

**A Comparison Between Megafaunal Presence and Oxygen Concentration at Two
Sites in the Barkley Canyon, Vancouver Island**

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Abstract

Barkley Canyon is a submarine canyon located on the west continental margin of Vancouver Island, British Columbia in the Northeast Pacific Ocean. This area is known for seasonal upwelling, which accounts for lower, temporally varying oxygen levels along the margin at depth. Oxygen concentration data from in situ CTD's and video footage, obtained from Ocean Network Canada installations in Barkley Canyon, were used to examine correlations between megafaunal abundance and diversity, and oxygen fluctuations from two sites at Barkley Canyon. The Upper Slope site is located along the slope ridge and at a depth of approximately 400 meters and the Mid-Canyon site is located within the canyon towards the base at approximately 890 meters. There is a decrease in the number of species present at the Mid-Canyon site, in correlation with the decrease in oxygen concentrations. A similar correlation was not observed at the Upper Slope. Oxygen is necessary for most organisms to live, whose importance increases at depths that contain lower oxygen levels than surface waters.

The deep sea is home to a variety of geological features such as abyssal plains, mid-ocean ridges, trenches, and submarine canyons. Barkley Canyon is a submarine canyon located off of the west continental margin of Vancouver Island, British Columbia. Submarine canyons can be formed via different processes such as river erosion from when sea levels were lower, exposing the continental margin, glacial retreat, and underwater landslides. Barkley Canyon resides along an active boundary between the Pacific and North American Plates, making it a unique site rich in hydrate mounds. Sediments are also accreted onto the slope as the Pacific Plate subducts, changing the physical shape and structure of the canyon slowly over time (Herzer, 1981).

Submarine canyons affect many oceanic processes, including increasing upwelling within the canyon, increasing and concentrating the deposition of detritus and sediment to a focused area, and creating a biological hotspot within the deep sea (De Leo, 2010). These features are a result of the canyons channeling nutrients that are typically sparse in the deep sea down to the bottom of the ocean. The canyon itself also acts as a disruption to current flow, creating a displacement of water away from the canyon, inducing upwelling within the canyon. This upwelling brings with it more nutrient-rich waters, further increasing bio-productivity within and around canyons (Allen, 2001).

Seasonal upwelling is another feature present at Barkley Canyon (Juniper, 2013). The Northeast Pacific undergoes seasonal upwelling along the coast during summer months, which can increase the influx of nutrients into the canyon. With seasonal upwelling come seasonal blooms that occur within the photic layer of the ocean. As the blooms end, there is an increase in the amount of marine snow that will reach the deep sea at an increased rate due to the increased circulation within the canyon. This is yet

another source of resources that allow Barkley Canyon to be a more productive area than the surrounding deep sea (Allen, 2001).

Physical properties affecting water flow may also change the water mass properties. Oxygen concentration within water masses can be correlated to the temperature, colder water retains more gasses, productivity (photosynthesis and respiration of organisms) and therefore age (more oxygen is typically younger). Water that is upwelled tends to be low in oxygen, high in nutrients, and colder, which are observed with the upwelling off the West North American coastline.

With an increase in the resources available within a canyon site there will be an observed increase in the amount of organic material and life present within the deeper regions of the canyon. Shallower regions in the canyon have too high of a water flux to allow for the settling of the majority of detritus that falls into the canyon (Allen, Physical). A decrease in the water flux with depth allows for detritus to gradually settle out and deposit along the canyon floor, which is where species diversity will begin to increase (De Leo, 2010).

The purpose of this study is to compare megafauna at two different sites along Barkley Canyon over a three-month time frame. One site, the Upper Canyon, is at a shallower depth of approximately 400 meters and is located along the canyon ridge. The other site is located within the canyon, the Mid-Canyon, and is at a depth of approximately 890 meters located towards the canyon's basin. The comparison of megafauna by morphotype will include a species count in order to determine who and how many are present at each study site (Fig. 1).

Some hypotheses that this paper will test are:

1. Mobile organisms will be observed in greater quantities than benthic organisms at the Upper Slope site in correlation to the fluctuations in oxygen.
2. Megafaunal species richness will be depressed at the Mid-Canyon site, when compared to the Upper Slope site, due to lower oxygen concentrations.

Methods

Data was collected through the archived files available online via the Ocean Networks Canada Northeast Pacific underwater observatory stations located along Barkley Canyon (Ocean Networks Canada Data Archive, 2013-2014). Color and black and white video footage from cameras and oxygen concentration data from CTD's stationed at two sites were utilized in correlating megafaunal abundance and oxygen fluctuations over a three month time frame.

CTD Data

Using the oxygen concentration data collected by the CTD, plots showing the fluctuations in oxygen were created. Oxygen concentrations were collected every hour by the CTD. The hourly data was averaged in order to determine the average oxygen concentration. This was done to remove some of the fluctuations that occur on a daily scale, in order to ensure the maximum and minimum days were analyzed for megafaunal versus oxygen correlations. Once the days with the highest and lowest oxygen concentrations (in relation to the oscillating changes in oxygen) and a few neutral days were determined, the associated video footage was analyzed.

Video Footage

The Upper Slope and Mid-Canyon sites contained its own color video camera with a view of the seafloor and a pipe scale marker. At the Mid-Canyon site, the camera took two types of video clips every two hours approximately. The first clip contained a scanned area of seafloor and paused at several different sites. The second clip was consistently taken at the same site for the same approximate time. As a result, only the second video clip was used in determining megafaunal abundance. At the Upper Slope site, the camera took video clips every two hours approximately, with the footage being of a consistent site. All footage was watched in order to count organisms that moved into the camera's view point later.

Species Classification

In order to determine megafaunal diversity at each site, the quantity of species based on morphotype, with the number of individuals, was counted. There were several technical difficulties with the footage from the Upper Slope site including loss of visible area due to lighting and a majority of video footage being black and white (despite being a color camera). Due to the video footage being pixilated and with inconsistencies in color at the Upper Slope sight, the presence of benthic (on the seafloor) and swimming (mobile within water column) shrimp-like organisms was done as a presence or absence, and was left out of any comparison calculations between the Upper Slope and Mid-Canyon sites. Unidentified organisms were determined from either:

1. Noticeable burrow with movement in and out of the burrow that doesn't follow the directional flow of water.

2. Coloration and movement of an organism within water column or along seafloor that is too small to be identified or shows no key identifying features due to poor video quality or lack of appropriate lighting.

Fish were counted if an identifying feature, such as a fin, appeared within the cameras view and they were identified to family type and then species if possible. However not all could be identified to species, so for the comparison between sites, the number of individuals in family was used. Mobile species were identified as organisms actively moving within the water column, while benthic organisms were identified as those present only on the sea floor.

Using the data collected every two hours, the number of individuals and species were compiled together in order to determine the how diverse the communities at the two sites are (Fig. 3). This data is then compared to oxygen concentrations (Fig. 4 & Fig. 5) in order to determine if the shifts in oxygen affect how many organisms inhabit the site or if certain species cannot handle the shifts in oxygen.

Results

The Upper Slope and Mid-Canyon sites yielded different dominant species, different oxygen concentrations and trends, and had different correlations between one another.

Upper Slope

The dominant species present at this shallower site were composed of urchins (*Strongylocentrotus fragilis*), a species of snail, referred to as Snail 2, and sea cucumbers

(Fig. 7). There is also a noticeable difference in the mobile species observed at the site. A higher diversity in fish is observed and while not all fishes could be identified to species, *Anoplopoma fimbria*, *Sebastes crameri*, and *Sebastes miniatus*, were a few that were identified conclusively using the Marine Life Field Guide from NEPTUNE Canada. Other organisms that were identified to species include the Dover Sole (*Microstomus pacificus*), Pacific Giant Octopus (*Enteroctopus dofleini*), and cnidarians (*Poralia rufescens* and *Voragonema pedunculata*). Shrimp were found to be consistently present and at very high concentrations. A count could not be completed for all the video footage; however, it was observed that there were far more shrimp-like organisms than any other species present and appeared to be correlated with the velocity of water. With the footage being primarily black and white, it was not possible to determine whether an organism was a shrimp or another species due to no distinctive coloration differences. In addition, the lighting in the black and white footage created larger contrasts making it impossible to count if shrimp-like organisms were present in the white spot created by the light or the contrasting black area.

This site has higher fluctuations in oxygen (Fig. 2), yet the species and individuals present during different oxygen concentrations does not appear to vary greatly (Fig. 4 & Fig. 5). The only noticeable difference is one of the points that are far higher during maximum oxygen levels, and this is due to the high amount of urchins throughout the day. The oxygen concentrations ranged from 0.8523 mL/L to 1.5501 mL/L, with a mean concentration of 1.1522 mL/L.

Mid-Canyon

This deeper site contained different dominant species in comparison to the shallower Upper Slope site. These species included crabs, snails, and shrimp. The snails observed at this site are different from the snail species primarily observed at the Upper Slope site. Video footage of the crab and shrimp species requires a higher resolution in order to identify them down to the species level, however a Grooved Tanner crab (*Chionoecetes tanneri*) was observed once. Other organisms that were identified included a hagfish (*Eptatretus* sp.) and some sablefish (*Anoplopoma fimbria*).

While this site doesn't have as dramatic fluctuations in oxygen concentrations as the Upper Slope site, the amount of oxygen is far lower with an overall mean of 0.2653 mL/L concentration. The oxygen concentrations ranged from 0.2498 mL/L to 0.2777 mL/L. With the smaller shifts in oxygen concentrations, there were shifts in the species present but not in the overall individuals present at the site (Fig. 3 & Fig. 4). The

Discussion

Megafaunal presence through periods of lower or higher than normal oxygen concentrations can give insights as to what the dominant organisms of the region are, and their sensitivity to oxygen concentrations. It can also help demonstrate whether or not oxygen may be the primary factor in determining the biological ecosystem at depth. At the Mid-Canyon site, there is a correlation between oxygen fluctuations and the number of species present, whereas the Upper Slope site did not have any correlations. This shows that oxygen is affecting which species are present at the Mid-Canyon site, but not the Upper Slope site.

The Upper Slope site contained more mobile organisms in the water column than benthic organisms. While some of the organisms on the seafloor are mobile, such as shrimp and urchins, they are categorized as benthic because they are not seen moving throughout the water column. At the Upper Slope, fluctuations in oxygen concentrations occurred over a greater range than at the Mid-Canyon site due to physical properties inducing mixing at a shallower depth (De Leo, 2010). The Mid-Canyon site had lower species richness than the Upper Slope (Fig. 3) due to the location of the site being located within an oxygen minimum zone (OMZ).

An OMZ in the deep sea is defined as a region of the ocean that has an oxygen concentration less than 0.5 mL/L (Levin, 2002). The Mid-Canyon site falls far below that and with an average oxygen concentration of 0.2653 mL/L, the site qualifies as an OMZ. Some species are more tolerant to slight oxygen shifts (Rogers, 2000) and have the ability to move away from lower oxygen areas as needed. Diversity is inhibited within OMZs, when oxygen concentrations are below 0.45 mL/L (Rogers, 2000), supporting the result of seeing less diversity at the Mid-Canyon site than the Upper Slope.

In order to determine if more physical properties are having other effects on the organisms, further studies need to be done and take into account tidal and seasonal water flow patterns, shifts in detritus material that makes its way into the canyon, including the rate of marine-snow fall, and over a more extensive time period. A problem with being limited to one frame meant that while the increase of turbidity could be observed, the presence of fish or other organisms could not be recorded because they never came into

the view of the camera. Increasing the area observed could also give more overall data to help make more definitive conclusions. In addition other events such as when snails burrow or emerge could provide an interesting study for the future.

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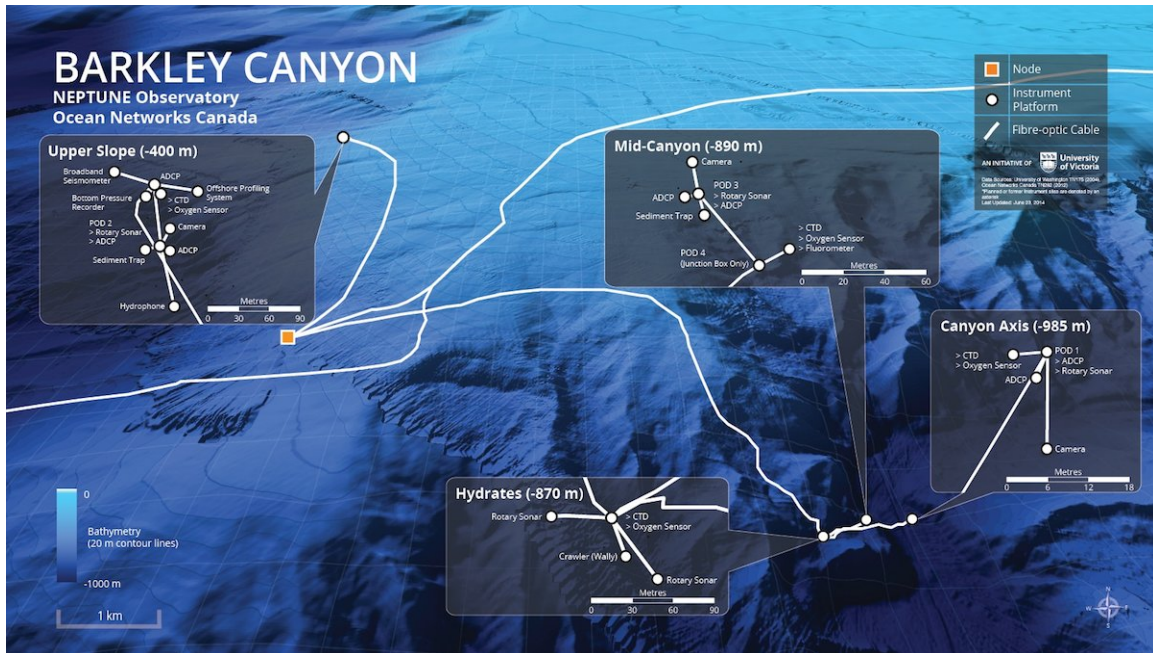


Fig. 1. A map of Barkley Canyon with the location, depth, and instruments associated with the sites. Ocean Networks Canada
<http://www.oceannetworks.ca/installations/observatories/northeast-pacific/barkley-canyon>

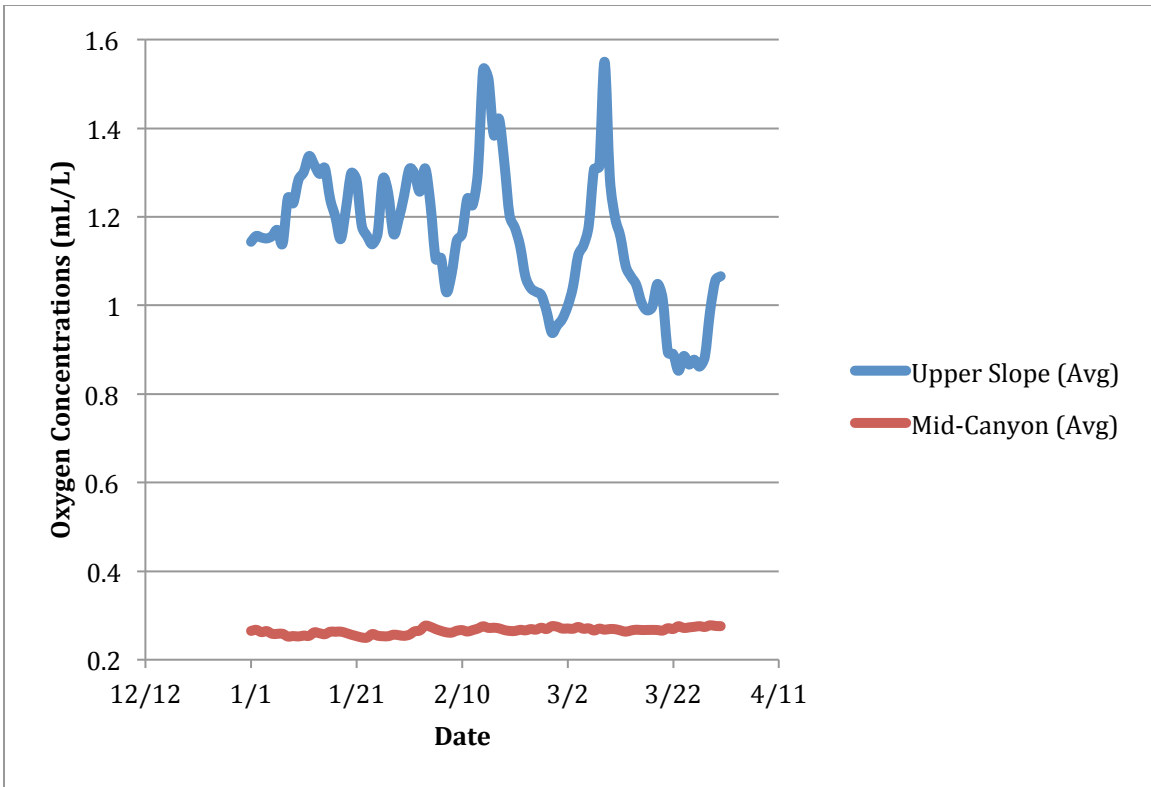


Fig. 2. This graph is a comparison between the oxygen concentrations in milliliters per liter over three months at two different locations at Barkley Canyon.

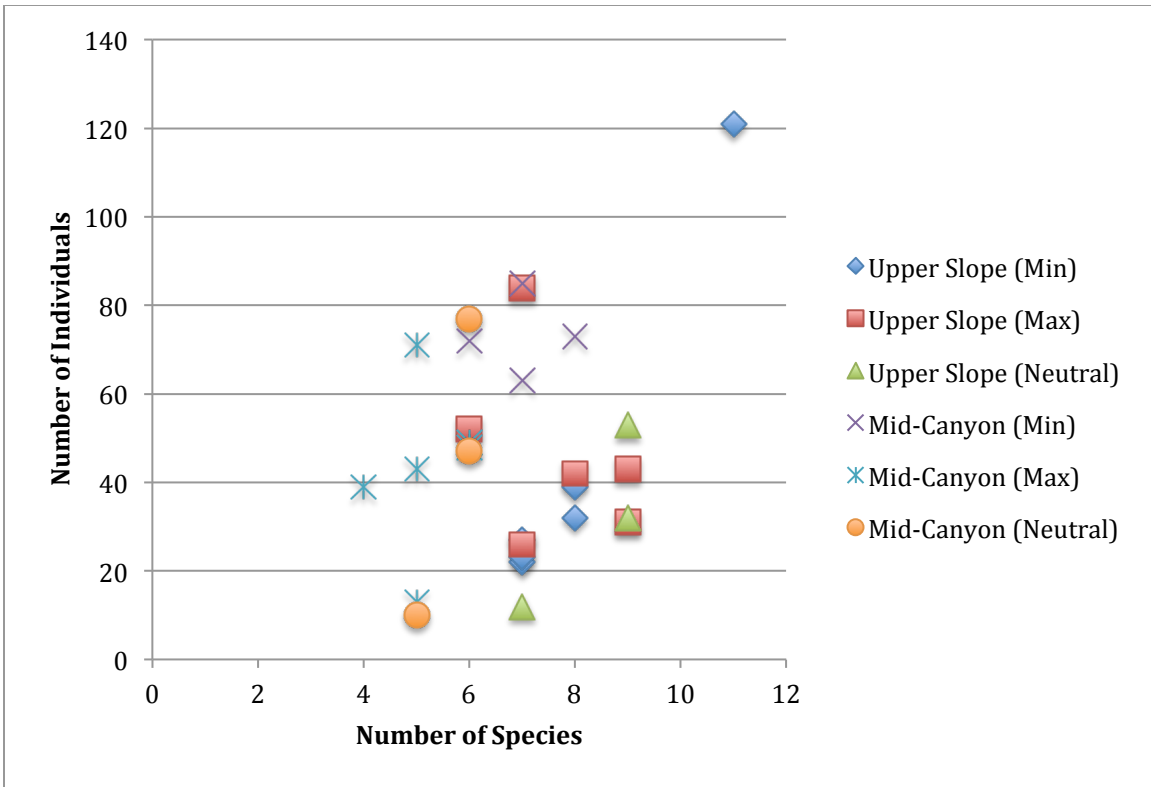


Fig. 3. This is a graph comparing the number of individuals with the number of species at the two sites during oxygen minimum (Min), maximum (Max), and intermediate (Neutral) concentrations.

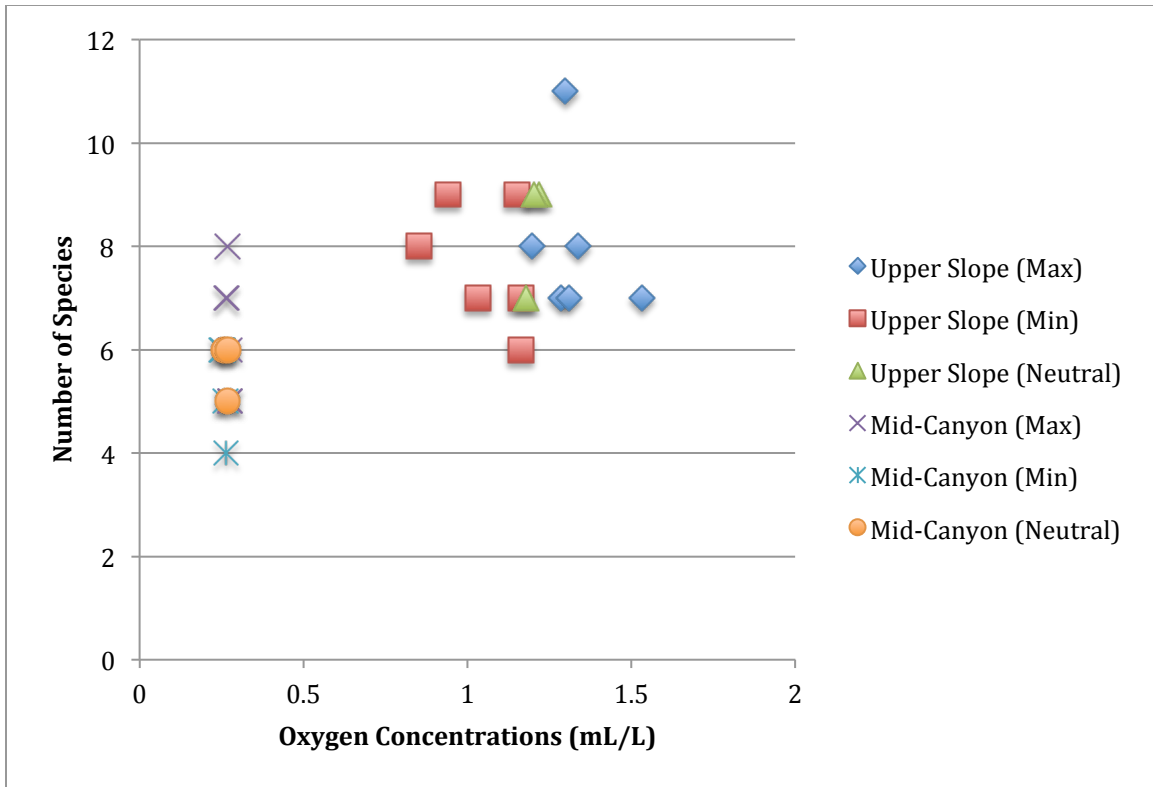


Fig. 4. This is a graph comparing the number of species with oxygen concentrations at the two sites during oxygen minimum (Min), maximum (Max), and intermediate (Neutral) concentrations.

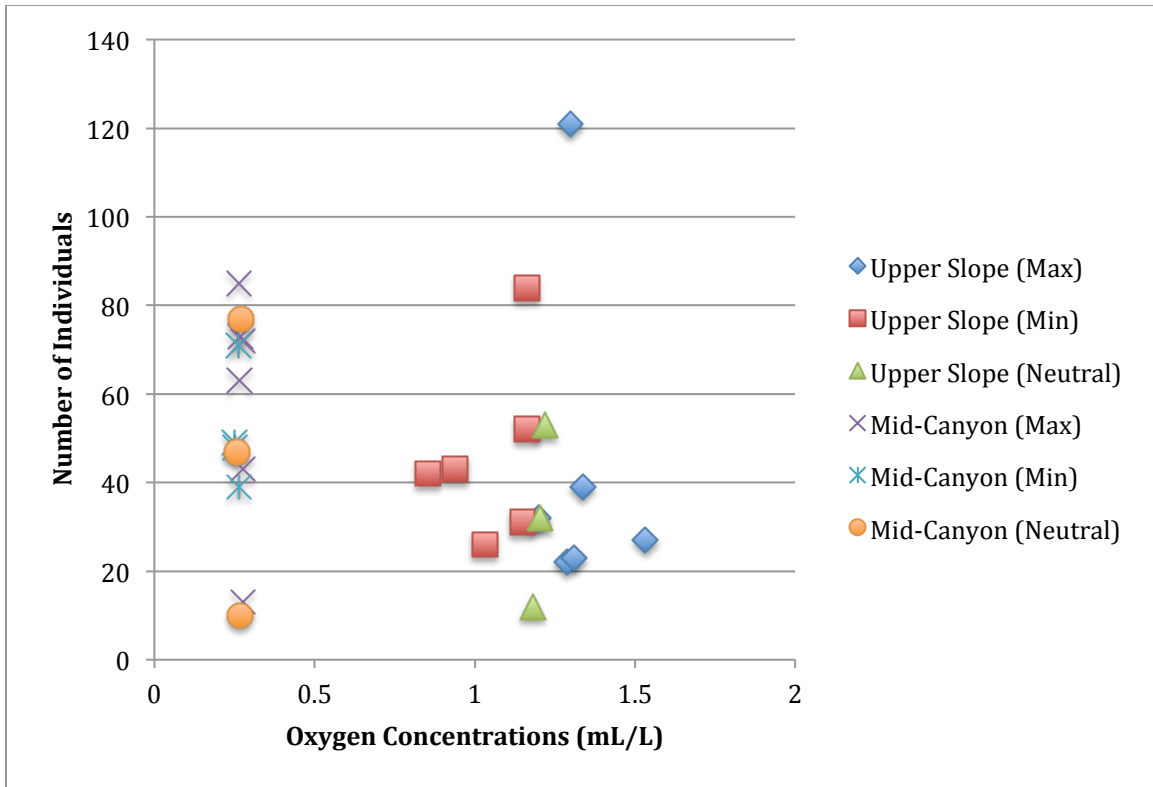


Fig. 5. This is a graph comparing the number of individuals with oxygen concentrations at the two sites during oxygen minimum (Min), maximum (Max), and intermediate (Neutral) concentrations.

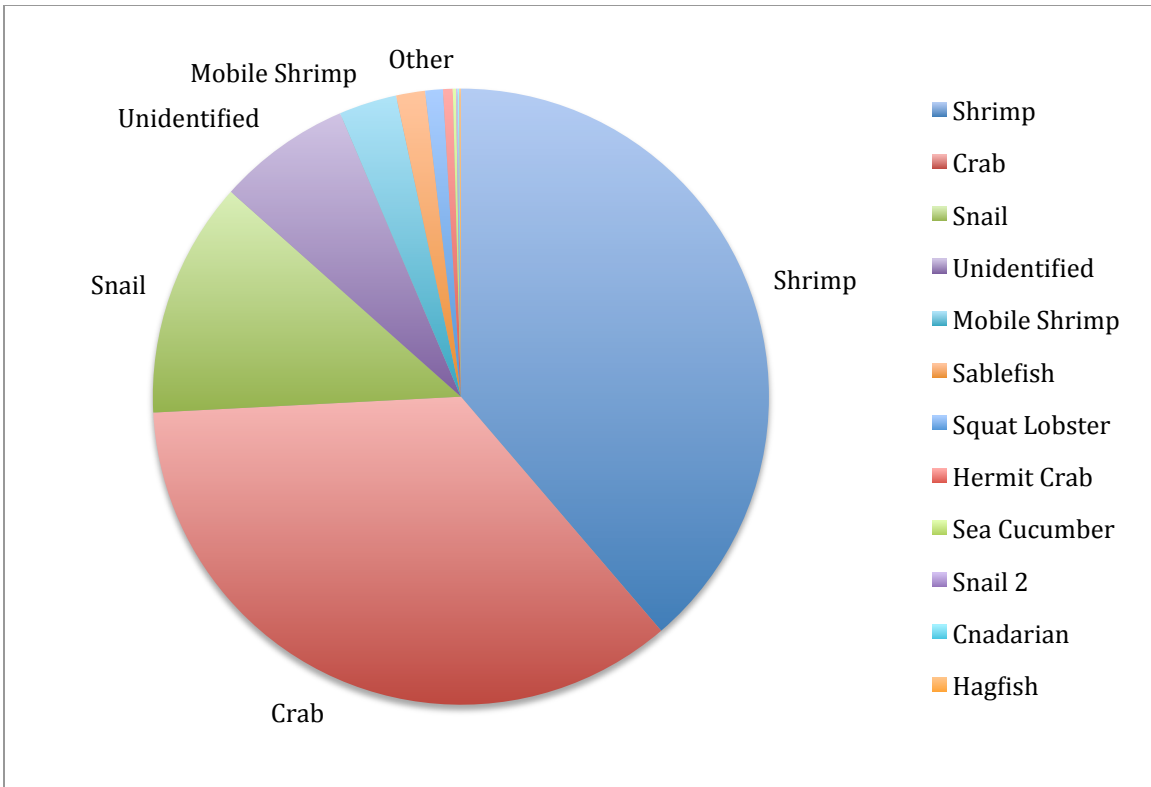


Fig. 6. This chart demonstrates the dominant species at the Mid-Canyon site. Mobile shrimp refers to the shrimp that are actively moving within the water column, versus shrimp, which refers to those that are stationary on the seafloor.

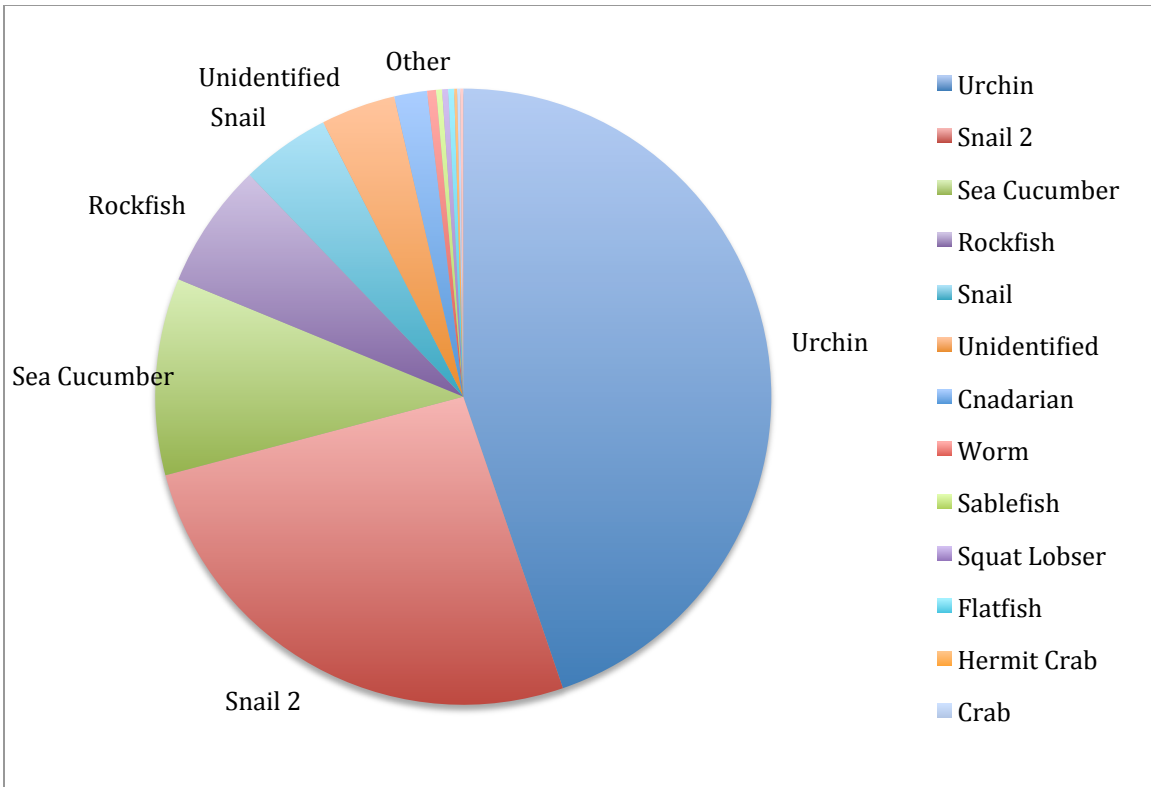


Fig. 7. This chart demonstrates the dominant species at the Upper Slope site. Shrimp has not been included due to presence/absence approach.