AQUATIC INVERTEBRATES

Of the Devereux Slough - 2018

SB AUDUBON – CCBER – COPR
DEVEREUX SLOUGH MONITORING PROJECT

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ABSTRACT

In 2018, the hardscape construction of NCOS (North Campus Open Space), a restored wetland on the Northern border of COPR (Coal Oil Point Reserve), was completed; thus approximately doubling the overall size of the wetland and offering the rather unique opportunity of being able to compare the two side-by-side. Basic water quality and aquatic invertebrate monitoring of both sites were undertaken to better understand the dynamics of how a newly constructed wetland developed into an established wetland.

The surprising result of this first year of monitoring is that COPR and NCOS were more or less equivalent in species richness and abundance, with the Shannon-Wiener Index giving a slight nod to NCOS for more diversity and Evenness in the data.

Four taxa are the most significant contributors to the total taxa observed – Copepods, Ostracods, Cladocera, and Corixidae. Additionally, we found Chironomids, Ceratopogonidae, Ephydridae, and Nematodes in significant abundance.

Sampling protocols were evaluated indicating that sampling in algae gives more than an order-of-magnitude greater abundance and diversity than in sampling in open water and that the Filtered Beaker method gives more precise species density information than the Sweep-Net method; when sampling at shallower depths where the Sweep-Net is not fully submerged.

Additionally, the effect on other aquatic invertebrates of the use of VectoBac for mosquito abatement was looked at – indicating a minimum, if any, affect.

II INTRODUCTION

The Santa Barbara Audubon Society has undertaken to support the management teams of the North Campus Open Space (NCOS) and Coal Oil Point Reserve (COPR) by developing and implementing a routine water quality and aquatic invertebrate monitoring program based on a Citizen Science approach. Taking a Citizen Science approach makes the program affordable, while simultaneously providing an opportunity for greater student and community involvement in understanding and protecting the Slough.

The Deveraux Slough is an important birding hotspot in the Santa Barbara area. Audubon is deeply interested in aiding COPR and NCOS in maintaining it as a ‘healthy’ habitat for birds. The abundance and diversity of birds at COPR and NCOS is impacted by the abundance and diversity of invertebrates. Many birds feed on invertebrates directly, or indirectly through consumption of something which feeds on invertebrates. Combining water quality with aquatic invertebrate monitoring is an attempt to develop a process to quantitatively evaluate the ‘health’ of the Slough. The

goal is to broaden the factors being monitored over time to create more comprehensive figures of merit.

This monitoring aides in observing the development of the NCOS system by comparing it with the more established COPR system. It is a rather unique situation to have a totally reconstructed landscape come into being on the border of an established one and have the opportunity to track the various plant and animal trajectories as they eventually fully combine into one ecosystem.

Our program consists of UCSB undergraduate volunteers, with majors generally ranging from environmental studies to various branches of biology. In addition, the program necessitates two paid interns who work closely with volunteers to ensure protocols and daily procedures run smoothly.

Invertebrate interns are in charge of training volunteers, not only in lab procedures, but field sampling as well. In addition, invertebrate interns coordinate field sampling from the different NCOS and COPR sites multiple times per quarter. The primary roles of the volunteers are to clean the samples of plant matter and debris, to identify, count and record all of the organisms contained in their sample. Then, specific interns check both the discarded ‘waste’, and the counted sample to help ensure accurate data.

As Closed Estuaries, such as the Devereux Slough, are not well-studied and COPR and NCOS adjoin the UCSB campus, a rare opportunity is provided for valuable UCSB student research.

III OBJECTIVES

1. Generate data which furthers understanding and informs management of the NCOS and COPR Estuary-Slough.
2. Generate data in a cost-effective manner; where ‘cost’ also includes the human and infrastructural resources required.
3. Develop a largely self-sustaining undergraduate program to collect and analyze the data. The two-part goal of which is to relieve COPR and NCOS staff from day-to-day management, while simultaneously providing an opportunity for UCSB undergraduates to gain project and data management experience in a scientific context.

IV SAMPLING PROTOCOLS

Aquatic (Planktonic) Invertebrates – Spineless organisms living in the water column above the benthic substrate.

A filtered-beaker protocol is used. Initially a 1000 um sweep net and protocol was used. However, as the season progressed, our sample sites became populated with dense algae, thus making that sweep net unusable. A quick test showed that the preponderance of invertebrates lived in the algae, rather than the open water. The filtered-beaker protocol was then implemented, as it allowed us to sample amongst the algae with minimal entrainment of the algae.

Fig. 1 Filtered-Beaker Method – Collecting the Sample

The filtered beaker method is implemented by using a plastic 500ml measuring cup to collect and transfer water into a 7.5 liter bucket. In recognition that abundance and species richness are highest within/near the algae cover, samples were collected as geographically close to algae as possible. To sample inside the algae cover, holes are parted in the algae mat by gently spreading the algae apart with one's hands. Two or three 'dips' of the measuring cup are then made. This process of parting the algae cover, 'dips', etc. are repeated until 7.5 liters of water have been collected. The random strands of algae inadvertently collected are then 'swished' back and forth and removed from the bucket. Samples are taken over an approximately two-meter-wide area, keeping one's shadow away from the sampling area.

In open water, the volunteers will wade into the sampling site and begin dipping the 500ml measuring cup at varying depths, from 0 to 50cm, avoiding areas where the mud has been kicked up, until 7.5 liters have been collected. Taking samples at different depths is essential in order to obtain a more accurate representation of the sampling sites since different invertebrates may inhabit different parts of the water column.

The contents of the 7.5 liter bucket are then poured through a 250um mesh filter into another bucket. The sample, caught by the filter, is then washed with denatured ethanol and passed through a funnel into a labeled 150ml sample bottle. Sample bottles are labeled with the date, sample site, and sample type (either Filtered Beaker Method, or ‘Core’). The filtered water in the bucket is either saved for use in dissolving ‘core’ samples or is discarded.

Fig. 2 Collecting Sample in 250um Filter

Fig. 3 Washing Sample with Denatured Ethanol

Benthic Invertebrates - are those living on or in the bottom substrate of the Slough.

A 5 cm diameter section of PVC pipe is pushed 5 cm deep into the bottom substrate. Using a twisting motion, coupled with sliding one's fingers over the bottom of the pipe, a 5 cm long x 5 cm diameter 'core' sample of the bottom substrate is obtained. This sample is then dissolved in the filtered water obtained as the by-product of the filtered-beaker procedure. Dissolving of the sample is achieved by using one's fingers to break up the 'core' sample into smaller and smaller pieces.

The water and specimens are then filtered through the 250 um filter and the result is first washed with water to remove as much dirt as possible and then with denatured ethanol, to preserve the specimens, into a 150 ml sample bottle, as with the aquatic protocol above.

Water Quality - Invertebrate Water Quality Sampling

For the invertebrate sampling in shallow water, less than 40cm deep, the YSI 2030 probe is held horizontally and 10 cm below the surface of the water. It is waved gently (about 5cm per second velocity), while the DO (Dissolved Oxygen), Conductivity, Temperature, and Barometric readings are taken.

Before the readings are taken, the DO calibration is checked using the YSI quick-calibration procedure.

In deeper water (40 to 60 cm), an additional set of measurements is taken about 10 cm above the bottom.

Additionally, the pH is measured.

Salinity and pH calibration is done every 3 months using standard solutions.

Fig. 4 Invertebrate Water Quality Sampling.

Standard Water Quality Sampling

The YSI 2030 probe is first checked and calibrated for DO. Then, hanging the probe vertically downwards, samples are taken at 10, 50, 100, 150, 200, … cm, depending on the depth of the water. This procedure is used at the Pier and Venoco Bridge locations (where there is sufficient water depth).

V SAMPLING LOCATIONS

The Deveraux Slough consists of two portions: COPR, a relatively untouched closed estuary for at least the past 40 years, and NCOS, a newly reclaimed portion, having been a golf course for more than 60 years, directly to the North and bordering on COPR.

There are a total of fourteen water quality and thirteen invertebrate sample sites (only water quality was sampled at the Pier), six in COPR and eight in NCOS. These are intended to be representative of the different microbiomes of each location.

Description of Sites:

<u>COPR</u>

1. MO1 – Mouth of the Slough – saline to hyper-saline, shallow, sandy bottom.
2. PIER – Deepest part of the Slough (+/- 5 m) – saline to hyper-saline, clay bottom.
3. CUL1 – Culvert exit on Slough Road – Part of main body of Slough water during wet portion of year – separate small hypersaline pond during dry portion of year. Appears to have water year-round. Clay bottom with shallow organic layer.
4. VBR1 – South side of Venoco Bridge – clay bottom, about 0.6 to 1.2 m deep during year. Channel edged with pickle-weed. Top layer of water can be relatively fresh-to-brackish during rainy season, saline to hypersaline at bottom.
5. DSP – Dune Swale Pond – Seasonal, shallow, brackish-water pond with cat-tails along edge. Clay and organic sediment bottom.

6. CVP – COPR Vernal Pool – Seasonal, very shallow fresh water pond during rainy season and for a couple of months after. Grass bottom on clay.

NCOS

7. NVBR – North Venoco Bridge – Scraped-bare earth, clay bottom. Brackish near surface during and just after rainy season. Sampling site is about 30 meters across the road from VBR1 in COPR.

8. NEB – Slough-side of East Bridge – scraped-bare earth, clay bottom. Fresh-to-saline water depending on time of year.

9. NMC – Main Channel (during rainy season, sampled with kayak). Scraped-bare earth, clay bottom. Brackish-to-Saline depending on season.

10. NPB – Slough-side of Phelps Bridge – Entrance of Phelps Creek into Slough. Scraped-bare earth, clay bottom with some medium boulders. Fresh-to-probably saline depending on season.

11. NWP – West Pond – Scraped-bare earth, clay bottom. Fresh water pond.

12. NDC – Deveraux Creek – Relatively original, narrow setting, clay bottom with some organic material at top. Fresh water.

13. NVP2 – Vernal Pool #2 – Scraped-bare earth, clay bottom. Fresh water pond.

14. NVP4 - Vernal Pool #4 – Scraped-bare earth, clay bottom. Fresh water pond.

Fig. 5 Map of Sampling Locations

VI SORTING PROTOCOL

Sorting is done to first separate the invertebrates from the algae and general detritus collected. Then the invertebrates are divided into taxa and counted. This allows us to make comparisons between sites and create questions and hypotheses based on said comparisons.

The process of sorting begins with gathering the necessary materials. A microscope, tweezers, pipet, petri dish(es), denatured ethanol, small sample bottles, and a waste container is needed in order to sort. The volunteers take a sample from the “to be sorted” box, a larger sample vial for the waste, and small sample vial, containing 95% denatured ethanol, for the invertebrate specimens. A portion of the sample is poured into a petri dish and looked at under a microscope. The waste is then separated from the invertebrates. The invertebrates are then identified & counted. When complete, the waste-vial and sample-vials, along with a form containing the invertebrate-counts, are placed in the “To-Be-Checked” box. A designated checker then reviews the vials and form to verify the accuracy. If acceptable, the waste-vial is emptied and the sample vial is stored in the designated cabinet. The data is then recorded in a log book and uploaded into a database.

VII INTRODUCTION TO RESULTS

We have limited this report to the calendar year 2018. About 1/3 into this year, our data checking processes had matured enough to realize that a significant number of volunteers had blind spots for different taxa. We upgraded our process to include saving the waste from the sorting process and having a more experienced person check the volunteer’s results. This has allowed for directed feedback to aid in the learning process; as well, boost the accuracies of identification and counting.

We checked the 2017 data and have amended the data; but are unable to determine what part was inadvertently thrown away as waste. Moreover, we only began sampling at NCOS in March 2018. Thus, we are restricting the reported data to 2018.

Additionally, a section of our water quality log went missing for mid-March through August. Fortunately, CCBER (Cheadle Center for Biodiversity and Ecological Restoration) independently takes water quality readings at many of the same sites that we do and we were able to use their data when it occurred within a few days of our sampling.

We have now instituted a process for making more frequent transcriptions of the logs into the database and backing up the database.

VIII RESULTS

Taxa Distribution by Site

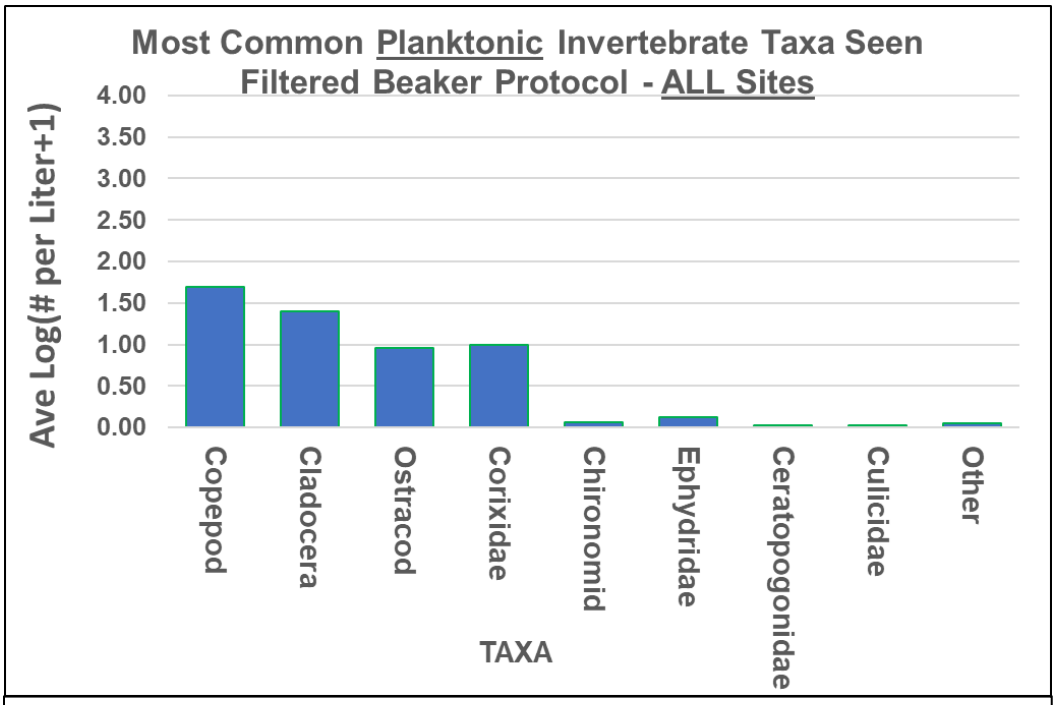


Fig. 6a Planktonic taxa abundance

Noting the log scale in Fig.6a, the four dominant taxa range on, average, from about 50 to 8 specimens per liter for the planktonic samples. Three of the four are of the subphylum, Crustacea (Copepod, Cladocera, and Ostracod).

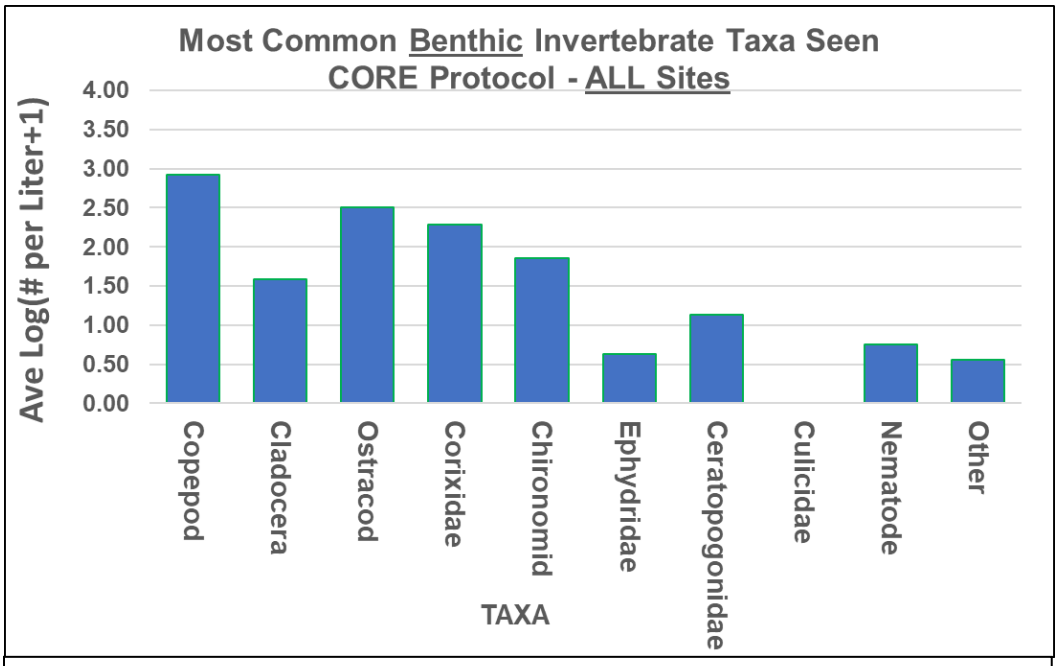


Fig. 6b Benthic taxa abundance

In Fig. 6b, two differences from Fig. 6a stand out:

1. there are 8 taxa with significant presence (those from Fig. 6b plus Chironomid, Ephydridae, Ceratopogonidae, Nematode);
2. the specimens per liter are significantly larger – from 845 specimens/liter down to 3, with three taxa above 100 specimens/liter.

An unresolved issue here is that, in converting from 5cm diameter x 5cm long sample volume to liters, the full sample volume was used. However, it is likely that, depending on substrate type (clay, sand, peat, etc.), the specimens may be only concentrated in the first 1cm, or even 0.5cm of substrate; which would then give specimen densities 5 or10 times higher than presently stated. This would be very interesting to look at; if we can get the resources to do it.

In the following Figures, we give a sampling of the site results, using the 'All Sites' chart as a reference – the full set are in the appendix.

Planktonic Taxa Distribution by Site – VBR1 v NVBR

VBR1 = COPR side of Venoco Bridge

NVBR = NCOS side of Venoco Bridge – 30 meter separation of sites

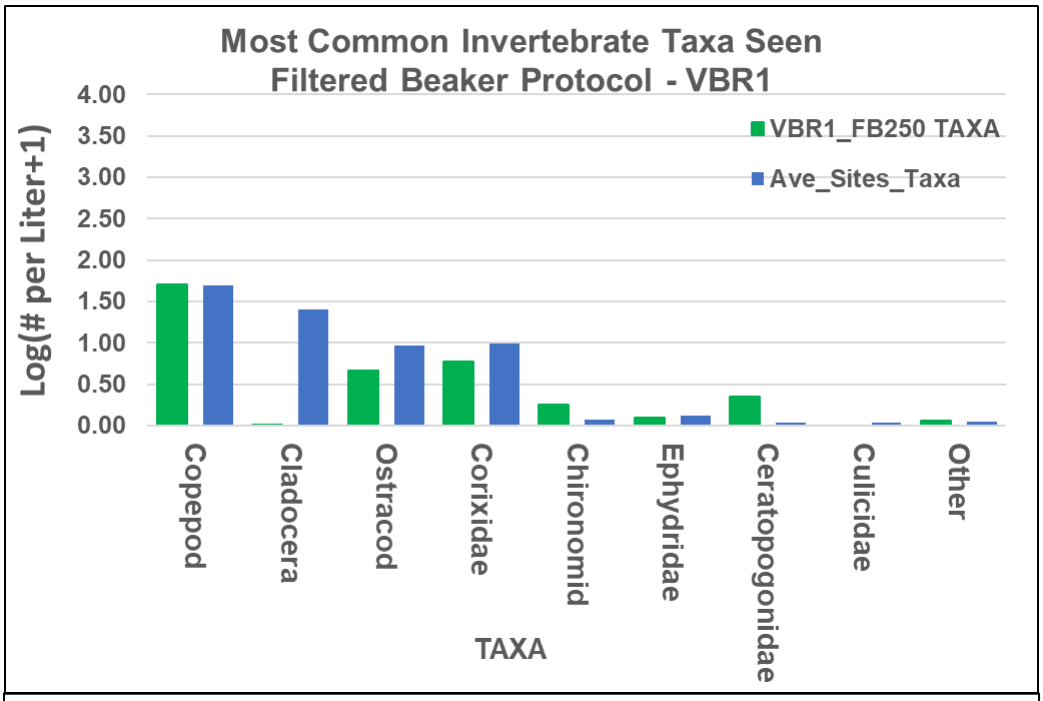


Fig. 7a Planktonic taxa abundance - Venoco Bridge - COPR

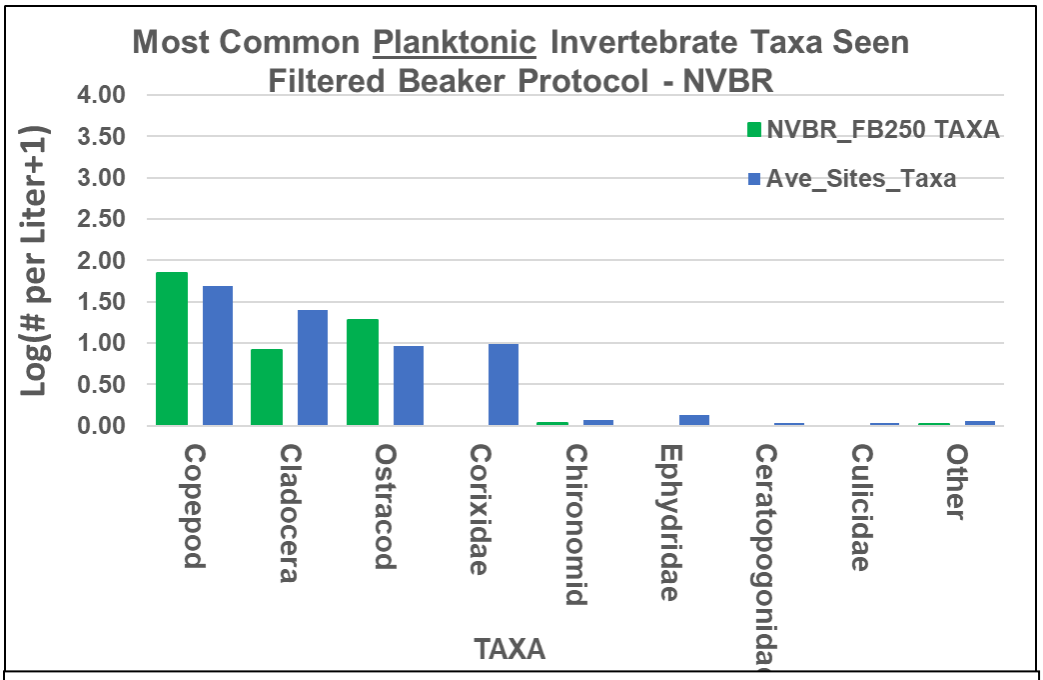


Fig. 7b Planktonic taxa abundance - Venoco Bridge - NCOS

Benthic Taxa Distribution by Site – VBR1 v NVBR

VBR1 = COPR side of Venoco Bridge

NVBR = NCOS side of Venoco Bridge

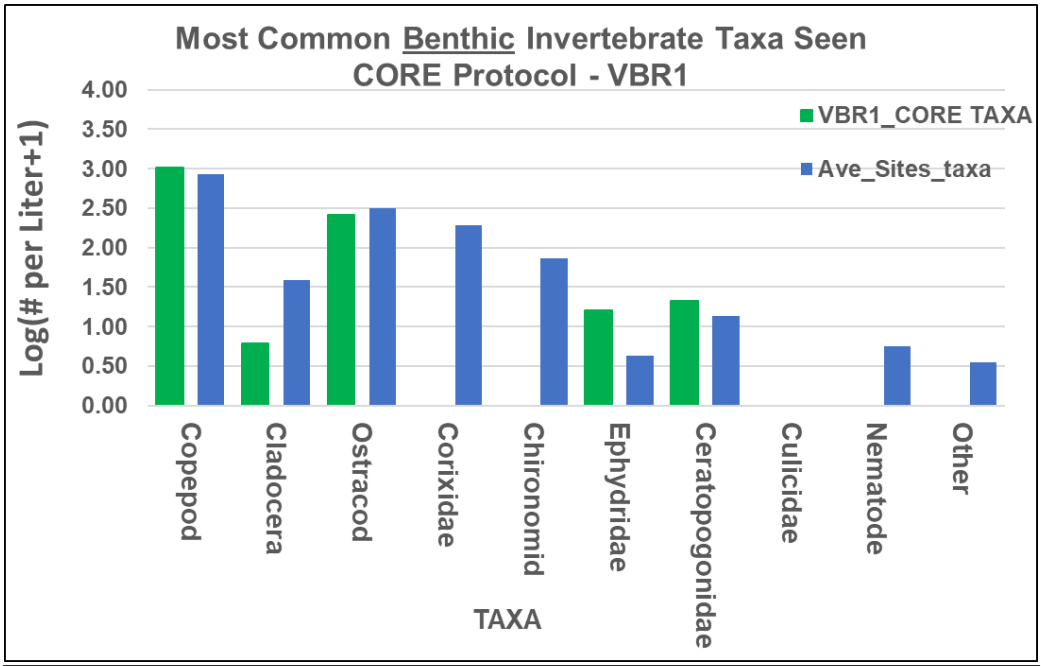


Fig. 8a Benthic taxa abundance - Venoco Bridge - COPR

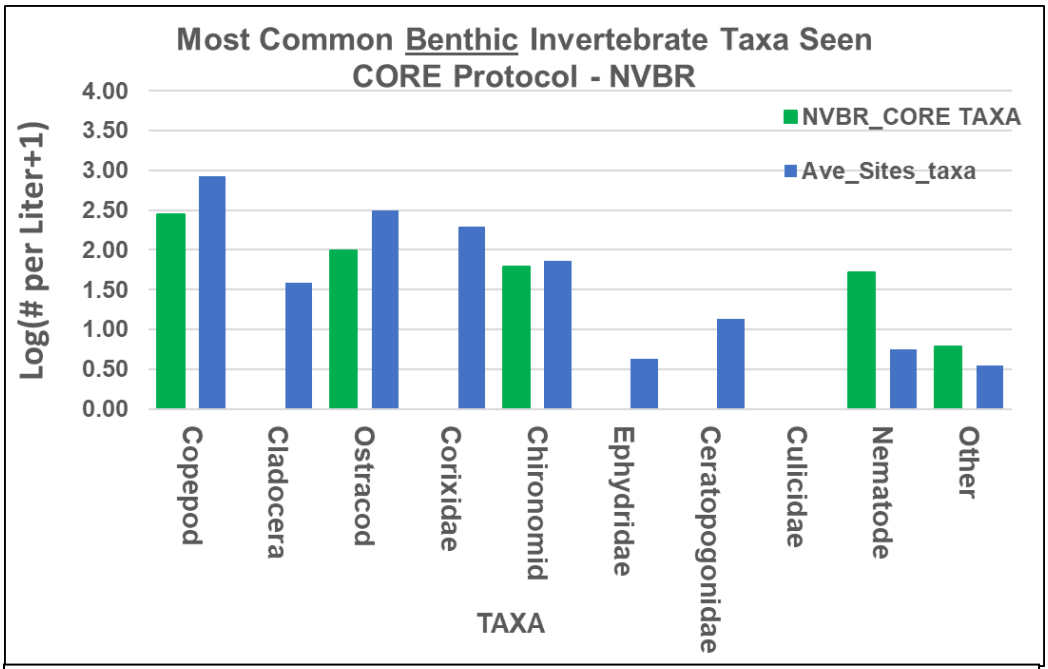


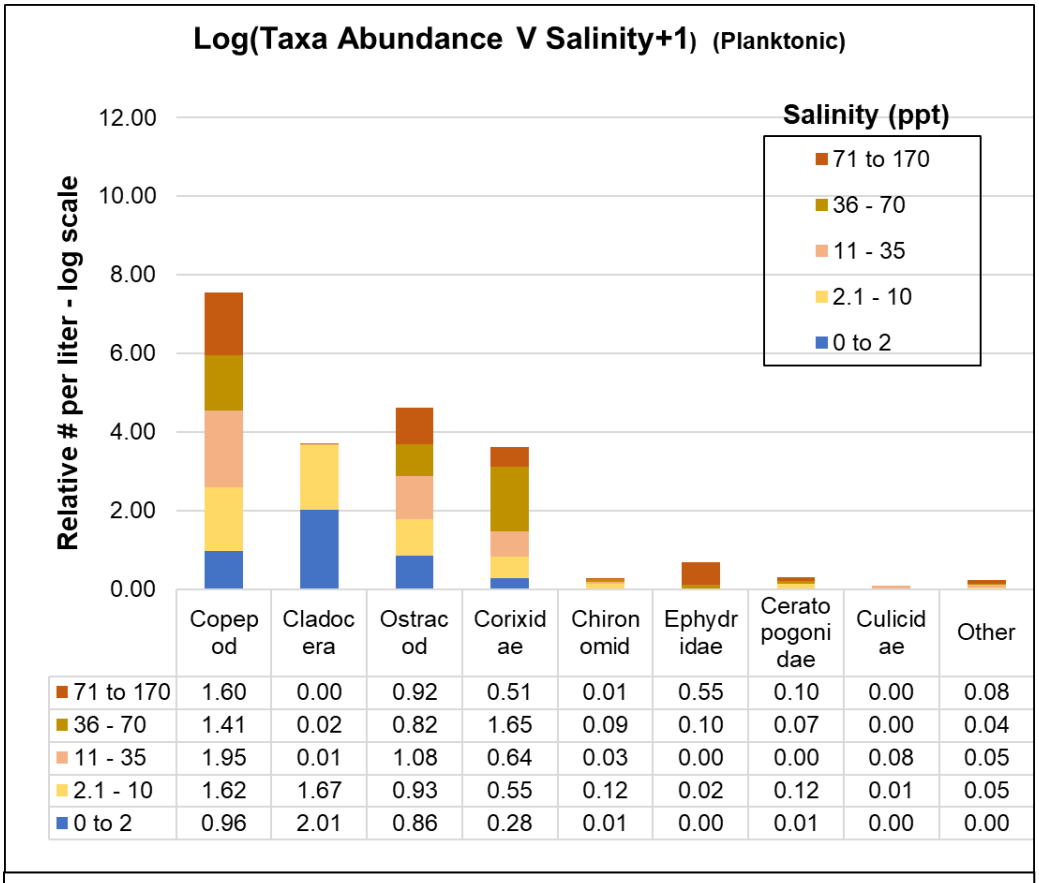
Fig. 8b Benthic taxa abundance - Venoco Bridge - NCOS

The remaining site charts reflect the pattern shown in Figs. 8a & 8b. While individual entries vary, the pattern of dominance of the major species remains. The full results are in the appendix.

Taxa Distribution by Salinity

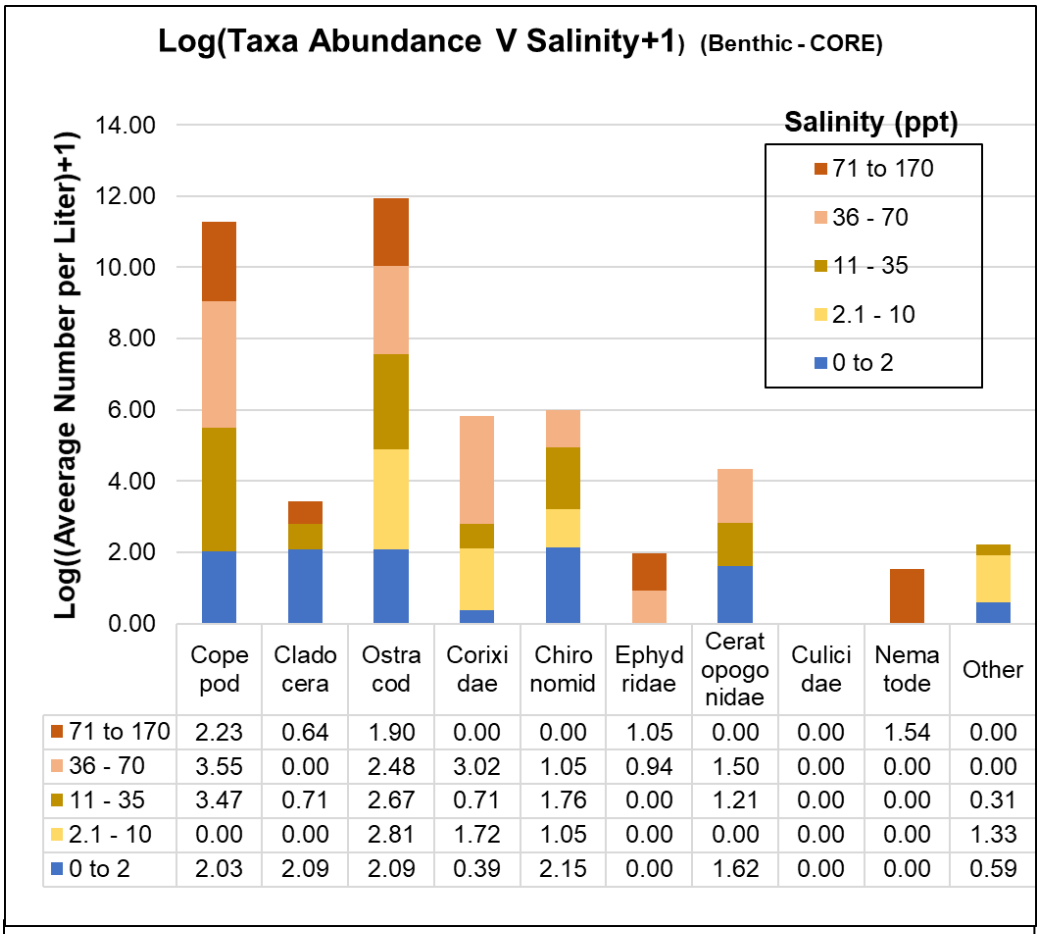
The degree of salinity has a pronounced effect on some taxa; particularly Cladocera. While each segment of the particular column accurately reflects the value for that individual and degree of salinity, note that with the vertical scale, being logarithmic, adding the logs is equivalent to multiplying the individual entries together – clearly there were not ever 10^6 specimens per liter. Consequently, ***the vertical axis is just to give a relative basis for comparison***.

Note: freshwater is nominally 0 to 2 ppt salinity and seawater is nominally 35ppt.



	Copepod	Cladocera	Ostracod	Corixidae	Chironomid	Ephydridae	Ceratopogonidae	Culicidae	Other
71 to 170	1.60	0.00	0.92	0.51	0.01	0.55	0.10	0.00	0.08
36 - 70	1.41	0.02	0.82	1.65	0.09	0.10	0.07	0.00	0.04
11 - 35	1.95	0.01	1.08	0.64	0.03	0.00	0.00	0.08	0.05
2.1 - 10	1.62	1.67	0.93	0.55	0.12	0.02	0.12	0.01	0.05
0 to 2	0.96	2.01	0.86	0.28	0.01	0.00	0.01	0.00	0.00

Fig. 9a Planktonic taxa Abundance v Salinity – all sites



	Copepod	Cladocera	Ostracod	Corixidae	Chironomid	Ephydridae	Ceratopogonidae	Culicidae	Nematode	Other
71 to 170	2.23	0.64	1.90	0.00	0.00	1.05	0.00	0.00	1.54	0.00
36 - 70	3.55	0.00	2.48	3.02	1.05	0.94	1.50	0.00	0.00	0.00
11 - 35	3.47	0.71	2.67	0.71	1.76	0.00	1.21	0.00	0.00	0.31
2.1 - 10	0.00	0.00	2.81	1.72	1.05	0.00	0.00	0.00	0.00	1.33
0 to 2	2.03	2.09	2.09	0.39	2.15	0.00	1.62	0.00	0.00	0.59

Fig. 9b Benthic taxa Abundance v Salinity – all sites

Figures 9a and 9b indicate some consistent trends, e.g. the seeming insensitivity of Copepods and Ostracods to salinity and the preference of Ephydridae for salinity. There are also some apparent anomalies, e.g. the presence of Cladocera in hyper-saline conditions in the benthic samples.

One needs to remain aware that this is a complex ecosystem where salinity, for example, may not be directly affecting the individual; but rather, affects the individual's food supply or the existence of competitors; or perhaps, is more significant in one temperature range than another.

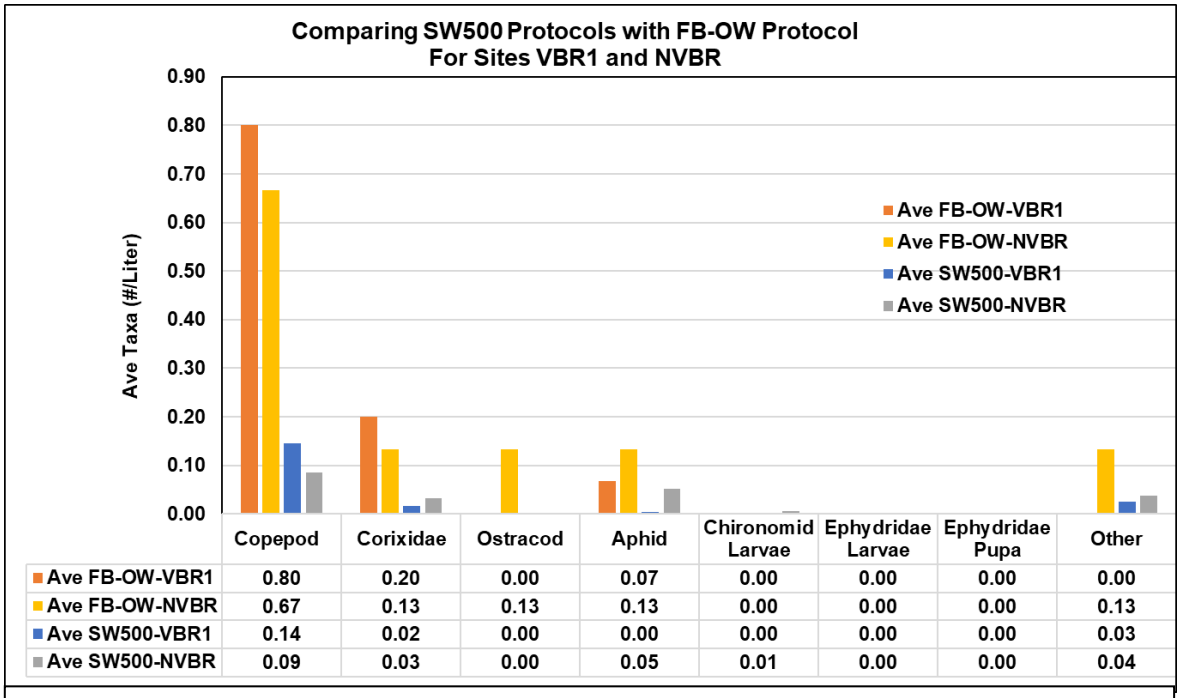
This study is a broad-brush investigation into first order relationships; which could present opportunities for more detailed investigations.

In any case, more clarity should come with a couple of more years of data.

Taxa Abundance by Sampling Protocol

A number of questions arose during the first year of sampling (2017) regarding protocols and how specific protocols might be influencing, or skewing, the data. For example, how will the results be different using the sweep-net v the filtered beaker protocol? Will using a 500um mesh give significantly different results from using a 250um mesh? Will sampling outside algae patches give different results than sampling within algae patches. An attempt to get some handle on these issues was made by conducting the following matrix of tests to more '*accurately indicate*':

1. The relationship of the results, if any, between the Sweep-Net and the Filtered-Beaker methods.
2. How the results differ between using a 500um mesh and a 250um mesh filter.
3. The degree of difference between the results of samples taken within the algae to samples taken outside of the algae.

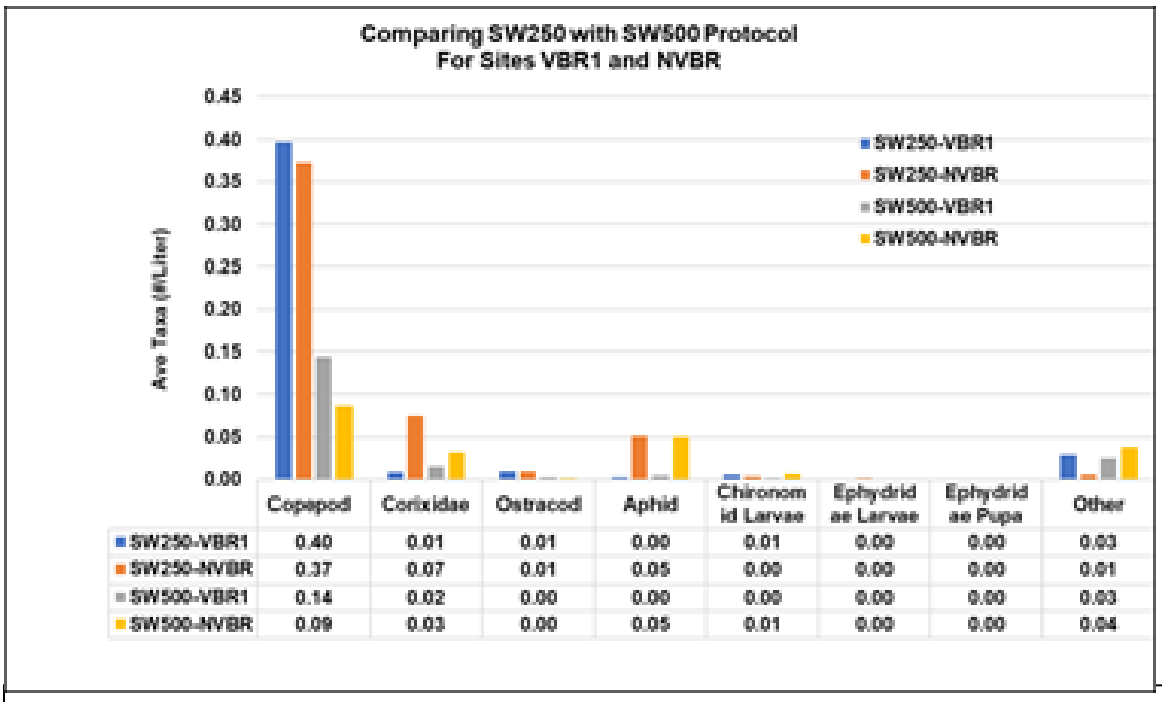


	Copepod	Corixidae	Ostracod	Aphid	Chironomid Larvae	Ephydridae Larvae	Ephydridae Pupa	Other
Ave FB-OW-VBR1	0.80	0.20	0.00	0.07	0.00	0.00	0.00	0.00
Ave FB-OW-NVBR	0.67	0.13	0.13	0.13	0.00	0.00	0.00	0.13
Ave SW500-VBR1	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.03
Ave SW500-NVBR	0.09	0.03	0.00	0.05	0.01	0.00	0.00	0.04

Fig. 10-1 Comparing Sweep Net to Filtered Beaker results

The results in Figure 10-1 show the Filtered Beaker protocol obtaining roughly 6x the taxa/liter as the sweep net. The larger taxa density obtained using the filtered beaker protocol is possibly due to the fact that the filtered beaker samples were taken in the top 40cm of the water column; while the sweep net samples were taken throughout the full 100 cm depth of the water column (the sweep net

pole being longer than my arm). At the Venoco Bridge, the water near the bottom tends to be anoxic; thus, possibly having a lower density of taxa.

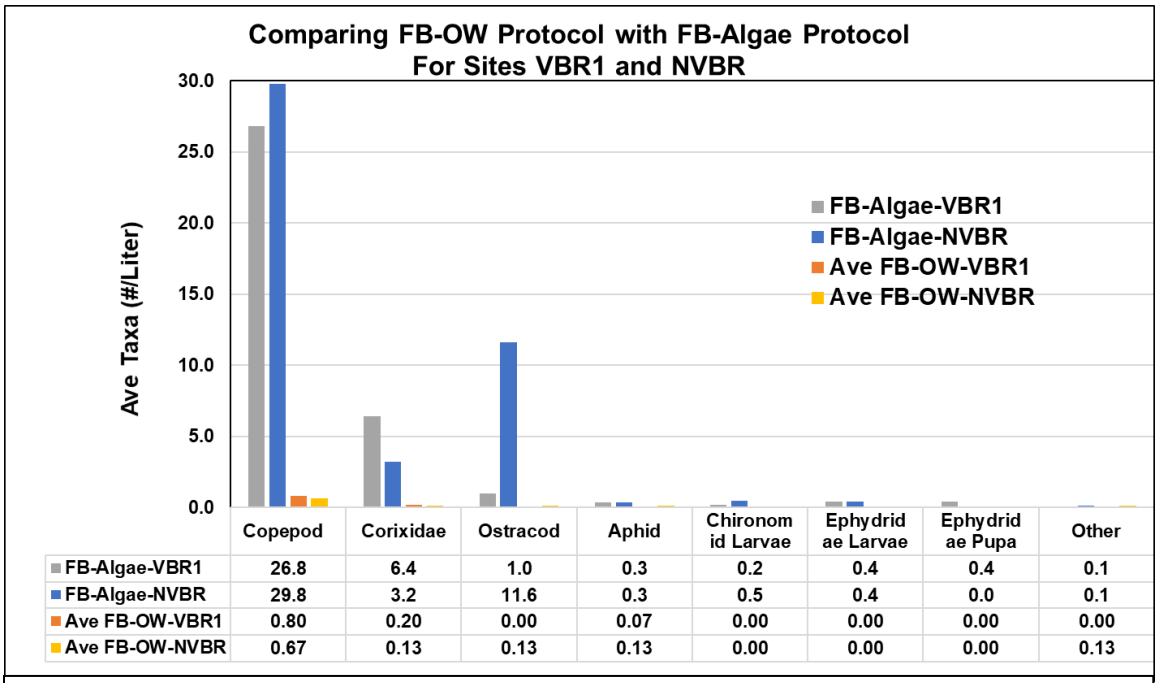


	Copepod	Corixidae	Ostracod	Aphid	Chironomid Larvae	Ephydridae Larvae	Ephydridae Pupa	Other
SW250-VBR1	0.40	0.01	0.01	0.00	0.01	0.00	0.00	0.03
SW250-NVBR	0.37	0.07	0.01	0.05	0.00	0.00	0.00	0.01
SW500-VBR1	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.03
SW500-NVBR	0.09	0.03	0.00	0.05	0.01	0.00	0.00	0.04

Fig. 10-2 Comparing 250um to 500um mesh results and results sampled 30m apart

Figure 10-2 shows the major difference between the 500um mesh and 250um mesh results are with the taxa that span that difference in range (Copepods and Ostracods); with approximately 4x more Copepods and 6x more Ostracods being collected with the 250um mesh. The numbers of larger invertebrates are largely unaffected by this difference in mesh size.

The difference in the results of sampling 30m apart was significant; but somewhat random. (With larger sample sizes, the NCOS side of the Bridge does show greater abundance/liter.)



	Copepod	Corixidae	Ostracod	Aphid	Chironomid Larvae	Ephydridae Larvae	Ephydridae Pupa	Other
FB-Algae-VBR1	26.8	6.4	1.0	0.3	0.2	0.4	0.4	0.1
FB-Algae-NVBR	29.8	3.2	11.6	0.3	0.5	0.4	0.0	0.1
Ave FB-OW-VBR1	0.80	0.20	0.00	0.07	0.00	0.00	0.00	0.00
Ave FB-OW-NVBR	0.67	0.13	0.13	0.13	0.00	0.00	0.00	0.13

Fig. 10-3 Comparing Open Water Sampling to Within Algae Sampling Results

Figure 10-3 illustrates the crux of the issue of how choice of protocol affects the results. Sampling the water within the algae (but excluding the algae) results in both a ***more diverse*** sample as well as ***around 30x more abundance*** (on the basis of essentially two trials and three taxa).

IX DISCUSION OF RESULTS

Figures of Merit

Complex systems such as an automobile, a large corporation, the world economy, or an ecosystem have 'Figures of Merit' to help people, who do not have all the specific knowledge to all the detailed information available to evaluate such a system. For an automobile, one has miles/gallon (city and highway), 0-60mph, braking distance, turning radius, etc. For a corporation, there is Price/Earnings, Price/Revenue, Price/Book, Short Ratio, etc.

For an ecosystem, there is not much. Apparently, there is not a lot of money to be made understanding or managing ecosystems - generally. Some work has been done with regards to forestry and agriculture.

For the general ecosystem, there are the Shannon-Wiener, Simpson, and Gini-Simpson Indexes. These three, being versions of the same approach, we take the Shannon-Wiener – which measures the uncertainty of species identity of an individual taken at random (the concept is lifted from code-breaking).

Applying the Shannon-Wiener Index to our data, we get the following:

	Shannon Index Comparisons	# of Sites Sampled	# of Species	# of Individuals	Shannon Index	Evenness
0	All Sites - Planktonic	13	18	49,444	**1.19**	0.41
0	All Sites - Benthic (CORE)	13	10	5,868	**0.90**	0.39
1	COPR- All Sites Planktonic	5	16	17,811	**0.93**	0.34
1	NCOS - All Sites Planktonic	8	13	31,633	**1.06**	0.41
2	COPR - All Sites Benthic (CORE)	6	9	3,447	**0.68**	0.31
2	NCOS - All Sites Benthic (CORE)	8	10	2,421	**1.01**	0.44
3	COPR - Slough Sites (Saline) Planktonic	3	16	16,356	**0.86**	0.31
3	NCOS - Slough Sites (Saline) Planktonic	4	11	17,907	**0.95**	0.39
4	COPR - Slough Sites (Saline) Benthic (CORE)	3	7	3,309	**0.56**	0.29
4	NCOS - Slough Sites (Saline) Benthic (CORE)	4	10	2,101	**0.75**	0.32
5	COPR - VBR1 (Saline) Planktonic	1	9	2,270	**0.71**	0.32
5	NCOS - NVBR (Saline) Planktonic	1	7	7,356	**0.89**	0.46
6	COPR - VBR1 (Saline) Benthic (CORE)	1	5	262	**0.65**	0.41
6	NCOS - NVBR (Saline) Benthic (CORE)	1	5	97	**1.18**	0.73

***NOTE: VBRI and NVBR are on either side of the Venoco Bridge**

Fig. 11a Shannon-Wiener Diversity Index and Evenness for various site configurations.

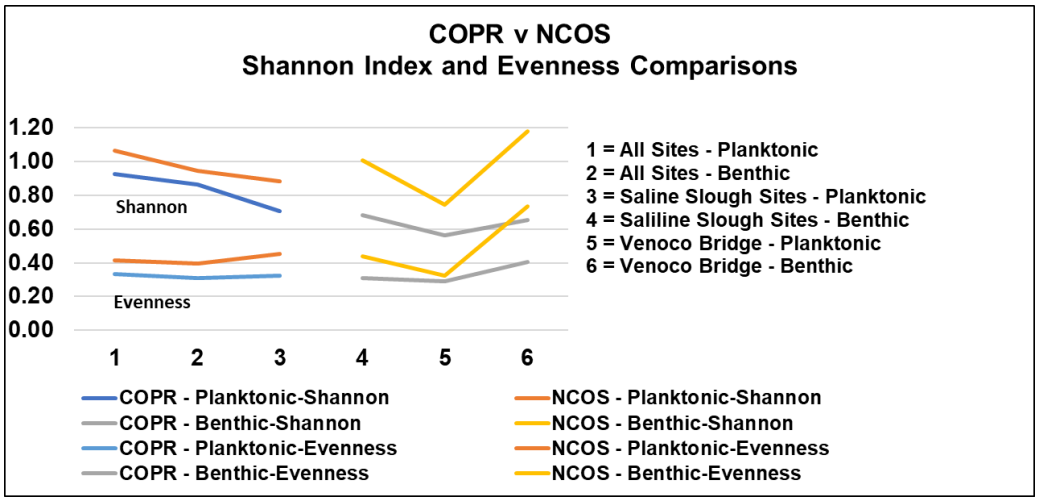


Fig. 11b Shannon-Wiener Diversity Index and Evenness for various site configurations. Another view of Fig. 11a – Note: **Yellowish lines denote NCOS, Bluish lines COPR**.

Figure 11b brings a lot of data into one chart. Its purpose is to simply to show how uniformly, with different sample sets, NCOS demonstrates more Diversity and Evenness than COPR – a very surprising result. This chart can be quite complex if one drills down into it and making a number of separate charts would be better if one wants to do that.

The six cases denoted in Fig. 11b compare the relative diversity of COPR with NCOS from the most general, down to the more specific cases of only the saline sites, and then down to very specific saline sites – either side of the Venoco Bridge.

This emphasis on the saline sites is largely due to the lack of 2018 data for the more freshwater sites; as we only began sampling at NCOS in March 2018, and the freshwater sites are mostly transitory – vernal pools and ponds. This has to some degree been remedied in 2019. One difficulty that will remain is to balance the number/percentage of saline/freshwater sites for both COPR and NCOS.

The logic of the comparisons is to first look at the most general case of all the sites for both the planktonic and benthic samples (Cases 1 & 2). Then to look at only the saline samples – which characterize the Slough-proper (Cases 3 & 4). And then, to look at the interface between COPR and NCOS, the Venoco Bridge; where the sampling sites are separated by only 30 meters (Cases 5 & 6). This is to emphasize that the **Shannon Diversity Index *difference* between COPR and NCOS exists at each level from the general, down to the very specific**.

Once this observation is noted, a number of possible explanations present themselves:

1. The NCOS slough sites tend to be less saline as inflows from Phelps and Devereux Creeks bring in fresh water, allowing more diversity.
2. Nutrients, or even invertebrates washing in from the creeks are more important than those generated internally in the slough.
3. Possibly there is a different microbial balance where NCOS is more conducive to invertebrate life; or some factor(s) that make life easier for the invertebrates initially in a new ecosystem.

Necessity for Species-Level Identification

Figure 11a shows that there is a **total of 18 planktonic taxa and 10 benthic taxa, of significant quantity, *reported***. This is rather conservative. For example, we certainly have two and probably more than three Copepod species; as well, at least two or three Ostracod species, and at least two Cladocera species. There are a number of issues here:

- Many of our UCSB undergraduate volunteers are challenged to distinguish between a Copepod and debris, much less, which kind of Copepod; so going to the species level with Copepod is not readily possible at this time.
- Given that the major goal of this research is to begin to quantify the 'health' of this ecosystem, does it significantly matter whether it is this Copepod or that Copepod (or this Ostracod or that Ostracod) – given their relative ecological niches? In other words, would the resources required for the additional accuracy be justified by the benefit obtained? At this point, we feel the answer is "no". If the choice is between 80% accuracy and no data (because it is too difficult to get, say 95% accuracy, then, at this point, we think that 80% accuracy or better, is acceptable.
- However, when using the Shannon-Weiner Diversity Index, that we have at least 23 different planktonic taxa, rather than 18 could be significant.
- Additionally, that with Copepods, we are at the level of 'Subclass'; with Ostracod, 'Class'; and with Chironomid, 'Family'; etc. The question becomes, "For the results to be truly meaningful, do we need to do our comparisons at, say, the 'Class' level? This begs a larger question, "Are these classifications particularly relevant to the ecological niche of the particular creature or are they mostly useful for assigning a name to a particular creature?" My feeling is that, due to a lack of 'Complete Knowledge' there is an unavoidable ambiguity here. Practically, we simply need a way to assign the best name that we can to a particular creature and work out, generally, what roles that creature plays in the ecosystem.

Taxa Abundance by Sampling Protocol

Combining the results shown in Fig. 7 with those in Fig. 8 raises larger procedural questions. *"If the densities of taxa are greater for benthic samples than for planktonic samples, shouldn't we be sampling the benthic more frequently?"*

This comes down to *"How to optimize the given monitoring resources to collect the most useful sets of data?"*

And that comes down to: *"Given what we now know, what is the ranking of most useful data?"*

Initially, it took say three-to-five times more effort to process benthic samples compared to aquatic samples due to the amount of debris entrained in these samples; hence, not knowing the relative specimen densities at that time, we decided to sample the easier-to-process aquatic samples more frequently.

Taking a step back, given an increase in size and efficiency of our volunteer workforce, is it better to sample the invertebrates more precisely or expand our efforts to include also sampling the algae and looking at who is eating what using DNA identification techniques? Feedback on these questions is very welcome.

Culicidae v Vector Control

The question arose whether the substance that Santa Barbara Mosquito & Vector Management was applying is the Slough would be adversely affecting the larger invertebrate population.

In researching the substance, VectoBac, the literature claims that it is a bacterium highly specific to mosquito larvae (Culicidae). In our data, we only saw two incidences of Culicidae (Devereux Creek, Planktonic, June 4th & Dec 30th). Meanwhile, two closely related Diptera Order taxa, Chironomid and Ceratopogonidae registered multiple significant reading at various sites.

X. CONCLUSION

The results reported here are an indication of the Slough environment; but at least a couple of more years of data, perhaps one or two non-drought years, and some fine tuning or testing of sampling protocols would give more depth and consistency to the data.

From the data so far, the Slough and its associated ponds and vernal pools contain a fairly small set of invertebrate inhabitants. While we will need more time to determine what NCOS's steady-state environment will be like, COPR's portion of the Slough has some relatively extreme conditions with regard to Salinity, Temperature, and Dissolved Oxygen.

Also, with more data, we will be better able to separate out the more freshwater/brackish ponds from the more saline/hyper-saline Slough. This, and the probability that the NCOS portion of the Slough is less harsh than the COPR portion, could help the total understanding of the dynamics involved. With another year or two of data we should be able to say something more definitive.

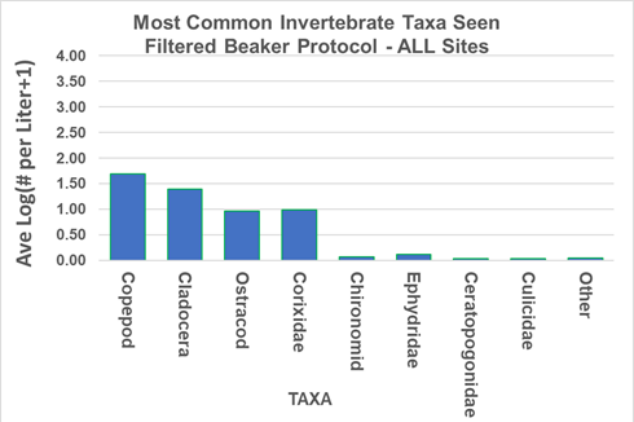
The take-aways:

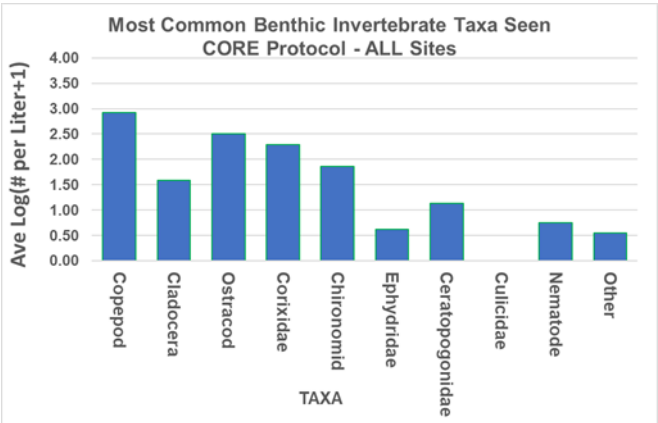
1. NCOS, in its first year of existence, has an equivalent, or slightly better, invertebrate diversity than the well-established COPR – as measured by the Shannon-Wiener Index.
2. Only four planktonic taxa appear in any great abundance: Copepod, Corixidae, Ostracod, and Cladocera.
3. There are eight benthic taxa of significant abundance: the four planktonic plus Chironomid, Ceratopogonidae, Ephydridae, and Nematode.
4. The benthic substrate has, generally, the higher concentration of taxa.

APPENDIX

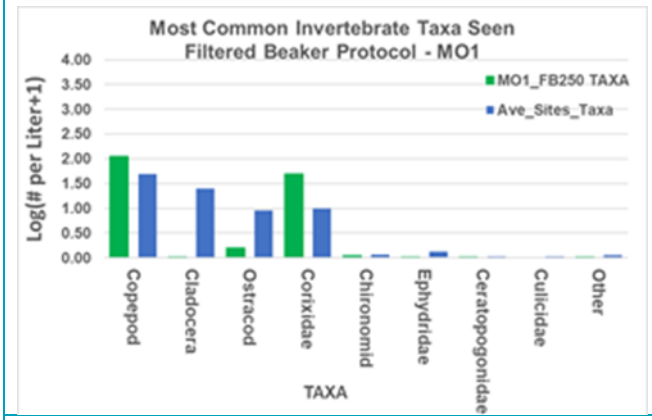
Taxa Abundance by Site - COPR

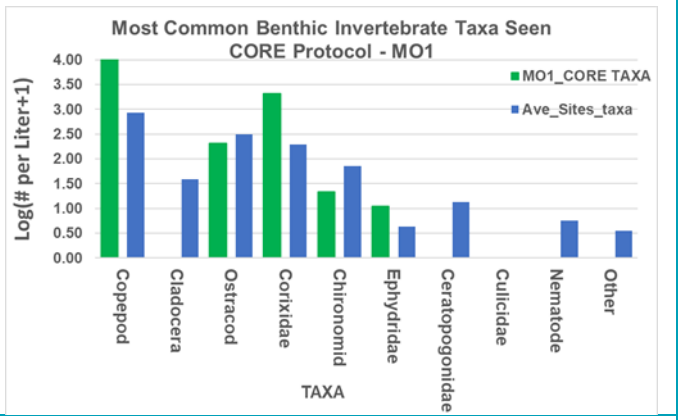
All Sites (COPR + NCOS)



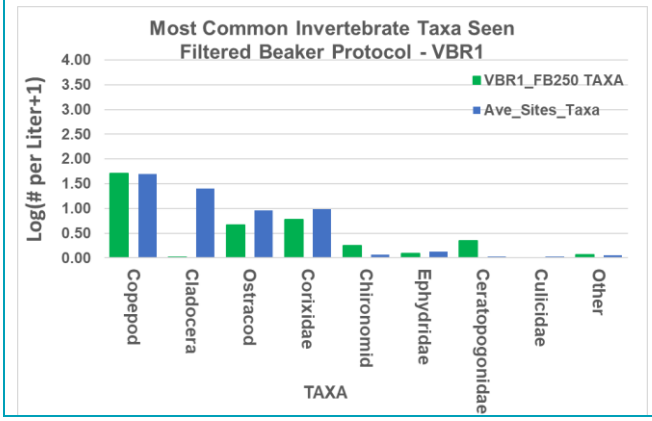


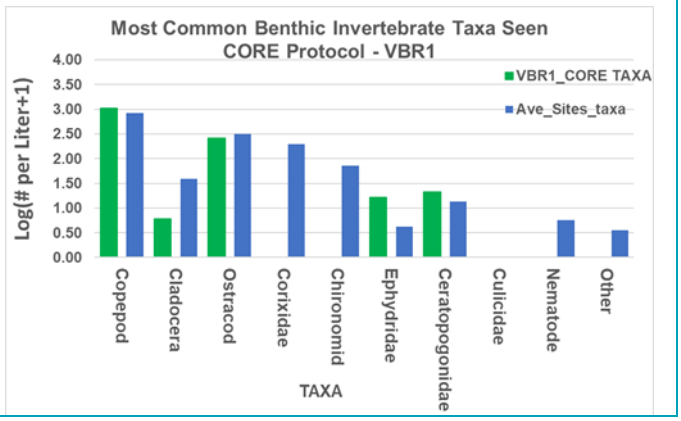
COPR – MO1 (Ocean Mouth of Slough)



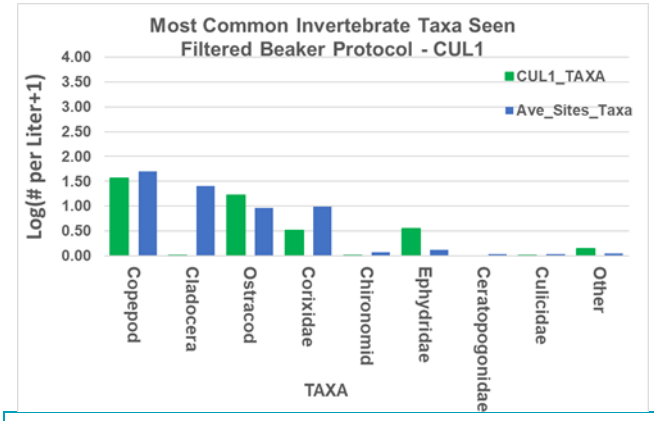


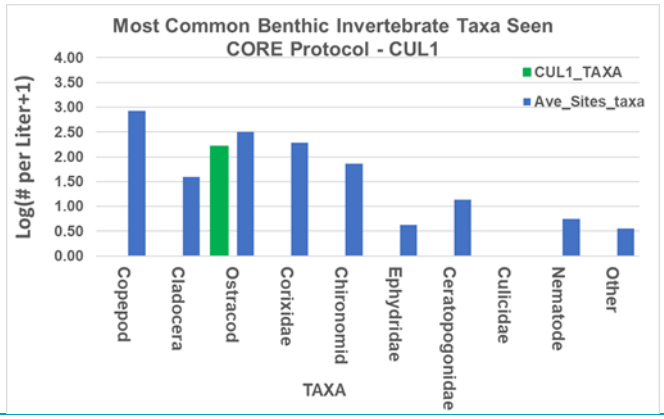
COPR – VBR1 (Venoco Bridge)



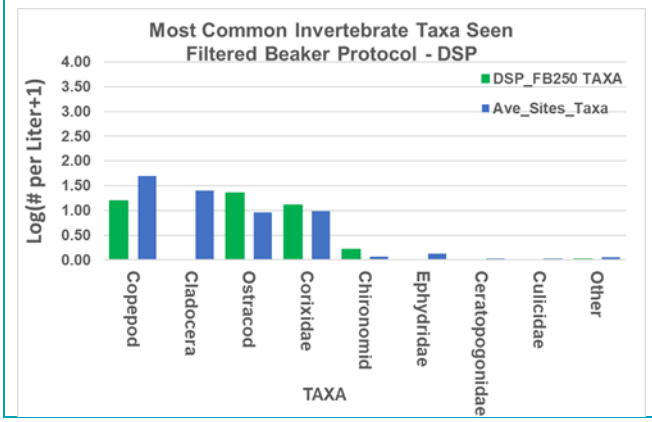


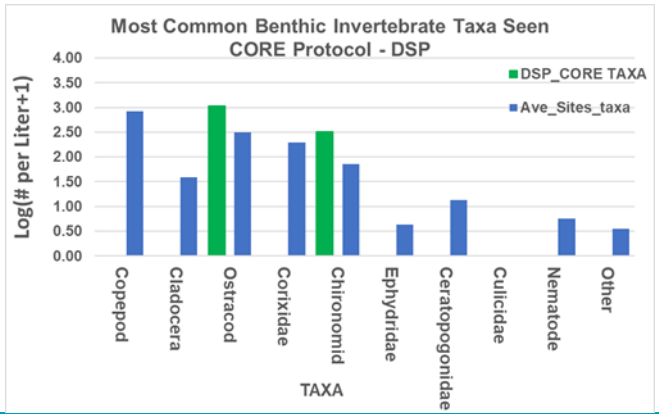
COPR – CUL1 (Culvert)





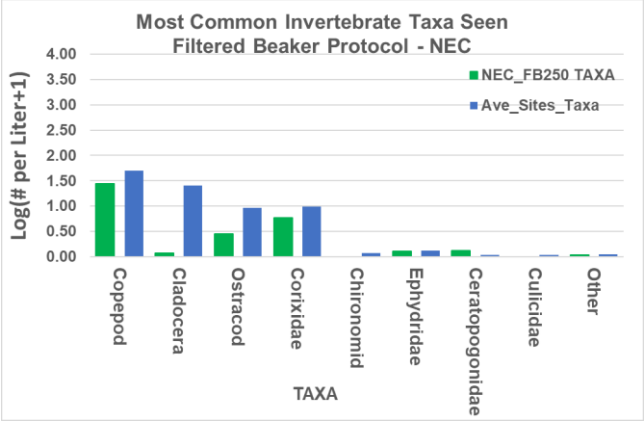
COPR – DSP (Dune Swale Pond)

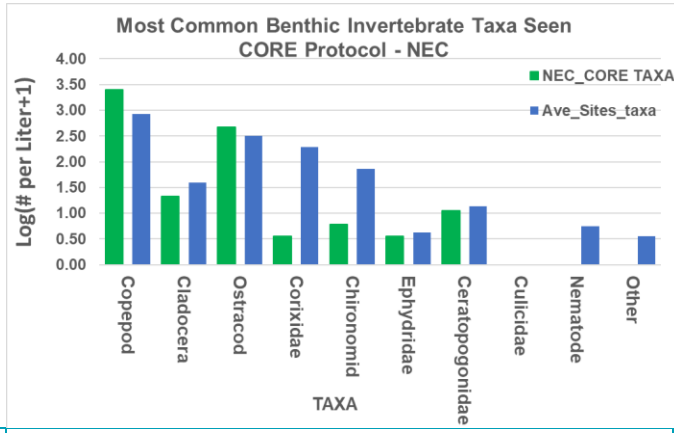




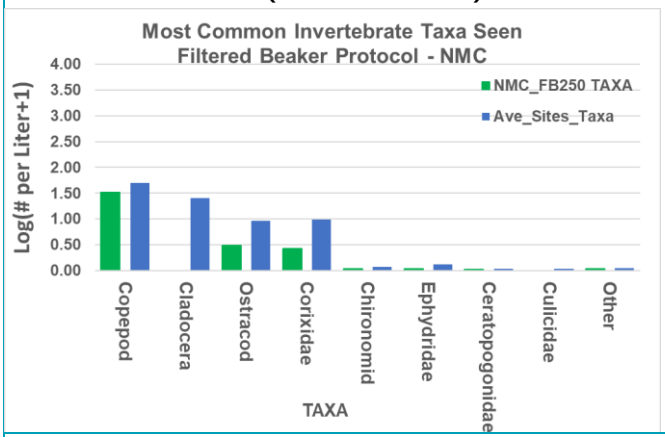
Taxa Abundance by Site - NCOS

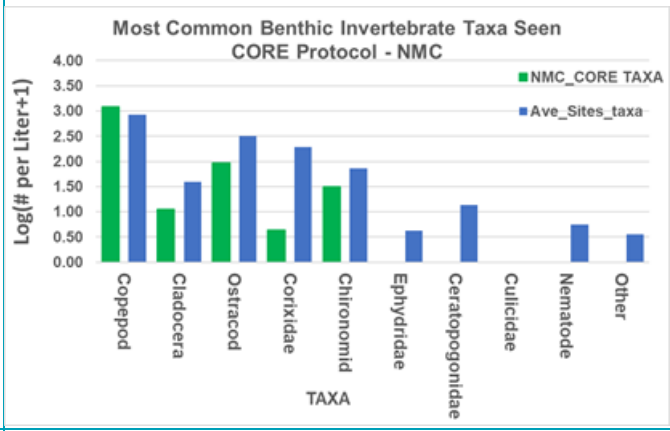
NCOS – NEC (East Channel)



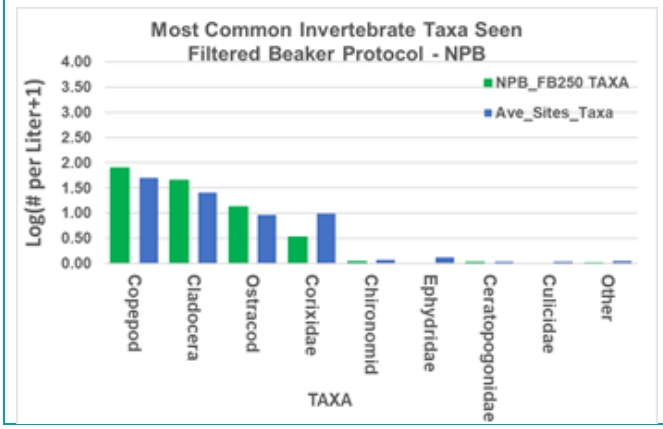


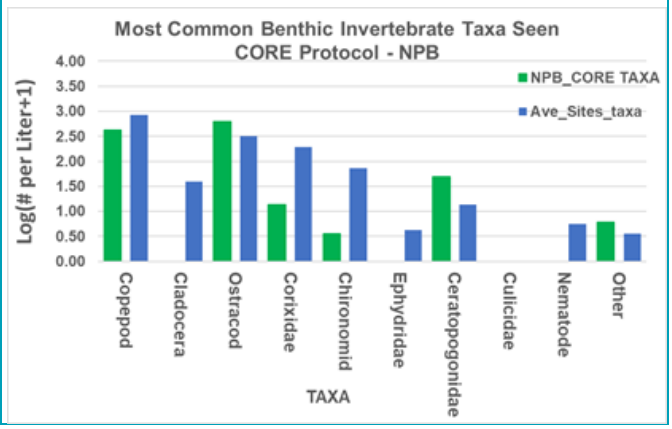
NCOS – NMC (Main Channel)



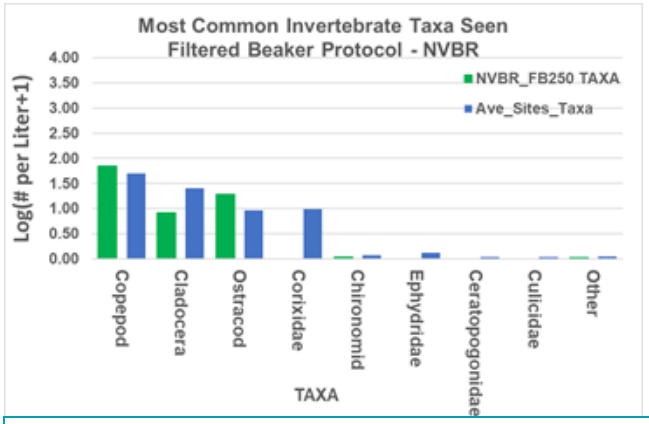


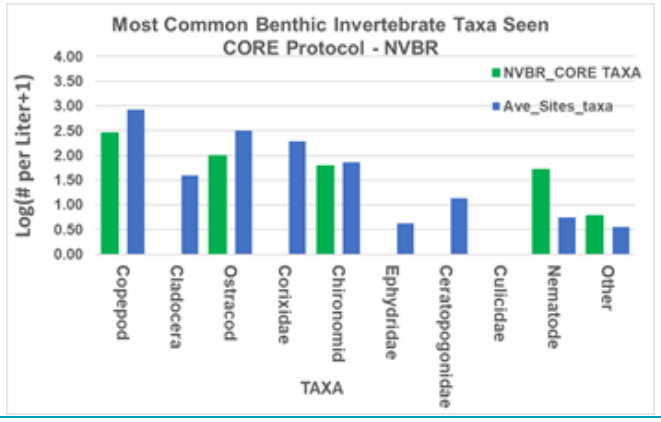
NCOS – NPB (Phelps Bridge)



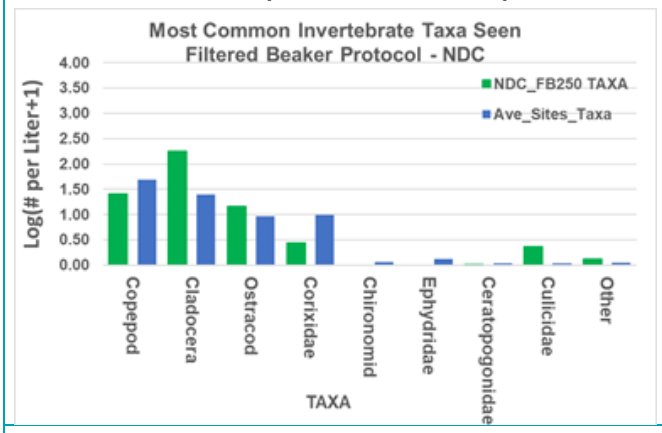


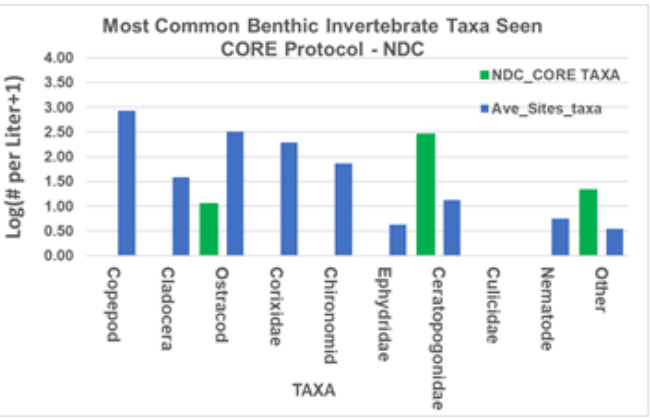
NCOS – NVBR (Venoco Bridge)



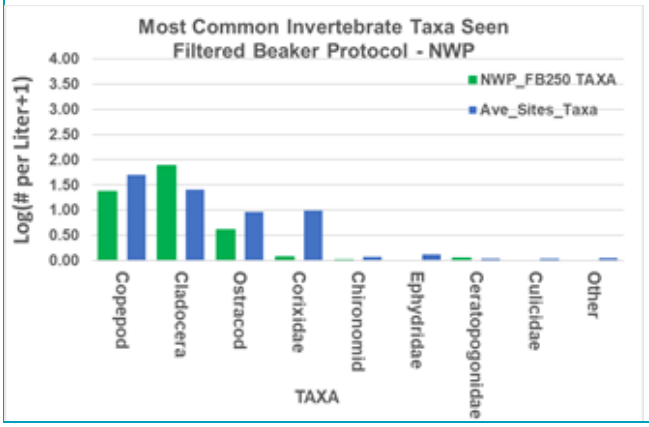


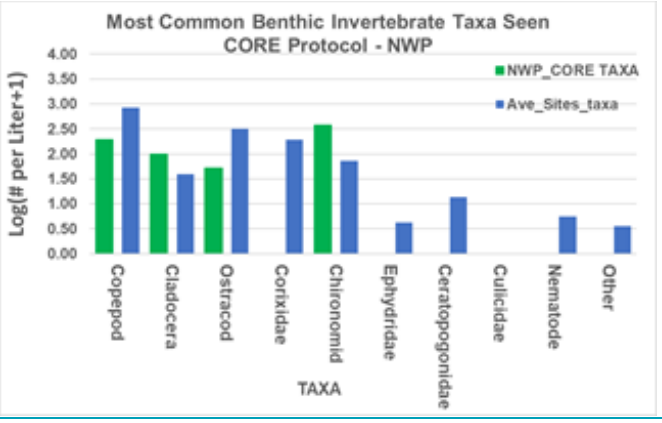
NCOS – NDC (Devereux Creek)



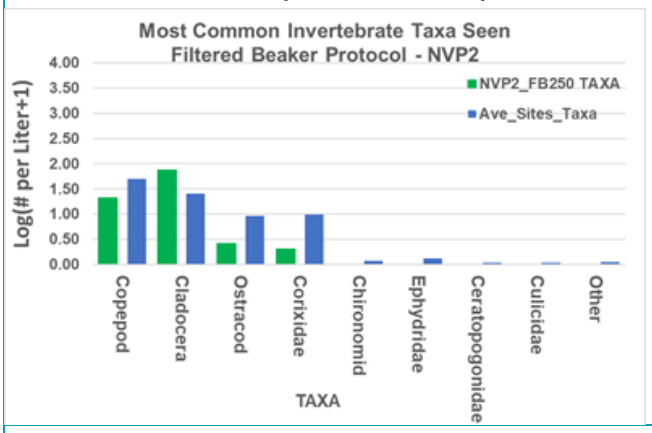


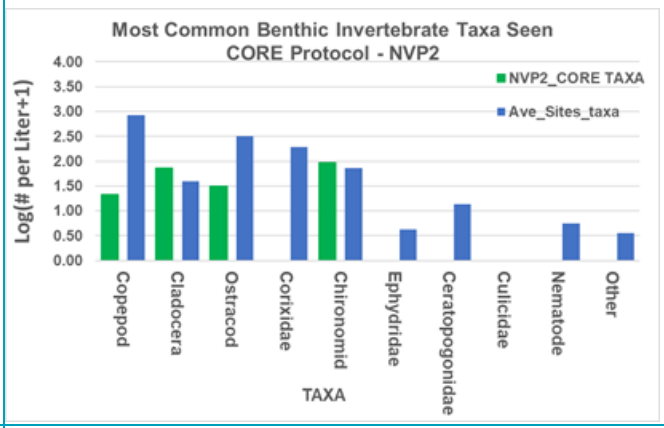
NCOS – NWP (West Pond)



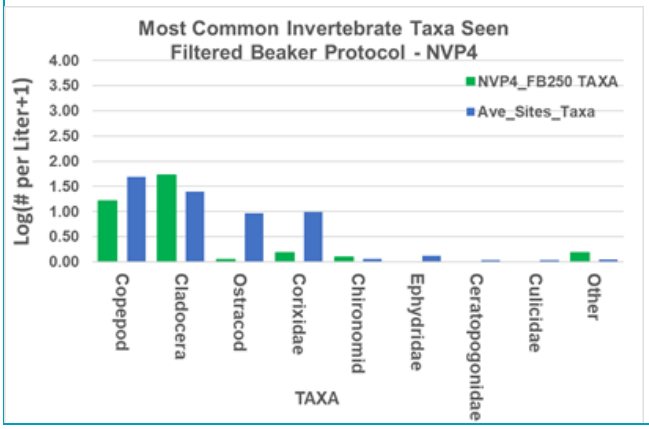


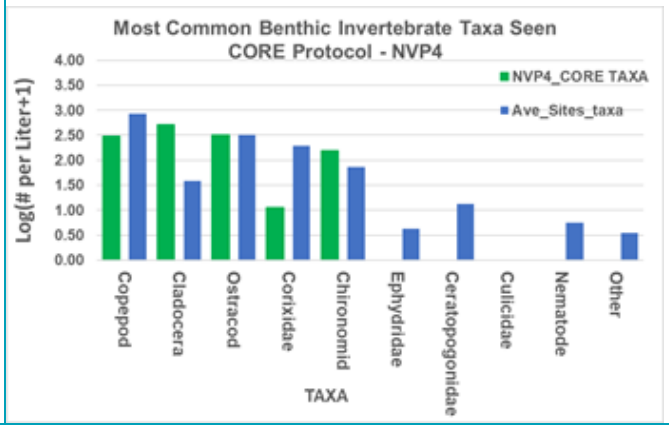
NCOS – NVP2 (Vernal Pool 2)





NCOS – NVP4 (Vernal Pool 4)

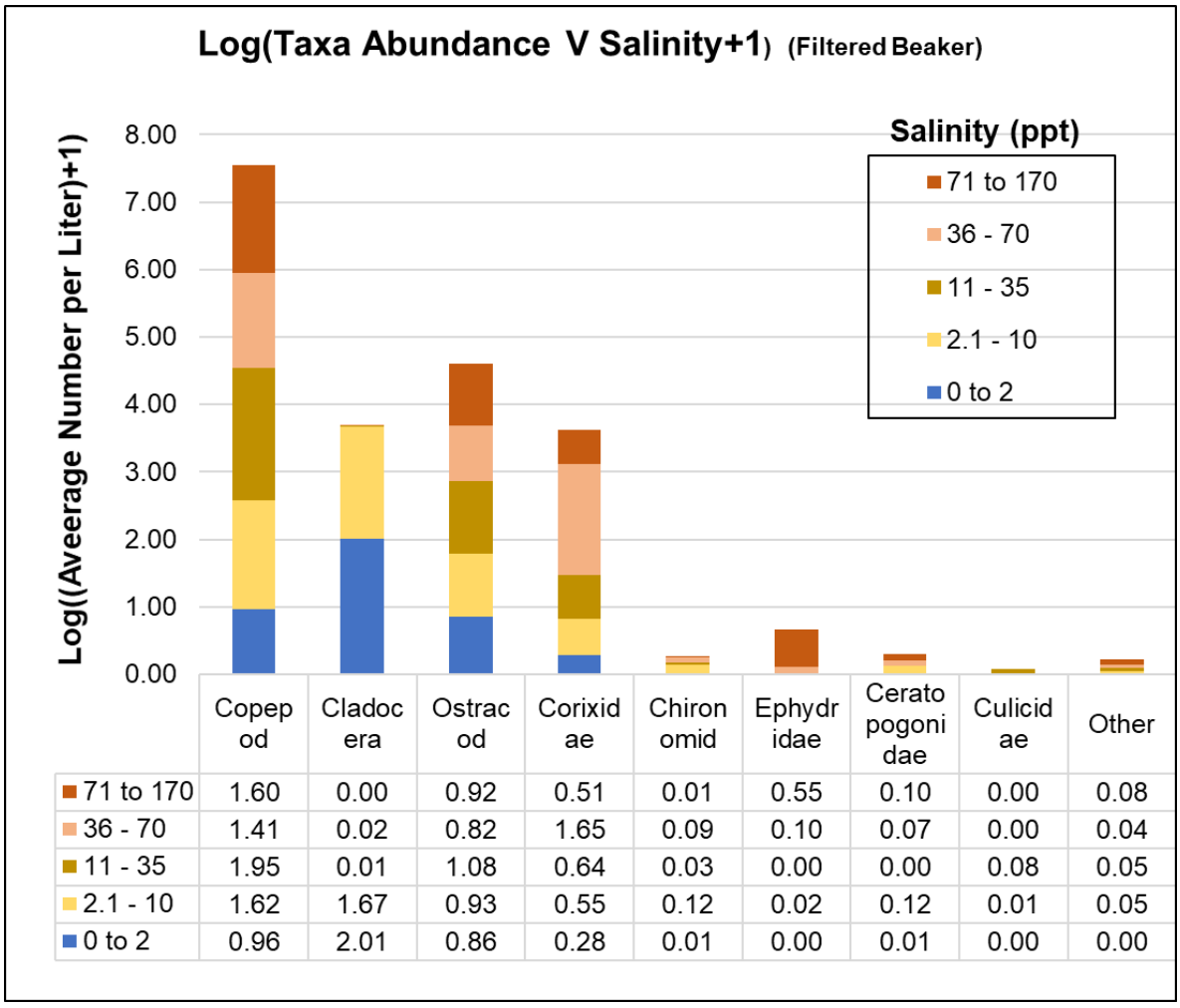




Taxa Abundance versus Salinity

For reference: Brackish water is greater than 2 ppt and Seawater is 35 ppt.

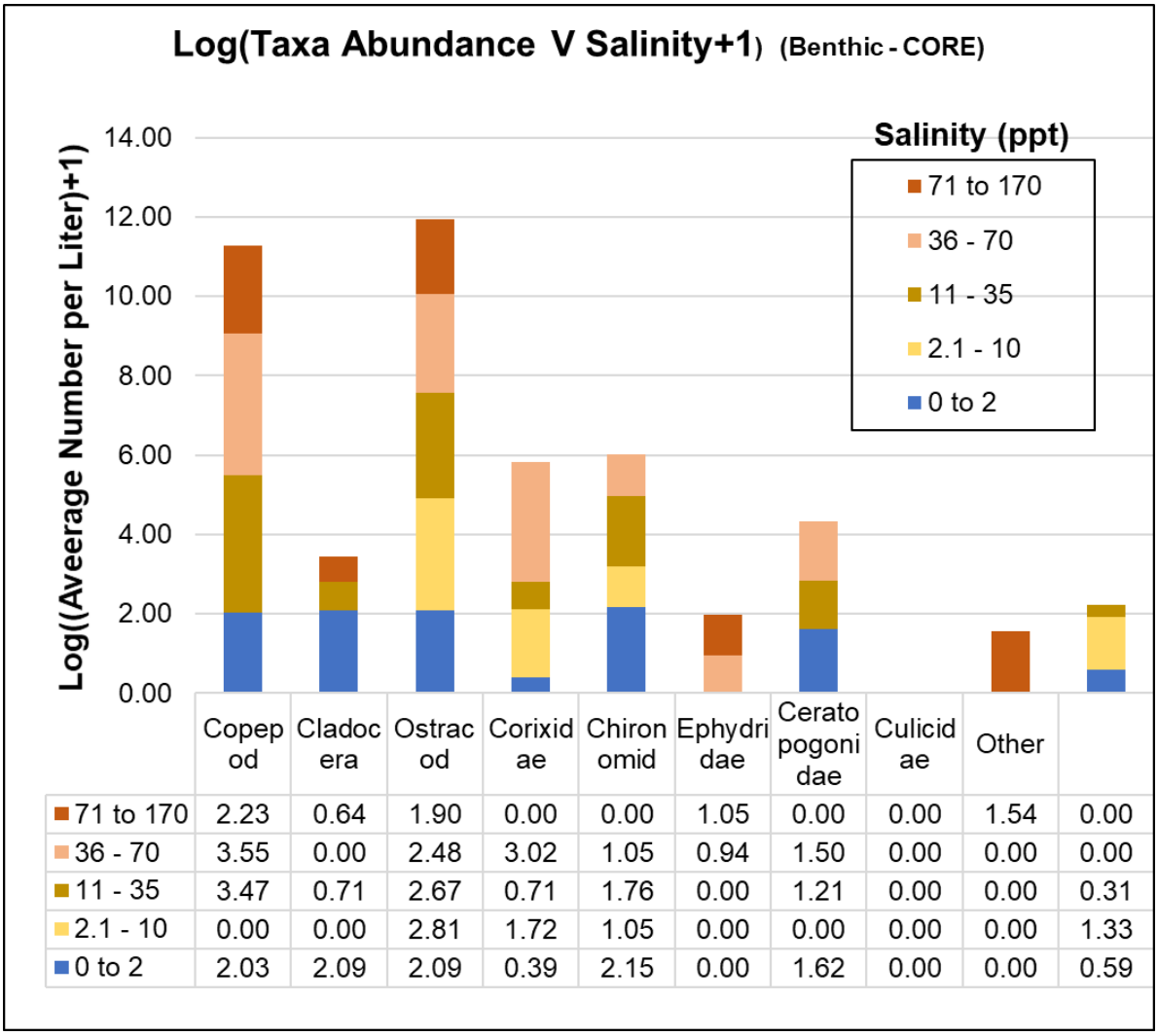
All Sites – Planktonic (Filtered Beaker) Average Taxa per level of Salinity



	Copepod	Cladocera	Ostracod	Corixidae	Chironomid	Ephydridae	Ceratopogonidae	Culicidae	Other
71 to 170	1.60	0.00	0.92	0.51	0.01	0.55	0.10	0.00	0.08
36 - 70	1.41	0.02	0.82	1.65	0.09	0.10	0.07	0.00	0.04
11 - 35	1.95	0.01	1.08	0.64	0.03	0.00	0.00	0.08	0.05
2.1 - 10	1.62	1.67	0.93	0.55	0.12	0.02	0.12	0.01	0.05
0 to 2	0.96	2.01	0.86	0.28	0.01	0.00	0.01	0.00	0.00

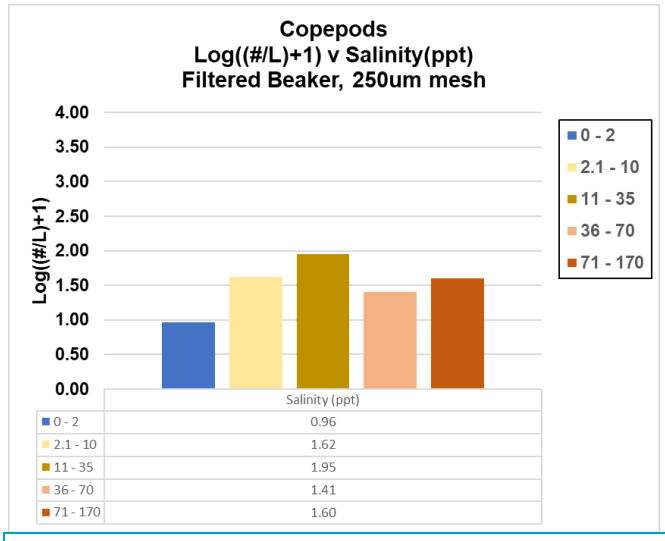
Note: The vertical axis is logarithmic. Therefore, while the number of individuals for each level of salinity is correctly indicated by the length of the colored bar, the total length, of all colors, does not give an accurate representation; e.g., we did not have 10^7 copepods per sample. Adding exponents of numbers is equivalent to multiplying the numbers together.

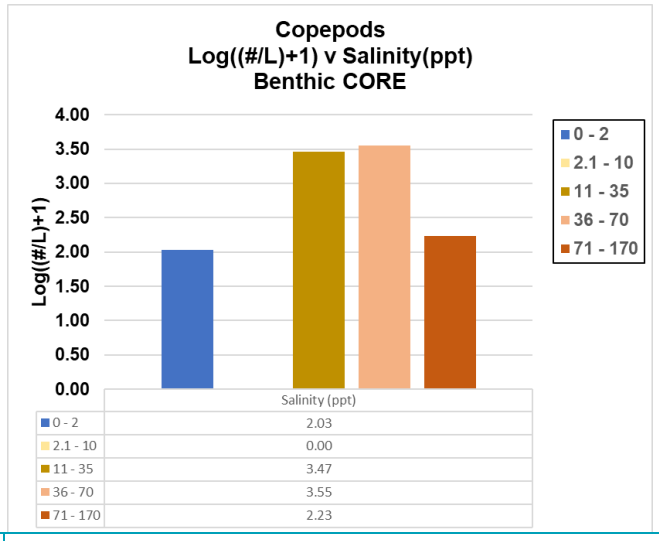
All Sites – Benthic (CORE) Average Taxa per level of Salinity



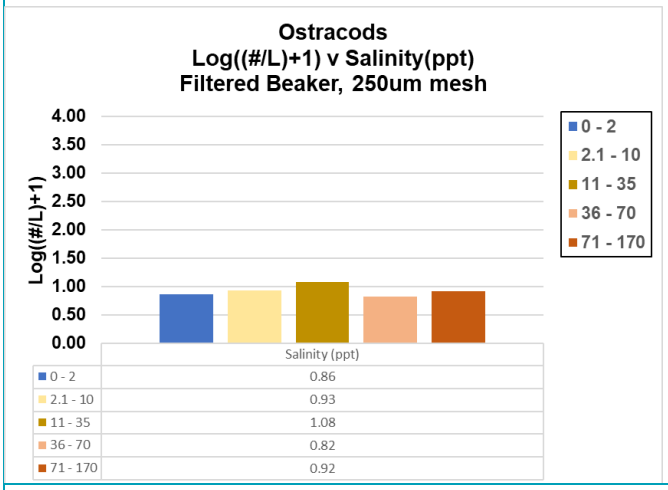
	Copepod	Cladocera	Ostracod	Corixidae	Chironomid	Ephydridae	Ceratopogonidae	Culicidae	Other	
71 to 170	2.23	0.64	1.90	0.00	0.00	1.05	0.00	0.00	1.54	0.00
36 - 70	3.55	0.00	2.48	3.02	1.05	0.94	1.50	0.00	0.00	0.00
11 - 35	3.47	0.71	2.67	0.71	1.76	0.00	1.21	0.00	0.00	0.31
2.1 - 10	0.00	0.00	2.81	1.72	1.05	0.00	0.00	0.00	0.00	1.33
0 to 2	2.03	2.09	2.09	0.39	2.15	0.00	1.62	0.00	0.00	0.59

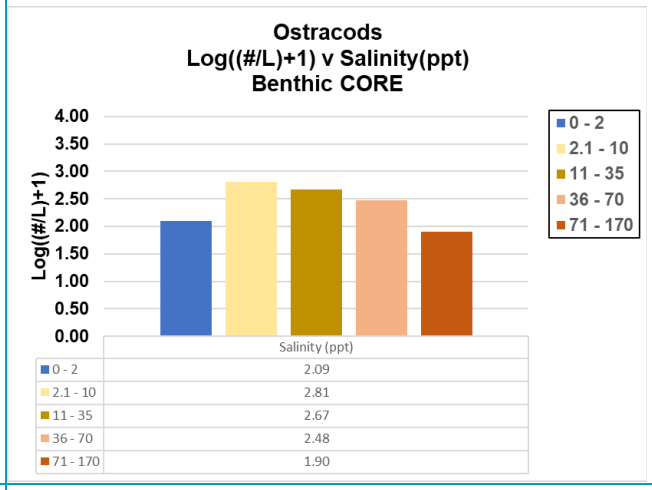
Copepod Abundance v Salinity Level



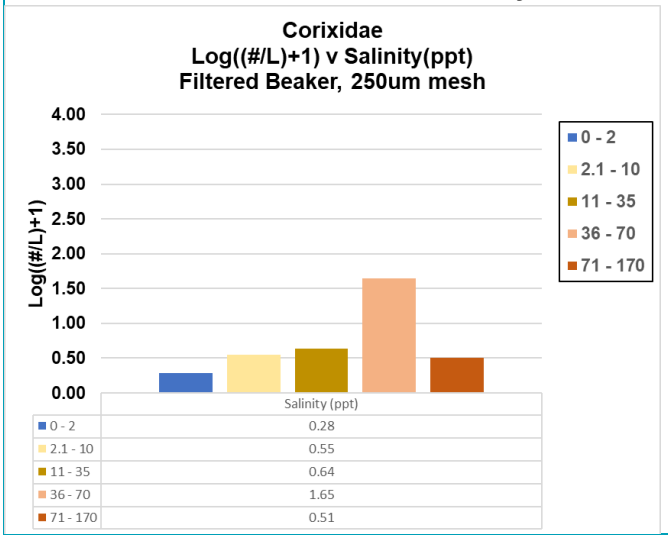


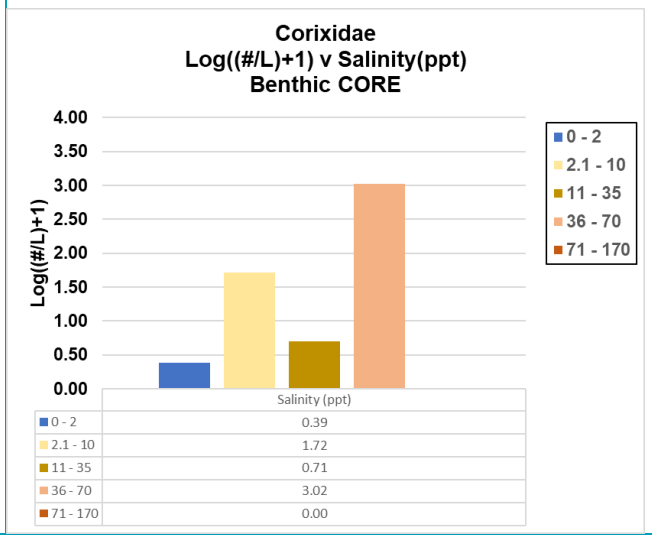
Ostracod Abundance v Salinity Level



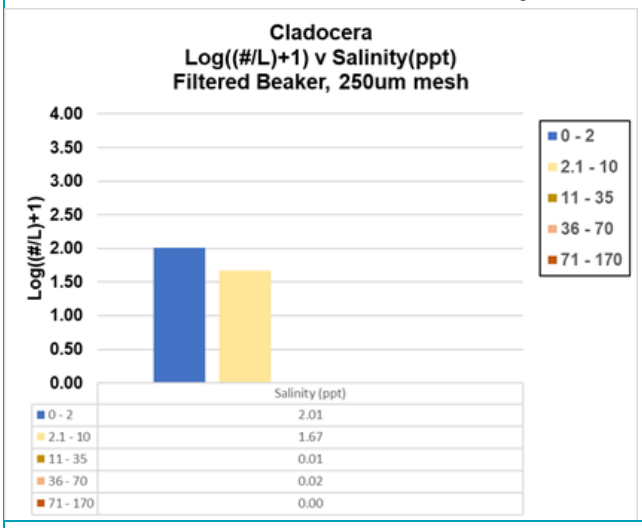


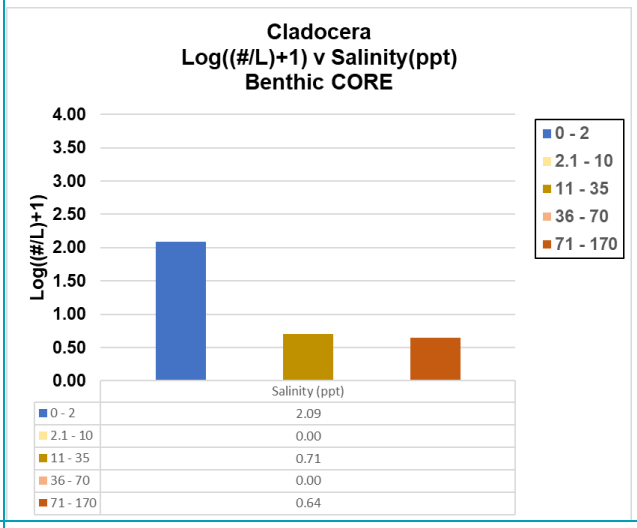
Corixidae Abundance v Salinity Level



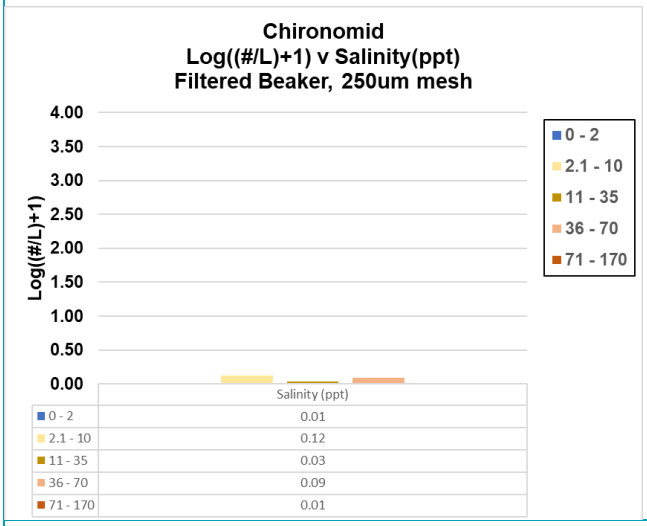


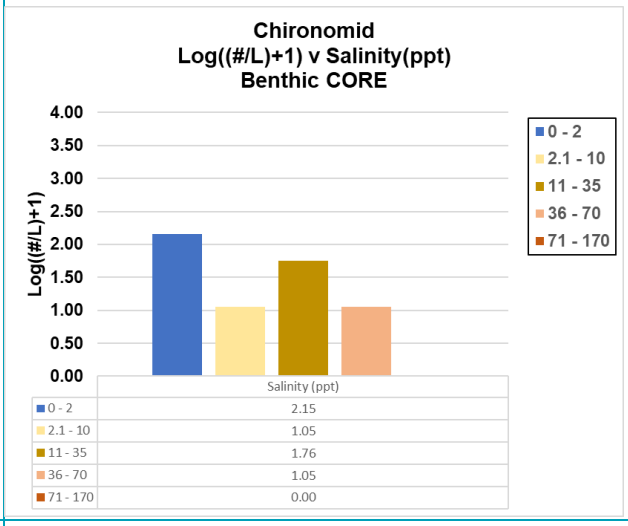
Cladocera Abundance v Salinity Level



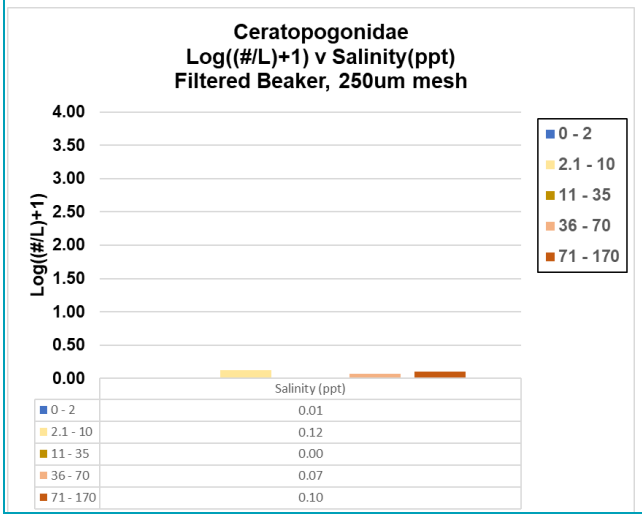


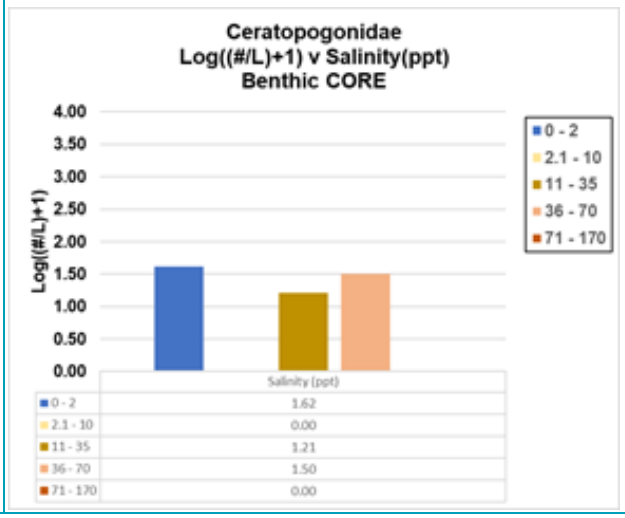
Chironomid Abundance v Salinity Level





Ceratopogonidae Abundance v Salinity





Culicidae Abundance v Salinity Level