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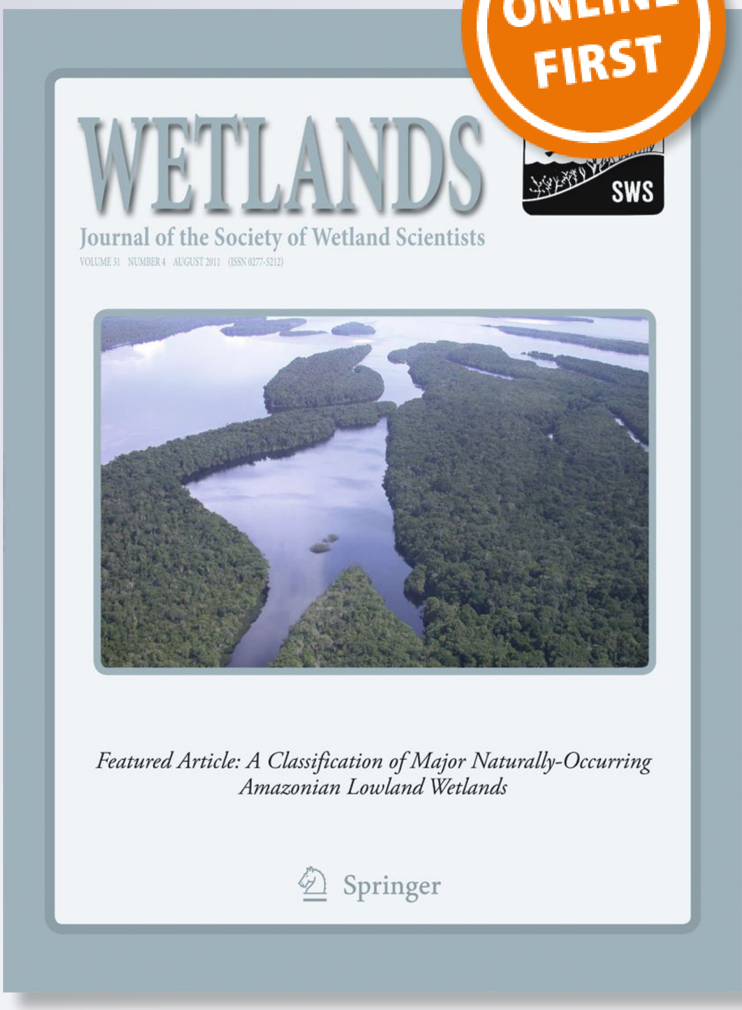

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ARTICLE

Comparisons of Bird, Aquatic Macroinvertebrate, and Plant Communities Among Dredged Ponds and Natural Wetland Habitats at Long Point, Lake Erie, Ontario

Michael L. Schummer · Jason Palframan · Emily McNaughton · Ted Barney · Scott A. Petrie

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Abstract Decreased wetland interspersion and need for dredging of lower Great Lakes coastal wetlands results from encroachment of open water by invasive cattail (*Typha* × *glauca, T. angustifolia*) and common reed (*Phragmites australis*). To increase wetland interspersion and fish and wildlife habitat at Long Point, Lake Erie, wetlands were dredged to restore open water ponds (0.4–4.0 ha ponds) in monotypic stands of cattail and common reed (hereafter cattail-reed), 2008–2010. We determined if bird, aquatic macroinvertebrate, and plant communities differed among dredged ponds, natural ponds, and areas of monotypic cattail-reed to investigate effects of dredging, May–August 2011. Marsh-bird relative abundance was 40 % greater at dredged and natural ponds than cattail-reed areas, and richness was at least 16 % greater at dredged ponds than natural ponds and cattail-reed areas. Relative abundance of macroinvertebrates was 77 % greater in dredged than natural ponds. Plant species richness was 57 and 54 % greater, respectively, and diversity 42 % greater at dredged ponds than natural ponds and cattail-reed areas. Our comparison of dredged ponds with natural wetland habitats highlights that dredging to restore interspersion and manage monotypic cattail-reed in lower Great Lakes wetlands can be beneficial to marsh-nesting birds and habitat resources used by fish and wildlife.

Keywords Cattail · Dredging · Great Lakes coastal wetland · Interspersion · *Phragmites* · Wetland restoration

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Introduction

Wetlands in the Laurentian Great Lakes region are used by a diversity of fish as nursery and spawning areas (Jude and Pappas 1992; Casselman and Lewis 1996) and by resident and migratory wildlife as breeding and foraging habitat (e.g., marsh-nesting birds; Prince et al. 1992; Meyer et al. 2010). However, wetland loss in states and provinces surrounding the Great Lakes is >60 % in most locales (Mitsch and Gosselink 2007). Loss of coastal wetlands on the Canadian shores of lakes Erie, St. Clair, and Ontario is >35 % (McCollough 1985), but in some areas exceeds 95 % (i.e., western Lake Erie; Herdendorf 1987). Stressors further degrading remaining coastal wetlands in the Great Lakes include encroachment by invasive species, continued drainage, stabilization of water levels, sedimentation, and other anthropogenic inputs and modifications (Detenbeck et al. 1999; Keough et al. 1999). Thus, maintaining, restoring, and enhancing the quality of remaining wetlands in the Great Lakes region is increasingly important for sustaining populations of wetland-dependent fish, wildlife, and vegetation (Bertram and Reynoldson 1992). To maintain, restore, or enhance carrying capacity of wetlands for fish and wildlife in the Great Lakes, restoration and management of hydrology and vegetation in coastal wetlands are increasingly common (Herdendorf 1987; Whillans 1996; Batzer and Sharitz 2007).

Wetlands with open water interspersed within areas of emergent vegetation (i.e., interspersion) often have greater biodiversity than those with homogenous stands of vegetation (Kaminski and Prince 1981; Murkin et al. 2000). Decreased interspersion because of encroachment by cattail (*Typha* × *glauca, T. angustifolia*) and common reed (*Phragmites australis*) is common in coastal wetlands of the Great Lakes and is exacerbated by several mechanisms, including agricultural run-off, sedimentation, and stabilization of lake levels (e.g.,

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Lake Ontario; Wilcox et al. 2008; Rippke et al. 2010). Wetlands with limited open water, such as those dominated by cattail and common reed, may be avoided by waterbirds (Poole et al. 2009; Meyer et al. 2010), anurans (Stevens et al. 2002), and fish (Jude and Pappas 1992; Keough et al. 1999; Croft and Chow-Fraser 2007), thereby reducing wetland biodiversity and utility to resource users (e.g., birdwatchers, anglers, and hunters). At inland and coastal wetlands within the Great Lakes region, abundances of waterbirds varied positively with interspersion (Rehm and Baldassarre 2007; Bartok 2010). For these reasons, wetland restoration, creation, and enhancement projects often increase interspersion by dredging and scraping openings in an irregular pattern where monotypic stands of cattail and common reed occur (Kaminski and Prince 1981; Mathers and Hartley 1995; Smith et al. 2004; Rehm 2006).

Relative abundance and species richness of birds in common reed habitats were studied previously at Long Point by Meyer et al. (2010), and they suggested, "reducing area [of common reed], increasing amount of edge, and improving stand structural diversity and local habitat diversity to increase its use by marsh-nesting birds, which could be accomplished by creating irregularly shaped channels and ponds or openings within common reed stands to improve habitat heterogeneity." Thus, to increase wetland interspersion and improve wildlife habitat at Long Point, Lake Erie, Ontario, Canada, ponds were dredged in areas of monotypic, invasive cattail and common reed, 2008–2010. Dredging of Great Lakes coastal wetlands has been used for decades to increase interspersion and enhance functions of wetlands for fish and wildlife (Grillmayer 1995; Mathers and Hartley 1995; Vincent 1995). Federal, state, and provincial permitting agencies generally require removal of dredge materials or limit maximum heights of spoil piles to minimize changes in microtopography, hydrology, and plants species composition in enhanced wetlands (USACE 2002). Despite that dredging is commonly used to enhance Great Lakes coastal wetlands and handling of spoil material is regulated, published evaluations on effects of dredging are limited (Middleton 1999). We initiated our study to understand effects of these activities on wetland flora and fauna for use in future conservation planning for Great Lakes coastal wetlands. Our objectives were to determine if bird, aquatic macroinvertebrate, and plant communities differed among dredged ponds and natural wetland habitats at Long Point, Lake Erie, Ontario.

Methods

Study Area

We conducted our study at dredged ponds, natural ponds, and in areas of monotypic cattail and common reed (hereon, cattail-reed areas) within coastal wetlands (i.e., protected lacustrine wetlands) at Long Point Crown Marsh and Long Point Provincial Park Marsh, Long Point, Lake Erie, Ontario, Canada (Fig. 1). Interspersion was increased by dredging fifteen ponds (~ 0.4–4.0 ha in size) in areas of monotypic cattail

Fig. 1 Locations of monitored dredged ponds (black) and survey points (circles) in Long Point Crown Marsh and Long Point Provincial Park, May–August 2011. Locations with similar numbers are survey blocks and letters that follow numbers denote dredged ponds (i.e., restored interspersion; R), N = natural ponds (N), and vegetated areas (i.e., cattail-reed areas; V)

and common reed, 2008–2010 (Fig. 1). Ponds were ≤1.5 m deep and dredge spoil (~0.25–2.0 m high) was placed at edges of dredged ponds and dispersed adjacent to ponds to minimize heights of spoil piles. We studied these marshes because they were subjected to dredging (2008–2010) to enhance wetland interspersion and had nearby (<300 m) natural ponds and areas of monotypic cattail and common reed, which enabled comparisons of bird, aquatic macroinvertebrate, and plant communities among these three habitat treatment types. We designated study areas as natural ponds if they were not subject to human disturbance of substrate in the past 10 years. Cattail-reed areas were dominated by cattail or common reed and had <10 % open water. Surveyed dredged ponds, natural ponds, and cattail-reed areas were distributed throughout the marshes (Fig. 1).

Long Point coastal wetlands are typified by a gradient of upland-marsh meadow habitat to the south, which transitions to emergent marsh and then shallow open-water habitats of the Inner Long Point Bay. Marsh-meadow habitats were primarily sedges (e.g., *Carex* spp.) and grasses (e.g., *Calamagrostis canadensis*), but also contained wetland forbs (e.g., *Scutellaria galericulata*) and shrubs (e.g., *Cornus sericea*). Emergent marshes were dominated by narrow-leaved and hybrid cattail (*Typha angustifolia* and *T.* × *glauca*; respectively) but also contained other wetland obligate plants, including broad-leaved cattail (*Typha latifolia*), bulrushes (*Schoenoplectus* spp.), spikerushes (*Eleocharis* spp.), and burreeds (*Sparganium* spp). Floating (e.g., white water lily [*Nuphar lutea*]) and submerged vegetation (e.g., coontail [*Ceratophyllum demersum*]) occurred in open-water areas within emergent marsh and shallow open-water habits at the marsh-Inner Long Point Bay interface. Common reed occurred throughout marshes but was most commonly associated with areas of marsh-meadow. Lake Erie water levels during our study were 0.12 m, 0.25 m, 0.16 m, and 0.10 m greater than long-term averages (LTA; 1918–2010) during May (LTA=174.30 m), June (174.30 m), July (174.32 m), and August (174.25 m), respectively (USACE 2011).

Study Design

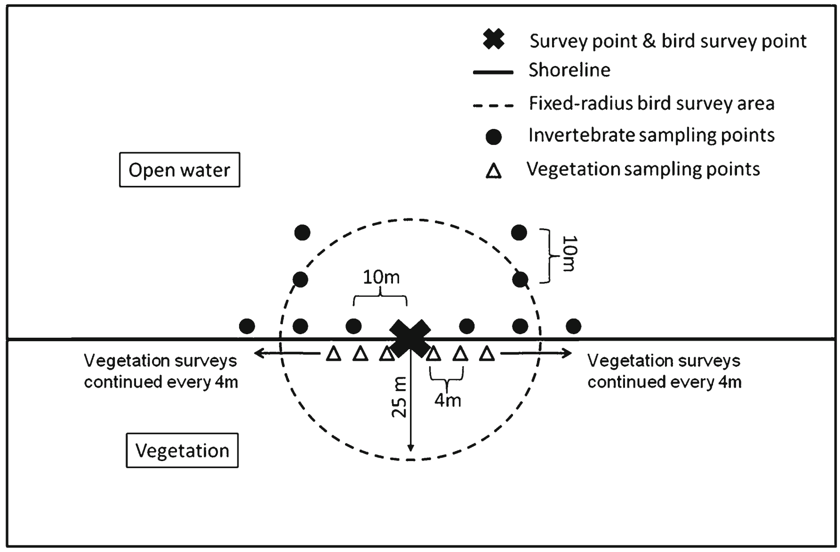
We considered the 15 ponds dredged at Long Point Crown Marsh and Long Point Provincial Park Marsh 2008–2010 as potential study sites. To maintain a 250 m sampling distance between dredged pond replicates and ensure that reference natural ponds and reference cattail-reed areas were available in the same block (i.e., a 3-treatment block), we used 11 of 15 dredged ponds for our study. We conducted initial reconnaissance of the 11 dredged ponds and randomly placed a survey point, at the emergent vegetation/open water interface (hereafter shoreline) of each pond. At each dredged pond survey point, we obtained latitude and longitude with a handheld Global Positioning System (GPS) with ± 3 m accuracy (Garmin 76C x). We also created a polygon of each dredged pond by walking the perimeter with the track function enabled on the GPS, allowing us to determine increased interspersion (m/ha; *sensu* Rehm and Baldassarre 2007) from dredging. At the office, we plotted dredged pond survey points and polygons of dredged ponds in Google Earth. To block natural ponds with dredged ponds, we randomly selected 1 of 8 evenly distributed compass headings (i.e., 0°, 45°, 90°, etc.) and used Google Earth to determine if a potential natural pond survey point existed at 250–350 m on that heading and was ≥250 m from other survey points in the marsh. If a natural pond survey point met these criteria, we entered the latitude and longitude into Google Earth and our GPS. We continued the aforementioned process from west to east until all natural pond locations meeting our criteria had been selected and then used the same method to select cattail-reed areas. We ground-truthed each survey point and, if necessary, adjusted the location of survey points to locate them at the shoreline of natural ponds and in cattail-reed areas dominated by cattail or common reed. We located all surveys of vegetation areas in cattail and common reed because monotypic stands of these habitat types were one of the main criteria used to determine locations of dredging to restore ponds. Our final sampling design had 11 survey blocks, each including a dredged pond, natural pond, and cattail-reed area (n=33 survey points; Fig. 1).

Bird Surveys

We used fixed-distance point counts to determine relative abundance (standardized methods among treatments, thus relative), species richness (total number of species detected at each pond and cattail-reed area), and species diversity (Shannon-Weiner Index) of birds at dredged ponds, natural ponds, and cattail-reed areas. We used the survey points established at each treatment (described above) as the center of our fixed-distance point counts, and points were ≥250 m apart to minimize the probability of multiple counts of individual birds during consecutive visits (Bird Studies Canada 2003; Meyer et al. 2010, Fig. 2). We marked the point with flagging on vegetation and used a GPS to find points on subsequent surveys. We surveyed points during three periods (19 May–6 June; 17 June–1 July; 21 July–30 July) with consecutive surveys of points >14 days apart.

We used a sampling radius of 25 m to survey birds because observers can detect birds to this distance in all habitats (Meyer et al. 2010; Fig. 2). At each survey point, we broadcast calls from an MP3 player with a portable, battery-powered speaker at a sound pressure of 90 decibels measured at 1 m in front of the speakers for the first five minutes to elicit vocal responses from secretive marsh birds

Fig. 2 Placement of the survey point, bird survey point and fixed-radius bird survey area, invertebrate sampling points, and vegetation sampling points at shorelines of dredged and natural ponds at Long Point Crown Marsh and Long Point Provincial Park, Lake Erie, Ontario, Canada, May–August 2011



(Gibbs and Melvin 1993; Rehm and Baldassarre 2007; Meyer et al. 2010). Broadcast calls were followed by five minutes of passive listening and observation for a total survey period of 10 min. The species (in order) of broadcast calls included were Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), least bittern (*Ixobrychus exilis*), common moorhen (*Gallinula chloropus*), American coot (*Fulica americana*), and pied-billed grebe (*Podilymbus podiceps*; Meyer et al. 2010). For all surveys, we recorded individuals detected by sight and sound within the 25-m-radius plot and aerial insectivores actively feeding in the air above the 25-m-radius plot (Meyer et al. 2010).

Aquatic Macroinvertebrate Surveys

We used a 30.48-cm-wide D-shaped sweep net with 500-μm mesh to sample aquatic macroinvertebrates at dredged and natural ponds during two periods (26 May–3 June; 27 June–7 July; Cheal et al. 1993). Starting at the survey point described in our study design above and within 3 m of the shoreline, we established three invertebrate sampling points at 10-m intervals on either side of the survey point (Fig. 2). At the second sampling point (at 20-m from the survey point), we established two more sampling points at 10-m intervals perpendicular to the shoreline. Our final sampling design included five invertebrate sampling points on either side of the survey point (n=10/pond). We randomly selected a side to sample during the first survey period and sampled the other side during the second survey period. We collected nektonic and benthic macroinvertebrates at each sample location by pushing the D-net through vegetation and along and in contact with substrate for 1-m (Cheal et al. 1993; Gray et al. 1999; Hagy 2010). Invertebrate samples were placed in labelled plastic bags and frozen within three hours of collection. At the lab, we thawed individual bags at room temperature and then quantified macroinvertebrate abundance by removing macroinvertebrates from debris using forceps and enumerated macroinvertebrates to the lowest taxonomic classification possible (i.e., order or family; Pennak 1989; Thorp and Covich 1991). We determined relative abundance (standardized methods among treatments, thus relative), taxa richness (total number of taxa detected at each pond), and species diversity (Shannon-Weiner Index) of aquatic macroinvertebrates at dredged and natural ponds.

Vegetation Surveys

We sampled vegetation in the later part of the growing season (25 July–10 August) to ensure representation of plant community richness and diversity. We developed species accumulation curves at a subsample of three blocks (n=9 species accumulation curves with all three treatments represented using 200 sampling points at 4 m intervals per location), 18–24 July before initiating our final vegetation surveys (Roberts-Pichette and Gillespie 1999). Our analysis indicated that 60 points were necessary to detect 100 % of plant species. We used each survey point (n=33) as described in the study design above as our initial location to start conducting vegetation surveys. We established 30 vegetation sampling points at 4-m intervals on either side of the survey point in vegetation and within 3 m of the shoreline (n=60 total vegetation sampling points; Fig. 2). Sampling within 3 m of the shoreline ensured that we could investigate effects of dredge spoil on vegetation at dredged ponds. When there were <240 m of shoreline at ponds, we evenly distributed the 60 vegetation sampling points along the available shoreline. At cattail-reed areas, we started at the survey point and evenly distributed 60 vegetation sampling points along transects at 4-m intervals in each of the cardinal directions (i.e., East, West, North, and South). When <15 vegetation sampling points could be established along a transect before leaving an area dominated by cattail or common reed (i.e., >50 % of plant species were cattail or common reed), we included additional points at a remaining randomly selected cardinal direction to ensure that we included 60 vegetation sampling points within each cattail-reed area. At each systematic sampling point, we identified and recorded each plant species touching a 3 cm diameter x 165 cm plastic PVC pipe touching the ground and held vertically (Grieg-Smith 1983; Fleming 2010).

We calculated plant community richness as total number of species detected at each pond and cattail-reed area. We calculated diversity using the Shannon-Weiner Index, where the measure of relative abundance of each plant species was its frequency of occurrence across all vegetation sampling points at a pond or cattail-reed area (Hair 1980). We used the USDA PLANTS database (USDA, NRCS 2011) to determine wetland indicator status of each plant species and determined percent occurrence of wetland obligate, facultative wetland, facultative, and facultative upland species at each pond and cattail-reed area by using the average of frequency of occurrence across all vegetation sampling points.

Data Analyses

We used a block design to determine if differences existed among dredged ponds, natural ponds, and cattail-reed areas for the following metrics 1) total bird abundance, 2) total bird species richness, 3) total bird species diversity 4) marsh-nesting bird abundance, 5) marsh-nesting bird species richness, 6) aerial insectivorous bird abundance 7) aerial insectivorous bird species richness 8) macroinvertebrate abundance, 9) macroinvertebrate taxa richness, 10) macroinvertebrate taxa diversity, 11) plant species richness, and 12) plant species diversity. Alpha (α) was designated *a priori* as 0.10, which is appropriate for addressing management objectives (Tacha et al. 1982). Covariance structures of dependent variables were evaluated based on Akaike's Second Order Information Criteria (AIC_c). Competing covariance structures were ranked according to Δ AIC_c values, and selection was based on the least Δ AIC_c value and biological interpretation of the covariance matrix. We selected compound symmetry (cs) from a suite of covariance structures for all analyses because it had the least AIC*c* ranking for each analysis (Littell et al. 2006). To evaluate homogeneity of variances, Studentized residuals of output models were plotted and examined for clustering and uniform distribution. Variances for relative abundance of invertebrates were log-transformed because resulting model residuals were not normally distributed (Littell et al. 2006). Log-transformations of these invertebrate data resulted in homogeneity of variances. Remaining models of response variables had normal error distributions.

Analysis of variance (ANOVA) was performed to test null hypotheses of no difference in the aforementioned bird and plant response variables among treatments (i.e., dredged pond, natural pond, and cattail-reed area; PROC MIXED, SAS 9.2.2). We also used ANOVA to test null hypotheses of no difference in the aforementioned invertebrate response variables between dredged and natural ponds (PROC MIXED, SAS 9.2.2). Treatments were a fixed effect, and blocks were a random effect. For birds and invertebrates, survey period was designated as a repeated measure to account for sampling the same treatment within the same block on repeated visits. Type 3 sums of squares were evaluated ($P>0.10$). Pair-wise multiple comparisons were used to evaluate significant differences among treatments (i.e., Tukey-tests). We presented results as least-squared means to account for variability attributable to repeated measures and random effects.

Results

Bird Surveys

We detected 22 total bird species, including 10 marsh-nesting birds and three aerial insectivorous birds (Appendix A). Total bird species richness and diversity did not differ among the three treatments ($P>0.10$; Table 1), but total bird abundance was greater at dredged (+18 %) and natural (+22 %) ponds than cattail-reed areas ($F_{2,\ 21.2}=3.08$, $P=0.06$; Table 1). Marsh-nesting bird relative abundance was 40 % greater at dredged and natural ponds than cattail-reed areas ($F_{2,\ 22.4}=3.08$, $P=0.07$; Table 1). Marsh-nesting bird species richness was 22 % greater at dredged ponds than natural ponds and 14 % greater at dredged ponds than cattail-reed areas ($F_{2,\ 20.4}=4.34$, $P=0.03$; Table 1). Neither relative abundance nor species richness of aerial insectivorous birds differed among treatments ($P>0.10$; Table 1).

Aquatic Macroinvertebrate Surveys

We detected and identified 4 phyla, 16 orders, and 29 families of macroinvertebrates (Appendix B). Macroinvertebrate taxa richness and diversity did not differ between dredged and natural ponds ($P>0.10$), whereas relative abundance was 1.7 times greater in dredged than natural ponds ($F_{1,\ 22}=3.92$, $P=0.06$; Table 1).

Vegetation Surveys

We detected 48 species of plants, of which 25 were obligate wetland species, 15 facultative wetland, 4 facultative, and 4 facultative upland (Appendix C). Plant species richness was 57 % greater at dredged than natural ponds and 54 % greater

Table 1 Least-squared means of relative abundance, species richness, and species diversity (± SE) for bird, invertebrate, and vegetation response variables at Long Point Crown Marsh and Long Point Provincial Park, Lake Erie, Ontario, Canada, May–August 2011. Within rows of response variables and columns (i.e., relative abundance, species richness, and species diversity), treatments (i.e., dredged ponds, natural ponds, and cattail-reed areas) with similar letters are not significantly different ($P>0.10$)

Response Variable	Relative abundance ($\bar{x}\pm$ SE)			Species richness ($\bar{x}\pm$ SE)			Shannon-Weiner species diversity ($\bar{x}\pm$ SE)		
	Dredged Ponds	Natural Ponds	Cattail-Reed Areas	Dredged Ponds	Natural Ponds	Cattail-Reed Areas	Dredged Ponds	Natural Ponds	Cattail-Reed Areas
Total birds	9.0±0.8 A	9.5±0.8 A	7.4 ±0.8 B	4.3±0.3 A	3.7±0.3 A	3.6 ±0.3 A	1.2±0.1 A	1.1±0.1 A	1.1±0.1 A
Marsh-nesting birds[a]	3.7±0.5 A	3.6±0.5 A	2.7±0.5 B	2.2±0.2 A	1.7±0.2 B	1.9±0.2 B	NC	NC	NC
Aerial insectivorous birds[a]	3.1±0.5 A	2.6±0.6 A	1.7±0.6 A	1.0±0.2 A	0.8±0.2 A	0.7±0.2 A	NC	NC	NC
Invertebrates[b]	57.8±1.2 A	32.6±1.2 B	NS	7.3±0.7 A	7.6±0.7 A	NS	1.4±0.1 A	1.5±0.1 A	NS
Vegetation[d]	NC	NC	NC	10.5±1.3 A	6.7±1.4 B	6.8±1.4 B	1.7±0.1 A	1.2±0.2 B	1.2±0.1 B

[a] Species diversity was not calculated (NC) for marsh-nesting nor aerial insectivorous birds because of relatively low species richness

[b] Only aquatic habitats were surveyed for invertebrates; thus, we did not survey (NS) invertebrates in cattail-reed areas

[c] We used a point intercept method to calculate frequency of occurrence, species richness, and species diversity of vegetation and thus had no measure of relative abundance for vegetation (NC)

at dredged ponds than cattail-reed areas ($F_{2,\ 19.6}$=2.01, P= 0.07; Table 1). Plant species diversity was 42 % greater at dredged ponds than natural ponds and cattail-reed areas ($F_{2,\ 29}$=3.65, P=0.04; Table 1). All plants at shorelines of natural ponds were facultative wetland or obligate wetland species, whereas shorelines of dredged ponds were mostly obligate and facultative wetland plants (92.5 % of plants recorded) but also had facultative (6.1 %) and facultative upland (1.4 %) plants (Table 2, Appendix C). Cattail-reed areas were dominated by either *Typha* spp. or *Phragmites australis* and other wetland obligate plants (97.8 %; Appendix C) but also included facultative (1.9 %) and facultative upland (0.3 %) plants.

Table 2 Percent occurrence of obligate, facultative wetland, facultative, and facultative upland plants[a] at shorelines of dredged ponds[b] and natural ponds[c] and within monotypic areas of cattail (*Typha* spp.) and common reed (*Phragmites australis*; i.e., cattail-reed areas[d]) at Long Point Crown Marsh and Long Point Provincial Park, Lake Erie, Ontario, Canada, August 2011

Wetland indicator status	Dredged ponds (%)	Natural ponds (%)	Cattail-reed areas (%)
Obligate	88.52±3.94	99.87±0.13	97.15±1.04
Facultative wetland	4.00±1.27	0.13±0.13	0.66±0.29
Facultative	6.06±2.97	–	1.93±1.00
Facultative upland	1.42±0.94	–	0.26±0.14

[a] Wetland indicator status as per USDA PLANTS database (2011)

[b] Areas of monotypic *Phragmites australis* (common reed) or *Typha* spp. (cattail) that were dredged to restore emergent wetland ponds

[c] Emergent wetland ponds that did not receive any dredging activity within the last 10 years

[d] Areas of monotypic *Phragmites australis* or *Typha* spp

Discussion

Wetland restoration has become a common tool used to manage fish and wildlife habitat throughout North America (Hammer 1992; Smith and Tome 1992; Hemesath and Dinsmore 1993). Food and habitat resources at wetlands (i.e., vegetation and invertebrates) play a key role in determining habitat suitability for wetland-dependent fish and wildlife (Kaminski and Prince 1981; Hemesath and Dismore 1993), but studies have not quantified these habitat metrics at areas dredged to restore interspersion at Great Lakes coastal wetlands. Our finding that relative abundance, species richness, and species diversity of aquatic macroinvertebrates and plants were as great, and in several cases even greater, at dredged ponds relative to other natural wetland habitats suggests that dredging to restore interspersion at Long Point, Lake Erie increased abundance and diversity of food and habitat resources (i.e., vegetation and invertebrates) for fish and wildlife. In accordance, we also detected similar trends in bird species richness and diversity among treatments, especially for marsh-nesting obligates. We did not investigate effects of dredging on biogeochemical processes that can influence underlying ecosystem functions often used to quantify success of wetland restoration efforts such as nutrient retention and transformation, toxicant retention, and oxidation of exposed organic soils (Bouchard 2007; Mitsch and Gosselink 2007).

A study at Long Point during 2001–2002 determined that cattail-reed areas provided habitat for birds at our study area, but habitat edges had greater total relative abundance and species richness than habitat interiors (Meyer et al. 2010). Dredging at Long Point increased wetland interspersion by 7,332 m, and in our study, these edge habitats had greater total relative abundance of birds than monotypic cattail-reed areas. Additionally, Meyer et al. (2010) determined that relative abundance, but not species richness, of marsh-nesting birds was greater in marsh-meadow habitat than in cattail-common reed areas during the breeding season. We detected greater species richness of marsh-nesting birds at dredged ponds relative to other treatments and that relative abundance of this guild also was greater at dredged and natural ponds than in cattail-reed areas. However, we conducted our surveys at the interface between open water areas and emergent marsh, whereas Meyer et al. (2010) studied differences among marsh-meadow, cattail, and common reed. Meyer et al. (2010) suggested restoring wetland interspersion by creating ponds within stands of common reed. The greater response of marsh-nesting birds in our study relative to Meyer et al. (2010) may be a result of new habitat that attracted a diversity of marsh-nesting birds to early successional edge habitats at the interface of open water and emergent marsh.

One goal of wetland restoration is to provide food resources to fish and wildlife (Hemesath and Dismore 1993). Aquatic macroinvertebrates in wetland habitats are important foods for growing fish and nesting and fledgling birds (Robertson 1973; Newton 1998; Casselman and Lewis 1996). Disturbance of wetland soils during restoration activity releases nutrients and can create conditions conducive to recolonization by invertebrates in the first year following restoration of interspersion (LaGrange and Dinsmore 1989; McKee and Baldwin 2000; Gleason et al. 2004). At Long Point, macroinvertebrate species diversity and richness were similar between dredged pond and natural wetlands, but relative abundance was greater in dredged ponds than natural wetlands. Similarity in macroinvertebrate species diversity and richness between dredged and natural wetlands, but greater relative abundance in dredged ponds than natural wetlands are consistent with existing aquatic macroinvertebrates communities responding to increased primary productivity from disturbance of soils and increased hydrologic flow. However, difference among our treatments was greatest for Chironomidae (midge larvae), which is an invertebrate family relatively tolerant of a wide range of conditions (Thorp and Covich 1991). Increased siltation from wave action on exposed soils on berms may increase turbidity and nutrient release, at least temporarily, and be conducive to greater colonization by Chironomidae, which are readily consumed by fish and waterbirds in larval stage and birds in adult (flying) stage (Scott and Crossman 1998; Smith et al. 1998; Schummer et al. 2008). Continued long-term monitoring of aquatic macroinvertebrates at these and other dredged ponds in Great Lakes coastal wetlands could be used to determine the length of time that changes to these communities following dredging are realized.

Management to encourage growth of early-succession vegetation often produces diverse and abundant food and habitat resources for wildlife (Fredrickson and Taylor 1982; Kellogg and Bridgham 2002). Disturbance of soils increases niches for plants and invertebrates that may attract a greater abundance of fish and wildlife (Fredrickson and Reid 1986; McKee and Baldwin 2000). Further, plants are adapted to a range of soil moisture and light conditions whereby germination occurs from seed banks when conditions are suitable (Kirkman and Sharitz 1994; Taft et al. 1997). We think that greater plant species richness and diversity at dredged ponds than natural ponds or cattail-reed areas resulted from increased diversity of niches on spoil piles and exposure of the seed bank created by movement of wetland soils. Specifically, in addition to the 35 plant species detected at natural ponds and cattail-reed areas, we also detected 13 plant species ($n=10$ wetland species) that occurred exclusively at edges of dredged ponds. These species include *Epilobium hirsutum*, *Eupatorium perfoliatum*, *Hypericum canadense*, *Impatiens capensis*, *Phragmites australis* (native variety), *Rubus hispidus*, *Scutellaria galericulata*, *Stachys aspera*, *Stachys palustris*, and *Typha latifolia*. Of these plants *Epilobium hirsutum* and *Stachys palustris* are introduced, with the former having invasive tendencies (USDA 2011).

Non-wetland (facultative upland) and facultative plants also occurred on spoil piles of dredged ponds, which also increased plant species richness and diversity compared to natural wetland areas of the marsh. However, some of these plants are considered invasive (including *Ambrosia artemisiifolia*, *Cirsium arvense, Solidago canadensis*, *Solanum dulcamara*), and wetland managers using dredging are cautioned to monitor plant communities post-dredging on berms to ensure that invasive plants do not out-compete desired vegetation. On average, at our study site, no single species of upland plant accounted for >3 % frequency of occurrence and facultative and upland plants occurred at 7.5 % of sampling points on berms of dredged ponds (compared to 0 % for natural ponds and 2.2 % at cattail-reed areas; Table 2, Appendix C). In our study, the lower percentage of wetland plants at dredged ponds did not reduce marsh-nesting bird abundance, richness, or diversity when compared to natural ponds and cattail-reed areas. Rather, increased species richness and diversity of plants, as well as abundant aquatic macroinvertebrates may have increased suitability of habitat for marsh-nesting birds at dredged ponds. However, differences in soil type, hydrology, seeds banks, and potential for seed dispersal from nearby areas among Great Lakes coastal wetlands requires site-specific monitoring of dredging activities and adaptive wetland management methods to ensure that non-desired, invasive plants do not reduce habitat quality.

Our comparison of dredged ponds to natural wetland habitats highlights that dredging to restore interspersion and manage monotypic cattail-reed areas in lower Great Lakes coastal wetlands can be beneficial to marsh-nesting birds and habitat resources also used by other fish and wildlife. Further, increased interspersion and juxtaposition of ponds to emergent marsh habitats following dredging may be beneficial to recovery of rare and endangered species (e.g., least bittern, Bartok 2010; Blanding's turtle [*Emydoidea blandingi*], Ross and Anderson 1990; Rowe and Moll 1991) but this requires further study. We think future conservation and management efforts in Great Lakes coastal wetlands should consider dredging to increase interspersion and biodiversity where feasible and desirable. We recommend further evaluations of dredging activities (including effects on wetland spawning and foraging fish) throughout the Great Lakes region to determine if regional, geophysical differences influence success of efforts to restore wetland interspersion and function. Lastly, we caution that dredging may increase likelihood of upland or invasive species establishing within Great Lakes coastal wetlands and further suggest that wetland managers and researchers continue to monitor vegetative colonization of dredge spoil areas to quantify senescence of spoil piles and long-term plant community metrics.

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References

Bartok ND (2010) Relative abundance and habitat associations of Least Bitterns (*Ixobrychus exilis*) at Long Point, Lake Erie, Ontario. M.Sc. Thesis, University of Western Ontario, London

Batzer DP, Sharitz RR (2007) Ecology of freshwater and estuarine wetlands. University of California Press, Berkeley

Bertram PE, Reynoldson TB (1992) Developing ecosystem objectives for the great lakes: policy, progress and public perception. Journal of Aquatic Ecosystem Health 1:89–95

Bird Studies Canada (2003) Marsh Monitoring Program: training kit and instructions for surveying marsh birds, amphibians, and their habitats. Bird Studies Canada, Environment Canada, and the U.S. Environmental Protection Agency, Port Rowan

Bouchard V (2007) Export of organic matter from a coastal freshwater wetland to Lake Erie: an extension of the outwelling hypothesis. Aquatic Ecology 41:1–7

Casselman JM, Lewis CA (1996) Habitat requirements of northern pike (*Esox lucius*). Canadian Journal of Fisheries and Aquatic Sciences 53(suppl 1):161–174

Cheal F, Davis JA, Growns JE, Bradley JS, Whittles FH (1993) The influence of sampling method on the classification of wetland invertebrate communities. Hydrobologia 257:47–56

Croft MV, Chow-Frasier P (2007) Use and development of the wetland macrophyte index to detect water quality impairment in fish habitat of Great Lakes coastal marshes. Journal of Great Lakes Research 33:172–197

Detenbeck NE, Galatowitsch SM, Atkinson J, Ball H (1999) Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. Wetlands 19:789–820

Fleming KS (2010) Effects of management and hydrology on vegetation, winter waterbird use, and water quality on Wetlands Reserve Program Lands, Mississippi. Thesis, Mississippi State University, Mississippi State, MS

Fredrickson LH, Reid FA (1986) Wetland and riparian habitats: a nongame management overview. In: Hale JB, Best LB, Clawson RL (eds) Management of nongame wildlife in the Midwest: a developing art. Northcentral Section, The Wildlife Society, Madison, pp 59–96

Fredrickson LH, Taylor TS (1982) Management of seasonally flooded impoundments for wildlife. U. S. Fish and Wildlife Service Resource publication no. 148. Washington, D.C.

Gibbs JP, Melvin SM (1993) Call-response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 57:27–34

Gleason RA, Euliss NH Jr, Hubbard DE, Duffy WG (2004) Invertebrate egg banks of restored, natural, and drained wetlands in the Prairie Pothole Region of the United States. Wetlands 24:562–572

Gray MJ, Kaminski RM, Weerakkody G, Leopold BD, Jensen KC (1999) Aquatic invertebrate and plant responses following mechanical manipulations of moist-soil habitat. Wildlife Society Bulletin 27:770–779

Grieg-Smith P (1983) Quantitative plant ecology, 3rd edn. Blackwell Scientific, London

Grillmayer R (1995) Transplanting aquatic vegetation in Collingwood Harbour. In: Kelso JRM, Hartig JH (eds.) Methods of modifying habitat to benefit the Great Lakes ecosystem. CISTI (Canadian institute of Science Technical Information) Occasional Paper No. 1. pp 73–81

Hagy HM (2010) Winter food and waterfowl dynamics in managed moist-soil wetlands in the Mississippi Alluvial Valley. Ph.D. Dissertation. Mississippi State University, Mississippi State

Hair JD (1980) Measurements of ecological diversity. In: Schemnitz SD (ed) Wildlife management techniques manual, 4th edn. The Wildlife Society, Inc., Washington, D.C, pp 269–275

Hammer DL (1992) Creating freshwater wetlands. Lewis, Chelsea

Hemesath LM, Dinsmore JJ (1993) Factors affecting bird colonization of restored wetlands. Prairie Naturalist 25:1–11

Herdendorf CE (1987) The ecology of the coastal marshes of western Lake Erie: A community profile. Rept. 85 (79) National Wetlands Research Center, Fish and Wildlife Service, United States Department of the Interior, Washington, D.C.

Jude DJ, Pappas J (1992) Fish utilization of Great Lakes coastal wetlands. Journal of Great Lakes Research 18:651–672

Kaminski RM, Prince HH (1981) Dabbling duck and macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1–15

Kellogg CH, Bridgham SD (2002) Colonization during early succession of restored freshwater marshes. Canadian Journal of Botany 80:176–185

Keough JR, Thompson TA, Guntenspergen GR, Wilcox DA (1999) Hydrogeomorphic factors and ecosystem responses in coastal wetlands of the Great Lakes. Wetlands 19:821–834

Kirkman LK, Sharitz RR (1994) Vegetation disturbance and maintenance of diversity in intermittently flooded Carolina bays in South Carolina. Ecological Applications 4:177–188

LaGrange TG, Dinsmore JJ (1989) Plant and animal community responses to restored Iowa wetlands. Prairie Naturalist 21:39–48

Littell RC, Milliken GA, Stroup WW, Wolfinger RD, Schabenberger O (2006) SAS for mixed models, 2nd edn. SAS Institute, Inc., Cary

Mathers A, Hartley K (1995) Sawquin Creek marsh channel creation project. In: Kelso JRM, Hartig J (eds) Methods of modifying habitat to benefit the Great Lakes ecosystem. CISTI (Canadian Institute of Science Technical Information) Occasional Paper No_ 1. pp. 197–199

McCollough GB (1985) Wetland threats and losses in Lake St. Clair. In: Prince HP, D'Itr FM (eds) Coastal wetlands. Lewis Publishing. Co, Chelsea, pp 201–208

McKee KL, Baldwin A (2000) Disturbance regimes in North American wetlands. In: Walker LR (ed) Ecosystems of disturbed ground. Elsevier, Amsterdam, pp 331–363

Meyer SW, Badzinski SS, Petrie SA, Ankney CD (2010) Seasonal abundance and species richness of birds in common reed habitats in Lake Erie. Journal of Wildlife Management 74:1559–1567

Middleton B (1999) Wetland restoration: flood pulsing and disturbance dynamics. John Wiley and Sons, New York

Mitsch WJ, Gosselink JG (2007) Wetlands, 4th edn. John Wiley and Sons, Inc., Hoboken

Murkin HR, Van der Valk AG, Clark ED (2000) Prairie wetland ecology. The contribution of the marsh ecology research program. Iowa State University Press, Ames

Newton I (1998) Population limitation in birds. Academic Press, San Diego

Pennak RW (1989) Freshwater invertebrates of the United States, 3rd edn. John Wiley and Sons, New York

Poole AF, Lowther P, Gibbs JP, Reid FA, Melvin SM (2009) Least Bittern (*Ixobrychus exilis*). In: Poole A (ed) The birds of North America online. Cornell Lab of Ornithology, Ithaca, http://bna.birds.cornell.edu/bna/species/017 Accessed 2 August 2011

Prince HH, Padding PI, Knapton RW (1992) Waterfowl use of the Laurentian Great Lakes. Journal of Great Lakes Research 18:673–699

Rehm EM (2006) Factors affecting marsh bird abundance and species richness of wetlands birds of New York. M.S.Thesis. SUNY College of Environmental Science and Forestry, Syracuse

Rehm EM, Baldassarre GA (2007) The influence of interspersion on marsh bird abundance in New York. The Wilson Journal of Ornithology 119:648–654

Rippke MB, Distler MT, Farrell JM (2010) Holocene vegetation dynamics of an upper St. Lawrence River wetland: paleoecological evidence for a recent increase in cattail (Typha). Wetlands 30:805–816

Robertson RJ (1973) Optimal niche space of the red-winged blackbird III. Growth rate and food of nestlings in marsh and upland habitat. Wilson Bulletin 85:209–222

Roberts-Pichette P, Gillespie L (1999) Terrestrial vegetation biodiversity monitoring protocols. Ecological Monitoring and Assessment Network Publication 9, Burlington

Ross DA, Anderson RK (1990) Habitat use, movements, and nesting of *Emydoidea blandingi* in central Wisconsin. Journal of Herpetology 24:6–12

Rowe JW, Moll EO (1991) A radiotelemetric study of activity and movements of the Blanding's turtle (*Emydoidea blandingi*) in northeastern Illinois. Journal of Herpetology 25:178–185

Schummer ML, Petrie SA, Bailey RC (2008) Dietary overlap of sympatric diving ducks during winter on northeastern Lake Ontario. Auk 125:425–433

Scott WB, Crossman EJ (1998) Freshwater fishes of Canada. Galt House, Oakville

Smith DA, Tome MW (1992) Wetlands restoration: will we make a difference? In: Landin MC (ed) Wetlands: Proceedings of the 13th Annual Conference of the Society of Wetlands Scientists. Society of Wetlands Scientists South Central Chapter, Utica, pp 61–69

Smith R, Hama M, Dallman M, Ewert D (1998) Spatial variation in foraging of the Black-throated Green Warbler along the shoreline of northern Lake Huron. Condor 100:474–484

Smith LM, Haukos DA, Prather RM (2004) Avian response to vegetative patterns in playa wetlands during winter. Wildlife Society Bulletin 32:474–480

Stevens CE, Diamond TW, Gabor ST (2002) Anuran call surveys of small wetlands on Prince Edward Island, Canada restored by dredging of sediments. Wetlands 22:90–99

Tacha TC, Warde WD, Burnham EP (1982) Use and interpretation of statistics in wildlife journals. Wildlife Society Bulletin 10:355–362

Taft JB, Wilhelm GS, Ladd DM, Masters LA (1997) Floristic quality assessment for vegetation in Illinois, a method for assessing vegetation integrity. Erigenia 15:3–95

Thorp JH, Covich AP (1991) Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego

USACE US Army Corp of Engineers (2002) Nationwide permit (27) stream and wetland restoration activities. http://www.saw.usace.army.mil/wetlands/NWP2007/PDF-SAW-NWP2007/NWP27_6-07.pdf. Accessed 20 April 2012.

USACE US Army Corp of Engineers (2011) Great Lakes Water Levels: Detroit District. www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/currentconditions/greatlakeswaterlevels/ Accessed 7 November 2011

USDA, NRCS (2011) The PLANTS Database National Plant Data Team, Greensboro. http://plants.usda.gov Accessed 6 September 2011

Vincent J (1995) Toronto Islands northern pike spawning habitat. In: Kelso JRM, Hartig JH (eds) Methods of modifying habitat to benefit the Great Lakes ecosystem. CISTI (Canadian institute of Science Technical Information) Occasional Paper No. 1. pp 139–144

Whillans TH (1996) Historic and comparative perspectives on rehabilitation of marshes as habitat for fish in the lower Great Lakes Basin. Canadian Journal of Fisheries and Aquatic Sciences 53 (Supplement 1):58–66

Wilcox DA, Kowalski KP, Hoare H, Carlson ML, Morgan H (2008) Cattail invasion of sedge/grass meadows and regulation of Lake Ontario water levels: photointerpretation analysis of sixteen wetlands over five decades. Journal of Great Lakes Research 34:301–323