# Zooplankton community composition and size distribution in relation to phytoplankton in the Galapagos Islands

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## *Non-technical Summary.*

Zooplankton size distribution and community composition were examined at 7 sites around the Galapagos Island and related to the size distribution of phytoplankton. Zooplankton samples were collected on the *R/V Thompson* from January 21-28, 2006, and kept in a glass jar and killed with formalin. A subsample was taken from the original sample and divided into 3 size groups, 102-209μm, 209-333μm and >333μm; each size group was then counted by families to find the total number of organisms in the sample and the size distributions of organisms in the sample. The data were then compared to the size distribution of phytoplankton (measured by Tasha Snow) at the same stations. Understanding the properties of zooplankton and how the ecosystems function is vital to fix potential problems that may occur in the ecosystems. Over the years, iron fertilization has been thought to be the key to stop global warming, although many scientists support the idea, we have little knowledge on what iron fertilization will do in the long term. Many studies have been done on the removal of carbon in the atmosphere by the phytoplankton in the oceans. Over the short term, addition of iron can increase the carbon removal and favors large phytoplankton. Large zooplankton have a slower generation time then the large phytoplankton, after a ample amount of time the grazers can catch up and start controlling the phytoplankton population. Many of the iron fertilization studies have been done on short time scales, not allowing the zooplankton grazing to come in effect. The waters around the Galapagos Islands have 2 very diverse properties; on the west side of Isabela Island, due to upwelling and iron coming off the islands, it is very nutrient rich (including iron); on the east side of Isabela Island, there is a low amount of nutrients, due to the lack of upwelling and iron addition. These 2 diverse

water properties are a perfect location to study the effects of long-term iron fertilization, the east side of Isabela Island is the control, the west side

## *Acknowledgements.*

I would like to thank my professors; Roy Carpenter, Mark Holmes and Seelye Martin for all the help they have given me write my paper. I would like to thank my professor Gabrielle Rocap and my TA Llyd Wells for helping me design my project, perform my experiment and all the other help along the way. I would also like to thank Kathy Newell for taking the wonderful pictures for me and Diego Figueroa for helping me perform my experiment and identify organisms.

## *Abstract.*

Zooplankton size distribution and community composition were examined at 7 sites around the Galapagos Island and related to the size distribution of phytoplankton. Zooplankton samples were collected by vertical net tows from the *R/V Thompson*, and placed in a jar and diluted to a known volume. After adding formalin to kill the organisms, 5mL from the total sample collected was run through 3 sieves, splitting the subsamples into 3 groups (102-209μm, 209-333μm and >333μm). Each group was placed on a counting track and counted by identity groups, to determine the amount and size distribution of organisms in the sample. The data were then compared to the size distribution of phytoplankton (measured by Tasha Snow) at the same stations. Understanding the properties of zooplankton is vital to fix potential problems that may occur in the ecosystems. Over the years, iron fertilization has been thought to be the key to stop global warming; many studies have been done on the removal of carbon in the atmosphere by the phytoplankton in the oceans. This fertilization technique favors the larger phytoplankton at first, since the Galapagos Islands has such diverse water compositions, it will allow us to examine a long term effects of these naturally fertilized areas with naturally unfertilized areas.

## *Introduction.*

Since phytoplankton and zooplankton are at the base of the marine ecosystems, understanding their properties and the relationships between them will allow us to detect and avoid a potential crash in the ecosystem (Figueroa and Hoefel 2005., Conway 2005). Not only are phytoplankton and zooplankton at the base of the food chain, they also are important for maintaining a livable environment. I hypothesized that where the size distribution of phytoplankton is shifted to larger sizes, the size distribution of zooplankton would also be shifted to larger sizes. My hypothesis was based on iron fertilization studies, which have shown that adding iron to high-nitrate, low-chlorophyll (HNLC) areas increases phytoplankton biomass and size, which in turn removes a significant amount of atmospheric $CO_2$, over short time scales (Martin et al. 1994). Where low iron concentrations are found in HNLC regions, small phytoplankton cells are favored, because they have larger surface area to volume ratios. Since they have a small volume, less iron is needed then for large cells, and with a larger surface area they are able to absorb enough iron to support themselves. This enables the smaller cells to compete more effectively for iron than bigger phytoplankton cells (Landry et al. 2000c). Those bigger phytoplankton may thus become iron-limited. When iron is added, however, the larger phytoplankton cells are no longer iron-limited, the surface area is less important since iron is easily absorbed to support the cell. Also, because most of the larger cells' grazers are large zooplankton with relatively long generation times, they are initially grazed less than the smaller phytoplankton cells, which are subject to more substantial predation by microzooplankton. The microzooplankton that are grazing on the phytoplankton were initially already found there, they also have shorter generation times

(Landry et al 2006b). The larger phytoplankton cells aren't controlled by grazing until the larger grazers are able to move in and start grazing and controlling the population. Initial iron fertilization studies have been on short time scales (Martin et al. 1994), not allowing enough time for the population of larger zooplankton to catch up with the rapidly-growing large phytoplankton and control them. In these studies it is hard to see a relation between the two. Landry et al. (2000a) did a study on the phytoplankton abundance and biomass in and outside the iron enrichment patches. In the control outside of the iron enrichment patch small phytoplankton cells dominated, while inside the iron enrichment patch, large phytoplankton cells dominated. After given enough time, grazers moved in to control the phytoplankton population and other nutrients were used up, and the large phytoplankton cells became nutrient-limited again, and the smaller cells were favored.

My study closely follows that of Rollwagen Bollens and Landry (2000), the first study that was done to assess the mesozooplankton community response to iron-fertilized phytoplankton bloom. Except instead of assessing the response to an iron-fertilized phytoplankton bloom, I assessed naturally rich or limited iron areas. All of the iron-enrichment experiments have been done on short time scales. The scales are to short to see the long-term grazing effects on the phytoplankton. Since adding iron can not cause phytoplankton abundances to exponentially increase, either the phytoplankton must use up the iron and small phytoplankton cells are favored again, or zooplankton grazers move in to control the phytoplankton population. In short time scale experiments, usually the iron is used up first. In naturally rich iron areas, iron is always being added, there must be something controlling the population, grazing. The Galapagos Islands are an ideal location of studying naturally rich and limited iron areas. On the west side of Isabela

Island, not only are nutrients coming up from the upwelling Equatorial Under Current (that smashes in to the Galapagos platform and is forced to upwell) but iron is believed to be blown off the Islands in to this area. On the east side of Isabela Island, these processes are not present, leaving this area nutrient-limited.

I sampled at 7 stations around the Galapagos Islands (Table 1, and fig 1) expected to support arrange of phytoplankton sizes (due to the expected iron-rich areas). In general, large phytoplankton in some areas are expected to reflect the higher natural levels of iron fertilization on a long term scale, unlike that of the iron fertilization experiments; therefore, I expected larger zooplankton to occur with the larger phytoplankton.

## *Methods*

All research was done aboard the *R/V Thompson* during the 21-28 of January, 2006, at 7 stations around the Galapagos Islands (Table 1, and Fig 1). The zooplankton samples were collected by a vertical tow using a 0.6m-diameter net with 102 micron mesh to 180 meters (except at shallow station Bio 2, where the net tow only went to 140 meters). Once the net was recovered shipboard, it was sprayed down so all the zooplankton were collected into the cod end. The specimens in the cod end were then transferred to a glass jar and diluted to a known volume. Once they were in the jar, they were killed by adding Borax-buffered formalin to a final concentration of 10%. After the sample was gently shaken (to make the specimens uniformly distributed) 5mL were removed, the rest of the sample was kept for Diego Figueroa. The 5mL subsample was run through a 102μm sieve over a used formalin jar (this was done to get rid of any organisms smaller than 102μm and to dispose of the formalin in the sample). Once all the formalin was out of the subsample, the specimens in the sieve were then transferred to a 333μm sieve with a jar underneath. Everything that did not go through the 333μm sieve was the first group, >333μm, which was then transferred to a petri dish for further analysis. Everything that did go through the 333μm sieve was collected in a jar, and was then run through a 209μm sieve. The organisms that did not go through this sieve, were the second group, 209-333μm, and were transferred to a petri dish for further analysis. The organisms that did go through the sieve were collected as the last group, 102-209μm, and transferred to a petri dish for further analysis.

For each size group at every station (except Bio 6), the sample was transferred to a track counter with 5 rows. Using a dissecting microscope, I counted all the copepods in

the first row. If the number of copepods in the first row was greater than 10, I stopped counting and multiplied this number by 5 (because there are 5 rows in the track counter and if they are uniformly distributed there should be the same number of copepods in all the row), thus finding the total number of copepods in this subsample size group. If there were less than 10 copepods in the first row, then the second row copepods were counted; I counted the organisms until I reached ≥10, and multiplied that number by a number to find the total in all 5 rows (thus, if I counted 2 rows, I would multiply the number by 5/2, likewise if I counted 3 rows, the number would be 5/3 and if I counted 4 rows, it would be 5/4). This counting method was done for *Euphausiids, Chaetognaths*, Jellies and Larvae/others also found in the subsample. If a zooplankton count was 0 in the first row, it was assumed not to be present and not counted further.

At Bio 6, the first station we arrived at, a different counting method was done. After adding the formalin to the whole sample, 5mL was taken out, and formalin was removed. Then the sample was transferred to a glass jar and diluted to a known volume. A 5mL subsample was removed from the original subsample and run through the 3 sieves, creating the 3 size groups (>333μm, 209-333μm, and 102-209μm). Every organism in the track counter was counted, and identified.

After I had the counts, I was able to find the total abundance in the whole sample, the average number of organisms in a cubic meter of water and the percent abundance of each group. These values helped me compare different stations. To find the total organisms in the sample, I first divided the total volume by the amount taken out, which was 5mL at every station. At Bio 6, I divided the total volume by the first 5mL subsample, multiplied it with the diluted subsample volume divided by the second 5mL

subsample. This accounted for the number of subsamples that could be taken from the total sample; by multiplying it by the number of organisms found in the subsample, the total number of organisms in the sample could be determined. To find the concentration of the organisms per cubic meter of seawater (organisms/$m^3$), the area of the net opening was multiplied by the depth of the tow. The number of organisms over this volume was the concentration. With the concentration we can compare the data to each station and to different size groups. The percent abundance of different organisms or size groups was also determined for comparative purposes.

At the first station we sampled at, Bio 6, I performed a different method for counting; this data was not as accurate as the other stations. The method for counting did not represent the main sample as a whole. Only about 0.03% of the population of the whole sample was counted, this causes large error in my data.

## *Results.*

On the west side of Isabela Island stations Bio 1 and Bio 3 had high zooplankton concentrations, ranging from approximately 3600-3300 organisms/$m^3$, while station Bio 2 had a low concentration of about 1900 organisms/$m^3$ (fig 2). On the east side of Isabela Island the concentrations likewise ranged from about 1700-3400 organisms/$m^3$ (fig 2). With Bio 4 having the lowest and XO1 having the highest, there was a trend of increasing concentrations to the south-east, from Bio 4 to XO1 (Fig 1 & 2).

In terms of percent abundance, copepods were dominant at every station and in every size group. Copepods at all the stations and size groups take up about 65-100% of the total population (fig 3), with the highest fraction in the 209-333µm size group of Bio 6. At all the stations the jellyfish, *Chaetognaths*, and *Euphausiids* were generally seen only in the larger size group, with some exceptions. Bio 1, 2 and 4 had jellyfish present in both the >333µm group and 209-333µm group, with the second group only containing small amounts (fig 4). At Bio 6, I found an *Euphausiids* larva in the 102-209µm group. Larvae and others were found in almost every station and group, with a higher percent abundance in the smaller size groups, 102-209µm and 209-333µm (fig 4). On the east side of Isabela Island, *Chaetognaths* had a larger percent abundant than on the west side. *Euphausiids* where mostly found at station Bio 2 and Bio 6 (found in the larval stage). The percent abundance of jellies on the west side of Isabela Island were greater than those on the east side (fig 4).

The percent size groups for each station (fig 5) allowed me to compare each station by what size zooplankton were dominant. If comparing each size group individually, the largest size group (>333µm) was most abundant at every station. But I

lumped 102-209µm and 209-333µm together to form the smaller size group and compared that with the >333µm size group. The stations on the west side of Isabela Island, Bio 1, 2 and 3, were all dominated by the larger size group, >333µm, from about 65-85%. While the stations on the east side of Isabela Island, Bio 4, 6 and XO1, were dominated slightly more by the smaller size group, 102-333µm, from about 55-60%. The exception was at station Bio 5, located on the east side of Isabela Island, the larger zooplankton dominated by about 65% of the zooplankton.

At station Bio 3 every jellyfish that was counted was the same type (fig 5a). At the first and last stations we sampled (Bio 6 and XO1) we found an interesting and beautiful copepod with a blue pigment; Diego Figueroa has identified it as *Pontellina plumata* (fig 5b).

## *Discussion.*

Rollwagen Bollens and Landry (2000) found that after iron was added, shortly after the peak of the phytoplankton bloom, zooplankton abundance and biomass decreased to initial levels. This was most likely due to predation. Just as zooplankton came in to feed on phytoplankton, zooplankton predators increased to graze on the abundant zooplankton. Another explanation for the decline of abundance and biomass of zooplankton was caused by the failure in their reproduction, possibly caused by the lack of nutrients in their food source, diatoms (Rollwagen Bollens and Landry 2006).

Once the concentrations were found for each station I could compare them easily. At first I was not quite sure why Bio 2 had relatively low concentrations compared to Bio 1 and Bio 3 since all three were in an expected high productivity area (thus there is an abundant food source for the zooplankton). Although now I know this was not the case, Bio 2 was lower in production and total chlorophyll than Bio 1 and 3 (Gilmore 2006, Snow 2006). With those low levels the zooplankton did not have an abundant food source, therefore the zooplankton were less abundant. Although Bio 2 had lower total chlorophyll than Bio 1 and 3, the total chlorophyll was much greater on the west side of Isabela Island than on the east side. With the highest chlorophyll at the chl max at Bio 1 and the lowest at Bio 4 (Snow 2006). Likewise the production at the surface was greater on the west side of Isabela Island than the east side, with the exception of Bio 2, which had low values of about $10\mu molCl^{-1}d^{-1}$. The highest value was at Bio 3 with about $50\mu molCl^{-1}d^{-1}$ and the lowest at Bio 4 with about $2\mu molCl^{-1}d^{-1}$. Bio 6 had a sub-surface maximum; the production rate was $30\mu molCl^{-1}d^{-1}$. Bio 2 is dominated (by over 80%) by large zooplankton; the small concentration may be due to some of the larger organisms

(Bio 2 had the largest concentration of jellyfish and *Euphausiids*) eating the smaller zooplankton, causing there to be less organisms.

I expected to have copepods dominating at every station but I didn't realize how dominating they would be. The total populations at all the stations were composed of about 80-95% copepods (fig 3). I was also surprised to see no real patterns and big differences in abundances between the west and east sides of Isabela Island. Greater taxonomic resolution perhaps would have enabled detection of more differences between the stations, a point especially relevant to the abundant copepods, in a similar study done by Rollwagen Bollens and Landry (2000).

My size group distribution was mostly as I had expected: where there was high productivity, high chlorophyll and the phytoplankton were dominated by larger species, the zooplankton feeding off these phytoplankton were also large. On the west side of Isabela Island, larger phytoplankton (>20μm) were dominant (fig 7)(Snow 2006), at those stations, the zooplankton size groups was dominated by the larger zooplankton, >333μm, that was what I had expected. On the east side of Isabela Island, the phytoplankton were dominated by small phytoplankton (<2μm, with the exception of XO1, at the chl max, it was dominated by larger phytoplankton) (fig7)(Snow 2006). At the chl max of XO1, there was also a high production rate and a high zooplankton concentration. The east side stations were dominated slightly more by the smaller zooplankton, 102-333μm, except at Bio 5, which was dominated by the larger zooplankton. This may be due to the fact that some of the larger zooplankton were feeding on the smaller zooplankton or due to random chance that would be corrected with more replications.

## *Conclusion.*

In general, I found that the zooplankton size distribution does reflect the size of the phytoplankton at the stations. Where there were larger phytoplankton present, a higher percent of the zooplankton were larger. Where there were smaller phytoplankton found, a higher percent to the zooplankton were smaller, with the exception at station Bio 5. There were small differences in the community composition at each station; the populations were dominated by copepods at every size group. Only a few types of organisms, jellyfish and *Euphausiids*, were located mostly the west side of Isabela Island, but they were found in such a low percent abundance that it was hard to conclude much.

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Table 1. Station arrival date and time, and station location

| Station | Date | Time | Lat. | Long. |
|---|---|---|---|---|
| BIO-1 | 21/01/06 | 17:45 | S 00 36.9963 | W 091 41.9812 |
| BIO-2 | 23/01/06 | 02:30 | S 00 36.9759 | W 091 18.9998 |
| BIO-3 | 22/01/06 | 14:00 | S 00 13.6160 | W 091 36.3927 |
| BIO-4 | 25/01/06 | 03:00 | S 00 00.9827 | W 091.07.9866 |
| BIO-5 | 24/01/06 | 07:30 | S 00 32.0035 | W 090 46.9851 |
| BIO-6 | 21/01/06 | 21:45 | S 00 55.0189 | W 089 59.9560 |
| XO-1 | 27/01/06 | 02:00 | S 02 00.0050 | W 088 59.9860 |

## *Figure Captions.*

Figure 1. Map of track lines and station locations

Figure 2. The Concentration of all the organisms at each station.

Figure 3. Graphs of the percent abundance at each size group at A. the stations on the west side of Isabela Island, and B. the stations on the east side of Isabela Island.

Figure 4. Graphs of the percent abundance, excluding copepods, at each size group at A. the stations on the west side of Isabela Island, and B. the stations on the east side of Isabela Island.

Figure 5. The Percent broken into the 3 size groups at each station.

Figure 6. A. A jelly specie found at station Bio 3. B. A copepod, *Pontellina plumata*, found at station Bio 6. All photos taken by Kathy Newell.

Figure 7. A. Percent phytoplankton size fractionation per station at the surface. B. Percent phytoplankton size fractionation per station at chl max. (Graphs taken from Snow (2006))

Figure 1.

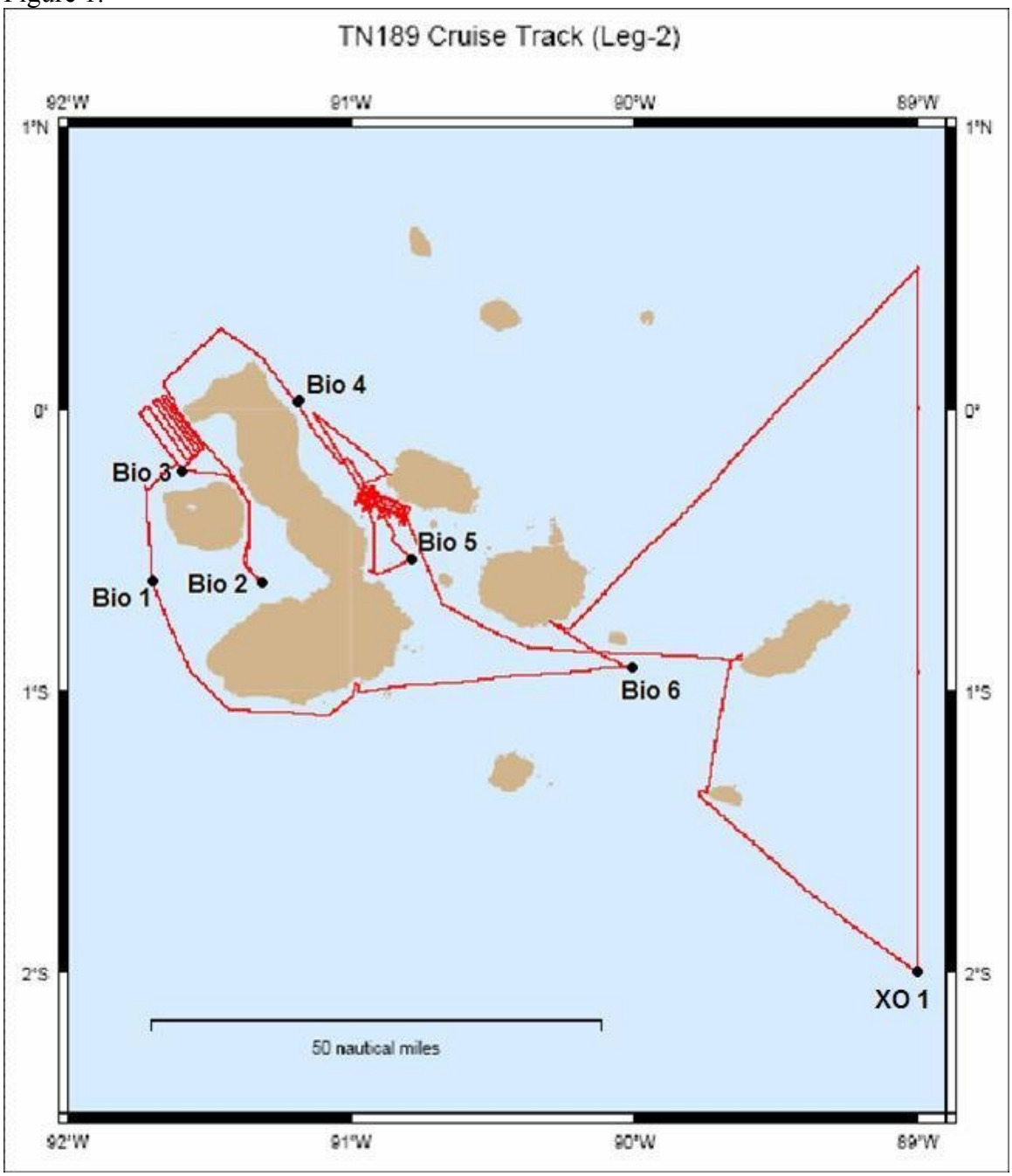

TN189 Cruise Track (Leg-2)
92°W
91°W
90°W
89°W
1°N
0°
1°S
2°S
Bio 1
Bio 2
Bio 3
Bio 4
Bio 5
Bio 6
XO 1
50 nautical miles

Figure 2.

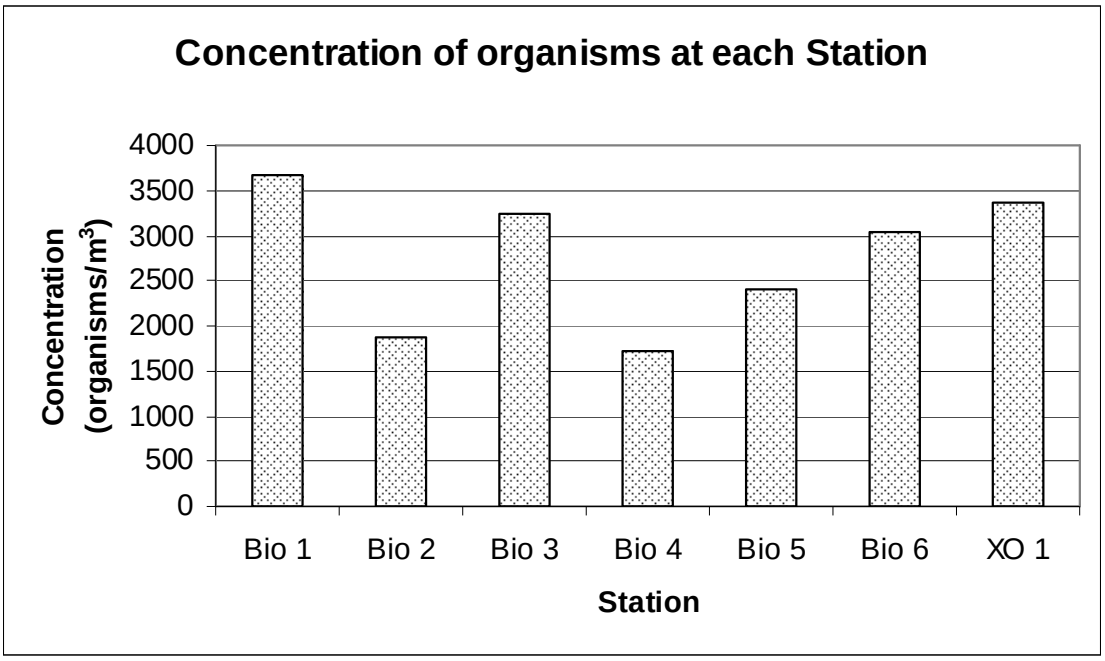
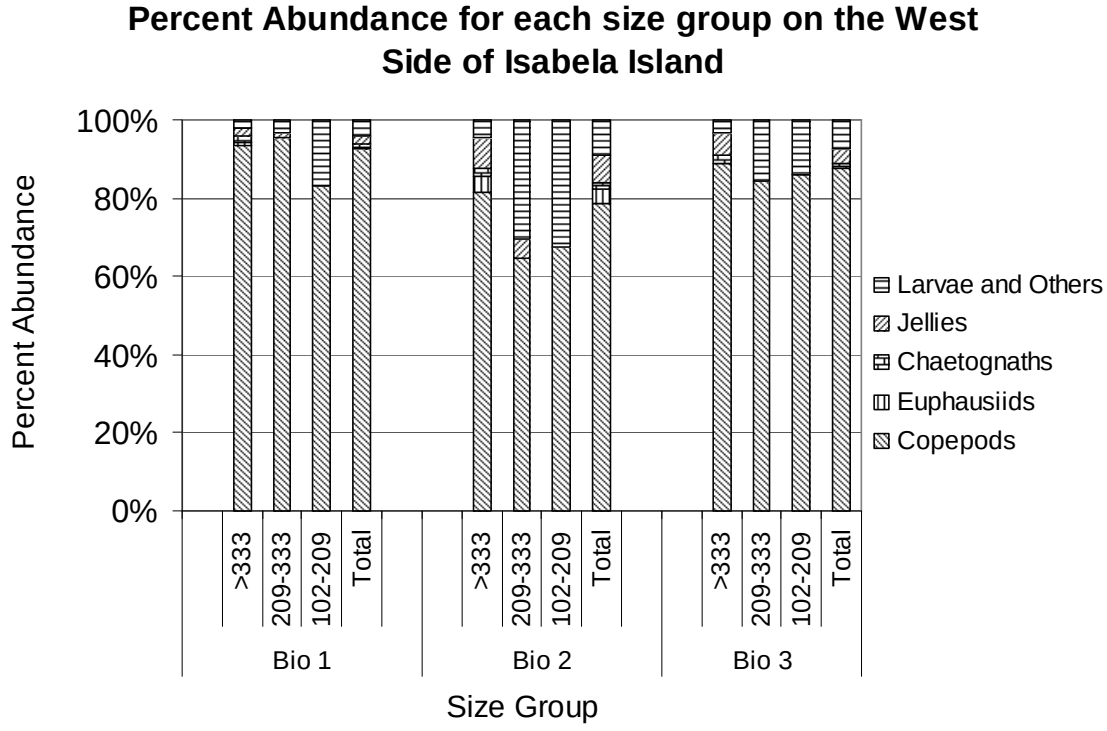

Concentration of organisms at each Station
Concentration (organisms/m3)
4000
3500
3000
2500
2000
1500
1000
500
0
Bio 1
Bio 2
Bio 3
Bio 4
Bio 5
Bio 6
XO 1
Station

Figure 3.

A.


Percent Abundance for each size group on the West Side of Isabela Island
100%
80%
60%
40%
20%
0%
Percent Abundance
>333
209-333
102-209
Total
Bio 1
Bio 2
Bio 3
Size Group
Larvae and Others
Jellies
Chaetognaths
Euphausiids
Copepods

B.

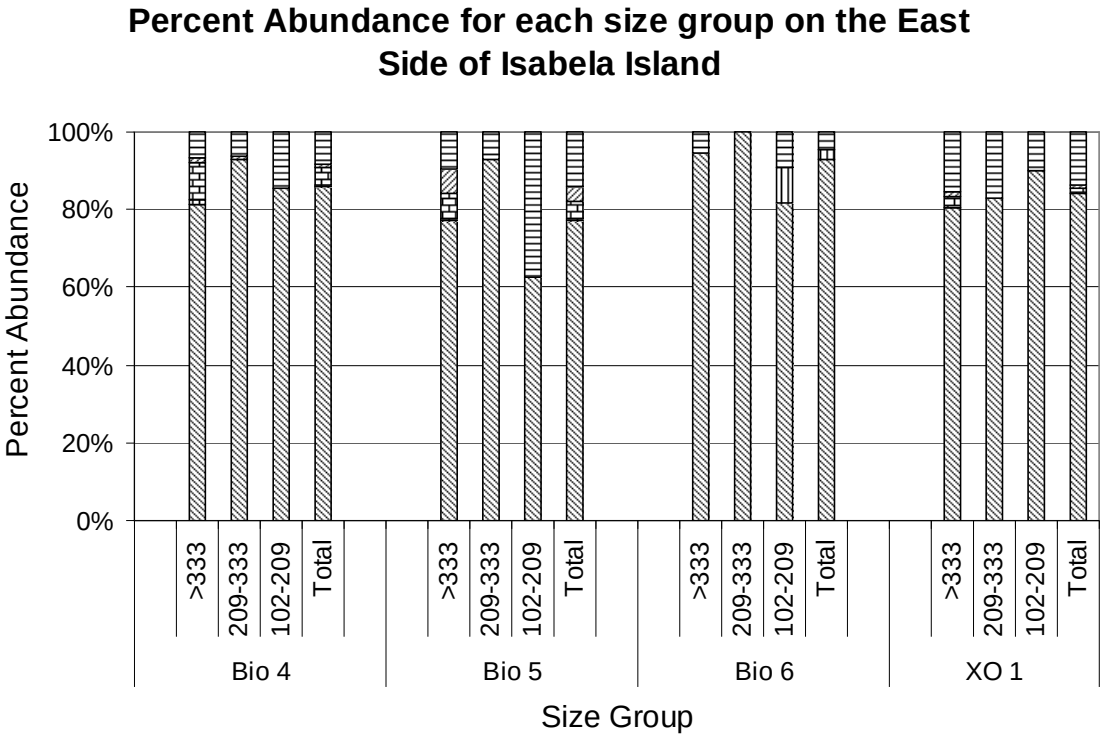
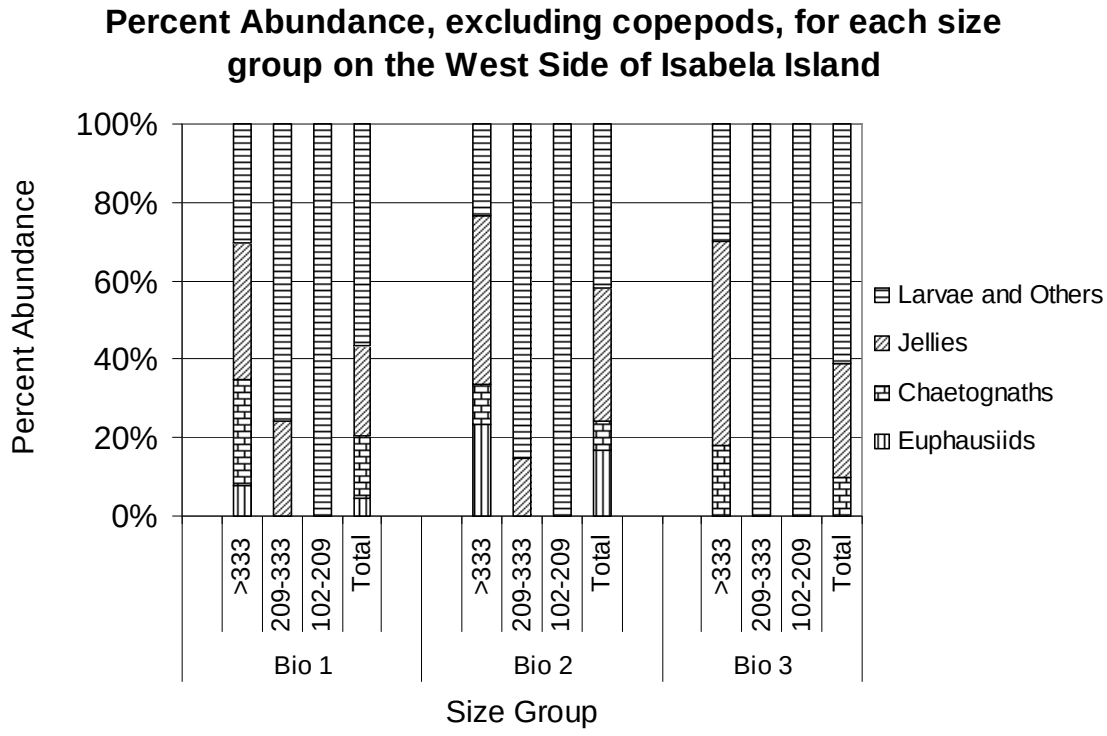

Percent Abundance for each size group on the East Side of Isabela Island
100%
80%
60%
40%
20%
0%
Percent Abundance
>333
209-333
102-209
Total
Bio 4
Bio 5
Bio 6
XO 1
Size Group

Figure 4.
A.


Percent Abundance, excluding copepods, for each size group on the West Side of Isabela Island
100%
80%
60%
40%
20%
0%
Percent Abundance
>333
209-333
102-209
Total
Bio 1
Bio 2
Bio 3
Size Group
Larvae and Others
Jellies
Chaetognaths
Euphausiids

B.

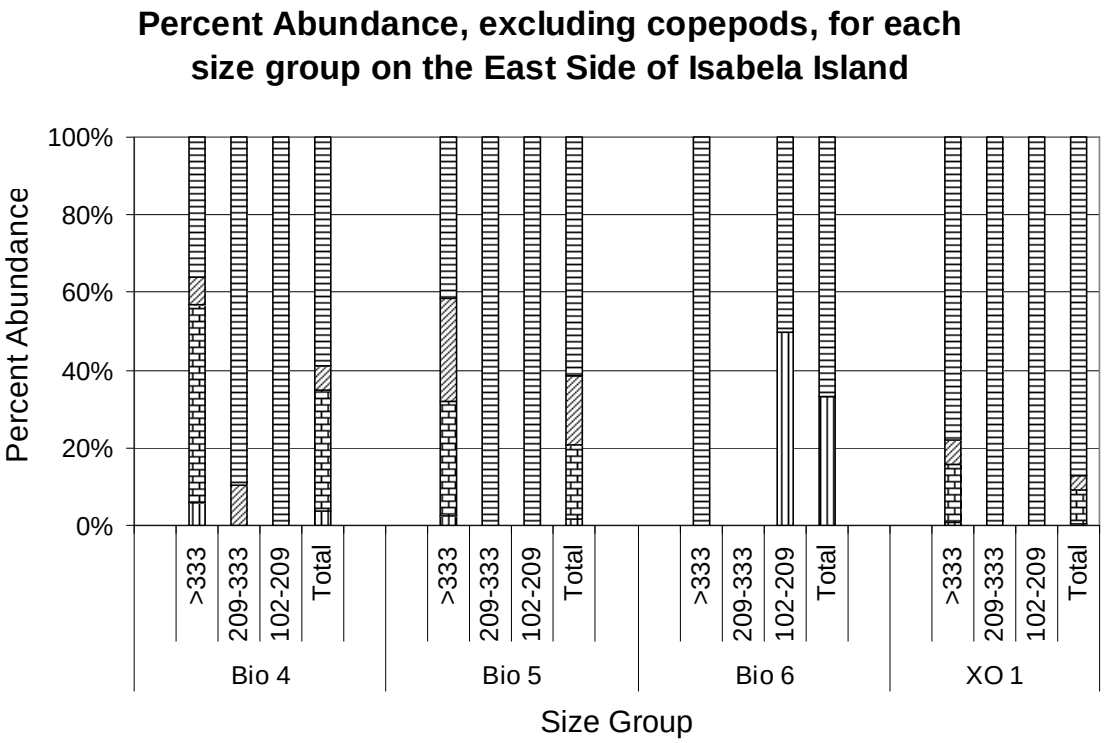

Percent Abundance, excluding copepods, for each size group on the East Side of Isabela Island
100%
80%
60%
40%
20%
0%
Percent Abundance
>333
209-333
102-209
Total
Bio 4
Bio 5
Bio 6
XO 1
Size Group

Figure 5.

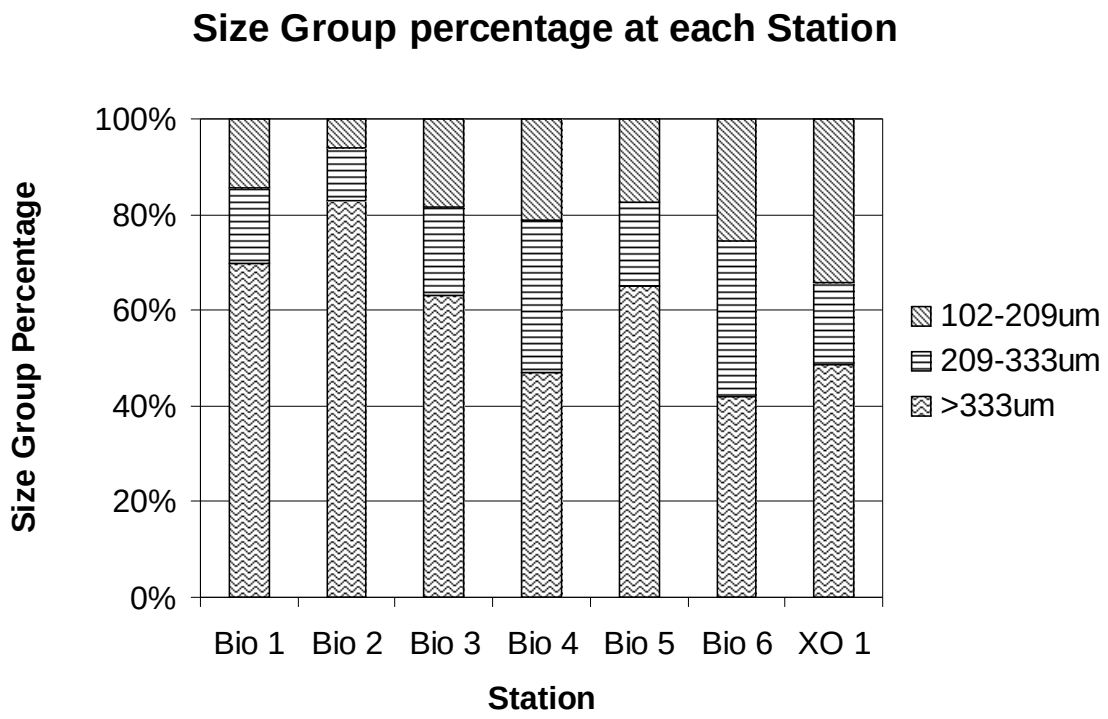
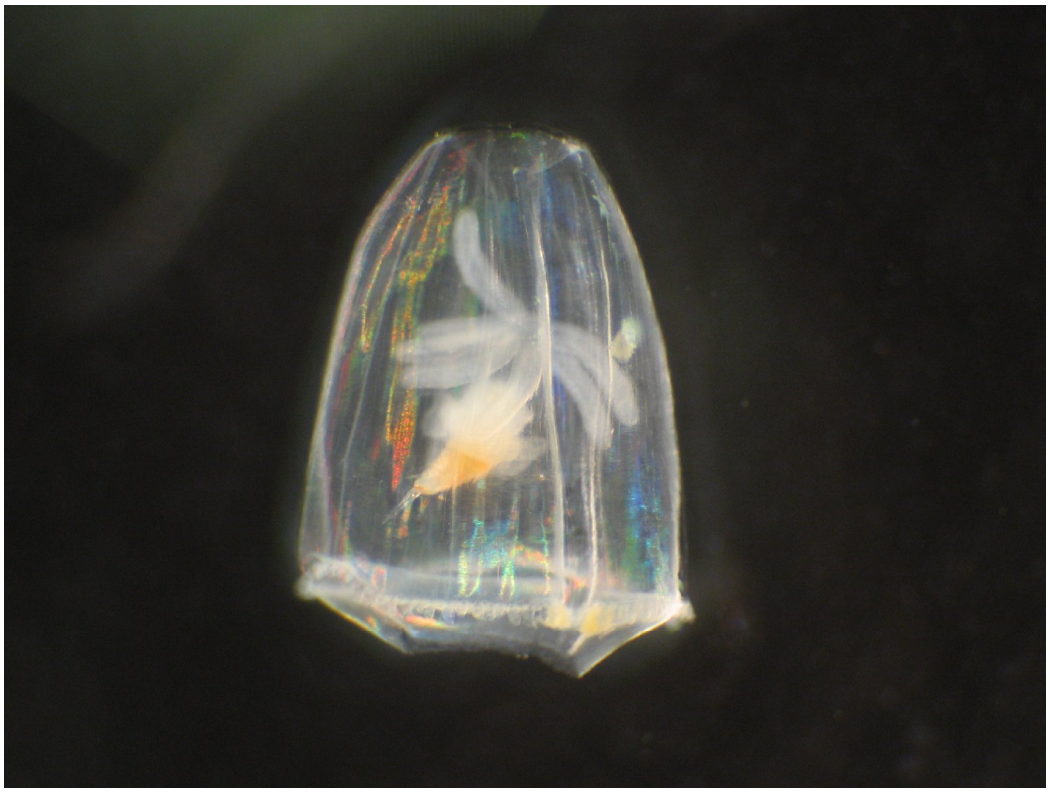

Size Group percentage at each Station
Size Group Percentage
100%
80%
60%
40%
20%
0%
Bio 1
Bio 2
Bio 3
Bio 4
Bio 5
Bio 6
XO 1
Station
102-209um
209-333um
>333um

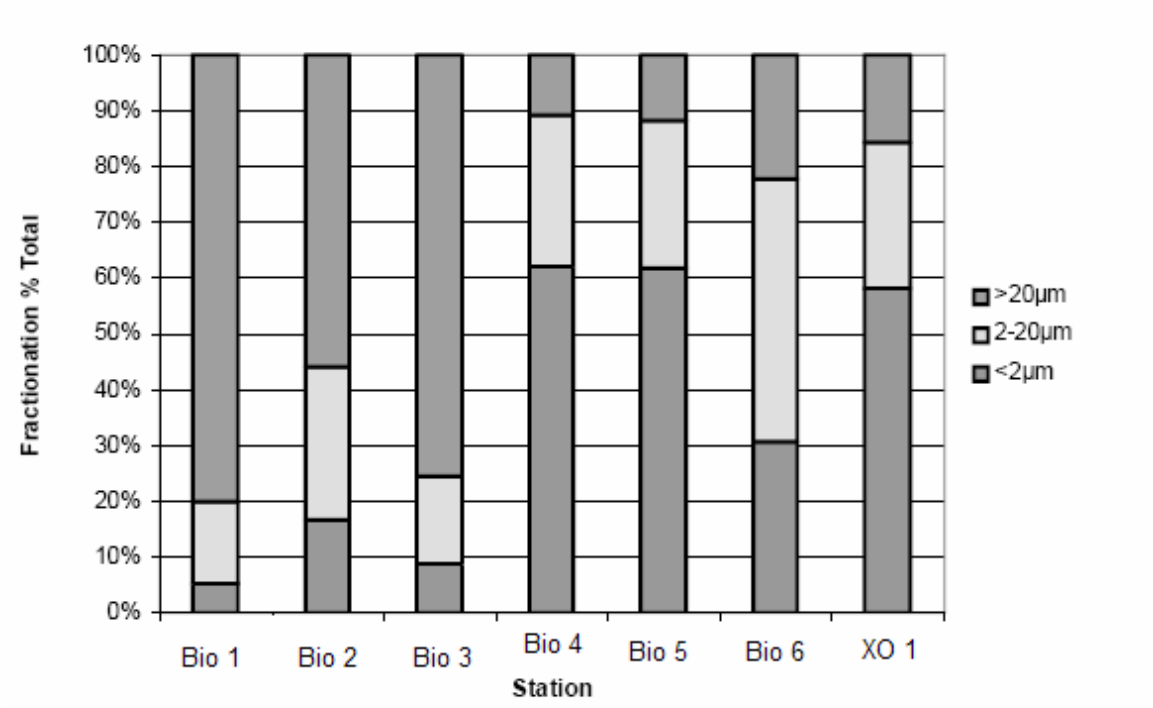
Figure 6.

A.

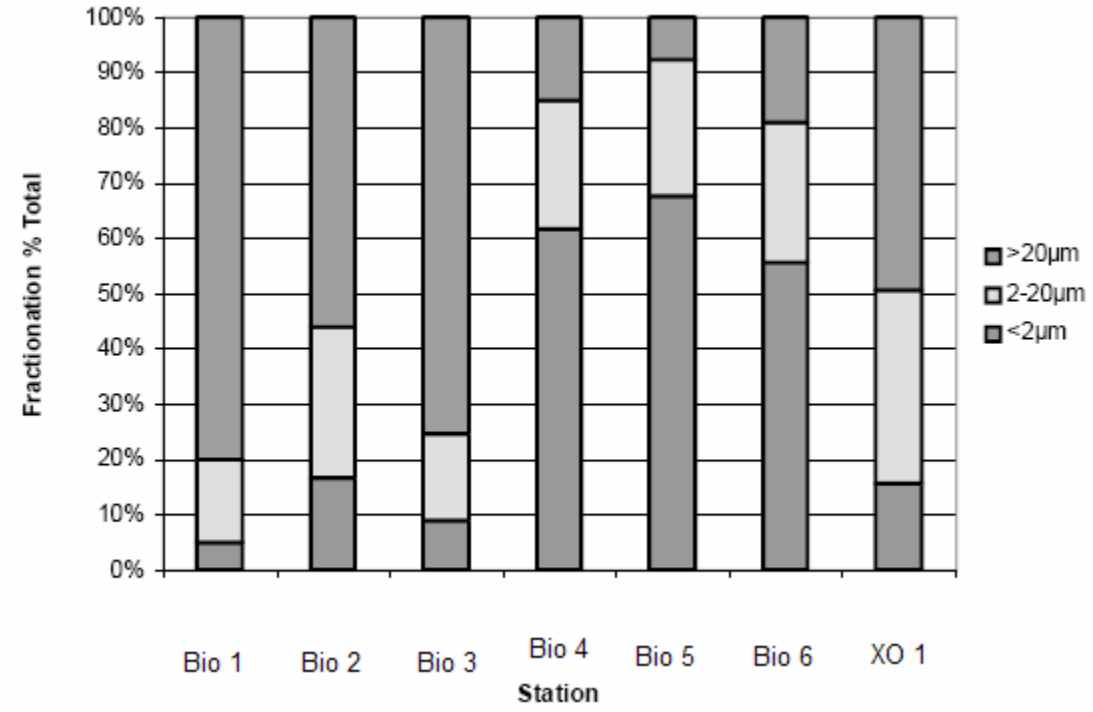


B.

Figure 7.
A.


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fractionation % Total
Bio 1
Bio 2
Bio 3
Bio 4
Bio 5
Bio 6
XO 1
Station
>20µm
2-20µm
<2µm

B.


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fractionation % Total
Bio 1
Bio 2
Bio 3
Bio 4
Bio 5
Bio 6
XO 1
Station
>20µm
2-20µm
<2µm