# The benthic community of Owasco Lake as an indicator of lake ecosystem health

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## Summary

In 2007, the macroinvertebrate community within benthic habitats deeper than 10 m in Owasco Lake included a diverse array of native crustaceans, molluscs, insect larvae, and worms. Particularly encouraging was the presence of the amphipod *Diporeia* and the fingernail clam *Pisidium* that are both indicators of healthy benthic environments. The high productivity of the lake has not led to low oxygen concentrations or "dead zones" that can be lethal to benthic organisms. A high supply of organic matter to shallow sediments, particularly on the south end of the lake, may be enhancing productivity of decomposers such as oligochaete worms and chironomid midge larvae. Lower flux of organic matter to the deep central basin is reflected by lower invertebrate abundances in those regions. Exotic zebra mussels (*Dreissena polymorpha*), first detected in the lake in 1997, are firmly established in shallow (<10 m) habitats. They represent a large proportion (30-90%) of the benthic organisms at the 10 m sites. Although present at deeper sites, they have been limited by the cold water temperatures and the lack of hard substrate in deeper habitats. They are forced to colonize the shells of other mussels, forming small clumps or "druzes". The potential spread of quagga mussels (*Dreissena rostriformis bugensis*) is probably of greatest concern for the future of the benthic community of Owasco Lake. This species can colonize soft substrates and tolerate cold temperatures. Quagga mussels have invaded nearby Cayuga and Seneca Lakes to the west and Oneida and Onondaga Lakes to the east, where they have replaced or are in the process of replacing zebra mussels.

## Introduction

A recent study ranked Owasco Lake last in terms of water quality out of seven Finger Lakes (Halfman and Bush, 2006). This low rating reflected Owasco Lake's high productivity with high nutrient levels, high phytoplankton biomass (chl *a*), and low water clarity. Although not going so far as classifying the lake as eutrophic, the study raised concern for the health of the lake. Owasco Lake has a large watershed area relative to its volume (17:1 ratio) so is more sensitive to nutrient loading than other Finger Lakes. Several efforts are underway to identify and control sources of nutrients in the watershed. New York State Senator Michael F. Nozzolio secured funding from the state for continued study of the lake in 2007 (Halfman et al. 2008).

One component of the 2007 study was our investigation of the benthic community of Owasco Lake. The diverse collection of invertebrates in lake sediments acts as sensitive indicators of lake health. Insect larvae, worms, crustaceans, and molluscs live within the sediments and consume organic matter that sinks from surface production. These benthic macroinvertebrates are an important part of the diet of many fish species, so therefore represent a crucial link between phytoplankton and fish. The abundance and composition of the benthic communities tell us a lot about how well the ecosystem is functioning. Some indicator species are very sensitive to pollutants whereas other species can tolerate a wide range of conditions. Benthic invertebrate-based indices have long been useful tools in evaluating the condition of streams and lakes (Beck 1955).

Generally, the abundance of benthic organisms increases with increased food supply. However, dissolved oxygen concentrations can become a limiting factor in productive lakes. Summer stratification of the water column restricts the replenishment of oxygen in deep water. Oxygen concentrations decline as bacteria and benthic invertebrates consume organic matter. Many invertebrate species cannot tolerate low oxygen concentrations and can be lost from the community. In extreme cases, anoxic "dead zones" occur where no benthic organisms survive. Therefore, the balance of oxygen concentration and food supply is critical for benthic organisms.

Invasive species have disrupted the balance of benthic communities in local lakes. Several exotic organisms have spread to the Finger Lakes from the Great Lakes via the New York State Barge Canal System. Many of these are native to Eastern Europe and arrived in ballast tanks of commercial ships. For example, zebra mussels (*Dreissena polymorpha*) were observed in Cayuga and Seneca Lakes by 1991 and 1992, just a few years after their spread throughout the lower Great Lakes (USGS NAS Database). Quagga mussels (*Dreissena rostriformis bugensis*) were also observed in the two lakes by 1994. There was a time lag before zebra mussels reached the smaller Finger Lakes. Zebra mussels were first observed in Keuka and Canandaigua Lakes in 1994, Skaneateles Lake in 1995, and Otisco Lake in 1996. Owasco Lake was one of the last Finger Lakes that zebra mussels colonized in 1997. Additional benthic exotics in the region include the Asian clam (*Corbicula fluminea*) and the amphipod *Echinogammarus ischnus*. The clam was observed in Seneca Lake in 1999 (USGS NAS Database). The amphipod has been in Lake Ontario since 1995 (USGS NAS Database) and in Oneida Lake but has not been confirmed in any Finger Lake (Witt et al. 1997, USGS NAS Database). These organisms have the potential to disrupt lake food webs and displace native species.

We have two primary objectives in studying the benthic community of Owasco Lake using lake-wide surveys:

*1) Does the abundance and composition of the benthic community in Owasco Lake indicate that the lake is a healthy, functional ecosystem?*

*2) What is the status of invasive organisms in the benthos (i.e. zebra mussels and exotic amphipods)?*

## Methods

We conducted benthic surveys in June and October 2007. On June 10 and October 4, 2007 triplicate standard Ponars were collected at 10 sites along a north-south transect (squares in Figure 1). Sites were distributed every 10 m depth to the 50 m deep central basin and then shallower to the south end. The sediment collected was sieved through a 500 um sieve, and all benthic organisms collected were preserved in 85% ethanol (selected specimen photos in Figure 2). On June 13, 2007 several shallow sites on the north and south ends were sampled for *Hexagenia*, a burrowing mayfly (triangles in Figure 1). A standard Ponar samples an area of 0.0530 $m^2$ of lake bottom, yielding a conversion factor from raw numbers to individuals per $m^2$ of 18.87. We report the average abundance and one standard error for each taxon group at each site for the two surveys. We also report relative abundances for looking at community shifts. The area of substrate in the lake represented by specific depth intervals was taken from the hydrographic analysis of the Finger Lakes in Birge and Juday (1914) (Table 1).

## Results

In June, the total abundance of benthic organisms decreased with depth from both the north and south ends to the 54 m deep central basin (Figure 3). The 10 m site on the south end was particularly high (mostly zebra mussels) at levels near 15000 individuals per $m^2$. Omitting this outlier, total abundance is strongly and negatively correlated to depth ($r = -0.88$). Sites from 10-30 m depth had abundances near 3000 per $m^2$, while abundances in the deep basin are near 1000 per $m^2$ (Table 2). In October, total benthic abundances were generally higher for all stations and again highest at the10 m site on the south end.

The native benthic amphipod *Diporeia* was important at sites deeper than 10 m in Owasco Lake (Figure 4). For both June and October, the abundance of this organism was bimodal with peaks at 20 to 40 m depth at the north and south ends at levels near 1500 per $m^2$. *Diporeia* had low abundance levels at the 50 m sites and was rare at the 10 m sites. *Diporeia* represented 20-50% of benthic biota at depths from 20 to 40 m but only 5-10% of benthic biota at the two 50 m sites. The native benthic amphipod *Gammarus fasciatus* replaced *Diporeia* at the 10 m sites with levels near 180 per $m^2$ and it's abundance decreased with depth (Figure 5). In October, the abundance of *G. fasciatus* was particularly high at the 10 m station on the south end exceeding 1000 per $m^2$. The exotic amphipod *Echinogammarus ischnus* was not observed in our samples.

Exotic zebra mussels dominated the benthos at 10 m sites, representing 77% of organisms on the north end and 94% of benthic organisms on the south end in June (Table 2 and 3). Repeated (n=6) sampling at 10 m depth on the south end on June 13 measured an average of 3645 (s.e. 1525) per $m^2$, comparable to the north end average of 2887 (s.e. 151) per $m^2$. In June, zebra mussels were collected at all deeper depths but at low abundance levels (<100 per $m^2$) except for the 30 m site on the south end (900 per $m^2$) (Figure 6). In October, the 20-40 m sites on the south end had levels of zebra mussels near 900 per $m^2$. No quagga mussels were collected from Owasco Lake during either survey in 2007.

The most common insect larvae collected were those of non-biting midges. These include the large red "bloodworm" *Chironomus* and smaller greenish midge larvae. In June, several midge larvae had developed into pupae at the 10 m site on the north end. *Chironomus* larvae were most abundant at the 20 m sites on the north end. Overall, midges had a bimodal distribution with peaks at 20 m depth on the north and south ends (Figure 7). At these abundance peaks the larvae represented nearly 30% of the fauna. Larvae of the burrowing mayfly *Hexagenia* were not found during either survey in 2007.

Oligochaete worms were another common benthic invertebrate found at all depths. The worms were particularly abundant at the 20 m site on the north end of the lake in June and the 10 m and 20 m sites on the south end in October (Figure 8). Oligochaetes represented 30% of the organisms at the two 50 m sites in June and the two shallowest sites on the south end in October. Native fingernail clam *Pisidium* (Sphaeriidae) was also important at the 50 m sites, representing 20% of the fauna in June and more than 50% in October. Clams were most abundant at the 40 m site on the north end during both surveys (Figure 9). The large difference in the absolute abundance of clams for the two surveys may be an artifact of sample processing (i.e. October counts may include empty shells). The opossum shrimp *Mysis diluviana* (formerly *Mysis relicta*) was caught in low numbers.

**Discussion**

*Assessment of Ecosystem Health*

The macroinvertebrate community within benthic habitats deeper than 10 m in Owasco Lake includes a diverse array of native crustaceans, molluscs, insect larvae, and oligochaete worms. Particularly encouraging are the presence of the amphipod *Diporeia* and the fingernail clam *Pisidium* that are both indicative of healthy benthic environments. The high productivity of the lake has not led to low oxygen concentrations and "dead zones" that can be lethal to benthic organisms. A high supply of organic matter to the sediments may be enhancing productivity of detrital feeders such as oligochaete worms and chironomid midge larvae, particularly on the southern end of the lake.

A greater abundance of organisms in shallow benthic habitats compared to deep habitats is a common observation in lakes. Shallow habitats are within the photic zone, the site of primary production, and thus are supplied with freshly produced organic matter. These habitats are also in close contact to terrestrial sources of detritus. Although having high abundance, the shallow benthic communities of Owasco Lake have very low diversity because of the dominance of exotic zebra mussels. The area most impacted by mussels (0-10 m depth interval) represents nearly 20% of the lake's benthic habitat (Table 1). Midge larvae and the amphipod *Gammarus* are probably the preferred prey item for fish in this habitat. Benthic habitats deeper than 20 m have abundant native species including *Diporeia*, fingernail clams, and oligochaetes. The native amphipod

*Diporeia* and the epibenthic opossum shrimp *Mysis diluviana* are probably the prey items selected by fish in deep benthic habitats.

*Status of Dreissenids*

Zebra mussels were extremely abundant at our 10 m sites. Our data suggests that zebra mussels have firmly established themselves in shallow (<10 m) habitats since their introduction in 1997. They were also collected at all deeper sites but only in significant quantities (1000 per $m^2$) from 20-40 m at the south end. These filter feeders have dramatically lowered phytoplankton concentrations and increased water clarity in lakes of the Great Lakes Basin and likely affect Owasco Lake. Zebra mussels are not likely to become abundant in deeper habitats because the species prefers rocky substrates and warm water temperatures. However, the congeneric and similar quagga mussel can expand to all depths because it tolerates soft substrates, low food, and cold temperatures. They are found in water depths more than 200 m in Lake Ontario (Watkins et al. 2007). Although quagga mussels were not observed in this survey, they are present in nearby Cayuga and Seneca Lakes to the west where they have largely replaced zebra mussels, and in Onondaga and Oneida Lake to the east were they are in the process of replacing zebra mussels. When quagga mussels arrive to Owasco Lake, we expect that they will colonize all water depths in the lake.

*Crustaceans*

Freshwater scuds or amphipods are common benthic crustaceans in lakes. There are two common native species, *Gammarus fasciatus* and *Diporeia hoyi*. *Gammarus* prefers warm water temperatures and eats detritus while *Diporeia* requires colder water temperatures (5-10°C) and eats settled phytoplankton. *Gammarus* prefers rocky substrates while *Diporeia* burrows in silty sediments. Their different temperature requirements lead to distinct depth ranges. Both amphipods are important and highly nutritious food items for fish. *Diporeia* is recognized as a keystone species for lakes in the Great Lakes basin because of its value as prey for native fish species. Its recent decline in Lakes Erie, Ontario, Michigan, and Huron is of great concern (Watkins et al. 2007, Nalepa et al. 2009). *Diporeia* populations in these lakes are genetically similar to those of the Finger Lakes (Pilgrim et al. 2009). Fortunately, *Diporeia* populations in smaller lakes in the region appear to be persisting even if exposed to dreissenid mussels (Dermott et al. 2005). The coexistence of *Diporeia* with high abundances of zebra mussels in the 20-40 m depth interval on the south end of the lake is encouraging and consistent with this observation. The low abundance of *Diporeia* at the 10 m sites is probably more due to warm water temperatures than the presence of zebra mussels.

*Gammarus fasciatus* was rarely collected in our surveys but most common at the 10 m sites on either end of the lake. In October the species was particularly abundant at the 10 m site on the south end. The species is often associated with rocky substrates and zebra mussels (Mayer et al. 2002) The exotic amphipod species *Echinogammarus ischnus* that competes with the native amphipod *Gammarus* in Lake Ontario has not been observed to date in Owasco Lake.

The opposum shrimp *Mysis diluviana* was found in a few benthic grabs. The value of *Mysis* as prey for fish populations is comparable to that of *Diporeia*. This up to 25 mm long shrimp is highly mobile and can avoid benthic grabs, and are therefore seldom observed in benthic surveys. This species migrates from the sediments to the water column each night to eat zooplankton (Rudstam 2009). Their presence indicates that the bottom waters in Owasco Lake are oxygenated most of the time.

*Insect Larvae*

Midge larvae were the most common insect larvae found in sediments of Owasco Lake and are commonly found in aquatic habitats. The larvae are important prey for fish and emerge as huge swarms of non-biting flies during the summer. The larvae are very tolerant of a wide range of conditions and are detritivores. Large (1 cm) blood red midge larvae ("bloodworms") of the genus *Chironomus* were common at the 10 m sites. The red color is a hemoglobin-like respiratory pigment that allows the larvae to tolerate low oxygen concentrations and burrow into low oxygen sediments. Several midge pupae were collected in June at the north end indicating an emergence event. Smaller midge larvae were a common component of deeper sediments. Sensitive taxa such as mayflies and stoneflies were absent. There was no evidence of oxygen stress during the June survey. Dissolved oxygen concentrations in June were at saturation levels throughout the water column, but was reduced to 6 ml/L (60% of saturation) at the base of the epilimnion in August (Halfman et al. 2008).

*Oligochaete Worms*

Oligochaete worms are an important consumer of organic matter. They burrow deeply into the sediment and thereby contribute to sediment mixing. They were common residents in the sediments of all depths of Owasco Lake. In June, oligochaetes were particularly important (30% of community) at the deep 50 m site, while in October, they were important at the 10 and 20 m sites on the south end. High inputs of organic matter to the south end from Owasco Inlet may have contributed to high abundances of detritivores including oligochaetes, *Gammarus* amphipods and midge larvae in October.

*Molluscs*

The Finger Lakes hosted a wide diversity of native freshwater mussels (Unionids) as recently as the late 1960s (Harman 1970). For example, the lampshade mussel *Lampsilus radiata siliquoidea* was observed in Owasco Lake in the late 1960s. These large molluscs filter fed phytoplankton from the water column. These mussels are now rarely observed in any lake in New York State and were not found in this survey. Their food web role has been largely replaced by exotic dreissenid mussels.

The small (5 mm) native fingernail clam *Pisidium* (Sphaeriidae) was collected in this survey and were particularly abundant in the deepest benthic habitats. The presence of this native clam is a positive sign for the Owasco Lake benthos.

**Acknowledgements**

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**Table 1. Area of substrate for specific depth intervals in Owasco Lake. from Birge and Juday (1914)**

| Depth Interval | Area ($km^2$) | % of Total Area |
|---|---|---|
| 0-10 m | 5.4 | 20.2 % |
| 10-20 | 4.3 | 16.1 % |
| 20-30 | 2.4 | 9.0 % |
| 30-40 | 4.4 | 16.5 % |
| 40-54 | 10.2 | 38.2 % |
| Total | 26.7 $km^2$ | |

**Table 2. Absolute Abundance of selected benthic taxa, # per m$^2$ (one s.e.) Other less common organisms not shown are included in total.**

**June 10, 2007**

| Site | Depth m | Zebra Mussel | Diporeia | Oligochaete Worms | Midge Larvae | Fingernail Clams | Total |
|---|---|---|---|---|---|---|---|
| 1 | 10 | 2887(151) | 0(0) | 340(57) | 189(0) | 19(0) | 3774(147) |
| 2 | 20 | 25(25) | 1447(114) | 352(144) | 1396(338) | 0(0) | 3585(479) |
| 3 | 30 | 157(157) | 749(174) | 145(83) | 868(375) | 189(180) | 2680(567) |
| 4 | 40 | 44(35) | 585(227) | 182(64) | 270(120) | 522(100) | 1812(523) |
| 5 | 50 | 31(6) | 107(44) | 258(77) | 189(33) | 157(87) | 830(153) |
| 10 | 50 | 44(6) | 107(44) | 233(82) | 151(39) | 165(145) | 811(272) |
| 9 | 40 | 6(6) | 1019(136) | 189(19) | 340(121) | 182(17) | 1906(196) |
| 8 | 30 | 906(479) | 1799(217) | 484(159) | 585(86) | 44(27) | 3982(675) |
| 7 | 20 | 160(161) | 576(161) | 774(359) | 736(475) | 9(9) | 2698(534) |
| 6 | 10 | 14049(6331) | 0(0) | 264(208) | 75(44) | 123(122) | 14926(6591) |

**October 4, 2007**

| Site | Depth m | Zebra Mussel | Diporeia | Oligochaete Worms | Midge Larvae | Fingernail Clams | Total |
|---|---|---|---|---|---|---|---|
| 1 | 10 | 3617(1200) | 88(88) | 1151(526) | 1107(166) | 403(98) | 7762(1785) |
| 2 | 20 | 31(31) | 824(95) | 327(137) | 1535(109) | 327(41) | 3654(116) |
| 3 | 30 | 107(107) | 1264(47) | 384(106) | 1994(122) | 1315(107) | 5384(83) |
| 4 | 40 | 340(160) | 755(105) | 509(11) | 723(98) | 4095(1210) | 6774(1206) |
| 5 | 50 | 101(27) | 270(50) | 629(213) | 491(54) | 1944(1214) | 4107(999) |
| 10 | 50 | 94(66) | 359(11) | 321(39) | 1510(692) | 2308(834) | 5183(1047) |
| 9 | 40 | 830(830) | 1289(154) | 459(79) | 509(126) | 1352(211) | 4812(644) |
| 8 | 30 | 1812(785) | 1692(148) | 208(82) | 837(132) | 340(47) | 5240(799) |
| 7 | 20 | 1132(670) | 541(101) | 2082(142) | 1730(139) | 698(66) | 6586(741) |
| 6 | 10 | 3699(2135) | 75(44) | 5774(3334) | 2535(1464) | 962(556) | 15700(9064) |

**Table 3. Relative abundance (percent of total) of selected benthic invertebrates from north to south. Other less common organisms make up the rest of the total.**

**June 10, 2007**

| Depth | %Zebra | %*Diporeia* | %Worms | %Midges | %Clams |
|---|---|---|---|---|---|
| **N-10** | 76.5 | 0.0 | 9.0 | 1.8 | 0.5 |
| **N-20** | 0.7 | 40.3 | 9.8 | 18.2 | 0.0 |
| **N-30** | 5.9 | 28.0 | 5.4 | 31.8 | 7.1 |
| **N-40** | 2.4 | 32.4 | 10.1 | 12.9 | 28.9 |
| **N-50** | 3.8 | 12.8 | 30.8 | 13.5 | 18.8 |
| **S-50** | 5.4 | 13.1 | 28.5 | 14.6 | 20.0 |
| **S-40** | 0.3 | 53.3 | 9.9 | 15.5 | 9.5 |
| **S-30** | 22.7 | 45.1 | 12.1 | 13.2 | 1.1 |
| **S-20** | 5.9 | 21.3 | 28.7 | 37.1 | 0.3 |
| **S-10** | 94.1 | 0.0 | 1.8 | 0.9 | 0.8 |

**October 4, 2007**

| Depth | %Zebra | %*Diporeia* | %Worms | %Midges | %Clams |
|---|---|---|---|---|---|
| **N-10** | 46.6 | 1.1 | 14.8 | 14.1 | 5.2 |
| **N-20** | 0.9 | 22.5 | 9.0 | 42.0 | 9.0 |
| **N-30** | 2.0 | 23.5 | 7.1 | 34.6 | 24.4 |
| **N-40** | 5.0 | 7.8 | 7.5 | 9.7 | 60.4 |
| **N-50** | 2.5 | 6.6 | 15.3 | 10.3 | 47.3 |
| **S-50** | 1.8 | 6.9 | 6.2 | 29.1 | 44.5 |
| **S-40** | 17.3 | 25.5 | 9.5 | 10.6 | 28.1 |
| **S-30** | 34.6 | 32.3 | 4.0 | 14.3 | 6.5 |
| **S-20** | 17.2 | 8.2 | 31.6 | 26.3 | 10.6 |
| **S-10** | 23.6 | 0.5 | 36.8 | 16.1 | 6.1 |

**Figure 1. Benthic sampling sites for Owasco Lake, June 10 and 13 and October 4, 2007. Site numbers are marked for N-S transect (squares). The same sites that were sampled on June 10 were also sampled on October 4. Numbers to right are station identifiers.**

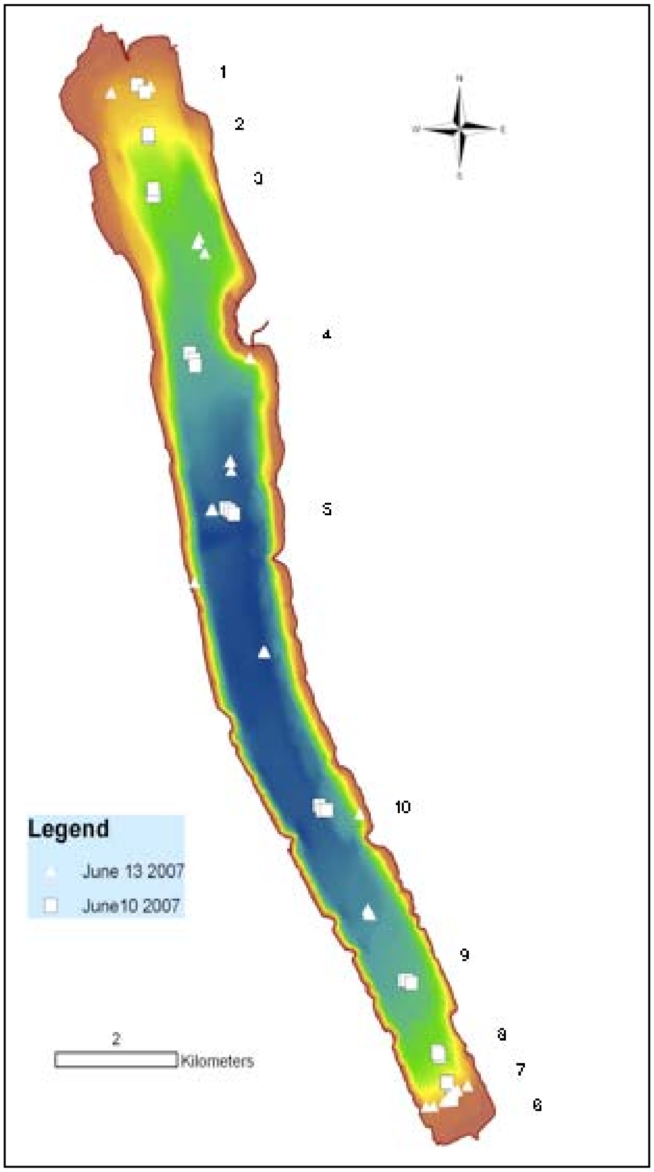
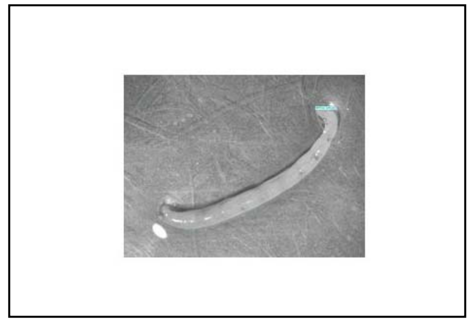


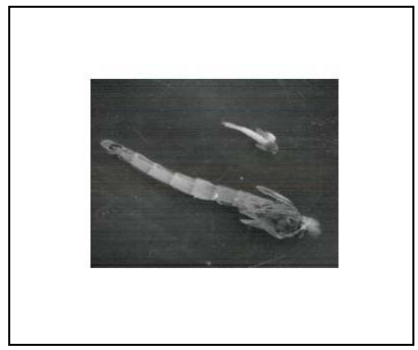
**Figure 2. Photos of Common Benthic Invertebrates in Owasco Lake Sediments**

Native Amphipod *Diporeia spp*.

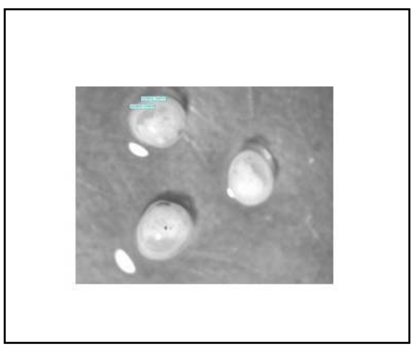


Native Aquatic Insect Larvae of a Chironomid Midge

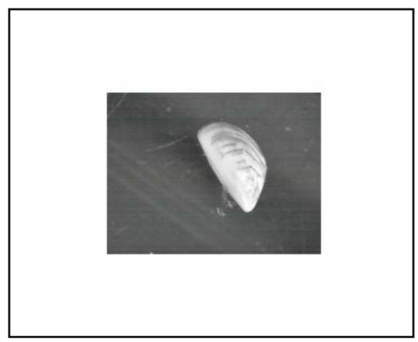
Native Amphipod *Gammarus fasciatus*



Chironomid Midge Pupae

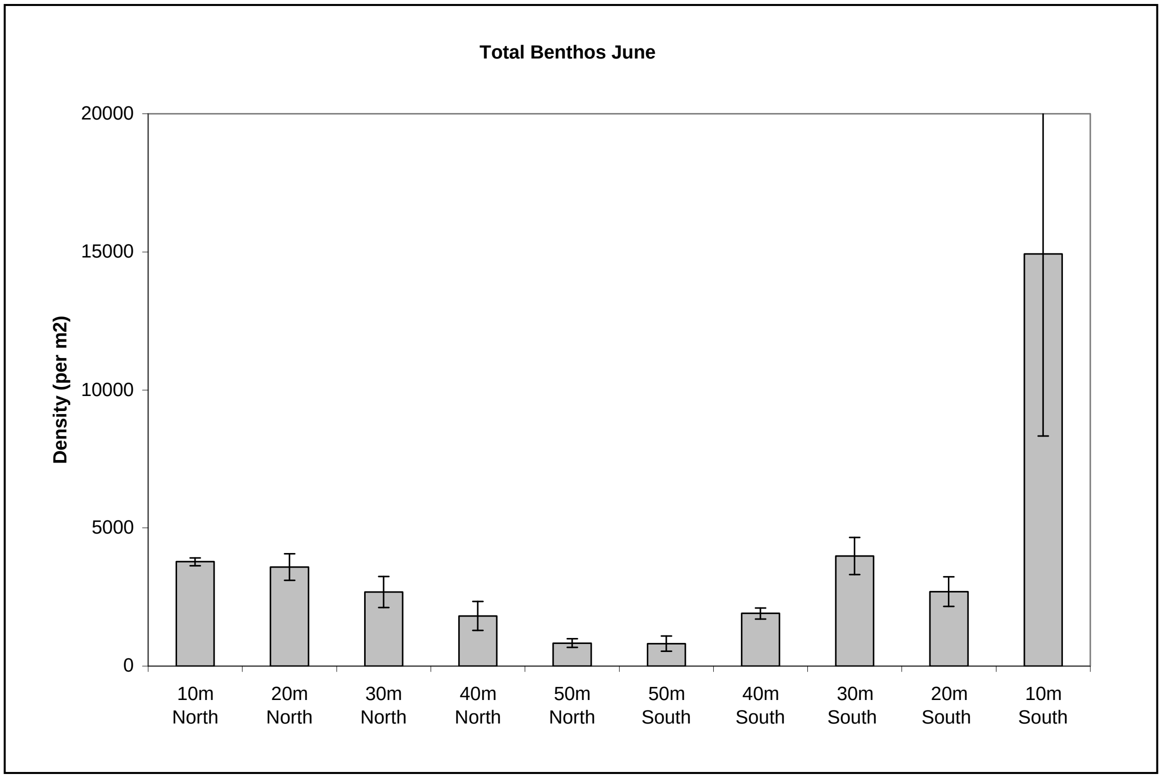


Native Mollusc *Pisidium* (Fingernail Clams)



Exotic Zebra Mussel (*Dreissena polymorpha*)

**Figure 3. Total abundance of benthic macroinvertebrates (individuals per m$^2$) for June and October surveys (error bars one SE).**



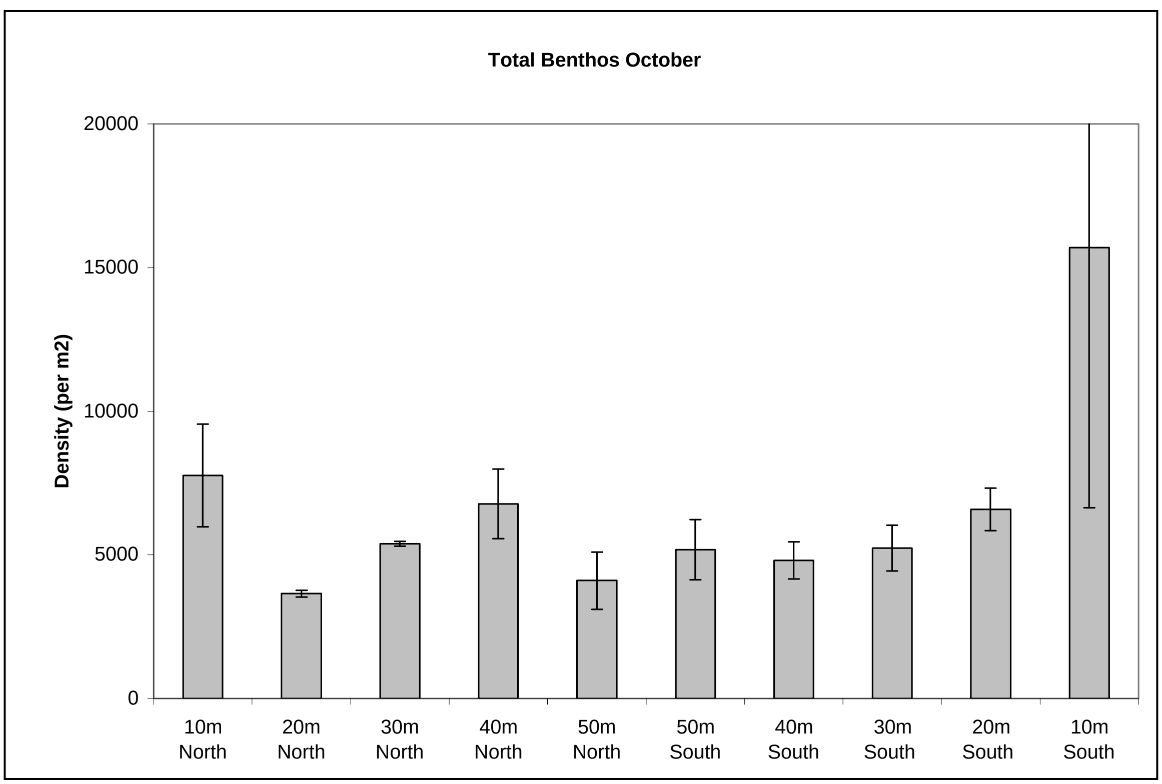
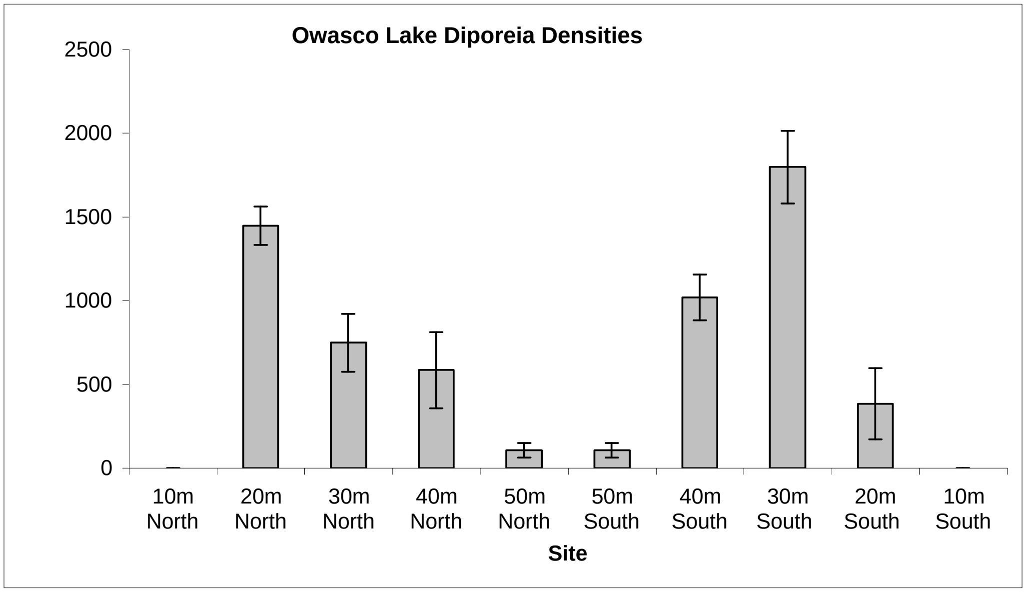



**Figure 4. Abundance of amphipod *Diporeia* (individuals per m$^2$) for June and October surveys (error bars one SE).**



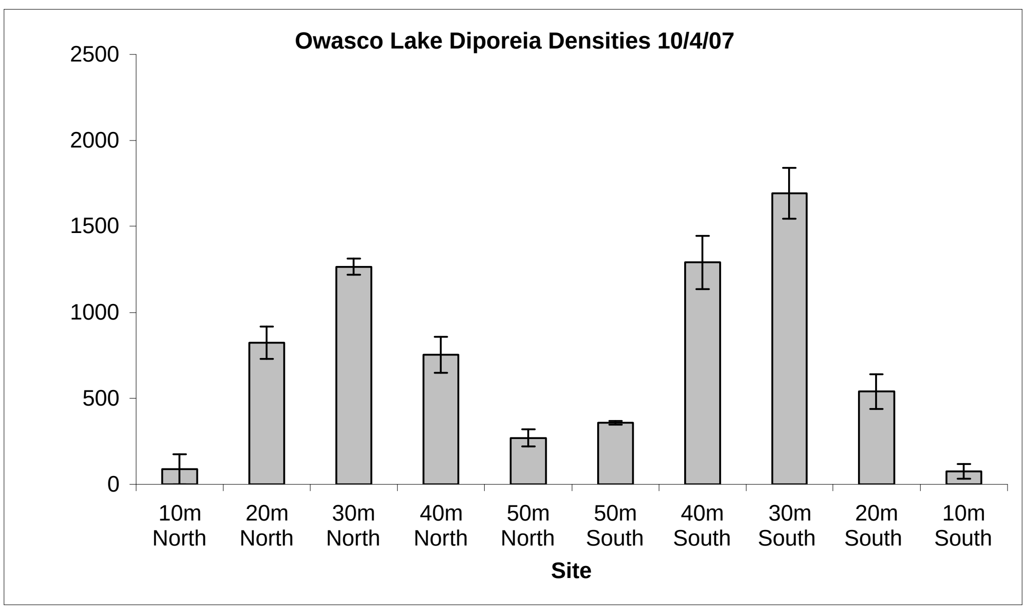



**Figure 5. Abundance of amphipod *Gammarus* (individuals per m$^2$) for June and October surveys (error bars one SE).**

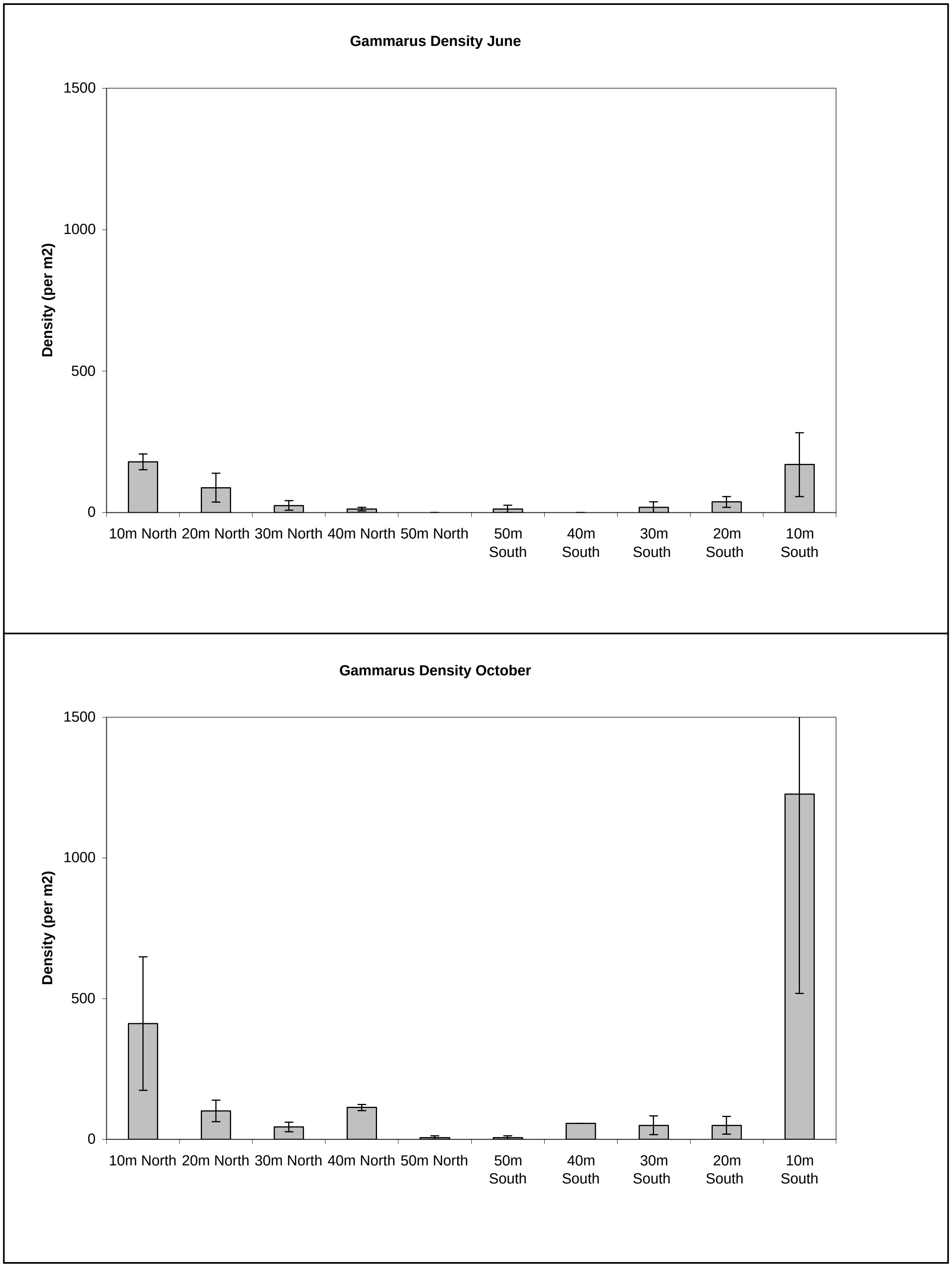
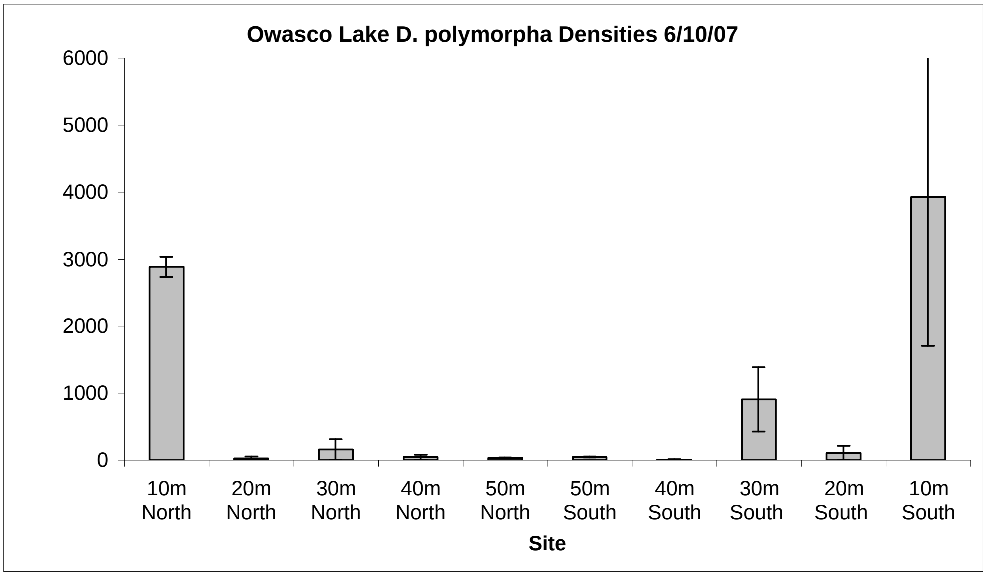


**Figure 6. Zebra mussel abundance (individuals per m$^2$) for June and October surveys (error bars one SE).**



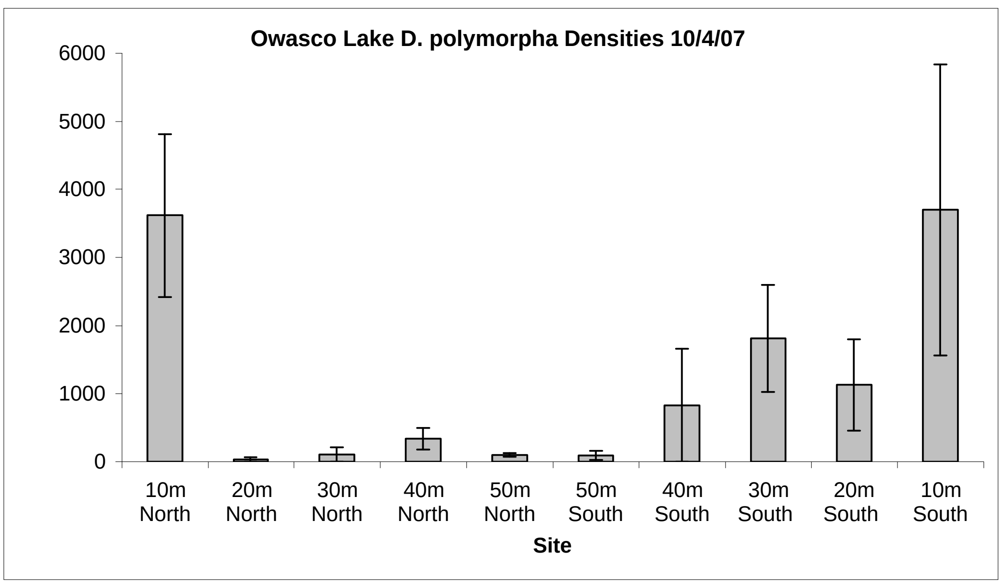
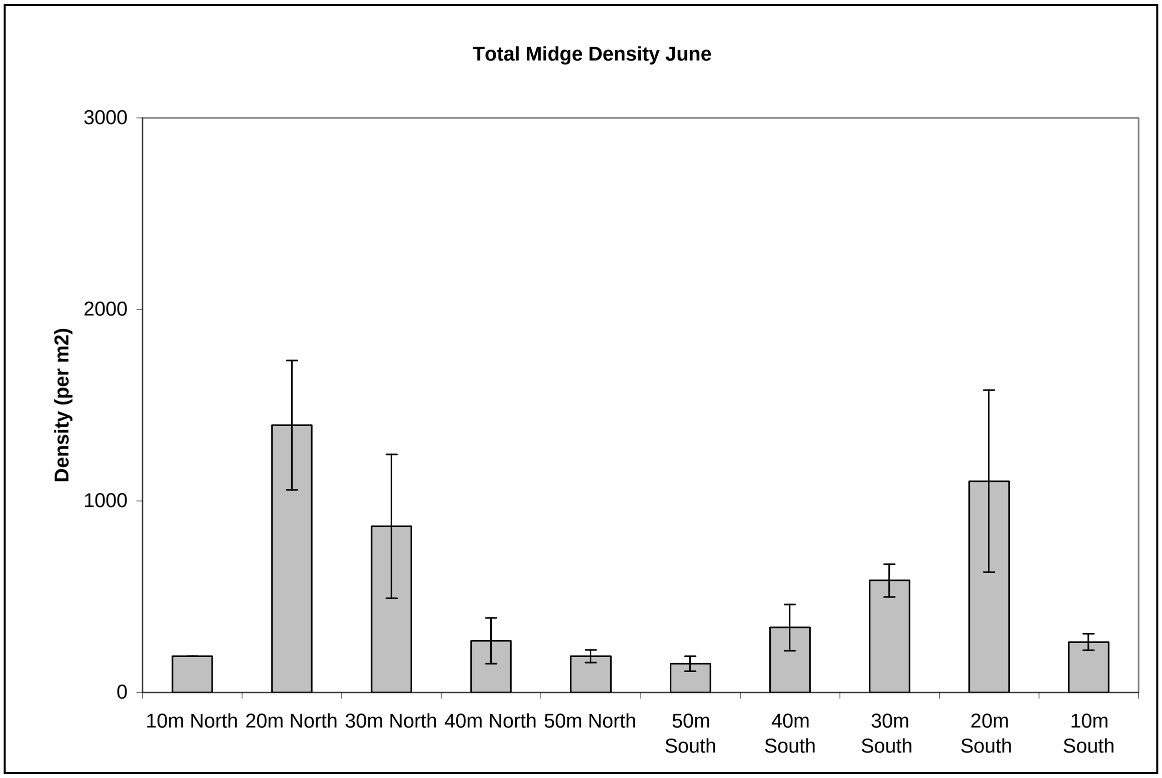



**Figure 7. Abundance of midge larvae (individuals per m$^2$) for June and October surveys (error bars one SE).**



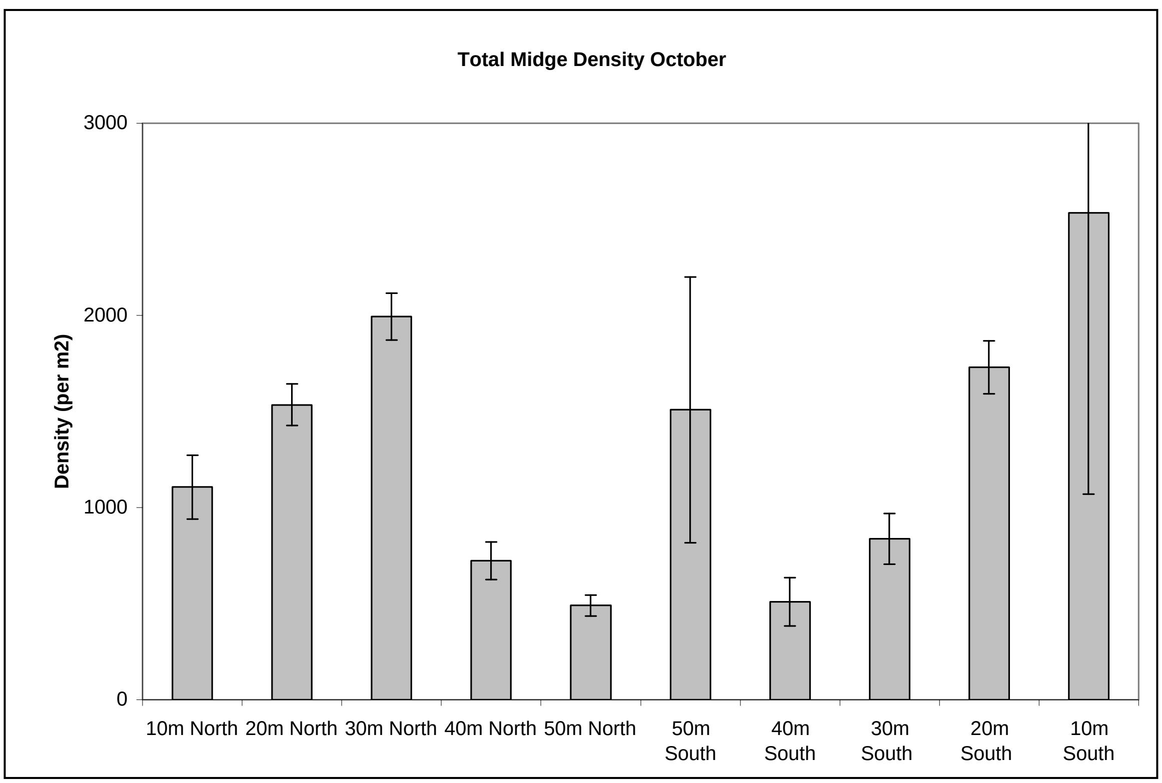
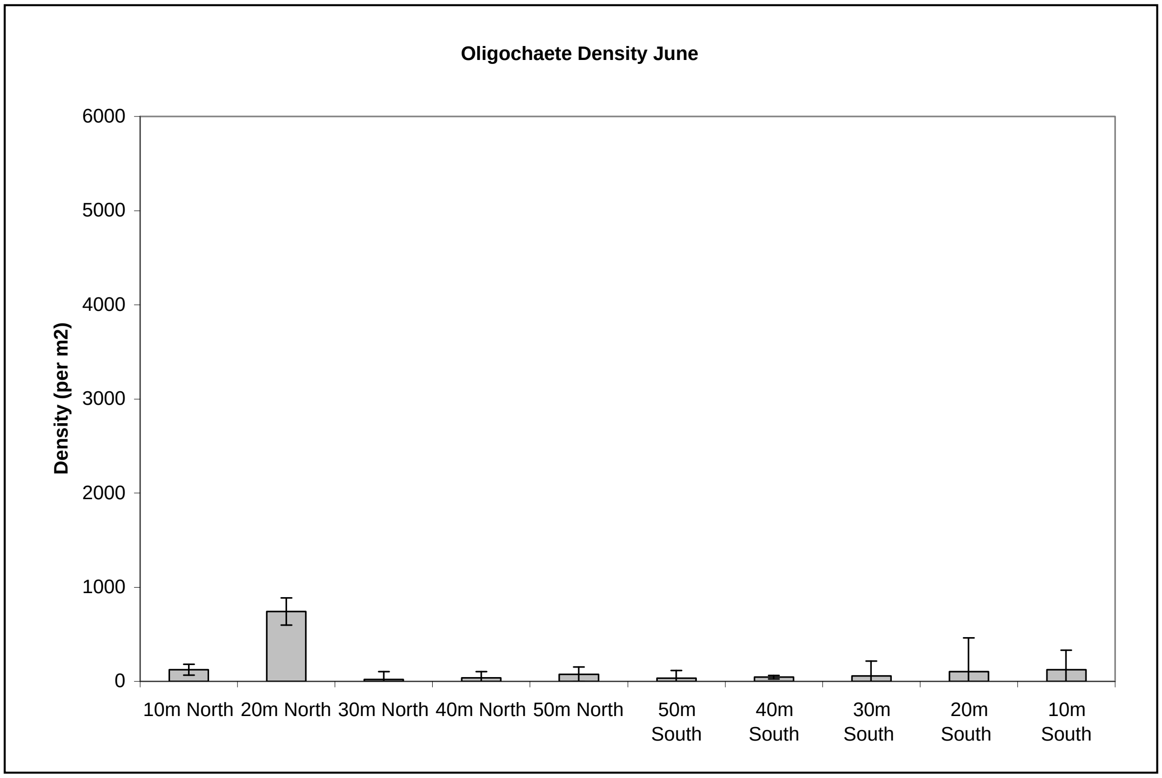



**Figure 8. Abundance of oligochaete worms (individuals per m$^2$) for June and October surveys (error bars one SE).**



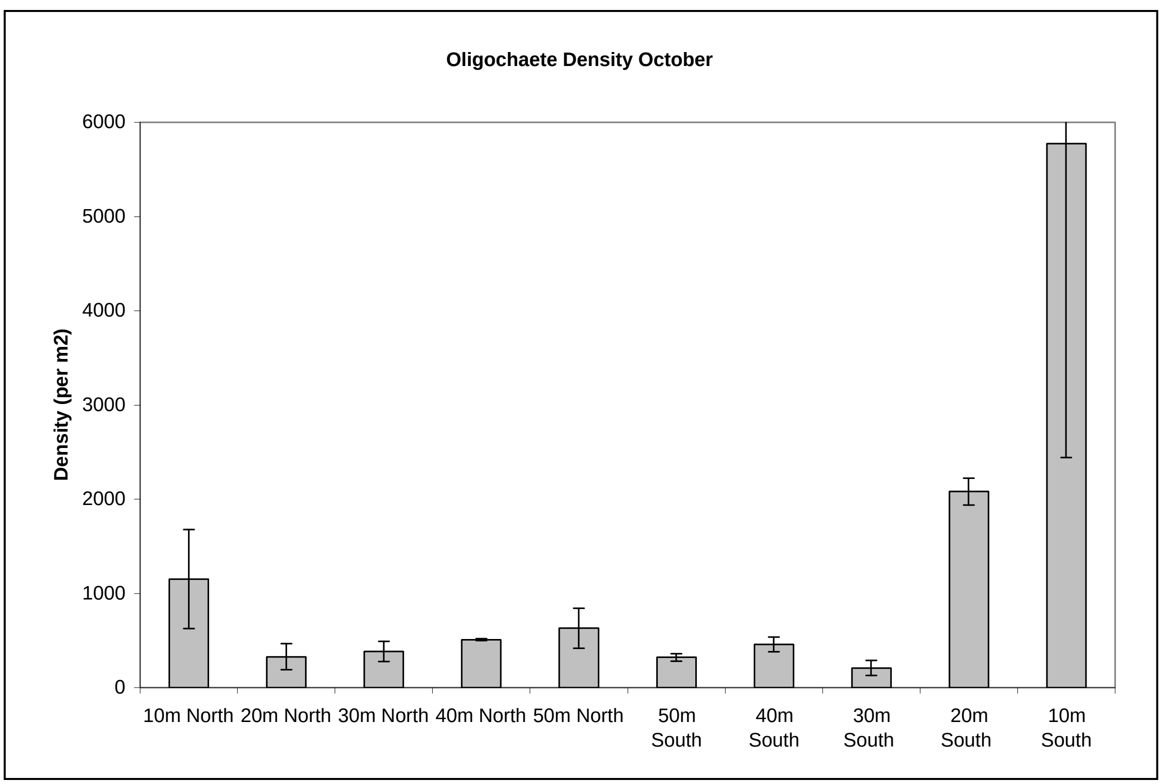



**Figure 9. Abundance of fingernail clams (individuals per m$^2$) for June and October surveys (error bars one SE).**