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# A comparison of benthic community diversity between two depressions within Douglas Lake, Michigan

## Introduction

Island biogeography is a theoretical approach used to predict species richness and evenness of island communities. These factors can include length of isolation, stochastic events, geographic isolation, allopatric speciation, distance from the mainland and the size of the island (Macarthur & Wilson, 1967). The theory of island biogeography focuses primarily on the affect of island size and distance from source pool on the species abundance and diversity of an island. This theory maintains that large islands support more species than small islands. It also states that islands that are distant from their source pool experience less immigration, which leads to reduced species richness (Gotelli, 2008). Although an island is traditionally thought of as a terrestrial system surrounded by unsuitable water habitat, island biogeography can also be applied to any viable habitat surrounded by uninhabitable environment for a given species or biological community. In an aquatic system, it is possible that this may apply to deep depressions that are surrounded by shallow waters, in particular, with regard to organisms that exist primarily in an anaerobic environment or travel only vertically in the water column.

In this study, the species diversity of the aquatic terrain of Douglas Lake, Michigan will be examined in relation to island biogeography theory. Specifically, bottom sediment community differences of two deep depressions within the lake, namely South Fishtail Bay Depression and Sedge Point Depression, will be explored. This study will not discuss distance from source pool in relation to island biogeography theory because the source pool for these “islands” is undetermined. Instead, this study will focus primarily on investigating whether the difference in area of the two depressions’ respective benthic layers affects species abundance and diversity.

Douglas Lake of Pellston, Michigan was formed by the Laurentide Ice Sheet, which receded approximately 11,000 years ago. It is very likely that large ice chunks from this glacier left the five major deep depressions, or kettle holes, that currently exist in the bottom of the lake (University of Michigan Biological Station) (Figure A). Each kettle hole is separated by shallows that range in depth from approximately two to twelve meters. In this way, the kettle holes can be thought of as underwater valleys, separated by underwater mountains, which for benthic communities may be suitable habitat surrounded by unsuitable habitat. Therefore, it is entirely possible that factors that contribute to island biodiversity can influence the communities of the kettle hole sediments, especially if organisms are unable or unwilling to travel outside the area of the kettle hole.

Douglas Lake is dimictic; it turns over biannually in the spring and autumn due to the similarity in water temperature throughout the lake (Horne & R., 1994). During the summer and winter, the lake becomes stratified into three distinct layers as determined by water temperature (Welch & Eggleton, 1935). The process of stratification begins in the spring when an increase in solar exposure causes water at the surface of the lake to become warmer and less dense than the water beneath it, creating the epilimnion layer. A colder middle, or metalimnion, layer is also formed, acting as an effective barrier by preventing mixing with the even colder, denser water at the bottom hypolimnion layer of the lake. In the winter, a similar stratification occurs, but a frozen sheet of ice insulates the lake. However, turnover occurs in the spring and fall, allowing waters throughout the lake to mix (Horne & R., 1994). As this happens, there is opportunity for free floating organism movement, and therefore gene flow, throughout the lake.

In contrast, the communities living in the sediments of the kettle holes are much less likely to be affected by turnover, and thus remain secluded over time. An extensive study by Eggleton and Welch (1931) tested the abiotic factors within the water column and sediment of all five depressions and concluded that each kettle hole acted, abiotically, like a separate lake (Eggleton F. E., 1932). It is possible that the abiotic differences between the kettle holes are due, at least partially, to their geographic isolation. This isolation may or may not be enough to constrict gene flow between kettle holes to the point where they can be considered individual islands. If so, geographic isolation may lead to differing community compositions. To explore the extent to which the abiotic differences may have lead to biotic differences, our investigation examines and compares communities of sediment organisms within South Fishtail Bay and Sedge Point Depression.

Materials

UMBS Pontoon Boat (1)

Eagle Depth sensor (1)

Eckman-Birge dredge (2)

10 L Plastic Buckets (15)

¼ inch ‘coarse’ sieve (1)

Forceps (4)

100mL Glass Jars (50)

95% ethanol (3L)

Petri dishes (4)

Dissection Microscope (1)

Camera (1)

Buoys

- 1 gallon Milk Jugs (2)
- Cement Blocks (2)
- 22m Rope (2)

Methods

Using a depth sensor, the deepest parts of South Fishtail Bay and Sedge Point Depression were located. At each location (approximately 21 meters deep) a buoy was placed in order to mark the collection site. Sediment samples were collected within each depression using an Eckman-Birge dredge with a capacity of 225cm$^2$. Samples were emptied into a labeled bucket and brought back to shore. Each sample was then passed through a coarse ¼ inch sieve sitting atop another bucket, which collected the filtrate. Visible organisms were removed with forceps and placed into a labeled vial containing 95% ethanol. Each sediment sample, now slightly diluted with lake water, was passed through the sieve a second time to minimize human and equipment error.

Each ethanol solution sample was poured into a petri dish and every organism was inspected and recorded. In order to identify each species found, pictures were taken using a dissecting microscope.  Research was conducted to identify organisms to the best of our ability. Samples were then preserved in jars containing ethanol.

To ensure the day of sampling was not a confounding variable, the organisms taken from Sedge Point Depression on June 3, 2009 were compared to the samples taken on June 6, 2009 using a chi square test. A chi square test was then performed on all data excluding the June 3, 2009 data in order to compare the proportion of each species represented within the respective populations of South Fishtail Bay and Sedge Point Depression.  The average amount of each organism existing in the benthic layer at eighteen to twenty-one meters was also calculated for each depression.

## Results

Sampling limitations existed due to weather conditions. On June 3, 2009, while sampling Sedge Point Depression, harsh winds caused the Eckman-Birge dredge to sink through the water column at an angle. The dredge is connected to a 23 meter rope, while the bottom of the kettle hole is as deep as 21 meters. The over-extension of the rope and steep diagonal slope of the sinking dredge indicates that these samples are unlikely to contain sediment of a 21 meter depth. Hence, these samples most likely contain specimens from a shallower depth in the kettle hole. The clay sediment also did not resemble the darker, looser sludge found at the bottom of Sedge Point Depression in the June 6, 2009 samples. Data from June 3, 2009 also reveal a scarce amount of specimens found when compared to samples collected on June 6, 2009.  A chi square test comparing samples taken from Sedge Point Depression on June 3, 2009 and June 6, 2009 found the samples to be significantly different with a $P<0.05$ (Figure B). Since the June 3, 2009 samples appear not to be representative of the Sedge Point Depression benthic communities, they were excluded from the data set. A new chi square test comparing South Fishtail Bay and Sedge Point Depression without June 3, 2009 data indicated that there was a significant difference between the two benthic communities with a $P<0.05$ (Figure C).

Only four of the eight species identified were present in South Fishtail Bay. Two of the species, namely *Limnodrilus hoffmeisteri* and Ceratopogonidae, represented less than 1 percent of the populations in each kettle hole.  *Chironomus plumosus* (bloodworm) was the most prevalent species in the Sedge Point Bay samples and the second most prevalent species in the South Fishtail Bay samples.  *Chaoborus punctipennis* (phantom midge), on the other hand, was the most prevalent organism in the South Fishtail Bay samples and the second most prevalent organism in the Sedge Point Bay samples. All other organisms were greatly less-represented in each kettle (Figure D).

Eight samples were taken from Sedge Point Depression and sixteen from South Fishtail Bay. The average number of each species found per 225cm$^2$ sample was calculated for each depression (Figure E).

<u>Discussion</u>

According to our data, the types and distribution of organisms differed significantly between the sediment samples taken from Sedge Point Depression and South Fishtail Bay Depression. Sedge Point Depression is a smaller kettle hole, with an approximate area of 23,000m$^2$ at a depth of 21m, while South Fishtail Bay has an approximate area of 124,000m$^2$ at a depth of 21m (Figure E). The theory of island biogeography is used in order to predict biodiversity according to island size. According to this theory, greater species diversity would exist in a larger area (Gotelli, 2008). In this case, the smaller kettle hole, Sedge Point Depression has both a more abundant and more diverse community of organisms. It is possible that the difference in community distribution and diversity may be explained by variances in abiotic factors, which may have led Sedge Point Depression to serve as a more favorable environment. This may help to explain the opposing predominance of bloodworms and phantom midges in the two kettles, as well as the absence of Trichoptera, *L. hoffmeisteri*, and two species of the family Sphaeriidae from South Fishtail Bay.

Studies conducted by Paul Welch during the 1920s looked closely at abiotic differences between the six major depressions of Douglas Lake. According to his data collected over several years, the South Fishtail Point Depression had higher mean bottom levels of free $CO_2$ than Sedge Point Depression. Dissolved oxygen levels in both depressions remained near zero for most of the year for a period of five years. However, isolated incidences of dissolved oxygen level increase occurred for both South Fishtail Bay Depression and Sedge Point Depression at different times and intervals throughout the period of study. Data taken in the summer of 1926 also demonstrated that the mean bottom temperature of Sedge Point Depression was much higher than the mean bottom temperature of South Fishtail Bay Depression. This temperature difference was mainly due to the lack of thermal stratification in Sedge Point Depression during the summer of 1926.  In previous years, including 1922, stratification occurred in both depressions. (Welch P. S., 1928) This discrepancy in the formation of thermal stratification within the two kettles provides further evidence that they each act as unique and separate lakes.

The two most prevalent species found in both depressions were two types of midge larvae: phantom midge and bloodworm. For both species a statistically significant difference between the kettle hole populations was found. Their contrasting prevalence suggests that phantom midges prefer Sedge Point Depression while bloodworms prefer South Fishtail Bay Depression. Life history strategy research, however, contradicted these initial suggestions. After completing their fourth instar stage, phantom midges pupate and become flying adults. These non-feeding adults live for a few days, in which they mate and lay eggs on the water surface (University of New Hampshire Center for Freshwater Biology, 2009). Bloodworms undergo a similar cycle (Pinder, 1986). Since adults mate on land, there is no geographic isolation between the two populations, and gene flow is therefore likely. It is also not clear whether the adults are able to discriminate as to where they deposit their eggs on the lake. Even so, the eggs are vulnerable to water current movements and are unlikely to sink straight down at the location where they were originally ovideposited.

Phantom midge larvae spend their first two instars in a planktonic stage and live in the water column. Once they enter their third and fourth instars, phantom midges are benthic only during the day, feeding on zooplankton in the water column at night. (University of New Hampshire Center for Freshwater Biology, 2009). As phantom midges are not bound to remain in the sediment, and had a significantly larger population in Sedge Point Depression, one could argue for the larvae's preference of this kettle hole. Long term studies are needed in order to investigate if this trend holds constant in the future. Bloodworms remain benthic throughout their later instar stages and thus seem less able to act upon habitat preferences. The larger population of bloodworms found in South Fishtail Bay Depression thus likely reflects stochastic events rather than species preference.

*L. hoffmeisteri* was found in both South Fishtail Bay Depression and Sedge Point Depression. These annelids are benthic, feeding on organic matter in the sediment. *L. hoffmeisteri* usually prefer shallower water, which may explain the comparatively small representation found in both communities. The adults are hermaphroditic. They lay their eggs in the sediment and are benthic throughout their whole life (Moran, n.d.). The two populations of *L.*

*hoffmeisteri* found may be geographically isolated due to the clay and sand sediment in the elevated intermediary area between South Fishtail Bay Depression and Sedge Point Depression. These annelids feed on sediment organic matter (Moran), which is likely to be scarce in the hard clay and sand sediment. More extensive sampling of the shallows between Sedge Point Depression and South Fishtail Bay Depression is necessary in order to determine whether *L. hoffmeisteri* is able to migrate.

Family Ceratopogonidae is a type of midge found in both Sedge Point Depression and South Fishtail Bay Depression. Its larvae are benthic and pupate into biting midges which lay their eggs near or on the water surface (Merritt & W., 1995). Due to the scarce amounts of Ceratopogonidae found, the existence of adult female preference for either Sedge Point Depression or South Fishtail Bay Depression could not be determined.

The caddisfly larva, of the order Trichoptera, pupates into a flying adult, which can live up to two months and lays its eggs on the water surface (Drees & J., 1999). The caddisfly was only found in Sedge Point Depression, indicating a possible preference for this kettle hole over the South Fishtail Bay Depression. Data collected over a number of years is needed in order to investigate whether the local trichopterans shows continuous selection for the Sedge Point Depression.

Two members, of the Sphaeriidae family, one with a black shell and one with a tan shell, were found in the Sedge Point Depression. These clams are ovoviviparous, giving birth to live young, and live at the bottom of lakes, rivers and ponds. Since Sphaeriidae move only via water currents (Lee, 2001), the only major migration these populations may experience would theoretically happen during the biannual turnover of the lake. Abiotic differences between Sedge Point Depression and South Fishtail Bay Depression may indicate that Sphaeriidae have a preference for either kettle hole. More long-term sampling as well as an in-depth analysis of the abiotic differences between the two depressions may lead to more definitive conclusions.

The morphospecies 1 found in our sampling could not be identified. Therefore, no information regarding life history strategies could be analyzed at this point.

<u>Limitations</u>

Constraint of this experiment involved errors due to equipment limitations. A ¼ inch sieve was used to sift sediment. It is possible that smaller organisms may have fallen through the sieve undetected. To compensate for this problem, every sample was poured through the sieve twice, which theoretically should have standardized the amount of organisms lost. According to *Limnological Analyses 3rd edition*, more organisms are retained with a smaller mesh size; however, more sediment is also retained. This increases the sieving and sorting time considerably. (Wetzel & Likens 2000). Therefore, the sieve size used was based on a compromise between retention of organisms and amount of time spent sieving each sample.

A third limitation to this experiment is human error. Organisms may have been missed due to limitations of sight. Additionally, identification of organisms was conducted based on limited resource availability. Expert analysis would be necessary to verify identification.

Also, due to their respective life history strategies, certain organisms might be under or over emphasized in our particular samples because we sampled within a three-week period during the spring. Data would need to be collected throughout the year in order to reveal a complete spectrum of species composition differences between the sediment layers of the two kettle holes. Long-term data could provide more conclusive evidence as to whether geographic isolation truly exists between the two kettle holes.

## Conclusion

As island biogeography could not be applied to this data set, it may indicate that the Douglas Lake depressions do not act as individual islands. Although the statistical data supports that the two kettle holes may be geographically isolated, the differences in organism distribution that the data demonstrated (in type, distribution, and number) could exist without the effects of geographic isolation. While few organisms were found at the fifteen meter depth, this does not necessarily eliminate the possibility of migration between communities in Sedge Point Depression and South Fishtail Bay Depression. Further investigation, especially of the shallows, is necessary in order to exclude migration possibilities and thus determine whether true geographic isolation separates the two kettles in question. Additionally, analysis of life history strategies of the species indicates that mobility of different larval stages may be common. While there may be a preference for either depression by specific organisms, gene flow is likely for all organisms that can exist outside the benthic layer. Hence, even geographic isolation at the larval stage may not have an effect on the resulting adult communities. Geographic isolation is a more likely condition for the Sphaeriidae organisms, as well as *L. hoffmeisteri* as these populations remain benthic from gestation to senescence. Realistically, however, data collection was limited due to time constraints and the sample size may be too minimal for conclusive results. With a larger sample size, comparisons between life-long benthic organisms may provide more information about the possible geographic isolation of the two kettle holes.

In order to draw a stronger conclusion, long term trends of the communities as well as migration patterns would have to be investigated. The results obtained from this study may only indicate a random selection by this year's populations. This data cannot be used to predict long term trends without further sampling in years to come.

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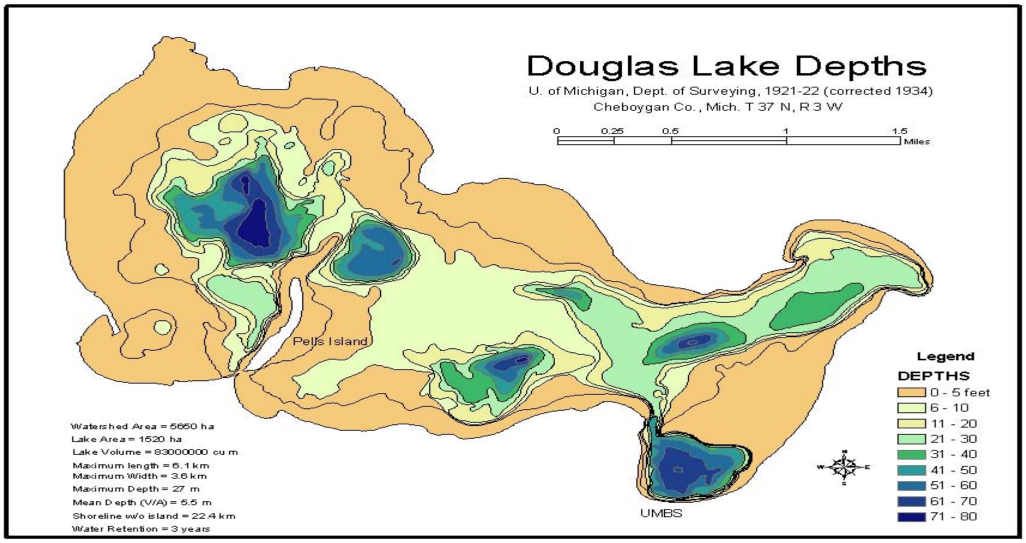
# Appendix

## Figure A




## Figure B

**Test Statistics**

| Habitat | | Species |
|---|---|---|
| NOne | Chi-Square[a,b] | 15.737 |
| | df | 3 |
| | Asymp. Sig. | .001 |
| NTwo | Chi-Square[a,b] | 2200.509 |
| | df | 7 |
| | Asymp. Sig. | .000 |

## Figure C

**Test Statistics**

| Habitat | | Species |
|---|---|---|
| NTwo | Chi-Square[a,b] | 2200.509 |
| | df | 7 |
| | Asymp. Sig. | .000 |
| S | Chi-Square[a,b] | 343.030 |
| | df | 3 |
| | Asymp. Sig. | .000 |

## Figure D

| | *Chaoborus punctipennis* | *Chironomus plumosus* |
|---|---|---|
| Sedge Point Depression | 76 | 14.2 |
| South Fishtail Bay Depression | 30.1 | 69.1 |

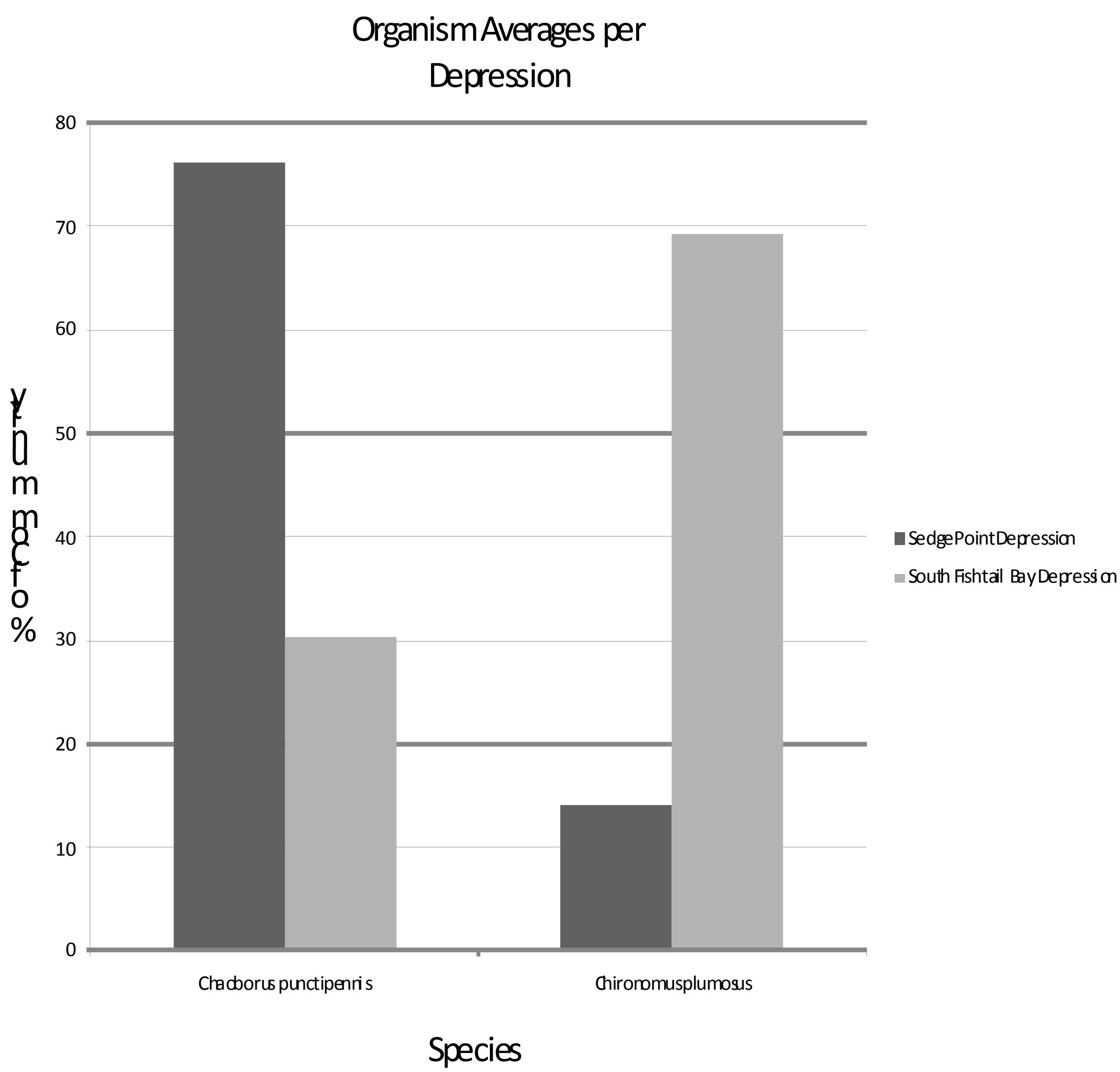


**Figure D continued**

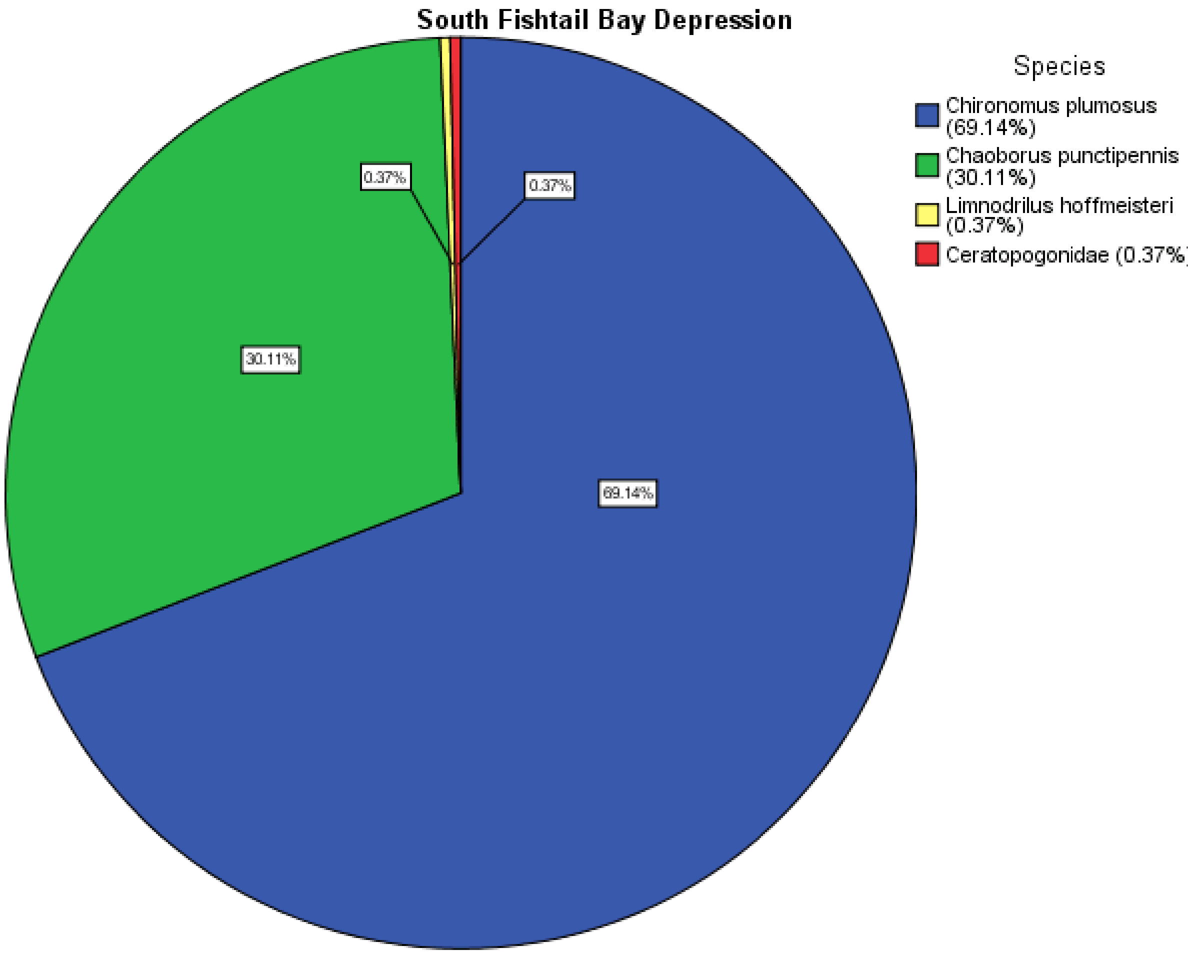
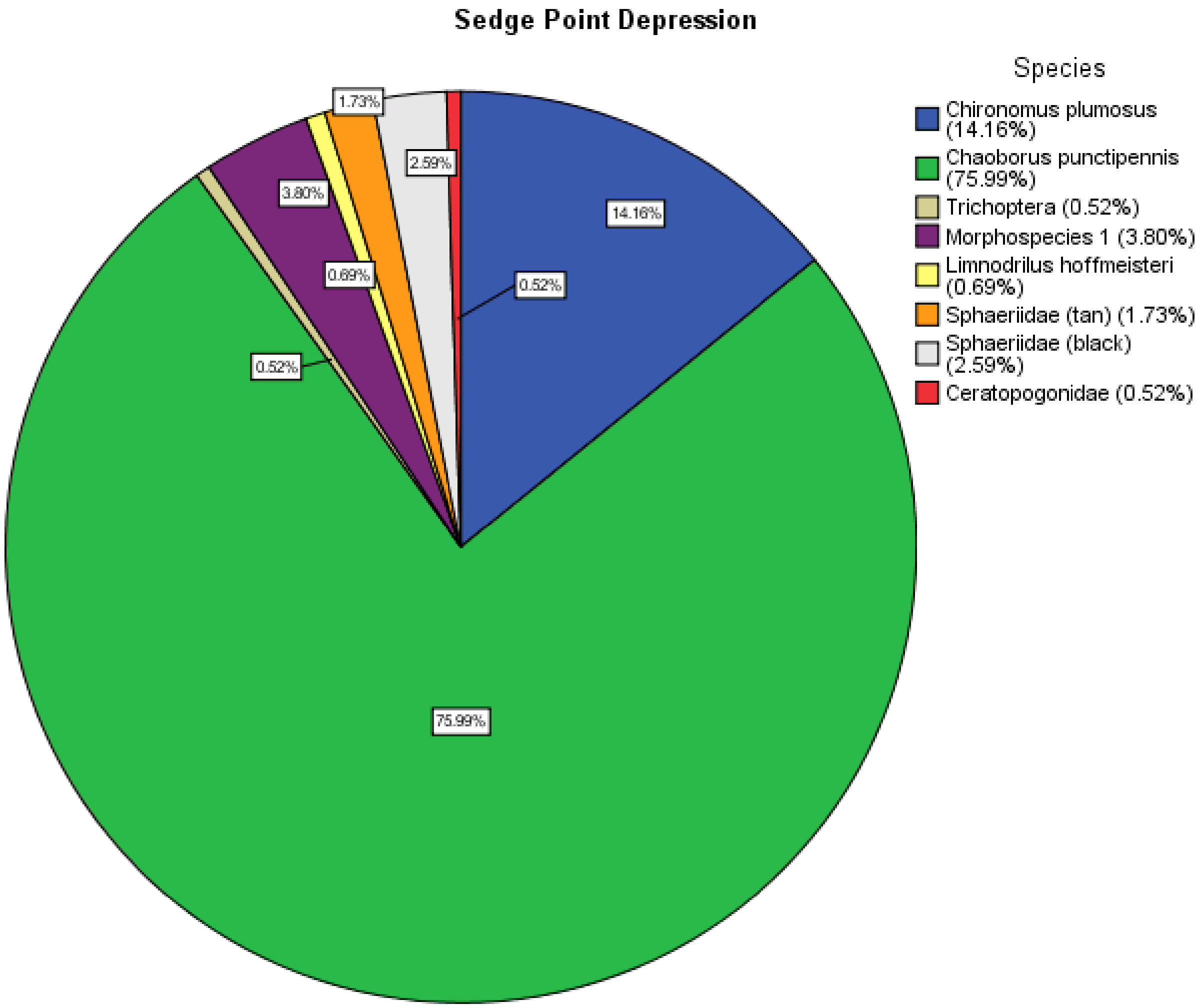


**Figure D continued**



## Figure E

| Species | Sedge Point Depression | South Fishtail Bay Depressio |
|---|---|---|
| | | |
| | 23,000 m^2 | 124,000 m^2 |
| | | |
| *Chaoborus punctipennis* | 54.5 | 5.06 |
| *Chironomus plumosus* | 9.88 | 11.63 |
| Ceratopogonidae | 0.25 | 0.06 |
| *L. hoffmeisteri* | 0.5 | 0.06 |
| Morphospecies 1 | 2.38 | 0 |
| Trichoptera | 0.25 | 0 |
| Sphaeriidae (black) | 1.88 | 0 |
| Sphaeriidae (tan) | 1.25 | 0 |