

The Effect of a Deep Seamount on Zooplankton Abundance and Diversity

Ryan Schwartz

09 June 2005

SEA cruise S199

ABSTRACT

Seamounts are common throughout the Pacific Ocean and may be a source of biological patchiness that is now being exploited by fisheries which trawl for the benthic nekton that live over them. Despite their abundance, their effects on marine ecosystems remain under-researched and poorly understood. This study attempts to characterize the impact one seamount has on the zooplankton communities that surround it. An unnamed seamount in the Eastern Central Pacific was identified with a peak height of 824 m below sea level. 3 sampling sites were chosen: one upstream of the summit, one near the summit, and one downstream of it. At each location, a neuston net was towed on the surface and a meter net was towed through the deep scattering layer. The collected sample was measured for density by calculating its biovolume and 100-counts were done to approximate the composition of the zooplankton community. The density of zooplankton was 3 times higher downstream of the seamount than upstream and over it. The downstream sampling site also had more trophic diversity with higher trophic level organisms present. In conjunction with two other studies, this data indicates that this seamount can be characterized by upwelling that is swept downstream to create subsequent phytoplankton and zooplankton blooms.

INTRODUCTION

Seamounts are large submarine topographic features that significantly alter the environment around them. Seamounts harbor abundant populations of nekton and are usually associated with increased fish biomass when compared to the surrounding open ocean (Genin 2004). In fact, they have recently become the target of commercial fishing boats, which use deep-water trawls to catch the large benthic fish that inhabit them (Koslow 1997). While their importance is widely recognized, the mechanisms by which seamounts impact local communities have been understudied and remain relatively unknown (Genin 2004). Subject to the physical processes that surround them, and as cornerstones for complex food webs, zooplankton offer an excellent marker for marine life. Yet, few studies examining zooplankton communities over seamounts exist. Identifying the physical and biological processes associated with seamounts will be insightful for understanding oceanographic phenomenon and will offer data necessary to realize the long-term ecological effects of current fishing practices over seamounts.

Many studies have found increased zooplankton abundance over seamounts (Rogers 1994). Recently translated Russian research has documented zooplankton abundance eight times greater over seamounts than in the surrounding open ocean (Rogers 1994). Two major explanations have been given for the observed phenomenon. The first, known as the 'classic hypothesis,' is considered to be a 'bottom-up' explanation, in which productivity increases are first seen in phytoplankton and cascade up the food chain. The classic hypothesis argues that the change in topography created by seamounts results in upwelling that brings nutrients

to the photic zone in a spiral around the topography, known as a Taylor column (Dower and Mackas 1996). The other explanation given for increased zooplankton abundance over seamounts is their aggregation due to advection, in which they are retained in the spiral of currents around the seamount (Rogers 1994, Mullineaux and Mills 1997). In this theory, zooplankton do not amass because of primary production blooms, but rather enter the system from an environment far upstream. Anti-cyclonic eddies associated with Taylor columns circulate plankton around the seamount and prevent them from leaving the ecosystem. Recent research into abundant zooplankton communities over seamounts suggests that the trapping theory is more likely than the classic hypothesis (Rogers 1994). However, a recent study of the Great Meteor Seamount, above which a highly defined Taylor column was observed, found no total increase in abundance of zooplankton inside the column when compared to water outside of it (Martin and Nellen 2004). This and other studies (Rogers 1994, Dower and Mackas 1996) have found zooplankton decreases over abrupt topography and contradict earlier research.

Three major mechanisms have been proposed to explain this lack of zooplankton. The first, a biological response of zooplankton to avoid abrupt topography (Dower and Mackas 1996) has not been significantly studied. The second hypothesis suggests that zooplankton get ‘washed’ downstream of the seamount (Dower and Mackas 1996). This has been proposed for seamounts over which no significant Taylor column was observed. Instead of currents rotating in eddies over the seamount, they continue in a unilinear direction away from it. Any primary production blooms and increased zooplankton density caused by upwelling over the raised topography will thus be seen downstream of the seamount instead of over it.

The third explanation for zooplankton gaps above seamounts is increased predation by the nekton that inhabit the seamount. This occurs both by the movement of predators upward to feed and the vertical migration of many species of zooplankton downward during the day, presumably to avoid predators by escaping to regions of low light (Rogers 1994). Differences in community composition show that vertically migrating species disappear over seamounts while more static species remain abundant (Genin et al. 1994). Such a ‘seamount effect’ on zooplankton diversity has been observed in one study up to one seamount diameter away from the seamount itself (Dower and Mackas 1996). However, such an effect is only expected over shallow seamounts that peak in the upper couple hundred meters of the ocean (Genin et al. 1994). Such a phenomenon is

not expected for seamount peaks deeper than 400 m to 500 m because the surface of the seamount is too deep for nekton to come in contact with zooplankton (Genin 2004). In fact, a study of a seamount that rises to only 730 m below the surface found no differences in zooplankton diversity characteristic of such predation (Saltzman and Wishner 1997). A study of copepod carcasses over four Pacific seamounts that peak between 100 m and 527 m have suggested that the predation effect becomes more visible as the seamount gets closer to the surface and disappears entirely at seamounts with peaks more than 500 m below sea level (Haury et al. 1995).

This study focused on the composition and abundance of zooplankton above and around an unnamed seamount in the Central Eastern Pacific between the Hawaiian and Line Island chains that peaks at 824 m below sea level. Data gathered at several sampling sites were compared to answer the following questions:

- Does zooplankton abundance increase over the seamount?
- Does the composition of the zooplankton community change over the seamount?

Because upwelling was not expected to reach the photic zone since the seamount summit is 824 m deep, no zooplankton increases due to primary production blooms were expected. It was expected that any observed Taylor column would be too weak to reach the surface and there would thus be no closed current spiral capable of trapping zooplankton. Furthermore, the deep seamount peak makes zooplankton gaps caused by predation highly unlikely. Thus, no significant effect on zooplankton abundance or diversity was expected to be observed.

METHODS

Three locations were sampled with 333 μ m mesh neuston 1-meter nets: off the seamount in both the upstream and downstream locations and near the center of the seamount (Table 1, Figure 1). S199-004 was taken upstream of the seamount, S199-005 occurred at the highest elevation traversed, and S199-006 represents the downstream location (Donhowe 2005). Such a transect was necessary to determine if zooplankton are being swept downstream or trapped in cyclical currents. While navigational chart data shows the summit of the seamount to be at 824 m below sea level, the shallowest depth this study sampled over (at S199-005) was 1029 m below the surface (Donhowe 2005). Tows occurred for 30 minutes at a boat speed of 2 knots. Samples were taken both at the surface using the neuston net and at the deep-scattering layer using the meter net. The deep

scattering layer was determined by a 75KHz Acoustic Doppler Current Profiler, which tracks the movement of suspended particles using sonar soundings. The amplitude of an echo returned from a specific depth reflects the amount of biomass in the water for that depth. The deep scattering layer was estimated from areas in the water column with increased zooplankton biomass (Figures 2, 3, 4). For comparable results, samples should have been taken at similar times of the day; however, time constraints necessitated sampling from morning twilight until mid-afternoon. Sampling at the deep-scattering layer should have helped to correct any differences caused by diurnal migration.

Station	Date	Time In	Ship Log	Lat	Long	Depth (m)	Temp (C°)	Salinity (psu)
S199-004-NT	12-May-05	0619	231.2	18°52.9'N	156°59.9'W	0	25.7	34.49
S199-004-MN	12-May-05	0610	231.2	18°52.9'N	156°59.9'W	164	25.7	34.49
S199-005-NT	12-May-05	0934	240.0	18°43.5'N	157°5.8'W	0	25.7	34.50
S199-005-MN	12-May-05	0918	240.0	18°44.0'N	157°5.3'W	115	25.7	34.50
S199-006-NT	12-May-05	1418	253.1	18°36.2'N	157°12.4'W	0	25.8	34.51
S199-006-MN	12-May-05	1408	253.1	18°36.4'N	157°12.0'W	242	25.8	34.51

Table 1: Time, location, depth, temperature, and salinity of sampling stations

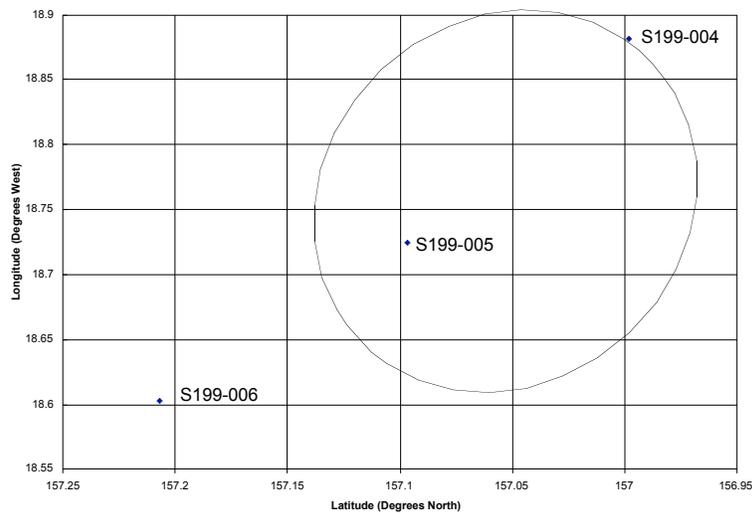


Figure 1: Sampling Locations and Approximate Area of Seamount

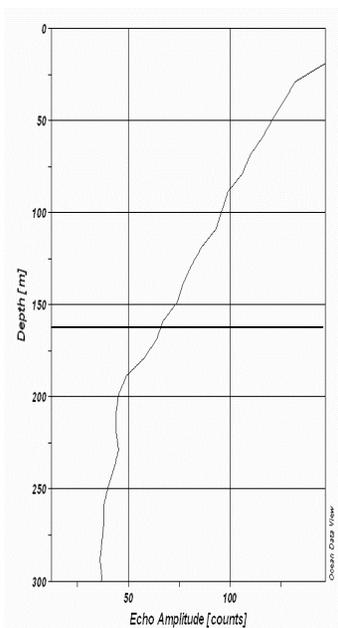


Figure 2: Echo Amplitude from S199-004 (164 m)

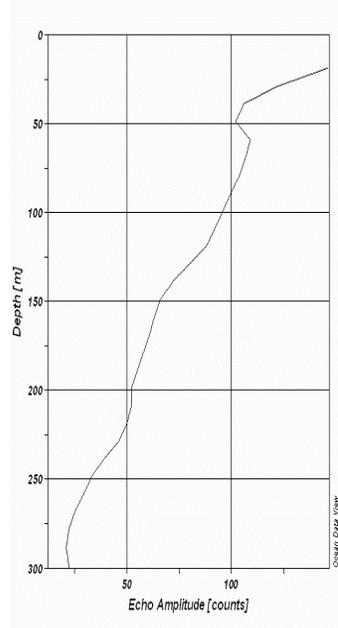


Figure 3: Echo Amplitude from S199-005 (115 m)

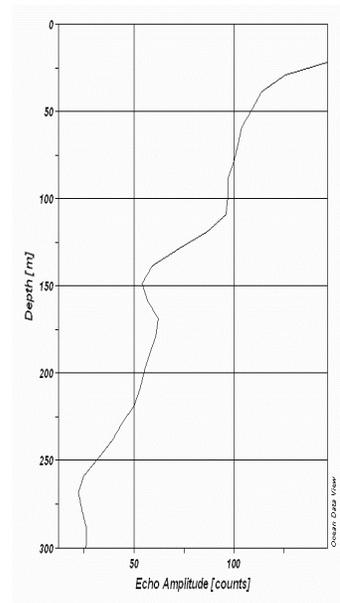


Figure 4: Echo Amplitude from S199-006 (242 m)

The biovolume of zooplankton was measured to approximate overall abundance by adding the sample to a graduated cylinder to measure its displacement after filtering it through a 333 μ m sieve. The total biomass was then standardized for tow length and volume of water that flowed through the net to give the density of the biomass collected. Each collected sample was then examined under a dissecting microscope and the first 100

organisms were identified. Zooplankton were classified to the most specific taxonomic level possible using on-board guides, and the abundance of each type was recorded.

RESULTS

Surface zooplankton density decreased as the sampling locations moved from upstream to downstream of the seamount. The total biomass density measured by neuston tows were 0.019 mL/m² upstream, 0.001 mL/m² over the seamount, and 0.002 mL/m² downstream of the seamount (Figure 5). The meter nets were towed through the deep scattering layers at 164 m at S199-004, 115 m at S199-005, and 242 m at S199-006, and produced zooplankton densities of 0.011 mL/m³, 0.010 mL/m³, and 0.038 mL/m³ respectively (Figure 6).

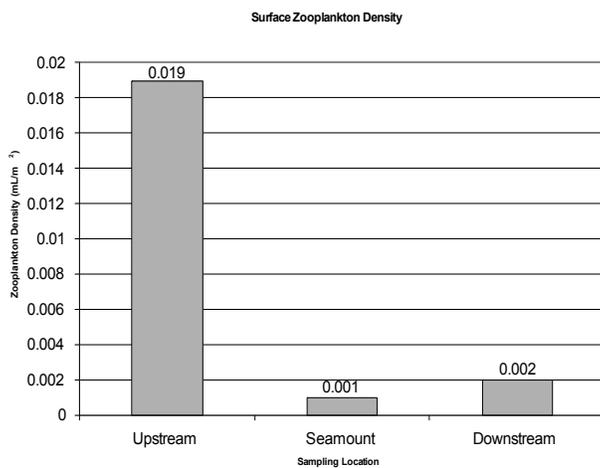


Figure 5: Surface zooplankton density

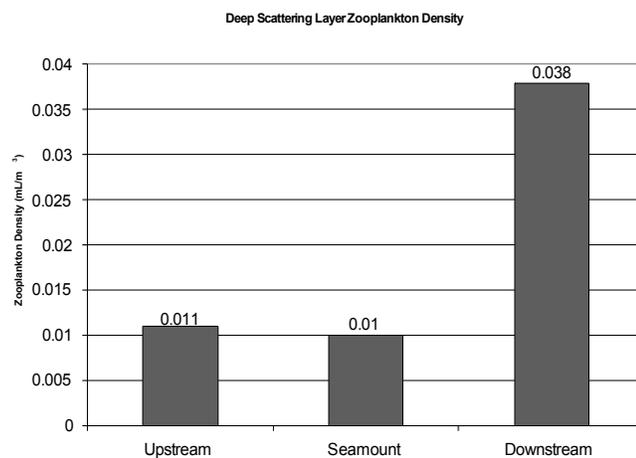


Figure 6: Deep scattering layer zooplankton density

Figure 2: Density from Neuston Tows

Figure 3: Density from Meter Nets

The composition of the zooplankton community also changed depending on the sampling location. 100-count data from the neuston and meter nets were combined for each site to account for both migrating and non-migrating zooplankton. Uncommon organisms (those that occurred fewer than 10 times out of the total 600 organism sample) were not included in the analysis. The following types of organisms were included: pteropods, Copepods, hyperiid amphipods, fish eggs, radiolarians, and foraminifera (Figure 7).

The percentage of fish eggs did not significantly differ by location and changed less than 2% throughout the transect. Copepods decreased to 66% downstream of the seamount, while they were 75% and 77% of the seamount and upstream communities. Hyperiid Amphipods decreased from 4% of the total upstream and

downstream of the seamount to 1% of the total over it. The largest differences between sampling locations were found among three organisms. The percentage of Pteropods fluctuated from 10% upstream to 2% over the seamount and back up to 19% downstream. Radiolarians spiked over the seamount at 9%, compared to 1% upstream and 5% downstream. Foraminifera were found only over the seamount and comprised 7% of the zooplankton community at that location.

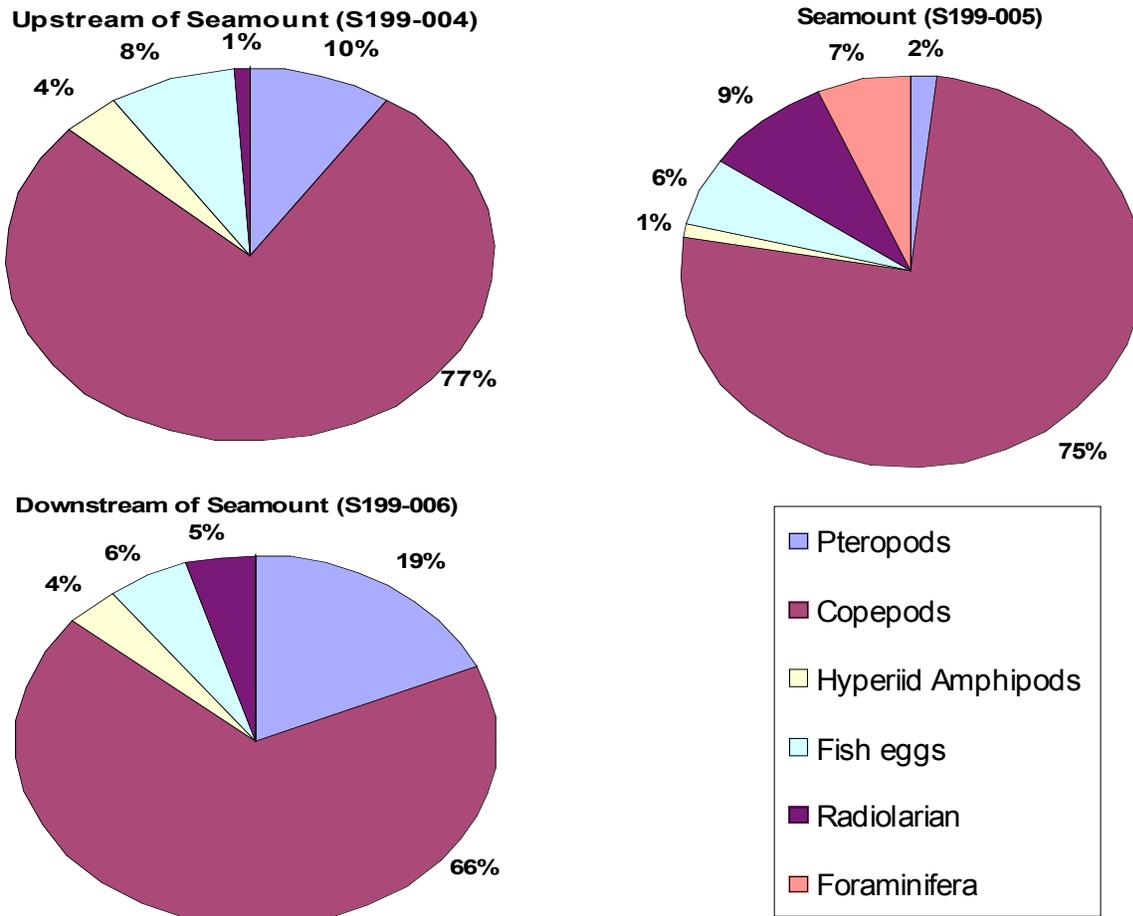


Figure 7: Zooplankton community composition by percentage

Macroscopic organisms from each tow were also recorded. While their scarcity makes any major trends difficult to report, several differences were observed (Table 2). 6 Nudibranchs were caught downstream of the seamount while none were found upstream or over it. Similarly, 5 *Porpita Porpita* were observed downstream compared to 1 caught upstream and 0 caught over the seamount. Finally, 2 leptocephali were found downstream of the seamount and none upstream or over it.

	upstream	seamount	downstream
Nudibranchs	0	0	6
Porpita Porpita	1	0	5
Leptocephali	0	0	2

Table 2: Macroscopic organisms captured in net tows

DISCUSSION

The data collected in this study must be cautiously accepted due to the constraints of the ship's cruise track. During sampling, a cyclonic eddy was present and the three sites were all present near the Northwest edge of the eddy (Markman and Schwartz 2005). Without a doubt, the eddy and seamount data were confounded and it is nearly impossible to isolate the specific effects of each. However, surface currents in the area were generally moving toward the Southeast and thus water most likely moved from the eddy core away from the seamount (Figure 8).

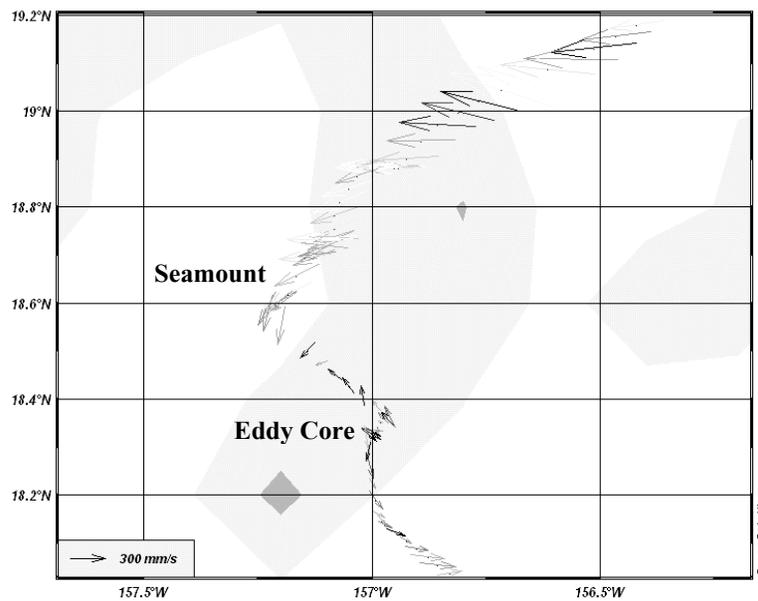


Figure 8: Magnitude and direction of surface currents (Donhowe 2005)

Furthermore, given that all three sampling locations were in the same eddy in nearly the same location relative to the eddy core, it is likely that the eddy had a similar effect on all three sites. Finally, even if the downstream

sampling site, which was closest to the eddy core, was affected more than the other sites, the impact would not be great enough to explain all of the total increase in zooplankton density found downstream. As shown in figure 9, the biomass density from the deep scattering layer at the downstream location was more than twice that found in the eddy core, which is expected to have the greatest zooplankton density of all areas in the eddy (Markman and Schwartz 2005). Therefore, variation among the sites can reasonably be attributed to the seamount alone.

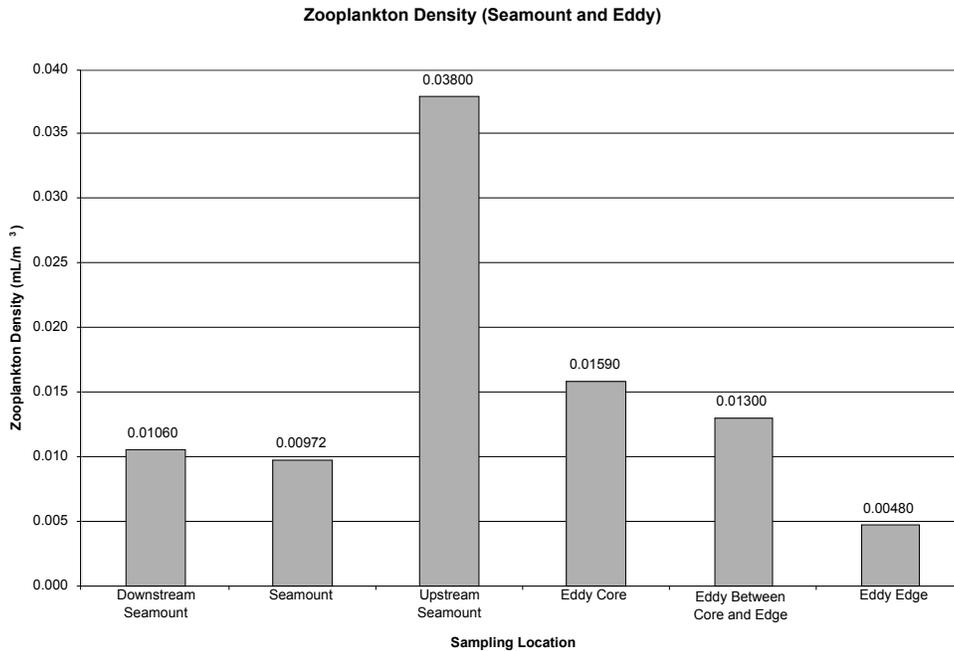


Figure 9: Zooplankton density from the deep scattering layer (Markman and Schwartz 2005)

The trends for zooplankton abundance were opposite for the neuston tows and the meter nets. However, since most zooplankton organisms vertically migrate down during the day, the neuston tows were heavily skewed by the different sampling times. The upstream location occurred right before sunrise while the later two sites were sampled later in the day. Therefore, the data from the neuston tows are probably more indicative of diurnal vertical migration than seamount-related effects and cannot be used as accurate reflections of zooplankton density. On the other hand, the meter nets were towed at the depth of the greatest concentration of biomass and are therefore less likely skewed by time of day. While the deep scattering layer was expected to become deeper throughout the morning that sampling was done, it became shallower over the seamount. Although such a change could reflect an error in locating the deep scattering layer, it could have also occurred

due to the raised topography, possible upwelling, or the raised isothermals and isopycnals found over the seamount (Kelso 2005). The meter nets show a clear three-fold increase in zooplankton abundance downstream of the seamount, and this was considered to be a more accurate reflection of zooplankton abundance than the neuston net data.

Given that no Taylor column or other cyclonic current structure was found over the seamount (Donhowe 2005), the trend in zooplankton abundance is not surprising. Both theories of density increase above seamounts rely on circulating currents above the seamount peak to maintain upwelled nutrients and plankton. With the unidirectional currents that characterize the surface above this seamount (Donhowe 2005), any increases in zooplankton density above the raised topography would likely be a result of phenomenon far upstream. Similarly, the significant increase in zooplankton abundance found downstream of the seamount suggests the seamount affects the environment that surrounds it. This data thus refutes the original hypothesis that the seamount was too deep to have a noticeable impact.

The differences in zooplankton community composition also indicate an uplift of nutrients over the seamount resulting in zooplankton blooms downstream. The highest proportion of primary producers (radiolarians) and lowest level consumers (foraminifera) were found at the station over the seamount. Secondary consumers (copepods) comprised most of each zooplankton community but were found in the lowest proportion downstream of the seamount. This was likely caused by predation from tertiary consumers (pteropods), which were found in the greatest ratio downstream of the seamount. Larger and even higher level consumers, such as *Porpita Porpita*, Nudibranchs, and *Leptocephali*, were also found in their greatest abundance downstream of the seamount. Thus, the downstream sampling location had the greatest trophic diversity in addition to the greatest density of the three sites sampled.

The trends found in this study suggest that upwelling associated with the raised topography of the seamount brings nutrients into the photic zone that subsequently produce phytoplankton and zooplankton blooms downstream of the seamount. The lack of higher trophic level zooplankton over the seamount might explain the larger proportion of primary producers and lowest level consumers that was found over the seamount. The intensity of the deep chlorophyll maximum was also lowest over the seamount when measured

by an in-situ fluorometer (Kelso 2005). The lower abundance of food most likely decreased the density of zooplankton and a zooplankton bloom did not occur until phytoplankton biomass increased further downstream as a result of uplifted nutrients over the seamount. Interestingly, the amount of dissolved oxygen measured throughout the first 600 m of the water column was roughly equivalent for S199-005 and S199-006, but both showed an increase in relation to what was measured upstream (Kelso 2005). One possible explanation for the similarity is that increased zooplankton density downstream was coupled with an increased phytoplankton density to maintain a constant level of dissolved oxygen despite the higher total biomass.

The data from this study indicate that predation of zooplankton over the seamount was unlikely. The smallest distance between the deep scattering layer and the top of the seamount was greater than 500 m, and migrating zooplankton most likely did not come in contact with larger benthic predators. Furthermore, the constant proportion of fish eggs, while not necessarily indicative of fish biomass, suggests no increased nekton abundance over the seamount. Additionally, a zooplankton 'gap,' in which zooplankton abundance is lower over the seamount when compared to both the upstream and downstream sites, was not observed. Instead, zooplankton density was less for both the upstream and seamount peak locations. Despite these data, predation can not be completely dismissed as one explanation for the results. The higher proportion of lower trophic level organisms found over the seamount may be caused by the loss of higher trophic level organisms due to higher level predation, which disappears downstream. In addition, the deep chlorophyll maximum over the seamount was less intense than its upstream counterpart (Kelso 2005). The diurnal vertical migration of zooplankton from above the deep chlorophyll maximum during the night and at S199-004 through it during S199-005 may explain this difference because zooplankton passing through the deep chlorophyll maximum would graze on its phytoplankton, decreasing its intensity. However, an alternative explanation is that there are more zooplankton over the seamount than indicated by the meter net but they are being consumed by larger nekton. Again, zooplankton grazing would decrease the intensity of the deep chlorophyll maximum and would explain the differences found by Kelso (2005).

This study can be easily repeated by future researchers on a similar cruise track. However, several changes in methodology can improve the results and offer greater insight into how the seamount affects the

zooplankton community around it. Given that the zooplankton density data from the neuston tows was found to be confounded by diurnal vertical migration, the neuston tows could be replaced with more meter net tows at locations over the flanks of the seamount. This would help determine the scope of the change of trophic diversity found in this study. Furthermore, the measurement of gelatinous zooplankton, while originally planned for this study, was not done for all three sampling sites and thus could not offer insights into another important trophic level. Additionally, each 100-count was done by a different person, and this dynamic most likely factored as another variable that decreased the accuracy of the results. In a future study, each 100-count should be replicated at least three times in rapid succession to prevent rotting of the sample.

CONCLUSION

Despite having a peak greater than 800 m below sea level, the seamount studied affected its surrounding oceanic environment enough to see noticeable changes in the zooplankton community. The total abundance of zooplankton increased downstream of the seamount compared to the upstream and over the seamount locations. More trophic diversity was found downstream of the seamount as well, with higher level consumers comprising a larger proportion of total zooplankton than the other two sites. While other oceanographic phenomena, such as a cyclonic eddy, may have complicated the results, the data offer a reliable characterization of the effects of this seamount on the zooplankton community that surrounds it.

Given that the currents over the seamount move in a unilinear direction, the most likely explanation for the observed phenomenon is that the raised topography creates an upwelling of nutrients and an uplifting of the thermocline and pycnocline. This leads to a phytoplankton bloom downstream after phytoplankton have utilized the nutrients and reproduced. The increase in phytoplankton fosters a similar increase in total zooplankton abundance. The overall more productive community creates the conditions necessary for increased trophic diversity and the development of a more complex and multi-layered food web.

ACKNOWLEDGEMENTS

This study depended on the hard work and cooperation of the entire S199 Robert C. Seamans class and crew. Special thanks is offered to Kara Lavender for her support and assistance in planning the research and reviewing the collected data.

REFERENCES

- Donhowe, K., 2005. Seamount circulation in the Eastern Pacific. *In: Student Research Reports: S-199*, Sea Education Association, P.O. Box 6, Woods Hole, MA 02543.
- Dower, J.F., Mackas, D.L., 1996. "Seamount effects" in the zooplankton community near Cobb Seamount. *Deep-Sea Res.*, 43, 837-858.
- Genin, A., 2004. Bio-physical coupling in the formation of zooplankton and fish aggregations over abrupt topographies. *Jour. Mar. Sys.* 50, 3-20.
- Genin, A., C. Greene, L. Haury, P. Wiebe, G. Gal, S. Kaartvedt, E. Meir, C. Fey, J. Dawson, 1994. Zooplankton patch dynamics: daily gap formation over abrupt topography. *Deep-Sea Res.*, 41, 941-951.
- Haury, L., Fey, C., Gal, G., Hobday, A. and Genin. A., 1995. Copepod carcasses in the ocean. I. Over seamounts. *Mar Eco Prog Ser.* 123, 57-63.
- Kelso, M., 2005. The effects of a deep seamount on nutrient, oxygen and chlorophyll distributions in the water column. *In: Student Research Reports: S-199*, Sea Education Association, P.O. Box 6, Woods Hole, MA 02543.
- Koslow, J.A., 1997. Seamounts and the ecology of deep-sea fisheries. *Am. Sci.* 85, 168-176.
- Markman, N., Schwartz, R., 2005. Characterizing productivity of geostrophic eddies. *In: Student Research Reports: S-199*, Sea Education Association, P.O. Box 6, Woods Hole, MA 02543.
- Martin, B., Nellen, W., 2004. Composition and distribution of zooplankton at the Great Meteor Seamount, subtropical north-east Atlantic. *Arch. Fish. Mar. Res.* 51, 89-100.
- Mullineaux, L.S., Mills, S.W., 1997. A test of the larval retention hypothesis in seamount-generated flows. *Deep-Sea Res.* 44, 745-770.
- Rogers, A.D., 1994. The biology of seamounts. *Adv. Mar. Biol.* 30, 305-350.
- Saltzman, J., Wishner, K.F, 1997. Zooplankton ecology in the eastern tropical Pacific ocean minimum zone above a seamount: 1. General trends. *Deep-Sea Res.* 44, 907-930.