Diel migration dynamics of an island-associated sound-scattering layer

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Abstract

The Hawaiian mesopelagic boundary community, consisting of island-associated, midwater sound-scattering layers, undergoes diel migrations with both vertical and horizontal components. To understand the dynamics of the community's migration at fine temporal scales, we utilized a bottom-mounted, 200-kHz active-acoustic mooring that transmitted 10 signals every 15 min, from dusk until dawn for 5 days. Five moorings were deployed 1.0–3.0 km from the leeward coast of Oahu in 0.5 km intervals. Two layers within the boundary community were observed to undergo simultaneous diel vertical and horizontal migration. The shallow layer came within 10 m of the surface and 1 km of the shoreline. The deeper layer remained 90 m from the surface and 2.5 km of the shoreline. Vertical migration rates were measured at 0–1.7 m min\textsuperscript{–1} while the horizontal rate averaged 1.7 km h\textsuperscript{–1}, swamping the vertical movement. The turning point of the migration pattern was observed 45 min before the midpoint between sunset and sunrise. Until the migration's turning point, scattering strength increased relatively constantly as the animals migrated towards shore, with the highest scattering densities found in the shallowest areas at midnight. Total scattering strength measured at the leading and trailing edge of the layer support the hypothesis that increased animal densities nearshore are related to packing as mesopelagic animals avoid the surface and the bottom. We observed high levels of biomass moving rapidly, over a great distance, into shallow waters very close to shore providing insight into the significant link the mesopelagic boundary community provides between nearshore and oceanic systems.

Keywords: Vertical migration; Horizontal migration; Temporal dynamics; Mesopelagic boundary; Scattering layers; Acoustics USA; Hawaiian Islands

1. Introduction

Sound scattering layers are distributed worldwide and have been studied since World War II (Gjosaeter and Kawaguchi, 1980). Scattering layers of micronekton are important components of oceanic ecosystems; they consume a significant portion of the zooplankton produced (Clarke, 1973) and are an important link to higher trophic levels (Rasmussen and Giske, 1994). Many of the micronektonic animals making up these layers are found in different 'vertical life-zones' during the day and at night because of diel vertical migrations of tens to hundreds of meters (Longhurst, 1976).
Longhurst described vertical migration: “...as night approaches, very great quantities of animals migrate actively upwards from the deeper, dark waters towards the surface layers, where they spend the night until at dawn they descend again”. Descriptions of the movement of these animals and the timing of movement have not often been made at finer resolution because of sampling limitations. Most studies using nets have focused on comparing daytime and nighttime observations of micronekton presence at various, discrete depths (Badcock and Merrett, 1977; Longhurst, 1976; Pearcy et al., 1977; Williams and Koslow, 1997). Studies utilizing acoustic sampling often only compare the depth distributions of scattering layers between daytime and nighttime (for example Ebeling et al., 1970) or at 3-h intervals (see, for example Haigh, 1970). The best descriptions of the temporal dynamics of vertical migration of scattering layers have come from continuous recording of an echosounder at one location (Balino and Aksnes, 1993; Rasmussen and Giske, 1994). However, this technique does not allow observation of spatial effects.

Knowledge about the vertical distributions of mesopelagic animals and how they vary with time is necessary for a real understanding of the structure and function of pelagic ecosystems (Pearcy, 1971). This is particularly true in the highly dynamic scattering layers found where steep slope edges interact with deep waters (Isaacs and Schwartlose, 1965; Young et al., 1996). Slope-associated mesopelagic communities have unique and complex dynamics, sometimes exhibiting both diel horizontal and vertical migrations (Omori and Ohta, 1981; Sasaki, 1914). These migrations can provide a significant link between oceanic and neritic systems; however, the difficulties associated with sampling migrations occurring in three-dimensions have limited our understanding of this connection.

In the Hawaiian Islands, there is a distinct resident community of micronekton distributed along a narrow band where the upper slopes of the islands meet the oceanic mesopelagic environment (Reid et al., 1991). This nearshore, midwater sound-scattering layer migrates vertically, reaching depths as great as 700 m during the day, but coming within 10 m of the surface at night (Reid et al., 1991). The boundary layer also undergoes diel horizontal migrations, coming within 1 km of the shoreline at the midpoint of the night (Benoit-Bird et al., 2001). A high-resolution description of temporal patterns of the mesopelagic boundary community in Hawaii is an important step for understanding its importance to both neritic and oceanic ecosystems as well as the potential it has to link these two systems. However, ship-based surveys are not capable of the temporal resolution and spatial coverage necessary to assess changes in the distribution of the mesopelagic boundary community throughout its migration. The objective of this work was to detail the diel horizontal and vertical migrations of the boundary community with fine temporal resolution, over long periods of time, in multiple locations simultaneously to understand its potential linkage between nearshore and oceanic systems. Specifically, we wanted to: (1) observe the rates of horizontal and vertical migration (2) determine when the migrations occur within the night (3) characterize the vertical extent of the layer as a function of the diel migrations and (4) observe the movement of biomass and distribution of density throughout the diel migrations.

2. Methods

2.1. Moorings

To understand the spatial and temporal dynamics of the horizontal and vertical migrations of the mesopelagic boundary community at a smaller scale than is possible from shipboard surveys, we used active acoustic moorings. Each mooring consisted of an echosounder circuit board, a microcontroller with an analog-to-digital converter and memory, a clock, and batteries within a pressure housing and an upward looking transducer. The circuit board from a Computrol, Tournament Master Fishfinder NCC 5300 was modified to read the envelope of the echo directly into the microcontroller. The echosounder used a 200 kHz signal with a pulse length of 130 µs. A Persistor CF1 microcontroller was programmed to sample
10 echoes (over a total of 5 s) from the sounder every 15 min, from an initial ‘wake-up’ trigger at 1800 h until 0700 h. Digital alarm clocks, synchronized with each other, triggered the microcontroller within each mooring to begin the sampling regime. An Ocean Embedded Systems CF1 analog-to-digital converter was used to digitize the envelope of the echo at a sampling rate of 10 kHz. The data were collected in blocks of 2048, representing 156 m of vertical space and saved onto a compact flash memory card. The transducer was mounted on top of the pressure housing, looking upwards with a 10-degree conical beam.

Each echosounder was calibrated by an indirect procedure incorporating reference targets as in Benoit-Bird et al. (2001). The moorings were anchored to the bottom with a large, concrete block. The buoyant pressure housing was mounted with 4 lines to the anchor, keeping the transducer pointed towards the surface. A retrieval line was anchored along the bottom until it was outside the widest point of the transducer’s beam and was then pulled to the surface with a float.

2.2. Deployment

Five remote echosounder systems were deployed at 0.5 km intervals across the slope off the leeward coast of Oahu. The first mooring was located 1 km from the shoreline and the last 3 km from the shoreline at a depth of 40, 70, 105, 145, and 160 m, respectively. The depth of the moorings was limited by the 156 m range of the echosounder and the pressure rating of the housing. Within 1 km of the last mooring, the depth reaches 1500 m. The moorings were placed according to their distance from the shoreline rather than depth because distance from shore, rather than depth, has been shown to be correlated with the horizontal movements of the boundary community (Benoit-Bird et al., 2001). Echosounder surveys showed similar patterns in the layer at 1.5 km from the shores of the leeward coasts of Oahu where the depth averages 50 m and Hawaii where the depth averages 800 m. The moorings were deployed for 5 days, beginning 10 March 2002 between Makua and Yokohama Bays. The moon was new on the first night of the deployment. Tidal currents were never coherent with the observed migration.

2.3. Data analysis

To determine the rates of horizontal migration, the times of first arrival of the mesopelagic layer at each mooring were compared, as were the times of last sighting of the layer. This also permitted the determination of when within the night the migrations occurred. The top and bottom of the mesopelagic layer, and consequently its vertical extent, were also characterized at each interval at each mooring. The vertical movement of the layer was measured by looking at the distance travelled by the top of the layer in each 15-min interval at each mooring.

Acoustic data were directly interpreted as scattering intensity per unit volume. To relate these measures to biologically relevant measures, numerical density of mesopelagic animals was also estimated through echo energy integration (MacLennan and Simmonds, 1992) as in Benoit-Bird et al. (2001). Unfortunately, traditional methods of in situ sampling for these animals have proved quantitatively ineffective in these shallow waters so some assumptions need to be utilized to relate the scattering strength to numerical density. Density estimates are not intended to be absolute values, but conservatively low estimates, presenting a minimum value for the number of animals present. Utilizing the scattering strength for the strongest scatterers, myctophids, accomplishes this, giving an order of magnitude density value to the scattering strength values. Trawling studies in deeper water in the same area have also shown that myctophid fishes, primarily Benthosema fibulatum, account for more than 90% by number and biomass of the shallow component of the mesopelagic boundary community (Reid, 1994). To conservatively estimate density, a target strength of −37 dB, the target strength of an approximately 7 cm myctophid from the boundary community (the mean size, corrected for net avoidance, of the most abundant component of the boundary community (Reid, 1994)) with 5 dB added for the largest change due to changes in the fish’s angle (Benoit-Bird and Au, 2001), was used. This target
strength, –37 dB, is also the mode measured in the field for all returns attributed to the boundary community (Benoit-Bird et al., 2001). Target strengths of mesopelagic animals measured in Benoit-Bird and Au (2001) were also measured from the ventral surfaces of approximately half of the animals in each biological class. Within each animal group, paired t-tests showed no significant differences between the dorsal- and ventral-aspect target strengths (p > 0.05 for all comparisons). Consequently, the same target strength values could be used to estimate density, permitting densities obtained from surface measurements and the bottom-mounted moorings to be compared. It should be noted that myctophids from this area do not have functional, air-filled swimbladders, and swimbladders are not the dominant scattering mechanism in myctophid fishes of the boundary community in Hawaii (Benoit-Bird and Au, 2001).

Biomass was estimated by applying the relationships between acoustic scattering and calories of mesopelagic animals measured by Benoit-Bird and Au (2002), assuming the primary component of the nearshore community is myctophid fishes. Again, because myctophids have the highest scattering strength of any mesopelagic group, this assumption allows only conservative minimum estimates of the available biomass to be made.

The method described by Webster (1973) was used to determine edges of the boundary layer and density differences in the mesopelagic boundary community. A 2 m+2 m vertical window was employed to determine discontinuities in density. The mean density in one window covering 2 m of vertical space was subtracted from the mean density of the other 2 m window and divided by the standard deviation of the sample. Edges of the layer were defined as areas with density significantly greater, z = 0.05, than the background density as determined by a one-tailed t-statistic with a progressive Bonferroni correction comparing the 2 m windows (Legendre and Legendre, 1998). The same technique was used to define internal density difference boundaries. Because of the large differences in density between the layer and the background, this technique was robust in identifying boundary community edges regardless of window size (0.5–5 m), p-value selected (0.005–0.15), and whether it was applied directly to volume backscattering (σ) or density estimates.

To observe the movement of biomass and the distribution of density throughout the diel migrations, interpolations were utilized in a fashion similar to Greenlaw and Pearcy (1985). Simple linear interpolations for the top and bottom of a layer as well as density contouring allowed the estimation of the biomass in different depth strata. The overall structure of the sound-scattering patterns was obtained by determining contours of volume backscattering strength, biomass, and numerical density versus depth and horizontal location.

3. Results

3.1. Migration rates

The mean inshore horizontal migration rates were measured by looking at the time of the layer’s first appearance at each mooring. The mean rates of offshore horizontal migration were measured by observing the time of the layer’s last presence at each mooring. There were no differences in the time of arrival at each mooring between the nights measured (Fig. 1). For both the inshore and offshore migrations, the layer began moving slowly, taking 30 min to move between moorings before increasing its rate to pass the next moorings within 15 min. The overall horizontal rate of migration, both inshore and offshore, was 1.7 km h⁻¹.

Fig. 1. Time of arrival and departure of the mesopelagic boundary layer at each mooring. The mean horizontal migration rates in each direction were 1.7 km h⁻¹. No differences in layer arrival or departure times were observed between the four nights sampled.
The vertical migration rates of the primary layer were measured by looking at the differences between the depth shallowest point of the layer at each 15 min interval. The vertical migration rates varied from 0 to 1.7 m min\(^{-1}\) (Fig. 2). Variance between nights at each mooring was small, less than 10%. The vertical rates were most rapid near the beginning and end of the migration. Downward rates at each mooring were 15–25% more rapid than the upward rates. The small arrow on the \(x\)-axis indicates sunset (sunrise is off the graph) and the broken vertical line shows the midpoint between sunset and sunrise.

3.2. Migration patterns

The vertical migration rates of the primary layer were measured by looking at the differences between the depth shallowest point of the layer at each 15 min interval. The vertical migration rates varied from 0 to 1.7 m min\(^{-1}\) (Fig. 2). Variance between nights at each mooring was small, less than 10%. At each mooring, the rate was more rapid at the very beginning and end of the migration. The downward migration was also more rapid than the upward migration, between 15% and 25% faster depending on the distance from the shoreline.

The distribution patterns of the boundary layer indicated that the vertical migration of the boundary layer was continuous. The upper edge of the boundary layer reached a minimum depth near the midpoint of the migration at all five moorings (Fig. 3). The vertical migration was coupled with the horizontal migration.

The overall effect of the boundary community’s migration on its distribution is best observed by looking at the entire layer at all five moorings at once (Fig. 4). The distribution of the boundary layer was roughly symmetrical about the midpoint of the migration. Consequently, patterns during the second half of the night were the inverse to those shown in the figure. The primary boundary layer moved upwards and towards shore, for the first half of the night. At 2315 h, the primary layer was no longer observed over mooring 5, 3.0 km from the shoreline. It moved back over mooring 5 at 0130 h. A second, deeper layer appeared at 2230 h and migrated inshore over mooring 4,
2.5 km from the shoreline 15 min later. The second layer was no longer present over either mooring by 0145 h. The offshore edge of this second layer was never observed; its seaward extent is unknown.

Not only did the extent of the boundary layer move inshore during the horizontal migration, but the majority of its biomass did as well. The mean and maximum density of boundary community patterns changed similarly as a function of time at each mooring (Fig. 5). The highest animal and acoustic backscatter densities, both mean and maximum, were observed at the mooring closest to shore, at 0015 h, indicating that the horizontal migration was continuous. The mooring 1.5 km from shore also had a density peak at 0015 h. However, comparable densities were found between 2315 and 0045 h. Mooring 3, 2 km from the shore, had its highest densities near 2215 and 0130 h, with nearly equal densities between these times. However, the two moorings farthest from the shoreline had density peaks near 2100 and 0300 h as the primary boundary layer passed over these points and the lower density, trailing edge of the primary layer moved over these points.

### 3.3. Timing

The migration of the boundary layer was offset towards sunset rather than being centered between sunset and sunrise. This can be seen in the vertical
Fig. 5. The mean and maximum scattering density and estimated mesopelagic animal density as a function of time at each mooring. The entire range of the mean and maximum density values observed in the 4 nights were within 10% of those shown and standard error bars are within the points on the graph. The times of sunset and sunrise are shown on the x-axis and the midpoint of the night is indicated with a broken vertical line.
migration rates (Fig. 2). The upward peak in vertical migration rate occurred 4.2 h before the midpoint between sunset and sunrise, while the downward peak occurred 2.3 h after the midpoint. The offset can also be observed in Fig. 3, which shows the vertical distribution of the boundary layer at each mooring. For example, the primary layer passed mooring 5, 1.5 h before the midpoint of the night, while on the outward migration, it passed mooring 5, only 45 min after the midpoint of the night. The secondary layer appeared 2.2 h before the midpoint of the night and disappeared 1 h after the night’s midpoint. Peaks in the density of mesopelagic animals were also centered on 0015 h, rather than 0040 h, the real midpoint of the dark hours (Fig. 5).

### 3.4. Packing

The maximum densities of mesopelagic animals achieved at each mooring changed inversely with the depth of the mooring (Fig. 6). To investigate the effect of the decrease of potential habitat, the vertical extent of the layer and the mean acoustic backscattering and numerical density in the first and last appearances of the layer are shown in Fig. 7. The animals at the shoreward edge of the layer moving over each mooring were presumably the same, allowing investigation of the effects of decreased vertical habitat. The total scattering volume, corrected for beam area, was calculated for each night. The total backscatter from mesopelagic animals remained relatively constant throughout the migration, even while mean density changed.

### 3.5. Biomass

Assuming the nearshore boundary layer is primarily composed of myctophid fishes (which would bias the estimates towards lower values), the maximum energy density was estimated at 8847 kcal m⁻³. This maximum was observed at the mooring nearest to the shoreline, at 0015 h. The
The minimum energy density was 9 kcal m\(^{-3}\) and the mean was estimated to be 83 kcal m\(^{-3}\). The total biomass of the leading edge of the layer was 85 kcal (standard deviation 5.6). The total biomass of the trailing edge of the layer was 74 kcal (standard deviation 6.7). Because caloric estimates are based on total backscattering cross-section, as are density estimates, their temporal patterns are similar.

4. Discussion

This work provides a temporally detailed description of the dynamics of a micronekton sound-scattering layer's migration. The most rapid vertical movements were observed at the ends of the migration, similar to other sound-scattering layers (Balino and Aksnes, 1993). The downward migration was faster than the upward migration, with differences in rate similar to those observed by Gjosaeter (1984). The vertical migration rate reached a maximum of 1.7 m min\(^{-1}\) (0.1 km h\(^{-1}\)), was 1–3 orders of magnitude below the maximum rates measured in other areas (Balino and Aksnes, 1993; Pieper and Bargo, 1980; Tokarev and Sokolov, 1989). The measurement techniques used here, stationary systems looking at vertical movement in small intervals, could potentially measure short-term, rapid movements of the layer more effectively than the more integrative approaches used in other studies. Clearly, the vertical migration rate of this nearshore layer was low, perhaps because of the limited depth range created by the island's slopes.

Unlike most deep-scattering layers studied, the vertical migration of the Hawaiian mesopelagic boundary layer was overwhelmed by its accompanying horizontal movement. The horizontal migration of micronekton, reached rates of 1.7 km h\(^{-1}\), an order of magnitude or two greater than its vertical rate. The horizontal migration of mesopelagic micronekton is less commonly studied (Benoit-Bird et al., 2001; Omori and Ohta, 1981; Sasaki, 1914; Suh et al., 1995), and rates of migration have not been reported for these other layers. The maximum sustained swimming rate for a species of shrimp closely related to a member of the mesopelagic boundary in Hawaii is reported as 0.22 km h\(^{-1}\) (Cowles, 2001), well below the horizontal movement rates observed here. This suggests that shrimp may not be part of the shallow, rapidly moving primary boundary layer, or are at least not at its leading edge. Swimming rate estimates are not available for myctophid fish or mesopelagic squid. Myctophids, however, easily avoid trawls moving at rates well exceeding 2 km h\(^{-1}\) (Kenchington, 1989), and the measured rates of horizontal movement are well within the sustained swimming rates (1.1–11.3 km h\(^{-1}\)) attainable by fish in this size range (5–10 cm in length) (Sambilay, 1990). Squids of equivalent size to those found in the boundary community are estimated to achieve sustained swimming speeds of nearly 30 km h\(^{-1}\) (Yatsu et al., 1999).

The offset of the boundary community's migration towards sunset by between 20 min and 1 h (depending on the measure used), rather than the midpoint of the night, provides interesting clues about the migration. It is hypothesized that the upper-limit of the mesopelagic community is set by in situ light levels (Young, 1983). Mesopelagic vertical migrators elsewhere have been shown to utilize light as a cue, following levels of light during their vertical movements (Blaxter, 1974; Clarke, 1970; Ringelberg, 1995). The downward migration of the mesopelagic boundary occurs primarily before in situ light levels increase; the light hypothesis was not supported by the observations. Animals could not be following the same levels of light on their upward and downward migration. Many of the fish in the mesopelagic boundary have been shown to maintain daytime depths at light levels greater than the light levels that mesopelagic animals elsewhere will tolerate (Reid et al., 1991). Perhaps the clear water in the Hawaiian Islands, with its high light transmissivity, precludes the utilization of this mechanism of vertical orientation. The reasons why the layer might migrate into deeper water earlier than predicted may also be related to foraging factors. The animals may be satiated or their high densities may have depleted the available resources, secondarily causing vertical migration (Ringelberg, 1995).

Two distinct layers were evident within the mesopelagic boundary community. Multiple sound
scattering layers have been reported in many systems (Balino and Aksnes, 1993; Pearcy et al., 1977; Williams and Koslow, 1997). The shallow layer was observed to be less than 2 km in horizontal extent for some of the night, and its entire extent was covered by the distribution of sonar moorings for at least part of the night. The second, deeper layer also migrated both vertically and horizontally. Only half a kilometer of the layer’s landward most edge was observed during the turning point of the boundary community’s migration. The migration rates of this layer could not be measured because of the short time in which it was observed by the two moorings on which it was recorded. The compositional differences between the two layers are unknown, however significant layering in the backscattering cross-section within these solid micronekton layers suggest differences in size class or species composition both within and between the two layers. The differences in the behavior between these two layers suggest that they are distinct parts within the boundary community, really two different communities with two different strategies. One group of organisms was moving into the nearshore areas, while the other was remaining further out. Near midnight, these offshore sampling locations were catching the trailing edge of one part of the community and the leading edge of another, both migrating horizontally and vertically. There may also have been more layers further away from the shoreline within this island-associated community.

The daytime distribution of either boundary community layer, or other deeper layers, currently remains uninvestigated. If the primary, shallow boundary layer were to maintain the maximum rate of vertical migration observed, we can estimate the maximum depth it could achieve during the day. The vertical migration could potentially continue until about noon. Measuring from the last observed depth of the primary layer at 0500 h, the upper limit of the shallow boundary layer could reach 720 m by midday, the maximum depth of the upper mesopelagic boundary community described by Reid et al. (1991). If the boundary layer maintains its approximate vertical distance from the bottom, roughly 30 m, this would put the layer approximately 12 km off the leeward coast of Oahu. If instead, the layer maintains its horizontal rate of migration, the layer could be nearly 15 km from the shores of the island, well past the limit of the boundary community determined by Reid et al. (1991). The boundary layer clearly cannot maintain its rate of horizontal migration for extended periods or it would be forced outside of its slope-associated habitat.

The maximum depth of the boundary layer relative to the bottom remained nearly consistent, approximately 30 m except at the extreme ends of the migration. The layer came within 10 m of the bottom at the shallowest mooring, which was only just over 40 m deep. At all five moorings, the primary, shallow boundary layer came within 7–10 m of the surface at the migration’s midpoint, regardless of depth. The maximum vertical range of the boundary layer seems to be controlled by the bottom topography as the animals avoid the surface and maintain their distance from the bottom. The increase in acoustic and animal density as bottom depth decreased, even while estimates of total scattering strength at the layer’s edges remain constant support the packing hypothesis proposed by Benoit-Bird et al. (2001). Animal density was increased by their mesopelagic habits: remaining midwater by avoiding the surface and seafloor interfaces. This may account for differences in density observed between areas with shallow slopes, like Waianae, Oahu, and steep slopes, like Kona, Hawaii. The densities in shallow slope areas where the extent of the boundary layer was reduced are much higher than the densities in steep slope areas where the extent of the layer was not limited by bottom topography.

In all measures taken, vertical position of the layer, acoustic or numerical density, and migration rates, there was very little variance between the four nights measured. All nights were at the beginning of a new moon so little variance in in situ light levels, hypothesized to control vertical migration patterns (Blaxter, 1974), between nights is expected. However, the variance in all measures was lower than that observed in ship-based surveys under similar lunar conditions (Benoit-Bird et al., 2001). The fixed position of the moorings eliminates effects of location. The fixed position of the
moorings on the bottom rather than on the surface also removes movement caused by tides and waves. Between nights, the variance in the depth of the bottom edge of the layer was lower than the variance in the depth of the top edge. This suggests that the animals in the mesopelagic boundary community may be using bottom topography or a secondary cue associated with the bottom for orientation off the Waianae coast where the slope of the island is shallow. The consistency in results from bottom-mounted sonar moorings permits this technique to measure the potential impact on the boundary community of environmental factors with small effect sizes.

Previous work has shown that the mesopelagic boundary layer is extensive, covering kilometers, over the slopes of many of the Hawaiian Islands (Benoit-Bird et al., 2001). This work shows the high levels of biomass, up to 8800 kcal m\(^{-3}\), that are moving rapidly, over a great distance, into shallow waters very close to shore. This suggests that the boundary community provides a link between nearshore and oceanic ecosystems by moving energy and nutrients between them. Significant impacts of the migration on Hawaii’s coastal ecosystem have been observed. The movement of the mesopelagic boundary community draws typically pelagic predators inshore at night (Benoit-Bird and Au, 2003). The boundary community’s migration patterns affect the many predators that utilize it (Haigh et al., 1993; He et al., 1997; Norris et al., 1994), as the costs and benefits of foraging upon the layer for each predator are altered over the migration. The large changes in the boundary community’s depth even eliminate the opportunity for certain predators to forage on it at some times (Norris and Dohl, 1980). The high density of micronektonic animals must also cause a large input of nutrients from animal waste into nearshore, nutrient-poor waters. The downward, offshore migration of the boundary community moves energy derived from nearshore waters into energy-poor, deep waters.

The impacts of the boundary community’s migration, particularly the link that it provides between nearshore and pelagic systems in the Hawaiian Islands, suggest that it may play a critical role in these waters. Its importance to the pelagic system’s predators, including tunas, billfish, and spinner dolphins (He et al., 1997; Norris et al., 1994), and even those in deep-water benthic systems (Haigh et al., 1993), has been established. However, the extent of the boundary community into nearshore, shallow waters, the amount of time it spends each night in these waters, and the high densities it obtains in these shallow areas indicate that it serves an important role in nearshore systems as well, even potentially impacting reef systems. Few studies have concentrated on this important, potentially crucial component of the ecosystems surrounding the Hawaiian Islands (Benoit-Bird et al., 2001; Reid et al., 1991). Our increasing understanding of the mesopelagic boundary community’s dynamics augments our appreciation for the importance of this community and its potential impacts on the systems that it moves between.

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