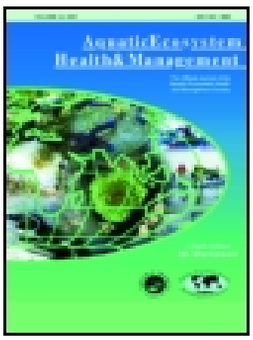

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Biodiversity in protected coastal wetlands along the west coast of Lake Huron

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Lake Huron protected (barrier-protected) wetlands occur within 1 km of the lake, in swales, interdunal ponds, and other shallow depressions. These wetlands are not directly connected via surface water to Lake Huron, although their hydrology is influenced by lake levels. Biodiversity in them has not been well documented. We compiled plant and animal species occurrence data from published and unpublished sources for the U.S. coast of Lake Huron. Many data sources were reports written by the authors and/or by scientists of the Michigan Natural Features Inventory. Species occurrence data were supplemented with data from published wetlands literature and dissertations and theses. We did not do a thorough compilation for Canadian wetlands and only added limited Canadian data from the "Ontario Great Lakes Coastal Wetlands Atlas".

We estimate that total species richness exceeds 1400 species with about an equal number of plants and animals (600–700 species each). We documented the occurrence of 466 macrophytes in Lake Huron's protected marshes, fens, and swamps and estimated total plant species richness to be >600. Invertebrate species richness was estimated to be 500–600 with more than half of these being macroinvertebrates (>0.5 mm) and the remainder being microinvertebrates (<0.5 mm).

Vertebrate species richness was estimated to be >200 as follows. Fish species richness was estimated to be <10 because of low oxygen, periodic dry periods, and lack of surface water connection to Lake Huron. Amphibian species richness was estimated to be >20 with 10 frogs and toads and 7 salamander species documented. Reptile species richness was estimated to be >20 based on very limited data and published distribution maps with >10 turtle species and >10 snake species but no lizards in Lake Huron marshes (although 4–5 lizard species occur on sandy ridges near swale marshes). More than 50 mammal and 80 bird species were estimated to occur in protected wetlands. Occasional additional use by birds and other species combined with the addition of rare species as additional sampling occurs are likely to increase the number of vertebrate species to >200.

Keywords: Fens, Great Lakes, invertebrates, plants, vertebrates, marshes, swamps, wet meadows

Introduction

Lake Huron "protected" (Keough et al., 1999) or "barrier-protected" coastal wetlands (Albert et al., 2005) are not connected via surface water to Lake Huron, and therefore are not exposed to waves, storm surges, seiches or other short term lake level oscillations. These wetlands occur within 1 km of the lake in swales, interdunal ponds, and other shallow depressions that are "protected" (i.e. isolated) from exposure to lake waves and storm surges by dunes, low sand ridges or other natural barriers.

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There were no surface water connections between the lake and these wetlands when we sampled them, although it is possible that some were connected when Lake Huron approached peak levels in recent decades. Protected wetlands are influenced by Lake Huron levels through effects of lake level on the water table and groundwater flow patterns (Botts, 1999; Visocky, 1977; Stanley, 2000).

Knowledge about Great Lake coastal wetlands has increased substantially in the last 25 years. Several review articles, special issues of journals, books and working papers of the State of the Lakes Ecosystem Conferences have been published reflecting rapid increases in knowledge about these systems. Most reviews and papers on flora and fauna in coastal wetlands, however, have emphasized lacustrine or riverine wetlands (e.g. Albert, 2003; Albert et al., 1988; Botts, 1999; Brazner, 1997; Brazner and Beals, 1997; Burton et al., 2002, 2004; Gathman; 2000; Gathman et al.,1999 and 2005; Hecnar, 2004; Herdendorf et al., 2006; Keddy and Reznicek, 1986; Keough et al., 1999; Lougheed and Chow-Fraser, 2002; Lougheed et al., 2001; Minc; 1996; Minc and Albert, 1998; Uzarski et al., 2005; Wilcox et al., 2002). Protected wetlands have received much less attention and are poorly known ecologically in comparison with lacustrine and riverine coastal wetlands. Wilcox (1995) reviewed the role of coastal wetlands of Lake Huron as nearshore habitat, but his emphasis was on lacustrine and riverine wetlands. Our objective in this paper was to review and report on biodiversity of macroscopic plants and animals in Lake Huron protected coastal wetlands.

The U.S. shore of Lake Huron has been divided into northern and southern lacustrine influenced ecological regions (Albert, 1995). In each ecoregion, protected coastal wetlands occur in: (a) saturated swales and groundwater seepages without standing water and (b) semi-permanently flooded swales, depressions and seepages, and (c) intermittently flooded or saturated wetlands on low flat terrain on islands (Tepley et al., 2004).

Most available data were from wetlands along the west (Michigan) shore of Lake Huron. Data from the Ontario Great Lakes Coastal Wetlands Atlas (Environment Canada and Ontario Ministry of Natural Resources, 2003) on rare species were used to supplement the species lists. We assumed that rare species reported from Ontario but not from Michigan would most likely be collected in Michigan with additional sampling effort. We made no attempt to review the many reports and unpublished data from Canadian wetlands, since our research on protected wetlands was funded by the State of Michigan in cooperation with the U.S. Environmental Protection Agency and the Coastal Management Program of the U.S. National Oceanic and Atmospheric Administration. Our estimates for the Michigan coast of Lake Huron likely contain the majority of common species for both coasts of the lake but likely underestimate the total number of rare species that occur in these wetlands.

Tepley et al., (2004) described plant communities of forested and shrub dominated swamps within 1 km of Lake Huron and Lake Michigan in Michigan. This report included herbaceous, shrub, and tree species growing in coastal swamps. It did not include herbaceous dominated marshes, since Teppley et al., and other Michigan Natural Feature Inventory (MNFI) biologists had already produced several reports on plant communities of Great Lakes marshes. We sampled invertebrates from herbaceous and woody plant dominated Lake Huron protected wetlands (i.e. from fens, marshes and swamps) from 2002 to 2004. We compiled data from these two sources and from project reports (e.g. Prince and Burton, 1996; Burton et al., 2003; Burton et al., 2005), theses and dissertations (e.g., Gathman, 2000; Riffell, 2000; Keas, 2002; Whitt, 1996; Stanley, 2000; Vaara, 2001), and reports from MNFI. We also reviewed the published literature for Michigan wetlands to compile species lists for this review.

Biodiversity in Lake Huron coastal depressional wetlands

Plant communities – wet meadows, lake plain prairies, fens and marshes

We compiled a list of 181 species of plants that have been reported from shallow wet meadow marshes, fens, and lake plain prairies of Lake Huron (Table 1). It was not feasible to separate lacustrine and protected wet meadows based on site data given in reviewed reports, but most wet meadow species occur in protected swales as well as in wet meadow and lake plain prairie zones extending inland from lacustrine marshes.

The transition from wet meadow or lake plain prairie to swamp includes many shrubs and tree seedlings and some rare herbaceous species. These transition zones were not systematically sampled

Table 1. Macrophytes of depressional and lacustrine wet meadows of Lake Huron[1,2] *(nomenclature from Interagency Taxonomic Information Systems (http://www.itis.gov))*.

Acorus calamus - sweetflag, obl
Agalinis gattingeri - roundstem false foxglove, facw
Alisma gramineum - narrowleaf water plantain, obl
A. plantago-aquatica - American water plantain, obl
Alnus incana ssp.*rugosa* - speckled alder, obl
Andropogon gerardii - big bluestem, fac-
Anemone canadensis - Canadian anemone, facw
Apocynum cannabinum - Indian-hemp, fac
Argentina anserina - silverweed cinquefoil, facw+
Arnoglossum plantagineum - Groovestem Indian Plaintain, fac
Asclepias hirtella - green milkweed, upl
A. incarnata - swamp milkweed, obl
A. purpurascens - purple milkweed, facu
A. sullivantii- prairie milkweed, upl
Astragalus neglectus - Cooper's milk vetch, facu-
Bartonia paniculata - twining screw stem, obl
Betula pumila - bog birch, obl
Bidens cernua - nodding beggar tick, obl
B. coronata - crowned beggar tick, obl
Buchnera americana - American bluehearts, fac-
Calamagrostis canadensis - bluejoint, obl
Calystegia sepium - hedge bindweed
Campanula aparinoides - bedstraw bellflower, obl
Carex aquatilis - water sedge, obl
C. bebbii - Bebb's oval sedge, obl
C. buxbaumii - brown bog sedge, obl
C. comosa - longhair sedge, obl
C. crinita - fringed sedge, facw+
C. cryptolepus - northeastern sedge, obl
C. diandra - lesser panicled sedge, obl
C. emoryi - Emory's sedge, obl
C. flava - yellow sedge, obl
C. hystericina - porcupine sedge, obl
C. lacustris - lakebank sedge, obl
C. lasiocarpa - wooly fruit sedge, obl
C. pellita - wooly sedge, obl
C. pseudocyperus - cypresslike sedge, obl
C. rostrata - beaked sedge, obl
C. sartwellii - Sartwell's sedge, facw+
C. stricta - upright sedge, obl
C. tentanica - rigid sedge, facw
C. viridula - green sedge, obl
C. vulpinoidea - common fox sedge, obl
Castilleja coccinea - Indian paintbrush, fac
Cicuta bulbifera - bulblet-bearing water hemlock, obl
C. maculata - common water hemlock, obl
Cirsium arvense - Canada thistle, facu
C. muticum - swamp thistle, obl
Cladium mariscoides - smooth sawgrass, obl
Clinopodium arkansanam - limestone calamint, facw
Comarum palustre - purple marshlocks, obl
Coreopsis tripteris - tall tickseed, fac
Cornus ammomum - silky dogwood, facw+
C. sericea - redosier dogwood, facw
Cyperus erythrorhizos - redroof flat sedge, obl
Dasiphora floribunda - shrubby cinquefoil, facw
Doellingera umbellata- parasol flat-topped white aster, facw
Drosera spp. - sundew, obl
Dulichium arundinaceum - threeway sedge, obl
Eleocharis acicularis - needle spikerush, obl
E. elliptica- elliptic spikerush, facw
E. palustris - common (Small's) spikerush, obl
E. quinqueflora - few flower spikerush, obl
E. rostellata - beaked spikerush, obl
Elymus repens - quackgrass, facu
Epilobium hirsutum - hairy willow herb, facw+
Equisetum arvense - field horsetail, fac
E. fluviatile - water horsetail, obl
E. hyemale - scouring rush horsetail, facw-
Eupatorium maculatum - spotted joe-pye weed, obl
E. perfoliatum - common boneset, facw+
Fissidens spp. - fissidens moss
Fragaria virginiana - wild strawberry, fac-
Fraxinus pennsylvanica - green (or red) ash, facw
Galium obtusum - Bluntleaf bedstraw, facw+
G. trifidum - threepetal bedstraw, facw+
Gentianopsis procera procera - lesser fringed gentian, obl
Geum laciniatum - rough avens, facw
Glyceria canadensis - rattlesnake manna grass, obl
Helianthus spp. - sunflower
Helenium autumnale - common sneezeweed, facw+
Heteroanthera dubia- grassleaf mudplaintain, obl
Hypericum kalmianum - Kalm's St. Johnswort, facw-
Hypoxis hirsuta - eastern yellow star-grass, fac
Impatiens capensis - spotted touch-me-not, facw
Iris lacustris - dwarf lake iris, fac
I. versicolor - harlequin blueflag, obl
Juncus acuminatus - sharp fruit rush, obl
J. articulatus - jointed rush, obl
J. balticus - Baltic rush, obl
J. brevicaudatus - narrow-panicle rush, obl
J. effusus - common rush,obl
J. nodosus - knotted rush, obl

(continued on next page)

Table 1. Macrophytes of depressional and lacustrine wet meadows of Lake Huron[1,2] *(nomenclature from Interagency Taxonomic Information Systems (http://www.itis.gov)) (Continued)*.

J. pelocarpus - brownfruit rush, obl
Lathyrus japonicus - beach pea, facu
L. palustris - marsh pea, facw
Leersia oryzoides - rice cut grass, obl
Liatris cylindracea - Ontario blazing star, upl
L. spicata - dense blazing star, fac
Linum medium - stiff yellow flax, facu
Lobelia kalmii - brook lobelia, obl
Lycopus americanus - American water horehound, obl
L. uniflorus - northern water-horehound, obl
Lysimachia quadriflora - fourflower yellow loosestrife, obl
L. terrestris - earth loosestrife, obl
L. thrysiflora - tufted loosestrife, obl
Ludwigia polycarpa - manyroot primrose- willow, obl
Lythrum alatum - wing-angle loosestrife, obl
L. salicaria - purple loosestrife, obl
Mentha arvensis - field mint, facw
Myrica gale - sweet gale, obl
Oligoneuron houghtonii - Houghton's goldenrod, obl
O. ohioense - Ohio goldenrod, obl
O. riddellii - Riddell's goldenrod, obl
Onoclea sensibilis - sensitive fern , facw
Panicum rigidulum - redtop panic grass, facw
P. virgatum - switchgrass, fac+
Parnassia glauca - fen grass of Parnassus, obl
Phalaris arundinacea - reed canary grass, facw+
Phragmites australis - common reed, facw+
Picea mariana - black spruce, facw
Pinguicula vulgaris - common butterwort, obl
Platanthera blephariglottis - white fringed orchid, obl
P. leucophaea - eastern prairie fringed orchid, facw+
Poa spp. - bluegrass
P. palustris - fowl bluegrass, facw+
Polygonum amphibium - water smartweed, obl
P. careyi - Carey's smartweed, facw+
P. lapathifolium - dock-leaf smart weed, facw+
P. scandens - climbing false buckwheat, fac
Populus deltoides - eastern cottonwood, fac+
Primula mistassinica - Mistassini primrose, facw
Pycnathemum virginiamum - Virginia mountainmint, facw+
Rhexia virginica - common meadow beauty, obl
Rorippa nasturtium-aquaticum - watercress, obl
R. palustris - marsh yellow cress, obl
Rubus spp. - blackberry, dewberry, raspberry
Rudbeckia hirta - blackeyed susan, facu
Rumex crispus - curly dock, fac+
Rumex maritimus - golden dock, facw+
Sagittaria latifolia - common arrowhead, obl
Salix candida - Sageleaf willow, obl
S. petiolarus - meadow willow, facw+
Sarracenia purpurea - pitcherplant, obl
Scleria verticillata - low nutrush, obl
Schoenoplectus acutus - hardstem bulrush, obl
S. pungens - common three square, obl
S. tabernaemontani - softstem bulrush, obl
Scirpus atrovirens - green bulrush, obl
Scutellaria galericulata - marsh skullcap, obl
S. lateriflora - blue skullcap, obl
Silphium compositum var. *reniforme* - kidney leaf rosinweed, facu
Sium suave - hemlock water parsnip, obl
Sporobolus heterolepis - prairie dropseed, facu
Solanum dulcamara - bitter nightshade, fac
Solidago uliginosa - bog goldenrod, obl
Spartina pectinata - prairie cord grass, facw+
Sphagnum spp. - sphagnum, obl
Spiraea alba - white meadowsweet, facw+
Spiranthes lucida - shining ladies'-tresses, facw+
Stachys tenuifolia - smooth hedge nettle, obl
Symphyotrichum boreale - northern bog aster, obl
S. dumosum - rice button aster, fac+
S. puniceum - purplestem aster, obl
Taraxacum officinale - common dandelion, facu
Teucrium canadense - American germander, facw-
Thuja occidentalis - northern white-cedar, facw
Thelyptris palustris - marsh fern, facw+
Triadenum fraseri - Fraser's marsh St. Johnswort, obl
T. virginicum - marsh St. Johnswort, obl
Triglochin maritimum - shore arrowgrass, obl
Typha angustifolia - narrowleaf cattail, obl
T. latifolia - broadleaf cattail, obl
Urtica dioica - stinging nettle, fac+
Verbena hastata - blue vervain, facw+
Vernonia gigantea - giant ironweed, fac
Veronicastrum virginicum - Culver's root, fac
Viola affinis - sand violet, facw
V. cucullata - marsh blue violet, obl
Vitis riparia - riverbank grape, facw+
Xyris difformis - bog yellow eyed grass, obl

[1] from Albert et al., (1988), Albert (2003), Albert and Minc (1996), Albert, Burton and Uzarski from northern Lake Huron unpublished, Environment Canada and Ontario Ministry of Natural Resources (Ontario Great Lakes Atlas) (2003), Stanley (2000).
[2] Obl = obligate wetland plant, facw = facultative wetland plant, facu = facultative upland plant, upl = upland plant; + or - sign means plant has tendency towards upper (+) or lower (-) end of designated category.

in many studies that we reviewed. Some shrubs and tree seedlings were recorded, but we estimate that up to 20 species of trees, shrubs and other species were missed in poorly sampled transition zones between wet meadow and wooded wetlands. We also estimate that an additional 40-50 species of emergent, submergent, floating, and floating-leafed plants occurred in the poorly sampled, deeper, semi-permanent or permanent marsh areas in swales and other protected marshes. Adding these 60–70 additional estimated species to the 181 documented species from shallow wet meadows, we estimated that 240-250 plant species occurred in protected coastal marshes of Lake Huron. This is similar to Keddy and Reznicek's estimate of 200–225 species for Great Lakes coastal wet meadows.

Most biomass in wet meadows was contributed by bluejoint grass, *Calamagrostis canadensis*, and 2–3 species of sedges (*Carex*). For example, bluejoint grass and three sedges, *Carex aquatilis, C. sartwellii,* and *C. stricta*, dominated the wet meadow communities of Saginaw Bay (Stanley, 2000; Stanley et al., 2005). Bluejoint grass and two sedges, *C. stricta* and *C. lasiocarpa*, contributed the greatest amount to total stem counts (28-37 %) in northern Lake Huron wet meadows with smaller but significant contributions from several additional sedges including *C. aquatilis* and from several species of rushes (*Juncus*) and spike rushes (*Eleocharis)* (Gathman et al., 2005).

Plant communities – protected swamps

Tepley et al., (2004) sampled 447 plots from 42 protected swamps with 26 sampled from Lake Huron and 16 from Lake Michigan. Fifteen species contributed 95% of basal area, although total species richness was 303. The dominant trees in the swale, hardwood swamp near shore in the southern ecoregion of Lake Huron were green ash (*Fraxinus pennsylvanica*, 41% of basal area), silver maple (*Acer saccharinum*, 35% of basal area), cottonwood (*Populus deltoides*, 14% of basal area), swamp white oak (*Quercus bicolor*, 5% of basal area) and American elm (*Ulmus Americana*, 4% of basal area). Black ash (*F. nigra*) and paper birch (*Betula papyrifera*) were also present (Tepley et al., 2004). The peat swamps in the swales farther inland were dominated by northern white cedar (*Thuja occidentalis,* 96% of basal area) and tamarack (*Larix laricina,* 3% of basal area). The protected coastal swamp hardwood flats on islands such as those on islands in Wildfowl Bay in the southern ecoregion were dominated by green ash, 90% of basal area, silver maple, 7% of basal area, and American elm, 2% of basal area. In swamps in the northern part of the southern ecoregion, swales near shore were dominated by green ash and red maple (*Acer rubrum*) with balsam fir (*Abies balsamea*) present.

In the northern ecoregion along Lake Huron in Michigan's upper peninsula, peat and hardwood swamps near shore were dominated by northern white cedar, 81% of basal area, with paper birch, black ash, red maple, white and black spruce (*Picea glauca* and *P. mariana*), and balsam fir each contributing 1-3% of basal area. Drier inland swales were dominated by green ash.

The combined total of 303 plant species for Lake Huron protected swamps included 23 tree, 41 shrub and 239 herbaceous species (Tepley et al., 2004). Adding species listed for swamps of Lake Huron from Appendix P of the Ontario Great Lakes Coastal Atlas (Environment Canada and Ontario Ministry of Natural Resources, 2003) added <10 species to Tepley et al.,'s list. Therefore, we estimate that plant species richness in Lake Huron coastal swamps is 310–350.

Plant communities–conclusions

We estimate that protected coastal marshes and swamps support a combined vascular plant species richness of 550-600 species. We compiled a list of 181 species from Lake Huron wet meadows and emergent marshes (Table 1) with an additional 60-70 species estimated to occur in the wettest and driest areas of protected coastal marshes. Tepley et al., (2004) compiled a list of 303 species of plants from Lake Huron protected coastal swamps. Since 58 species co-occurred in swamps and marshes, the documented species list for protected, coastal Lake Huron wetlands was 468 species. We expect this species list to increase with additional sampling effort as rare species are added and estimate total species richness to be more than 600.

Animal communities–invertebrates

No one has documented invertebrate species richness in Lake Huron protected wetlands at the species level because of difficulty in identifying larval invertebrates, although some work has been reported for some taxa for specific areas (Burton et al., 2002, 2004; Gathman et al., 1999; Keas,

2002). Investigators often report macroinvertebrate (those >0.5 mm in size) "species" richness using operational taxonomic units (OTUs = the number of taxa based on identification to species, genus, subfamily or higher level using readily available keys such as those in Merritt and Cummins 1996 and Thorp and Covich, 2001). We compiled a list of 30 OTU taxa of non-insects and 85 OTU taxa of insects from protected Lake Huron marshes and swamps using published data cited above and our unpublished data from 2002 to 2004 (Tables 2 and 3). We only identified four Chironomidae OTUs from Lake Huron protected wetlands but estimate that identification of all Chironomidae would increase species richness by more than 40 species based on Botts (1999) report that 42 species occurred in wetlands on Presque Isle in Lake Erie. Botts (1999) also reported the occurrence of 34 species of Trichoptera, >50 species of Odonata, and 26 species of Coleoptera from protected and lacustrine Presque Isle wetlands. Adding species from these and other species rich groups that we identified only to genus or subfamily would likely increase species richness several fold. Thus, we estimate that total macroinvertebrate species richness is likely to exceed 300 species.

Microinvertebrate (those <0.5 mm in size) species richness is poorly known compared to macroinvertebrate richness. Gathman et al., (1999) reported 52 species of Copepoda and Cladocera from lacustrine coastal wetlands of St. Marys River and Saginaw Bay. Ostracoda were not identified to species even though they often made up more than 50% of abundance and biomass (Brady and Burton 1995). Lougheed and Chow-Fraser (2002) reported 60 Cladocera and 78 rotifer species from 70 inland and coastal Great Lakes basin marshes. Most species reported by them are likely to occur in Lake Huron protected wetlands. Adding Ostracoda and other microinvertebrates probably would increase species richness to >200. Therefore, we estimate microinvertebrate species richness to be 200-300 in Lake Huron protected wetlands.

In summary, we collected 115 OTU taxa of macroinvertebrates from Lake Huron coastal protected wetlands. Many taxonomic groups not identified below subfamily or genus are known to contain large numbers of species; therefore we estimate that total macroinvertebrate species richness is likely to exceed 300. We estimate that microinvertebrate species richness is likely to be 200-300. Thus, combined macro and micro invertebrate species richness in Lake Huron protected wetlands is likely to exceed 500-600 species.

Fish

Most coastal depressional wetlands dry up periodically and do not support fish. Prince and Burton's (1996) crew collected large numbers of brook sticklebacks, *Culaea inconstans*, mudminnows, *Umbra lima*, and fathead minnows, *Pimephales promelas,* from a limited number of semi-permanent, protected marshes near Fish Point on Saginaw Bay. We also occasionally collected them while sampling invertebrates in this and subsequent studies. Ninespine sticklebacks (*Pungitius pungitius*) are probably also common in protected Lake Huron wetlands, since they have been reported from nearby beaches and nearshore areas (Brown et al., 1995; Wilcox 1995, Uzarski and Burton unpublished data) and tolerate low oxygen environments. Few other fish tolerate the low oxygen found in shallow, semi-permanent wetlands, and we estimate species diversity in them to be <10, even though species richness in nearby lacustrine wetlands may be as high as 90 species (Gathman and Keas 1999; Gathman 2000; Uzarski et al., 2005).

Amphibians – Frogs and Toads

Protected coastal wetlands provide habitat for >10 species of frogs and toads. Protected, seasonally dry coastal wetlands are where nearly all calls originate during breeding seasons because of the lower risk of fish predation in them compared to lacustrine coastal wetlands nearby. During very low lakes levels, some frogs and toads that usually only breed in protected wetlands are able to breed in lacustrine wetland pools that are isolated from fish predation by low water (Price et al., 2004). We monitored breeding frog and toad calls in 1994 and 2002 on several routes along Saginaw Bay. Large numbers of northern spring peepers, *Pseudacris crucifer crucifer*, striped chorus frogs, *P. triseriata*, gray tree frogs, *Hyla versicolor* and *H. chrysocelis*, green frogs, *Rana clamitans*, northern leopard frogs (*R. pipiens*), and American toads (*Bufo americanus*) were calling. All of these species except *H. chrysocelis* were reported as occurring at rates of 21 to 60% of sites within their range in Lakes Michigan and Huron wetlands in a survey of 93 calling sites (Price et al., 2004). We assume that

Table 2. Non-Insect Aquatic Taxa Reported from Lake Huron coastal depressional wetlands.

Taxon - common name	Swamps[1,2]	Emergent Marshes[1,2]	Wet Meadows[1,2,3]
Annelida - Segmented worms			
1. Lumbricidae – earthworms	nr,A	nr, nr	nr,nr
Naididae - Tubificid worms	C,A	U,C	U,U
2. *Stylaria lacustris*	nr,U	nr,nr	nr,nr
Tubificidae - Tubificid worms	C,U	U,U	nr,U
3. *Branchiura* spp.	nr,nr	nr,U	nr,U
4. Annelida - Hirudinea - leeches	U,nr	C,U	nr,U
Mollusca - Sphaeriidae - fingernail clams	A,nr	C,nr	U,nr
5. *Sphaerium spp.*	nr,A	nr,U	nr,A
Mollusca - Gastropoda - snails[3]			
Hydrobiidae snails	U,nr	U,nr	U,nr,nr
6. *Amnicola walkeri*	nr,nr	nr,nr	nr,nr,U
Lymnaeidae snails			
7. *Fossaria obrussa*	C,nr	C,nr	nr,nr,U
8. *F. parva*	nr,nr	nr	nr,U,U
F. spp.	nr,nr	nr,nr	U,A,nr
9. *Pseudosuccinea columella*	C,A	U,nr	nr,C-A,nr
10. *Stagnicola elodes*	A,nr	C,nr	nr,A,nr
Physidae snails			
11. *Aplexa elongata*	A,U	nr,nr	C,nr,A
12. *Physa gyrina*	C,nr	A,nr	A,nr,C
P. spp	nr,U	nr,nr	nr,C-A,nr
Planorbidae snails			
Gyraulus spp.	C,nr	A,nr	nr,nr,nr
13. *G. deflectus*	nr,nr	nr,nr	nr,nr,C
14. *G. parvus*	nr,nr	U,nr	C,nr,C
15. *G. circumstriatus*	nr,nr	U,nr	C,nr,nr
16. *Heliosoma spp.*	nr,nr	nr,nr	nr,A,nr
17. *Planorbella spp.*	U,nr	U,U	nr,nr,nr
18. *P. trivolvis*	nr,U	nr,nr	A,nr,nr
19. *P. companulata*	nr,nr	nr,nr	nr,nr,U
20. *Planorbula armigera*	nr,nr	nr,nr	nr,nr,A
21. *Promenetes exacuous*	U,A	nr,U	nr,U-A,nr
Bithyniidae snails			
22.*Bithynia tentaculata*	nr,nr	nr,nr	nr,C,C
Arthropoda - Arachnida			
Hydracarina -water mites	C,nr	C-A,nr	nr,nr
23. *Hydrachna spp.*	nr,nr	nr,nr	nr,A
24. *Trombidium spp.*	nr,nr	nr,nr	nr,U
Arthropoda - Crustacea			
Isopoda - Asellidae - isopods			
25. *Caecidotea* spp.	A,A	nr,nr	nr,nr
Amphipoda - scuds, amphipods			
26. Crangoncyctidae - *Crangonyx* spp.	A,nr	nr,nr	nr,nr
27.Gammaridae - *Gammarus* spp.	U,C	nr,nr	nr,A
28. Talitridae - *Hyalella azteca*	U,U	nr,nr	nr,U
29. Decapoda, Crayfish, *Orconectes spp.*	U,nr	nr,nr	nr,nr
30. Cnidaria - *Hydra* spp.	nr,nr	nr,nr	nr,U
31. Nematoda - round worms	nr,A	nr, C	nr,C
32. Turbellaria - flat worms	nr,U	nr,nr	nr,nr

A = abundant, C = common, U = uncommon, nr = not recorded at all at this taxonomic level. [1]our 2002–2003 data , [2]from Gathman et al., 1999, [3]from Keas, 2002.

Table 3. Aquatic Insect Taxa Reported from Lake Huron coastal depressional wetlands.

Taxon - common name	Swamps[1,2]	Emergent Marshes[1,2]	Wet Meadows[1,2]
Ephemeroptera - mayflies			
Baetidae			
1. *Baetis* spp.	nr,nr	U,nr	nr,nr
2. *Callibaetis* spp.	nr,nr	U,nr	nr,nr
Caenidae			
3. *Caenis* spp.	nr,nr	U,C	nr,C
4. Habrophlebiodes	nr,nr	nr,nr	U,nr
Odonata - dragonflies, damselflies			
Coenigrionidae - damselflies			
5. *Enallagma* spp.	U,U	U,nr	nr,U
6. *Ishnura verticalis*	nr,nr	nr,nr	nr,U-C
7. *Nehalennia* spp.	nr,nr	nr,nr	nr,A
Lestidae - damselflies			
8. *Lestes* spp.	nr,nr	C,nr	nr,U
Libellulidae - dragonflies	U,U	U,nr	U,U
9. *Leucorrhinia intacta*	U,nr	U,nr	U,nr
10. *Sympetrum* spp.	U,U	U,nr	nr,nr
11. *Libellula* spp.	nr,nr	U,nr	nr,nr
Aeshnidae - dragonflies			
12. *Aeshna umbrosa*	U,nr	U,nr	U,nr
13. *Anax junius*	nr,nr	U,nr	U,nr
Hemiptera - True Bugs			
Belostomatidae			
14. *Belostoma* spp.	nr,nr	U,nr	nr,nr
Corixidae - water boatmen	U,nr	nr,nr	nr,nr
15. *Hesperocorixa* spp.	nr,nr	U,nr	nr,nr
16. *Palmacorixa* spp.	nr,nr	U,nr	nr,nr
17. *Trichocorixa naias*	nr,nr	nr,U	nr,nr
Gerridae - water striders	U,nr	U,nr	U,nr
18. *Gerris* spp.	nr,nr	U,nr	nr,C
19. *Trepobates* spp.	nr,nr	U,nr	nr,nr
Macroveliidae - water striders	nr,nr	nr,nr	nr,U
20. *Macrovelia* spp.	U,nr	nr,nr	nr,nr
Mesoveliidae			
21. *Mesovelia* spp.	nr,nr	C,nr	nr,nr
22. Notonectidae	nr,nr	U,nr	nr,nr
Nepidae			
23. *Ranatra* spp.	nr,nr	U,nr	nr,nr
Pleidae			
24. *Neoplea* spp.	nr,nr	U,nr	nr,nr
Veliidae			
25. *Microvelia* spp.	nr,nr	U,nr	nr,nr
Megaloptera - fish flies			
Corydalidae			
26. *Chaliodes* spp.	U,C	nr,nr	nr,nr
Trichoptera - caddisflies			
Hydroptilidae			
27. *Oxyethira* spp.	nr,nr	U,nr	nr,nr

Table 3. Aquatic Insect Taxa Reported from Lake Huron coastal depressional wetlands *(Continued)*.

Taxon - common name	Swamps[1,2]	Emergent Marshes[1,2]	Wet Meadows[1,2]
28. *Triaenodes* spp.	nr,nr	C,nr	nr,nr
Leptoceridae			
29. *Nectopsyche* spp.	nr,nr	nr,nr	nr,U
Limnephilidae			
30. *Limnophilus* spp.	C, A	C,nr	nr,A-U
Phryganeidae			
31. *Agrypnia vestita*	nr,nr	nr,nr	nr,U
32. *Banksiola* spp.	nr,nr	nr,nr	nr,U
Lepidoptera - aquatic moths			
33. Pyralidae	U,nr	U,nr	nr,nr
Coleoptera - beetles			
34. Circulionidae	U,nr	U,nr	nr,C
Dytiscidae			
35. *Acilius* spp.	U,nr	U,nr	U,nr
36. *Agabetes* spp.	U,nr	U,nr	U,nr
37. *Agabus* spp.	U,nr	U,nr	U,nr
38. *Colymbetes* spp.	nr,nr	U,nr	nr,U
39. *Coptotomus* spp.	U,nr	nr,nr	nr,nr
40. *Deronectes* spp.	nr,nr	nr,nr	nr,C
41. *Derovattelus* spp.	nr,nr	nr,nr	nr,C
42. *Dytiscus* spp.	U,nr	U,U	nr,U-C
43. *Graphoderus* spp.	nr,nr	U,nr	nr,nr
44. *Hydroporus* spp.	U,nr	U,nr	nr,nr
45. *Hygrotus* spp.	U,nr	C,nr	nr,nr
46. *Ilybius* spp.	U,nr	U,nr	nr,nr
47. *Laccophilus* spp.	nr,nr	U,nr	nr,C
48. *Matus* spp.	nr,nr	U,nr	nr,nr
49. *Potamonectes* spp.	nr,nr	U,nr	nr,nr
50. *Rhantus* spp.	U,nr	nr,nr	nr,C
51. *Uvarus* spp.	nr,nr	nr,nr	nr,C
Hapliplidae	nr,nr	nr,nr	nr,U
52. *Haliplus* spp.	U,nr	C,nr	U,nr
53. *Peltodytes* spp.	U,nr	U,nr	nr,nr
Hydrophilidae			
54. *Anacaena* spp.	C,nr	U,nr	nr,U
55. *Berosus* spp.	U,nr	C,nr	nr,nr
56. *Derallus* spp.	nr,nr	U,nr	nr,U
57. *Enochrus* spp.	U,nr	U,nr	nr,nr
58. *Hydrobius* spp.	U,nr	U,nr	nr,nr
59. *Hydrochara* spp.	U,nr	nr,nr	nr,nr
60. *Paracymus* spp.	U,nr	nr,nr	nr,nr
61. *Tropisternus* spp.	U,nr	U,nr	nr,C
Helophoridae			
62. *Helophorus* spp.	U,nr	nr,nr	nr,nr
Hydrochidae			
63. *Hydrochus* spp.	U,nr	nr,nr	nr,nr
64. Lampyridae	U,nr	nr,nr	nr,nr
Gyrinidae			

(Continuued on next page)

Table 3. Aquatic Insect Taxa Reported from Lake Huron coastal depressional wetlands *(Continued)*.

Taxon - common name	Swamps[1,2]	Emergent Marshes[1,2]	Wet Meadows[1,2]
65. *Gyrinus* spp.	nr,nr	U,nr	nr,U
Scirtidae			
66. *Microcara* spp.	nr,nr	nr,nr	nr,C
67. *Prionocyphon* spp.	U,nr	nr,nr	nr,nr
Diptera - true flies			
Ceratopogonidae - biting midges	nr,nr	nr,nr	nr,U-A
68. *Bezzia* spp.	U,nr	A,nr	C,nr
Chaoboridae	nr,nr	U,nr	nr,nr
69. *Chaoborus* spp.	A,A	A,C	C,C-A
Chironomidae - non-biting midges	A,nr	A,nr	nr,nr
70. Chironomini	U,nr	A,nr	C,nr
71. Tanytarsini	U,nr	C,nr	C,nr
72. Tanypodinae	U,nr	C,nr	U,nr
73. Orthoclodinae	A,U	U,U	U,U
Culicidae - mosquitos	A,nr	U,nr	nr,A
74. *Aedes* spp.	U,nr	U,nr	U,nr
75. *Anopheles* spp.	U,nr	nr,nr	U,nr
76. *Culex* spp.	U,nr	nr,nr	nr,nr
77. *Mansonia* spp.	nr,nr	nr,nr	nr,U-C
Dixidae - dixid midges	nr,nr	nr,nr	nr,C
78. *Dixella* spp.	nr,nr	nr,nr	nr,U
79. Psychodidae - moth flies	U,nr	U,nr	nr,C
80. Tabanidae - horse & deer flies	U,U	nr,nr	nr,U
81. Tipulidae - craneflies	U,nr	U,nr	nr,nr
82. Sciomyzidae - marsh flies	U,nr	U,nr	nr,nr
Stratiomyiidae - soldier flies	C,nr	nr,nr	nr,nr
83. *Odontomyia or Hedriodiscus*			
84. Syrphidae - rat-tailed maggots	nr,nr	U,nr	U,nr
Collembola -Springtails			
85. Sminthuridae			

A = abundant, C = common, U = uncommon, nr = not recorded, [1]our data from 2003, [2]data from Gathman et al., 1999.

wood frogs, *R. sylvatica*, were present in coastal wetland ponds early in the Spring before our surveys began, since it was reported as occurring in 15 of 91 calling sites by Price et al., (2004), and we have observed small wood frogs in the wetlands we sampled later in the summer. Wood frogs were reported as one of 8 common species in the basin by the Marsh Monitoring Program (Timmermans and Eoin Craigie, 2002) and the Michigan Frog and Toad monitoring survey (Genet, 2004). Wood frogs were previously reported from Saginaw Bay wetlands (Bura and Burton in Wilcox 1995, personal observations). Relatively rare species in terms of occurrence include bullfrogs, *R. catesbeiana*. We observed bullfrogs only once in a Saginaw Bay protected wetland. Bullfrogs were reported from 2 of 93 sites sampled by Price et al., (2004). The pickerel frog, *R. palustris*, occurs in low numbers in Lake Huron protected wetlands (Bura and Burton in Wilcox, 1995; Harding, 1997; Genet, 2004). The mink frog, *R. septentrionalis*, should occur in northern Lake Huron wetlands based on distribution maps of Harding (1997). Hecnar (2004) listed 10 species of frogs and toads collected from Lake Huron wetlands. Blanchard's cricket frog was reported calling from only one site in the survey of Price et al., (2004) around Lakes Huron and Michigan.

Amphibians–salamanders

No systematic sampling of salamanders has been done in protected coastal wetlands to our knowledge. Based on distribution maps of Harding (1997), the following salamanders should occur in Lake Huron protected wetlands: mudpuppies, *Necturus maculosus*, eastern newts, *Notophthalmus viridescens*, spotted and blue-spotted salamanders, *Ambystoma maculatum* and *A. laterale*, four-toed salamanders, *Hemidactylium scutatum*, and the red-backed salamander, *Plethodon cinereus*. The red-backed salamander is a primarily terrestrial, forest dwelling and breeding species but can be collected from the drier edges of wetlands. Hecnar (2004) reported the occurrence of 7 salamanders from Lake Huron wetlands including the 6 species that we listed plus the two-lined salamander, *Eurycea bislineata*, a primarily stream and stream side species. Based on the above plus distribution maps of Harding (1997), we estimate salamander diversity to be >10 species and total amphibian diversity to be >20 species.

Reptiles

Wilcox (1995) reported that five turtles and three snakes had been reported from coastal wetlands based on observations of Bura and Burton and others. The five turtles included painted turtles, *Chrysemys picta*, spotted turtles, *Clemmys gutata*, wood turtles, *Clemmys insculpta,* Blanding's turtle, *Emydoidea blandingii,* and common snapping turtles, *Chelydra serpentina*. Additional turtles that should occur in the southern ecoregion of Lake Huron are the common musk turtle, *Sternotherus odoratus*, the common map turtle, *Graptemys geographica*, and the spiny softshell turtle, *Apolone spinifera* (Harding, 1997).Except for snapping and painted turtles, these reptiles occur in protected coastal wetlands exclusively or much more often than in fringing lacustrine wetlands (personal observations). The three snakes previously reported were common garter snakes, milk snakes and eastern Massasauga rattlesnakes (*Thamnophis sirtalis, Lampropeltis triangulum,* and *Sistrurus catenatus)*. Additional snakes likely to occur in protected coastal wetlands include the northern water snake, *Nerodia sipedon,* the queen snake, *Regina septemvittata,* Butler's garter snake, *Thamnophis butleri*, and the ribbon snake, *Thamnophis sauritus* (Harding, 1997).There are several other primarily terrestrial snakes that can occasionally be found in wetlands. There are no lizards that occur in Great Lakes wetlands, but several skinks and other lizards can be found on sandy habitat including ridges adjacent to wetlands. Based on estimates of >9 turtles, >10 snakes, but 0 lizards, we estimate reptile diversity to be >20 species.

Birds

Prince and Flegel (1995) reported the occurrence of 80 species of birds in Lake Huron wetlands. Using the Michigan Bird Atlas (Brewer et al., 1991), Prince and Burton (1996) compiled a list of 63 species of birds that were known to use wetlands of Saginaw Bay for feeding and or breeding out of a total species list for the area of 123 species. Weeber and Vallianatos (2000) summarized data from the Marsh Monitoring Program for 1995-1999 and reported that 53 of the 207 species recorded from the entire Great Lakes basin by observers were closely associated with wetlands (45 marsh nesters and 8 aerial feeders above the marsh surface). Whitt (1996) documented use of wetlands by 39 bird species for Saginaw Bay wetlands with 35 species using protected coastal wetlands. Riffell (2000) documented the occurrence of 55 species of birds in wet meadows of northern Lake Huron with 26 classified as probable wet meadow nesters. The combined lists of 66 species documented as using Lake Huron protected wetlands by Whitt (1996) and Riffell (2000) included 83% of birds reported as users of Lake Huron wetlands by Prince and Flegel (1995). Neither Whitt nor Riffell reported use of protected coastal wetlands by gulls and terns with the exception of the black tern. Since most protected coastal marshes dry up annually and few support fish populations, the absence or minimal use of them by gulls, terns and other fish eating birds was not surprising. We estimate that total species richness of birds in protected wetlands is likely to exceed 80 species with inclusion of occasional wetland and upland avian users.

Mammals

We compiled a list from Baker (1983) of 48 mammal species that were likely to occur in Lake Huron protected wetlands. Prince and Burton's (1996) crew sampled small mammals for 1283 trap nights from six wet meadows around Saginaw Bay from 1993-1995. Eight species and 436 individuals were

captured. These, in decreasing numbers caught, included white footed and deer mice (*Peromyscus leucopus* and *P. maniculatus*), meadow voles (*Microtis pennsylvanicus*), short-tailed shrews (*Blarina brevicauda*), masked shrews (*Sorex cinereus*), meadow jumping mice (*Zapus hudsonius*), least weasels (*Mustela nivalis*), and eastern moles (*Scalopus aquatica*). Sixteen additional mammals observed in or near wetlands included opossums, *Didelphis virginiana,*, star-nosed moles, *Condylura cristata,* eastern cottontails, *Sylvilagus floridanus*, eastern chipmunks, *Tamias striatus,* woodchucks, *Marmota monax*, fox squirrels, *Sciurus niger*, muskrats, *Ondatra zibethicus*, house mice, *Mus musculus,* coyotes, *Canis latrans*, red and gray foxes, *Urocyon cinereoargenteus* and *Vulpes vulpes,* raccoons, *Procyon lotor*, long-tailed weasels, *Mustela frenata,* mink, *M. vision,* striped skunks, *Mephitis mephitis*, and white-tailed deer, *Odocoileus virginianus*. Thus, Prince and Burton (1996) documented the occurrence of 24 mammal species from Saginaw Bay wetlands. Combining their 24 species with 7 non-overlapping species from Wilcox (1995) results in a total of 31 species from only limited observations and sampling effort. This is 65% of the 48 species compiled from Baker (1983). Allowing for addition of bats that are known to use these wetlands and extra species from additional surveys to Baker's list plus addition of an additional species or two not reported from these wetlands, we estimate that 50 species of mammals are likely to occur in Lake Huron protected coastal wetlands.

Conclusions – plant and animal species richness

Total species richness for plants in protected Lake Huron coastal wetlands, not including algae, is estimated to exceed 600 species with >250 species occurring in protected marshes and >300 species occurring in protected swamps. Total animal species richness, not including the smallest microscopic species, is estimated to be 700–800 species with 550–600 species of invertebrates and 150–200 species of vertebrates. Thus, total plant and animal species richness is estimated to exceed 1400 species. Species present in any one of these isolated wetlands is often less than 20% of the 1400 species described for all the protected wetlands included in this compilation of data. Thus, preservation of diversity in protected Great Lakes wetlands will require protection and sustainable management of a relatively large number of these wetlands in each major ecoregion of the Lake Huron shoreline.

There are some major gaps in these data. There have been few, if any, studies of microinvertebrates (e.g. zooplankton) in these protected wetlands. Our estimate for them is based on studies done in more open lacustrine wetlands and wetlands farther inland. Macroinvertebrate studies need to be expanded from the operational taxonomic unit basis that we used in our studies to observations at the species level. Likewise, mammals, salamanders and snakes of these wetlands have been poorly studied. Turtle studies are often based on by-catch and observations of them when monitoring fish, birds, invertebrates, and plants. Our estimates for mammals, snakes, turtles, and salamanders were also partially estimated from range maps in field guides and from limited on site observations. These and other poorly studied groups point to the need for additional studies of these groups in order to truly understand their occurrence and role in protected Lake Huron wetlands.

Many predictions of climate change suggest that Great Lakes water levels will decline by a meter or more over the next 30-50 years exposing bottom lands along shallow sloping shorelines of the Great Lakes from tens to hundreds of meters wide. In fact, the decline in lake levels of Lake Huron over the last decade to near historic lows has illustrated this process in Saginaw Bay, the Les Cheneaux Islands and elsewhere. Because Michigan legally owns bottom lands below the mean high water mark, the amount of exposed land in public ownership along the U.S. coast of Lake Huron has increased and will continue to do so if climate change predictions are accurate. As wetlands migrate offshore, shallow areas of lacustrine wetlands will be isolated enough to become protected coastal wetlands. Our data documenting the importance of protected coastal wetlands as centers of biodiversity along with data on the importance of lacustrine wetlands from others (e.g. Wilcox, 1995) should be useful in convincing the public of the value of protecting these newly exposed lands.

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