Distributions of Rare Midwater Animals: A look at uncommon fauna and their seasonality in Monterey Bay

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ABSTRACT

Using an extensive observational video transect time-series, this study seeks to illustrate any seasonal or non-seasonal patterns that may exist within Monterey Bay's rare midwater animal community. 20 unique midwater species were selected from a database based on their relative frequency and ease of identification. While no statistical standardization exists to define a "rare species," this study chose to focus on species that were observed with a frequency of approximately ≤1%. Total species abundance was averaged into monthly totals and compared to various factors including mixed-layer depth (MLD), upwelling, seasonal currents, and a Multivariate El Niño Southern Oscillation Index (MEI). Based on multidimensional scaling (MDS), seasonal correlations appear to exist within every selected factor with a possible lagged correlation within the non-seasonal MEI and overall annual species abundance.

INTRODUCTION

Located in Moss Landing, California, the Monterey Submarine Canyon is a topographical novelty, offering researchers easy access to deep water habitats relatively close to shore. Compounded with new technologies like ROVs (Remotely Operated Vehicles), the Monterey Bay Aquarium Research Institute (MBARI) is situated in an ideal position to study midwater communities (Robison, 2004).

The largest habitat on Earth, the ocean's midwater is home to a vast pelagic community previously thought to be devoid of life (Robison, 2004). Thriving in almost complete darkness, these residents have adapted to form a very unique ecosystem. Like all communities, the midwater is home to a diverse range species, some who occur more frequently than others. To better understand community dynamics, a prevalent practice among community analysts is to focus on a habitat's more abundant or common species (Cunningham and Lindenmayer, 2005; Ellingsen, 2007). Statistically, rare species present a problem for many analysts because their inherently low abundances tend to skew data. When compared to a common species, the sample size of a rare species' can differ by several orders of magnitude, essentially splitting the community in two (**Figure 1**). For this reason, infrequent or rare species are often ignored by ecological studies, either disregarded or discarded as statistical noise (Cao et al., 1998). However, with proper resolution, a rare species can become a significant indicator of ecological change or degradation (Cao et al., 1998; Novotný and Basset, 2000). For more than 20 years, MBARI has maintained a massive video transect time-series using various camera-mounted ROVs thus allowing this study ample statistical resolution.

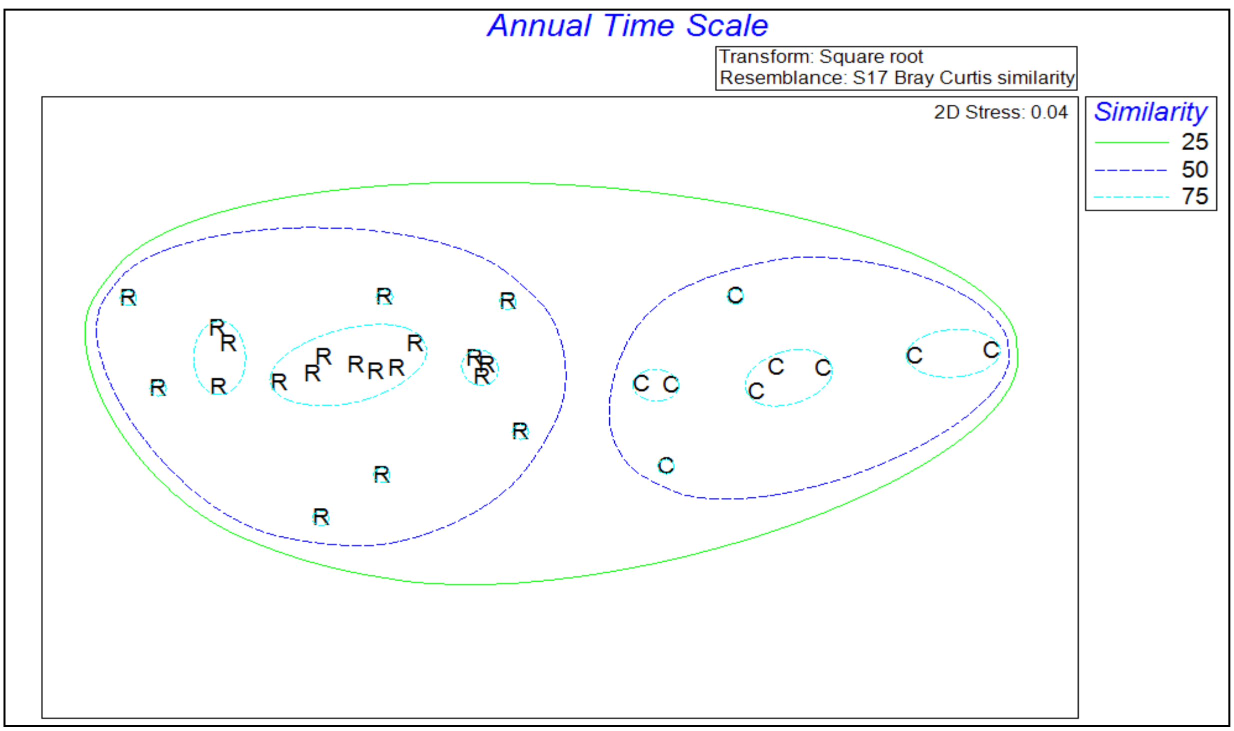


Figure 1: The statistical similarity between common species' (C) and rare species' (R) abundance. Both C and R show a distinct separation in terms of similarity. Note that this multidimensional scaling was plotted after conducting a square root transformation.

In this study, we focused on analyzing the distributions of 20 different midwater species found in the Monterey Submarine Canyon. All 20 weer specifically selected according to their relatively low occurrence in the water column (**Table 1)**. While certain studies have examined common or individual midwater species (Robison et al. 1998; Schlining B, 1999; Steinberg et al., 1994) few have focused exclusively rare species. The goal of this analysis was to determine if distributions of relatively rare species correspond to any regular seasonal or non-seasonal trends. However, the subjective term “common” or “rare” lacks a proper statistical definition. As a result many researchers are forced to arbitrarily define their own standards of rarity (Cao et al., 1998; Yu and Dobson, 2000). Ellingsen et al. (2007) observed how more common individuals tend to only belong to a very few number of species, while rare species represent only a small number of individuals. This is true for both terrestrial and marine systems. For this study, we will determine our own definition of rarity.

Table 1: A list of each rare midwater species this study investigated. Listed on the right is the number of observations made for each species over a 17 year time-series dating from 1997 to 2013.

Rare Species	**No. of Observations**
Aegina citrea	315
Bathocyroe fosteri	1048
Chiroteuthis calyx	346
Colobonema sericeum	818
Doliolinetta	700
Doliolula equus	64
Eutonina indicans	306
Forskalia edwardsi	166
Gigantocypris agassizii	34
Gymnopraia lapislazula	107
Kiyohimea usagi	65
Munneurycope murrayi	389
Mesochordaeus erythrocephalus	1000
Pandea rubra	55
Pantachogon haeckeli	669
Periphylla periphylla	161
Praya dubia	525
Ptychogena lactea	335
Resomia ornicephala	223
Tetrorchis erythrogaster	75

METHODS

For this study, transect data was used to maintain a degree of methodical standardization. ROV transects were carefully monitored to maintain a regular operational speed of approximately one knot for a period of 10 minutes at each scheduled depth. With these standardizations, transects are able to keep measured seawater volume relatively constant across the entire time-series. A series of ROVs were used to record our data: the ROV *Tiburon* (93 dives), the *Doc Rickkets* (111 dives), and *Ventana* (2297 dives). Due to mechanical limitations, transect depth range varied per ROV. ROV *Ventana* typically dove from the surface (0 meters) to 1000 meters, the *Doc Ricketts* from 200 to 1000 meters and the *Tiburon* from 100 to 3500 meters in increments of 100 meters. All relevant observations originated from a single midwater station, Midwater 1 (**Figure 2**) with ROV video footage assessed on shore and logged into MBARI's comprehensive Video Annotation and Reference System (VARS).

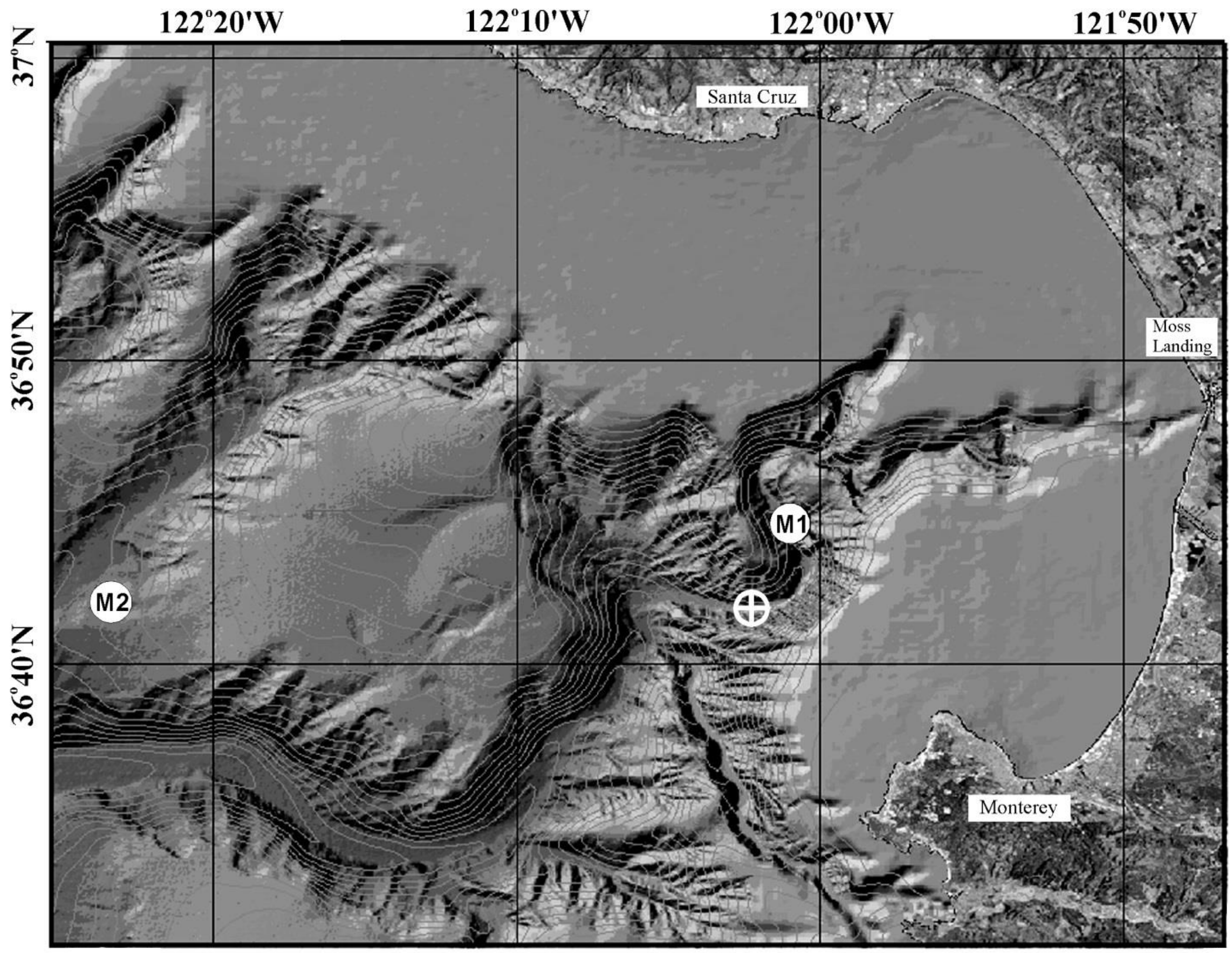


Figure 2: Displays the location of the Midwater 1 survey site as indicated by the symbol (+). Datasets originating for Mooring Station 1 (M1) provided important data regard mixed-layer depth and seasonal currents.

All transect data dated between 1997 and 2013 and was retrieved from the VARS database to create a relatively linear 17 year time-series. To select for rare midwater organisms, 20 unique species were chosen based on their relative frequency and confidence of identification. A species was considered "rare" if it occurred ≤1% during the entire given time-series. Due to the nature of video footage, species were only selected if all specimens could be confidently identified taxonomically to a species-level Abundance counts were totaled and standardized based on the number of transects conducted each year to control for years that saw fewer or more transects than others.

The standardized data was averaged into months for each species and totaled to form an aggregate average monthly sum. To calculate similarity, the aggregate monthly sums were square root transformed and analyzed using multidimensional scaling (MDS) in the statistical software program PRIMER. Months with shared similarity were compared to different seasonal cycles including mixed-layer depth (MLD), California currents cycles, and upwelling to reveal any possible correlations. MLD (Michisaki, unpublished data) and seasonal currents were calculated from datasets originating for Mooring Station 1 (**Figure 2)**. Upwelling data was retrieved from an open-access NOAA Upwelling Index recorded at a station near Pacific Grove, California.

To test for non-seasonal patterns, standardized abundance data was sorted into separate annual averages and correlated to a Multivariate El Niño Southern Oscillation Index (MEI).

RESULTS

i. Seasonal Cycles

MDS plotted monthly abundance data revealed three distinct similarity groups, with the exception of February and March (**Figure 3**). Four months showed particularly strong similarities: the months of July and August shared a 90% similarity along with the months of October and November. Collectively, all 12 months showed a similarity of at least 80%. Notably, all months within the three groups line up consistently with a standard calendar year. This is especially apparent after superimposing this sequence over a different figure displaying Monterey Bay's annual average MLD (**Figure 3**). The group of months comprised of April, May, and June appear to coincide with a consistently shallow MLD, while July and August appear to coincide with a peak shallow period. The group consisting of September through

January appear to coincide with a period of rapid depth increase with October and November appearing to be at the peak of this depression. The months of February and March coincide with a period of decreasing MLD depth with fairly wide margins for error. A similar trend was observed when monthly averages were correlated with known California seasonal currents and an upwelling index (**Figure 4**). Months February and March appear to have reduced intensity when compared to other associated Upwelling and Davidson months.

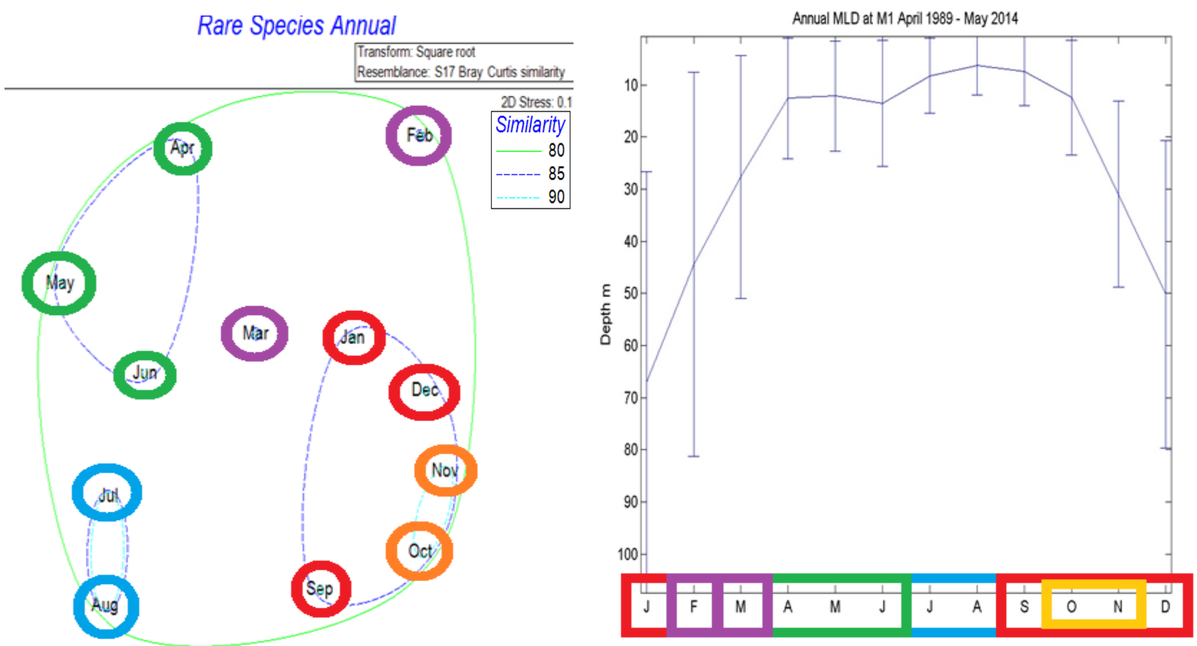


Figure 3: A multidimensional scaling (MDS) plot displaying the similarities between the monthly abundances of all 20 rare species (shown left). Shown right is the average mixed-layer depth over an annual period. Boxed-in months indicate periods that have increased similarity as seen on the MDS.

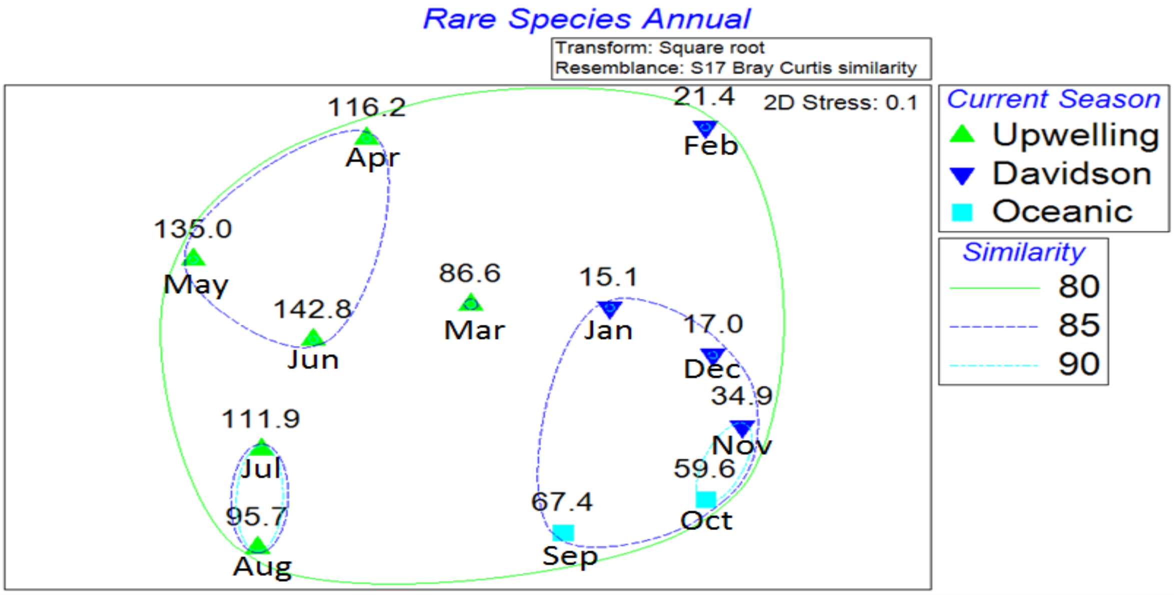
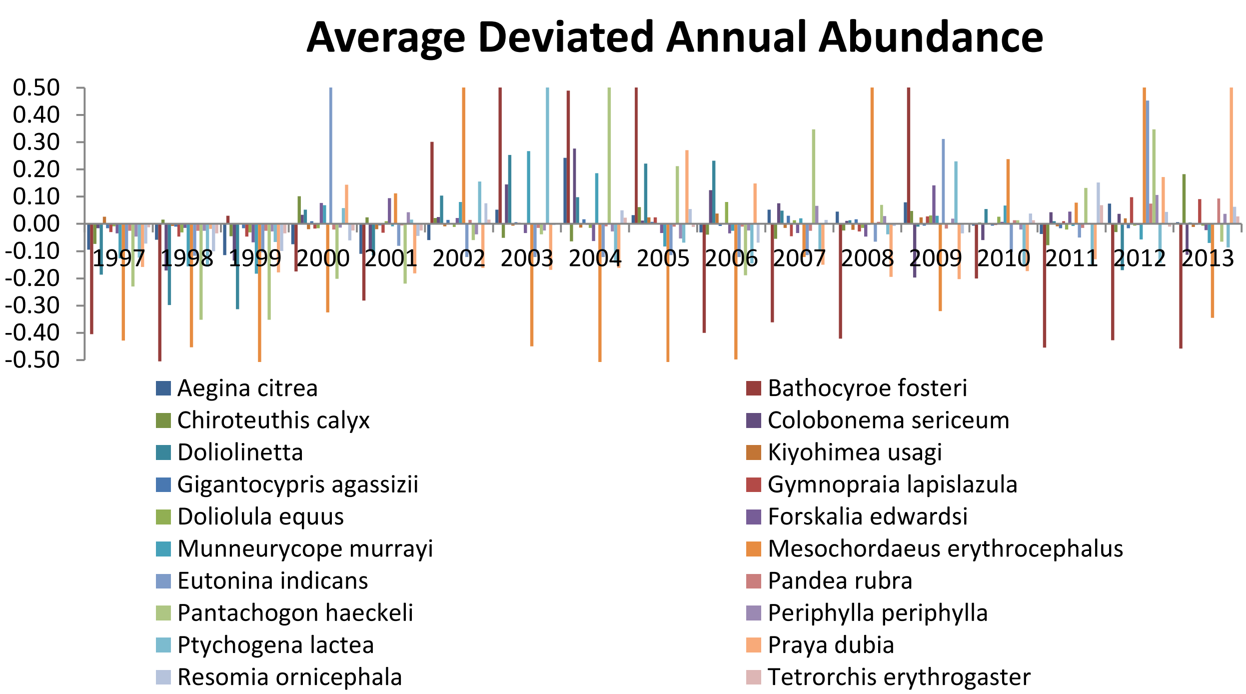


Figure 4: Total monthly average abundances in relation to California seasonal currents and upwelling. High numbers indicate a greater degree of upwelling during the given month.

ii. Non-seasonal Cycles

Correlations appear to exist between annual abundances and MEI (**Figure 5**). Years 1997 and 1998 show a universal decline in average abundance deviation. Similarly, years 1997 and 1998 are associated with particularly strong MEI readings. However, the year 1999 continues to show a decreased deviation in spite of a strong negative MEI reading during that year. Other possible trends appear less obvious with further analysis.



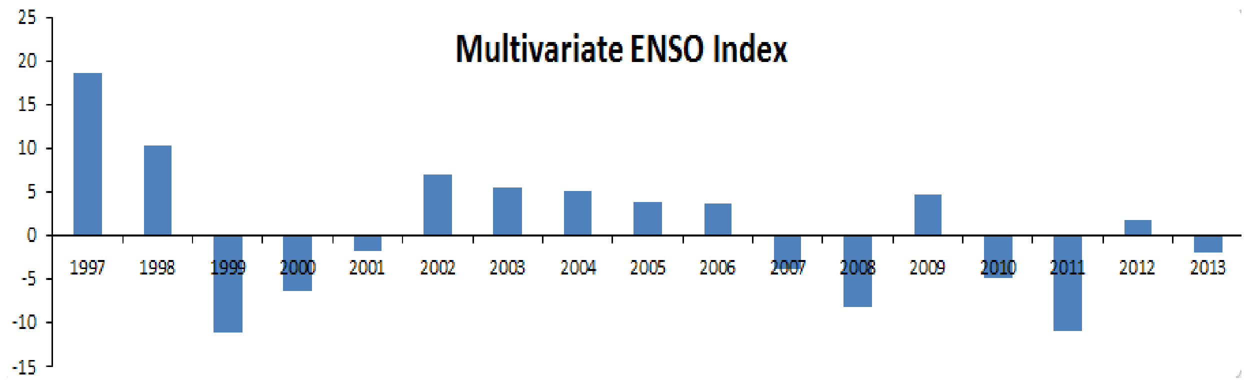


Figure 5: Average deviated annual abundances in correlation to Multivariate ENSO Index (MEI). A possible negative lagged correlation appears to exist.

DISCUSSION

Monthly relationships generated by the MDS plot (**Figure 3**) revealed some interesting similarities. The three distinct groups formed in the plot appeared to correspond to seasonal trends. The months of April through June appear to correspond with Spring, July through August (Summer), and September through January (Fall and Winter). While the months of February and March shared no strong similarities, it is still interesting that they occur in sequential order. However, while these correlations show promise, they are generally weak in terms of explanation. To further explore this relationship the next logical step was to investigate factors that were influenced by the changing seasons.

It is fairly well known that seasonal fluctuations affect a variety of midwater species (Robison, et al., 1998; Lampitt, R. S., 1993). Despite their lack surface interaction, much of the midwater ecosystem depends upon annual surface productivity. Therefore investigating factors that affect seasonal primary productivity is necessary to understand these cycles. Functioning as an accurate indicator for upwelling, MLD follows a fairly consistent cycle in Monterey Bay. Using data generated from Monterey Bay Station M1 (**Figure 3**), average monthly MLD was compared to the same patterns observed in the average monthly abundances. The results were promising as the grouped monthly abundances appeared to lineup with trends in MLD. Months previously correlated with Spring followed a trend of relatively shallow MLD with the Summer months showing a distinct upward fluctuation. Meanwhile, the abundances associated with Fall and Winter appeared to line up with a distinct depth increase. This correlation also revealed a plausible explanation for the dissimilarities observed in February and March. February and March appear to line up with an decreasing trend in MLD leading to the characteristic Spring shallow depth period. This may suggest February and March function as a sort of transition period between these shallow and deeper water periods. In addition, the amount of corrected error observed during these two months is the greatest of any other monthly period. This high degree of variability may explain why these two months are the most dissimilar from any other.

Seasonal currents and upwelling intensity also appear to coincide with MLD and abundance patterns (**Figure 4)**. Fluctuations in the upwelling index appear to match with the previously established abundance patterns. Periods of high upwelling correlate with a shallow MLD while the Davidson and Oceanic currents appear to coincide with periods of deepening upwelling. This is to be expected as Davidson currents typically see a reverse in current flow (Reid and Schwartzlose, 1962) while Oceanic currents typically push open ocean waters into the coastal areas. The upwelling index also further supports the assertion that February and March serve as a transitional period between seasonal currents. In terms of currents, February is defined as having an upwelling current, while March is defined as a Davidson current. During these months, the relative upwelling values appear reduced. With an upwelling index value of 86.6, March has the lowest upwelling value when compared to other upwelling months. The same can be said of February in relation to the Davidson current. One possible explanation would be these months function as a transitional period between the Upwelling and Davidson currents, thus their values are highly variable and dissimilar from their associated seasons.

A lagged correlation appears to exist between the average annual abundance data and MEI (**Figure 5**). Years associated with a strong MEI signature in 1997 and 1998 appear to correlate with a universally reduced annual average abundance. This was to be expected since El Niño's are infamously associated with reduced abundance, growth and reproduction in many marine animals (Raskoff, 2001). However, during the following year, 1999, MEI readings revealed a strong negative signature, but the abundance average for the same year still showed a universally negative average. It is not until the year 2000 that abundances begin to increase again. If this trend is repeatable, the possibility of a lagged correlation appears plausible, but remains indeterminate as of the writing of this paper. Notably, several species in the study appear to function independently of MEI entirely. *Bathocyroe fosteri* and *Mesochordaeus erythrocephalus* show several instances of negative correlation throughout the time-series, suggesting that perhaps another factor may be influencing their abundances. It may also be possible that these species simply respond to MEI differently. The effects of stalled primary production on the midwater community remains largely undescribed, but it may be possible that a lagged correlation exists, but on a different scale.

CONCLUSION/RECOMMENDATIONS

Based on this preliminary study, the possibility that a rare midwater species follows a regular seasonal cycle seems plausible, but with so many untested factors our understanding is still limited. Avenues for future research include, but are not limited to further ecological analysis of individual species: Competition, as well as other inter or intraspecies interactions. Biological and physiological limitations may also restrict certain species as well as biotic and abiotic factors such as temperature or depth range. In conclusion, the implications of this research suggest rare midwater species are not merely random occurrences, but are functioning members of the local midwater community.

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