University of Victoria

Department of Biology

Plankton Sampling and Water Quality Analysis in Gorge Waterway and Gorge Creek

Work Term Report

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by

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Abstract:

Plankton are the base of the marine food chain and are major contributors to the global carbon cycle through photosynthesis. Plankton communities serve as an important resource for higher trophic levels as a key source of nutrients as well as being bioindicators for water quality. This study sampled plankton community composition in Gorge Creek and Gorge Waterway in Esquimalt (Victoria BC, Canada) as well as water quality measurements with a YSI Pro Quatro. The samples were completed at six different sites, with two each completed for three different habitat types: the rocky intertidal, seawall coastline with muddy substrate and rock enforced creek bed. It was found that the rocky intertidal habitat has a higher abundance of individuals for more plankton groups than the other two habitats, and for all eight plankton groups analyzed the rocky intertidal was never found to be least abundant. This could be due to the fact that natural coastlines as opposed to human engineered ones support more individuals as well as increased biodiversity. Trends comparing abiotic water quality measurements to biotic plankton community composition were also analyzed and showed no drastic trends but there were distinct ranges for water quality factors that showed increased abundance in certain plankton groups. In terms of using plankton as bioindicators of water quality this study determined that in the muddy seawall and creek bed could have more pollution, decreasing plankton diversity, as well as the waterway potentially being a eutrophic environment due to distribution and composition of Foraminiferans. Due to the restoration projects set to proceed in Gorge Creek to enhance forage fish habitat, this study is important in determining food availability for fish as well as getting a good indication of the overall health of the creek and waterway in general.

Introduction:

Plankton are an important area of research for many reasons including carbon processing, contributing to earth's atmosphere through photosynthesis and fueling marine food webs (Worden *et al.*, 2015). The marine environment is responsible for approximately half of global primary production through phytoplankton, which also act as the base of the oceanic food chains (Worden *et al.*, 2015). Thus, it is evident that plankton communities play a key role as a resource for higher trophic levels and have been shown to form complex interaction networks driven by biotic and abiotic factors (Chust *et al.*, 2017). Further, the importance of plankton in regards to the carbon cycle has been highlighted (Chust *et al.*, 2017) as phytoplankton photosynthesize and simultaneously alter the cycles of other organic elements such as nitrogen and silica (Worden *et al.*, 2015). The importance of plankton communities to marine ecosystems through carbon cycling and the food web is highlighted in Figure 1 provided by Worden *et al.* (2015). In this figure DOM refers to dissolved organic matter and POM refers to particulate organic matter.

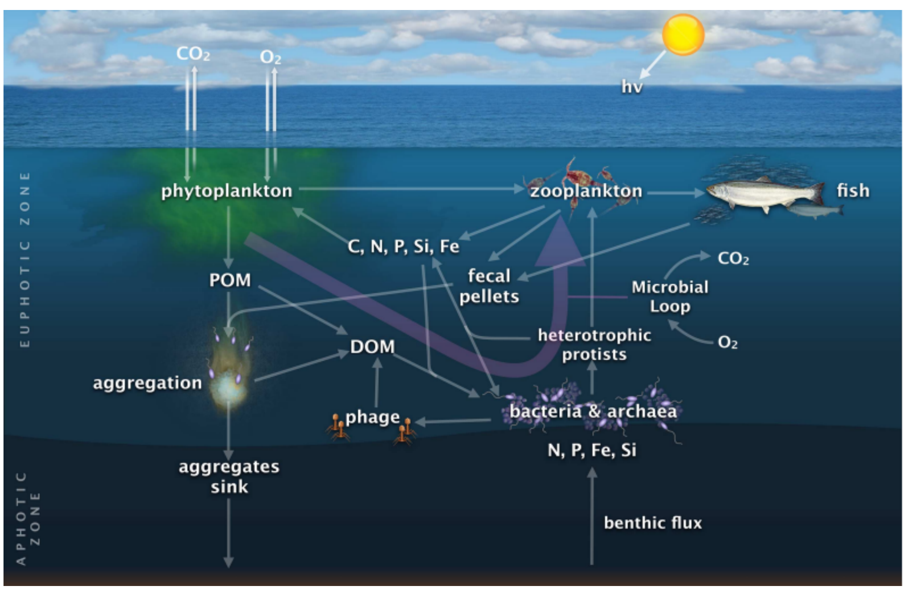
In this study, six sample sites were chosen in the Gorge Waterway and Gorge Creek in Esquimalt (Victoria BC, Canada), two of which were in the creek, two were in the rocky intertidal and two alongside man made sea walls with muddy substrate that serves as eelgrass habitat. Plankton samples were taken at each of the sites with a 65 micron plankton net as well as water quality data that was measured with a YSI pro quatro. The samples were analyzed under a compound microscope to identify eight distinct groups of organisms: Diatoms (suborder Bacillariineae), subclass Copepoda (Orders Harpacticoida, Calanoida and Cyclopoida), Veliger larva (class Bivalvia and Gastropoda), phylum Rotifera and Nauplius larva (subphylum Crustacea, often subclass Cirripedia). The collected data was compared between the six sites as well as to the water quality data to look for correlations and was plotted in scatter and bar plots to visualize trends.

This study is important as analyzing plankton community composition has been found to be an indicator of water quality (Bianchi *et al.*, 2003), which could provide insight on the overall health of Gorge Creek and Gorge Waterway. There are currently plans for habitat restoration projects to occur in Gorge Creek to promote the return of forage fish and coho salmon; thus, planktonic community assessment would be beneficial in determining ecosystem function as it relates to food availability for higher trophic levels (Nemcek *et al.*, 2019) such as forage fish and migrating salmon into Gorge Creek and Gorge Waterway. There are two upcoming restoration projects that will take place in Gorge Creek, one below the walking bridge and one upstream from the bridge which will be led by GreenShores and World Fisheries Trust, respectively. The restoration performed by Greenshores involves forage fish habitat enhancement through the removal of riprap, riparian and native plantings and beach nourishment with sediments that improve forage fish habitat (Green Shores Esquimalt Gorge Park Concept Diagram, 2022). The project above the walking bridge also involves enhancing forage fish habitat as well as coho smolt and cutthroat trout. This project plans on creating dendritic channels and intertidal pools as well as introducing new substrate (gravel/sand) and native plants to the saltmarsh area (Environmental Protection and Restoration Plan: Gorge Creek Estuary, D.R. Clough Consulting, 2022). However, there has been no research conducted into food availability for forage fish and subsequently higher trophic levels. As such, plankton sampling in Gorge Creek and Waterway is helpful in determining the overall health of these ecosystems as well as giving insight into nutrient availability for forage fish (Nemcek *et al.*, 2019).

In addition, planktonic assessment is beneficial for determining if there are areas of the Gorge that should be protected due to the occurrence of specific species. An example of this is a species of interest in the Gorge Waterway, *Ostrea Lurida* (Olympia Oyster). The olympia oyster is the only oyster species native to BC, whose aquaculture industry experienced a collapse in the 1950's and has yet to make a significant comeback due to competition with the non native *Crassostera gigas* (Pacific Oyster) (Baker, 1995). In 2003, the Olympia Oyster was added to the Canadian species at risk act as a species of "Special Concern" and as such, monitoring the significant, stable population of the oyster in the Gorge is especially important (World Fisheries Trust, 2021). The Olympia Oyster has a larval bivalve veliger planktonic stage that can be observed in plankton samples (Smith and Johnson, 1996), thus, sample analysis in the waterway could determine relative abundances of larval olympia oyster and thus provide insight on the expected numbers of mature oysters in the future.

Further, this study hopes to correlate abiotic measurements of water quality with the abundances of plankton groups. Water quality measurements taken with the YSI Pro Quatro and relative abundances of plankton groups will be compared and will provide insight on the ranges of different water quality metrics that sustain the highest populations of plankton groups. This will show what aspects of water quality are important for monitoring as certain ranges of water quality can support higher levels of plankton.

Overall, this experiment hopes to determine the relative abundances of phytoplankton and zooplankton species in Gorge Creek and Gorge Waterway using a 65 micron plankton net. Multiple samples at each site were performed over different phases of the tidal cycle. The relative abundances were compared between different sites and comparisons were made with water quality data that was collected with a YSI Pro Quatro at the same time as the plankton samples. This data will give valuable information about the health of the Gorge ahead of restoration projects set to happen in the saltmarsh area of Gorge Creek as well as insight on the occurrence of specific species such as the Olympia Oyster. This study hopes to answer the following questions (1) In an Urban area such as Gorge creek and Gorge Waterway what is the plankton community composition at different sample sites? (creek, muddy seawall and rocky intertidal) (2) How does the abiotic environment of the surrounding seawater (salinity, pH, etc..) affect the planktonic community composition? (3) Due to the Planktonic community composition are there any indicators of Gorge Creek and Waterway health?



Worden *et al.*, 2015, *Science*, 347, 11. Figure 1. An illustration of marine microbial food webs that highlights the importance of plankton to marine food webs and carbon cycling.

Methods:

Study Area:

The study site is located on the Lekwungen territory of the Esquimalt and Songhees Nations. It is located on the southern end of Vancouver Island within the Coastal Douglas-fir (CDF) Biogeoclimatic zone. The study sites will be found along the Gorge Creek as well as the Waterway with two sites in Gorge Creek and four sites in the Waterway.

Table 1. Sample sites for plankton pulls and water quality assessments

Sample Site Name	Coordinates	Habitat/Notes
Waterway 1	48.4442572, -123.3952933	Rocky Intertidal at Curtis Point
Waterway 2	48.4462452, -123.4001229	Rocky Intertidal Under Tillicum Bridge
Waterway 3	48.4469295, -123.4028390	Eelgrass patch at sea wall site
Waterway 4	48.4510009, -123.4151064	Reef balls (WFT) at sea wall site
Creek 1	48.4459692, -123.4077830	Upstream from the bridge in the creek
Creek 2	48.4438206, -123.4055584	Settling Pool 1 in the creek

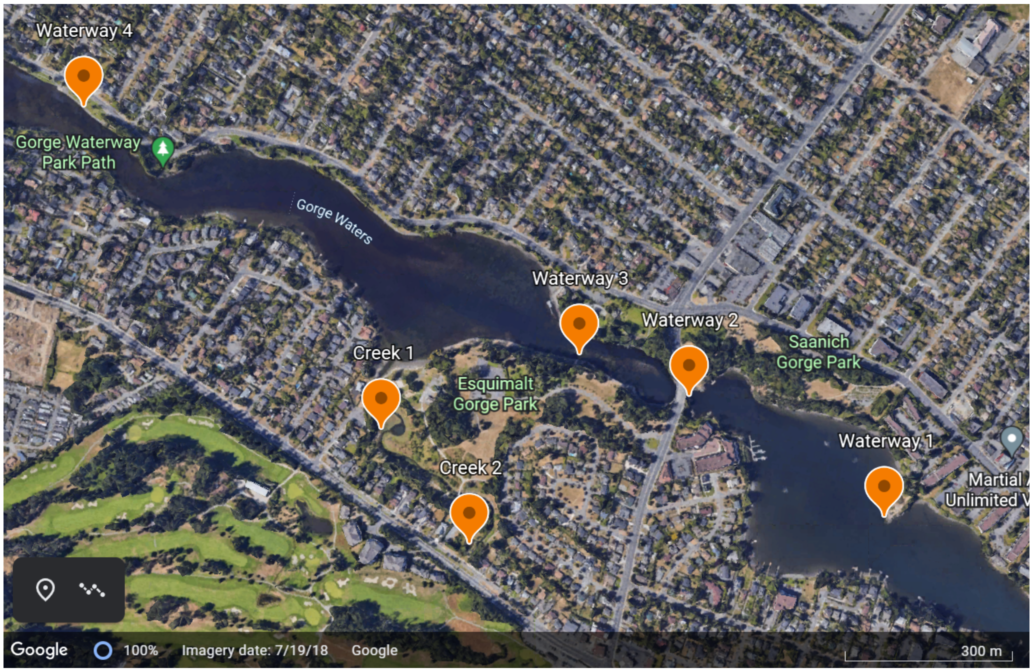


Figure 2. A map of the six study sites along the Gorge. Map data was sourced from Google Earth.

<u>In the Field:</u>

Six sample sites were chosen the length of Gorge Waterway and Gorge Creek and these sample sites are highlighted in *Table 1* with coordinates and on a map (*Figure 2*). During sampling, a three meter transect was laid down and a plankton pull with a 65 micron plankton net was performed, making sure to keep the net fully submerged the length of the pull. At each study site after the pull occurred and the sample was stored, abiotic conditions of the water were measured with the YSI Pro Quatro, such as temperature (C), Pressure (mmHg), Dissolved Oxygen (DO) in %, g/mL, ppm, SPC (mS/cm), COND (mS/cm), Salinity (ppt), TDS (g/L), RES (kohm-cm), pH, pHmV and ORP (mV). The samples for both plankton and water quality were taken over different stages of the tidal cycle over a four week period starting July 25th 2022 and ending August 16th 2022, for a total of 8 samples per site, except for Creek 2 and Waterway 4 where only 7 samples occurred. To keep the plankton in the samples alive they were kept in a cool environment (half submerged in a bin of cool water). To avoid cross contamination between samples, the plankton net was rinsed out twice at each site before the pull was performed.

In the Lab:

The samples were first viewed with the naked eye to see if there was anything to view macroscopically. Then, 5 drops from the sample were transferred to a slide with a standard 5 mL pipette. The zooplankton and phytoplankton samples were viewed at 4x magnification and identified by distinct groups of organisms and their relative abundances were recorded. Relative abundances of plankton species are defined by four categories, rare, occasional, common and abundant. The abundance categories are defined as: rare being two or less individuals, occasional being between three and ten individuals, common being between 10 and 20 individuals and abundant being more than 20 individuals. This process occured twice for each sample to make sure that certain species were not excluded from plankton counts. Species ID came from multiple different resources but primarily from “A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae - Second Edition" (Smith and Johnson, 1996) and “Introductory Guide to Zooplankton Identification” from Integrated Marine Observing System (Slotwinski *et al.*, 2014).

Data Analysis:

Using Rmarkdown in RStudio, with the tidyverse package (dplyr, readr and ggplot), two sets of graphs were made. First, a bar plot with habitat type on the x axis, the number of samples performed on the y axis and a legend with different colors describing the abundance categories of a plankton group. Thus, the bars are split into different colours based on the abundance of a specific plankton species. To provide more replicates, study sites were combined based on similar habitat structure, walled creek habitat containing Creek 1 and 2, rocky intertidal continuing Waterway 1 and 2 and seawall with muddy substrate containing Waterway 3 and 4.. The second set of plots are scatter plots with the date on the x axis, a water quality metric on the y axis and a legend with different colors describing the abundance categories. The kinds of plankton that were focused on for relative abundance data are: Diatoms (suborder Bacillariineae), subclass Copepoda (Orders Harpacticoida, Calanoida and Cyclopoida), Veliger larva (class Bivalvia and Gastropoda), phylum Rotifera and Nauplius larva (subphylum Crustacea, often subclass Cirripedia). A table of all collected results (including plankton for which no data analysis occurred) for each sample site is included in appendix B, while all collected water quality data can be found in appendix A.

Results:

The analysis of collected data focused specifically on eight distinct groups of organisms: Diatoms (suborder Bacillariineae), subclass Copepoda (Orders Harpacticoida, Calanoida and Cyclopoida), Veliger larva (class Bivalvia and Gastropoda), phylum Rotifera and Nauplius larva (subphylum Crustacea, often subclass Cirripedia). Bar plots of plankton abundances at differnt habitat types (Appendix D) can be used to create abundance proportions for different sites and tables showing abundance proportions for both each individual site and habitat can be found in Appendix C. For Bacillariineae, the muddy sea wall was most abundant with an abundance proportion of 0.467 (7 Samples), followed by the rocky intertidal (0.438) and the enforced creek (0.400). The rest of the relative abundances of Bacillariineae at muddy sea wall habitat from common, occasional, rare and none were; 0.333, 0.067, 0.067, 0.067 (Appendix C.1). The remaining relative abundances of Bacillariineae in the rocky intertidal were; 0.313, 0.188, 0.000, 0.063 (Appendix C.1). For the enforced creek the relative abundances were; 0.400, 0.133, 0.067, 0.000 (Appendix C.1). For Order Copepoda, subclass Calanoida, the abundance proportions in the rocky intertidal were; 0.188, 0.250, 0.250, 0.063, 0.250 (Appendix C.2). At the muddy sea wall habitat the proportions were; 0.200, 0,200, 0.000, 0.000, 0.600 (Appendix C.2). The enforced creek had the highest abundance of calanoid copepods (4 samples) with proportions of; 0.267, 0.133, 0.200, 0.067, 0.333 (Appendix C.2).

Order Copepoda, subclass Cyclopoida has the highest abundant samples in the rocky intertidal with 6 samples (0.375), followed by the muddy seawall (0.333) and then the enforced creek (0.267) (Appendix C.3). The rest of the relative abundances of Cyclopoida in the rocky intertidal from common, occasional, rare and none were; 0.250, 0.188, 0.063, 0.125 (Appendix C.3). The remaining relative abundances of Cyclopoida at the muddy seawall were; 0.133, 0.000, 0.000, 0.533 (Appendix C.3). For the enforced creek the remaining relative abundances were; 0.200, 0.333, 0.133, 0.067 (Appendix C.3). Subclass Copepoda, Order Harpacticoida was most abundant in the rocky intertidal (3 samples) with abundance proportions (abundant, common, occasional, rare, none) of; 0.188, 0.313, 0.188, 0.000, 0.313 (Appendix C.4). At the muddy sea wall the proportions of Harpacticoida were; 0.133, 0.200, 0.267, 0.000, 0.400, and at the enforced creek the proportions were; 0.000, 0.400, 0.333, 0.133, 0.133 (Appendix C.4).

Bivalve veligers had no samples where they were considered abundant, however they were the most common in the rocky intertidal with 2 samples (0.125), and equally as common at the muddy seawall and the enforced creek (0.067) (Appendix C.5). The rest of the abundance proportions (occasional, rare, none) for the rocky intertidal were; 0.313, 0.063, 0.500 (Appendix C.5). For the muddy sea wall the proportions were; 0.467, 0.000, 0.467 and the enforced creek bed had remaining abundance proportions of; 0.067, 0.067, 0.800 (Appendix C.5). Gastropod veligers were the most abundant in the rocky intertidal, 0.188 (2 samples), and there were no samples at the muddy sea wall or the enforced creek that were considered abundant (0.000) (Appendix C.6). The rest of the rocky intertidal proportions (common, occasional, rare, none) were; 0.063, 0.125, 0.063, 0.563 (Appendix C.6). The muddy seawall had remaining abundance proportions of; 0.200, 0.200, 0.133, 0.467 and for the enforced creek bed the remaining abundance proportions were; 0.000, 0.000, 0.067, 0.933 (Appendix C.6).

Rotifera were most abundant at muddy seawall habitat with one sample (0.067), and no abundant samples in the rocky intertidal or the enforced creek (0.000) (Appendix C.7). The muddy intertidal had remaining abundance proportions (common, occasional, rare, none) of; 0.200, 0.600, 0.000, 0.133 (Appendix C.7). The rocky intertidal had remaining values of; 0.375, 0.500, 0.000, 0.125, and the enforced creek bed had remaining values of; 0.067, 0.133, 0.067, 0.733 (Appendix C.7). Lastly, Nauplius larva were the most abundant in the walled creek with 8 samples (0.533), with rocky intertidal and muddy seawall habitat having no abundant samples (0.000) (Appendix C.8). The remaining proportions for the enforced creek (common, occasional, rare, none) were; 0.333, 0.067, 0.000, 0.067 (Appendix C.8). For the rocky intertidal the remaining abundance proportions were; 0.063, 0.500, 0.125, 0.313, and for the muddy sea wall the proportions were; 0.067, 0.467, 0.067, 0.400 (Appendix C.8).

For each group of plankton, different water quality metrics were found to influence their abundance. Suborder Bacillariineae was seen to be most abundant between a pH of 7.6 and 8.2, however, Bacillariineae seems to tolerate a variety of water quality measurements and survive in reasonable numbers (Appendix D.1). Temperature seems to have an effect on subclass Copepoda (Appendix D.2, D.3, D.4) and it seems that copepods are most abundant in a mid temperature range of 21 -26 C. Further, Cyclopoid copepods (Appendix D.3) and Calanoid Copepods (Appendix D.4) seemed to be more abundant at lower to mid tidal heights, being the most abundant between 0.2 m and 0.8 m. Bivalve veligers (Appendix D.5) seem to be more abundant at higher salinities (above 25 ppt) and lower pH (mV) ranging from -60 to -80. Gastropod veligers (Appendix D.6) seem to be able to withstand more of a spectrum of water quality measurements with the only parameter with a trend being temperature where they were most abundant from 20-25 C. Nauplius larva withstand large ranges of water quality parameters and don't show any defined trends. Last, phylum Rotifera (Appendix D.8) seems to be most common in a temperature range of 22-26 as well as in a pH of 8 and over.

A final note is that Foraminiferans were seen three times, only at Waterway site 4 with rare abundance and they seem to be the most common at TDS (g/L) around 26, and at SPC (mS/cm) around 40 and salinity around 25 ppt (Figure 3).

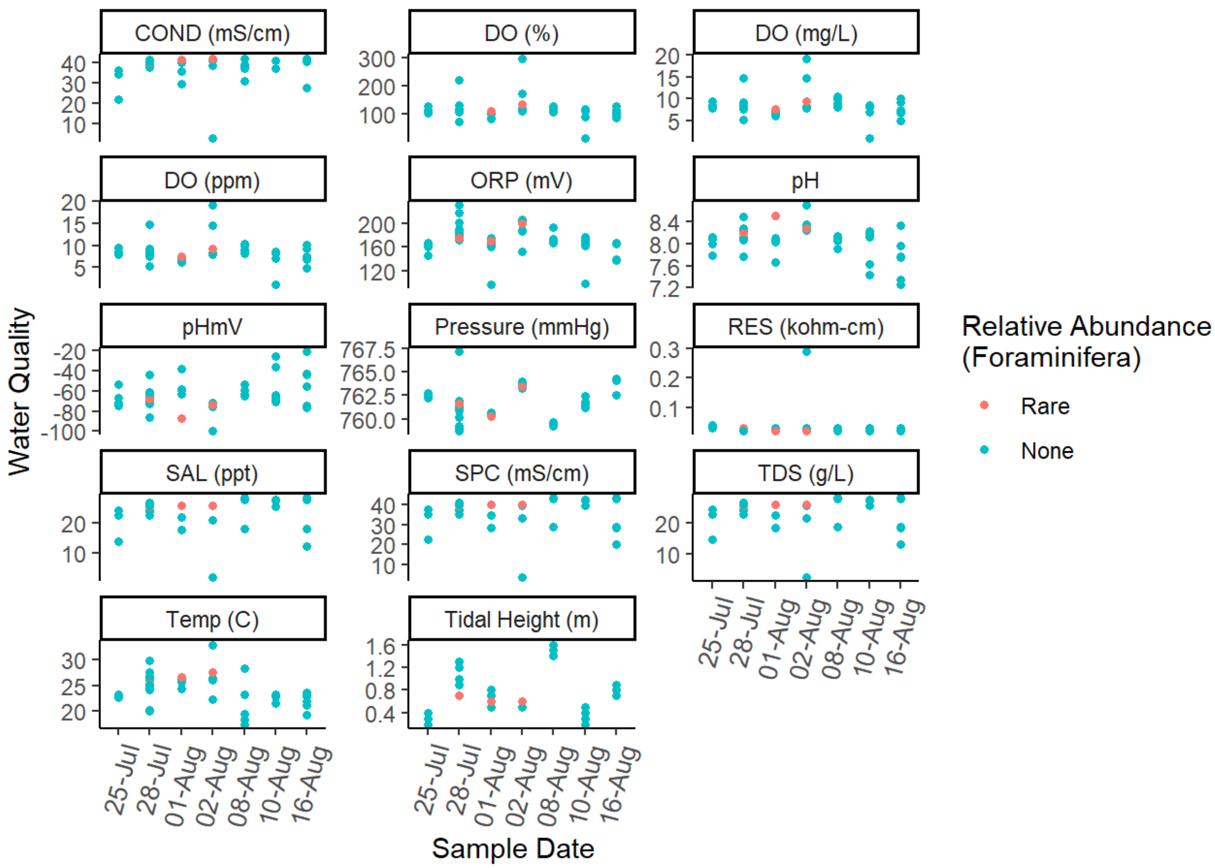


Figure 3. Plots showing the relative abundances of phylum Foraminifera compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of phylum foraminifera over all different sample sites in the Gorge.

Discussion and Conclusions:

There were three main objectives for this study (1) What is the plankton community composition at different habitats in an urban area such as the Gorge (creek bed, rocky intertidal, seawall with muddy substrate)? (2) What are the effects of the abiotic environment (Temperature, pH, salinity etc…) on plankton community composition? (3) Given the plankton community composition observed, are there any indicators of the health of the Gorge?

A 65 uM net and a YSI Pro Quatro were used for the plankton samples and water quality measurements, respectively. The samples were then analyzed under a compound microscope and plankton data was recorded in terms of relative abundance of plankton groups in a sample. The data was then plotted in two ways, (1) Comparing habitat types to relative abundances of a plankton group. (2) Comparing water quality metrics to relative abundances of a plankton group. Bar plots (Appendix D), show us how the abundances of plankton groups compare over different habitats. From these bar plots, abundance proportions for plankton groups were found and compared between habitats. Bacillariineae was the most ubiquitous in the creek (none = 0), least often found and most abundant at the muddy sea wall (none = 0.067, abundant = 0.467). Order Calanoida was found to be the most abundant in the enforced creek (abundant = 0.267), most ubiquitous in the rocky intertidal (none = 0.250) and least often found at the muddy sea wall (none = 0.600). For Order Cyclopoida, the highest abundance was in the rocky intertidal (abundant = 0.375), the most ubiquitous habitat was the enforced creek (none = 0.067) and Cyclopoida was the least often found in the muddy intertidal (none = 0.533). Order Harpacticoida was the most abundant in the rocky intertidal (abundant = 0.188), most ubiquitous in the creek (none = 0.133) and least often found at the muddy seawall (none = 0.400). For Bivalve veligers, there were no abundant samples, however, they were most common in the rocky intertidal (common = 0.125), most ubiquitous at the muddy seawall (none = 0.467) and least often found in the creek (none = 0.800). Gastropod veligers were most abundant in the rocky intertidal (abundant = 0.188), most ubiquitous at the muddy seawall (none = 0.467) and least often found in the creek (none = 0.933). For Phylum Rotifera, they were found to be the most abundant at the muddy seawall (abundant = 0.067), most ubiquitous in the rocky intertidal (none = 0.125) and the least often found in the creek (none = 0.733). Last, Nauplius larva was the most abundant and the most ubiquitous in the creek (abundant = 0.533, none=0.067) and the least often found at the muddy seawall (none = 0.400). From these abundance proportions we can see that the rocky intertidal has a higher abundance of individuals for more plankton groups than the other two habitats and none of the eight plankton groups analyzed are least often found in the rocky intertidal. This could be because natural coastlines, as opposed to human engineered seawalls, are known to promote more biodiversity (Gittman *et al.*, 2016). Compared to natural shorelines, seawalls had 45% fewer organisms and 23% lower biodiversity (Gittman *et al.*, 2016). This could also explain why the rocky intertidal had more plankton groups with higher abundances than the seawall habitat. Further, Gorge creek was diverted and channelized, the riparian area is largely riprap and lacks plant diversity (Environmental Protection and Restoration Plan: Gorge Creek Estuary, D.R. Clough Consulting, 2022), the lower plankton diversity in the area could be a result of the engineered structure of the creek as opposed to a natural creek bed. Another possible reason for less diversity of plankton in the creek is the lower salinity level. Telesh *et al.* (2011) discusses that in estuaries (such as Gorge Creek) the salinity gradient is the variable that plays the biggest role in defininting the plankton community characteristics. Telesh *et al.* (2011) discovered that in the Baltic Sea, plankton diversity peaked at an intermediate salinity (between 5% and 8% salinity) and dropped off below and above that. Thus, it's possible that the creek has lower diversity of plankton species simply because the salinity levels are too low (average of 20.54 ppt) to support them. One could also consider the impacts of pollution in the creek and the muddy substrate below the seawall in reducing plankton abundance and diversity. Both rocky intertidal sites have an observationally higher level of current than the muddy sea wall and creek sites, this would mean that any pollutants would most likely settle in the creek or seawall sites as pollutants are transported through marine systems from high energy environments with higher current velocity to low energy environments (Cunningham *et al.*, 2020). Thus, it is possible that there are higher concentrations of pollutants (organic matter, oil, industrial waste) in the creek and at seawall sites which could cause diversity to fall and subsequently plankton biomass and number of organisms would also fall (Gray, 1979).

In terms of how abiotic factors affect the composition of plankton communities there were no defined trends in the plankton groups but there were specific ranges of certain water quality measurements that seemed to support higher numbers of certain plankton groups.These ranges are highlighted in scatter plots that are included in Appendix D. A common trend was that subclass Copepoda seemed to be most abundant in a temperature range between 22 C and 27C. Copepod species in temperate waters seem to be tolerant to temperature fluctuation over the year (seasonal variation) (Webber and Roff, 1995) which is confirmed by the samples in this study as Copepods were able to withstand higher water temperatures. Halsband-Lenk *et al.* (2002), performed a study on the Copepod genera *Centropages* and *Temora*. The Copepods were studied to determine temperature responses (2C to 35C) over all developmental stages of the Copepod Species (Halsband-Lenk *et al.*, 2002). Halsband-Lenk *et al.* (2002) found that the Copepod genera *Centropages* and *Temora* had a higher proportion of mortality (60 to 100%) above 25 C. This correlates with the data for this study as we see a lower abundance of Copepods above 25 C. However, Halsband-Lenk *et al.* (2002) shows that Copepod mortality rate was very low at temperatures below 15 C, thus it would be beneficial to perform further plankton samples at lower water temperature to see if Halsband-Lenk *et al.* (2002) data lines up with the trends seen in the Gorge.

Another key result was that Bivalve Veligers were most common at salinities above 20 ppt and between temperatures of 20 and 25 C. Salinity and water temperature have been found to influence the survival, growth, activity and physiology of bivalves (van der Gaag *et al.*, 2016). Van der Gaag *et al.* (2016), found that certain species Bivalve Veligers had the lowest percent mortality at higher salinities between 20 and 36 ppt which correlates with the results of this study. Gastropod Veligers were most common in a pH range from 8.0 to 8.2, this could be due to the fact that lower pH's negatively impact the ability of Gastropods to form their shells (Bogan *et al.*, 2019). Bogan *et al.* (2019) found that at pH 7.5 and below, shell growth decreased significantly between pH 7.6 and 7.5 in larvae and juveniles. While Nauplius larva were the most abundant in the creek, there are no particular trends in the data that can show why this is, it is possible that they are prevalent in lower Salinity (ppt), TDS (g/L) and SPC (mS/cm). However, not enough samples were performed at the lower ranges of these water quality metrics to be able to say for certain that these trends could explain Nauplius larva abundance.

Phylum Foraminifera were found to only be present in the Waterway 4 sample site in the walled sea wall habitat. While it seems that foraminifera were mostly present at an intermediate salinity of around 25 ppt, Winter *et al.* (1983) argues that benthic Foraminifera are able to tolerate wide salinity ranges. It would be used to conduct further surveys at Waterway site 4 to confirm Foraminifera abundance and continue tracking water quality data to distinguish a trend in relation to foraminifera abundance. Foraminifera are also known to be bioindicators of water quality as the type of foraminifera that grows in a certain coastal environment depends upon factors such as food supply and salinity of water (Prazeres *et al.*, 2020). The Foraminiferans found in the Waterway 4 samples resemble most closely stress tolerant foraminiferans, which could indicate that the Gorge is a eutrophic environment and only stress tolerant foraminiferans are able to survive (Prazeres *et al*., 2020).

Bianchi *et al.* (2003) completed a two year hydrochemical and biological survey in the Lagoon of Venice determining that plankton could be used as bioindicators of water quality in areas subject to human impacts. The study location provides some similarity to the Gorge as both sites are influenced by many forms of pollution such as industrial and urban, as well as intense tidal inflow and outflow (Bianchi *et al.*, 2003). Bianchi *et al.* (2003) determined that phytoplankton abundance is closely dependent on nutrient distribution and subsequently zooplankton life cycles of many species have been found to depend on the quantity of food available, and the more food (phytoplankton), the more growth is accelerated (Bianchi *et al.*, 2003). In areas where there was a high concentration of phytoplankton species but growth and abundance of zooplankton species did not occur, Bianchi *et al.* (2003) discusses that this is the result of industrial pollution at the sample site that interferes with the life cycles of phytoplankton groups such as diatoms. Thus, while Bacillarineae were most abundant at the muddy seawall and most ubiquitous in the creek, yet most zooplankton species were the most abundant in the rocky intertidal, it is possible that there is a higher level of industrial pollution at the creek and seawall sites.

There are a couple points that may have impacted the data. First, predation occurring once the samples were collected could have biased our samples against phytoplankton and towards larger grazing zooplankton. Further, this data provides adequate presence data but cannot be used to interpret plankton absences as only a fraction of the sample was analyzed. However, absence data can be a good indicator that the plankton groups seen the most are the most abundant in the sample. In terms of future research, further plankton sampling could be performed in the creek once restoration projects are completed to see if community composition has changed due to increased habitat.

To summarize, our results determined an estimate of relative abundances of plankton groups in three separate habitats in the Gorge. The results also showed water quality metrics for each plankton sample and correlations were made to show how different plankton groups were affected by the abiotic environment of the surrounding seawater. We determined that the rocky intertidal habitat has a higher abundance of individuals for more plankton groups than the other two habitats, and for all eight plankton groups the rocky intertidal was never found to be least abundant. It can be speculated that this is due to the importance of a natural coastline in supporting biodiversity as opposed to human engineered shore lines (Gittman *et al.*, 2016). Further, there are certain planktonic indicators of water quality that can tell us some information regarding the Gorge. Foraminifera abundance and composition suggests that the Gorge may be a slightly eutrophic environment (Prazeres *et al.*, 2020) while the distribution of phytoplankton and zooplankton suggest that the creek and seawall habitats sampled may be subject to higher industrial pollution than the rocky intertidal (Bianchi *et al.*, 2003). Thus, since the results give information regarding the health of the Gorge; this gives a baseline of information from which to build off of to improve the health of the Gorge and support habitat for forage fish and subsequently, spawning coho salmon and herring.

References

Baker, P. 1995. Review of ecology and fishery of the Olympia Oyster, *Ostrea lurida* with annotated bibliography. *Journal of Shellfish Research* **14**:501-518.

Bianchi, F., F. Acri, F. B. Aubry, A. Berton, A. Boldrin, E. Camatti, D. Cassin, and A. Comaschi. 2003. Can plankton communities be considered as bioindicators of water quality in the Lagoon of Venice? *Marine Pollution Bulletin* **46**:964-971.

Bogan, S. N., J. B. McMahon, J. A. Pechenik, and A. Pires. 2019. Legacy of multiple stressors: Responses of Gastropod larvae and juveniles to ocean acidification and nutrition. *Biological Bulletin* **236**:159-173.

Chust, G., M. Vogt, F. Benedetti, T. Nakov, S. Villeger, A. Aubert, S. M. Vallina, D. Righetti, F. Not, T. Biard, L. Bittner, A. S. Benoiston, L. Guidi, E. Villarino, C. Gaborit, A. Cornils, L. Buttay, J. O. Irisson, M. Chiarello, A. L. Vallim, L. Blanco-Bercial, L. Basconi, and S. D. Ayata. 2017. Mare Incognitum: A glimpse into future plankton diversity and ecology research. *Frontiers in Marine Science* **4**:9.

Clough, D. R., C. April, R. Daykin, and R. Neilsen. 2022. Environmental Protection and Restoration Plan: Gorge Creek Estuary. Project Proposal.

Cunningham, E. M., S. M. Ehlers, J. T. A. Dick, J. D. Sigwart, K. Linse, J. J. Dick, and K. Kiriakoulakis. 2020. High abundances of microplastic pollution in deep-sea sediments: evidence from Antarctica and the Southern Ocean. *Environmental Science & Technology* **54**:13661-13671.

Gittman, R. K., S. B. Scyphers, C. S. Smith, I. P. Neylan, and J. H. Grabowski. 2016. Ecological consequences of shoreline hardening: A meta-analysis. *Bioscience* **66**:763-773.

Gray, J. S. 1979. Pollution-induced changes in populations. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **286**:545-561.

Lassen, M. F., M. E. Bramm, K. Richardson, F. Yusoff, and M. Shariff. 2004. Phytoplankton community composition and size distribution in the Langat River Estuary, Malaysia. *Estuaries* **27**:716-727.

Lees and Associates (Landscape Architectects + Planners). 2022. Concept Diagram, Green Shores Gorge Esquimalt Park.

Nemcek, N., M. Hennekes, and I. Perry. 2019. Seasonal dynamics of the phytoplankton community in the salish sea from HPLC measurements 2015-2019. Pp. 141-145 in *State of the Physical, Biological and Selected Fishery Resources of Pacific Canadian Marine Ecosystems in 2018.*

Prazeres, M., M. Martinez-Colon, and P. Hallock. 2020. Foraminifera as bioindicators of water quality: The FoRAM Index revisited. *Environmental Pollution* **257**:13.

Smith, L. D., K. B. Johnson. 1996. *A guide to coastal plankton and marine invertebrate larvae Second Edition*, Kendall/Hunt Publishing Company, Iowa.

Slotwinski, A., F. Coman, A. J. Richardson. 2014. Introductory guide to zooplankton identification. *Integrated Marine Observing System*, Brisbane, Australia.

Telesh, I. V., H. Schubert, and S. O. Skarlato. 2011. Revisiting Remane's concept: evidence for high plankton diversity and a protistan species maximum in the horohalinicum of the Baltic Sea. *Marine Ecology Progress Series* **421**:1-11.

van der Gaag, M., G. van der Velde, S. Wijnhoven, and R. Leuven. 2016. Salinity as a barrier for ship hull-related dispersal and invasiveness of dreissenid and mytilid bivalves. *Marine Biology* **163**:13.

Webber, M. K., and J. C. Roff. 1995. Annual biomass and production of the oceanic copepod community off Discovery-Bay Jamaica. *Marine Biology* **123**:481-495.

Winter, A., A. Almogilabin, Y. Erez, E. Halicz, B. Luz, and Z. Reiss. 1983. Salinity tolerance of marine organisms deduced from the Red-Sea quaternary record. *Marine Geology* **53**:17-22.

Worden, A. Z., M. J. Follows, S. J. Giovannoni, S. Wilken, A. E. Zimmerman, and P. J. Keeling. 2015. Rethinking the marine carbon cycle: Factoring in the multifarious lifestyles of microbes. *Science* **347**:11.

World Fisheries Trust. 2021. Olympia Oysters in the Gorge waterway. Écologie, accessed 12 September, 2022. <https://worldfish.org/olympia-oysters-in-the-gorge-waterway/>

Appendix A: Water Quality Data

A1. Table showing water quality data at Waterway 1 sample site

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL (ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
25-Jul	9:13:47	0.3 m	22.7	762.5	106.3	7.99	7.99	37.89	36.19	24.1	24.63	0.03	8	-66.5	166.6
28-Jul	10:24:51	0.7 m	24.7	761.9	107.4	7.72	7.72	40	39.74	25.5	26	0.02	8.13	-64.2	190.3
28-Jul	19:07:40	1.3 m	24.2	759.1	107.8	7.78	7.78	40.72	40.14	26.1	26.47	0.02	8.09	-61.5	217.7
01-Aug	12:45:13	0.5 m	25.8	760.3	102.1	7.2	7.2	40.15	40.74	25.6	26.1	0.02	8.11	-63.2	162.9
02-Aug	15:37:46	0.6 m	26.1	763.6	120.3	8.43	8.43	40.19	41.04	25.6	26.12	0.02	8.33	-75.8	187.4
08-Aug	20:58:08	1.6 m	19.4	759.6	116.2	9.06	9.06	43.42	38.74	28	28.23	0.02	8.05	-59.2	171.3
10-Aug	11:09:13	0.5 m	22.9	762.4	111.9	8.21	8.21	42.71	41	27.5	27.76	0.02	8.19	-68.2	175.7
16-Aug	11:42:32	0.7 m	19.3	764.3	113.9	10.04	10.04	28.96	41.82	28.1	27.92	0.02	7.26	-76.6	139.3

A2. Table showing water quality at Waterway 2 sample site

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL(ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
25-Jul	8:57:34	0.3 m	23.1	762.5	105.3	8.33	8.33	22.64	21.81	13.7	14.71	0.04	8.09	-71.8	161.5
28-Jul	12:59:47	1.0 m	26.6	761.2	132.7	9.24	9.24	39.78	40.96	25.3	25.86	0.03	8.28	-73	187.3
28-Jul	20:37:16	1.3 m	20.1	758.9	114.7	8.9	8.9	41.35	37.48	26.6	26.88	0.02	8.19	-66.4	187.2
01-Aug	11:39:44	0.6 m	25.6	760.7	99.7	7.05	7.05	40.09	40.52	25.6	26.06	0.02	8.05	-59.4	160.3
02-Aug	14:39:38	0.5 m	26.3	764	112	7.84	7.84	39.98	40.95	25.5	25.99	0.03	8.31	-74.6	203.8
08-Aug	20:11:39	1.5 m	17.5	759.2	129.1	10.42	10.42	43.5	37.29	28.1	28.28	0.02	8.15	-64.6	171.3
10-Aug	10:20:06	0.3 m	23	761.7	117.3	8.59	8.59	42.65	41.02	27.5	27.73	0.02	8.23	-70.4	171.9
16-Aug	10:41:22	0.8 m	22	764.2	100.4	7.47	7.47	43.24	40.74	27.9	28.25	0.02	7.97	-55.6	166.2

A3. Table showing water quality data from Waterway 3 sample site

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL(ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
25-Jul	8:46:03	0.4 m	22.8	762.7	113.2	8.49	8.49	37.87	36.25	24.1	24.61	0.03	8.13	-74.2	161.4
28-Jul	12:46:26	1.0 m	26.8	760.9	131.7	9.13	9.13	39.73	41.11	25.3	25.83	0.03	8.27	-72.2	181.8
28-Jul	20:26:21	1.3 m	20.3	758.7	116.4	9	9	41.33	37.6	26.5	26.86	0.02	8.2	-67.1	179
01-Aug	10:34:31	0.8 m	24.3	760.4	87.7	6.34	6.34	40.28	39.73	25.7	26.18	0.02	8.04	-58.6	174.7
02-Aug	14:24:19	0.5 m	26.5	763.3	117.1	8.16	8.16	40.05	41.19	25.5	26.03	0.02	8.25	-71.4	206.1
08-Aug	20:00:09	1.5 m	18.3	759.3	123.7	9.84	9.84	43.49	37.92	28.1	28.27	0.02	8.11	-62.7	173.9
10-Aug	10:06:18	0.3 m	22.8	761.5	115.5	8.48	8.48	42.66	40.88	27.5	27.73	0.02	8.14	-65	167.2
16-Aug	10:54:59	0.8 m	21.1	764.3	91.4	6.9	6.9	43.46	40.2	28.1	18.68	0.03	7.77	-44.2	166.7

A4. Table with water quality data from Waterway 4 sample site

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL(ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
28-Jul	11:04:10	0.7 m	25.3	761.6	117.7	8.38	8.38	39.62	39.86	25.3	25.75	0.03	8.2	-68.3	175.1
28-Jul	18:43:30	1.2 m	25.1	759.2	117.4	8.36	8.36	40.29	40.39	25.7	26.19	0.02	8.07	-60.8	230.2
01-Aug	12:17:19	0.6 m	26.7	760.3	109.4	7.59	7.59	40.01	41.31	25.5	26.01	0.02	8.52	-87	170.1
02-Aug	15:16:15	0.6 m	27.5	763.5	136	9.32	9.32	40.1	41.99	25.6	26.07	0.02	8.28	-73.4	198.8
08-Aug	20:36:59	1.5 m	19.5	759.2	108.5	8.45	8.45	43.35	37.76	28	28.17	0.02	8.15	-65.3	167.1
10-Aug	10:48:49	0.4 m	22.8	761.8	117.5	8.63	8.63	42.65	40.89	27.5	27.73	0.02	8.13	-64.4	176.7
16-Aug	11:25:17	0.7 m	23.6	764.1	127.9	9.25	9.25	42.95	41.83	27.7	28.11	0.02	8.34	-74.7	139.1

<u>A5.Table with water quality data from Creek 1 sample site</u>

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL(ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
25-Jul	9:44:08	0.2 m	23.3	762.2	126.8	9.52	9.52	35.31	34.17	22.3	22.95	0.03	7.78	-53.5	146.6
28-Jul	12:27:10	0.9 m	29.9	760.2	221.5	14.72	14.72	37.82	41.34	23.9	24.59	0.03	8.49	-86.1	171.5
28-Jul	20:06:12	1.3 m	26.3	767.2	108.3	7.56	7.56	40.37	41.38	25.8	26.24	0.02	8.23	-70.2	201.5
01-Aug	10:50:12	0.7 m	26.6	760.5	105.6	7.5	7.5	34.67	35.74	21.8	22.54	0.03	8.03	-58.7	167.6
02-Aug	13:55:13	0.5 m	32.9	763.6	298.7	19.21	19.21	33.32	38.37	20.7	21.66	0.03	8.71	-99.8	185.7
08-Aug	19:44:27	1.4 m	23.3	759.3	112.7	8.19	8.19	42.96	41.59	27.7	27.92	0.02	8.11	-63.6	171.6
10-Aug	9:48:37	0.2 m	21.5	761.4	91.7	6.99	6.99	39.52	36.88	25.2	25.69	0.03	7.63	-36.2	162.8
16-Aug	10:08:10	0.8 m	22.9	762.5	87.9	6.82	6.82	28.74	27.57	17.8	18.82	0.03	7.75	-43.3	137.9

A6. Table for water quality data from Creek 2 sample site

Date	Time	Tidal Height	Temp (C)	Pressure (mmHg)	DO(%)	DO(mg/L)	DO(ppm)	SPC(mS/cm)	COND(mS/cm)	SAL(ppt)	TDS(g/L)	RES (kohm-cm)	pH	pH mV	ORP(mV)
28-Jul	11:52:30	0.7 m	26.1	761.3	73.3	5.19	5.19	37.52	38.33	23.8	24.39	0.03	7.77	-43.9	173.7
28-Jul	19:52:19	1.3 m	27.5	758.8	114.8	8.21	8.21	35.53	39.57	22.3	23.08	0.03	8.08	-62.1	200.8
01-Aug	11:07:13	0.7 m	26.5	760.3	84.6	6.16	6.16	28.59	29.39	17.6	18.59	0.03	7.67	-37.7	98
02-Aug	13:39:19	0.5 m	22.3	763.9	171.6	14.62	14.62	3.476	3.329	1.8	2.259	0.29	8.35	-76.1	152.7
08-Aug	19:30:31	1.4 m	28.3	759.3	118.6	8.35	8.35	29.04	30.93	17.9	18.88	0.03	7.92	-53.5	192.2
10-Aug	9:34:59	0.2 m	23.3	761.2	15.6	1.14	1.14	42.42	41.04	27.3	27.57	0.02	7.44	-25.7	99.3
16-Aug	9:58:22	0.9 m	23.1	764.3	105.4	4.96	4.96	20.35	27.75	12.2	13.23	0.03	7.35	-20.8	138.11

Appendix B: Plankton Data

Waterway 1: Plankton groups and their relative abundances over each sample

	Date							
	25-Jul	28-Jul -AM	28 -Jul -PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	A	C	C	O	O	A	C	N/A
Bivalve Veligers	O	C	O	N/A	N/A	R	N/A	O
Calanoid Copepods	C	A	N/A	C	C	N/A	O	N/A
Ciliates	N/A	N/A	N/A	O	C	N/A	N/A	N/A
Coscinodiscineae (suborder of centrales)	N/A	N/A	N/A	N/A	N/A	O	N/A	N/A
Cyclopoid Copepods	A	A	R	C	A	N/A	C	N/A
Fragilariophyceae (suborder of Bacillariales)	N/A	N/A	C	O	N/A	N/A	N/A	N/A
Harpacticoid Copepods	O	C	C	C	C	N/A	N/A	N/A
Gastropod Veligers	A	O	N/A	N/A	N/A	N/A	N/A	N/A
Molt of barnacle Exoskeleton (cirripede)	N/A	N/A	N/A	O	N/A	N/A	N/A	N/A
Nauplius larva	O	N/A	O	O	O	O	N/A	N/A
Navicula sp.	C	O	C	N/A	O	O	O	C
Nematoda (Phylum)	N/A	N/A	O	O	N/A	N/A	N/A	N/A
Polyclad Flatworms	N/A	N/A	R	O	N/A	N/A	N/A	N/A
Rotifers (Phylum)	O	O	O	C	C	O	C	N/A
Spionidae larva	O	O	O	N/A	N/A	N/A	N/A	O
Zoea (Decapoda)	N/A	N/A	R	N/A	N/A	N/A	N/A	N/A

Waterway 2: Plankton groups and their relative abundances over each sample

	Date							
	25-Jul	28-Jul-AM	28-Jul PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	A	A	A	A	C	A	O	C
Bivalve Veligers	N/A	C	N/A	N/A	O	N/A	O	N/A
Calanoid Copepods	O	A	O	A	C	R	N/A	O
Ciliates	N/A	N/A	C	N/A	N/A	R	N/A	N/A
Cirripede Cypris larva	O	O	N/A	O	N/A	N/A	N/A	N/A
Coscinodiscineae (suborder of centrales)	N/A	N/A	C	N/A	N/A	O	N/A	N/A
Cyclopoid Copepods	A	A	C	A	C	O	O	O
Euphausiid Protozoa	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fragilariophyceae (suborder of Bacillariales)	A	N/A	N/A	N/A	O	N/A	N/A	N/A
Gastropod Veligers	A	O	N/A	C	N/A	N/A	A	R
Harpacticoid Copepods	C	A	A	A	O	N/A	N/A	O
Molt of barnacle exoskeleton (Cirripede)	O	N/A	N/A	C	N/A	N/A	N/A	N/A
Navicula sp.	N/A	C	N/A	N/A	N/A	O	N/A	A
Nauplius larva	N/A	O	O	C	N/A	O	R	R
Nematoda (Phylum)	O	O	N/A	N/A	N/A	N/A	N/A	N/A
Polyclad Flatworms	N/A	A	N/A	O	R	N/A	C	R
Rotifers (Phylum)	C	O	C	O	O	N/A	C	O
Spionidae larva	O	N/A	O	C	N/A	C	N/A	O
Zoea (Decapoda)	R	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Waterway 3: Plankton groups and their relative abundances over each sample

Date

	25-Jul	28-Jul-AM	28-Jul-PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	A	A	A	A	C	A	C	C
Bivalve Veligers	O	O	O	N/A	O	N/A	N/A	N/A
Calanoid Copepods	A	C	N/A	N/A	A	N/A	C	N/A
Coscinodiscineae (suborder of centrales)	N/A	N/A	C	N/A	N/A	O	N/A	N/A
Cyclopoid Copepods	A	A	N/A	N/A	C	N/A	C	N/A
Euphausiid Proteozoea	R	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fragilariophyceae (suborder of Bacillariales)	A	N/A	N/A	O	N/A	R	N/A	N/A
Gastropod Veligers	C	O	O	R	C	N/A	N/A	N/A
Harpacticoid Copepods	C	A	N/A	O	A	N/A	N/A	N/A
Nauplius larva	O	N/A	N/A	C	R	O	N/A	O
Navicula sp.	N/A	O	N/A	C	A	N/A	N/A	N/A
Nematoda	O	N/A	O	N/A	N/A	N/A	N/A	N/A
Polyclad Flatworms	R	N/A	N/A	N/A	O	N/A	N/A	N/A
Protoperidinium (Dinoflagellate)	N/A	N/A	R	N/A	N/A	R	N/A	N/A
Rotifers (Phylum)	O	O	O	C	O	O	A	N/A
Spionidae larva	O	N/A	N/A	O	O	O	C	N/A
Unidentified eggs	R	N/A	N/A	N/A	R	N/A	N/A	N/A
Zoea (Decapoda)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	R

Waterway 4: Plankton groups and their relative abundances over each sample

Date

	Jul 28 -AM	Jul 28 - PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	O	A	C	C	A	N/A	R
Bivalve Veligers	O	O	O	N/A	N/A	N/A	C
Calanoid Copepods	C	N/A	A	N/A	N/A	N/A	N/A
Coscinodiscineae (suborder of centrales)	N/A	N/A	N/A	N/A	O	N/A	N/A
Cyclopoid Copepods	A	N/A	A	N/A	N/A	N/A	A
Foraminifera	R	N/A	R	R	N/A	N/A	N/A
Gastropod Veligers	O	N/A	N/A	C	N/A	N/A	R
Harpacticoid Copepods	O	O	C	C	O	N/A	N/A
Nauplius larva	N/A	N/A	O	O	O	N/A	O
Navicula sp.	C	C	A	A	O	O	O
Nematoda (Phylum)	N/A	N/A	N/A	R	N/A	N/A	N/A
Polyclad Flatworms	C	N/A	C	N/A	N/A	O	N/A
Rotifers (Phylum)	C	N/A	C	O	O	O	O
Spionidae larva	O	N/A	R	N/A	N/A	N/A	N/A
Zoea (Decapoda)	C	N/A	N/A	N/A	N/A	N/A	N/A

Creek 1: Plankton groups and their relative abundances over each sample

	Date							
	25-Jul	28-Jul AM	28-Jul-PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	A	A	A	A	O	C	C	C
Bivalve Veligers	N/A	N/A	C	N/A	N/A	O	N/A	N/A
Calanoid Copepods	O	C	R	O	C	N/A	N/A	N/A
Ciliates	C	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coscinodiscineae (suborder of centrales)	N/A	O	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopoid Copepods	C	C	O	O	R	O	N/A	R
Harpacticoid Copepods	O	N/A	R	O	C	R	O	O
Gastropod Veligers	N/A	N/A	N/A	N/A	N/A	R	N/A	N/A
Nauplius larva	N/A	A	C	A	A	C	C	A
Nematoda (Phylum)	N/A	O	N/A	N/A	N/A	N/A	N/A	N/A
Navicula sp.	C	O	N/A	N/A	N/A	N/A	O	N/A
Prorocentrum sp.	N/A	N/A	O	R	N/A	N/A	O	N/A
Spionidae larva	N/A	N/A	C	N/A	N/A	N/A	N/A	N/A
Rotifers (Phylum)	N/A	N/A	N/A	N/A	N/A	C	O	N/A

Creek 2: Plankton groups and their relative abundances over each sample

	Date						
	28-Jul -AM	28-Jul -PM	01-Aug	02-Aug	08-Aug	10-Aug	16-Aug
Bacillariineae (suborder of Bacillariales)	A	A	C	O	C	C	R
Bivalve Veligers	N/A	N/A	N/A	R	N/A	N/A	N/A
Calanoid Copepods	A	O	A	A	N/A	N/A	A
Cyclopoid Copepods	O	A	A	A	O	C	A
Fragilariophyceae (suborder of Bacillariales)	C	C	N/A	N/A	N/A	O	N/A
Harpacticoid Copepods	C	N/A	C	C	O	C	C
Nauplius larva	O	C	A	A	A	C	A
Navicula sp.	C	N/A	O	C	N/A	O	N/A
Nematoda (Phylum)	O	C	R	N/A	N/A	N/A	N/A
Polyclad Flatworms	C	A	N/A	R	N/A	N/A	N/A
Prorocentrum sp.	N/A	N/A	A	A	O	A	C
Rotifers (Phylum)	N/A	N/A	R	N/A	O	N/A	N/A
Spionidae larva	N/A	N/A	O	N/A	O	N/A	N/A
Unidentified eggs	O	N/A	N/A	N/A	N/A	N/A	R

Appendix C: Proportion of Relative Abundances

C.1 Proportions of Relative Abundance: Bacillarineae at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop. N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.438	0.250	0.313	0.375	0.188	0.250	0.000	0.000	0.063	0.125
	W.2	8		0.625		0.250		0.125		0.000		0.000
Muddy Seawall	W.3	8	0.467	0.625	0.333	0.375	0.067	0.000	0.067	0.000	0.067	0.000
	W.4	7		0.286		0.286		0.143		0.143		0.143
Enforced Creek	C.1	8	0.400	0.500	0.400	0.375	0.133	0.125	0.067	0.000	0.000	0.000
	C.2	7		0.286		0.429		0.143		0.143		0.000

C2. Proportions of Relative Abundance: Order Calanoida at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.188	0.125	0.250	0.375	0.250	0.125	0.063	0.000	0.250	0.375
	W.2	8		0.250		0.125		0.375		0.125		0.125
Muddy Seawall	W.3	8	0.200	0.250	0.200	0.250	0.000	0.000	0.000	0.000	0.600	0.500
	W.4	7		0.143		0.143		0.000		0.000		0.714
Enforced Creek	C.1	8	0.267	0.000	0.133	0.250	0.200	0.250	0.067	0.125	0.333	0.375
	C.2	7		0.571		0.000		0.143		0.000		0.286

C3. Proportions of Relative Abundance: Order Cyclopoida at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.375	0.375	0.250	0.250	0.188	0.000	0.063	0.125	0.125	0.250
	W.2	8		0.375		0.250		0.375		0.000		0.000
Muddy Seawall	W.3	8	0.333	0.250	0.133	0.250	0.000	0.000	0.000	0.000	0.533	0.500
	W.4	7		0.429		0.000		0.000		0.000		0.571
Enforced Creek	C.1	8	0.267	0.000	0.200	0.250	0.333	0.375	0.133	0.250	0.067	0.125
	C.2	7		0.571		0.143		0.286		0.000		0.000

C4. Proportions of Relative Abundance: Order Harpacticoida at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.188	0.000	0.313	0.500	0.188	0.125	0.000	0.000	0.313	0.375
	W.2	8		0.375		0.125		0.250		0.000		0.250
Muddy Seawall	W.3	8	0.133	0.250	0.200	0.125	0.267	0.125	0.000	0.000	0.400	0.500
	W.4	7		0.000		0.286		0.429		0.000		0.286
Enforced Creek	C.1	8	0.000	0.000	0.400	0.125	0.333	0.500	0.133	0.250	0.133	0.125
	C.2	7		0.000		0.714		0.143		0.000		0.143

C5. Proportions of Relative Abundance: Bivalve Veligers at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.000	0.000	0.125	0.125	0.313	0.375	0.063	0.125	0.500	0.375
	W.2	8		0.000		0.125		0.250		0.000		0.625
Muddy Seawall	W.3	8	0.000	0.000	0.067	0.000	0.467	0.500	0.000	0.000	0.467	0.500
	W.4	7		0.000		0.143		0.429		0.000		0.429
Enforced Creek	C.1	8	0.000	0.000	0.067	0.125	0.067	0.125	0.067	0.000	0.800	0.750
	C.2	7		0.000		0.000		0.000		0.143		0.857

C6. Proportions of Relative Abundance: Gastropod Veligers at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.188	0.125	0.063	0.000	0.125	0.125	0.063	0.000	0.563	0.750
	W.2	8		0.250		0.125		0.125		0.125		0.375
Muddy Seawall	W.3	8	0.000	0.000	0.200	0.250	0.200	0.250	0.133	0.125	0.467	0.375
	W.4	7		0.000		0.143		0.143		0.143		0.571
Enforced Creek	C.1	8	0.000	0.000	0.000	0.000	0.000	0.000	0.067	0.125	0.933	0.875
	C.2	7		0.000		0.000		0.000		0.000		1.000

C7. Proportions of Relative Abundance: Rotifera at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.000	0.000	0.375	0.375	0.500	0.500	0.000	0.000	0.125	0.125
	W.2	8		0.000		0.375		0.500		0.000		0.125
Muddy Seawall	W.3	8	0.067	0.125	0.200	0.125	0.600	0.625	0.000	0.000	0.133	0.125
	W.4	7		0.000		0.286		0.571		0.000		0.143
Enforced Creek	C.1	8	0.000	0.000	0.067	0.125	0.133	0.125	0.067	0.000	0.733	0.750
	C.2	7		0.000		0.000		0.143		0.143		0.714

C8. Proportions of Relative Abundance: Nauplius larva Abundance at different samples sites

Habitat	Site	# Samples	Prop. A (Hab.)	Prop. A (Site)	Prop. C (Hab.)	Prop. C (Site)	Prop. O (Hab.)	Prop. O (Site)	Prop. R (Hab.)	Prop. R (Site)	Prop.N (Hab.)	Prop. N (Site)
Rocky Intertidal	W.1	8	0.000	0.000	0.063	0.000	0.500	0.625	0.125	0.000	0.313	0.375
	W.2	8		0.000		0.125		0.375		0.250		0.250
Muddy Seawall	W.3	8	0.000	0.000	0.067	0.125	0.467	0.375	0.067	0.125	0.400	0.375
	W.4	7		0.000		0.000		0.571		0.000		0.429
Enforced Creek	C.1	8	0.533	0.500	0.333	0.375	0.067	0.000	0.000	0.000	0.067	0.125
	C.2	7		0.571		0.286		0.143		0.000		0.000

Appendix D: Scatter Plots and Bar Plots

D.1 Plots containing information for Bacillariineae

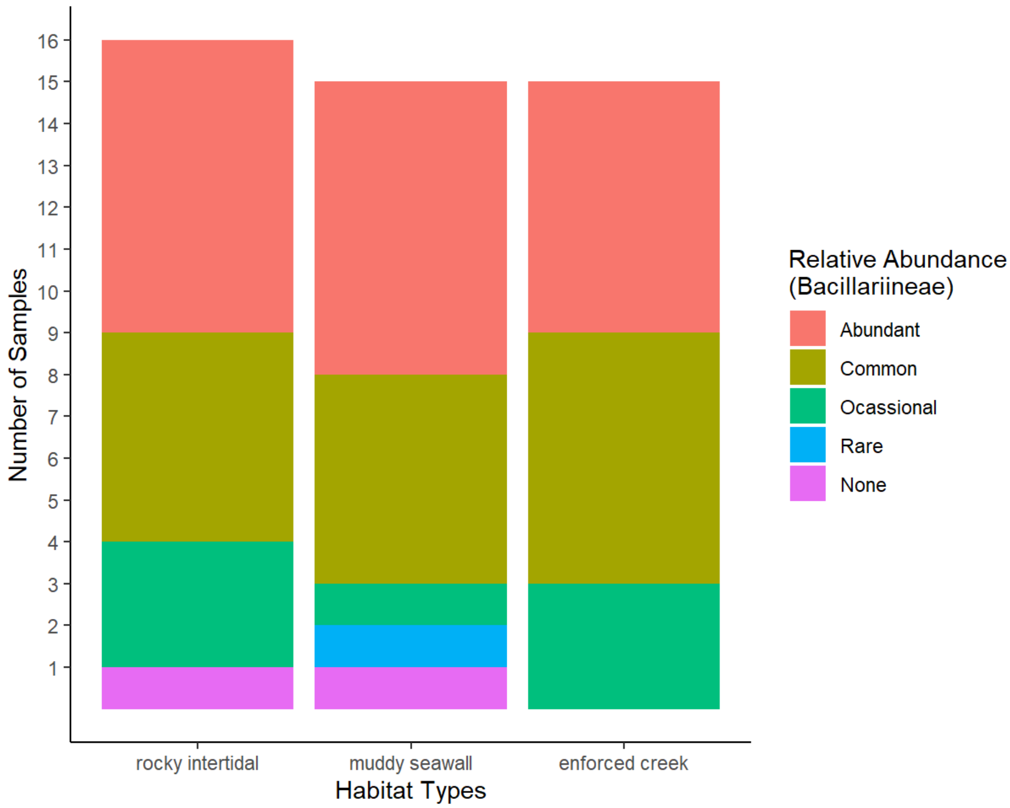


Figure 4. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for the diatoms Bacillariineae. The bars are proportioned by color depending on the relative abundances of Bacillariineae in each sample.

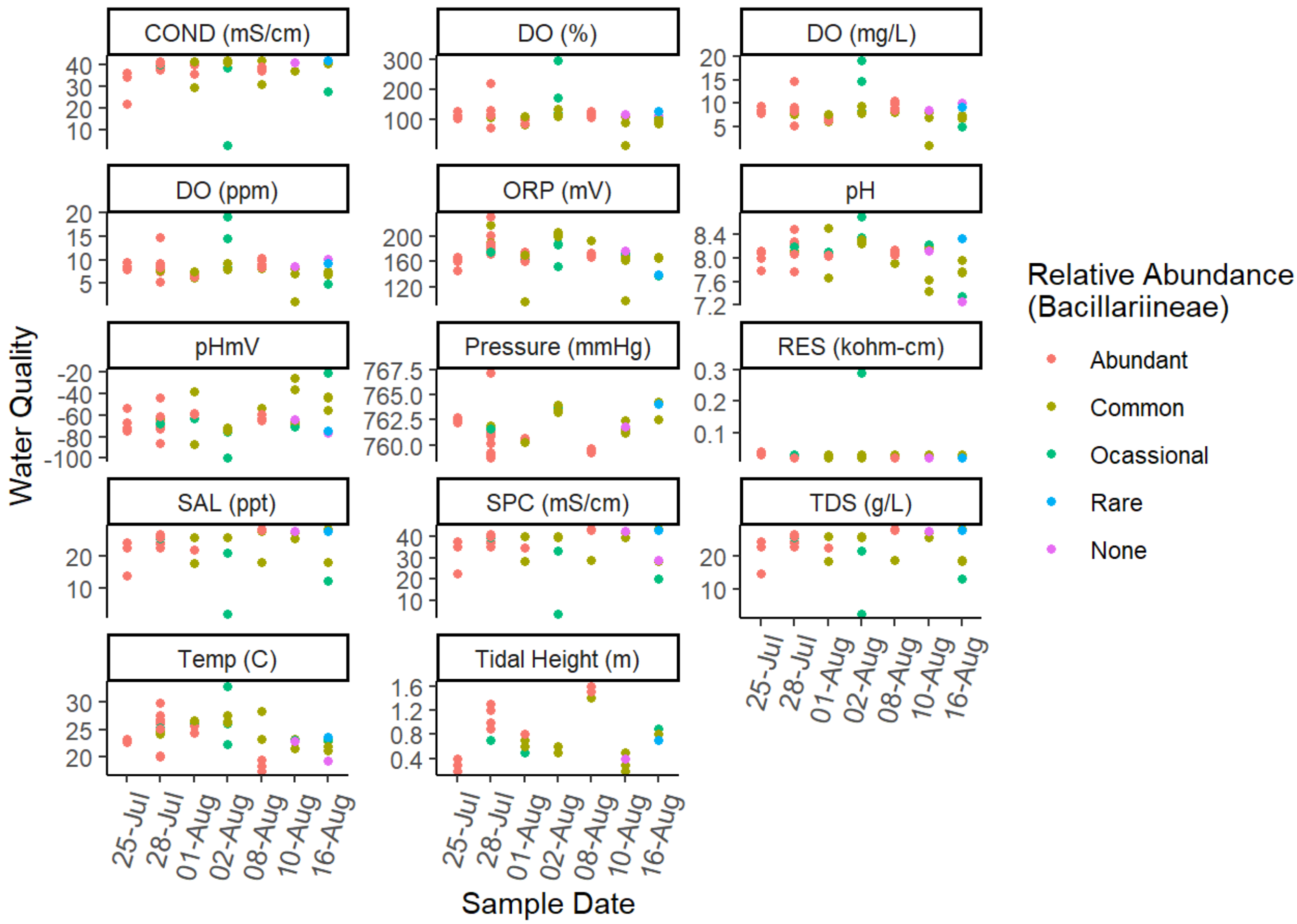


Figure 5. Plots showing the relative abundances of Bacillarineae compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Bacillarineae over all different sample sites in the Gorge.

D.2 Plots containing information for Order Calanoida

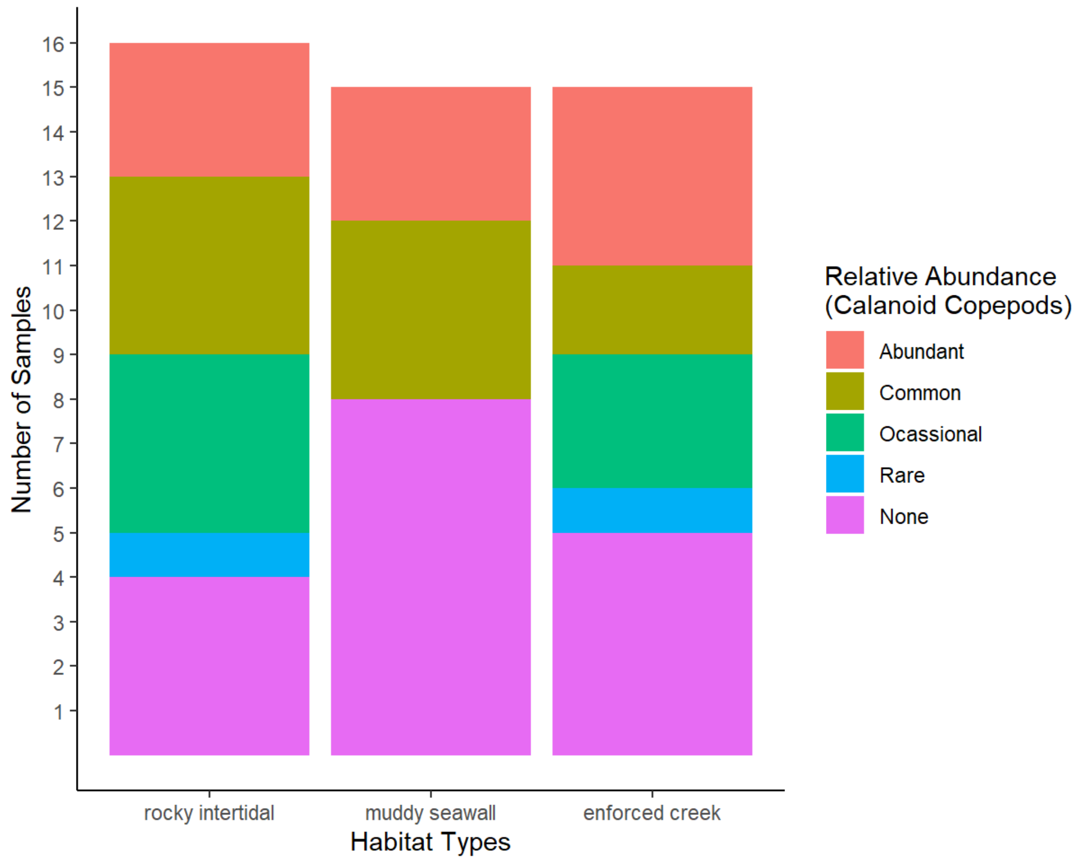


Figure 6. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Order Calanoida. The bars are proportioned by color depending on the relative abundances of Bacillariineae in each sample.

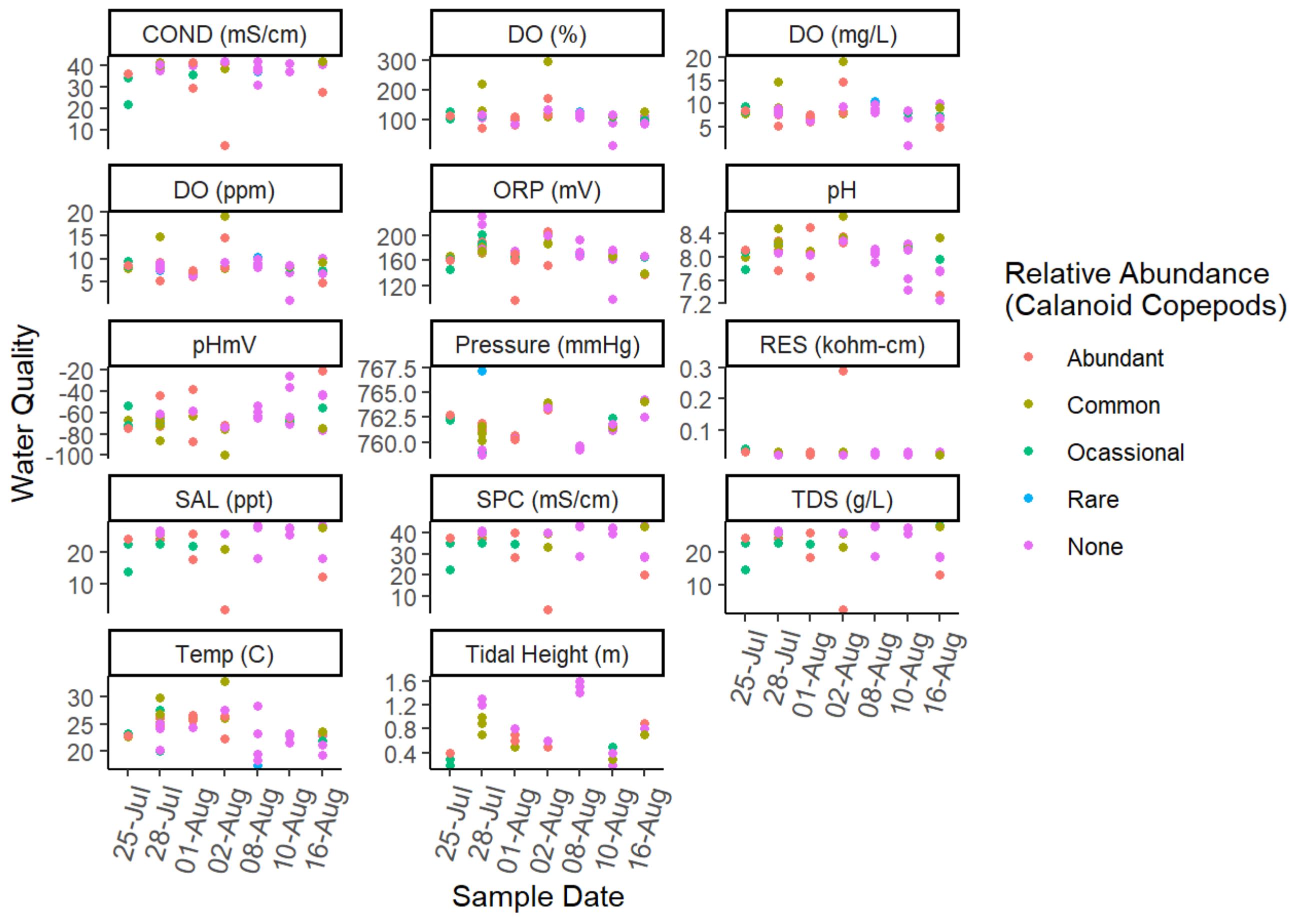


Figure 7. Plots showing the relative abundances of Order Calanoida compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Order Calanoida over all different sample sites in the Gorge.

D.3 Plots containing information for Order Cyclopoida

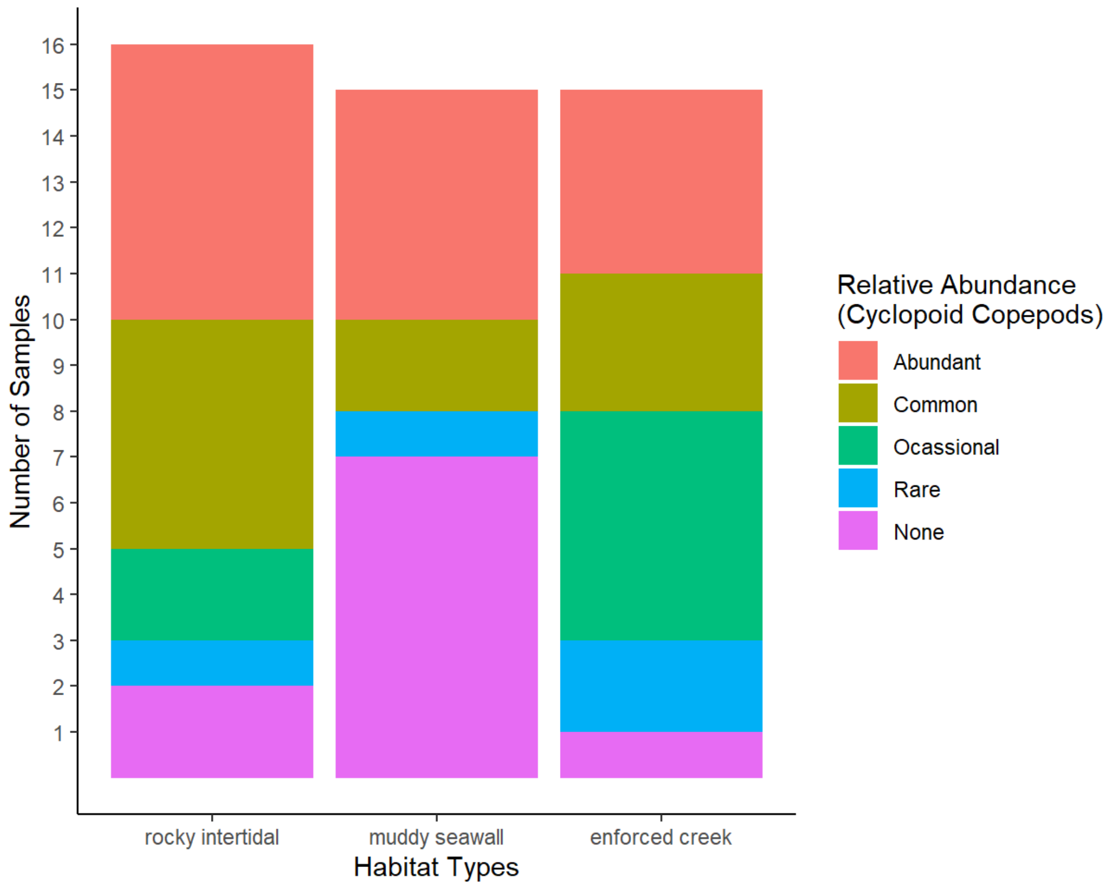


Figure 8. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Order Cyclopoida. The bars are proportioned by color depending on the relative abundances of Bacillariineae in each sample.

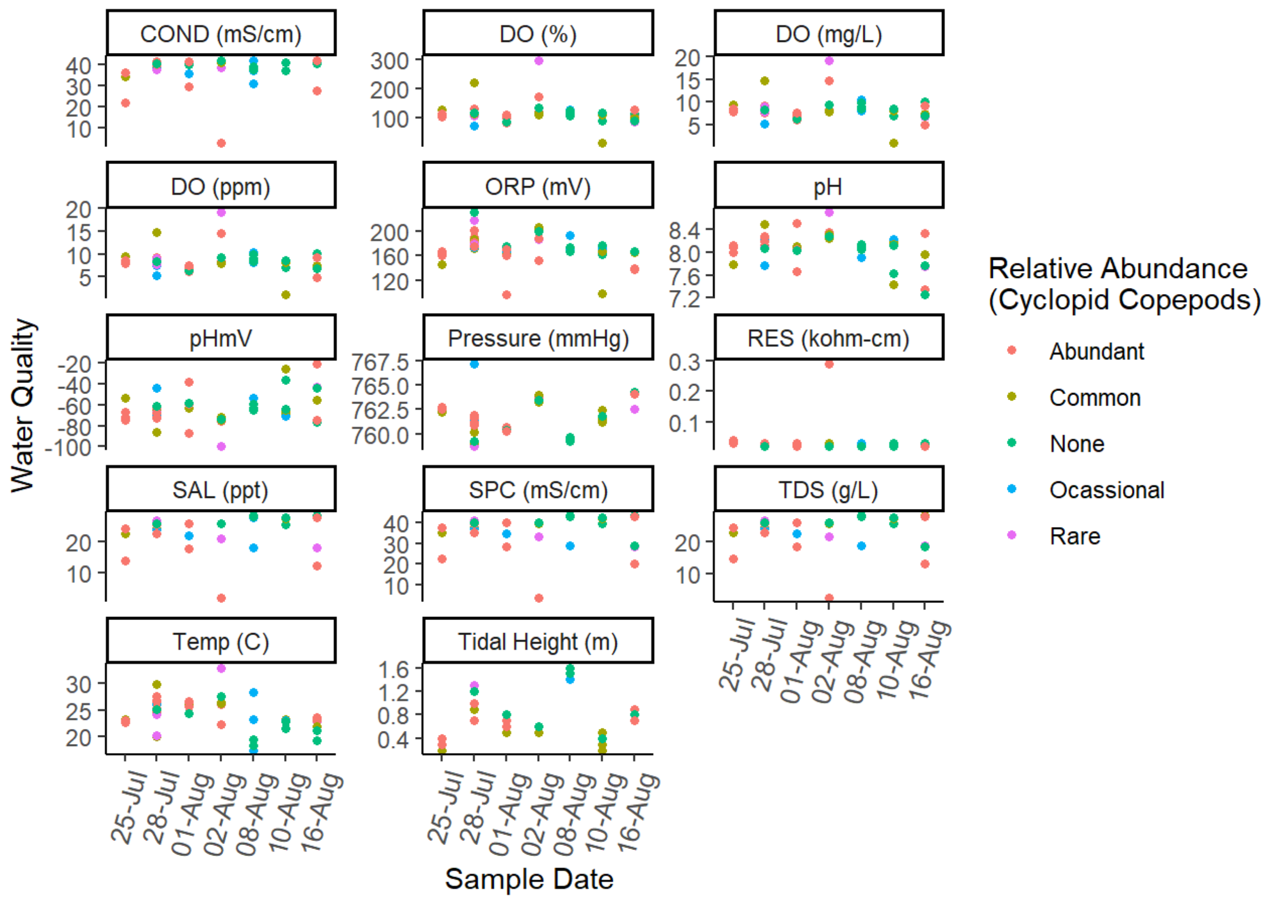


Figure 9. Plots showing the relative abundances of Order Cyclopoida compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Order Cyclopoida over all different sample sites in the Gorge.

D4. Plots containing information for Order Harpacticoida

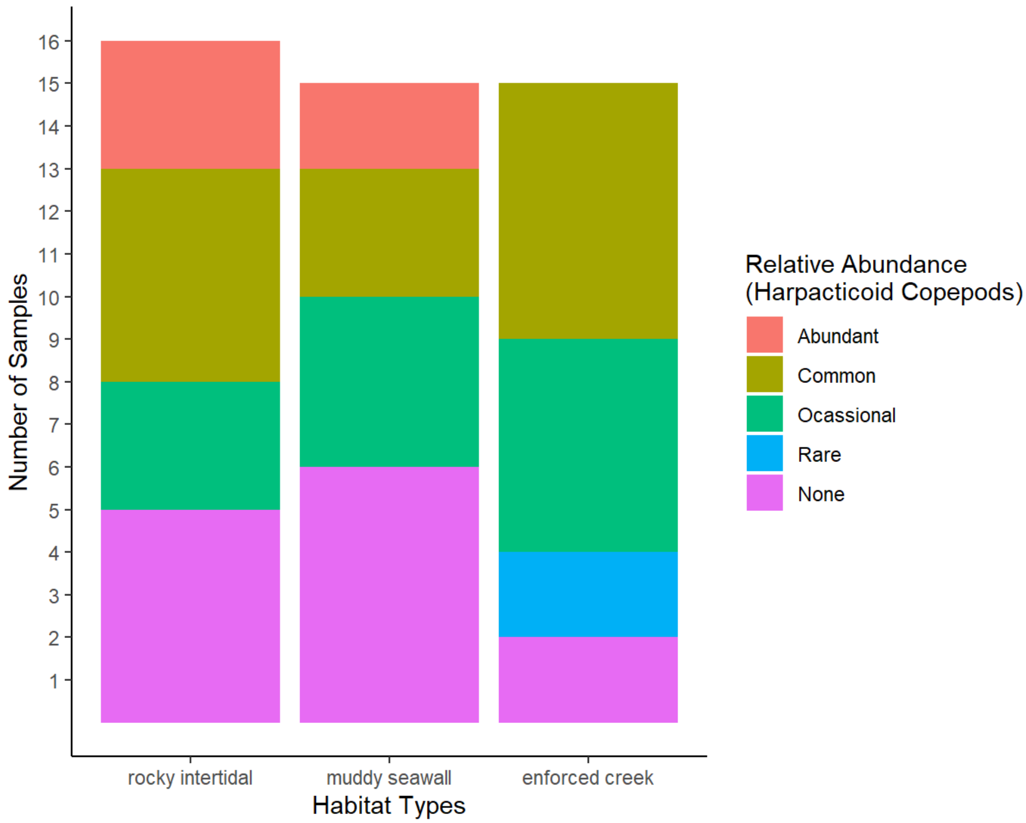


Figure 10. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Order Harpacticoida. The bars are proportioned by color depending on the relative abundances of Order Harpacticoida in each sample.

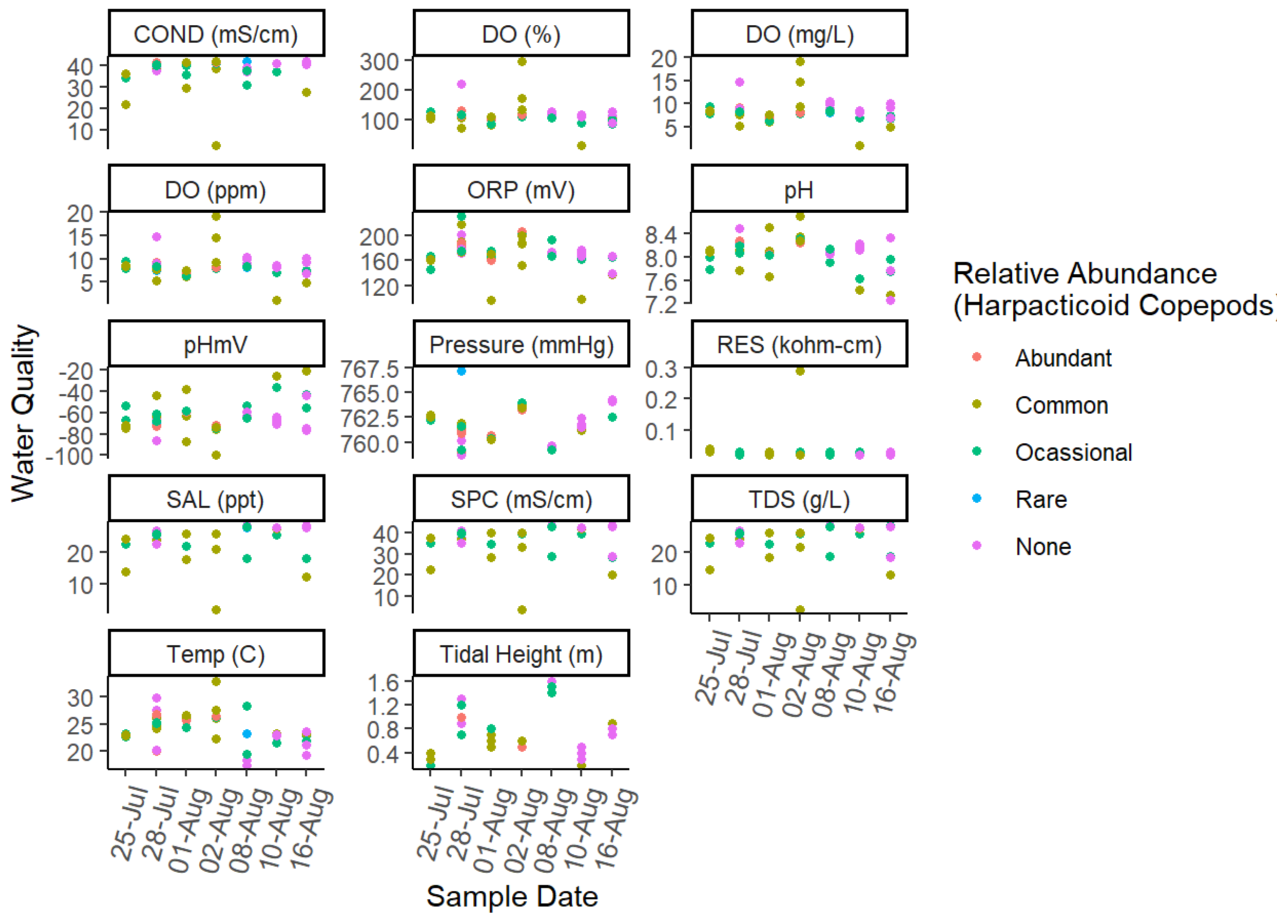


Figure 11. Plots showing the relative abundances of Order Harpacticoida compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Order Harpacticoida over all different sample sites in the Gorge.

D5. Plots containing information for Bivalve Veligers

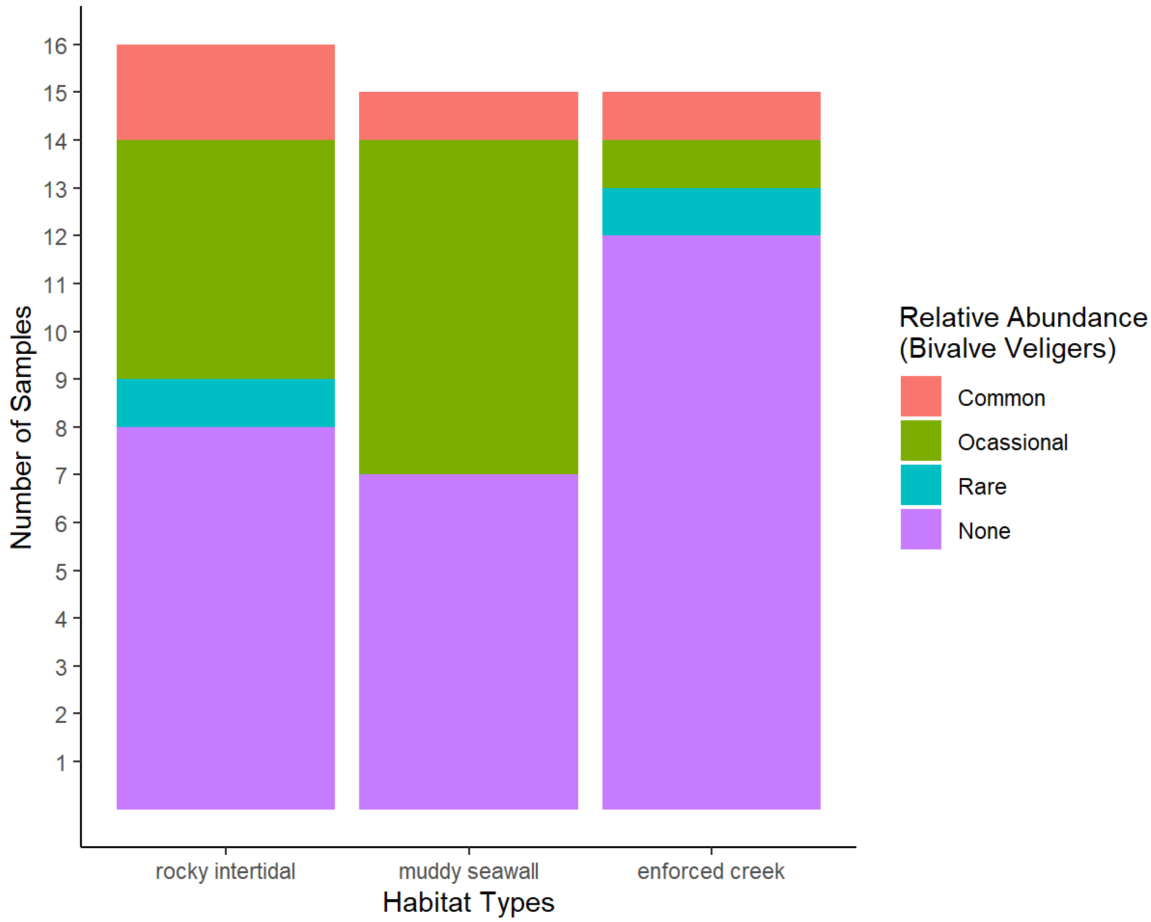


Figure 12. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Bivalve Veligers. The bars are proportioned by color depending on the relative abundances of Bivalve Veligers in each sample.

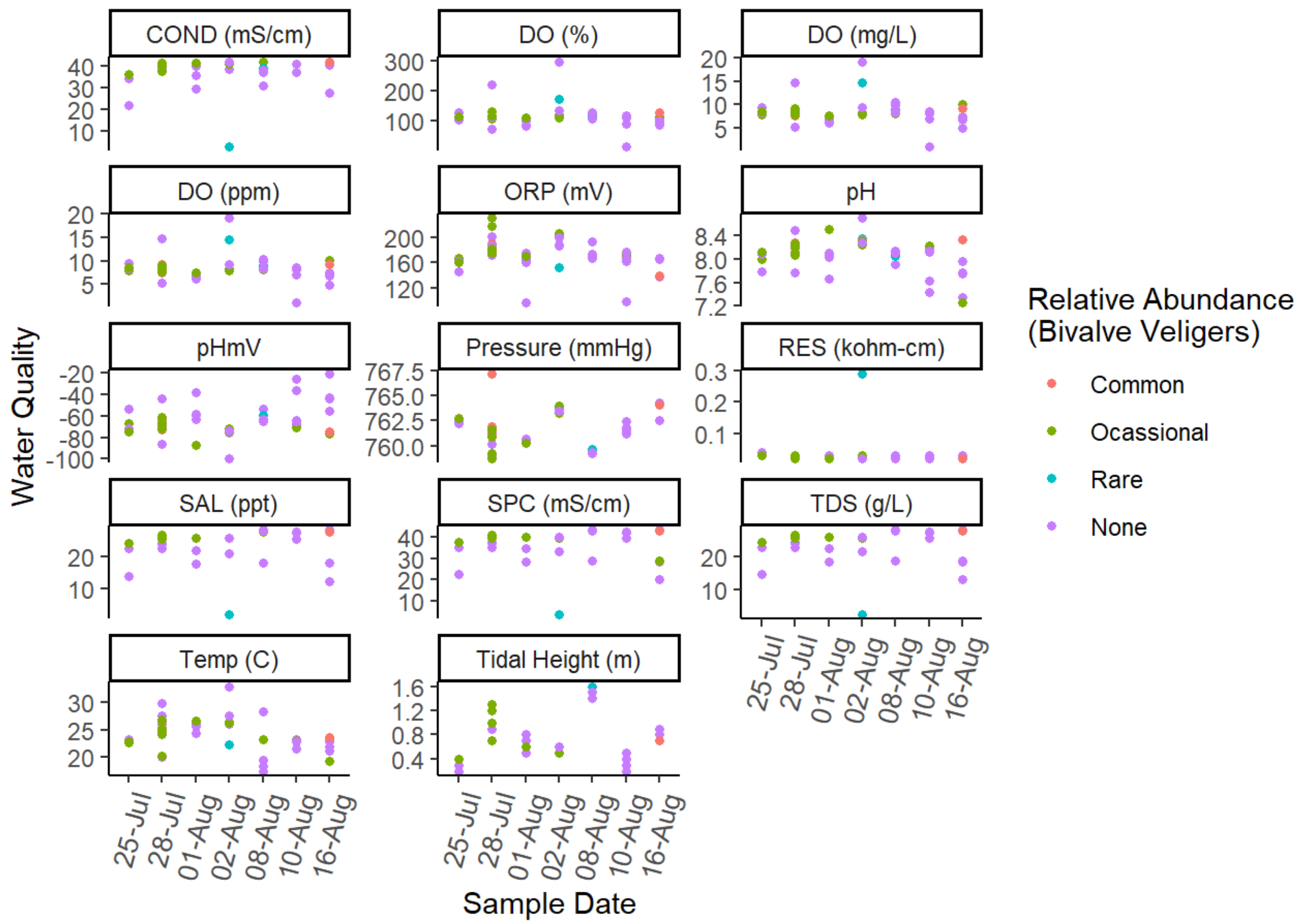


Figure 13. Plots showing the relative abundances of Bivalve Veligers compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Bivalve Veligers over all different sample sites in the Gorge.

D6. Plots containing information for Gastropod Veligers

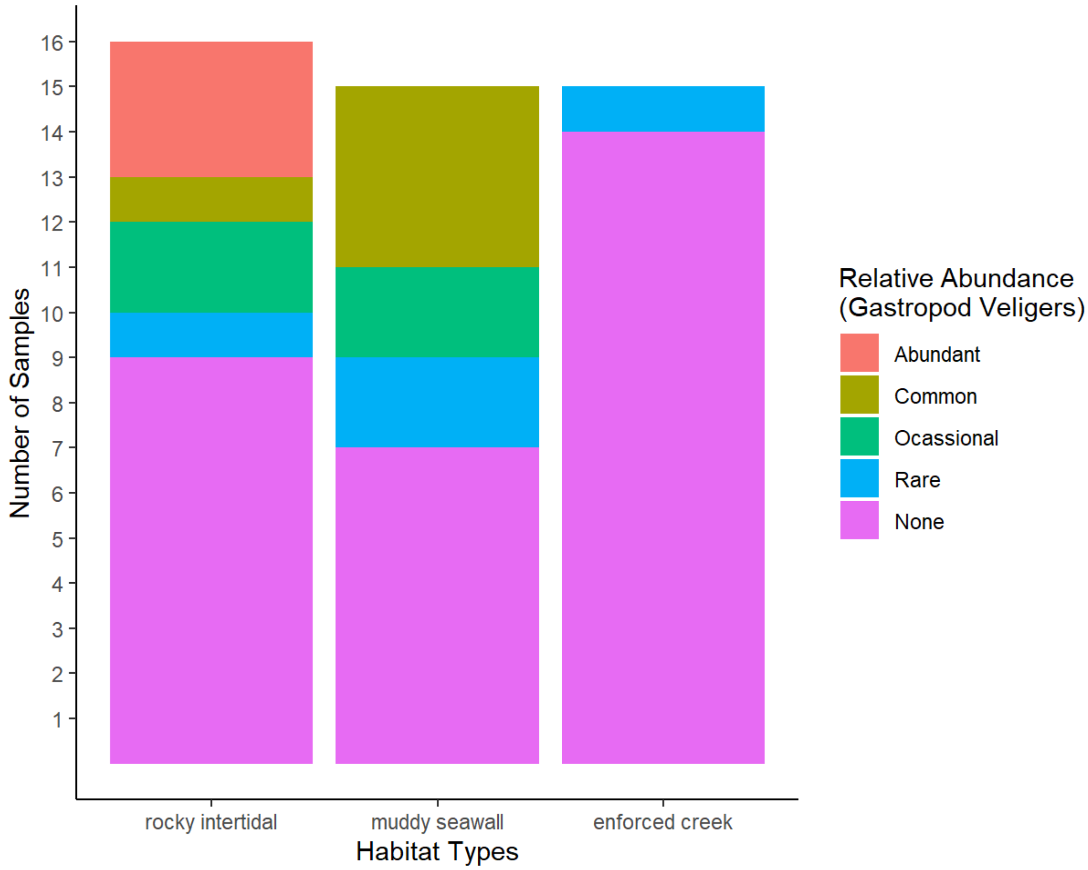


Figure 14. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Gastropod Veligers. The bars are proportioned by color depending on the relative abundances of Gastropod Veligers in each sample.

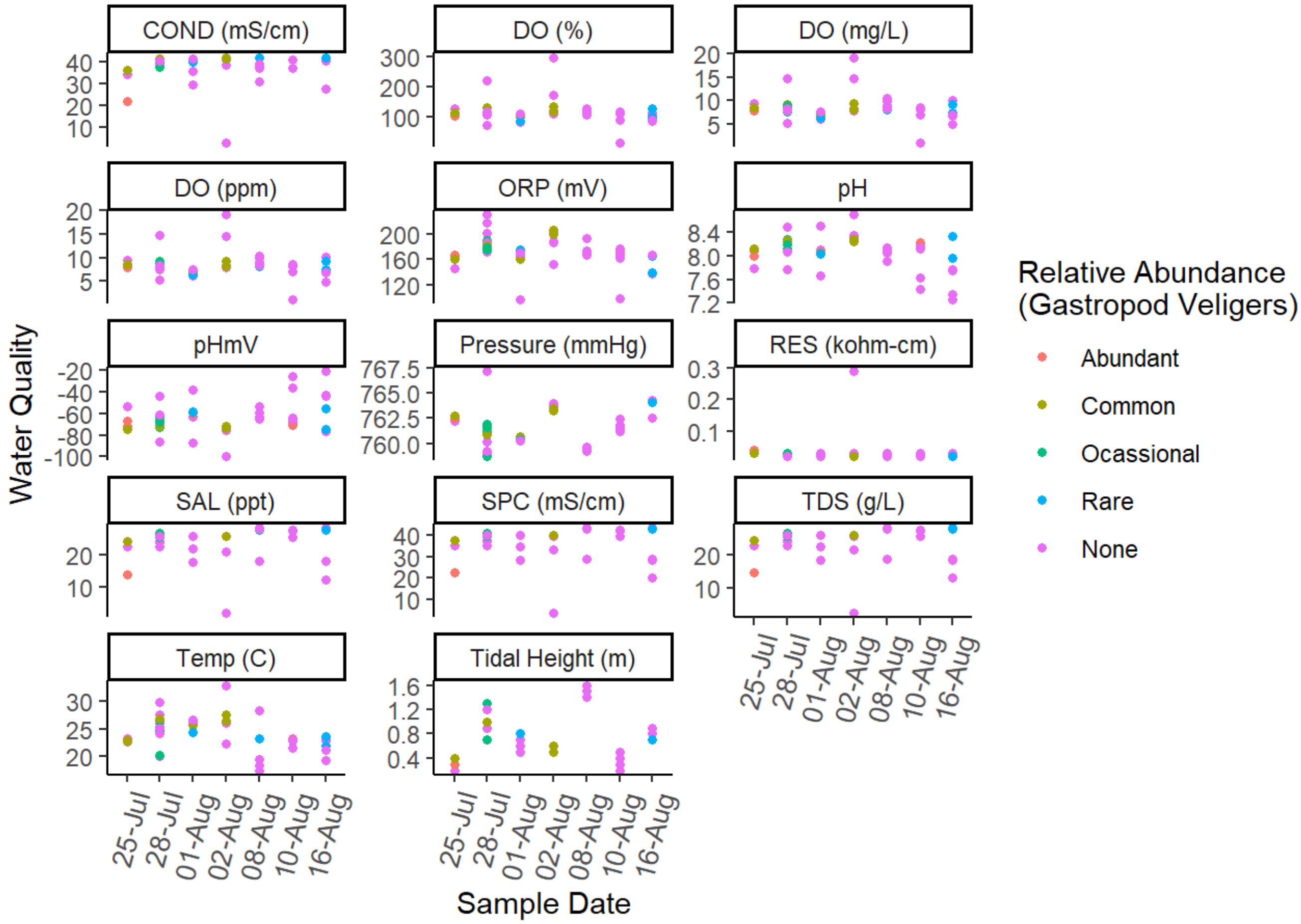


Figure 15. Plots showing the relative abundances of Gastropod Veligers compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Gastropod Veligers over all different sample sites in the Gorge.

D7. Plots containing information for Phylum Rotifera

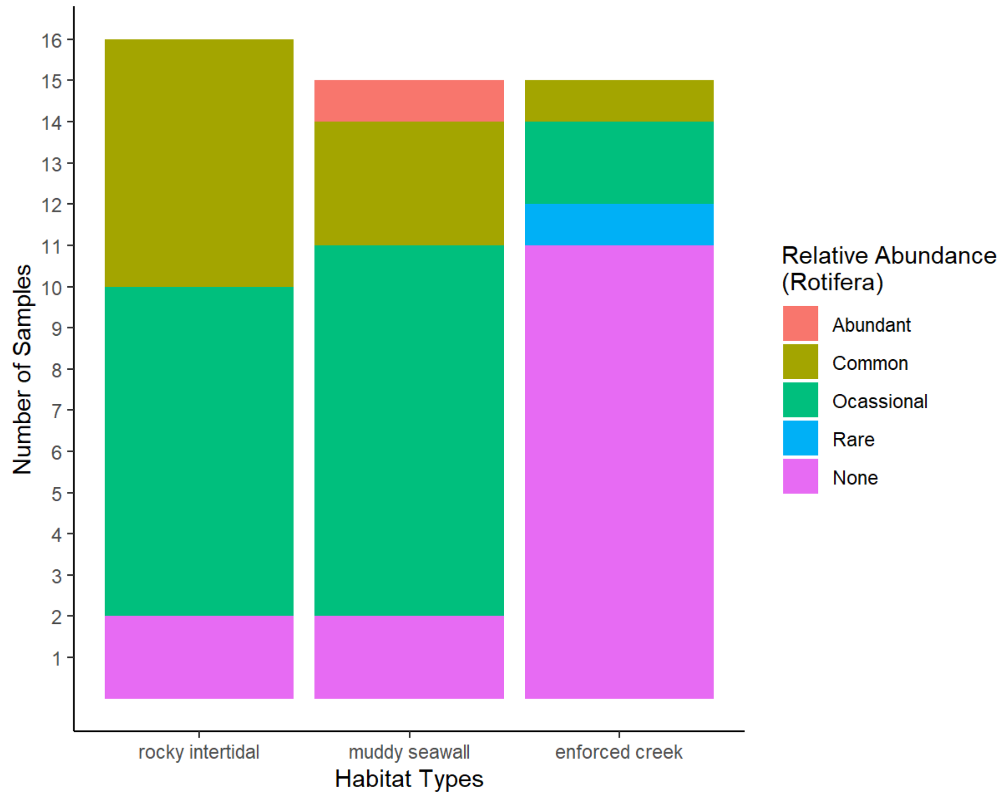


Figure 16. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Phylum Rotifera. The bars are proportioned by color depending on the relative abundances of Phylum Rotifera in each sample.

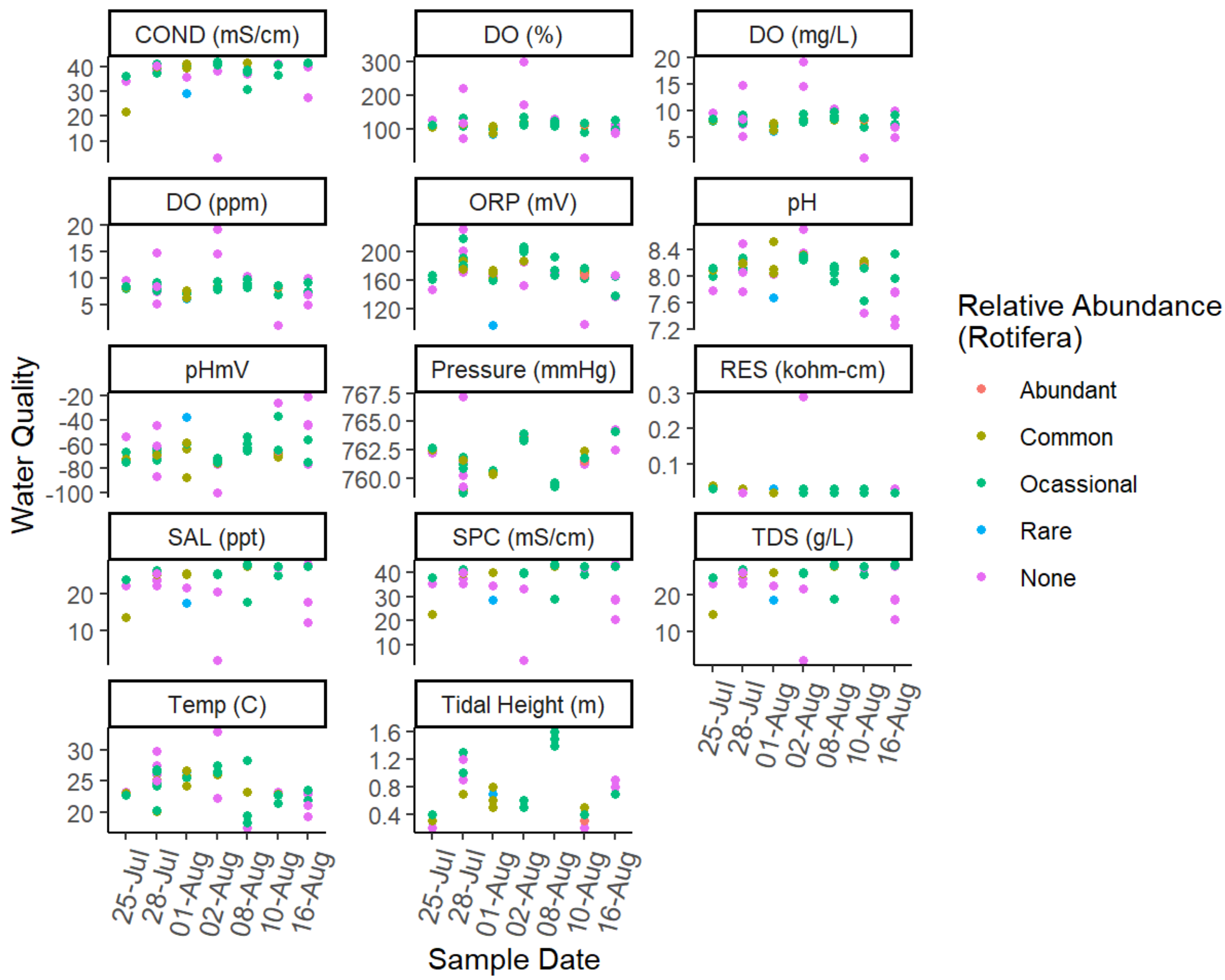


Figure 17. Plots showing the relative abundances of Phylum Rotifera compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Phylum Rotifera over all different sample sites in the Gorge.

D8. Plots containing information for Nauplius larva

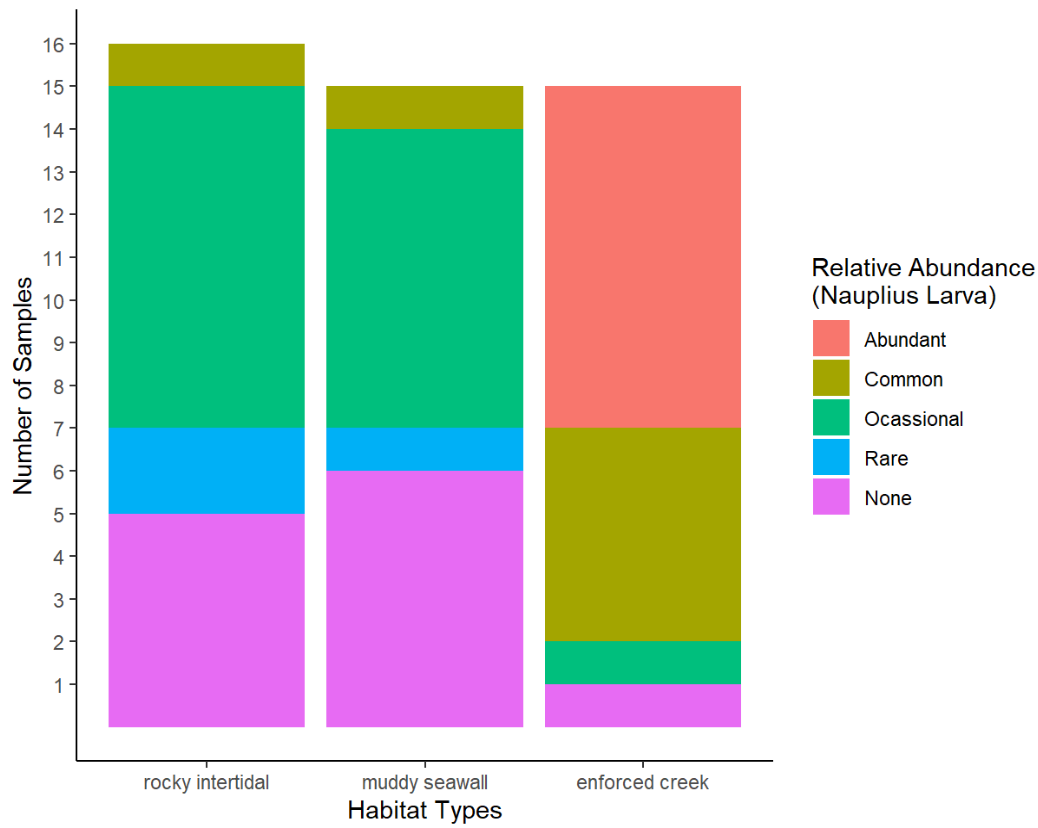


Figure 18. Bar plots showing different habitat types on the x-axis and the number of samples at each habitat type on the y-axis, for Nauplius larva. The bars are proportioned by color depending on the relative abundances of Nauplius larva in each sample.

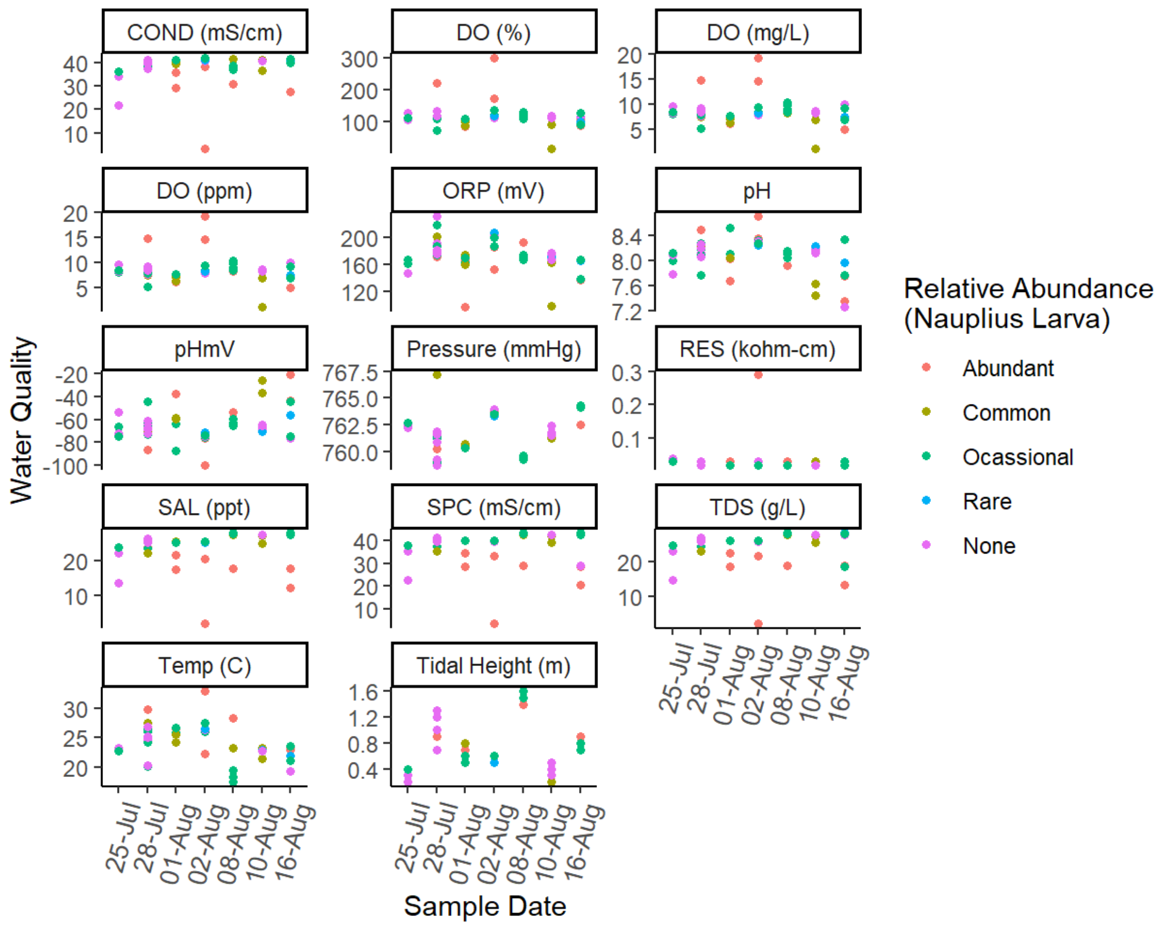


Figure 19. Plots showing the relative abundances of Nauplius larva compared to different water quality metrics (measured with the YSI Pro Quatro). Scatterplots show different water quality metrics on the y axis and the date the sample was taken on the x axis. The points are coloured based on relative abundance of Nauplius larva over all different sample sites in the Gorge.