Pre-restoration Assessment of Biological Condition

for

Radio Tower Bay in the St. Louis River Estuary

by

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Introduction

The St. Louis River originates in northeast Minnesota and the lower 20 miles forms a 4856 ha freshwater estuary along the border with northwest Wisconsin. At the confluence with Lake Superior, the harbor is home to one of the busiest shipping ports on the Great Lakes. Despite more than 100 years of industrial use and urban development in the region, the St. Louis River estuary remains a significant source of biological productivity for western Lake Superior. Land use alterations through years of residential expansion and active industrial operations have created conditions in the estuary ranging from heavily impacted to those that remain relatively pristine. The estuary provides numerous sand and gravel beaches, islands, upland forests, sheltered bays, wetlands complexes, and other aquatic habitat types deemed essential for maintaining viable fish and wildlife communities.

The lower St. Louis River and surrounding watershed was designated an "area of concern" (AOC) under the Great Lakes Water Quality Agreement in 1989 due to chemical contaminants, poor water quality, reduced fish and wildlife populations, and habitat loss. Nine beneficial use impairments have been identified in the AOC, including loss of fish and wildlife habitat, degraded fish and wildlife populations, degradation of benthos, and fish tumors and deformities. The St. Louis River Alliance is a community-sponsored organization that facilitates collaborative efforts associated with the St. Louis River AOC. Following the recommendations of the St. Louis River AOC Stage II Remedial Action Plan, the St. Louis River Alliance completed the ***Lower St. Louis River Habitat Plan*** (Habitat Plan) in 2002 as "an estuary-wide guide for resource management and conservation that would lead to adequate representation, function, and protection of ecological systems in the St. Louis River, so as to sustain biological productivity, native biodiversity, and ecological integrity" (SLRA 2002). The St. Louis River Alliance also facilitated development of "delisting targets" for each beneficial use impairment (BUI) in the St. Louis River AOC in December 2008.

Radio Tower Bay is a small (18 ha) bay located in the upper reaches of the estuary near Gary, MN. Radio Tower Bay contains shallow open water, emergent and submergent aquatic vegetation, and is influenced hydrologically by both river currents and seiche activity. Historically, a sawmill operation in the early 1900s left the bay with significant amounts of wood waste and support pilings. The Minnesota DNR (MNDNR) and Minnesota Land Trust (MLT) secured funding from NOAA's Marine Debris Removal Program to begin the restoration process by removing wood waste, pilings, and abandoned radio tower footings from the site. An adjacent reference location (North Bay) was included in the habitat assessment in order to provide an opportunity to establish comparisons both temporally and spatially regarding a target condition as restoration progresses in Radio Tower Bay.

The Natural Resources Research Institute (NRRI), in cooperation with MLT and MN DNR, sampled Radio Tower Bay and North Bay to establish baseline information benthic macroinvertebrates, adult, juvenile, and larval fish assemblages and accompanying sediment and vegetation types. The project has been informed by previous collaborative efforts among NRRI, MLT, USFWS, MPCA, and MNDNR through the 40th Avenue West and 21st Avenue West remediation-to-restoration efforts.

Task 1. Benthic Macroinvertebrate Surveys

Sample sites

Macroinvertebrate sample locations within North Bay and Radio Tower Bay were visited between 31 August and 1 September 2011. Collections occurred at 31 points (approximately 15 points each) along a sampling grid based on pre-selected coordinates that were tracked on-site using a hand-held GPS (NAD 83 UTM, accuracy ± 3 m) (Figure 1, Appendix 1).

Macroinvertebrate and sediment characterization

Benthic samples were collected using a petite ponar dredge sampler. Field crews made on-site point adjustments in order to establish appropriate sampling depths and optimize sediment and habitat conditions. Petite Ponar samples were hand-washed through 250 um mesh according to methods outlined in the Great Lakes Environmental Indicators (GLEI) project, or followed subsequent standard operating procedures (NRRI 1999, 2003, and USEPA 2003). Dominant and subdominant substrate and vegetation types were also recorded from each point as each collection occurred, and a representative sediment sample was archived for potential future analysis.

Each ponar sample was evaluated, then field processed only if the sampling device contained $\geq$ 25 percent of the total ponar volume. Following three failed attempts to meet the minimum volume (e.g., rocks lodge in ponar jaws, or wood waste interfering with proper ponar operation, resulting in loss of content during retrieval), a supplemental approach was used involving a D-frame sweep procedure (c.f., NRRI 1999, 2003). This procedural substitution only occurred at points with water depths < 1 m.

An effort was made to quantitatively sample the macroinvertebrate assemblage associated with the remnant woody debris concentrated in the center of Radio Tower Bay. Consequently, a comparable habitat was pursued in North Bay to balance the sampling effort. Due to the lack of woody debris in North Bay, open water habitats with sparse vegetative cover were targeted in order to provide the best comparison available. Only one sample point in Radio Tower Bay provided a combination of water depth and manageable wood particles that could be extracted, measured, and consistently processed to obtain a quantitative ‘wood scrub’ sample. In most cases, sample points contained wood particles that were either too large to be safely extracted by hand, too small to efficiently “scrub”, or just large enough that particles wedged in the device and not enough wood material was collected to constitute a sample. Under those conditions, the most efficient method of obtaining a representative sample of invertebrates associated with the wood substrate was the previously described D-frame sweep procedure (NRRI 2003, Appendix 1).

Invertebrate samples were preserved in the field using Kahle's solution and labeled both internally and externally with unique identification. All samples were recorded during field collections and verified via chain-of-custody forms after returning to NRRI.

Sample processing

Benthic samples were processed at NRRI following GLEI protocols (NRRI 1999, 2003) under the supervision of the NRRI invertebrate lab manager and NRRI invertebrate taxonomists. Each sample was evaluated prior to processing to determine estimated overall effort, then sub-sampled accordingly to meet approved quality assurance project plan (QAPP) guidelines.

Invertebrates were identified by a qualified NRRI invertebrate taxonomist using standard identification guides (e.g., Merritt et al. 2008, Thorp and Covich 2010). Family-level identifications were proposed for this project, but familiar, easily-identifiable taxa were identified to the lowest level commonly used in the NRRI lab. This step was completed without increasing the cost per sample or overall processing time. Insects that are more difficult to identify, or specimens that are too young or were damaged during sample processing, were also identified to Family. The exception being midge larvae (Diptera Chironomidae) that were identified to sub-family. Remaining invertebrates, such as Oligochaeta and Nematoda, remained at a phylum or class-level identification.

Macroinvertebrate and point data were entered into electronic spreadsheets and then incorporated into the Access database created for the project (see below for details). All sample point information was georeferenced.

Quality control

NRRI invertebrate lab personnel QC checked 100% of samples to verify that processing was removing 95% of organisms from each sample. Six samples had > 5% of invertebrates missed during initial picking (range 5-10%, in 4 ponars and 2 D-net samples), and these samples were re-picked. All other samples passed QC with >95% of invertebrates being removed by the initial picking. Overall, picking of D-net samples resulted in an average of 4% of invertebrates being missed, with only 3% of invertebrates missed during ponar sample processing. With the exception of one sample, those failing the initial QC were processed first, and by new technicians becoming familiar with the procedures.

NRRI did not experience any taxonomic identification issues for the Radio Tower Bay project, and all macroinvertebrates were identified in-house. Outlying data values were double-checked against field and laboratory data sheets. Taxonomic information was merged with the Integrated Taxonomic Information System (ITIS) database to ensure proper nomenclature.

Data analyses

Macroinvertebrate data collected using quantitative gear (petite ponars) were converted to density estimates (number per square meter) for each point. While true macroinvertebrate productivity cannot be calculated from single point-in-time samples, and true biomass measurements require destruction of the samples themselves, density estimates can be used to infer information about productivity and biomass.

Descriptive assemblage calculations included proportion of major taxa types and proportions by trophic level, functional feeding group, and behavioral group. These were all done at the site (bay) level. Taxonomic richness by major taxonomic group and overall taxa richness were calculated for each bay and by sample type (D-net and ponar). Simpson's diversity and dominance indices were calculated for each bay (Brower et al.1990) using both sample-level data (on all sample types) and site-level data (ponar samples only). These calculations allowed comparison of the similarity of the invertebrate assemblages collected in ponar samples using Morisita's index of community similarity, calculated at the bay (site) level (Brower et al. 1990). Pollution/disturbance tolerance scores were calculated at the bay level using the Hilsenhoff IBI (Hilsenhoff 1987) and EPA tolerance scores (EPA 1999). In addition, proportion of tolerant individuals was calculated using EPA tolerance values. Pollution/tolerance calculations were made on the ponar sample data only. Macroinvertebrate assemblage summaries were also created for each site using all samples together and by sample type (D-net or ponar), based on proportions.

Habitat data were briefly summarized for mean water depth, dominant substrate types, and dominant vegetation types at sample points. T-tests, rank-sum tests (when data failed the equal variance test required for t-tests) and summary statistics were calculated in SigmaPlot (SigmaPlot 2006).

Results and Discussion

Although the total number of points distributed between the bays was equal, differences in the substrate encountered resulted in a modification to the sample numbers collected by each gear-type. In North Bay, 13 of the 15 macroinvertebrate samples collected were quantitative petite ponar samples, with the other two samples being qualitative D-net samples (Appendix 1). In Radio Tower Bay, however, the presence of the large woody debris required that a number of samples be collected as qualitative D-net sweep or scoop samples. In Radio Tower Bay, 7 samples were D-nets, 8 were petite ponar dredge samples, and 1 was a wood scrub (see Methods for details). Densities of macroinvertebrates were calculated for each bay based on the ponar sample assemblages (D-net samples are not quantitative and so should not be converted to density data in most circumstances).

Habitat

Dominant and subdominant substrates at macroinvertebrate sample points differed between the two bays, but because these data were collected qualitatively, we did not try to test these results statistically. Dominant substrates at North Bay sampling points were mostly muck (73% of points), with silt coming in a distant second (20% of points; Figure 2, Table 1, Appendix 1). At Radio Tower Bay sampling points, muck again was the most common dominant substrate (56% of points), but wood was also common (38% of points). Subdominant substrates at North Bay points tended to be silt (67% of points), while at Radio Tower Bay they were detritus (50% of points), with muck being the second most common subdominant substrate in both bays (33% and 31%, respectively; Figure 2, Table 1; Appendix 1). Figure 3 shows the location of the various substrate types within each bay.

Table 1. Dominant and subdominant substrate types at macroinvertebrate sampling points, summarized as proportion of points with each substrate type for each bay.

Site	Level	Muck	Clay	Silt	Detritus	Wood
North	Dom	0.73	0.07	0.20	0.00	0.00
RadioTower	Dom	0.56	0.00	0.06	0.00	0.38
North	Subdom	0.33	0.00	0.67	0.00	0.00
RadioTower	Subdom	0.31	0.00	0.06	0.50	0.13

As expected, wood substrates were only found within Radio Tower Bay. The heavy vegetation in areas of this bay resulted in macrophyte detritus being a common subdominant substrate in these areas. Field crews reported that vegetation was not as dense in North Bay, perhaps because North Bay was slightly deeper (see below).

Dominant and subdominant vegetation types at sampling points were reasonably variable at sampling locations with each bay and between the two bays. Because of the highly quantitative nature of the observations, and because other groups were collecting more detailed vegetation data, we have simply mapped the dominant vegetation types (Figure 4) and listed the types of vegetation found in each bay (Table 2).

Table 2. Vegetation types noted as dominant or subdominant at macroinvertebrate sampling points within each of the two bays.

North Bay	Radio Tower Bay
Marsh marigold (*Caltha*)	Marsh marigold
Coontail (*Ceratophyllum*)	Coontail
	Waterweed (*Elodea*)
Water milfoil (*Myriophyllum*)	Water milfoil
	Yellow pond lily (*Nuphar*)
White water lily (*Nymphaea*)	White water lily
Open water	Open water
Pondweed (*Potamogeton*)	Pondweed
	Arrowhead (*Sagittaria*)
Bulrush (*Schoenoplectus/Scirpus*)	Bulrush
Bur-reed (*Sparganium*)	Bur-reed
Cattail (*Typha*)	Cattail
Eelgrass (*Vallisneria*)	Eelgrass

Water and secchi disk depths were significantly different between the two bays, based on data collected at the approximately 15 macroinvertebrate sampling points in each bay. Depth was significantly greater in North Bay with an average depth of 0.86 m versus a mean depth of 0.47 m in Radio Tower Bay (rank sum test $p<0.001$; Figure 5). Secchi depth (water clarity) was also significantly greater in North Bay, but the difference was much less pronounced. North Bay had a mean secchi depth of 0.55 m versus the Radio Tower Bay mean of 0.47 m (t-test $p=0.03$; Figure 5). Because we were not collecting quantitative data on submergent aquatic vegetation, which would be most affected by water clarity, it is not known whether the lower water clarity in Radio Tower Bay is different enough to be biologically meaningful.

Macroinvertebrates

Mean benthic macroinvertebrate densities were roughly 25,000/m^2 for North Bay and 29,500/m^2 for Radio Tower Bay (Figure 6, Table 3). This difference was not significant. North Bay had somewhat greater total taxa richness (66) than Radio Tower Bay (57) (Table 4), but this difference could not be statistically tested because it was created using all of the available data. Ponar sample taxa richness was the same between the two bays (mean of 16 taxa per bay; Figure 7). There was greater mean taxa richness in the D-net samples from Radio Tower Bay, but this is a misleading result because there were 7 D-net samples taken from Radio Tower Bay, but only 2 from North Bay (results not statistically tested due to the low number of D-net samples from North Bay). Greater sampling effort is often correlated with greater taxa richness and greater habitat diversity (note that there were more vegetation types listed for Radio Tower Bay than for North Bay at invertebrate sampling points [Table 2]).

Interestingly, overall taxa richness for Radio Tower Bay is lower than that for North Bay, despite mean taxa richness in ponar samples being the same as that for North Bay, and there being a trend for greater taxa richness in the D-net samples. We also calculated Simpson's dominance (l) and diversity (Ds) indices for both bays using all the data together from all sample gear types. These results (Table 3) show relatively low dominance and high diversity, and very similar index values for each index across both bays. Simpson's dominance is the random chance that any two individual invertebrates plucked from the community at random will belong to the same taxa. These two indices are the opposite of each other (dominance = 1-diversity), so assemblages with low dominance will have high diversity and vice versa (Brower et al. 1990). These results show that, overall, the macroinvertebrate assemblages in the two bays were not very different from each other in terms of taxa richness.

Table 3. Various metrics calculated on the macroinvertebrate assemblages collected from both bays. SE = standard error. Information in parentheses tells whether metrics were calculated only on ponar (quantitative) samples or using all gear types combined.

Metric	North	Radio Tower
Mean Density (ponar, #/m2, SE)	25,023 (3,912)	29,549 (6,953)
Taxa Richness (overall)	66	57
Simpson Dominance (overall)	0.11	0.15
Simpson Diversity (overall)	0.89	0.85
Number of predator taxa (overall)	21	21
Proportion ETO (overall)	0.06	0.047
Proportion Chironomids (ponar)	0.34	0.53
Proportion Chiron+Oligo (ponar)	0.49	0.62
Proportion worms (CNO; ponar)	0.71	0.74
Hilsenhoff IBI (ponar)	6.88	6.7
EPA mean tolerance (ponar)	6.91	6.81
Prop. Tolerant (ponar)	0.65	0.72
Morisita's Similarity (overall)	0.49	

Benthos assemblages (averaged across both gear types [D-net and ponar dredge]) are similar, although that from North Bay appears a bit more balanced (Figure 8). Both bays' assemblages are dominated by chironomid midges, with somewhat higher proportions in Radio Tower Bay (31% for North Bay vs. 42% for Radio Tower Bay, t-test p<0.05). Amphipods (scuds) and isopods also make up a large percentage of the Radio Tower Bay invertebrate assemblage at 24%; this is higher than North Bay's 10%, which is statistically significant (rank sum test p=0.012). The North Bay assemblage contains a higher percentage of round worms (Nematoda; 19%) and oligochaete worms (16%) than does Radio Tower Bay, and the difference is statistically significant for the round worms (t-test p<0.01). There is also a statistically significant greater proportion of fingernail clams (Sphaeriidae) in North Bay (9% vs. 2%; rank sum test p=0.001). Note that mayflies, caddisflies, dragonflies, damselflies, bugs, and beetles make up only a very small proportion of the assemblage collected in samples (Figure 8, Tables 3 and 4). Appendix 2 contains a complete list of the taxa found in each bay.

Using the entire assemblage with all samples combined, we calculated Morisita's Index of Community Similarity (Im) to compare the two bays. The index ranges from 0 to 1, with 0 being not similar to 1 being identical (Brower et al. 1990). Our calculations showed the assemblages from the two bays to be about 50% similar overall (Table 3).

Table 4. Number of invertebrate taxa in each of the major macroinvertebrate groups found in North and Radio Tower bays. Data from all gear types were used for this analysis.

Taxa	**North Bay**	**Radio Tower**
Mayflies	2	3
Caddisflies	12	6
Damsel/dragonflies	5	4
True Bugs	6	4
Beetles	5	6
Flies	14	11
Other Insects	3	2
Snails	8	9
Leeches	1	3
Other inverts	10	9
Total Richness	**66**	**57**

Because combining macroinvertebrate data collected using different gear types can be confusing, we also separated the invertebrate assemblages from each of the major gear types, D-nets and petite ponar dredges (Figure 9). D-nets are more likely to capture insects and invertebrates that live amongst the vegetation or in plant detritus on the surface of the sediments, or, in this particular case, on the woody debris in Radio Tower Bay. Mayflies, caddisflies, damselflies, dragonflies, amphipods, and isopods are more common in these D-net samples. The D-net samples from North Bay appear more balanced than those from Radio Tower Bay and contained more of the macroinvertebrates that we consider less tolerant of disturbance, such as caddisflies (Trichoptera) and damselflies and dragonflies (Odonata). These two D-net samples were collected within emergent vegetation. The Radio Tower Bay samples were much more dominated by chironomid midges, probably because many of these samples were collected from wood, a substrate that chironomid larvae would use. Again, because of the unbalanced number of D-net samples taken in the two bays, these results were not tested statistically.

Dredge samples are better at capturing the invertebrates that live in the sediments, often the types of invertebrates that we collectively call "worms." Dredge samples were dominated by roundworms (Nematoda), segmented worms (Oligochaeta, or aquatic earthworms), midge larvae (Chironomidae), and fingernail clams (Sphaeriidae). Over half of the Radio Tower Bay dredge invertebrate assemblage was comprised of chironomid midges (53%), versus only 34% in North Bay (significantly different by t-test, p=0.003). North Bay's assemblage also contained non-significantly higher percentages of round worms (Nematoda; 22% vs. 12%) and oligochaetes (15% vs. 9%), and statistically significantly higher percentages of fingernail clams (Sphaeriidae; 11% vs. 3%; rank sum test p=0.02).

Comparing the proportions of "worms" that make up the bays' ponar dredge invertebrate assemblages shows that most of the difference between the bays is due to chironomid larvae, which are a significantly greater proportion of the Radio Tower Bay assemblage. Although nematodes and oligochaetes are greater proportions of the North Bay assemblage, these differences are not significant when compared to Radio Tower Bay. Interestingly, when the proportions of "worms" are added together (Chironomidae + Nematoda + Oligochaeta), the proportions become very similar between the two bays: 71% of the North Bay assemblage versus 74% of the Radio Tower Bay assemblage (Table 3). The rest of the dredge macroinvertebrate assemblages are made up of fingernail clams and amphipod/isopods (Figure 9).

Invertebrates thought of as less tolerant of disturbance make up only a small percentage of the invertebrate assemblage, even when looking at all gear types combined(since D-nets are more likely to capture these invertebrates [Figure 8]). Mayflies (Ephemeroptera), caddisflies (Trichoptera), and dragonflies and damselflies (Odonata) comprised only 5-6% of the combined assemblage (Table 3), and there was very little difference between the bays. The highest proportions of these more sensitive invertebrates were collected in D-net samples taken amongst wetland vegetation in North Bay (Figure 9), but because these samples were not balanced against comparable habitat in Radio Tower Bay (where D-nets were used to collect invertebrates from woody debris), conclusions should be drawn very conservatively.

Another way to compare invertebrate assemblages is to look at the various ways the invertebrates feed, their trophic levels, and their behavior types. We compared trophic levels and functional feeding groups across all sample types because there was little difference among gear types. Proportions of macroinvertebrates in each trophic group were reasonably similar between the bays, although there were more detritivores (not significant) and herbivores (statistically significant, rank sum p=0.02) in North Bay, and more omnivores (not significant) in Radio Tower Bay (Figure 10). Functional feeding group proportions were also relatively similar between the two bays (Figure 10), although Radio Tower Bay was somewhat more dominated by collector-gatherers than was North Bay (not significant), and North Bay had a greater percentage of collector-filterers (significant, rank sum p=0.001). As might be expected in an area with more wood and detritus, Radio Tower Bay had a slightly greater proportion of shredding invertebrates than did North Bay (significant, rank sum p=0.027).

Behavioral groups differed by both gear type and bay, at least to some extent, and so we have presented these data with the invertebrate assemblages from the different gear types shown separately (Figure 11). As we would expect, more invertebrates in the ponar dredge samples are classified as burrowers than those found in D-net samples. The high number of burrowers in D-net samples is partially a reflection of the tendency for most chironomid midge larvae and most oligochaetes and nematodes to be classified as burrowers even though some of them are climbers on vegetation and other structures. Clingers and climbers, on the other hand, are better captured by D-net type sampling methods, and this is reflected in the data (Figure 11). The high proportion of sprawlers in the D-nets from Radio Tower Bay probably reflect the use of these D-nets to capture invertebrates that were using the wood substrates. D-net samples taken in North Bay were used in the emergent macrophyte vegetation and so were more likely to capture climbing invertebrates and those that skate on the water's surface. None of these differences were tested statistically because the D-net samples were not collected in a similar manner and in similar numbers between the two bays.

The ponar samples are more directly comparable between the two bays. There was a significantly greater percentage of burrowers in North Bay (t-test p=0.014), and significantly more sprawlers in Radio Tower Bay (t-test p=0.046). The sprawlers may have been using the wood substrate as habitat. Clinger and swimmer percentages were slightly different between the two bays, but these differences were not statistically significant.

Finally, we calculated some tolerance indices for the macroinvertebrate assemblages from the ponar samples. Because these calculations need to be based on absolute, rather than relative, abundances, they are most appropriate for quantitative samples, and should be used with extreme caution when combining sample types or when sampling effort is not standardized. Thus, we restricted our calculations to the quantitative ponar samples. Overall, the tolerance indices show very little difference between the two bays (Table 3). Both Hilsenhoff's 1987 Index of Biotic Integrity (Hilsenhoff 1987) and the US EPA's tolerance index (US EPA 1999) rank each invertebrate taxon on a scale of 0 to 10 for its tolerance to pollution, with 0 being most sensitive and 10 being most tolerant (Hilsenhoff 1987). The indices create an overall mean tolerance score for all of the invertebrates collected by ponar dredge in each bay, and range between 6.7 and 6.9. These numbers are what we would expect for benthic macroinvertebrates in a wetland area, which is a much harsher environment than a stream riffle. Note that both indices were developed for use in streams and rivers, not wetlands.

The final metric, proportion tolerant invertebrates, uses the EPA's tolerance scores to calculate the proportion of invertebrates collected by ponar dredge with a tolerance score of 7 or higher. Again, the bays are very similar with 65% (North Bay) to 72% (Radio Tower Bay) of the macroinvertebrate assemblage being rated as "tolerant." This again highlights the fact that wetland environments are harsher systems than streams and are typically inhabited by invertebrates capable of surviving these conditions. It also again shows the dominance of the hardy benthic burrowers (Oligochaeta, Nematoda, Chironomidae) in these samples.

Summary

Overall, the differences in the macroinvertebrate assemblages seem to be influenced primarily by the invertebrate response to habitat differences between the two bays. Radio Tower Bay is both smaller, shallower, contains a large amount of large woody debris, and has more dense and diverse vegetation than does North Bay. Because of this, we had to collect macroinvertebrates using D-nets in many more instances in Radio Tower Bay. D-nets capture invertebrates more closely associated with structure within the water column (e.g., vegetation or wood). In addition, the invertebrates themselves were making use of the abundant wood as habitat. These differences show up most clearly in Figure 9, where the contrast between invertebrates associated with emergent vegetation and those using wood can be seen by looking at the D-net samples since D-nets in North Bay were used amongst emergent vegetation while those collected in Radio Tower Bay primarily sampled invertebrates associated with wood. These invertebrates are more likely to be clingers and climbers than the burrowers collected using the petite ponar dredge (Figure 10).

Ponar samples offered the best comparison of invertebrates using similar habitats in both bays. These samples show relatively few differences between the macroinvertebrate assemblages, especially in metrics such as trophic levels, feeding and behavioral groups, and pollution/disturbance tolerance. The differences that we identified do not appear to be major. Radio Tower Bay had a higher percentage of chironomid midges and shredding and sprawling macroinvertebrates than did North Bay. Radio Tower Bay had a lower percentage of fingernail clams and filtering macroinvertebrates, and a lower overall number of taxa than did North Bay. Several of these differences are consistent with the woody debris present in Radio Tower Bay, particularly the higher percentages of shredders (which shred vegetation and sometimes wood) and sprawlers (which sprawl on the available substrate rather than burrowing into it). The lower taxonomic richness in Radio Tower Bay is somewhat puzzling since this bay had a greater number of habitat and vegetation types than did North Bay, and habitat richness typically increases macroinvertebrate taxa richness.

Following restoration, when the macroinvertebrate assemblages of these two bays are again sampled, we recommend using both types of sampling gear (D-nets and petite ponar dredges) equally in both bays to allow D-net invertebrate assemblages to be better compared. For example, if 8 ponar dredge samples were collected in the more open and deeper areas of each bay, and 8 D-net samples were collected in the shallower and more vegetated areas (particularly the emergent vegetation), then the combined assemblage would accurately represent nearly the complete invertebrate assemblage using each bay, while keeping sample numbers at a reasonable level of 16 points sampled per bay. In addition, the samples could also then be statistically compared between bays by each gear type separately because the sampling design would be balanced and have enough replication.

Task 2. Fisheries Assessments

Sample sites

Fish assemblages were surveyed in Radio Tower Bay and North Bay during overnight events using fyke nets and larval light traps. Fishing events were set to coincide with new moon phases that occurred on 30 July and 29 August 2011. Within each bay, three sampling points were positioned along nearshore zones and chosen to represent the dominant habitats available. All points included water depths ≤ 1 m to appropriately accommodate available gear. Fish assemblages were surveyed on 29 July and 30 August, 2011. Larval fish sampling occurred both concurrently with the fyke net effort, plus specific larval trap-only events taking place within a few days (4 August and 2 September 2011) of the original effort. Because the second light trap event actually occurred in the following calendar month, both light trap events and the corresponding fyke net collection will be referenced as either the "July" event for the period between 29 July and 4 August, or "August" for samples collected between 29 August and 2 September 2011. Coordinates at each sampling point were recorded on-site using a hand-held GPS (NAD 83 UTM, accuracy ± 3 m) and downloaded to a project file at the NRRI-GIS Laboratory.

Fish sampling

Fyke net- A single large-frame and two small-frame fyke nets were deployed in both bays during the July sampling period according to MNDNR general survey protocols (MNDNR 2009). Nets were placed perpendicular to shore with the box frame at the edge of a habitat zone (submergent or emergent vegetation). Leads (40' long with 3/16" mesh) extended from the box frame towards shore, and were positioned within the emergent vegetation to near zero depth. In order to better capture a fish assemblage making use of the woody debris found in the center of Radio Tower Bay, the August sampling event implemented a lead-to-lead array configuration (consisting of two large-frame fyke nets set lead-to-lead, also called a 'double pot' design) in the middle of each bay. This arrangement replaced two of July's single-net sets near shore. However, a small-frame fyke was also set near shore in each bay to maintain the required 3-net effort.

Nets were set in the daylight during the afternoon or evening, and allowed to fish overnight for at least 18 hours. All fish > 2.5 cm length were identified (Becker 1983, Hubbs and Lagler 2004), counted, size-classed when appropriate, with at least 25 individuals weighed and measured (total length) to the nearest mm. Fish smaller than 2.5 cm total length were noted, but discarded from fyke net samples because the mesh size does not accurately retain such small fish. Representatives of these small fish should have been captured in the larval light traps. A representative number of unidentified species were euthanized and returned to the lab for positive identification. Larger fish were photographed and released on site. Any external anomalies on fish (e.g., parasites, tumors, lesions, etc.) were also noted.

Larval light traps – Light traps provided by MNDNR were deployed following MNDNR methods (Cindy Tomko, MNDNR, personal communication). Traps were outfitted with 6 mm openings 500 µm mesh and set in or near areas that provided adequate vegetation for larval concealment, but sparse enough cover that larvae fish could detect the light from a distance. As with fyke net sampling, two traps in each bay were moved away from the shoreline vegetation to represent differences between open water habitats in the two bays during the August new moon period (30 Aug. and 2 Sept.). All traps were set and pulled during daylight, so the effective time fished for catch per unit effort (CPUE) estimates was determined as the time between sunset and sunrise. Traps in both bays fished for 8.95 hrs on 7/29/11, 9.2 hrs on 8/4/11, 10.48 hrs on 8/30/11, and 10.65 hr on 9/2/11. Contents of all traps were preserved in the field in formalin, which was replaced by 70% ethanol immediately prior to identification.

All larvae were sorted under magnifying lamps (3-5x magnification), counted, measured (total length to nearest 0.1 mm), and identified under dissecting microscopes to lowest possible level using appropriate keys (Auer 1982, Buynak and Mohr 1980, Fuiman et al. 1983, and Snyder et al. 1977). Supplemental primary literature was referenced for recently invading species (c.f., French and Edsall 1992, Simon and Vondruska 1991). Quality control was accomplished by sending a sub-set of identificed larval fish to ichthyoplankton expert, Dr. Nancy Auer of Michigan Technological University. Dr. Auer was responsible for correcting mis-identified individuals and provided assistance on problematic individuals as they occurred.

Analysis

Because fyke net configurations and frame-size were identical between sites and events, data did not need to be standardized by catch-per-unit-effort (CPUE) and remain as counts per net. Total abundance and taxa counts by location and sample date, plus mean abundance of individual taxa for those same class variable were compared using a one-way analysis of variance (ANOVA) statistical procedure (SAS 1998).

Very few species were collected in sufficient numbers in both bays and over both sampling events to compare by year-class within each species (Figure 12). Consequently, analyses with length/weight relationships were conducted using the entire pool of individuals within a species. For those taxa consistently occurring in either bay, data were transformed using a natural log, and linear regressions were run on individual length with corresponding weights to determine length to weigh relationships (SAS 1988).

An estimate of growth rate (slopes and intercepts from the length/weight regression) was selected as an indicator of productivity, or overall habitat quality, between the two sampling locations. Individual fish with both a measured length and corresponding weight provide a separate data point on each plot. Due to electronic balance limitations, small individuals (< 1 gram) were counted and weighed collectively (i.e. batch weight) and summarized as one data point. The difference in slope between sample dates was used to determine a difference in the rate of growth occurring between locations over time, and the intercept was used to provide a separation in overall biomass between locations. To determine if the length-to-weight relationship for each species was uniform between sample dates and location, an ANCOVA statistical procedure was run in R (R 2011) using the regression slopes and intercepts with contrasts for comparison.

Community comparisons scores were generated by location and by individual net using Shannon and Simpson diversity indices (c.f., Shannon 1948, Simpson 1949). These indices are based on total taxa and total abundance ratios and were use for comparing fish assemblages in a similar fashion as previously described for the benthic macroinvertebrate data analysis.

Results and Discussion-Fish Assemblage

Fyke net- A total of 25 fish species were collected from both bays over the two sampling events, with 17 species collected during the July sampling period, and 23 species caught during August. North Bay produced 14 and 19 species in July and August, respectively (Table 5). The Radio Tower Bay assemblages consisted of 11 and 17 species on those same dates. Shorthead and river redhorse, walleye, smallmouth bass, and logperch were unique to North Bay, with central mudminnow and northern brook silverside unique to Radio Tower Bay. Large and smallmouth bass in North Bay were more abundant than in Radio Tower Bay during July sampling, but there were no such differences during August. Spottail and golden shiners responded with a similar change in abundance between locations over the sample period (Table 5).

Throughout both sampling periods, the mean number (± standard error) of fish species collected per net was 10.2 ± 1.21 and 9.8 ± 0.98 from North Bay and RadioTower Bay, respectively. Total fish abundance collected during this survey was not significantly different when analyzed by location or by sampling period. Various fish traits calculated by individual abundance or taxa counts by behavioral adaptions, taxonomic classification, or functional feeding mechanisms were also not significant between locations or sampling period. Total mean length for individual species was not different either, but in a few cases body mass (mean total weight for individuals of a selected species) did show both a significant difference over time and/or between locations. Both black crappie and pumpkinseed sunfish, on average, were larger during the first sampling date in Radio Tower Bay (Figure 13). Mass of both species increased between July and August in both bays, but only North Bay contained significantly heavier sunfish on average than Radio Tower Bay by the August sampling period.

This result was confirmed by evaluating the slope from the length/weight relationships for all sunfish taxa combined. The August data shows that the length/weight slope for sunfish in North Bay was significantly greater than the slope for Radio Tower Bay sunfish. It is possible that a few larger adults influenced this length/weight relationship. Although a real difference is noted, it may be a one-time event which could be mitigated during future sampling with an increase in nets or sampling events. No other significant differences in growth were found between North

Table 5. Fish species by common name collected overnight using fyke-nets in North and Radio Tower Bay within the St. Louis River estuary. Data represent a total count of individuals captured in all sets.

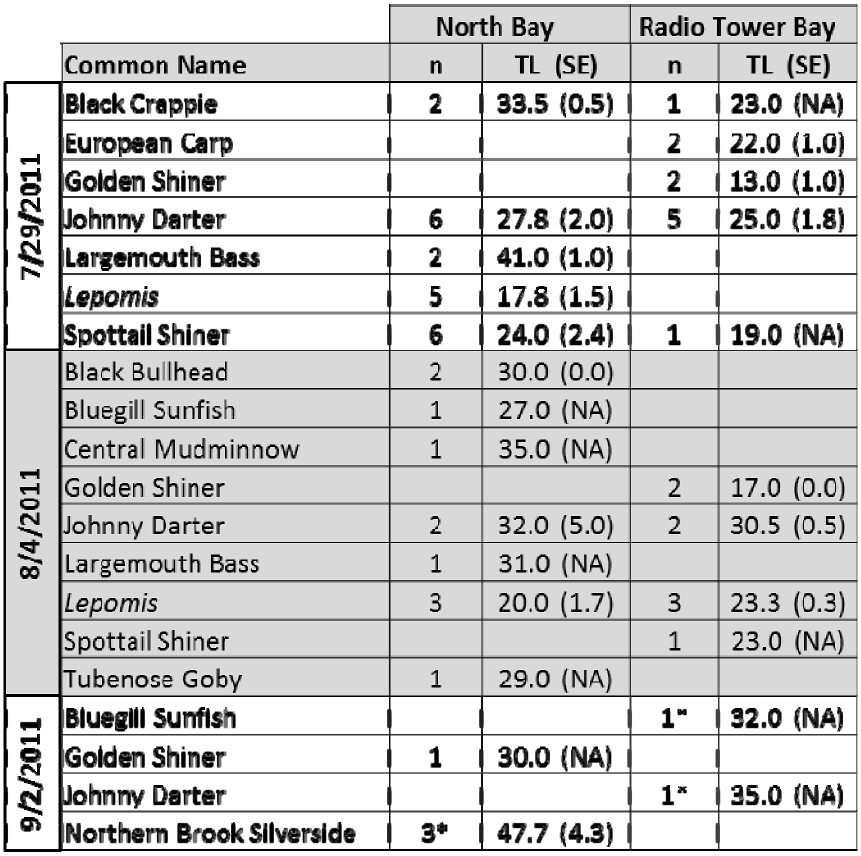
Date	Common Name	North Bay	Radio Tower Bay
July	Black Bullhead	35	60
	Black Crappie	332	123
	Bluegill Sunfish	3	6
	Central Mudminnow		5
	European Carp	7	20
	Golden Shiner	34	
	Johnny Darter	13	7
	Largemouth Bass	31	1
	Northern Pike	2	2
	Northern Rock Bass	4	
	Pumpkinseed Sunfish	12	14
	Smallmouth Bass	9	
	Spottail Shiner	534	2
	Tadpole Madtom	2	5
	Tubenose Goby	2	
	White Sucker	1	3
	Yellow Perch	2	4
July Total		**1023**	**252**
August	Black Bullhead	2	5
	Black Crappie	234	260
	Bluegill Sunfish	16	
	YOY Sunfish	73	581
	Eurasian Ruffe	18	2
	European Carp		8
	Golden Shiner	2	34
	Johnny Darter	2	13
	Largemouth Bass	6	4
	Logperch	30	
	Northern Brook Silverside		3
	Northern Rock Bass	14	6
	Pumpkinseed Sunfish	34	12
	Shorthead Redhorse	4	
	Silver Redhorse	4	
	Smallmouth Bass	26	
	Spottail Shiner	6	4
	Tadpole Madtom		9
	Tubenose Goby	1	3
	Walleye	2	
	White Sucker	2	2
	Yellow Perch	164	57
August Total		**640**	**1003**
Grand Total		**1663**	**1255**

Bay and Radio Tower Bay (Figure 14). Again, nets were set to best survey comparable habitats in both bays. Consequently, both bays had in common at least some shoreline structure and vegetative habitat. As a result, both bays produced fairly comparable numbers of fish, with the exception of some taxa unique to each location.

Overall, North Bay produced a Shannon index score for fish of 0.1836 compared to 0.2589 from the Radio Tower Bay assemblage. Probabilities from North and Radio Tower Bay using Simpson's Diversity were 0.7922 and 0.6894, respectively.

Larval Light Traps- Larval fishing effort was delayed from more optimal sampling dates earlier in the season by contract delays. Thus, larval fish catches were not optimal, and many fish captured were better classified as young-of-the-year rather than true larvae. Larval fish catch for each event was too variable, and sample size too low, to display any significant differences between sites, sample period, or habitat. Numerous sunfish captured during this study were in a size class that was not appropriate for identification to species either the Auer (1982) larval key or standard adult keys. Consequently, those individuals were assigned to the genus *Lepomis*. Johnny darter, spottail shiner, and *Lepomis* species were the most abundant taxa captured in both bays. A compilation of species, number, and mean size for each bay by sample period is shown in Table 6.

Table 6. Species, number of individuals (n), and mean total length (TL) with standard error (SE) for Radio Tower and North Bays during the 7/29/11, 8/4/11, and 9/2/11 larval trap sample dates. No fish were caught in either bay on 8/30/11. Three larval traps were set in each bay on each sample date. An asterisk (*) designates fish captured in traps in open water, all other traps were set overnight near vegetation.



		North Bay		Radio Tower Bay	
	Common Name	n	TL (SE)	n	TL (SE)
7/29/2011	**Black Crappie**	**2**	**33.5 (0.5)**	**1**	**23.0 (NA)**
	European Carp			**2**	**22.0 (1.0)**
	Golden Shiner			**2**	**13.0 (1.0)**
	Johnny Darter	**6**	**27.8 (2.0)**	**5**	**25.0 (1.8)**
	Largemouth Bass	**2**	**41.0 (1.0)**		
	Lepomis	**5**	**17.8 (1.5)**		
	Spottail Shiner	**6**	**24.0 (2.4)**	**1**	**19.0 (NA)**
8/4/2011	Black Bullhead	2	30.0 (0.0)		
	Bluegill Sunfish	1	27.0 (NA)		
	Central Mudminnow	1	35.0 (NA)		
	Golden Shiner			2	17.0 (0.0)
	Johnny Darter	2	32.0 (5.0)	2	30.5 (0.5)
	Largemouth Bass	1	31.0 (NA)		
	Lepomis	3	20.0 (1.7)	3	23.3 (0.3)
	Spottail Shiner			1	23.0 (NA)
	Tubenose Goby	1	29.0 (NA)		
9/2/2011	**Bluegill Sunfish**			**1***	**32.0 (NA)**
	Golden Shiner	**1**	**30.0 (NA)**		
	Johnny Darter			**1***	**35.0 (NA)**
	Northern Brook Silverside	**3***	**47.7 (4.3)**		

The earlier larval trap sample periods of 29 July and 4 August had a higher total catch and CPUE in fish/hr than the later sampling for both bays (Figure 15). Furthermore, North Bay larval traps captured a greater total number of fish and had a greater mean CPUE than Radio Tower Bay across all sample periods when fish were captured (Figure 15). The number of species captured was similar in both bays for most sample periods. Five species were captured in both bays on 29 July, zero on 30 August, and only two species were captured in each bay on 2 September. On 4 August six species were captured in North Bay versus four in Radio Tower Bay, which was the only sample period which differed on total number of species captured (Figure 16). Across all samples North Bay larval traps captured ten different species, while Radio Tower Bay traps captured seven species. Black bullhead, central mudminnow, largemouth bass, northern brook silverside, and tubenose goby were unique to North Bay, while European carp was the only species unique to Radio Tower Bay larval traps. Note that in North Bay on 4 August, *Lepomis* is present with bluegill sunfish (Table 6), which were lumped together to represent one taxa in Figure 16 and for the number of species captured by site.

Few conclusions can be made about the differences between the open water habitat of Radio Tower and North Bays. This is due in part to the traps sampled on 30 August capturing no fish, so all comparisons relied on the 2 September sample date when only a few fish were captured. The only fish caught in larval fish traps in open habitat in North Bay were the northern brook silversides (Table 6), which were a species unique to traps set away from vegetation. The traps set in open habitat in Radio Tower Bay captured a bluegill sunfish and johnny darter, while the trap set near vegetation was empty. None of the fish captured on 2 September were larval. While this data is limited, it would appear that the woody debris of Radio Tower Bay offers little if any unique larval fish habitat that is not already offered by vegetation.

Many of the fish captured in the larval traps were juveniles (Auer, 1982) with total lengths (TL) capable of being represented in fyke net catches (Table 6). The late trap set dates may explain the low numbers collected. This supposition is supported by the decrease in catch rates between the July and August sampling periods. By the end of August and early September few fish are likely to be in the larval stage, and the 6 mm trap openings restrict capture of juvenile fishes. Tanner et al. (2004) sampled larval fish in Allouez Bay, St. Louis River, between 20 May and 9 August. Light traps set by Pierce et al. (2007) for juvenile northern pike in Northern Minnesota were set from 1 May to 3 June. Based on our results and our brief literature survey, we believe that a more accurate representation of the larval assemblages in both bays could be made if larval traps were set in May and June. This time frame would also allow comparisons to other data and literature values.

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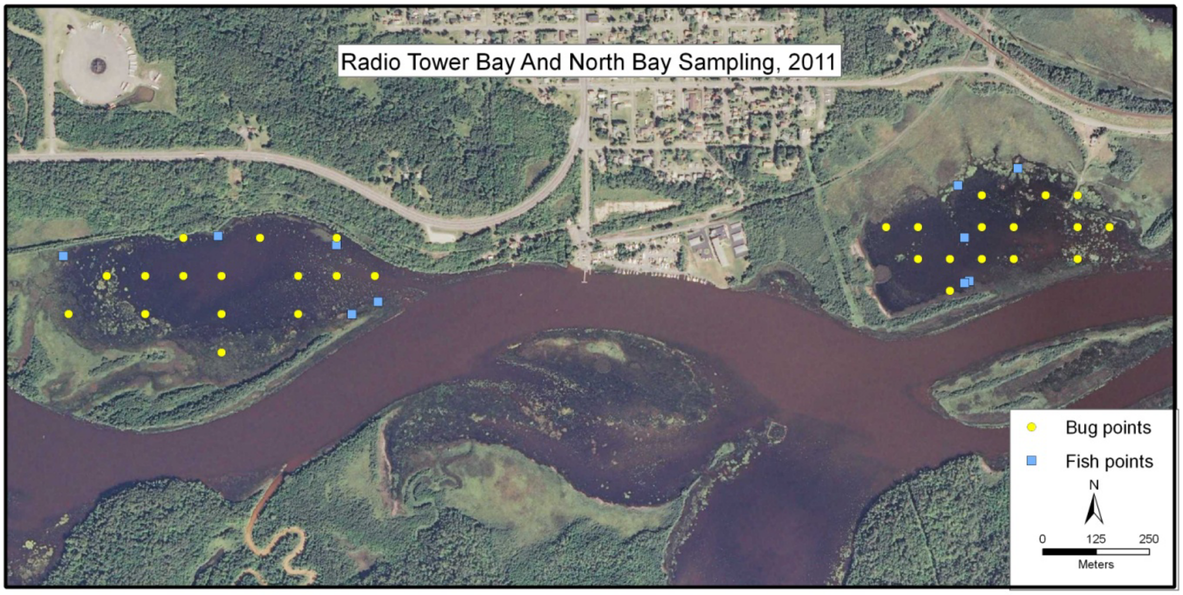


Figure 1. Fish and macroinvertebrate sampling locations in North Bay (on the left) and Radio Tower Bay (right) for summer 2011 sampling.

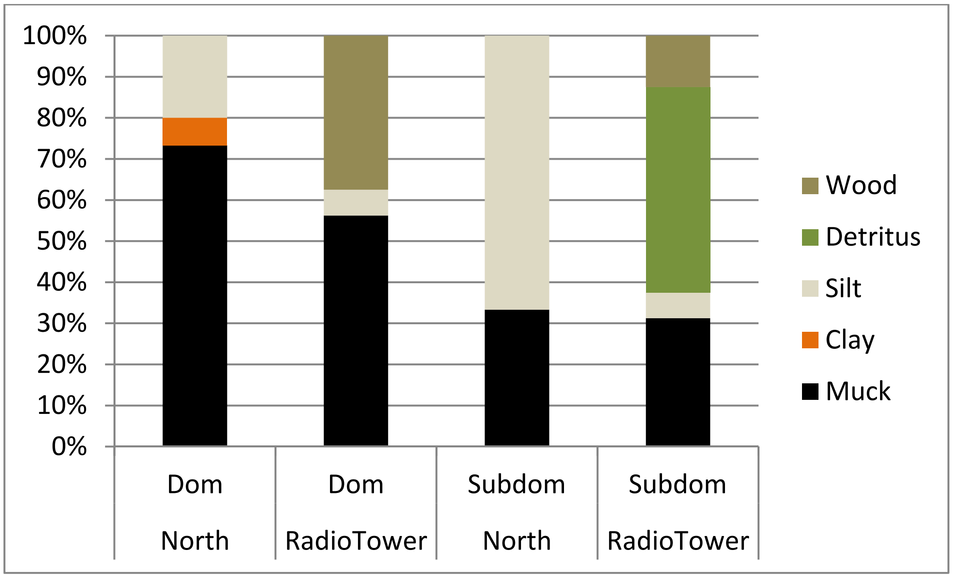


Figure 2. Dominant and subdominant substrates at macroinvertebrate sampling points in each bay. Data are simply the percentage of points in each bay having the given substrates.

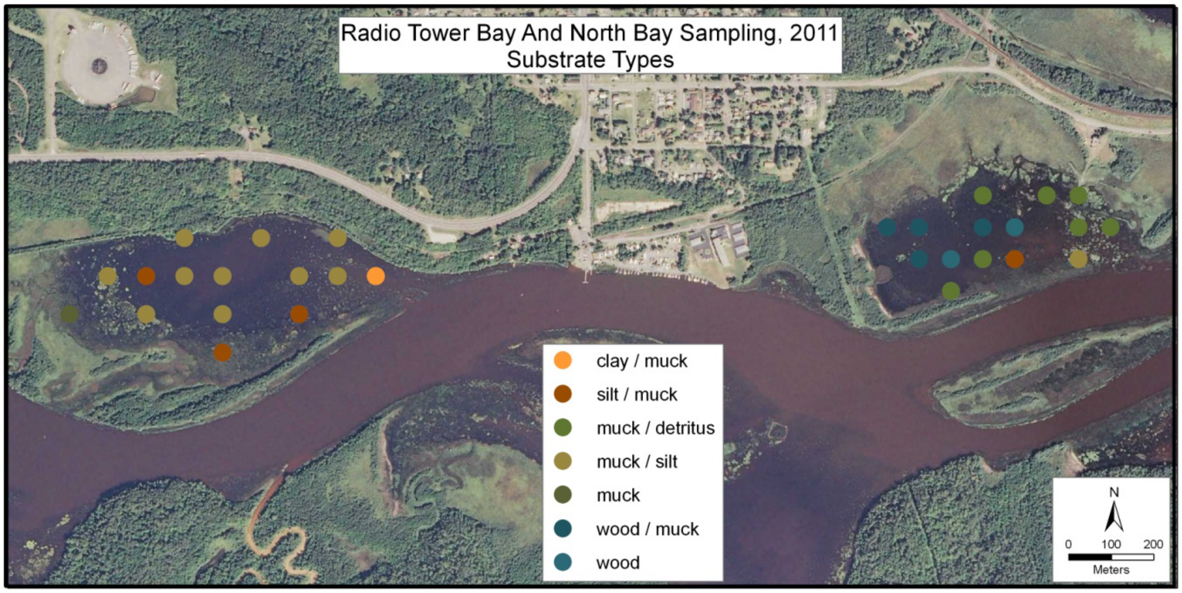


Figure 3. Dominant and subdominant substrate types at each macroinvertebrate sampling point in North Bay (left) and Radio Tower Bay (right) during summer 2011 sampling.

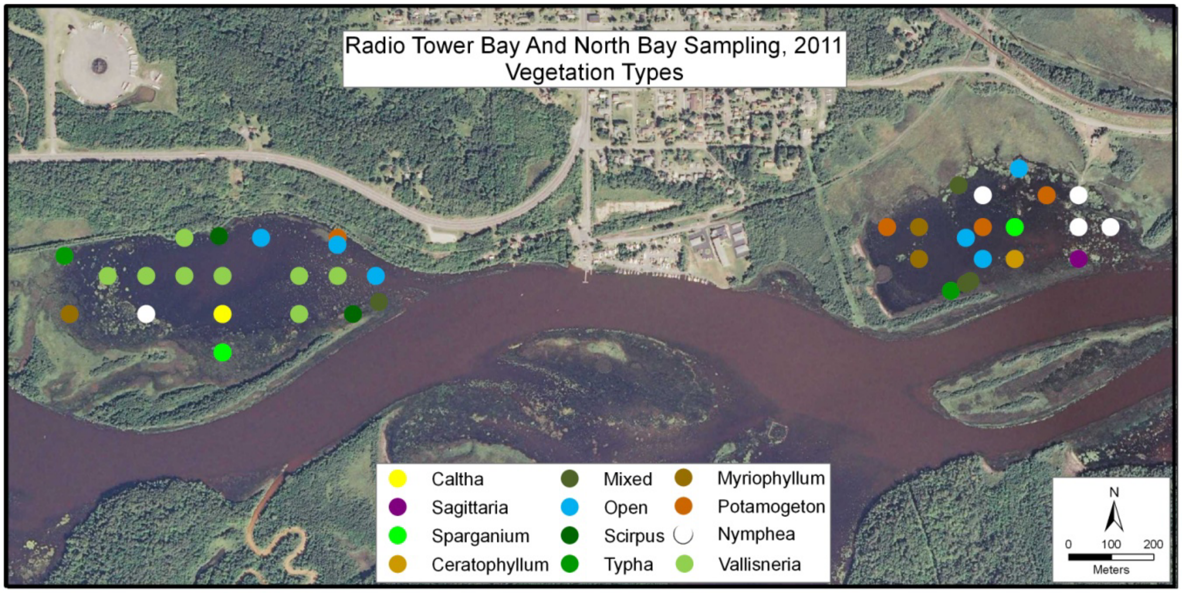


Figure 4. Dominant vegetation types at each macroinvertebrate sampling point in North Bay (left) and Radio Tower Bay (right) during summer 2011 sampling. Subdominant vegetation types not mapped due to the number of types. See Appendix 1 for full data.

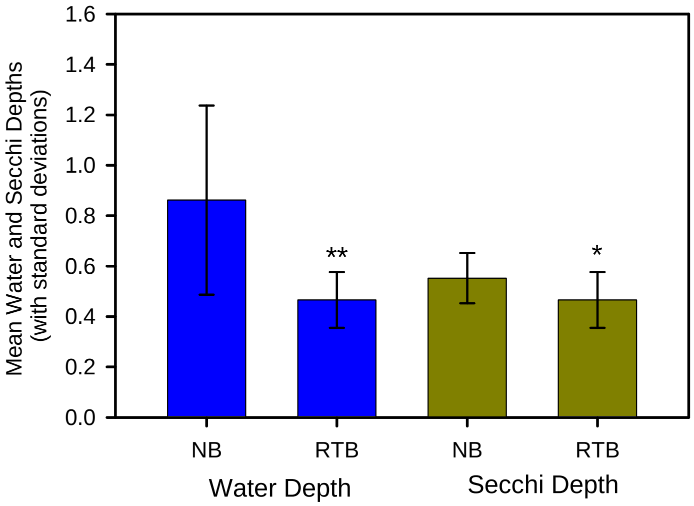


Figure 5. Means and standard deviations of water and secchi disk depth at macroinvertebrate sampling points in North Bay (NB) and Radio Tower Bay (RTB) during summer 2011. Water depth and secchi depth were both significantly different between the two bays (p<0.001 and p=0.03, respectively).

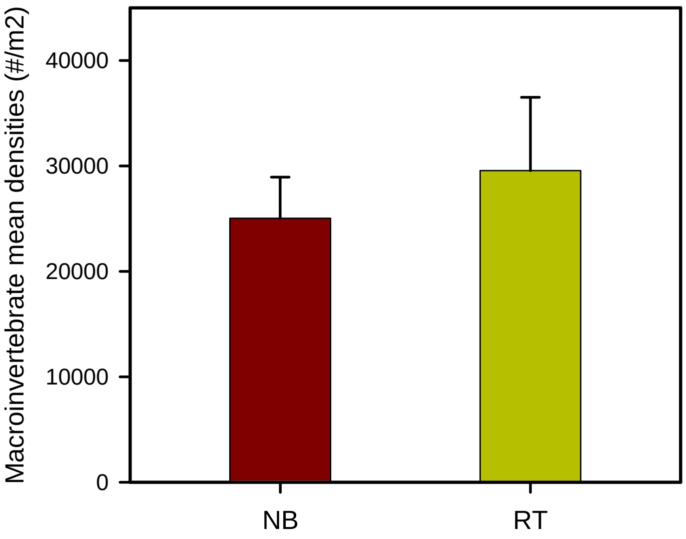


Figure 6. Means and standard errors of macroinvertebrate densities in ponar samples from North Bay (NB) and Radio Tower Bay (RTB) during summer 2011. The difference in density is not statistically significant.

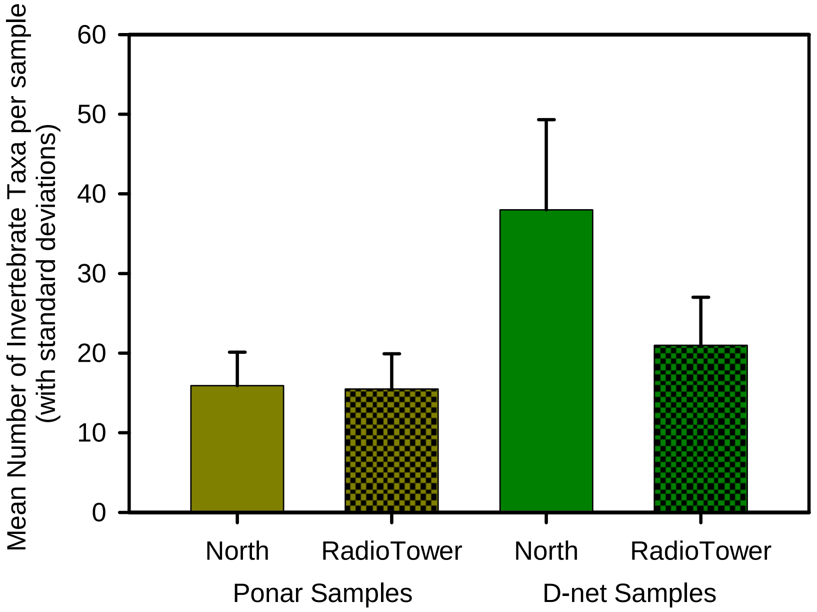


Figure 7. Means and standard deviations of macroinvertebrate taxa richness in ponar and D-net samples from North Bay (NB) and Radio Tower Bay (RTB) during summer 2011. D-net samples not tested statistically due to unbalanced sampling.

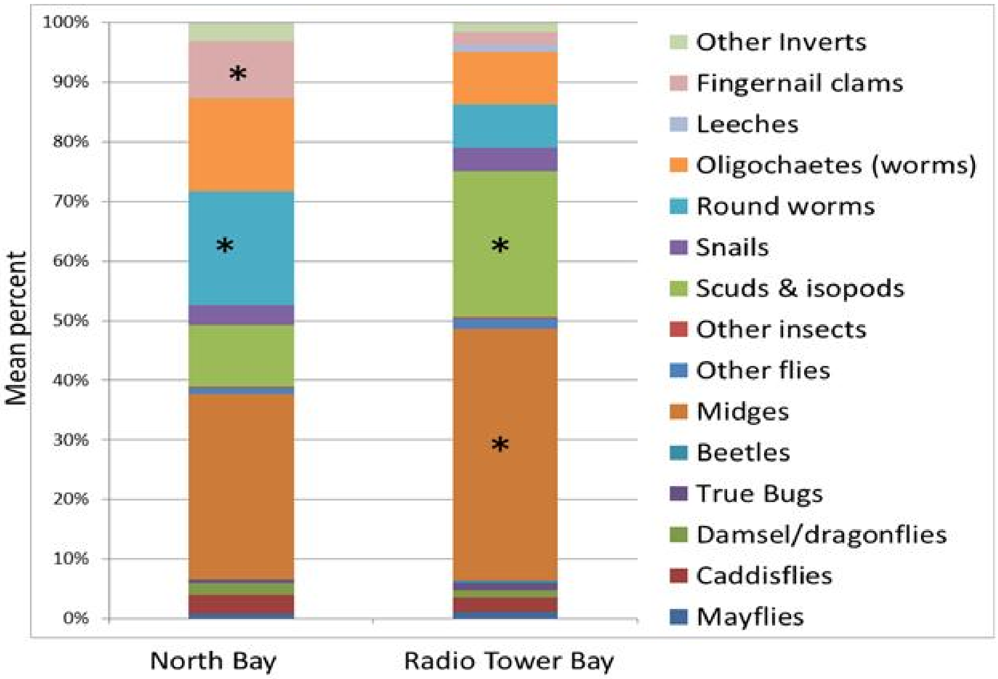


Figure 8. Overall macroinvertebrate assemblages, as percentages, for both bays using data collected by all sampling methods. Invertebrate types marked by * are statistically greater percentages of the marked community (t-test or rank sum test p<0.05).

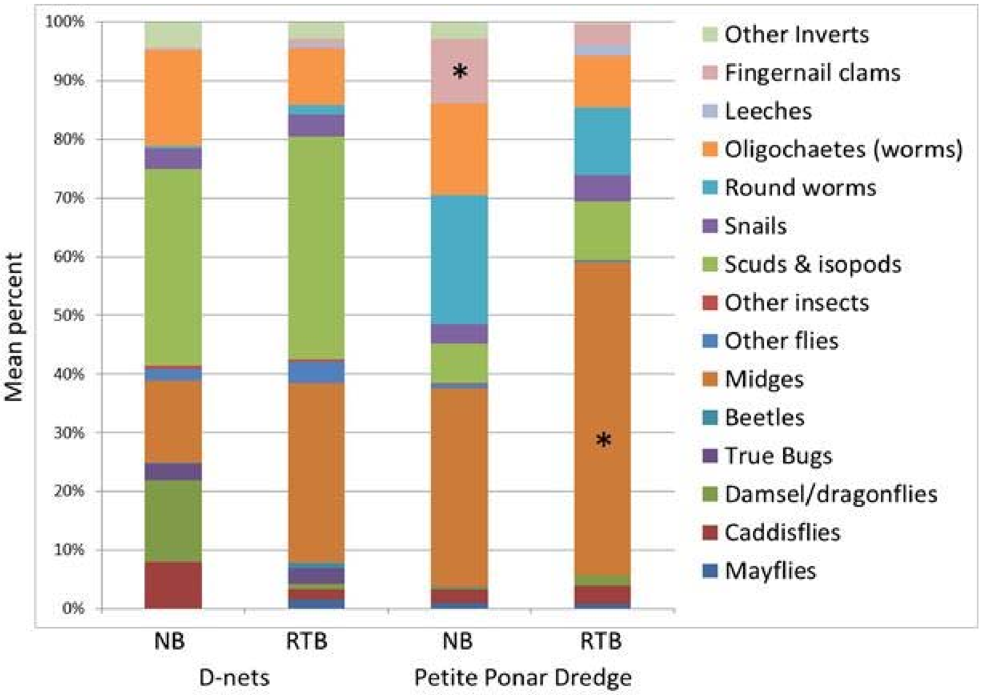


Figure 9. Macroinvertebrate assemblages, as percentages, for both bays with data collected by each sampling method shown separately. Invertebrate types marked by * are statistically greater percentages of the marked community (t-test or rank sum test p<0.05) for ponar samples only. D-net samples were not tested statistically due to unbalanced sample numbers.

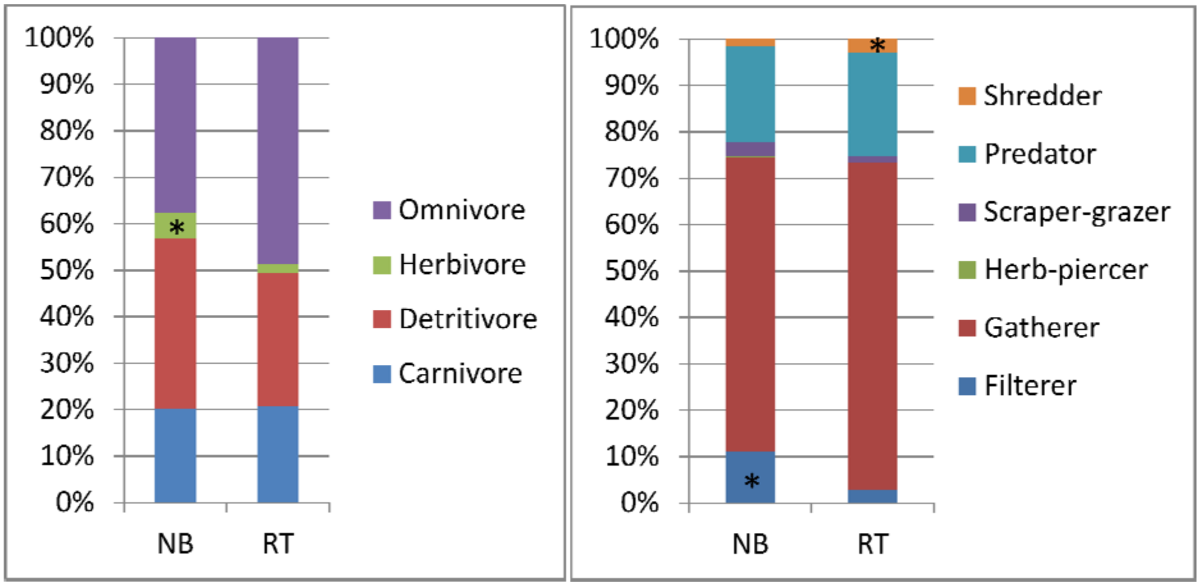


Figure 10. Macroinvertebrate trophic levels (left) and functional feeding groups (right), as percentages, for both North Bay (NB) and Radio Tower Bay (RT) with data collected by all sampling methods combined. Asterisks indicate significantly greater percentages between bays.

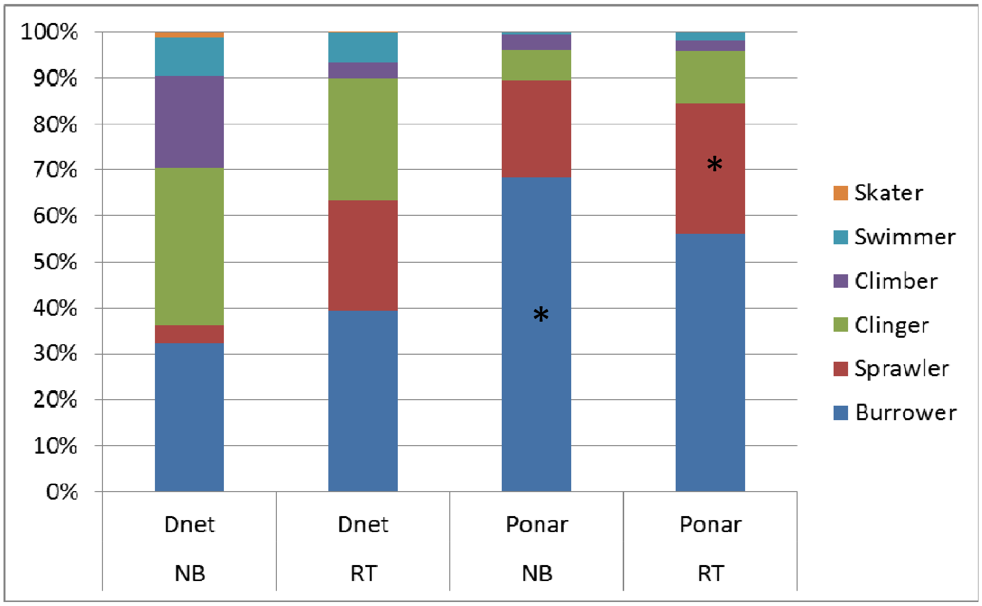


Figure 11. Macroinvertebrate behavioral groups as percentages, for both North Bay (NB) and Radio Tower Bay (RT) showing data collected the two primary sampling methods. Asterisks indicate significantly greater percentages among sites within a sampling method.

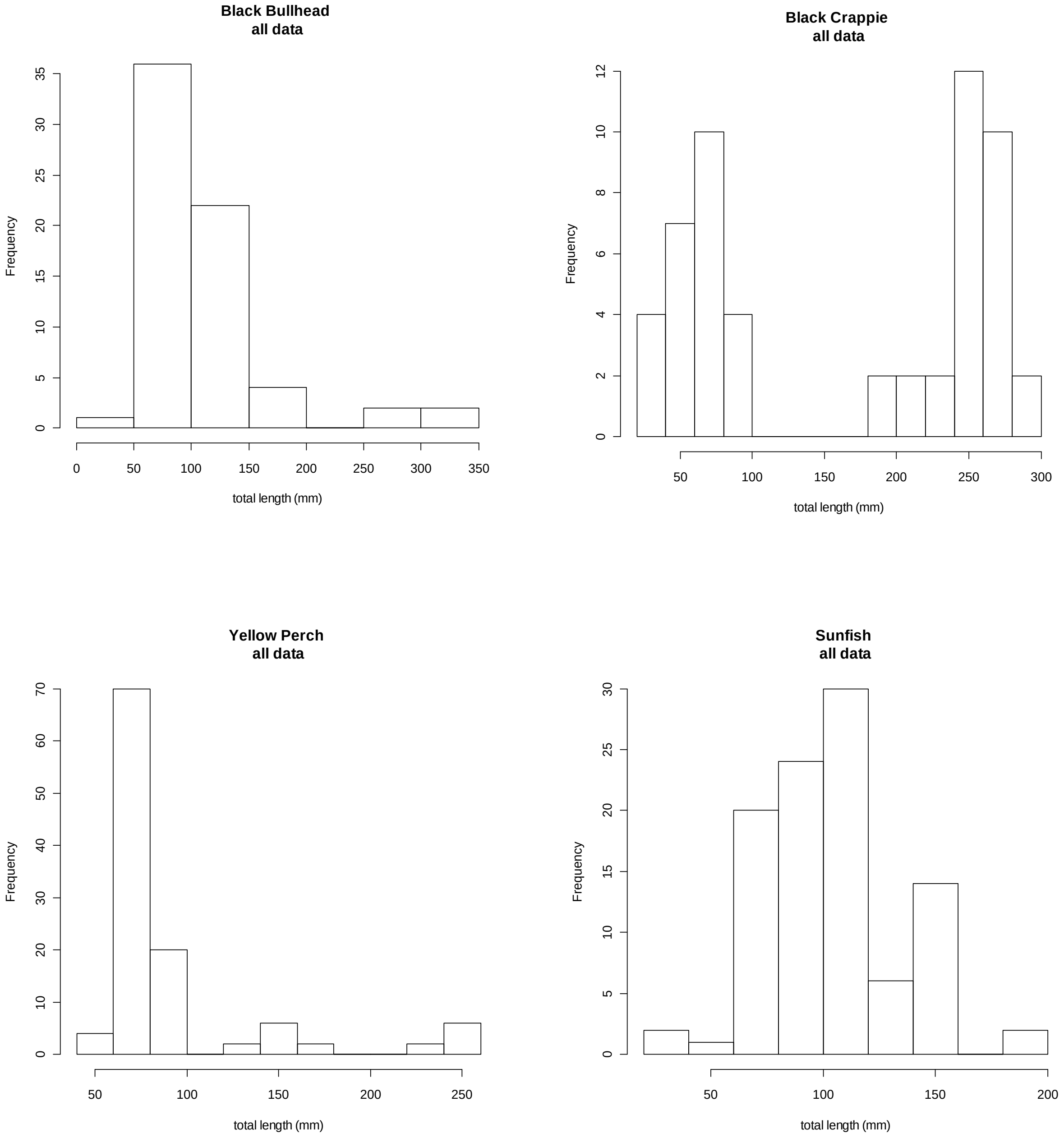


Figure 12. Histograms for four commonly occurring fish species captured in all nets over both sampling events. Although when pooled, counts and length data indicate suitable structure for separate year-class analysis, once data were stratified by location and sample event there were insufficient numbers available to determine difference by class. Consequently all age classes were included and analyzed by location and sampling event. Numbers indicate individual counts (y axis frequency) by a total fish length distributed by bin size (x axis).

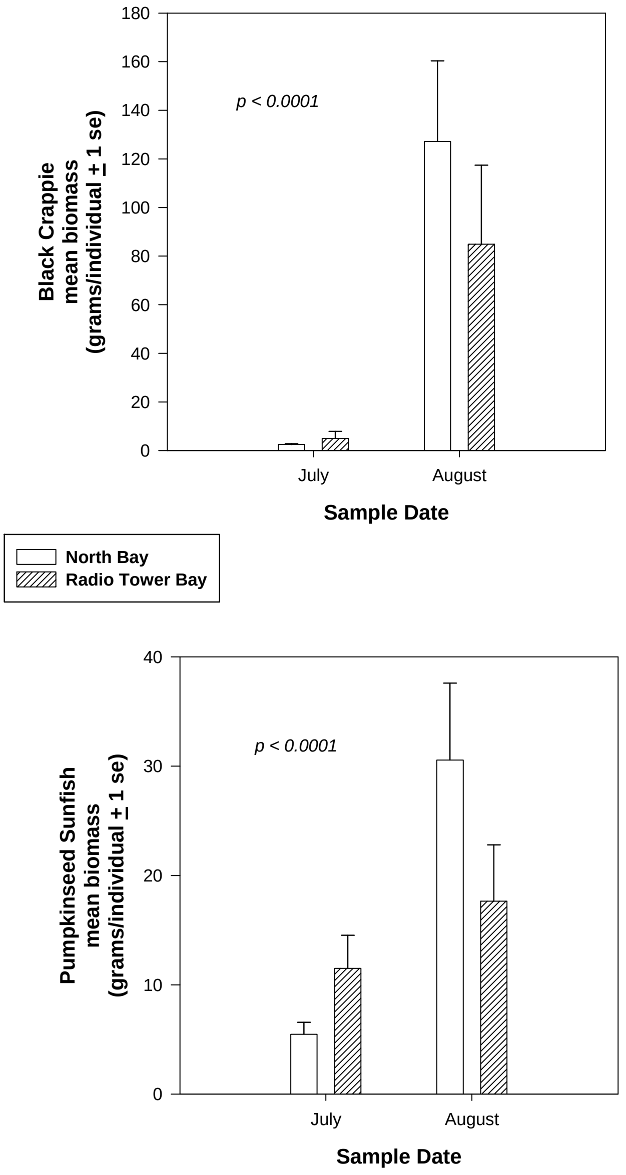


Figure 13. Mean weight of individual Black Crappie and Pumpkinseed Sunfish collected overnight using fyke-nets in North and Radio Tower Bay within the St. Louis River estuary. Data represent a mean weight of individuals (grams), ± 1 standard error, with all age-classes combined. Value *p* is from the overall ANOVA using site and date as class variables (SAS, 1988).

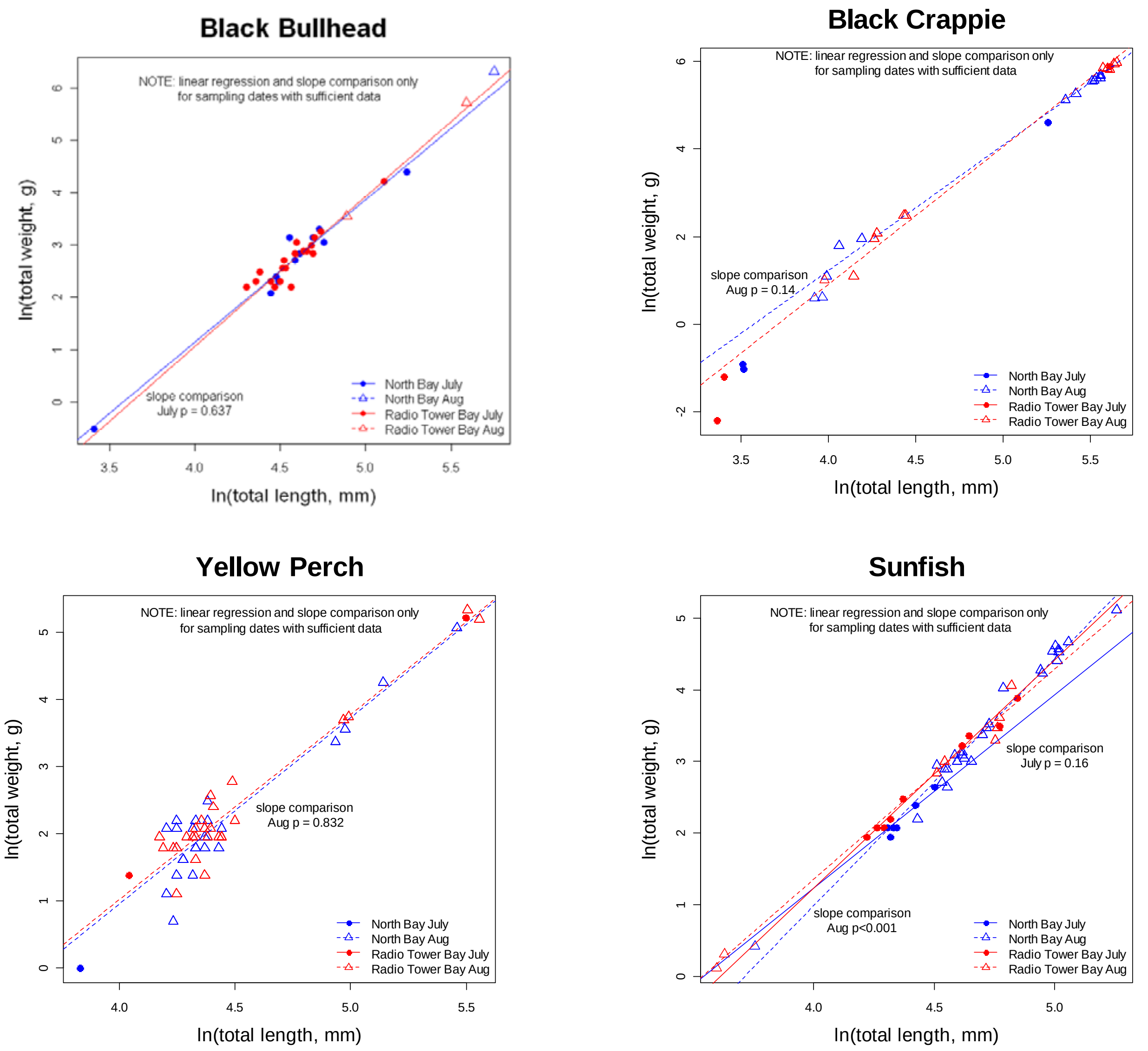


Figure 14. Total length to total weight regression relationships for four common fish species collected in North Bay and Radio Tower Bay on two sampling events in July and August, 2011. Although lengths were measured for all individuals plotted, the mean for several YOY were pooled as one point on the plot due to a batch-weight being the only method to record mass for those individuals. All other points represent individual lengths and corresponding weights of juvenile and adult fish. Data were analyzed separately by date to compare slopes and intercepts between sampling locations using an ANCOVA analysis procedure in the R statistical language.

Figure 15**.** A larval trap set in Radio Tower Bay during the 7/29/2011 sample event. Larval traps were set near aquatic vegetation edges and close to fyke net locations.

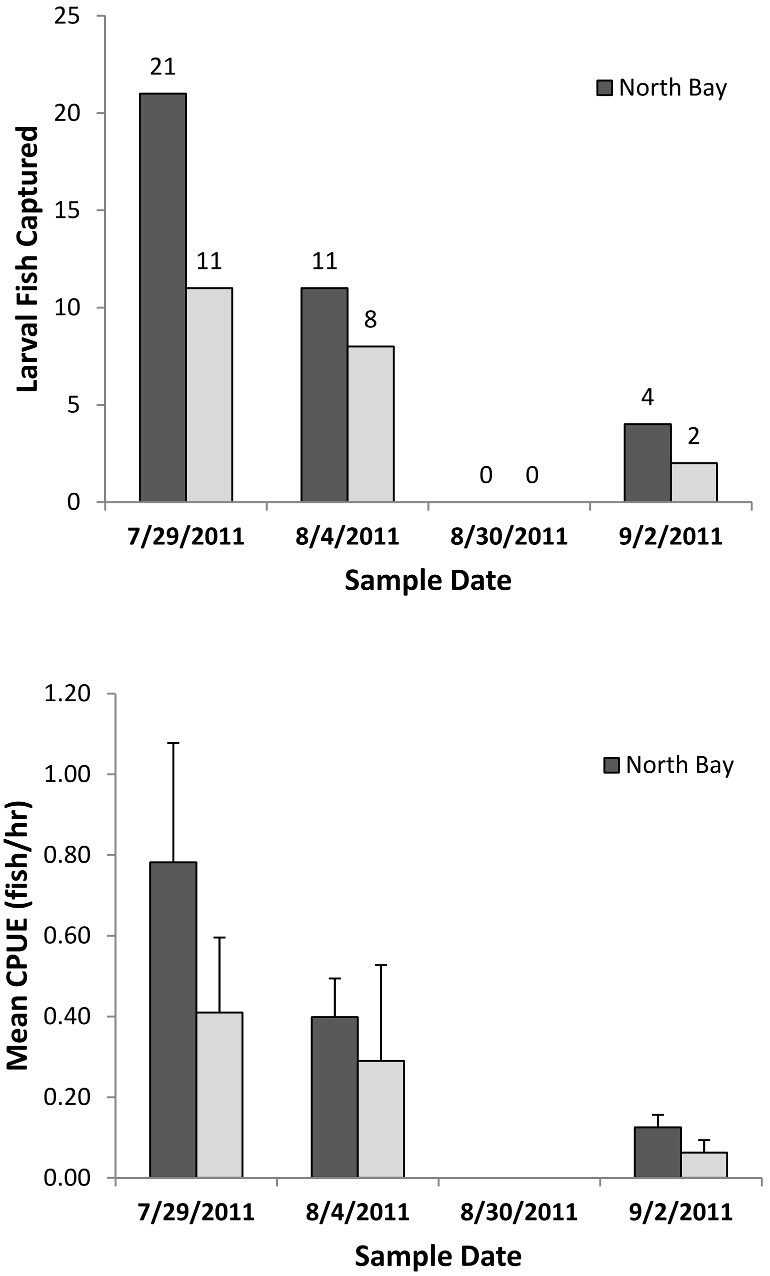
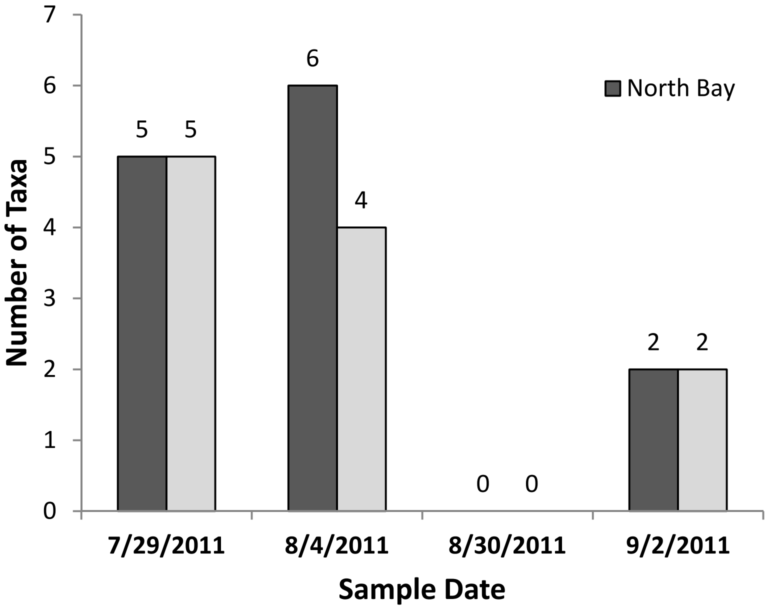


Figure 16. Total number of larval fish captured within Radio Tower and North Bays by sample date (top), and mean CPUE of fish/hr in Radio Tower and North Bays by sample date (bottom). Data represent total count or means ± 1 standard error (lower). For each bar n=3.



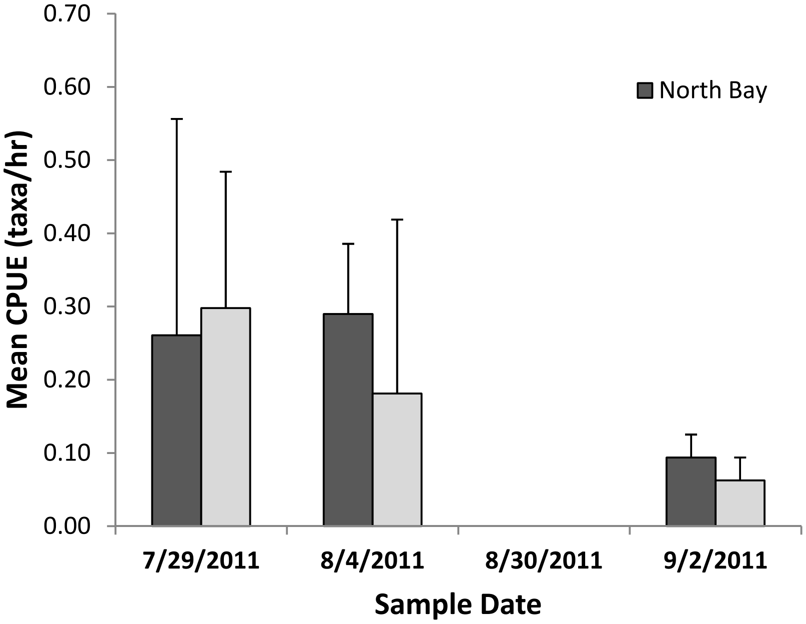


Figure 17. Number of larval fish species captured within Radio Tower and North Bays by sample date (top), and mean CPUE of taxa/hr in Radio Tower and North Bays by sample date. Data represent total count or means ± 1 standard error (bottom). For each bar n=3.

Appendix 1. Macroinvertebrate sample gear types, sampling dates, sampling locations, and habitat for data collected summer 2011.

Site	Point	Gear	Unique ID	Date	Ponar (%)	Sed Dom	Sed Sub	Depth (m)	Secchi (m)	Veg Dom	Veg Sub	Lat (dd)	Long (dd)
North Bay	1	Dnet(swp)	260	31-Aug-11		silt	muck	0.4	0.4	Sparganium	Schoenoplectus	46.6517	-92.2376
North Bay	3	Dnet(swp)	257	31-Aug-11		muck	muck	0.4	0.4	Myriophyllum	Sparganium	46.6526	-92.2423
North Bay	5	Pponar	533	31-Aug-11	75	muck	silt	0.59	0.49	Nymphea	Caltha	46.6526	-92.2399
North Bay	7	Pponar	536	31-Aug-11	50	muck	silt	0.7	0.6	Caltha	Ceratophyllum	46.6526	-92.2376
North Bay	9	Pponar	263	31-Aug-11	50	silt	muck	0.81	0.55	Vallisneria	Nymphea	46.6525	-92.2352
North Bay	12	Pponar	528	31-Aug-11	75	muck	silt	0.73	0.73	Vallisneria	Caltha	46.6534	-92.2411
North Bay	13	Pponar	255	31-Aug-11	100	silt	muck	1.4	0.5	Vallisneria	Nymphea	46.6534	-92.2399
North Bay	14	Pponar	525	31-Aug-11	75	muck	silt	1.3	0.69	Vallisneria		46.6534	-92.2387
North Bay	15	Pponar	540	31-Aug-11	75	muck	silt	1.5	0.5	Vallisneria		46.6534	-92.2376
North Bay	17	Pponar	513	31-Aug-11	75	muck	silt	1.2	0.69	Vallisneria		46.6533	-92.2352
North Bay	18	Pponar	509	31-Aug-11	75	muck	silt	0.7	0.54	Vallisneria	Nymphea	46.6533	-92.2340
North Bay	19	Pponar	520	31-Aug-11	25	clay	muck	0.8	0.6	open		46.6533	-92.2329
North Bay	21	Pponar	522	31-Aug-11	25	muck	silt	0.5	0.46	Vallisneria	Nymphea	46.6542	-92.2387
North Bay	23	Pponar	518	31-Aug-11	100	muck	silt	1.3	0.55	open		46.6542	-92.2364
North Bay	25	Pponar	541	31-Aug-11	75	muck	silt	0.6	0.58	Potamogeton		46.6542	-92.2340
Radio Tower	3	Dnet(swp)	544	1-Sep-11		muck	detritus	0.25	0.25	Typha		46.6529	-92.2152
Radio Tower	5	Dnet(swp)	548	1-Sep-11		wood	muck	0.52	0.52	Myriophyllum	Elodea	46.6536	-92.2162
Radio Tower	6	Dnet(scp)	553	1-Sep-11		wood	wood	0.44	0.44	open		46.6536	-92.2152
Radio Tower	7	Pponar	561	1-Sep-11	25	muck	detritus	0.53	0.53	open		46.6536	-92.2142
Radio Tower	8	Pponar	248	31-Aug-11	50	silt	muck	0.45	0.45	Ceratophyllum	Elodea	46.6536	-92.2132
Radio Tower	10	Pponar	266	1-Sep-11	50	muck	silt	0.43	0.43	Sagittaria	Sparganium	46.6535	-92.2113
Radio Tower	11	Dnet(scp)	220	1-Sep-11		wood	muck	0.37	0.37	Potamogeton	Caltha	46.6543	-92.2171
Radio Tower	12	Dnet(scp)	556	1-Sep-11		wood	muck	0.43	0.43	Myriophyllum	Potamogeton	46.6543	-92.2162
Radio Tower	14	Dnet(scp)	221	1-Sep-11		wood	muck	0.6	0.6	Potamogeton		46.6542	-92.2142
Radio Tower	15	Scrub	253	31-Aug-11		wood	wood	0.5	0.5	Sparganium		46.6542	-92.2132
Radio Tower	17	Pponar	271	1-Sep-11	50	muck	detritus	0.6	0.6	Nymphea	Sparganium	46.6542	-92.2113
Radio Tower	18	Pponar	269	1-Sep-11	50	muck	detritus	0.4	0.4	Nymphea	Vallisneria	46.6542	-92.2103
Radio Tower	21	Pponar	216	1-Sep-11	25	muck	detritus	0.58	0.58	Nymphea	Potamogeton	46.6549	-92.2142
Radio Tower	23	Pponar	214	1-Sep-11	25	muck	detritus	0.52	0.52	Potamogeton	Nymphea	46.6549	-92.2122
Radio Tower	24	Pponar	150	1-Sep-11	75	muck	detritus	0.58	0.58	Nymphea	Nuphar	46.6549	-92.2113

Appendix 2. List of all macroinvertebrate taxa identified from North Bay (NB) and Radio Tower Bay (RT) in the St. Louis River Estuary in summer 2011. Also included are the trophic, functional feeding, and behavior group classifications, along with tolerance rating from Hilsenhoff (1987) and US EPA (1999).

Site	Phylum	Class	Order	Family	Taxa	Trophic Group	Funct Group	Behavior	HIBI 87	EPA Tol
Both					Nematoda	omnivore	gatherer	burrower		5
RT	Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	Erpobdellidae	carnivore	predator	swimmer		3
RT	Annelida	Clitellata	Hirudinea		Hirudinea	carnivore	predator	swimmer		
Both	Annelida	Clitellata	Oligochaeta		Oligochaeta	detritivore	gatherer	burrower		9
Both	Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	Glossiphoniidae	carnivore	predator	swimmer		7
NB	Annelida	Polychaeta			Polychaeta					
Both	Arthropoda	Arachnida	Acari		Acari	carnivore	predator	climber		8
Both	Arthropoda	Crustacea	Isopoda	Asellidae	Caecidotea	detritivore	gatherer	sprawler	8	8
Both	Arthropoda	Gastropoda	Basommatophora	Physidae	Physella	herbivore	grazer	clinger		8
RT	Arthropoda	Insecta	Coleoptera		Coleoptera	omnivore	gatherer	clinger		
NB	Arthropoda	Insecta	Coleoptera	Chrysomelidae	Chrysomelidae	herbivore	shredder	clinger		
Both	Arthropoda	Insecta	Coleoptera	Curculionidae	Curculionidae	herbivore	shredder	clinger		
RT	Arthropoda	Insecta	Coleoptera	Dytiscidae	Agabus	carnivore	predator	swimmer		
RT	Arthropoda	Insecta	Coleoptera	Dytiscidae	Ilybius	carnivore	predator	swimmer		5
NB	Arthropoda	Insecta	Coleoptera	Elmidae	Elmidae	detritivore	gatherer	clinger		4
Both	Arthropoda	Insecta	Coleoptera	Haliplidae	Haliplus	herbivore	piercer	climber		8
NB	Arthropoda	Insecta	Coleoptera	Haliplidae	Peltodytes	omnivore	shredder	climber		
RT	Arthropoda	Insecta	Coleoptera	Hydraenidae	Hydraena	carnivore	predator	clinger		
RT	Arthropoda	Insecta	Coleoptera	Lampyridae	Lampyridae					
Both	Arthropoda	Insecta	Collembola		Collembola	detritivore	gatherer	skater		7
NB	Arthropoda	Insecta	Diptera		Diptera	omnivore	gatherer	sprawler		
Both	Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia	carnivore	predator	burrower	6	6
Both	Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogonidae	omnivore	predator	sprawler		5.7
Both	Arthropoda	Insecta	Diptera	Ceratopogonidae	Probezzia	carnivore	predator	burrower	6	6
NB	Arthropoda	Insecta	Diptera	Ceratopogonidae	Sphaeromias	carnivore	predator	burrower		
Both	Arthropoda	Insecta	Diptera	Chaoboridae	Chaoborus	carnivore	predator	sprawler	8	
Both	Arthropoda	Insecta	Diptera	Chironomidae	Chironomidae	omnivore	gatherer	burrower		6
Both	Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	omnivore	gatherer	burrower		
Both	Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	herbivore	gatherer	burrower		5
Both	Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	carnivore	predator	sprawler		7
Both	Arthropoda	Insecta	Diptera	Culicidae	Culicidae	detritivore	filterer	swimmer		

Appendix 2 (cont).

Site	Phylum	Class	Order	Family	Taxa	Trophic Group	Funct Group	Behavior	HIBI 87	EPA Tol
NB	Arthropoda	Insecta	Diptera	Ephydridae	Ephydridae	omnivore	gatherer	burrower		6
Both	Arthropoda	Insecta	Diptera	Stratiomyiidae	Odontomyia	detritivore	gatherer	sprawler		
NB	Arthropoda	Insecta	Diptera	Stratiomyiidae	Stratiomys	detritivore	gatherer	sprawler		
NB	Arthropoda	Insecta	Diptera	Tabanidae	Chrysops	detritivore	gatherer	sprawler	6	6
RT	Arthropoda	Insecta	Diptera	Tipulidae	Antocha	detritivore	gatherer	clinger	3	3
Both	Arthropoda	Insecta	Ephemeroptera		Ephemeroptera	detritivore	gatherer	swimmer		
Both	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetidae	detritivore	gatherer	swimmer		4
Both	Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis	detritivore	gatherer	sprawler	7	7
RT	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Hexagenia	detritivore	gatherer	burrower	6	
Both	Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae	carnivore	predator	swimmer		6
Both	Arthropoda	Insecta	Hemiptera	Corixidae	Trichocorixa	carnivore	predator	swimmer		
Both	Arthropoda	Insecta	Hemiptera	Hydrometridae	Hydrometra	carnivore	predator	skater		
NB	Arthropoda	Insecta	Hemiptera	Mesoveliidae	Mesovelia	carnivore	predator	skater		
NB	Arthropoda	Insecta	Hemiptera	Nepidae	Ranatra	carnivore	predator	climber		
RT	Arthropoda	Insecta	Hemiptera	Notonectidae	Buenoa	carnivore	predator	swimmer		
NB	Arthropoda	Insecta	Hemiptera	Saldidae	Saldidae	carnivore	predator	climber		10
Both	Arthropoda	Insecta	Lepidoptera		Lepidoptera	herbivore	shredder	climber		6
Both	Arthropoda	Insecta	Lepidoptera	Pyralidae	Paraponyx	herbivore	shredder	climber	5	
NB	Arthropoda	Insecta	Odonata		Zygoptera	carnivore	predator	climber		
RT	Arthropoda	Insecta	Odonata	Aeshnidae	Aeshna	carnivore	predator	climber	5	5
NB	Arthropoda	Insecta	Odonata	Aeshnidae	Anax	carnivore	predator	climber	8	
Both	Arthropoda	Insecta	Odonata	Coenagrionidae	Coenagrionidae	carnivore	predator	climber		
Both	Arthropoda	Insecta	Odonata	Coenagrionidae	Enallagma	carnivore	predator	climber	8	
NB	Arthropoda	Insecta	Odonata	Libellulidae	Libellulidae	carnivore	predator	sprawler		9
NB	Arthropoda	Insecta	Trichoptera		Trichoptera	detritivore	shredder	clinger		4
Both	Arthropoda	Insecta	Trichoptera	Dipseudopsidae	Phylocentropus	detritivore	filterer	burrower	5	5
NB	Arthropoda	Insecta	Trichoptera	Hydroptilidae	Agraylea	herbivore	piercer	climber	8	8
NB	Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilidae	herbivore	piercer	clinger		6
NB	Arthropoda	Insecta	Trichoptera	Hydroptilidae	Orthotrichia	herbivore	piercer	clinger		
NB	Arthropoda	Insecta	Trichoptera	Hydroptilidae	Oxyethira	herbivore	piercer	climber	3	3
RT	Arthropoda	Insecta	Trichoptera	Leptoceridae	Leptoceridae	omnivore	gatherer	climber		4
NB	Arthropoda	Insecta	Trichoptera	Leptoceridae	Nectopsyche	herbivore	shredder	climber	3	

Appendix 2 (cont).

Site	Phylum	Class	Order	Family	Taxa	Trophic Group	Funct Group	Behavior	HIBI 87	EPA Tol
Both	Arthropoda	Insecta	Trichoptera	Leptoceridae	Oecetis	omnivore	predator	clinger	8	8
Both	Arthropoda	Insecta	Trichoptera	Leptoceridae	Triaenodes	herbivore	shredder	swimmer	6	6
Both	Arthropoda	Insecta	Trichoptera	Phryganeidae	Phryganea	omnivore	shredder	climber	8	
NB	Arthropoda	Insecta	Trichoptera	Phryganeidae	Phryganeidae	omnivore	shredder	climber		
NB	Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropodidae	omnivore	filterer	clinger		6
Both	Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropus	omnivore	filterer	clinger	6	6
Both	Arthropoda	Malacostraca	Amphipoda		Amphipoda	omnivore	gatherer	swimmer		4
Both	Arthropoda	Malacostraca	Amphipoda	Gammaridae	Gammarus	omnivore	gatherer	clinger	4	4
Both	Arthropoda	Malacostraca	Amphipoda	Hyalellidae	Hyalella	detritivore	gatherer	clinger	8	8
Both	Coelenterata	Hydrozoa	Hydroida	Hydridae	Hydra	carnivore	predator	clinger		5
Both	Mollusca	Bivalvia	Veneroida	Sphaeriidae	Sphaeriidae	detritivore	filterer	burrower		8
RT	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Pseudosuccinea	herbivore	grazer	clinger		
Both	Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbella	detritivore	shredder	clinger		
NB	Mollusca	Gastropoda	Limnophila	Ancylidae	Ferrissia	herbivore	grazer	clinger		6.9
NB	Mollusca	Gastropoda	Limnophila	Lymnaeidae	Lymnaea	herbivore	grazer	clinger		
RT	Mollusca	Gastropoda	Limnophila	Lymnaeidae	Lymnaeidae	herbivore	grazer	clinger		6
RT	Mollusca	Gastropoda	Limnophila	Planorbidae	Armiger	detritivore	grazer	clinger		
Both	Mollusca	Gastropoda	Limnophila	Planorbidae	Gyraulus	detritivore	shredder	clinger		3
NB	Mollusca	Gastropoda	Limnophila	Planorbidae	Helisoma	herbivore	grazer	clinger		6
Both	Mollusca	Gastropoda	Limnophila	Planorbidae	Planorbidae	detritivore	shredder	clinger		7
Both	Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	Hydrobiidae	herbivore	grazer	clinger		7
Both	Mollusca	Gastropoda	Mesogastropoda	Valvatidae	Valvata	herbivore	grazer	clinger		8
RT	Mollusca	Pelecypoda	Unionoida	Unionidae	Unionidae	detritivore	filterer	burrower		8
NB	Platyhelminthes	Turbellaria			Turbellaria	omnivore	grazer	swimmer		4

Appendix 3. Location and habitat around fyke net fishing gear used in North Bay (NB) and Radio Tower Bay (RTB) in the St. Louis River Estuary, Summer 2011.

Site	Rep	Way point	Gear	Veg Type	% Emerg	Emerg Dom Sp	% Float Leaf	Float Dom Sp	% Submerg	Sub Dom Sp	% Bare/open	Lat	Long
NB	1	37	Fyke	Scirpus	60	Bulrush mix	0		0		40	N46.65253	W092.23357
NB	2	38	Fyke	Typha	75	Typha	0		20	Ceratophylum	5	N46.65382	W092.24241
NB	3	39	Fyke	Scirpus	60	Bulrush	10	Nuphar/Val.	10	Ceratophylum	20	N46.65421	W092.23766
NB	1	199	Fyke	Mixed	75	Scirpus/Sparg	0		5	Elodea	20	N46.65278	W092.23277
NB	Array	200	Fyke	Open	0		0		20	Vallisneria	80	N46.65400	W092.23403
RTB	1	34	Fyke	Open	10	Bulrush	30	Nuphar	20	Ceratophylum	40	N46.65547	W092.21308
RTB	2	35	Fyke	Mixed	40	Typha	40	Nuphar	15	Ceratophylum	5	N46.65513	W092.21494
RTB	3	36	Fyke	Mixed	80	Typha	0		0		20	N46.65310	W092.21461
RTB	3	197	Fyke	Mixed	80	Typha	0		0		20	N46.65305	W092.21475
RTB	Array	198	Fyke	Open	0		0		5	Coontail	95	N46.65402	W092.21474