Characterizing seasonal changes in Sur Ridge community composition via time lapse photography

Amanda Gannon, Monterey Bay Aquarium Research Institute

Mentors: James P. Barry, Steven Y. Litvin

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ABSTRACT

Understanding the temporal variability of deep-sea faunal assemblages is increasingly important as threats of climate change, ocean acidification, and pollution increase. Recent advances in technology allow for long term monitoring of previously inaccessible sites, such as the deep-water sponge and coral gardens of Sur Ridge. An autonomous time-lapse camera was deployed at Sur Ridge from March 2020 to March 2021 and captured hourly photos of a coral garden assemblage. A random sample of approximately 600 images was selected from this period and manually analyzed to determine macrofaunal community composition and abundance. The coral polyps (protruding/non-protruding) of 6 visible coral colonies were also recorded for each image. Analysis shows that community composition varied among seasons, with some groups exhibiting strong seasonality while others remain roughly constant throughout the year. Time of year was found to be a strong predictor for coral polyp behavior, with current velocity largely unrelated to changes in polyp protrusion. Our study provides a new understanding of variation in coral community composition and behavior enabled by high resolution time-lapse imagery and highlights the need for further research into the life histories of deep-water fauna.

1. INTRODUCTION

The deep sea is the largest biome on Earth yet remains one of the least explored. Comprising approximately 95% of the Earth's biosphere, the deep sea is defined as the area of ocean below 200m depth, outside of the sunlit photic zone (Danovaro et al., 2017). Surface waters and the deep are intrinsically linked through oceanic transport, making it imperative to gain a better understanding of deep-sea habitats and their associated faunal communities. Deep-water benthic communities face increased threats from climate change, pollution, and ocean acidification (Ramirez-Llodra et al., 2011; Sweetman et al., 2017). As such, it is critical to monitor these habitats to better understand both their strengths and vulnerabilities in the face of a changing ocean.

Sur Ridge, a rocky outcrop located 60km off Monterey Bay which ranges in depth from 800 to 1,300m below sea level, is a location of interest due to its old growth sponge and coral gardens. Advances in remotely operated vehicle (ROV) technology have allowed for increased scrutiny of deep-water pelagic and benthic habitats, with a marked expansion in the types and breadth of studies that can be conducted (Robison et al., 2017). Researchers conducted ROV surveys of Sur Ridge in order to establish a baseline taxonomic catalog of faunal residents in both the midwater and at the seafloor (Burton et al., 2017), but there has not been an attempt to quantify or temporally track Sur Ridge macrofauna until now. Cold water coral (CWCs) and sponges dominate the ecosystem at Sur Ridge and also form biogenic habitat, serving as habitat for many other benthic and demersal macrofaunal taxa.

One goal of our study was to assess variation in the behavior of corals, based on the protrusion of feeding polyps over hourly to seasonal time scales. Coral polyps are typically found to be extruded, retracted, or in a transitional state between the two phases. Past studies have shown evidence that the polyps of deep-water corals exhibit a positive correlation with current flow (Bell et al., 2006) and circadian rhythms (Zuazo et al., 2020). However, past studies focused on different species of corals than those present at Sur Ridge, or on corals existing at shallower, not entirely aphotic depths. Here, we hope to gain new insight into deep-water coral behavior specific to the environmental characteristics of Sur Ridge.

In order to deepen our understanding of these communities and their temporal variability, an autonomous time-lapse digital camera and an array of current sensors were deployed at a site in 1230m depth at Sur Ridge, positioned to capture images of a coral assemblage. Time-lapse photography offers a unique snapshot of this remote area over time and allows for assessment of potential patterns in faunal assemblage and coral polyp status. This paper explores two primary questions: 1) is there a significant change in the Sur Ridge composition of benthic and benthopelagic megafaunal assemblages over the course of a year and 2) do resident cold-water corals show any pattern of polyp extrusion and retraction over the observed period.

2. MATERIALS AND METHODS

2.1 STUDY SITE AND EXPERIMENTAL SET UP

Sur Ridge is a deep-sea rocky outcrop located roughly 60km offshore from Monterey, California, near the Davidson Seamount. It hosts a range of jagged peaks and troughs that extend between 800 to 1300m below sea level. The selected site was located at 1230m depth (Fig. 1). The Coral Cam apparatus was placed facing a vertical rock wall hosting corals and sponges of interest (Fig. 2).

To construct the Coral Cam apparatus, a Canon EOS digital camera was mounted in a pressure housing with an electronics package that enables partial camera control (ISO adjustment) and time-lapse sequencing control. This camera system was mounted atop a steel framed lander, including remotely releasable anchor weights and buoyancy sufficient to return the lander to the surface. Two flashes were positioned on either side of the camera. Images from the camera were captured at regular one-hour intervals from March 2020 through March 2021. During this period, 8,865 individual images were collected.

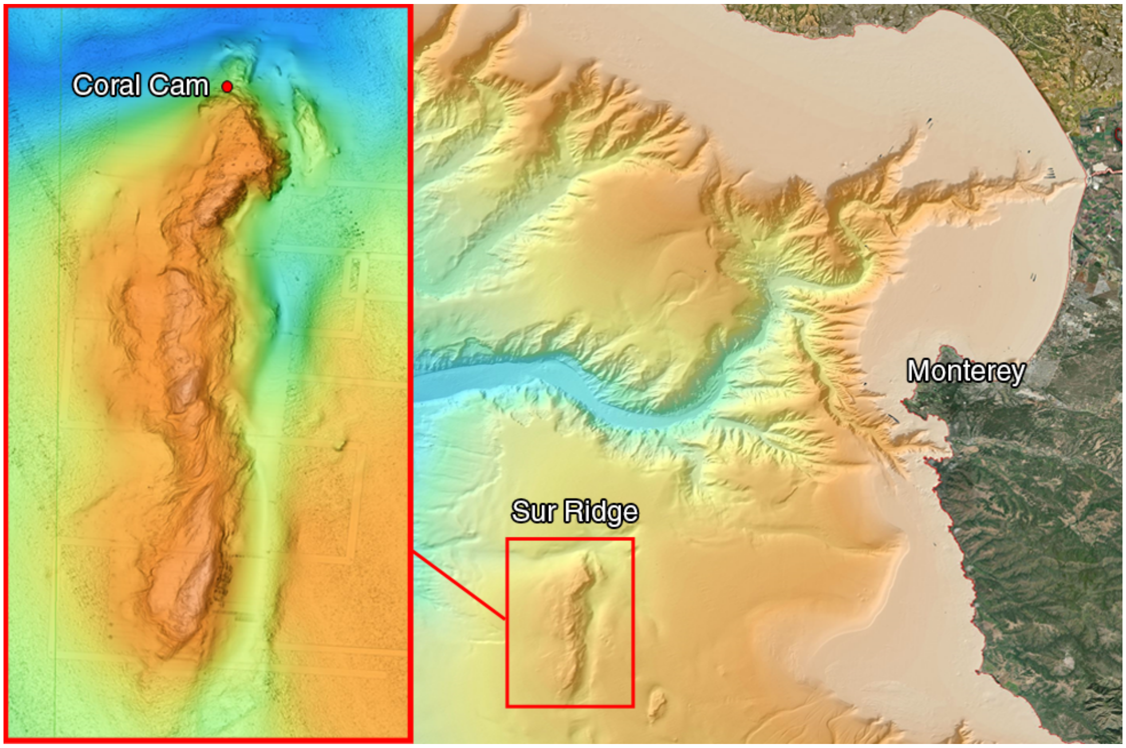

Figure 1: Figure 1: Map of Sur Ridge. The red circle indicates the approximate coordinates of the Coral Cam's placement.

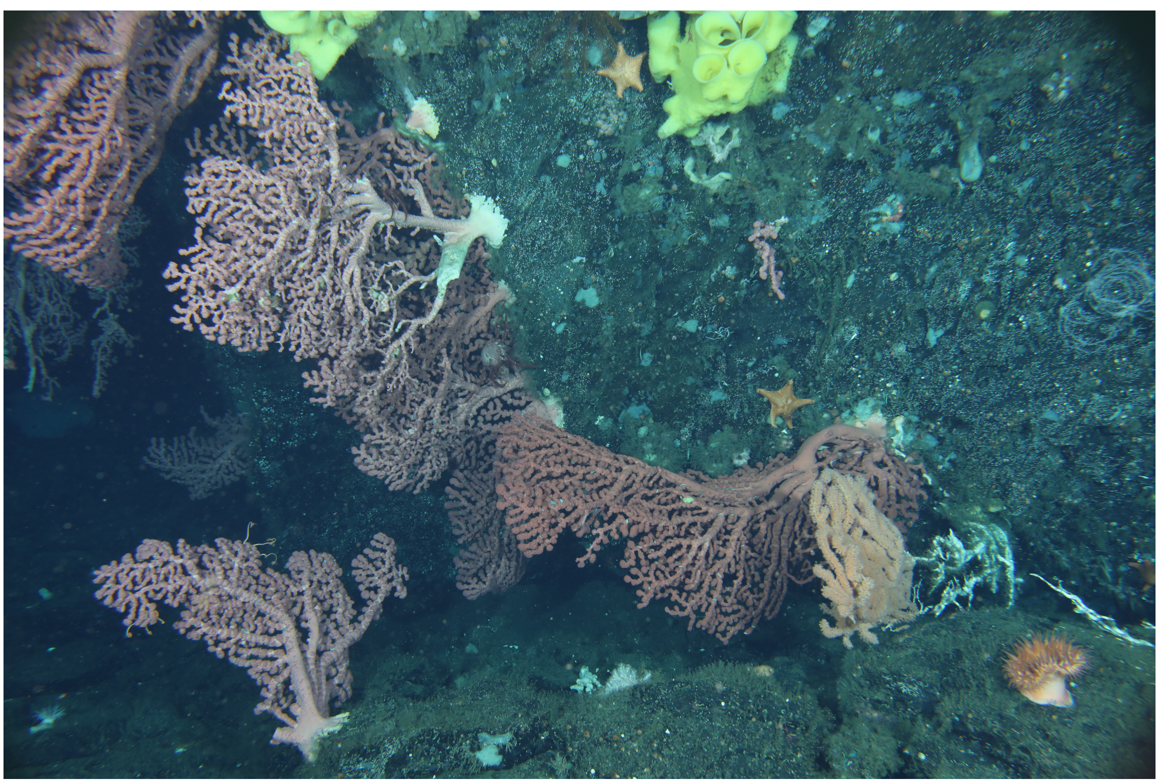

Figure 2: Photo showing the view of the coral garden that the Coral Cam captured during the study period.

Temperature, depth, and current flow data were monitored by an acoustic doppler current profiler (ADCP; RDI Sentinel, Nortek aquadopp). Current speed and direction data was collected at between 10-to-25-minute intervals throughout the year. Sediment traps deployed nearby captured the sinking flux off material through the year and a water column profiling system (McLane Profiler) measured several parameters (e.g., backscatter, fluorescence) between 400 to 800m depth over the seamount throughout the year. These data were not used in the present study.

2.2 IMAGE SAMPLING

Approximately 600 individual images were randomly selected from the image data set. Each image was lightened, toned, and overlaid with a grid for easier manual assessment. Images were then analyzed for 1) raw counts of megafaunal presence and 2) coral polyp extrusion status for visible coral colonies. Individual animals were grouped according to the lowest identifiable taxon. Some taxonomic groups are notably difficult to discern via image alone. Such cases were left as complexes (e.g, morphologically indistinguishable grenadier fishes were categorized as *Coryphaenoides acrolepis-filifer* complex). Large coral colonies visible within images were *Paragorgia arborea* (Linnaeus, 1758) (5 colonies) and a single colony of *Keratoisis* sp. Polyp extrusion status was recorded within a binary measure of "open" or "closed" (Fig. 3) for each image. Polyps in the intermediary stage between open and closed were recorded as "closed" until more than 50% of the polyps on an individual were fully extruded.

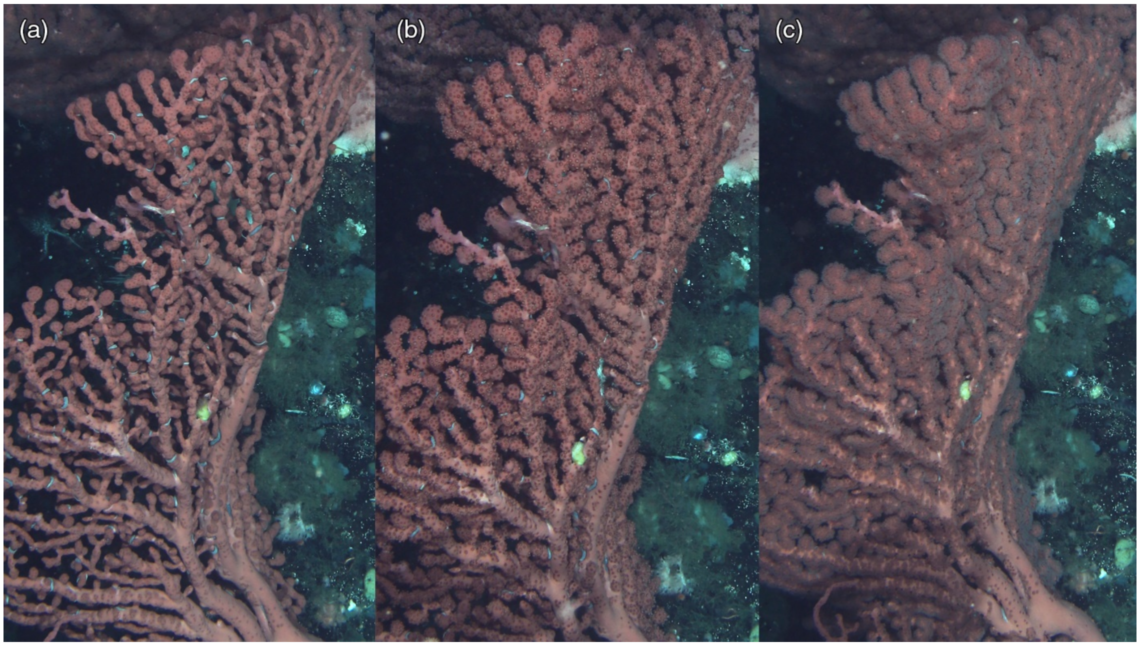

Figure 3: Different polyp extrusion statuses of Paragorgia arborea. a) Polyps retracted (closed state). b) Polyps intermediate sate between fully open and fully closed. c) Polyps extruded (open state).

2.3 SAMPLE ANALYSIS

Abundance data for the year were analyzed using the PRIMER/PERMANOVA software package (Clarke and Gorley, 2015; Clarke et al., 2014). To assess variation in community structure, we excluded sessile species from the analysis since they were present in all images and focused on variation in the abundance of mobile species. Abundance data were prepared in two sets, reflecting averaged or summed monthly totals. Non-metric multidimensional scaling (nMDS) plots were generated using a resemblance matrix based on Bray-Curtis dissimilarity coefficients that were calculated from square root transformed data. Cluster analysis was run concurrently and then overlayed onto the resulting nMDS plot.

3. RESULTS

3.1 MACROFAUNAL ABUNDANCE

We identified 37 unique taxa or groups in the ca. 600 images analyzed (Table 1). These groups were generalized into resident (sessile organisms present within all images) and non-resident (mobile organisms whose presence varied among images). These taxonomic groups were largely identified using the Sur Ridge Guide (Burton et al., 2017).

Our analysis of community similarity throughout the year identified distinct clusters of months with similar assemblage structure. When distributed in an nMDS plot (Fig. 4), a clear pattern and trajectory amongst the analyzed was evident. Clusters of 80% similarity are around groups of consecutive months, while the data as a whole share a similarity of greater than 60%.

Group	Taxa	Group	Taxa
ANNELIDA	Polynoidae	**MOLLUSCA**	*Tritonia tetraquetra*
ARTHROPODA	*Paralomis multispina*		*Benthoctopus* sp.
	Neolithodes diomedeae		*Neptunea-Buccinum* complex
	Lithodes couesi	**PORIFERA**	*Staurocalyptus* sp.
	Chionoecetes tanneri		Unknown porifera
	Pandalopsis ampla	**CHORDATA**	*Embassichthys bathybius*
	Munidopsis sp.		*Microstomus pacificus*
CNIDARIA	*Paragorgia arborea*		*Coryphaenoides acrolepis-filifer* complex
	Keratoisis sp.		*Merluccius productus*
	Actinaria (orange)		*Careproctus kamikawai*
	Actinaria (white)		*Nectoliparis pelagicus*
	Unidentified soft coral		*Sebastolobus* sp.
	Poralia rufescens (?)		*Pyrosoma* sp.
ECHINODERMATA	*Psolus squamatus*		Unknown Liparidae
	Hippasteria sp.		
	Asteronyx sp.		
	Henricia sp.		
	Asthenactis fisheri		
	Poraniopsis inflata		
	Goniasteridae		
	Zoroasteridae		
	Asteroidea (small, white)		
	Asteroidea (small, yellow)		

Table 1: List of macrofauna identified within time-lapse photography images at the Sur Ridge study site between March 2020 and March 2021.

Temporal trends in the presence of different taxa were found to vary between groups. Amongst common Sur Ridge fauna, grenadier fishes were found to have a higher average density in summer months than in winter months (Fig. 5). However, other common mobile animals had abundances that either fluctuated or remained roughly constant throughout the year. The density of the common spiny paralomis crab, *Paralomis multispina* (Benedict, 1894), did not exhibit a seasonal trend (Fig. 6).

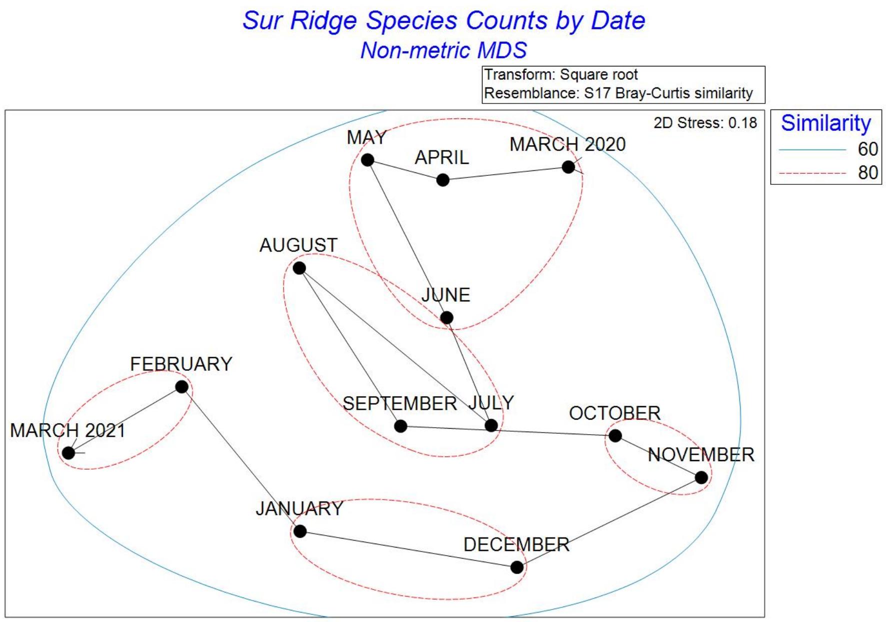

Figure 4: Non-metric multidimensional scaling (nMDS) plot of average monthly abundance. Distances between points visually indicate similarity, while dashed circles group points by percent similarity.

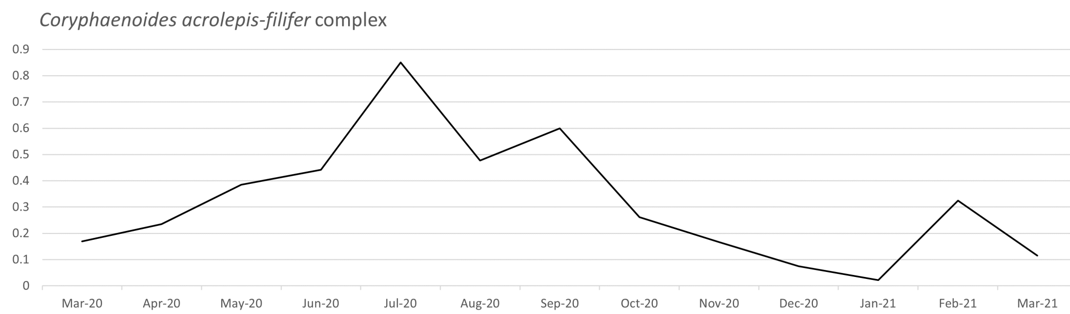

Figure 5: Graph showing change in average monthly abundance of grenadier fishes, *Coryphaenoides acrolepis-filifer* complex. A seasonal peak is seen in summer months, while there is a generally lower density in winter.

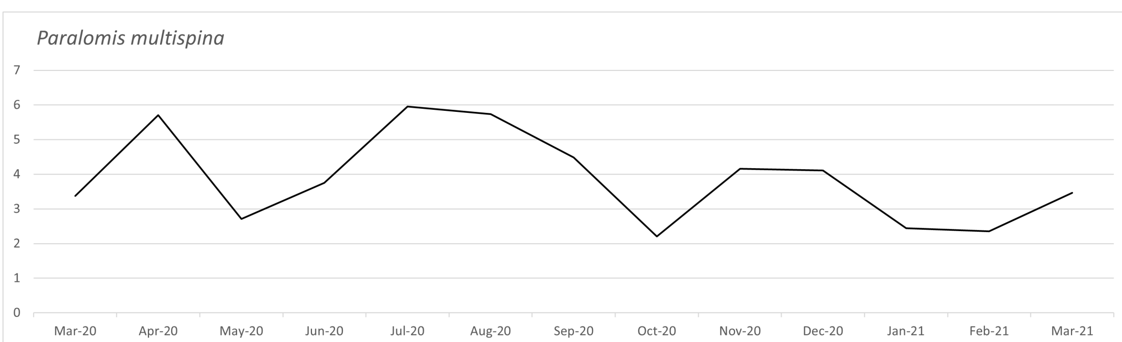

Figure 6: Graph showing change in average monthly abundance of spiny paralomis crabs, *Paralomis multispina*. No distinct seasonal trend was observed.

3.2 POLYP STATUS

Coral polyp extrusion data (i.e., polyps contracted or extruded) were collected simultaneously with abundance counts. Coral polyp openness peaked in the months of July and August 2020, with a majority of corals sampled in this period displaying extruded polyps. The lowest periods for polyp extrusion were found to be March 2020 and February 2020 (Fig. 7). Coral polyp status was then paired with current speed data collected via ADCP. Each sample was paired with the closest recorded current velocity as well as an hourly average. Currents oscillated in speed and direction with the tides, mainly along north-west or east-north-east axes. When plotted, no clear relationship between current speed or direction with polyp behavior was evident (Fig. 8).

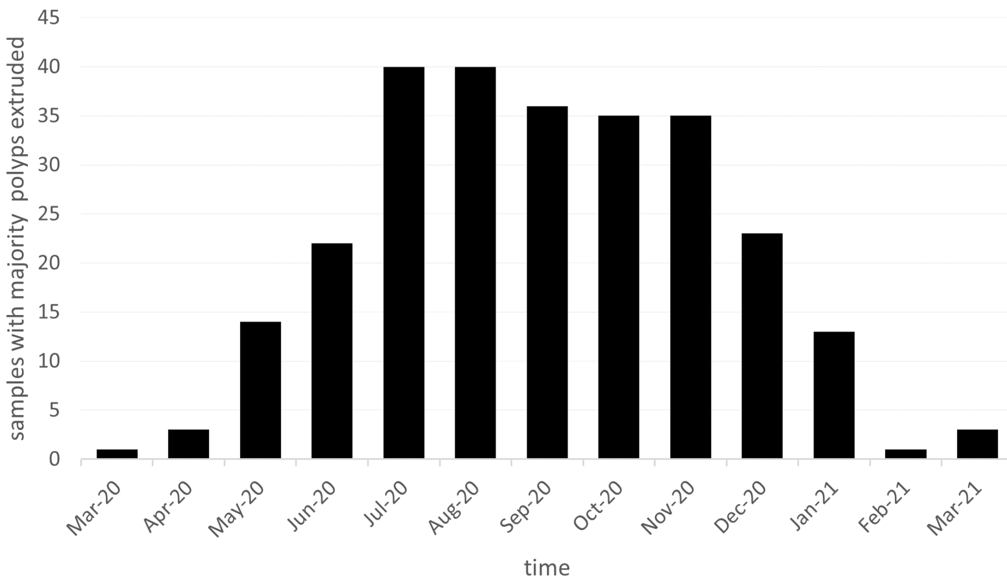

Figure 7: Distribution of samples per month where more than half of observed corals were extruded. Peaks occur in July 2020 and August 2020, whereas lowest number of extruded polyps were observed in March 2020 and February 2021.

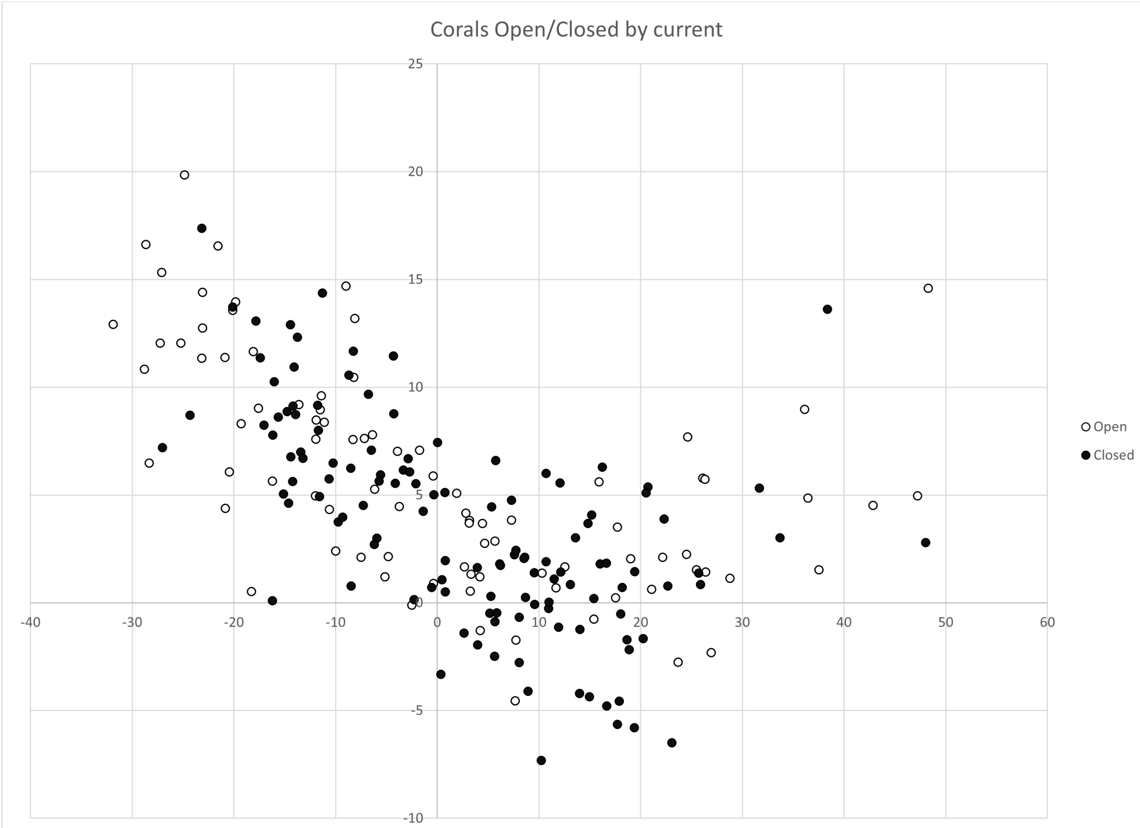

Figure 8: Plot showing the relationship between current velocities (cm/s) on the horizontal (east-west) and vertical (north-south) axes and polyp behavior (open/closed). Data from peak polyp activity months (July, August) and low activity months (March, April) are included.

4. DISCUSSION

Seasonal variation in the diversity and abundance of taxa visiting coral gardens at Sur Ridge may be related to several factors. The life histories of many deep-sea fauna are understudied, making it more difficult to assess reasons for seasonality or lack thereof. However, there is a growing body of literature on more general information about deep-water organisms, such as observed feeding mechanisms and parts of their life histories. Knowledge on feeding strategies can be coupled with extensive research done on surface productivity to provide insight into deep-water faunal behavior and movement.

While many deep-sea taxa are poorly understood, it is possible their variable life histories may contribute to presence and absence at specific times of year. Our data shows that grenadiers exhibited distinct seasonal presence during summer and autumn months, while presence of crabs such as *Paralomis multispina* (Benedict, 1894) did not change in a recognizably seasonal pattern.

The seasonal grouping and trajectory of the mobile assemblage observed in the MDS plot aligns with oceanographic variation in the region. Monterey Bay has a well-documented period of seasonal upwelling that begins in spring months and carries on throughout the summer. Researchers have identified three distinct oceanographic seasons centered around these trends: an upwelling season in spring through summer, an oceanic season in the late summer through fall, and winter or "Davidson Current" season (Pennington and Chavez, 2000; Skogsberg and Phelps, 1946).

Coupling between surface productivity and the deep sea has been characterized repeatedly, with studies estimating that particle transport from the surface can take on the order of weeks to months (Shanks and Trent, 1980). Factoring in organic carbon transport time, spring and summer surface productivity would therefore be in line with our observations of summer to autumn peaks in some mobile taxa and also may be key in stimulating corals to extrude polyps for feeding. It is perhaps more interesting that polyps are mostly closed in winter months. Is there an inherent risk to polyp extrusion that leads to feeding only when food is most abundant?

Many of the mobile macrofauna at Sur Ridge also employ variable feeding strategies that could influence their presence or absence throughout the year. Grenadiers are known scavengers and their density at Sur Ridge may dwindle when there is greater food availability elsewhere. Other studies of benthic deposit feeders have observed patterns in seasonal feeding that very by taxa, with the variability attributed to differences in life histories and feeding habits (Durden et al., 2020).

Past studies of grenadier presence at deeper, abyssal sites has shown evidence that population density increases further from the seafloor (Dunlop et al., 2020). Therefore, grenadier observations may be limited by the locomotive behaviors that put the fish out of range of camera observations. On the other hand, the presence of *P. multispina* does not correlate to season. Previous studies of *Paralomis* behavior observed similarly unclear patterns of movement when compared with tidal rhythms (Aguzzi et al., 2010).

Broader research into the movement patterns and life histories of *P. multispina* could help to shed light on this matter.

5. CONCLUSIONS/RECOMMENDATIONS

Our observations of Sur Ridge indicate that seasonal variation in macrofaunal abundance is clear for some, but not all taxa. Among some common mobile fauna, especially grenadiers, there was a notable seasonality, while spiny paralomis had a less clear pattern. This could be clarified by further research into the life histories, diets, and behaviors of local species. An analysis of the fluorometry data that correspond to the time series reviewed here could also elucidate the role of surface productivity and organic carbon flux in influencing seasonality at Sur Ridge. Examining further links between carbon flux (sediment traps are currently deployed) and the feeding, growth, and reproduction of corals and associated taxa will enhance our understanding of factors that influence deep-sea populations in these ecosystems. The results of this paper offer but a glimpse at Sur Ridge's community structure, underscoring the critical need for more long-term monitoring of deep-sea biodiversity and habitats.

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References:

Aguzzi, J., C. Costa, Y. Furushima, J.J. Chiesa, J.B. Company, P. Menesatti, R. Iwase, and Y. Fujiwara. 2010. Behavioral rhythms of hydrocarbon seep fauna in relation to internal tides. *Marine Ecology Progress Series* 418:47-56.

Bell, J.J., C. Shaw, and J.R. Turner. 2006. Factors controlling the tentacle and polyp expansion behaviour of selected temperate Anthozoa. *Journal of the Marine Biological Association of the United Kingdom* 86(5):977-992, 10.1017/S0025315406013956.

Burton, E.J., L.A. Kuhnz, A.P. DeVogelaere, and J.P. Barry. 2017. *Sur Ridge Field Guide: Monterey Bay National Marine Sanctuary*. National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, U.S. Department of Commerce. National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. , 1-122 pp.

Clarke, K.R., and R.N. Gorley. 2015. PRIMER v7: User Manual/Tutorial. Pp. 1-296 PRIMER-e (Quest Research Limited), Auckland, New Zealand.

Clarke, K.R., R.N. Gorley, P.J. Somerfield, and R.M. Warwick. 2014. CHANGE IN MARINE COMMUNITIES: An Approach to Statistical Analysis and Interpretation. Pp. 1-250 PRIMER-e (Quest Research Limited), Auckland, New Zealand.

Danovaro, R., C. Corinaldesi, A. Dell'Anno, and P.V.R. Snelgrove. 2017. The deep-sea under global change. *Current Biology* 27(11):R461-R465, https://doi.org/10.1016/j.cub.2017.02.046.

Dunlop, K.M., K.J. Benoit-Bird, C.M. Waluk, and R.G. Henthorn. 2020. Ecological insights into abyssal bentho-pelagic fish at 4000 m depth using a multi-beam echosounder on a remotely operated vehicle. *Deep Sea Research Part II: Topical Studies in Oceanography* 173:104679, https://doi.org/10.1016/j.dsr2.2019.104679.

Durden, J.M., B.J. Bett, C.L. Huffard, C. Pebody, H.A. Ruhl, and K.L. Smith. 2020. Response of deep-sea deposit-feeders to detrital inputs: A comparison of two abyssal time-series sites. *Deep Sea Research Part II: Topical Studies in Oceanography* 173:104677, https://doi.org/10.1016/j.dsr2.2019.104677.

Ramirez-Llodra, E., P.A. Tyler, M.C. Baker, O.A. Bergstad, M.R. Clark, E. Escobar, L.A. Levin, L. Menot, A.A. Rowden, C.R. Smith, and others. 2011. Man and the Last Great Wilderness: Human Impact on the Deep Sea. *PLOS ONE* 6(8):e22588, 10.1371/journal.pone.0022588.

Robison, B.H., K.R. Reisenbichler, and R.E. Sherlock. 2017. The Coevolution of Midwater Research and ROV Technology at MBARI. *Oceanography* 30(4):26-37.

Shanks, A.L., and J.D. Trent. 1980. Marine snow: sinking rates and potential role in vertical flux. *Deep Sea Research Part A. Oceanographic Research Papers* 27(2):137-143, https://doi.org/10.1016/0198-0149(80)90092-8.

Sweetman, A.K., A.R. Thurber, C.R. Smith, L.A. Levin, C. Mora, C.-L. Wei, A.J. Gooday, D.O.B. Jones, M. Rex, M. Yasuhara, and others. 2017. Major impacts of climate change on deep-sea benthic ecosystems. *Elementa: Science of the Anthropocene* 5, 10.1525/elementa.203.

Zuazo, A., J. Grinyó, V. López-Vázquez, E. Rodríguez, C. Costa, L. Ortenzi, S. Flögel, J. Valencia, S. Marini, G. Zhang, and others. 2020. An Automated Pipeline for Image Processing and Data Treatment to Track Activity Rhythms of Paragorgia arborea in Relation to Hydrographic Conditions. *Sensors* 20(21):6281.