Observing Early Colonizing Species On the Central Coast of British Columbia

ES 470: Conservation and Biodiversity of Coastal British Columbia
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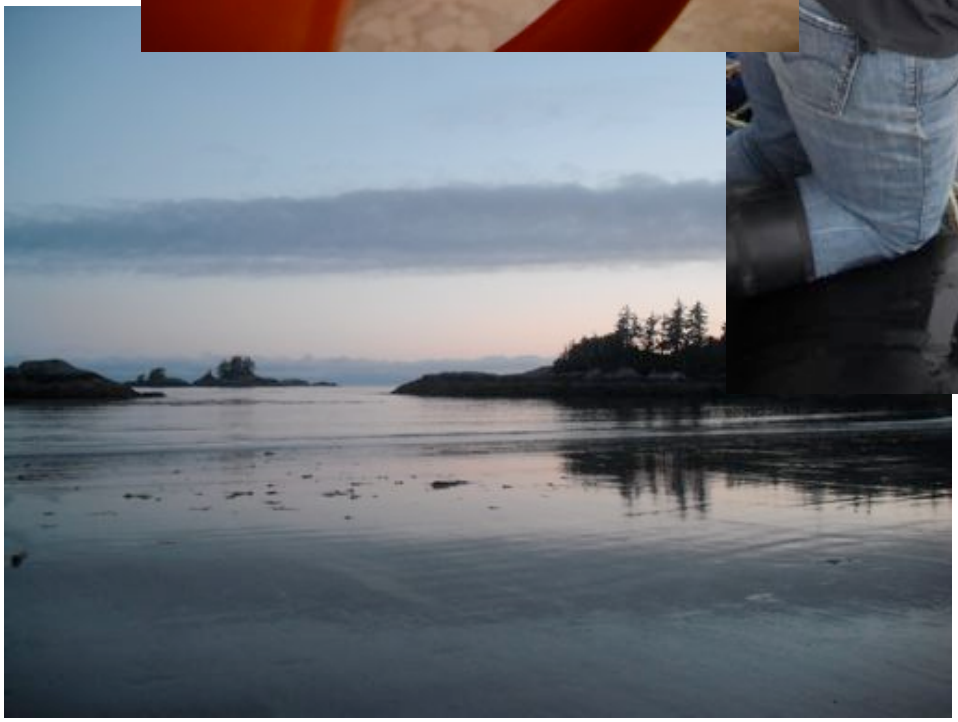

Abstract

Identifying early colonizing marine species is important for the recovery of an ecosystem after a disturbance, to determining the health of a system, and to understanding the community composition and species richness of an area. This study, conducted near Calvert Island in the Great Bear Rainforest, provides baseline information about healthy community systems for future reference. Ceramic mugs were used as settling plates; they were placed in the ocean for 12-days. The mugs were placed at sheltered and exposed locations with three depths at each location (2m, 10m, and 20m below surface). The organisms found on the mugs were divided into 11 groups based on similar characteristics; their presence or absence on each mug was recorded and multivariate statistics were used to analyze community structure. There was a significant difference between community structures at the exposed and sheltered sites across all depth groups. There was a significant difference in the species present only between depths of 2m and 20m across both exposure treatments. The percent contributions of each species to community structure were determined. From this analysis, inferences were made about the life history of species. The presence of algae near the surface was likely due to optimal photosynthetic conditions; the Amphipod and Copepod presence and percent contributions at almost all sites likely reflect r-selected characteristics; the Foam Algae's ability to handle lower photosynthetic levels may be suited to a niche at lower depths and shows that light reaches to at least 20m. The Algae seem to establish in sheltered areas and the Foam Algae may have been especially suited to low fetch areas.

Introduction:

Identifying early colonizing marine species is important in regards to the recovery of an ecosystem after a disturbance, to determining the health of a system (Risk, 1973), and to understanding the community composition and species richness of an area. Successful settlers control community structure (Diaz-Castañeda, 2000) and the recruitment of species is a foundation for all future interactions in an ecosystem (Woodin, 1991).

This study was conducted near Calvert Island, located on the central coast of British Columbia (BC). The area is part of the Great Bear Rainforest, a highly productive and diverse area, which hosts a relatively intact coastal temperate rainforest ecosystem. The Great Bear Rainforest is a protected area that accounts for one third of the north and central coast of British Columbia, covering five million hectares (Rainforest Solutions project, 2011).

Temperate coastal rainforests are one of the rarest and most productive forest types in the world (McAllister & Read, 2010). This protected area has a high proportion of coastline, and its health should not be considered separately from the ocean. There are many land-sea interactions and flows that make the health of the surrounding ocean important. For example, many birds, like the Marbled Murrelet, forage for food in the ocean and bring guano to the land (Norris *et al.*, 2007). There has been little research conducted regarding colonization in this area to date. Knowing more about ocean colonization and primary settlers in a healthy area is important in case of a major disturbance.

Settling plates have been a successful and effective tool for studying communities in many circumstances (Diaz-Castañeda, 2000; Lenz *et al.*, 2004); Hurley, 1973). A study in Todos Santos Bay, Baja California investigated the colonization process of polychaetes (Diaz-Castañeda, 2000). Using settling plates, Diaz-Castañeda (2000) was able to obtain significant results about the composition and structure of polychaete communities. Lenz *et al.* (2004) exposed the communities to intermediate disturbances by using settling plates with existing communities on them and exposing them to different levels of disturbance. They found that community stability was not positively correlated with community age and structure.

Settling plates also provide information about community composition. Some groups found at our test location include amphipods, copepods, algae, bivalves and molluscs. All have diverse and different life histories.

Gammaridea are the most abundant and diverse amphipod; they exist in most marine environments and at most depths (Gross *et al.* 1986). Female Amphipodia spawn in a 'mating embrace' that can last for several days (Ibid.). Eggs are laid in the female's sixth thoracic sternite and can number from 1 to 200 (Ibid.). Adult amphipods range from less that 1cm to 28 cm (Ibid.). Amphipods are a major source of food for many other marine species (Ibid.).

Copepoda are an essential link between phytoplankton and higher trophic levels because they are the largest class of crustaceans (Lavens & Sorgeloos, 1996). Adults are generally 1-5mm in length, and their heads have a central naupliar eye and very long antennae (Ibid.). Copepods are selective filter feeders. They moult at all stages as they grow (Ibid.). Some copepod species can produce dormant eggs with thick shells when faced with poor conditions. For example, birds or other animals can eat them, but the eggs will survive and be spread across great distances (Ibid.).

Gastropods are a very diverse group of animals and are found in just about every habitat on Earth (Bunje *et al.* 2004). The diversity of feeding methods demonstrated by the gastropods may enable this prolificness. Most aquatic gastropods are benthic, although some are planktonic (Ibid.). They all have a muscular foot, a hard shell, and a mantle that separates the soft body from the shell and secretes the shell material. The shell of a juvenile is usually a smaller version of the adult shell, and protects the animal from predation, desiccation, and wave forces.

Bivalves are molluscs that possess shells with two halves; they are also known as Pelecypoda and are without heads (Harbo, 1997). Most are filter feeders, however, some are predatory (Ibid.). There are about 10,000 known living bivalve species, 180 of which are in British Columbia (Ibid.). Of these, 70 species are intertidal to 50m deep (Ibid.). Most have separate sexes and are broadcast spawners (Ibid.). Eventually they settle, grow a shell, and attach to a hard surface (alternatively they may burrow; Ibid.); they are the world's oldest living animals (Ibid.). The number of intertidal bivalve species decreases northwards due to colder temperatures (Ibid.).

Algae are split up into three major groups: green algae, brown algae, and red algae (Mondragon & Mondragon, 2003). Green algae consist of approximately 8000 species and are part of the Phylum Chlorophyta. They have chlorophyll a and b, used for capturing sunlight and making food (Ibid.). Green algae are usually bright green and are often motile (Ibid.). Brown algae include about 2000 species that are almost entirely marine; all are multi-cellular (Ibid.). Brown algae can be yellow to dark brown or olive due to the chlorophyll a and c that they contain, as well as the brown accessory pigments (Ibid.). Red algae are members of the Phylum Rhodophyta, which has about 6000 species that are mostly marine (Ibid.). They possess chlorophyll a as well as a red accessory pigment. They also often have a blue accessory pigment, meaning that they can be various colours, ranging from light pink to red, yellow, brown, or almost black (Ibid.).

Barnacles have a hard shell that they secrete to protect themselves from desiccation and predators (Lohse & Raimondi). They are mostly filter feeders and use their legs to capture food (Ibid.). Adult barnacles are hermaphroditic, the "male" taps nearby barnacle with its elongated penis, and inseminates them if eggs are present (Ibid.). The eggs are brooded within the barnacle's shell and the larvae are then released into the water, this stage is their only free-floating stage; the rest of their life they attach to a hard substrate and are sessile (Ibid.).

Members of these groups of organisms are found near Calvert Island, BC. The purpose of this investigation was to look at the effects of varying depths (2m, 10m and 20m) and exposures (exposed and sheltered) on species richness and the presence or absence of settling organisms on artificial substrata. Emphasis was placed on gaining knowledge about species richness, as well as documenting which organisms have a fast colonization rate.

Materials & Methods:

Location

Our experiment compared settling organisms at two locations (Fig. 1) and three depths using settling plates. The locations were chosen based on total depth (a minimum of 25m deep at mid-tide) and a minimal slope of the ocean floor. A local fisherman was consulted regarding site selection; he advised using the two locations selected due to their appropriate depth and maximum variability between the site, within the boundaries of our means of transportation (Rod, pers. comm., 6/6/2011). Site 1 (lines a/A - e/E) was in Doger Strait (N 51º 39.83; W 128º 05.17) and Site 2 (lines f/F - j/J) was in Kwakshua Channel (N 51º 38.97; W 128º 05.26; Fig. 1).

To determine the exposure of the sites we used local knowledge and the measuring function in Google Earth. It was determined that Site 2 (~4km from land to the west; exposed) has an amount of fetch approximately four times greater than Site 1 (~1km from land to the west; sheltered) with prevailing winds going from west to east.

Figure 1. Map showing the two locations at which buoy lines were anchored for the 12 day time period. Adapted from Google Earth, 2011.

Depth

The three different depths were chosen based on Hurley's methods and results (1973), which found significant differences in settlement within 5 meters of the bottom in an area 30m deep when compared to shallower depths. Therefore, our locations were selected to be approximately 25m in depth (Table 1.) with our lowest mug attached to rope 20m below the buoy, our second lowest was attached 10m below the buoy, and the highest was attached 2m below the buoy (Fig. 2). Three mugs attached to each rope and five replicates at each location resulted in a total of 30 mugs (15 at each location, and 5 at each depth at each location). We allowed 20m of slack on each rope for the fluctuation of tides and possible shifting of the anchor on the ocean floor.

Materials

We obtained 30 ceramic glazed mugs, which were sanded by hand with sandpaper of grits 80 and 120. The mugs were then scraped through gravel to create roughage for optimal substrate for settling species. Other materials included ten 50m ropes, ten 15lbs anchors, ten buoys (see Fig. 2), two zap-straps to attach each mug to the ropes (60 in total), a depth finder and a Garmin eTrex Venture GPS device.

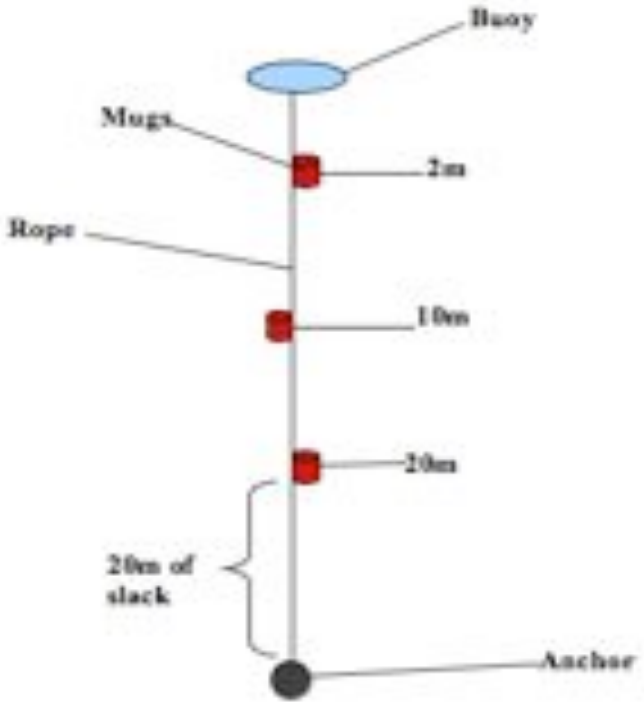

Figure 2. The layout of the lines left in the ocean, showing the buoy, rope, anchor and location of mugs along the line.

Deployment

We placed each of the anchors approximately 40m apart to minimize possible tangling of the ropes. For each line, we marked their GPS location with a Garmin GPS device and measured depth with a sonar detection unit (Raymarine chartplotter and GPS) installed on the boat. We then left our mugs in these two locations from Wednesday June 8 until Sunday June 19 - a total of 12 days (which was the maximum amount of time we were able to leave the mugs in the water).

Table 1 (below) shows the location and depth of each line, and the time of day they were deployed. There are two sets of coordinates because we used two GPS devices; together they give a zone of where line drop-off occurred. The tide was mid-high, so the depths varied from about 20.2m to 26.2m.

Table 1. Coordinates, depth and time of day recorded for line drop off using both a depth finder and a hand-held Garmin GPS device. (Sub-meter accuracy for GPS was not available and the lines shifted, so it was not possible match up the exact lines we deployed and collected.)

Line	Depth Finder	Handheld GPS	Depth Finder (at time of Garmin GPS Waypoint)

	Coordinates	Depth (m)	Time of Day (08/06/11)	Coordinates	Depth (m)
a	N51°39.852 W128°05.039	-	15:41	N51°39.849 W128°05.038	24.4
b	N51°39.849 W128°05.053	25.2	15:44	N51°39.845 W128°05.046	25.6
c	N51°39.862 W128°05.059	25.3	15:48	N51°39.861 W128°05.057	25.3
d	N51°39.892 W128°05.030	22.6	15:55	N51°39.886 W128°05.046	25.3
e	N51°39.878 W128°05.081	25.4	15:57	N51°39.887 W128°05.098	25.4
f	N51°39.026 W128°04.167	22.8	16:19	N51°39.028 W128°04.166	24
g	N51°39.046 W128°04.203	26.2	16:23	N51°39.049 W128°04.206	25.4
h	N51°39.043 W128°04.142	25.6	16:27	N51°39.041 W128°04.141	24.5
i	N51°39.068 W128°04.111	24.8	16:30	N51°39.073 W128°04.106	25.4
j	N51°39.112 W128°04.054	20.2	16:36	N51°39.114 W128°04.060	24.9

Two test mugs were hung off the Hakai Beach Institute dock. They were attached to anchored ropes and were placed 1.5m and 2m below the water's surface. Each cup was attached to the rope using two zap-straps. The water below the dock was approximately 2.5 meters deep at low tide, making this area shallower and very different than our experimental mugs. The purpose of these two mugs was to collect information on how to identify early settling species in nearby waters and to see if the substrate was suitable for colonization.

Retrieval

On June 19, 2011 all of the lines were taken out of the water. The mugs were only touched on the handles and were transported with minimal contact to other surfaces in order to lessen the impact on species present and to avoid accidental species loss. The coordinates, depth and time correlating to each line at pick-up are shown in Table 2. The tide was lower than at drop-off, so the depths vary from 15m to 29m.

Table 2. The coordinates, depth and time of line pick-up on 19/06/11. (Sub-meter accuracy for GPS was not available and the lines shifted, so it was not possible match up the exact lines we deployed and collected.)

Line	Coordinates	Depth	Time	Notes
A	N51°39.879 W128°05.065	22.7m	12:14	
B	N51°39.886 W128°05.031	21.5m	12:26	Kelp on rope
C	N51°39.864 W128°05.056	24m	12:30	Jingle, ulva linza
D/E	N51°39.844 W128°05.047	22m	12:35	Lines tangled together
F	N51°39.119 W128°04.020	26m	13:24	Less kelp found, graceful crab
G	N51°39.081 W128°04.088	19m	13:31	Missing 20m cup
H	N51°39.035 W128°04.129	15m	13:38	Tangled with anchor, pulled stuff up with it from bottom
I	N51°39.027 W128°04.149	18m	13:43	Lots of resistance on line
J	N51°39.053 W128°04.211	29m	13:49	

Data Collection

The mugs were photographed before any organisms were removed, and the organisms were transferred from both

the inside and outside of mugs to petri dishes. A representative piece of each type of organism was removed from the cup to make sure at least one piece of each category that was present was accounted for in our presence-absence data. They were viewed under a 2X dissecting microscope and photographs were taken to allow easier identification and grouping of similar organisms. The organisms were then divided into 11 species groups based on obvious physical similarities (please see appendix). The presence or absence of each species group at all lines and depths was recorded. Identification was carried out to the specificity available looking at online resources, books, and through contact with Amy McConnell, a SFU research assistant. (Lohse & Raimondi; Mondragon & Mondragon, 2003; Harbo, 1997; Bunje, 2004, Lavens & Sorgeloos, 1996; Gross *et al.* 1986, Amy McConnell pers. comm.).

Data Analysis

A multivariate data analysis program, PRIMER-6 was used to analyse the presence or absence of species found at each treatment (depth and exposure). First the data was transformed using the Bray-Curtis measure of similarity, by using a similarity matrix and then plotting the results. Next we used a multivariate 2-way crossed analysis of similarity (ANOSIM) to assess the similarities between the two exposure types (at all depths) and between the three depths (at both exposures). Similarity percentage (SIMPER) analysis was used after to determine the contribution of each category to dissimilarities and similarities within all exposure types and all depths. PRIMER-6 software package was used for these two analyses.

Results

There was a significant difference between the species present at the exposed and sheltered sites across all depth groups (see Fig. 3; ANOSIM, N=29, R=0.191, p=0.02). The groups of organisms most responsible for contributing to this difference as determined using a SIMPER analysis were Foamy Algae (19.35% contribution), Copepod 1 (13.95% contribution), Veiny Algae (13.38% contribution), and Amphipod (12.76% contribution; see Table 1). The species present on the sheltered mugs had an average similarity of 55.35, and the largest contributors to this similarity were Foamy Algae (33.28% contribution) and Veiny Algae (21.08% contribution; see Table 2). The species found on the exposed mugs had an average similarity of 40.87, and the largest contributors to this similarity were Algae (51.49% contribution) and Copepod 1 (25.88% contribution; see Table 3).

Table 1. Species contribution to community dissimilarity between sheltered and exposed mug locations across all

depths as found using a 2-way SIMPER analysis (ANOSIM, N=29, R=0.191, p=0.02).

Species	Contribution %	Cumulative %
Foamy Algae	19.35	19.35
Copepod 1	13.95	33.30
Veiny Algae	13.38	46.68
Amphipod	12.76	59.45
Algae	11.92	71.37
Copepod 2	9.40	80.76
Slime	7.54	88.31
Gastropod veliger	5.58	93.88

Table 2. Species contribution to community similarity at the sheltered mug location across all depths as found using a 2-way SIMPER analysis.

Species	Contribution %	Cumulative %
Foamy Algae	33.28	33.28
Veiny Algae	21.08	54.35
Copepod 1	16.48	70.83
Algae	11.29	82.13
Amphipod	9.03	91.16

Table 3. Species contribution to community similarity at the exposed mug location across all depths as found using a 2-way SIMPER analysis.

Species	Contribution %	Cumulative %
Algae	51.49	51.49
Copepod 1	25.88	77.37
Foamy Algae	7.92	85.29
Veiny Algae	5.04	90.33

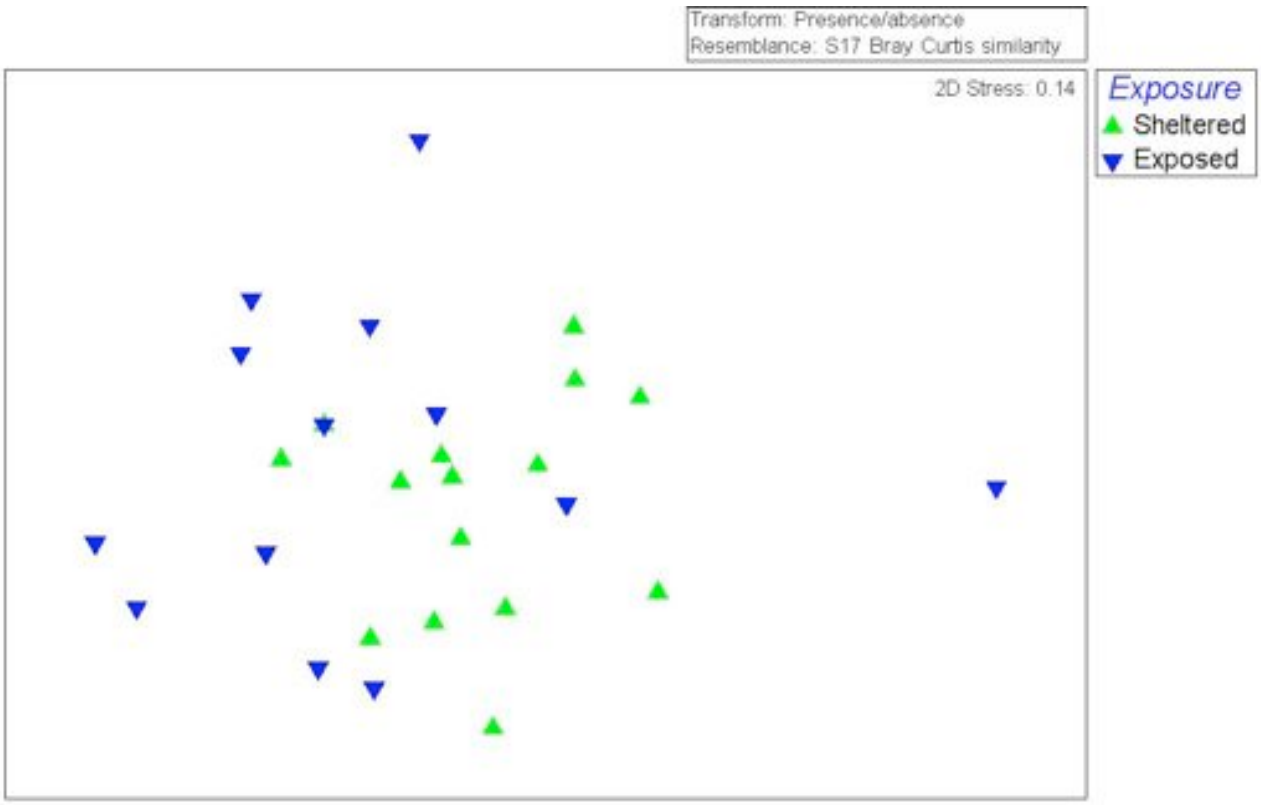

Figure 3. An nMDS showing sheltered (green) and exposed (blue) mug treatments in the Pruth Bay region. An ANOSIM test showed a significant difference between the exposure treatments (N=29, R=0.191, p=0.02). A 2D stress level of 0.14 makes this test viable.

There was a significant difference in the species present between depths of 2m and 20m across both exposure treatments (see Fig. 4; ANOSIM, N=29, R=0.189, p=0.039). Using a SIMPER analysis, the average dissimilarity between 2m and 20m was 51.86, and the biggest contributors to this difference were Copepod 1 (15.00% contribution), Copepod 2 (14.14% contribution), Veiny Algae (13.68% contribution), and Slime (11.84% contribution; see Table 4). The species present on the mugs at 2m had an average similarity of 54.62, and the largest contributors to this similarity were Algae (33.69% contribution) and Veiny Algae (17.88% contribution; see Table 5). The species found on the mugs at 20m had an average similarity of 53.66, and the largest contributors to this similarity were Foamy Algae (37.19% contribution) and Copepod 1 (25.24% contribution; see Table 6).

Table 4. Species contribution to community dissimilarity between mug depths of 2m and 20m across both exposures as found using a 2-way SIMPER analysis (ANOSIM, N=29, R=0.189, p=0.039).

Species	Contribution %	Cumulative %
Copepod 1	15.00	15.00
Copepod 2	14.14	29.15

Veiny Algae	13.68	42.83
Slime	11.84	54.67
Algae	11.50	66.17
Amphipod	8.52	74.69
Barnacle cyprid	7.72	82.40
Foamy Algae	6.15	88.56
Isopod	4.27	92.82

Table 5. Species contribution to community similarity at a mug depth of 2m across both exposures as found using a 2-way SIMPER analysis.

Species	Contribution %	Cumulative %
Algae	33.69	33.69
Veiny Algae	17.88	51.57
Copepod 1	16.48	68.06
Copepod 2	11.41	79.47
Foamy Algae	8.53	88.01
Amphipod	4.38	92.39

Table 6. Species contribution to community similarity at a mug depth of 10m across both exposures as found using a 2-way SIMPER analysis.

Species	Contribution %	Cumulative %
Foamy Algae	29.03	29.03
Veiny Algae	23.27	52.3
Algae	20.03	72.34
Copepod 1	19.68	92.01

Table 7. Species contribution to community similarity at a mug depth of 20m across both exposures as found using a 2-way SIMPER analysis.

Species	Contribution %	Cumulative %

Foamy Algae	37.19	37.19
Copepod 1	25.24	62.42
Algae	24.68	87.10
Amphipod	9.57	96.67

There was no difference in the species present between depths of 2m and 10m across both exposure treatments (ANOSIM, N=29, R=-0.084, p=0.843). Similarity, there was no difference in the species present between depths of 10m and 20m across both exposure treatments (ANOSIM, N=29, R=0, p=0.451). All group names can be seen in Table 8.

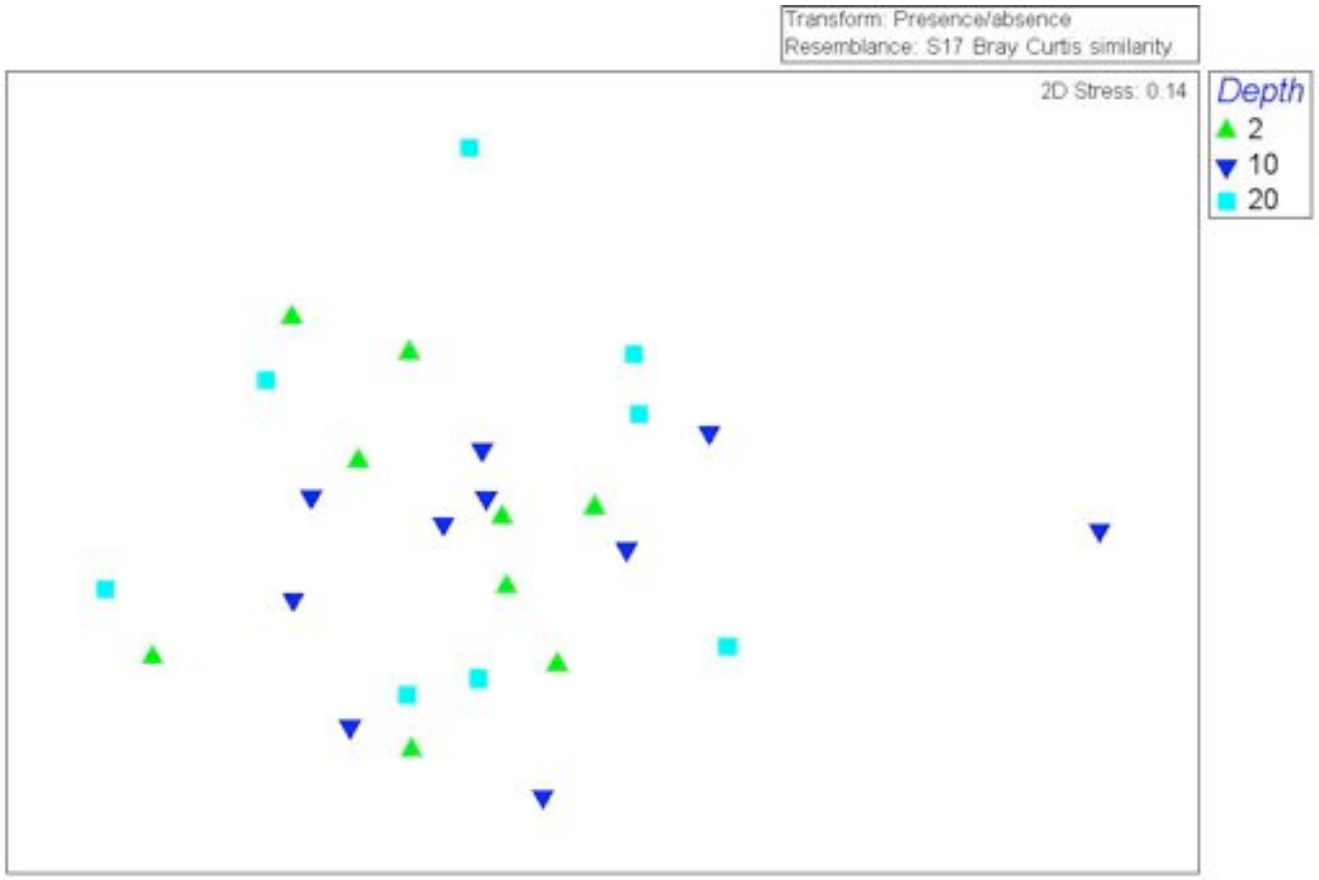

Figure 4. An nMDS showing mug depths of 2m (green) 10m (dark blue) and 20m (light blue) treatments in the Pruth Bay region. An ANOSIM test showed a significant difference between the 2m and 20m treatments (N=29, R=0.189, p=0.039) but not between the 2m and 10m (N=29, R=-0.084, p=0.843) or 10m and 20m (N=29, R=0, p=0.451) treatments. A 2D stress level of 0.14 makes this test viable.

The two mugs hung off the dock were observed to have visibly more colonization, although this data was not quantitatively assessed. The analysis of one of these mugs showed that the colonizing species were mostly small barnacles and barnacle cyprids.

Table 8. List of specimens

found on all mugs (N=29).

1. Amphipod
2. Gastropod veliger
3. Bivalve
4. Barnacle cyprid
5. Copepod 1
6. Slime
7. Algae
8. Veiny Algae
9. Foamy Algae
10. Copepod 2
11. Isopod

Discussion:

There were a number of trends present in the data collected. Different depths and exposures have species with varying influence on community compositions. Overall, there was a relatively low amount of colonization on the mugs in the experiment, especially in comparison to our observations of the test mugs placed off the dock. It is interesting to note that the mugs suspended off of the dock for nine days had a higher number of colonizers (primarily juvenile barnacles. The greater abundance of colonizers on the dock mugs could be attributed to the large colonized areas in close proximity, the shallower depth, or the site location in the end of a bay, which may have led to a greater amount of organic matter and plankton close by. The low settling rate on the experimental mugs demanded an analysis of the presence or absence of species in the community, and did not provide enough information to include abundance measures.

Low colonization could also be attributed to the glazed surface of the mugs. As noted previously, the mugs were sanded and scraped through gravel in order to roughen the surface; uniformity of glaze removal was attempted, but difficult to ensure because the process was executed by eight individuals. Materials such as wood, plastic and ceramic (unglazed) have been used in similar experiments with settling rates, and would likely provide a better surface than glazed ceramic mugs, especially as the sanding and scraping barely roughened the surface (Risk, 1973).

At a depth of 2m from the surface, the two lighter coloured algae (Algae and Veiny Algae) were dominant and contributed 33.69% and 17.88% respectively to influencing the community composition. All of the algae groups were top

contributors (Foamy Algae at 8.53%), which is likely due to the higher photosynthetic potential found closer to the top of the water column.

At 20m in depth, Foamy Algae had a strong influence on the community presence (37.19%), greater than that of Algae (24.24%), which could be due to its ability to thrive in low light conditions. Another reason Foamy Algae may occur at lower depths could be that it is out-competed by other algae species near the surface. As algae was present at 20m, we can assume that sunlight reaches this point and photosynthesis is possible. This assumption, however, could be wrong if the algae that was recorded on the mugs from 20m in depth only attached to the mugs upon the removal. Additionally, the 20m depth may not be exact due to line movement in the water. The 20m of extra slack line close to the bottom (which was set up originally to account for tide changes at a depth of 30m) may have also permitted greater movement of the mugs.

At the sheltered site, all of the algae had high contributions: they were the first (Foam 33.28%), second (Veiny Algae 21.08%) and fourth (Algae 11.29%) highest contributors to community composition. With less fetch in a sheltered area, algae might have had a greater opportunity to establish and settle on to the substrate (Lenz *et al.*, 2004). In the exposed site, Algae was very dominant in its contribution (51.49%), while the other two algae, Foamy Algae and Veiny Algae, were still top contributors, although less influential when compared to the sheltered site (7.92% and 5.04% respectively).

The top contributors to community similarity within each depth were the Amphipod and Copepod 1 species at both 2 and 20m. This could indicate that they are abundant, have high dispersal rates and are specialists in occupying new niches. These are typical characteristics of r-selected organisms. Copepods are strong contributors at all depths; they are known to be good swimmers and are found commonly in both pelagic and benthic communities (Kiorboe, 2010; Suarez-Morales & Morales-Ramirez, 2009). Copepod 1 is influential in both exposure conditions: 16.48% contribution in the sheltered area and 25.88% contribution in the exposed area. This reinforces the hypothesis that they are able to survive in many situations.

Bias in the specimens collected may have occurred during collection, when the mugs were allowed to dry. This creates a bias, as some specimens like algae may be more vulnerable to desiccation could be harder to see when dry. This is especially true for the group of mugs from the exposed location (J-D), as there was a delay before their analysis was completed. In other studies, settling plates have been transported in water in order to maintain an environment similar to that found in nature. Lenz *et al.* (2004) conducted an experiment where plates were carried in bags full of water, and the samples were all observed within fifteen minutes of extraction. Another potential source of error was the method used to identify and group all of the organisms. If two organisms were incorrectly grouped together, or multiple similar species were placed in different categories, the outcome of our results may not truly be representative of the actual communities.

It is possible that entire groups of organisms were underrepresented, excluded altogether or overrepresented

because of the red colour of the mugs. Recent studies have looked at settling behaviour in association with the colour of the substrate and shown significant results in substrate colour preference (Patrick Martone, pers. comm.).

Barnacles were present on three mugs, all of which were located at 2m in depth. This implies that barnacles prefer habitat located high in the water column and that light is important in survival. Finding them on only three mugs indicates that they are not as successful at colonizing an open water site when compared to amphipods, copepods or algae. There may have been larval stages could have too small to see with the 2x magnification microscope. Other microscopic organisms could have been left out as well, such as the expected diatoms..

Some of the outliers, or organisms that were very rare on the mugs may have been in the sediment in the water column or on the bottom. Two of the mugs scraped along the bottom (suspected due to the presence of sediment within), and all of the mugs had water dumped out of them. Some sediment or organisms could have become attached in this process, changing the results.

Time was another major concern with this experiment. The mugs were submerged in the ocean for a period of twelve days which is not an ideal length of time for a study of colonization; most research in this field is conducted over a period of months to years (Diaz-Castañeda, 2000; Hurley, 1973). This makes the mugs suitable only for early colonizers, and will not provide information on later successional stages. This experiment was not able to gather information that would give a clear idea of settling rates and species populations in this region.

Removal and set-up of the mugs could have also been sources of errors. This study was designed with three mugs on each rope, making them not completely independent. They were connected by a rope, which was possibly a passageway for colonization, potentially creating pseudo-replicates. The distance between the mug lines was also an issue as the spacing was not adequate, resulting in tangling between two of the ropes in the sheltered site. This could cause an extra large substrate that species would encounter with a greater probability (size effect), and could cross-contaminate colonizers, both of which would affect the study results. Additionally, the sample size was relatively small, with a total of 29 mugs retrieved. There were five replicates for each treatment and four replicates at the exposed 20m site where a mug was lost. A greater number of replicates would allow for a stronger analysis.

We conclude that there is a significant difference between communities found at sheltered and exposed sites, and between communities found at 2m and 20m. There were no significant differences between communities at 2m and 10m, nor communities at 10m and 20m. The species most responsible for the differences between 2m and 20m are Copepod 1 and Copepod 2 and between exposures are Copepod 1 and Foamy Algae.

This kind of experimentation is important because it provides baselines for which species to expect in localized

conditions. This knowledge, if gathered over a longer period of time, can predict the health of this system, within the protected Great Bear Rainforest. It can also help provide background information for further studies in this region.

Future research could be conducted over a longer time period to investigate later successional stages. More research would be useful in order to classify organisms into families or species groups. Abundance estimates would be helpful in gaining a greater understanding of community structures.

References:

Bunje, P. 2004. *The Gastropoda: Snails, slugs, limpets, and sea hares.* Retrieved on June 22, 2011, from: http://www.ucmp.berkeley.edu/taxa/inverts/mollusca/gastropoda.php

Diaz-Castañeda, V. 2000. The early establishment and development of a polychaete community settled on artificial substrata at Todos Santos Bay, Baja California, Mexico. *Bulletin of Marine Science.* 67(1): 321-335.

Gross, D.J., G.B. Pauly 7 D. Moran. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)US Fish and Wildlife Service National Wetlands Research Centre, Louisiana. Biological report 82.

Harbo, R.M. 1997. *Shells and Shellfish of the Pacific Northwest: A Field Guide.* Madeira Park, BC: Harbour Publishing.

Hurley, A.C. (1973). Larval settling behaviour of the acorn Barnacle *(Balanus pacificus)* and its relation to distribution. *Journal of Animal Ecology*. 42(3): 599-609.

Johnson, L.E. & R.R. Strathmann. 1989. Settling barnacle larvae avoid substrata previously occupied by a mobile predator. *Journal of Experimental Marine Biology and Ecology.* 128(1): 87-103.

Kiorboe, T. 2010. What makes pelagic copepodes so successful? *Journal of Plankton Research.*33(5): 677-685.

Lavens, P. & P. Sorgeloos. 1996. Manual on the Production and Use of Live Food for Aquaculture. *Food and Agriculture Organization of the United Nations.*

Lenz, M., M. Molis & M. Wahl. 2004. Testing the intermediate disturbance hypothesis: response of fouling communities to various levels of emersion intensity. *Marine Ecology Progress Series.* 278: 53-65.

Lohse, D.P. & P.T. Raimondi. Barnacles. *University of California, Santa Cruz.* Retrieved on June 23, 2011 from: bio.research.ucsc.edu/people/.../Barnacle%20chapter%20proofs.pdf

McAllister, I & N. Read. 2010. *The Salmon Bears: Giants of the Great Bear Rainforest.* Orca Book Publishers.

Mondragon, J. & J. Mondragon. 2003. *Seaweeds of the Pacific Coast: Common Marine Algae from Alaska to Baja California.* Montery, CA: Sea Challengers.

Norris, D.R., P. Arcese, D. Preikshot, D.F. Bertram, & K. Kyser. 2007. Diet reconstruction and historic population dynamics in a threatened seabird. *Journal of Applied Ecology.* 44: 875-884.

Rainforest Solutions Project. 2011. *Protected Areas*. Retrieved on June 23, 2011 from: http://www.savethegreatbear.org/region/protected_areas

Risk, M.J. 1973. Settling plates of cold-cure acrylic plastic replicated from natural surfaces. *Limnology and Oceanography.* 18(5): 801

Suarez-Morales, E. & A. Morales-Ramirez. 2009. Marine biodiversity of Costa Rica, Central America. Vol. 38: 291-305.

Tippet, R.1970. Artificial surfaces as a method of studying populations of benthic micro-algae in fresh water. *Journal of British Phycology.* 5: 187-199.

Woodin, S. 1991. Recruitment of infauna: positive or negative cues? *American Zoology.* 31: 797–807.

Appendix A: Representative Photo(s) for each Organism Group

1) Amphipod:

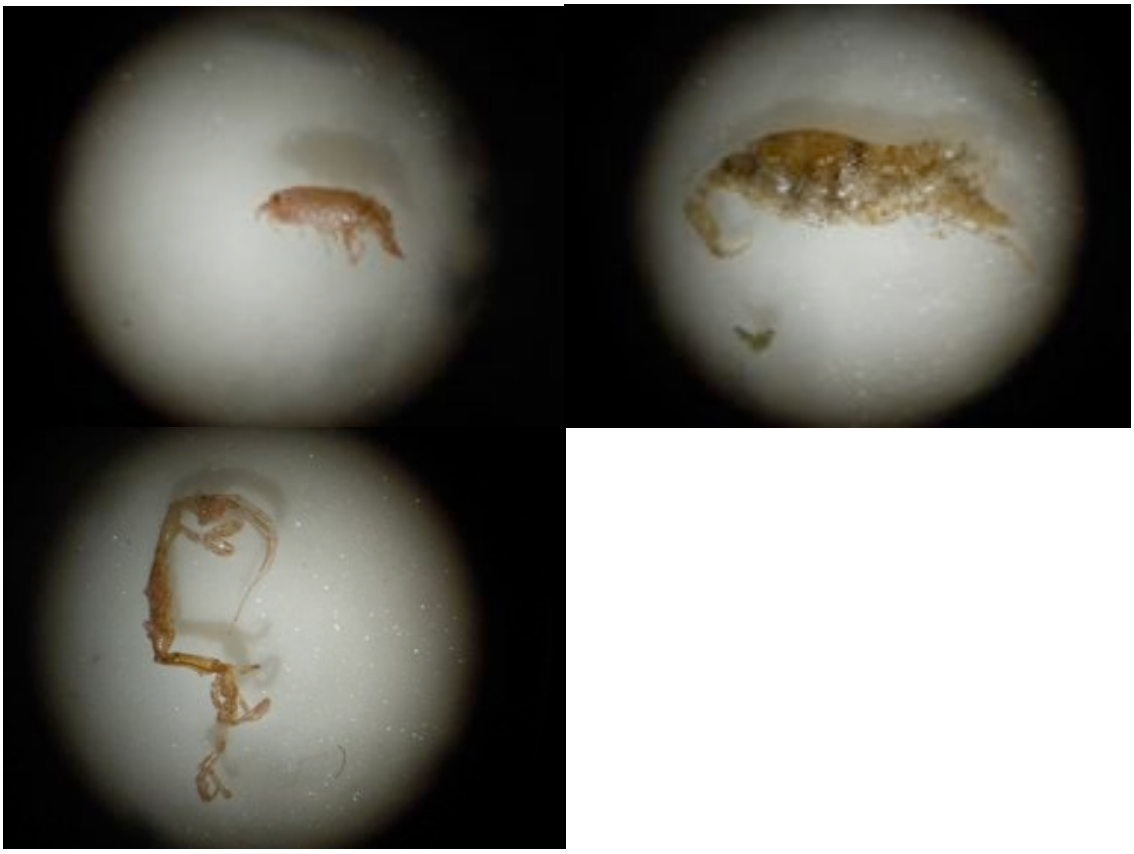

Figure 1. Sample organisms categorized into the Amphipod group. The bottom left specimen is a caprellid.

2) Gastropod Veliger:

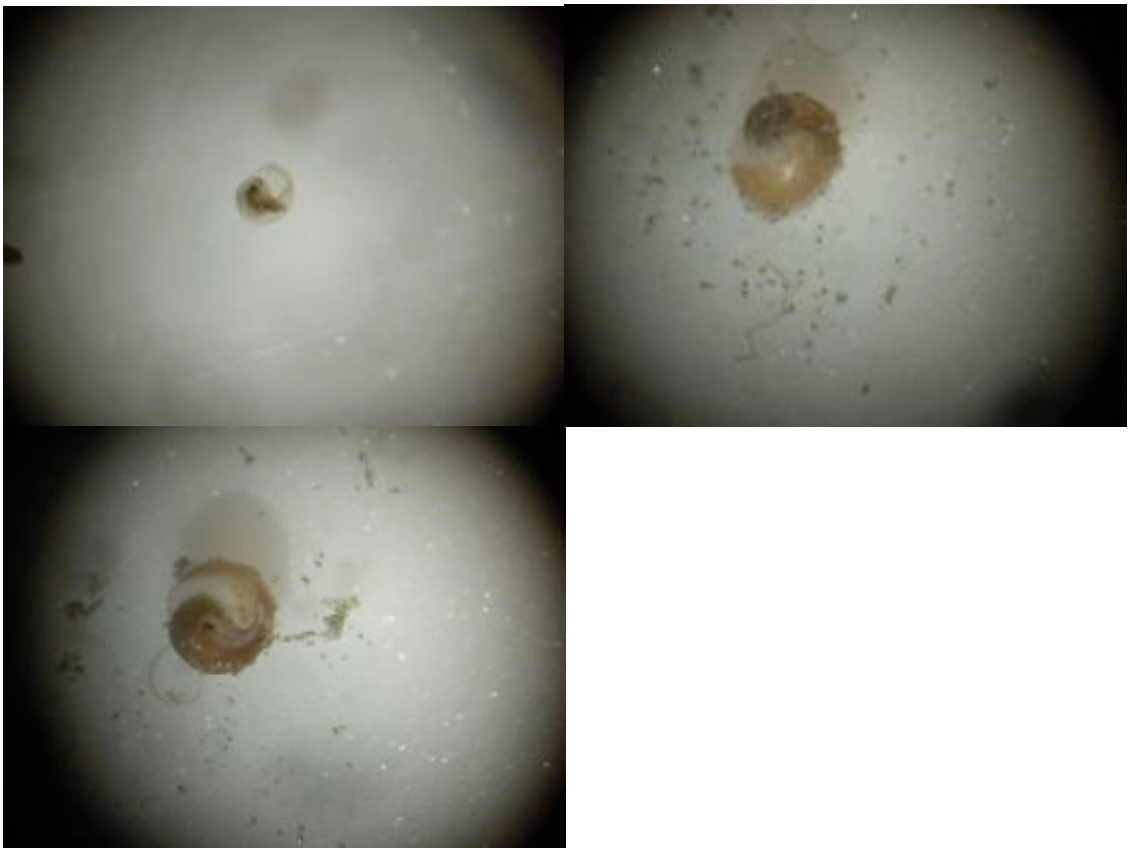

Figure 2. Sample organisms categorized into the Gastropod Veliger group.

3) Bivalve:

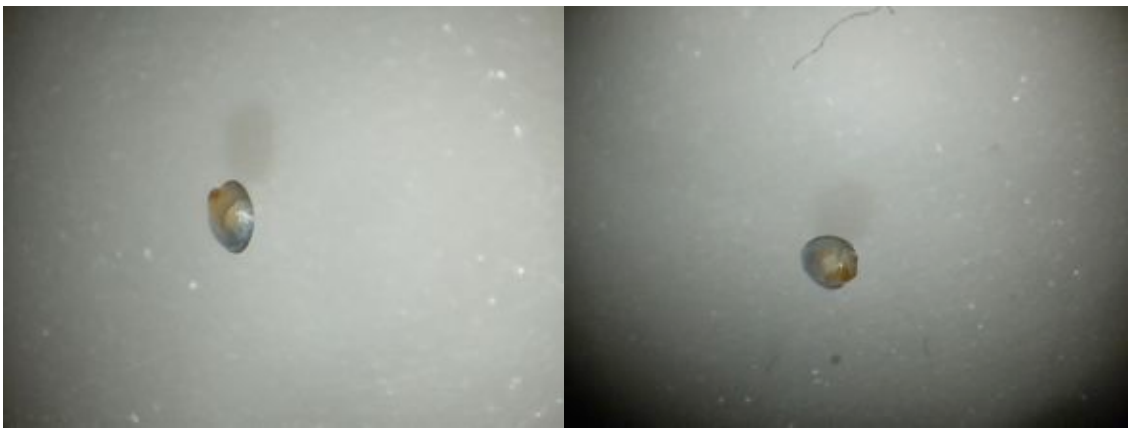

Figure 3. Sample organisms categorized into the Bivalve group.

4) Barnacle Cyprid

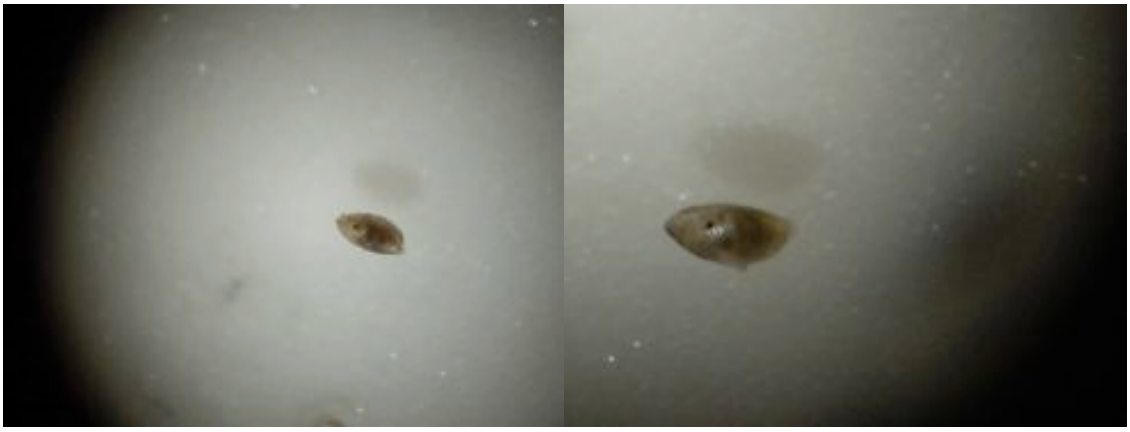

Figure 4. Sample organisms categorized into the Bivalve group.

5) Copepod 1

Figure 5. Sample organism categorized into the Copepod 1 group. The specimen shown is likely a harpacticoid copepod with an egg sac (Amy McConnell, pers. comm.).

6) Slime

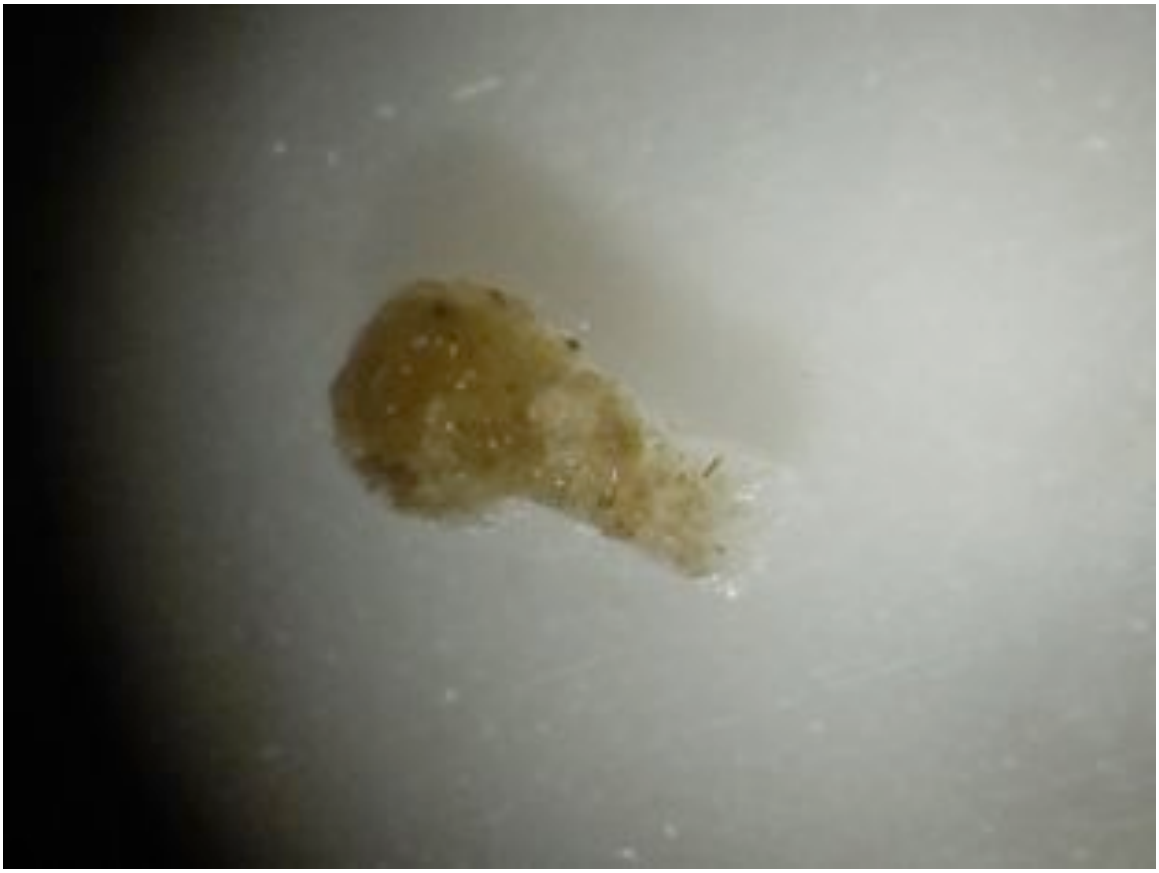

Figure 6. Sample organism categorized into the Slime group.

7) Algae

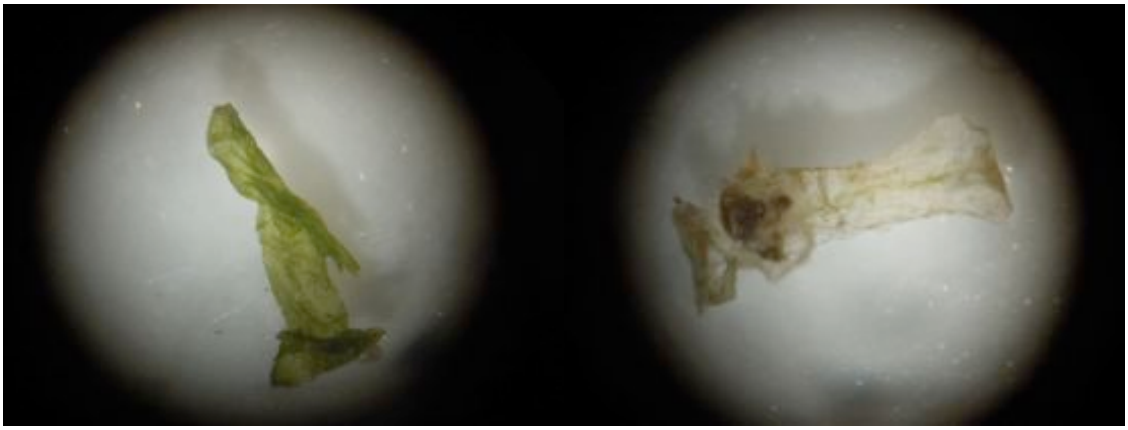

Figure 7. Sample organisms categorized into the Algae group.

8) Veiny Algae

Figure 8. Sample organisms categorized into the Veiny Algae group.

9) Foamy Algae

Figure 9. Sample organisms categorized into the Foamy Algae group.

10) Copepod 2

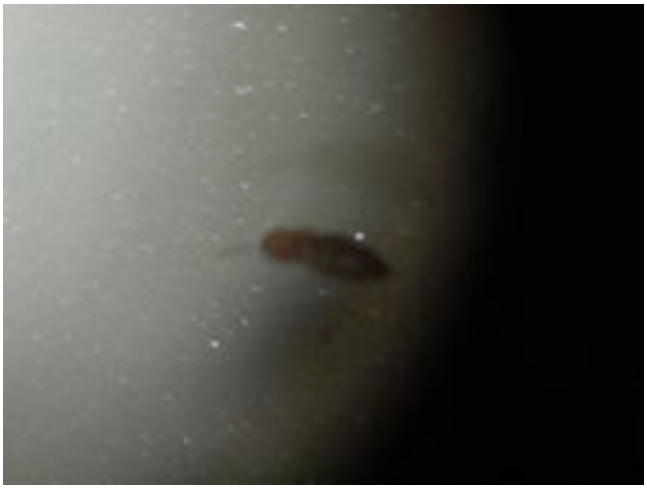

Figure 10. Sample organism categorized into the Copepod 2 group.

11) Isopod

Figure 11. Sample organisms categorized into the Isopod group.