FINAL REPORT
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MONITORING AND EVALUATION OF COASTAL HABITATS FOR POTENTIAL RESTORATION ACTIVITIES

To
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Michigan Dept. of Environmental Quality
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Introduction

Wetlands in the coastal zone of the Great Lakes have been converted to agriculture, urban, and suburban land uses since the 1800's with losses of more than 50 % of wetlands since European settlement of Michigan began (Dahl 1990, Comer et al. 1995). These losses are continuing for certain types of wetlands (Dahl 2000) and, perhaps, accelerating with the recent trends in urban sprawl. As losses of relatively pristine lands in private ownership occur, greater pressure is placed on publicly owned lands to provide habitat for wildlife, serve as repositories of biodiversity including protection of threatened and endangered species, and provide recreational opportunities for Michigan citizens including hunting, fishing, bird watching, wildlife viewing, etc. Thus, there is a need to: (1) identify converted or disturbed wetlands sites in public ownership that are suitable for restoration, (2) identify critical publicly owned high quality wetlands in the coastal zone so that managers can place a high priority on sustainable management of them, and (3) collect baseline data on biota of these wetlands to document their value and serve as a basis for comparison of their biotic integrity in the future.

Coastal wetlands originally formed an almost continuous fringe along much of Saginaw Bay and many other bays and shallow coastal areas of the Great Lakes shoreline (Comer et al. 1995, Minc 1997, Minc and Albert 1998, Keough et al. 1999). Only about 50 % of Great Lakes coastal marshes remain relative to historical estimates. The decline has resulted primarily from intensive land conversion and settlement within the Great Lakes basin, especially for the lower Great Lakes (Comer et al. 1995). Approximately 65,547 ha of coastal wetlands remain on the upper Great Lakes, with major complexes including Saginaw Bay (12,140 ha) and Georgian Bay (12,600) of Lake Huron and Green Bay (9,980 ha) and Big Bay de Noc (7,720 ha) of Lake Michigan (Prince et al. 1992). Despite the fairly extensive and numerous isolated complexes that remain, many aspects of the ecology of these systems remain poorly understood.

Several researchers have provided evidence that Great Lakes coastal marshes provide critical habitat for invertebrates, fish, birds and other species (see reviews in Krieger 1992, Jude and Pappas 1992, and Prince et al. 1992, Wilcox 1995, and Gathman et al. 1999). Prince et al. (1992) described coastal wetlands as important feeding and nursery habitats for waterfowl. Many species of Great Lakes fish feed heavily within coastal wetlands during at least some part of their life cycle (Brazner 1997, French 1988, Jude and Pappas 1992, and Liston and Chubb 1985). These studies suggest that coastal wetlands are critical habitats and nursery areas for maintenance of primary and secondary production in the Great Lakes. Despite the potential contribution of these wetlands to overall ecosystem function, research linking physical and floristic characterization of Great Lakes marsh types to the fauna is limited for Great Lakes coastal wetlands, especially for the wetlands inland of the mean high water mark.

For more than a decade, we have collaborated with several other researchers to systematically sample Lake Huron and Michigan coastal wetlands and explore many of the dominant characteristics of coastal wetlands that may be important structuring forces for plant, invertebrate, fish and bird communities. This research has resulted in numerous reports (e.g. Albert et al. 1987, 1988, 1989, Prince and Burton 1995, Minc 1997, Chow-Fraser and Albert 1998, Minc and Albert 1998, Gathman and Keas 1999), theses and dissertations (e.g. Brady 1992, 1996, Cardinale 1996, Whitt 1996, Young 1996, Kashian 1998, Gathman 2000, Riffell 2000, Stanley 2000, Stricker 2003, Vaara 2001), and refereed papers and book chapters (e.g. Brady and Burton 1995, Brady et al. 1996, Cardinale et al. 1997, 1998, Gathman et al. 1999, Kashian and Burton 2000, Burton et al. 2001, Riffell et al. 2001a, 2001b). This work has allowed us the opportunity to describe the communities from a diversity of habitats and begin to identify potential mechanisms contributing to the community composition.

In this report we define ‘coastal wetlands’ as including: (1) the fringing wetlands extending from the shore into the littoral zone of the Great Lakes, (2) the riparian wetlands along rivers and drowned river-mouth lakes that are potentially influenced by short-term (seiche and storm surge induced) changes in water levels, and (3) marshes and swamps in the coastal zone inland from the lakeshore that are not directly affected by short term water level changes in the Great Lakes. Before this project began, the majority of our research to date has emphasized the fringing, littoral and riverine wetlands with direct surface water connections to the Great Lakes, although some research on coastal zone wet meadows and other types of wetlands not directly connected to the lakes has been included (e.g. Burton et al. 2002, Stanley et al. 2000, Riffell et. al. 2002, 2003). Unlike the adjacent littoral marshes, the inland marshes and swamps are not directly exposed to waves, storm surges, or seiches, since they are only connected to the Great Lakes via subsurface water movements in most years. However, water level changes in the inland, coastal zone wetlands may be influenced by lake levels either through direct exchange of water via subsurface movements through sandy and other relatively porous soils or through changes in direction and rate of groundwater movements as lake levels influence depth of the water table in the coastal zone. Groundwater inputs from adjacent upland areas also influence these coastal zone wetlands and make them important transition zones between uplands and littoral wetlands.

With increased restoration efforts and funds, there is a great opportunity to begin restoring swamp forest, the component of coastal wetlands that saw the greatest level of elimination in the past (Comer et al. 1995), and to restore the mixed wetland/upland habitat that supports high biodiversity in the coastal zone of the Great Lakes. Swamp forest, lakeplain wet prairies and wet meadows were the coastal wetlands most easily converted to agricultural management, requiring less drainage than deeper emergent marshes. Once drained, these former wetlands also flooded less frequently than drained coastal marshes. Thus, little farmland created in this zone has been abandoned and allowed to return to functional wetland. One of the goals of this project was to sample coastal swamps and depressional wetlands in an effort to provide baseline data on biota characteristic of these sites. A second goal was to use our findings to identify sites in public ownership that have high potential for restoration. We used bioassement protocols to obtain baseline data while also providing us with a measure of anthropogenic disturbance a particular system is experiencing. We used these biotic data in conjunction with chemical/physical and land use/cover data to further develop our indices of biotic integrity.

We have developed a macroinvertebrate based bioassessment procedure for coastal wetlands in Michigan (e.g. Burton et al. 1999, Kashian and Burton 2000, Uzarski et al. submitted, also see summary report from the BAWWG web site (http://www.epa.gov/owow/wetlands/bawwg/case.html, the bioassessment wetlands working group organized by U.S. EPA)). Wilcox et al. (2002) attempted to develop wetland IBIs for the upper Great Lakes using macrophytes, fish, and microinvertebrates. Some of their metrics showed promise, but they concluded that natural water level changes were likely to alter communities and invalidate metrics. We have developed macroinvertebrate based IBI’s that take into account the fluctuating water levels of Great Lakes coastal wetlands by sampling within distinct plant community zones and basing the IBI only on inundated zones. We are confident that our macroinvertebrate IBI is valid under a wide range of water levels (e.g. Uzarski et al. submitted). We are working on fish and plant based metrics that can be adjusted over water level changes and believe that a viable IBI can be developed based on these taxa as well.

Minns et al. (1994) applied Karr's approach of using fish as indicators of stream biotic integrity (e.g., Karr 1981, Karr et al. 1986) to marshes of the Great Lakes' Areas of Concern. The metrics employed by Minns et al. (1994) were sensitive to impacts on ecosystem integrity by

exotic fishes, water quality changes, physical habitat alteration, and changes in piscivore abundance related to fishing pressure and stocking. Even though several authors and SOLEC 1998 have suggested use of fish as indicators of wetland ecosystem health for Great Lakes coastal wetlands, no widely accepted system for wetland evaluation based on fish has been developed. Our work and the work of Brazner (1997), Brazner and Beals (1997),Minns et al. (1994) and Thoma (1999) suggests that IBI development should be relatively straight-forward. Our data presented here appear very promising. All the fish research in 2003 was reported in the joint report on this project filed earlier by Don Uzarski and will not be in this report.

The objective of this study was to sample several wetlands in two areas of Lake Michigan (those associated with eastern Lake Michigan drowned river mouth wetlands and northern Lake Michigan fringing wetlands from the Straits of Mackinac to the Michigan shoreline of northern Green Bay including Little and Big Bay de Noc) and three areas of Lake Huron (Saginaw Bay, Thunder Bay, and Les Cheneaux Islands) to adequately characterize the flora and fauna to provide a baseline for restoration of wetlands in the coastal zone while quantifying the amounts of disturbance each system had already experienced. We also continued development and testing of indices of biotic integrity based on plant, invertebrate and fish communities that can be used to assess condition of existing sites and serve as a basis for measuring success of wetland restoration efforts in the coastal zone after they are undertaken.

Dr. Donald Uzarski has written up most of the data we collected on fringing and drowned river mouth wetlands and included it in our joint report that he submitted earlier. He also included data on the depressional (palustrine) wetlands sampled in the coastal zone of Lake Michigan. His report and this one are essentially reports of joint activities, since Drs. Uzarski and Burton jointly planned, integrated, and carried out all of their activities together on this and other coastal wetland projects with complete sharing of data. Thus, his report included Burton as a co-author, and most of our joint results were included in that report and will not be reported in this one. This report represents a summary of the remaining data collected by both or our crews for this project. Specifically, it includes all data collected from inland, depressional (palustrine) wetlands in the coastal zone of the Saginaw Bay, Misery Bay and Les Cheneaux areas of Lake Huron. Since these palustrine wetlands support few fish, the emphasis was on macroinvertebrates, frogs and toads, and call back recordings designed to elicit responses from secretive birds such as rails and bitterns. Dr. Albert (MSU-E) Albert has already submitted a report covering all of plant data collected for the project.

Methods

Great Lakes Palustrine Site Selection

Sites were selected based on proximity to the Great lakes as well as access through public lands. I will report on macroinvertebrate data collected from 12 sites located in the coastal zone of Lake Huron. Data from the coastal zone of Lake Michigan were included in the report from Uzarski as were data from all fringing wetlands sampled in 2002 on this and other funded research projects involving coastal zone wetlands. The frog and toad call surveys for Saginaw Bay included data from 24 call stations located at easy to access areas (generally along or at the ends of roads) in the coastal zone. Half of these call survey stations were located on the eastern side and the other half were located on the western side of the bay.

Sampling Procedures

Chemical and Physical Measurements- Basic chemical/physical parameters were sampled each time macroinvertebrate samples were collected. Analytical procedures followed Standard Methods for the Examination of Water and Wastewater (APHA 1985). These measurements included soluble reactive phosphorus (SRP), nitrate-N, ammonium-N, turbidity, alkalinity, temperature, dissolved oxygen (DO), and specific conductance. Quality assurance/quality control procedures followed protocols recommended by U.S. EPA.

Determination of Anthropogenic Disturbance - Six reference wetlands were sampled with three on Saginaw Bay (Au Gres at Noggle Road, Bradleyville Road, and Schmidt Road-Interior at Tobico Marsh) and three from the Alcona to Misery Bay (Alcona, Negewegon, and Misery Bay)(Figure 1). Four impacted sites were sampled; all four were located on Saginaw Bay (Vanderbilt Park Swamp, Vanderbilt Park Swamp-North, Tobico at Schmidt Road and Pinconning Swamp) (Figure 1). The extent of disturbance was determined using surrounding land use data obtained from existing digitized maps (MIRIS 2000), topographic maps, and personal observations. The percent urban plus agricultural land cover in a 1000 m buffer around the sample point was the primary criterion used in initial separation of sites. However, some of the "impacted" sites (e.g. the two Vanderbilt Park sites) were separated from adjacent agricultural land by a sandy, forested ridge and may not have been directly impacted by agriculture except through sub-surface flow.

Macroinvertebrates sampling - Macroinvertebrate samples were collected with standard 0.5 mm mesh, D-frame dip nets from May through July 2002. Macroinvertebrates were sampled from the center and edge of depressional wetlands in the coastal zone for relatively large wetlands. Most of the wetlands were small, and in those wetlands, all habitats were sampled in areas deep enough to permit sampling.

Dip net sampling entailed sweeps through the water at the surface and middle of the water column and above the sediment surface to ensure that an array of microhabitats were included if depth permitted. For most wetlands, however, shallow depths meant that dip nets would often extend from surface to the bottom. In the field, samples were placed in white pans and 50, 100, or 150 invertebrates were collected by picking all specimens from one area of the pan before moving on to the next. Plant detritus was sorted for a few additional minutes to ensure that sessile species were included in the sample. As a means of semi-quantifying samples, specimen picking was timed. Individual replicates were picked for one-half -person-hour, after which, if 150 specimens were not obtained, organisms were tallied, and picking continued to the next multiple of 50. Three replicate samples were collected within each plant community zone in order to obtain a measure of spatial variance within each zone.

Specimens were sorted to lowest operational taxonomic unit; this was most often genus or species. Taxonomic keys such as Thorp and Covich (1991) and Merritt and Cummins (1996), along with mainstream literature for species level, were used for identification. A reference collection of Trichoptera confirmed by Dr. Brian Armitage of the Ohio Natural History Survey and snails confirmed by Brian Keas of Ohio Northern University or Richard Snider of Michigan State University were also used in species identification.

Fish sampling - No fish sampling was conducted in the inland wetlands. When fish were present and collected in dip nets, their presence was recorded.

Initial work to identify and combine metrics into an IBI - Initially, correspondence analyses of invertebrate and fish community composition was used to determine if reference sites separate from impacted sites. When they did, individual taxa containing the most inertia responsible for the separation were deemed potential metrics. Mann-Whitney U tests were then used to determine if densities of these taxa at reference sites were significantly different from densities at impacted sites.

Attributes that showed an empirical and predictable change across a gradient of human disturbance were chosen as metrics and included in our multi-metric IBI. Pearson Correlation analysis was also used to link state with stressor by relating potential metrics to specific parameters impacted by anthropogenic disturbance. Finally, stressor-land use relationships were explored to aid in management decisions.

We used medians in place of means for measuring assemblages of invertebrates, since invertebrate parameters are highly variable. Medians are more resistant to effects of outliers. Our goal was to typify the wetland. If an area was sampled that was depleted or concentrated in the constituents of a metric, the area may have been isolated from anthropogenic disturbance, receiving a dose of disturbance not typical of the entire wetland or vegetation zone, or it may have contained some "natural" chemical/physical component that was unique. Regardless of the cause, the area was not representative of the entire wetland. The influence of those outliers was dampened by using the median in place of mean as a measure of central tendency.

Results

Palustrine Invertebrate Data - We collected invertebrate data from 10 forested, depressional (palustrine) wetlands in 2002 (Figure 1) with 6 of these sites located in the coastal zone of Saginaw Bay and the others in the coastal zone of Lake Huron between Saginaw Bay and Misery Bay, North of Alpena (Figure 1, Tables 1, 2). The two sites with (2) in parentheses (Figure 1) were subdivided into two sites with samples taken from different habitats several hundred meters apart. The four more northern sites included the AuGres site, since it was north of most Saginaw Bay sites and further away from the Bay than were other Saginaw Bay sites. Sites were also classified as reference (6) or impacted (4) based on land cover in a 1000 m buffer around each site using digital land cover data obtained from the MIRIS system of Michigan Department of Natural Resources (Table 3).

Total invertebrate taxa collected per site ranged from 15 to 27 for the 6 reference sites and from 15 to 34 for the 4 impacted sites (Table 3). Non-insect invertebrates dominated the invertebrate fauna at most sites with insect taxa being less important but still major components of total invertebrates collected (Tables 1, 2; Figures 1, 2).

The top ten non-insect invertebrate family (or higher) level taxa included one family of segmented worms (the Naididae), leeches (Hirudinea), fingernail clams (Sphaeriidae), 3 families of snails (plus an unknown group of snails that could not be identified), water mites (Hydracarina), an isopod family (Asellidae) and an amphipod family (Crangocytidae) with snails, fingernail clams, isopods and amphipods being the most important non-insect taxa at most sites (Figure 2).

Molluscan invertebrates were very important contributors to the invertebrate fauna from all sites (Tables 1, 2 and Figure 2). Aquatic snails (Gastropoda) in the Families Lymnaeidae, Physidae, and Planorbidae) comprised from 5.7 to 31.3 % relative abundance of all invertebrates for the reference sites (Table 1) and from 10.2 to 26.6 % for the four impacted sites (Table 2). All unidentified snails were collected from two of the impacted sites, and we suspect that they

were terrestrial snails. Fingernail clams (Bivalvia, Sphaeriidae) were also important components of the invertebrate fauna making up from 5.1 to 44.9 % relative abundance at the reference sites and from 3.8 to 48 % relative abundance at the impacted sites (Table s 1, 2 and Figure 2).

Crustaceans (primarily Isopoda and Amphipoda) were also very common contributors to the invertebrate fauna (Tables 1, 2). Isopods (Asellidae, *Caecidotea*) made up from 9.6 to 44.6 relative abundance at the reference sites (Table 1) and from 0 to 48.7 % relative abundance at the impacted sites (Table 2). The Vanderbilt Park Swamp site was unique in that no isopods were collected from it (Table 2). Amphipods (Crangocyctidae, *Crangonyx*) were also very important contributors to relative abundance at most sites (Tables 1, 2, Figures 1, 2).

The most important insect taxa at most sites included dragonflies and damselflies (Odonata), caddisflies (Trichoptera), several families of aquatic beetles (Coleoptera) and Diptera, especially midges (Chironomidae) (Tables 1, 2; Figure 3). Surprisingly, mosquitoes (Culicidae) were not very commonly collected in 2002, although we have collected large numbers of them from these or nearby wetlands previously.

One of our goals was to extend development of an Index of Biotic Integrity for forested wetlands (funded by U.S. EPA through MDEQ) to these wetlands. As we will report very soon in a final report on that project, we have identified 5 metrics that can be used to separate reference from impacted sites for such wetlands using samples taken from the center of the wetlands and another 5 metrics (2 new plus 3 of the same metrics used for center samples) for samples taken from the edge of the wetlands (Table 4). Center metrics include: (1) relative abundance of Physidae snails, (2) relative abundance of Chironomidae, (3) relative abundance of Hemiptera, (4) relative abundance of predators, and (5) number of mayfly + caddisfly taxa. Edge metrics include the same metrics listed as 1, 2, and 5 for the center samples plus relative abundance of fingernail clams and total taxa richness (Table 4). Using these metrics, we were able to rank all the Lake Huron coastal forested wetlands (including some sub-sites for some of the wetlands) as either reference or moderately impacted (Table 5). This ranking did not result in the same subdivision of the sites into impacted and reference sites as reported in Tables 1 and 2. The sub-division reported in Tables 1 and 2 were based on surrounding land use. However, many of the impacted sites are in swales which are separated from nearby agricultural land use by sandy forested ridges, and in some cases, drainage ditches which carry agricultural runoff away from the sites (e.g. Vanderbilt Park Swamp). Thus, some of the impacted sites may be well buffered from nearby agriculture including protection from direct surface inputs. Thus, none of our sites were expected to be heavily impacted and the ranking using the IBI developed from more inland wetlands (Table 5) may simply be reflecting that fact.

We also used correspondence analyses to see if the reference and impacted sites plotted separately using averages of samples taken from different areas of the wetlands including a couple of wetlands that were marshes instead of forested wetlands (Figure 4) or using data collected from the center of the wetland only (Figure 5). We also ran these analyses on only the 10 coastal wetland sites that were forested (Figure 6). None of these analyses resulted in separation of the sites into the impacted and reference sites. Instead, AuGres, Alcona and Misery Bay (3 of the 4 more northern sites) tended to plot apart from most of the Saginaw Bay sites (Figures 5-7), perhaps suggesting a need to separate Saginaw Bay sites from the more northern sites. However, the Negwegon wetland plotted near the Saginaw Bay sites. Even so, Shannon diversity was higher as predicted and Simpson diversity was lower as predicted for the reference sites than for the impacted sites (Figure 8).

Frog and Toad Surveys Conducted in 2002 - Call surveys were run according to MDNR protocols in 2002 for 26 survey stations along two routes located around Saginaw Bay.

Six species of frogs and toads were recorded during these surveys (Table 6). Bullfrogs were also heard calling from a road ditch at the Dickerson site. Thus, we recorded 7 species of frogs and toads from the coastal zone of Saginaw Bay.

Conclusions

This report summarizes data collected from forested depressional wetlands of Lake Huron during 2002.These data complete the report on the invertebrate and vertebrate data collected from the coastal zone in 2002. Most of the data collected and processed by the combined efforts of T. Burton's and D. Uzarski's crews for coastal fringing and drowned river mouth wetlands of Lakes Huron and Michigan were reported in the joint project report submitted by D. Uzarski and T. Burton as a final report on the Grand Valley State University grant. This joint project report also represents the combined efforts of both laboratories and includes the data not included in the report submitted by Grand Valley. Some preliminary analyses of these additional data are included. However, these data will be added to data collected from 2003 on the grants for the second year of this project and with funding from other sources. We are waiting until both years of data have been collected before analyzing the data in detail. Thus, this final report includes data that will be analyzed more fully in the report on the 2003 project, since we expect to conduct more detailed analyses when we have two years of data in hand.

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Table 1: Mean Relative Abundance-2002 Reference Coastal Sites (SE in parentheses)

	Alcona East	Au Gres - Noggle Rd	Bradley-ville Rd	Misery Bay Inland	Negwegon Swale 2	Tobico Interior
Nematoda	---	0.2 (0.2)	---	---	---	---
Platyhelminthes						
Turbellaria						
flatworms	---	---	---	---	---	0.3 (0.3)
Annelida						
Oligochaeta						
Naididae						
unknown	1.3 (--)	0.2 (0.2)	---	---	1.4 (--)	---
Tubificidae						
unknown	0.6 (--)	0.2 (0.2)	---	---	---	---
Lumbriculidae	---	---	---	---	---	1.1 (0.9)
Hirudinea	---	2.4 (0.8)	1.7 (1.7)	0.4 (0.3)	---	---
Mollusca						
Bivalvia						
Sphaeriidae	5.1 (--)	11.3 (5.9)	15.0 (2.8)	19.8 (6.2)	43.8 (--)	44.9 (9.0)
Gastropoda						
Lymnaeidae						
Pseudosuccinea columella	---	0.2 (0.2)	---	---	---	---
Stagnicola elodes	0.6 (--)	8.7 (1.5)	11.5 (6.2)	24.2 (5.8)	11.0 (--)	7.9 (2.7)
Physidae						
Aplexa elongata	3.2 (--)	11.9 (1.7)	5.4 (0.8)	2.0 (1.3)	---	3.1 (1.4)
Physa gyrina	---	---	---	0.8 (0.5)	---	0.2 (0.2)
Planorbidae						
Gyraulus parvus	1.9 (--)	---	---	1.8 (1.3)	---	---
Planorbula armigera	---	---	---	2.5 (0.7)	1.4 (--)	---
Promenetus exacuous	---	---	---	---	4.1 (--)	---

Table 1: con't

Arachnida						
Hydracarina	---	---	0.2 (0.2)	2.1 (1.0)	---	---
Table 1, con't.						
Crustacea						
Cladocera	---	---	---	---	---	0.2 (0.1)
Isopoda						
Asellidae						
Caecidotea	44.6 (--)	25.7 (10.4)	33.8 (6.1)	17.1 (1.5)	9.6 (--)	19.8 (6.7)
Amphipoda						
Crangonyctidae						
Crangonyx	1.9 (--)	---	23.2 (3.5)	---	1.4 (--)	12.0 (3.1)
Decapoda						
Cambaridae	---	---	0.5 (0.5)	---	---	---
Insecta						
Odonata						
Anisoptera						
Libellulidae						
Sympetrum obtrusum	---	19.5 (2.4)	---	5.4 (2.4)	---	---
Sympetrum rubicundulum	---	0.4 (0.4)	---	---	---	---
immature	---	---	---	---	2.7 (--)	---
Lestidae						
Lestes dryas	0.6 (--)	---	---	0.4 (0.3)	---	0.1 (0.1)
Lestes rectangularis	---	---	---	8.7 (4.6)	2.7 (--)	---
Lestes unguiculatus	---	---	---	---	---	0.2 (0.2)
Heteroptera						
Hemiptera						
Belostomatidae						
Belostoma	---	---	---	0.8 (0.5)	---	---
Corixidae						
immature	---	---	---	1.3 (0.6)	---	---
Notonectidae						
Notonecta	---	---	---	0.2 (0.2)	---	---

Table 1: con't

Trichoptera						
Limnephilidae						
Limnephilus	---	7.2 (1.5)	1.3 (0.7)	9.0 (3.2)	---	---
Coleoptera						
Adephaga						
Dytiscidae						
Acilius	---	0.2 (0.2)	0.2 (0.2)	---	---	0.7 (0.5)
Agabus	0.6 (--)	0.2 (0.2)	0.2 (0.2)	---	1.4 (--)	---
Dytiscus	---	0.2 (0.2)	---	0.6 (0.3)	---	0.2 (0.2)
Hydaticus	---	0.2 (0.2)	---	---	---	---
Hydroporus	0.6 (--)	1.3 (0.7)	0.4 (0.3)	---	12.3 (--)	---
Hygrotus	---	---	---	---	1.4 (--)	---
Ilybius	---	---	0.2 (0.2)	---	---	---
Liodessus sp.	---	0.2 (0.2)	---	---	---	---
Rhantus	0.6 (--)	---	---	0.3 (0.3)	1.4 (--)	---
Coleoptera						
Adephaga						
Gyrinidae						
Dineutus sp.	---	---	---	0.2 (0.2)	---	---
Gyrinus	---	---	---	0.8 (0.5)	---	---
Haliplidae						
Haliplus	---	---	---	0.6 (0.3)	1.4 (--)	---
Helophoridae						
Helophorus sp.	---	2.0 (1.4)	---	---	---	---
Hydrochidae						
Hydrochus sp.	---	2.6 (1.0)	---	---	---	---
Polyphaga						
Hydrophilidae						
Anacaena sp.	---	0.9 (0.9)	---	---	---	---
Berosus	---	---	0.3 (0.2)	0.4 (0.3)	---	---
Helocombus sp.	---	---	---	---	---	0.1 (0.1)

Table 1. Con't.

Hydrophilidae						
Hydrobius	---	---	---	---	---	0.1 (0.1)
Hydrochara	---	---	---	---	---	0.3 (0.2)
Scirtidae						
Prionocyphon	---	0.2 (0.2)	---	---	---	6.7 (2.7)
Diptera						
Nematocera						
Chironomidae						
Chironomini	33.1 (--)	2.4 (0.8)	1.3 (0.8)	0.4 (0.3)	4.1 (--)	2.0 (1.1)
Tanytarsini	---	---	4.6 (0.9)	---	---	---
Tanypodinae	0.6 (--)	0.2 (0.2)	---	---	---	---
Orthocladinae	4.5 (--)	0.9 (0.2)	---	0.4 (0.3)	---	---
Corynoneura	---	0.2 (0.2)	---	---	---	---
Dixidae						
Dixella sp.	---	0.2 (0.2)	---	---	---	---
Brachycera						
Stratiomyiidae						
unknown	---	---	---	---	---	0.2 (0.2)
Syrphidae						
unknown	---	---	0.3 (0.3)	---	---	---

Table 2: Mean Relative Invertebrate Abundance for 2002 for Impacted Coastal Sites (SE in parentheses)

	Pinconning Swamp	Tobico - Schmidt Rd	Vanderbilt Swamp	Vanderbilt Far North
Platyhelminthes				
Turbellaria				
flatworms	0.1 (0.1)	---	---	---
Annelida				
Oligochaeta				
Naididae				
Stylaria	0.1 (0.1)	---	---	---
unknown	0.4 (0.3)	---	---	---
Tubificidae				
unknown	0.8 (0.5)	---	0.2 (0.2)	0.3 (0.2)
Lumbriculidae	---	0.2 (0.2)	0.4 (0.4)	0.5 (0.2)
Hirudinea	0.4 (0.2)	0.3 (0.3)	---	0.1 (0.1)
Mollusca				
Bivalvia				
Sphaeriidae	46.0 (8.0)	3.8 (1.2)	41.5 (6.0)	48.0 (5.6)
Gastropoda				
Lymnaeidae				
Pseudosuccinea columella	---	0.2 (0.2)	---	---
Stagnicola elodes	12.2 (2.7)	1.7 (1.2)	14.0 (5.8)	2.4 (0.9)
Physidae				
Aplexa elongata	13.8 (2.6)	2.7 (0.3)	1.6 (0.8)	16.1 (2.1)
Physa gyrina	---	5.6 (0.8)	---	---
Planorbidae				
Gyraulus circumstriatus	---	---	0.2 (0.2)	---
Promenetus umbilicatellus	0.4 (0.3)	---	---	---
Promenetus exacuous	---	---	---	0.3 (0.2)
unknown	0.2 (0.2)	---	---	---
unknown terrestrial?	0.1 (0.1)	---	9.4 (3.9)	---
Arthropoda				
Arachnida				
Hydracarina	---	---	1.6 (1.4)	0.3 (0.3)
Crustacea				
Cladocera	1.2 (0.7)	---	0.3 (0.3)	1.8 (1.0)
Isopoda				
Asellidae				
Caecidotea	15.1 (7.3)	48.7 (9.7)	---	8.4 (2.7)
Amphipoda				
Crangonyctidae				
Crangonyx	1.0 (0.4)	34.4 (7.8)	---	15.4 (2.4)
Decapoda				
Cambaridae	---	0.2 (0.2)	---	---

Table 2, Con't.

Arthropoda				
Insecta				
Collembola				
Sminthuridae				
unknown	---	---	0.3 (0.3)	---
Odonata				
Anisoptera				
Libellulidae				
Sympetrum obtrusum	0.2 (0.1)	---	0.3 (0.3)	---
Sympetrum rubicundulum	0.1 (0.1)	---	---	---
immature	0.1 (0.1)	---	---	---
Lestidae				
Lestes sp.	0.1 (0.1)	---	---	---
Lestes dryas	0.7 (0.5)	0.7 (0.7)	---	---
Lestes rectangularis	1.0 (0.7)	0.7 (0.7)	---	---
Lestes unguiculatus	---	---	---	---
Heteroptera				
Hemiptera				
Corixidae				
immature	0.1 (0.1)	---	---	---
Gerridae				
Gerris	0.1 (0.1)	---	---	---
immature	---	---	0.5 (0.5)	---
Notonectidae				
Notonecta	0.1 (0.1)	0.3 (0.3)	---	---
Saldidae				
immature	---	---	0.2 (0.2)	---
Trichoptera				
Limnephilidae				
Limnephilus	0.2 (0.1)	---	---	0.2 (0.1)
Coleoptera				
Adephaga				
Dytiscidae				
Acilius	1.6 (0.6)	---	---	1.8 (0.5)
Copelatus	---	---	0.4 (0.4)	---
Dytiscus	0.1 (0.1)	---	---	0.1 (0.1)
Hydroporus	---	---	0.9 (0.7)	---
Hygrotus	---	---	0.3 (0.3)	---
Liodessus sp.	---	---	1.1 (0.7)	---
Gyrinidae				
Gyrinus	0.1 (0.1)	---	---	---
Hydrophilidae				
Anacaena sp.	0.1 (0.1)	---	0.4 (0.4)	0.4 (0.3)
Hydrobius	---	---	2.3 (1.2)	0.4 (0.3)

Table 2. Con't

Hydrochara	1.0 (0.4)	---	0.6 (0.4)	---
Arthropoda				
Insecta				
Coleoptera				
Polyphaga				
Lampyridae				
unknown	---	0.3 (0.3)	---	---
Scirtidae				
Scirtes sp.	0.1 (0.1)	---	---	---
Staphylinidae				
unknown	---	---	0.3 (0.3)	---
unknown	---	---	0.3 (0.3)	---
Diptera				
Nematocera				
Chironomidae				
Chironomini	2.1 (1.1)	0.2 (0.2)	13.8 (7.1)	0.8 (0.4)
Tanytarsini	---	---	0.4 (0.4)	0.3 (0.3)
Tanypodinae	---	---	0.2 (0.2)	---
Orthocladinae	---	---	1.6 (0.6)	---
Corynoneura	---	---	2.0 (1.8)	---
Chaoboridae				
Chaoborus	0.1 (0.1)	---	---	---
Culicidae				
Aedes	---	---	1.1 (1.1)	---
Tipulidae				
Tipula	---	---	2.0 (1.0)	---
Brachycera				
Syrphidae				
unknown	0.3 (0.1)	---	1.8 (1.0)	2.1 (1.5)
Tabanidae				
unknown	0.1 (0.1)	---	---	---

Table 3. Number of Taxa Collected From Lake Huron Forested Wetlands in 2002.

Reference Sites	Taxa
Alcona East of Road	15
Au Gres @ Noggle Rd.	27
Bradleyville Road	17
Misery Bay Inland Marsh	24
Negwegon Swale 2	15
Tobico @ Schimdt Rd- Interior	19
Impacted Sites	
Pinconning Swamp	34
Tobico @ Schimdt Rd	15
Vanderbilt Park Swamp	30
Vanderbilt Park Swamp- Far North	19

Table 4. Scoring criteria for edge and center station metrics, including the 95th percentile of the range of median values from each set of 3 sample reps (1999-2001 data) from which the scoring criteria were derived. A score of 5 represents least-impaired conditions, 3 moderate disturbance, and 1 indicates severe human disturbance.

Metrics	Min	Max	95th Percentile	IBI Score 1	3	5
Edge Metrics:						
% Sphaeriidae	0	82	68.1	0-23	23< x ≤46	>46
% Physidae	0	44.7	24.5	0-8	8< x ≤16	>16
% Chironomidae	0	81.6	46.7	>31	16< x ≤31	0-16
Total Taxa Richness	7	29	23	>17	12< x ≤17	0-12
% Predator	0.6	65.0	63.4	>42	21< x ≤42	0-21
Center Metrics:						
% Physidae	0	25.5	23.6	0-8	8< x ≤16	>16
% Chironomidae	0	91.6	53.1	>36	18< x ≤36	0-18
% Hemiptera	0	30.8	27.0	>18	9< x ≤18	0-9
Ephemeroptera+Trichoptera Richness	0	3	2	0	1	≥2
% Predator	0	61.3	55.2	>36	18< x ≤36	0-18

Table 5. Site IBI scores and assessment results for coastal zone forested wetlands sampled in 2002. Assessment categories assigned by trisecting the range of possible scores (10-50): a score > 36 = reference conditions, 24-36 = moderately impacted, 10-23 = severely impacted.

Site	Year	IBI Scores			*% of total possible*	Assessment Category
		Edge	Center	Total*		
ALCONA	2002	13	17	30	60	Moderately Impacted
AU GRES SWAMP	2002		19	19	76	Moderately Impacted
BRADLEYVILLE ROAD	2002	17	19	36	72	Moderately Impacted
KING ROAD	2002		21	21	84	Reference Conditions
KING RD-OPEN	2002		19	19	76	Moderately Impacted
KING RD-CLOSED	2002		17	17	68	Moderately Impacted
MISERY BAY	2002		17	17	68	Moderately Impacted
NEWEGON SWALE 1	2002		15	15	60	Moderately Impacted
NEWEGON SWALE 2	2002		17	17	68	Moderately Impacted
PINCONNING EAST	2002		21	21	84	Reference Conditions
PINCONNING SHORE	2002		21	21	84	Reference Conditions
PINCONNING PARK	2002		19	19	76	Moderately Impacted
TOBICO INTERIOR	2002	19	17	36	72	Moderately Impacted
TOBICO NR ROAD	2002		19	19	76	Moderately Impacted
VP SWAMP	2002	23	21	44	88	Reference Conditions
WFB PIGEON RD.	2002		13	13	52	Moderately Impacted
WFB WEALE RD. 1	2002		15	15	60	Moderately Impacted
WFB WEALE RD. 2	2002		17	17	68	Moderately Impacted

Table 6: Amphibian Surveys of Lake Huron Wetlands.

Wetland	Date	Run	WCF	SPE	NLF	AMT	EGF	GRF	notes
Allen Rd	04/16/2002	1	3	0	1	2	3	0	
Allen Rd	05/28/2002	2	0	0	0	1	1	0	
Allen Rd	06/26/2002	3	0	0	0	0	0	0	
Almeda	04/19/2002	1	0	2	1	0	0	0	
Almeda	06/01/2002	2	0	0	0	0	2	0	
Almeda	06/30/2002	3	0	0	0	0	1	0	
Bradford	04/16/2002	1	3	0	1	3	1	0	
Bradford	05/28/2002	2	0	0	0	2	1	1	
Bradford	06/26/2002	3	0	0	0	0	1	2	GRF calling in ditch
Bradleyville Rd	04/16/2002	1	3	0	0	2	1	0	
Bradleyville Rd	05/28/2002	2	0	0	0	1	1	0	
Bradleyville Rd	06/26/2002	3	0	0	0	0	1	2	GRF calling in ditch
Callahan Rd	04/16/2002	1	0	1	1	3	0	0	
Callahan Rd	05/28/2002	2	0	0	0	2	0	1	
Callahan Rd	06/26/2002	3	0	0	0	0	0	3	
Dickerson	04/16/2002	1	3	0	1	1	0	0	
Dickerson	05/28/2002	2	0	0	0	0	0	1	
Dickerson	06/26/2002	3	0	0	0	0	1	2	GRF, BF calling in ditch
Euclid Rd	04/19/2002	1	0	3	2	0	0	0	
Euclid Rd	06/01/2002	2	0	0	0	0	3	1	
Euclid Rd	06/30/2002	3	0	0	0	0	1	1	
Farley Rd	04/16/2002	1	0	0	1	3	0	0	

Table 6, Con't.

Wetland	Date	Run	WCF	SPE	NLF	AMT	EGF	GRF	notes
Farley Rd	05/28/2002	2	0	0	0	2	0	1	
Farley Rd	06/26/2002	3	0	0	0	0	0	2	GRF calling in ditch
Finn Rd	04/16/2002	1	0	0	1	3	0	0	
Finn Rd	05/28/2002	2	0	0	0	1	0	1	
Finn Rd	06/26/2002	3	0	0	0	0	0	2	
Jones Rd	04/16/2002	1	0	0	1	1	0	0	
Jones Rd	05/28/2002	2	0	0	0	1	0	0	
Jones Rd	06/26/2002	3	0	0	0	0	0	1	
King coastal	04/16/2002	1	3	0	0	3	2	0	
King coastal	05/28/2002	2	0	0	0	1	2	1	
King coastal	06/26/2002	3	0	0	0	0	1	1	GRF calling in ditch
King forested	04/16/2002	1	0	0	2	0	0	0	
King forested	05/28/2002	2	0	0	0	0	2	1	
King forested	06/26/2002	3	0	0	0	0	2	1	GRF calling in ditch
Loomis forested	04/16/2002	1	1	0	1	0	1	0	
Loomis forested	05/28/2002	2	0	0	0	0	1	1	
Loomis forested	06/26/2002	3	0	0	0	0	0	0	
Nayanquing	04/19/2002	1	2	2	1	1	0	0	
Nayanquing	06/01/2002	2	1	1	0	2	2	0	
Nayanquing	06/30/2002	3	0	0	0	0	2	2	
Nay. obs deck	04/19/2002	1	1	3	1	1	0	0	
Nay. obs deck	06/01/2002	2	0	2	0	1	3	1	
Nay. obs deck	06/30/2002	3	0	0	0	0	1	3	

Table 6, Con't.

Wetland	Date	Run	WCF	SPE	NLF	AMT	EGF	GRF	notes
Parrish Rd	04/19/2002	1	0	3	1	0	0	0	
Parrish Rd	06/01/2002	2	0	1	0	0	3	1	
Parrish Rd	06/30/2002	3	0	0	0	0	2	2	north of road
Pinconning	04/19/2002	1	2	0	0	0	0	0	
Pinconning	06/01/2002	2	0	0	0	0	1	0	
Pinconning	06/30/2002	3	0	0	0	0	0	0	
Pinconning N.	04/19/2002	1	0	3	2	0	0	0	
Pinconning N.	06/01/2002	2	0	0	0	0	2	1	
Pinconning N.	06/30/2002	3	0	0	0	0	0	1	north of road
Pincon. Park	04/19/2002	1	2	3	1	2	0	0	
Pincon. Park	06/01/2002	2	0	0	0	0	1	0	
Pincon. Park	06/30/2002	3	0	0	0	0	1	0	
Quanicassee	04/16/2002	1	1	0	1	2	0	0	
Quanicassee	05/28/2002	2	0	0	0	2	0	0	
Quanicassee	06/26/2002	3	0	0	0	0	2	1	
Tobico forested	04/19/2002	1	0	3	0	0	0	0	
Tobico forested	06/01/2002	2	0	0	0	0	0	0	
Tobico forested	06/30/2002	3	0	0	0	0	2	1	
Tobico marsh	04/19/2002	1	0	3	1	0	0	0	
Tobico marsh	06/01/2002	2	0	0	1	0	1	1	
Tobico marsh	06/30/2002	3	0	0	0	0	1	3	
Vanderbilt Park	04/16/2002	1	3	0	1	3	0	0	
Vanderbilt Park	05/28/2002	2	0	0	0	1	3	0	

Table 6, Con't

Wetland	Date	Run	WCF	SPE	NLF	AMT	EGF	GRF	notes
Vanderbilt Park	06/26/2002	3	0	0	0	0	1	0	
Vassar forested	04/16/2002	1	2	0	0	1	1	0	
Vassar Rd	04/16/2002	1	1	0	0	2	0	0	
Vassar Rd	05/28/2002	2	0	0	0	1	2	0	
Vassar Rd	06/26/2002	3	0	0	0	0	0	0	
Wigwam Bay	04/19/2002	1	1	3	0	1	0	0	
Wigwam Bay	06/01/2002	2	0	0	0	0	1	0	
Wigwam Bay	06/30/2002	3	0	0	0	0	0	0	

Species Recorded While Sampling Invertebrates.

Thomas Rd. Swale	07/11/2002							x	
Thomas Road	07/11/2002				x			x	
Mismer	07/16/2002							x	
Epoufette Bay	07/18/2002				x				
Nayanquing	07/25/2002						x	x	
Almeda Beach	07/25/2002				x			x	

WCF = W. Chorus Frog, SP = Spring Peeper, NLF = N. Leopard Frog, AMT = American Toad, EGF = E. Gray Tree Frog, GRF = Green Frog, BF = Bullfrog

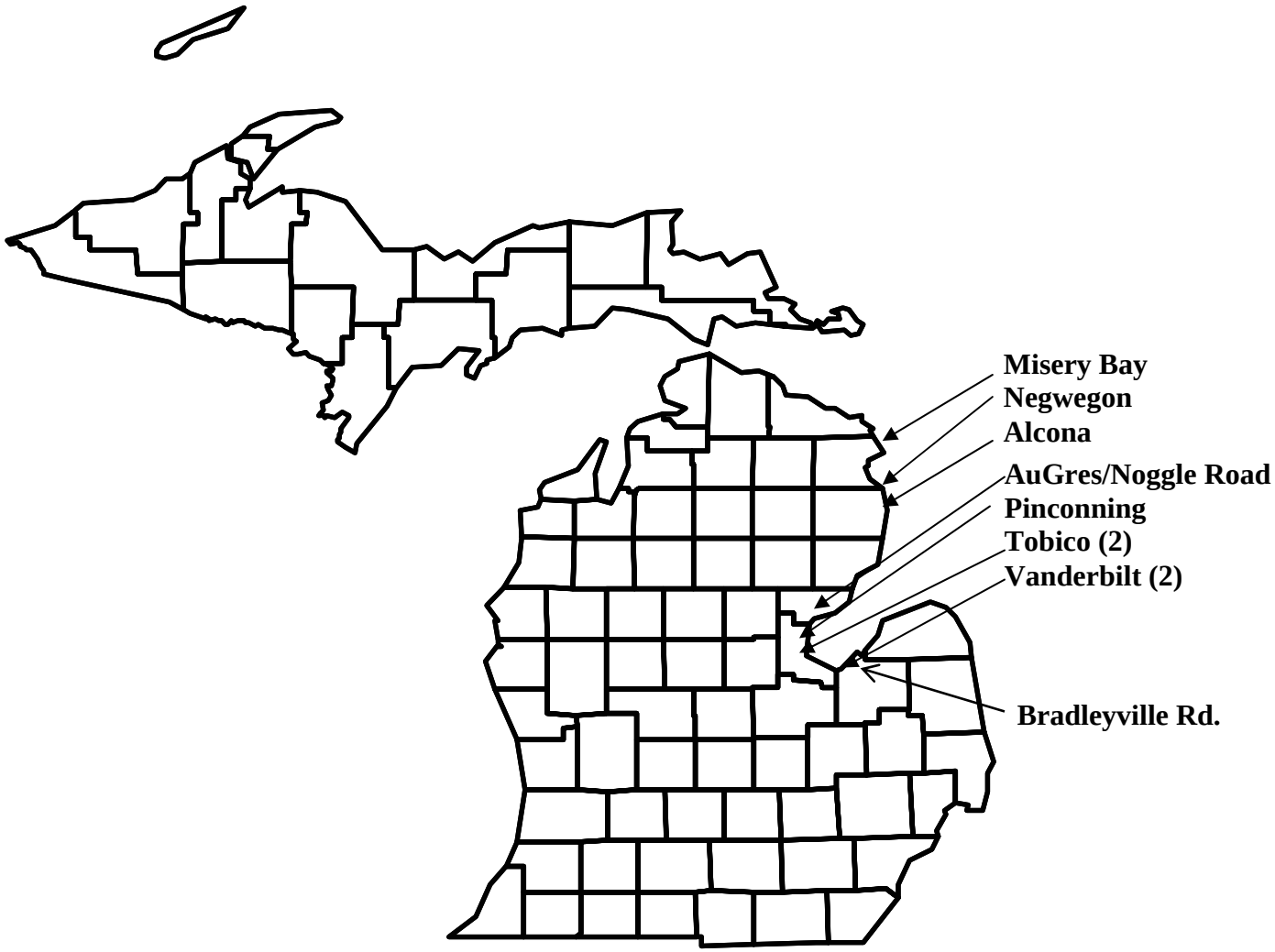

Figure 1. 2002 Great Lakes Forested, Coastal Wetland Sampling Sites (Two Sites Each for the Tobico & Vanderbilt Wetlands).

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Figure 2: 2002 Lake Huron Coastal Palustrine Wetlands
Top 10 Non-Insect Families

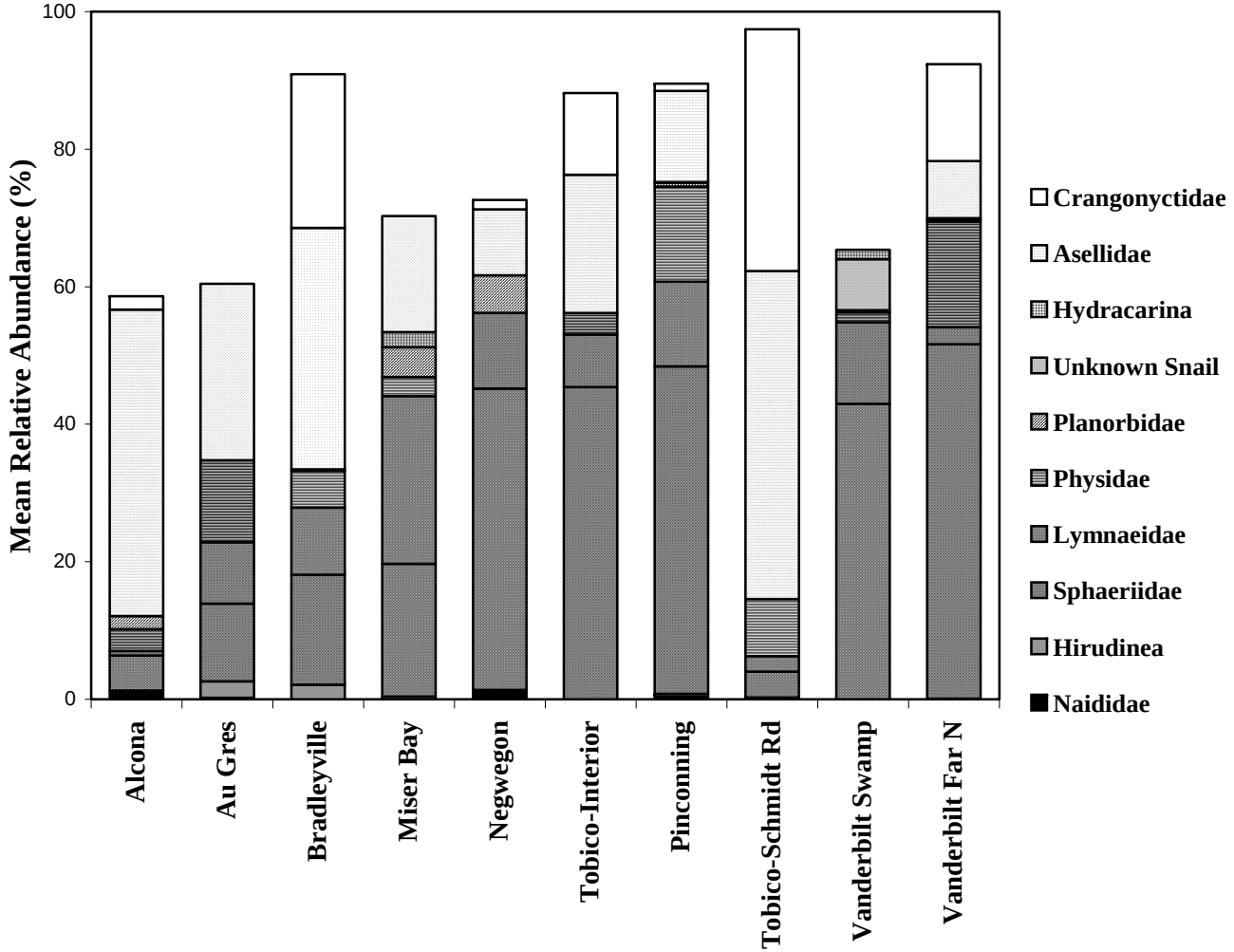


Figure 3: 2002 Lake Huron Palustrine Wetlands - Top 10 Insect Families

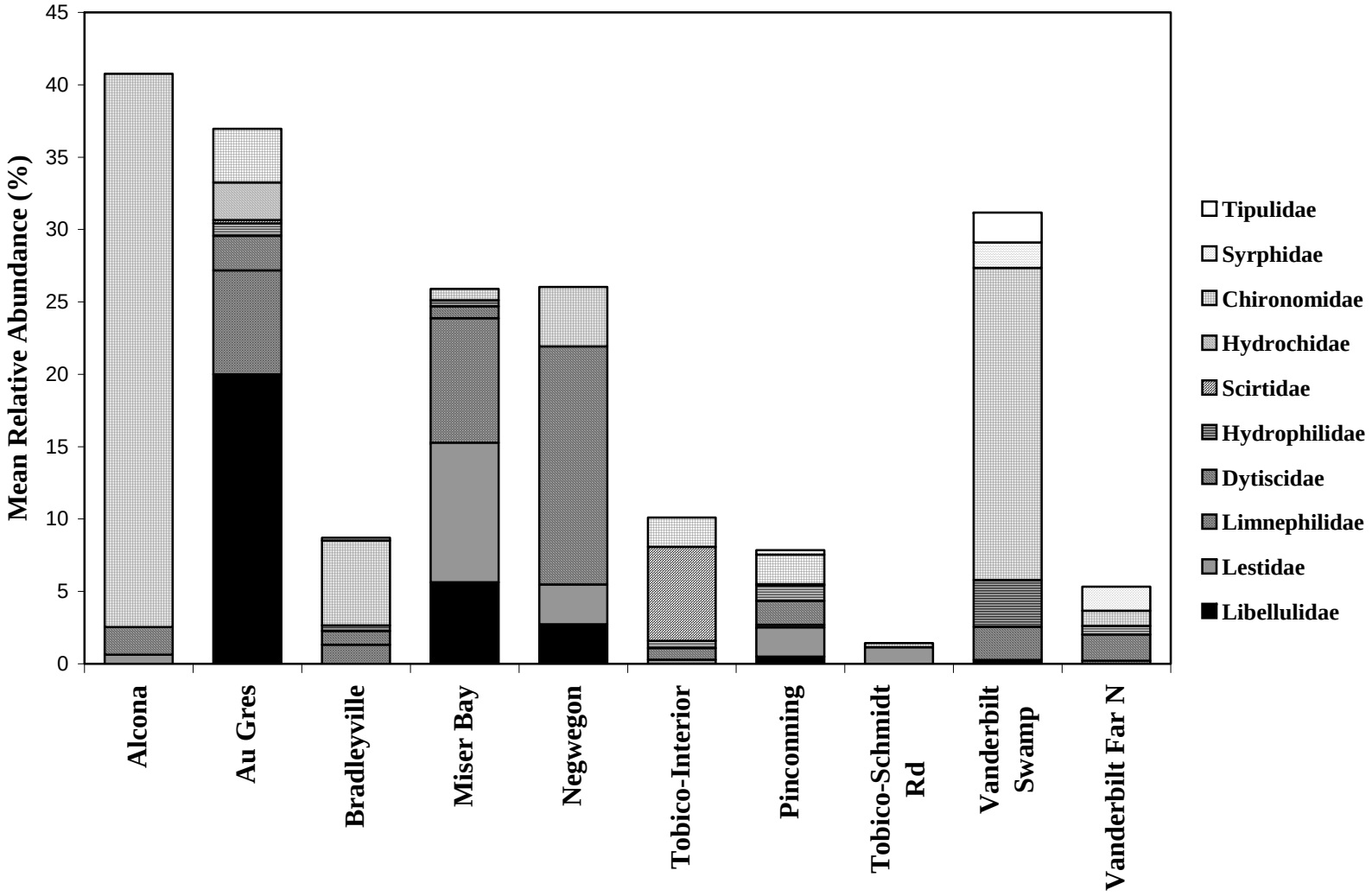
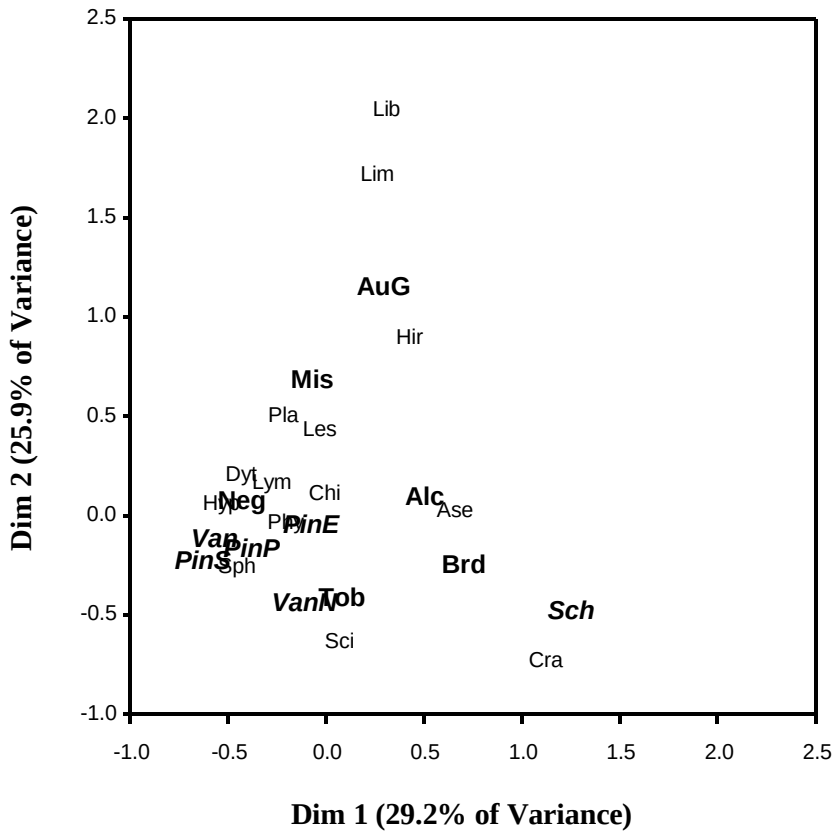


Figure 4: Correspondence Analysis of 12 Coastal Sites with 14 Families (2002 Data - average used for all sites)



Reference Sites

Alc = Alcona
AuG = Au Gres
Brd = Bradleyville Rd.
Mis = Misery Bay
Neg = Negwegon
Tob = Tobico-Interior

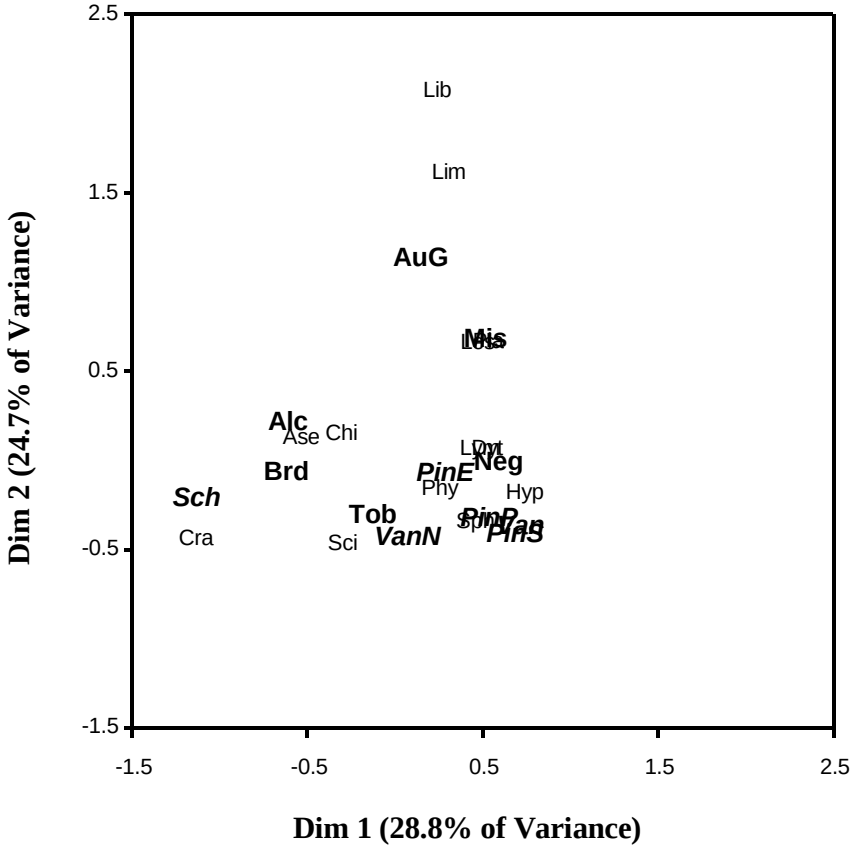
Impacted Sites

PinE = Pinconning East
PinP = Pinconning Park
PinS = Pinconning Swamp
Sch = Tobico-Schmidt Rd.
Van = Vanderbilt Swamp
VanN = Vanderbilt Far North

Family

Ase = Asellidae
Chi = Chironomidae
Cra = Crangonyctidae
Dyt = Dytiscidae
Hir = Hirudinea
Hyo = Hydrophilidae
Les = Lestidae
Lib = Libellulidae
Lim = Limnephilidae
Lym = Lymnaeidae
Phy = Physidae
Pla = Planorbidae
Sci = Scirtidae
Sph = Sphaeriidae

Figure 5: Correspondence Analysis of 12 Coastal Sites with 13 Families (2002 Data - center sample was used for each site)



Reference Sites

Alc = Alcona
AuG = Au Gres
Brd = Bradleyville Rd.
Mis = Misery Bay
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Impacted Sites

PinE = Pinconning East
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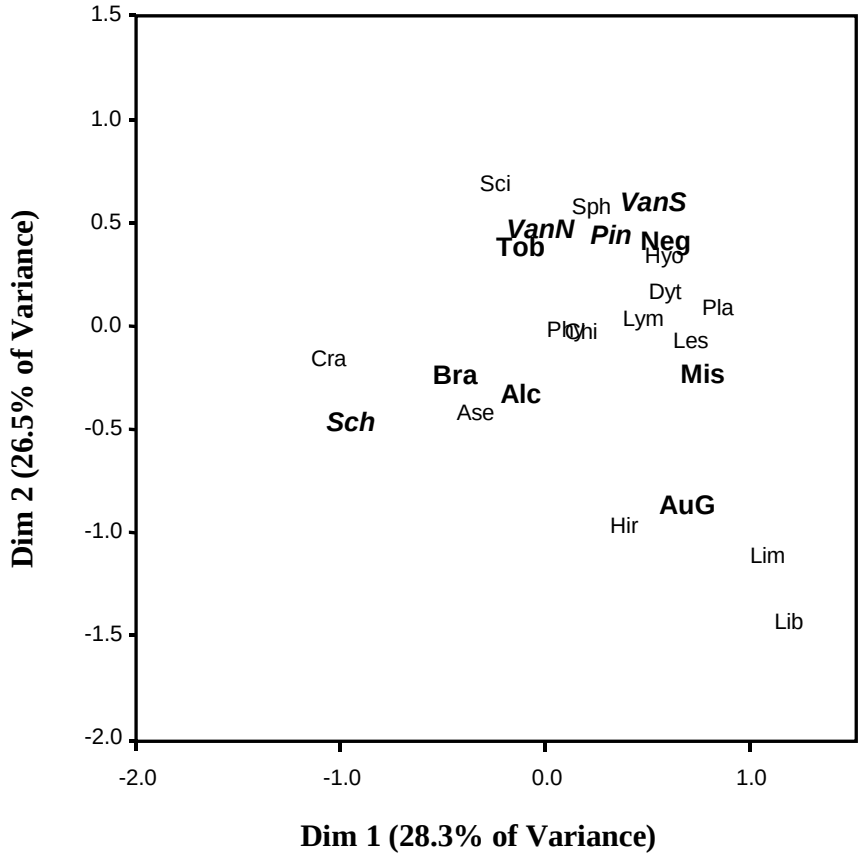
Sch = Tobico-Schmidt Rd.
Van = Vanderbilt Swamp
VanN = Vanderbilt Far North

Family

Ase = Asellidae
Chi = Chironomidae
Cra = Crangonyctidae
Dyt = Dytiscidae
Hyo = Hydrophilidae
Les = Lestidae
Lib = Libellulidae
Lim = Limnephilidae
Lym = Lymnaeidae
Phy = Physidae
Pla = Planorbidae
Sci = Scirtidae
Sph = Sphaeriidae

Figure 6: Correspondence Analysis of 10 Forested Coastal Sites with 14 Invertebrate Families (2002 data - average of all samples at each site)



Reference Sites

Alc = Alcona
AuG = Au Gres
Bra = Bradleyville Rd.
Mis = Misery Bay
Neg = Negwegon
Tob = Tobico-Interior

Impacted Sites

Pin = Pinconning
Sch = Tobico-Schmidt Rd.
VanS = Vanderbilt Swamp
VanN = Vanderbilt Far North

Family

Ase = Asellidae
Chi = Chironomidae
Cra = Crangonyctidae
Dyt = Dytiscidae
Hir = Hirudinea
Hyo = Hydrophilidae
Les = Lestidae
Lib = Libellulidae
Lim = Limnephilidae
Lym = Lymnaeidae
Phy = Physidae
Pla = Planorbidae
Sci = Scirtidae
Sph = Sphaeriidae

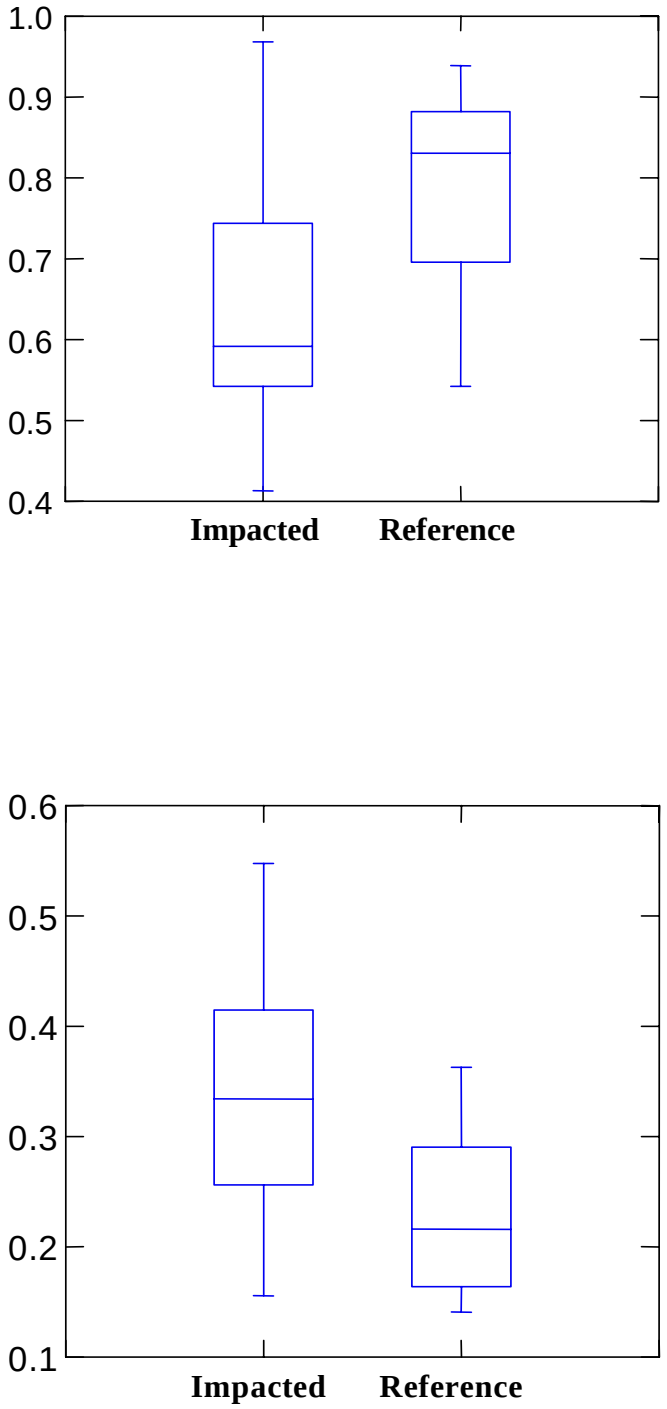



Figure 7: Shannon (Top) and Simpson (Bottom) Diversity for Invertebrates in Forested Depressional Wetlands in the Coastal Zone of Lake Huron.