegica* have been reported, but those reports have been of surface swarms often associated

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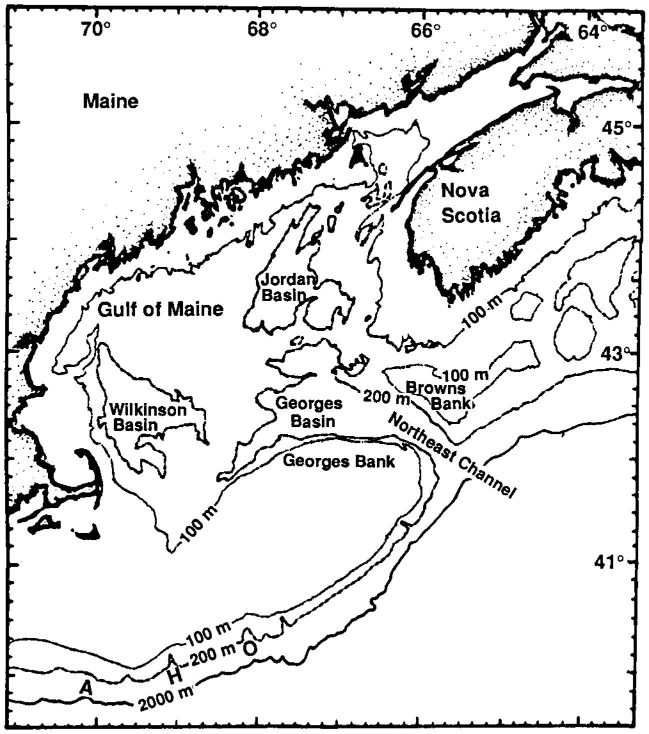
Fig. 1. Locations of submarine canyons south of Georges Bank where submersible dives were conducted: Atlantis Canyon, A; Hydrographer Canyon, H; and Oceanographer Canyon, O.



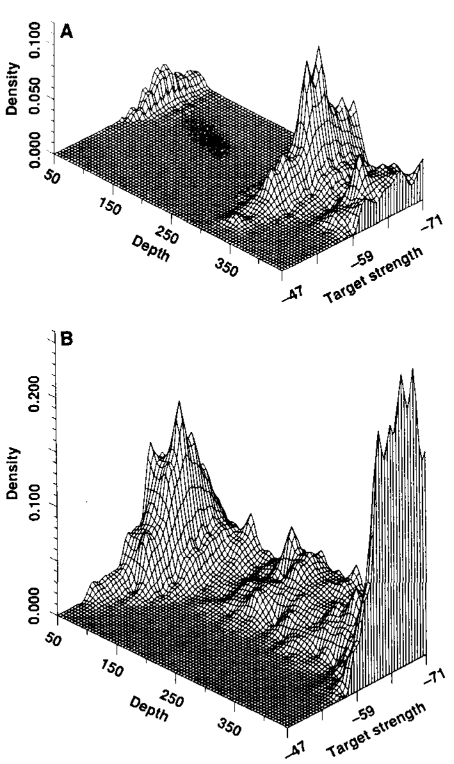


Fig. 2. (**A**) Daytime vertical profile of animal densities from the water column above Hydrographer Canyon. Densities (in animals per cubic meter) for each depth interval (in meters) were apportioned to different target strength classes (in decibels) (*6*). (**B**) Nighttime vertical profile from water column above Hydrographer Canyon.

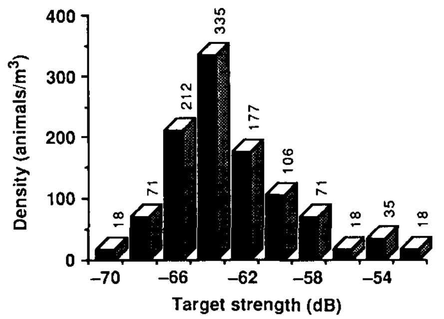


Fig. 3. Density estimates of different acoustical size classes of animals in the 50-m-thick demersal layer near the bottom of Oceanographer Canyon. Krill size range corresponds to target strength classes between −70 and −62 dB. Functional regressions for converting target strengths to lengths and wet weights are in (*6*).

with breeding behavior (*1, 2, 5*). Subsurface swarms and schools of krill are much more difficult to detect and survey with conventional sampling gear. In this report, we present acoustical evidence for the occurrence of high-density demersal layers of *M. norvegica* in the submarine canyons off Georges Bank.

The high-density layers of krill were detected during our September 1987 cruise to field test a high-frequency, dual-beam bioacoustical technique for studying zooplankton and micronekton distributions. This technique differs from previous acoustical techniques in that it enables investigators to analyze the echoes returning from individual animals, thereby providing direct estimates of the size distribution of the animal assemblage (*6*). We conducted acoustical profiling surveys of the water column from approximately 30 m off the bottom to the sea surface in three of the submarine canyons east of southern New England and south of Georges Bank (Fig. 1). All surveys were conducted on dives aboard the Johnson Sea Link submersible (*7*).

Typical profiles of the daytime and nighttime water-column distributions of acoustical targets in these canyons are presented in Fig. 2. The most abundant acoustical size classes, between approximately −62 and −71 dB, correspond to animals the size of mature krill. *M. norvegica* dominated the krill biomass at all dive sites, although several species of *Thysanoessa* were also common. During the day, krill densities were low in the upper 300 to 350 m of the water column and higher at greater depths. In contrast, during the night, krill were more uniformly distributed throughout the water column but often formed a strong near-surface scattering layer. A simple day-night comparison of the distributional patterns reveals two important features of krill ecology. First, changes in animal density in the upper 300 m of the water column suggest that krill exhibit vertical migrations of at least 300 to 400 m each way per day; second, an apparent increase in animals integrated over the water column during the night relative to the day suggests that more krill reside by day in high-density layers on or near the bottom (*8*).

Previous studies of *M. norvegica* with conventional sampling gear have yielded qualitative results consistent with our findings of extensive vertical migrations and high-density demersal layers (*1, 2, 9*). An unexpected finding was the magnitude of the densities observed in these demersal layers. During one dive in Oceanographer Canyon (Fig. 1), we conducted an acoustical survey of the demersal layer from 50 m above the sea floor to the bottom. Krill densities in this layer exceeded 1000 animals per cubic meter in many places and averaged 813 animals per cubic meter over the full 50-m layer (Fig. 3). These densities are two to three orders of magnitude greater than the highest densities that we estimated in the upper part of the water column. Such densities are unusually high for *M. norvegica* and other North Atlantic krill (*1, 2*), corresponding to an average biomass concentration of 614 g wet weight per cubic meter and a layer-integrated biomass of 30.7 kg wet weight per square meter.

We hypothesize that these high-density demersal layers are formed as the result of the interaction of depth and topography with the behavioral ecology of krill. Earlier studies have shown that underwater light levels regulate the diel vertical migrations of krill, which remain in coherent scattering layers as they migrate (*10*). In shallow oceanic regions, these scattering layers may coalesce in a high-density layer at the bottom when the krill migrate downward in the morning, thereby greatly concentrating the animals present (*11*). In addition, the topography of the submarine canyons may cause a funneling effect that would further concentrate the animals at the canyon bottom (*12*).

Better documentation of the spatial extent and temporal persistence of high-density demersal layers of krill will be essential for assessing the importance of these layers in high-latitude marine ecosystems (*13*). The Georges Bank ecosystem provides a good example. Georges Bank is one of the world's most productive fishing grounds (*14–17*), and krill are an important but variable dietary component of the Bank's commercially important squid and demersal fish stocks, including long- and short-finned squid, cod, flounder, haddock, hake, pollock, and redfish (*1, 18–20*). Recent analyses of secondary production on Georges Bank indicate that the levels of zooplankton and benthic production there are insufficient to support the high levels of squid and demersal fish production (*16, 21*). Hypotheses suggesting that there are high trophic efficiencies within the ecosystem do not seem to explain this discrepancy (*16*). A more plausible hypothesis is that squid and demersal fish stocks on Georges Bank are subsidized by exploiting krill production in the canyons and deep waters surrounding the Bank (*22*). Although krill rarely intrude on the shallower parts of Georges Bank, many squid and demersal fishes seasonally inhabit the deep, surrounding waters (*23*). Closer examination of the spatial and temporal coupling between predator and prey populations will determine the viability of this hypothesis. If it proves correct, then the excess squid and demersal fish production associated with Georges Bank may be attributed to the existence of high-density demersal layers of krill in the deep, surrounding waters.

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