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WATERFOWL USE OF THE LAURENTIAN GREAT LAKES

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ABSTRACT. Literature on habitat and limiting factors of waterfowl in Great Lakes wetlands and deep water habitats is reviewed; more than 30 species of waterfowl use coastal habitats at some time during the year. Waterfowl use of the Great Lakes has declined dramatically from presettlement times; the obvious cause is human encroachment on coastal wetlands and destruction of river delta and embayed wetland complexes. Loss of wetland habitats from diking and filling above the average water level constitutes a permanent habitat loss, especially during high water cycles. The greatest number of species and individuals use 15 concentration areas during the spring and fall migratory periods when use by diving ducks, sea and stiff tailed ducks, and swans and geese predominates. Lesser numbers of species use the coastal wetlands for breeding. Large concentrations of dabbling ducks, primarily mallards (Anas platyrhynchos) *and American black ducks* (A. rubripes), *and mergansers* (Mergus *spp.) are found on ice-free areas during winter. Wetland habitats have become more favorable, due to human modifications, to dabbling duck species found in the prairie habitats of North America. Mallards have become the most numerous species breeding in coastal wetlands along with a concomitant decline in black ducks, which may be a consequence of introgression. Habitat modifications, degradation, and loss have great potential to affect existing waterfowl populations negatively and to point the way toward future research.*
INDEX WORDS: Waterfowl, wetlands, species densities, wetland habitat, exotic species, Great Lakes.

HISTORY OF WATERFOWL IN THE GREAT LAKES REGION

"The North American Continent at one time was blessed with a wealth of wild fowl beyond that of any country in the world. In the spring and fall with the regularity of the seasons, a great army of ducks, geese and brant winged their way across the country, and they do so now in sadly diminished numbers." *Bruette 1934*

Adventurers and early settlers saw great flights of birds beyond their powers of description; "great clouds of ducks" and the sound made by the flushing of immense flocks of birds was like "thunder to tell before their eyes" (Briggs 1964). The vast area of wetlands along Great Lakes coast supported many of these birds during some seasons. Bednarik (1984) indicated that western Lake Erie marshes encompassed 121,500 ha (300,000 ac) that attracted ducks from eastern Canada and those migrating from the western prairies to winter along the Atlantic coast. Long Point, Ontario, was described by William Pope in 1834; "There are swans, geese, and such prodigious quantities of ducks as to blacken the water when they settle down, and when they rise the noise they make with their wings may be heard at the distance of a mile (Barrett 1976)." Waterfowl were appreciated as sources of meat and pleasure. A rich tradition of

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waterfowl hunting developed. The burgeoning eastern human population and primitive wilderness world of abundant game were the necessary ingredients that spurred market hunting of waterfowl (Kimball and Kimball 1969).

"You can form no idea how plenty Canvas-Backs were through the late fall and winter. . . they were so plenty that they commanded a very small price. . . they brought, at the bay, $.50 a pair, and even at that price, a good shot would bring from $10.00 to $20.00 per day (Leffingwell 1890)."

The days when wagon loads of ducks were hauled to Port Clinton, Ohio, placed in barrels, and shipped by train to Cleveland are barely a memory for a living few. Dramatic declines in numbers occurred in the late 1800s as recorded in the duck hunting club registers (Miller 1986).

The Lacey Act of 25 May 1900, helped close the market hunting era as waterfowl habitat and numbers began to dwindle. Waterfowl conservation in North America became international with the signing of Migratory Bird Treaty Act on 3 July 1918 by President Wilson.

Waterfowl hunters were denied the right to hunt ducks and geese for the market, hunt in spring, and use live decoys or bait as lures within a very short period of time. Federal and state or provincial authority needed to be established in the courts. Cooperative waterfowl management began in the 1930s after the right of federal authorities to control waterfowl hunting was established. This era was well documented by Hawkins *et al.* (1984).

Development in the 1800s kept the new settlers busy clearing the forest and tilling the soil. At first, wetlands were drained or filled at every opportunity. Regional settlement was marked by uncoordinated local drainage efforts. Dams and marsh drainage projects came next with the inevitable reduction of habitat and waterfowl (Hawkins *et al.* 1984). Waterfowl shooting clubs developed on areas of prime wetland habitat that were conducive to a variety of supplemental habitat management practices. Coastal wetland areas in the Great Lakes underwent large-scale conversion by draining or diking to agricultural croplands. Conversion of wetlands for agricultural or urban uses set a landward boundary much closer to average water levels than the natural boundaries and established the need for flood protection. Large areas of wetlands vulnerable to passive water level fluctuation were no longer subject to the ebb and flow of Great Lakes water levels established by long-term and storm-induced events (Bookhout *et al.* 1989). Consequently, high water cycles in coastal wetlands have resulted in net losses of habitat rather than redistribution of the vegetative zone that usually occurred in the predevelopment eras.

Although deepwater habitats have also been altered, the impact of alteration of coastal wetlands on waterfowl has been more dramatic. Wetland ecosystems were truncated by upland development which continues to the present. The net result of development was the large scale loss of areas with value for waterfowl and the need to intensify management practices on the remaining wetlands. Habitat preservation by private individuals and groups came first, followed by governmental efforts. Many parcels of key waterfowl habitat in the Great Lakes coastal wetlands have been preserved because of the tradition of hunting. Agency programs followed as economic forces eliminated many of the efforts by individuals or groups in the private sector. Management of wetlands using controlled water levels became the most effective form of habitat management for waterfowl using coastal wetland areas (Bookhout *et al.* 1989).

THE WATERFOWL COMMUNITY IN COASTAL WETLANDS

Wetland Ecosystems

The term coastal wetland will refer to the classification of wetland and deepwater habitats as defined by the Cowardin *et al.* (1979). More than 30 species of waterfowl representing seven tribes of the family Anatidae use the Laurentian Great Lakes and adjacent coastal wetlands during at least one season (Table 1). Greatest species diversity occurs during spring and fall migration periods. Equal numbers of species representing different communities breed or spend the winter.

A variety of wetland systems, which are used to some extent by waterfowl, is found in the coastal zone (Fig. 1). The vegetative composition, structure, size, and proximity to other wetlands are major determinants of the specific value to waterfowl. Shoreline morphology and hydrologic regime of Great Lakes coastal wetlands primarily influence distribution and structure of wetland habitats (Geis 1985). Geis (1985) identified four types of coastal wetlands systems based on shoreline morphology: lagoon wetlands, embayed wetlands, island and shoal wetlands, and riparian wetlands.

TABLE 1. Status of common waterfowl species of the Laurentian Great Lakes and their coastal wetlands.

Tribe (Waterfowl group)	Species	Common name	Status[a] Breeding	Migration	Wintering
Cygnini (Swans)	*Cygnus columbianus*	Tundra swan	N	C	N
	Cygnus cygnus	Trumpeter swan[b]	R	N	N
	Cygnus olor	Mute swan	C	N	C
Anserini (Geese)	*Branta bernicla*	Brant	N	U	N
	Branta canadensis interior	Interior Canada goose	N	A	N
	Branta canadensis maxima	Giant Canada goose	C	A	U
	Chen caerulescens	Snow goose	N	U	N
Anatini (Dabbling ducks)	*Anas platyrhynchos*	Mallard	C	A	C
	Anas rubripes	Black duck	C	C	C
	Anas acuta	Northern pintail	R	C	N
	Anas strepera	Gadwall	U	C	N
	Anas americana	American wigeon	U	C	N
	Anas clypeata	Northern shoveler	U	C	N
	Anas discors	Blue-winged teal	C	A	N
	Anas crecca	Green-winged teal	U	C	N
Cairinini (Perching ducks)	*Aix sponsa*	Wood duck	C	A	N
Aythyini (Diving ducks)	*Aythya valisineria*	Canvasback	N	C	R
	Aythya americana	Redhead	U	C	N
	Aythya collaris	Ring-necked duck	U	C	N
	Aythya affinis	Lesser scaup	R	A	R
	Aythya marila	Greater scaup	R	C	R
Mergini (Sea ducks)	*Bucephala clangula*	Common goldeneye	R	C	C
	Bucephala albeola	Bufflehead	R	C	R
	Melanitta nigra	Black scoter	N	U	R
	Melanitta fusca	White-winged scoter	N	U	R
	Melanitta perspicillata	Surf scoter	N	U	R
	Clangula hyemalis	Oldsquaw	N	C	C
	Lophodytes cucullatus	Hooded merganser	R	C	N
	Mergus serrator	Red-breasted merganser	U	C	U
	Mergus merganser	Common merganser	R	C	C
Oxyurini (Stiff-tailed ducks)	*Oxyura jamaicensis*	Ruddy duck	R	C	R

[a]A = abundant (many present every year); C = common (many present some years); U = uncommon (few present every year); R = rare (few present some years); N = none (none present or isolated records only).
[b]Extirpated in most of the lower 48 states of the U.S. in the 1800s; currently being reintroduced in the Great Lakes region.

Riparian coastal wetlands can be further classified as either delta wetlands or freshwater estuary wetlands (Herdendorf *et al.* 1981a). Some natural wetland habitats in the coastal zone have been modified by dikes to manage for waterfowl hunting, restore or preserve natural wetland communities, or contain dredged spoils.

Lagoon wetlands are located inland from the shoreline and are protected from the adjacent lake's wave energy by some natural barrier. Direct contact with the lake is limited to connecting channels or ground water. These are primarily palustrine emergent wetlands (Cowardin *et al.* 1979), but some are deep enough to include lacustrine aquatic bed components as well (Geis 1985). Lagoon wetlands have limited value as breeding and wintering habitat for waterfowl, but are used extensively by some species during migration.

Embayed wetlands are complexes of palustrine and lacustrine wetlands that develop in bays lacking protective barriers (Geis 1985). However, bays provide some protection from wind and wave energy, allowing extensive development of diverse wetlands in shallow areas. In an embayed wetland,

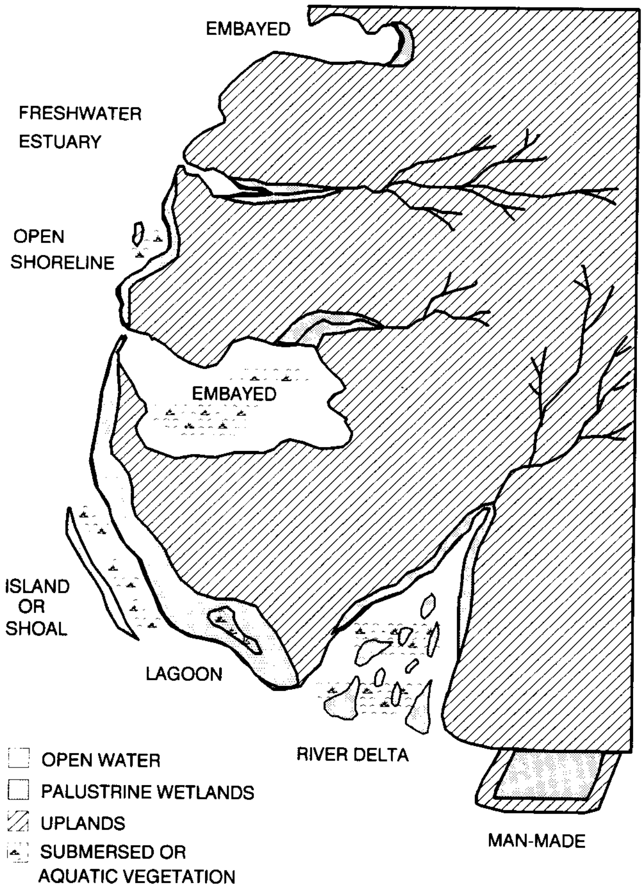

FIG. 1. Pictorial representation of coastal wetland systems based on shoreline morphology used by waterfowl in the Laurentian Great Lakes (modified from International Lake Erie Regulation Study Board 1981).

palustrine wetlands occur from the upland limits to the shoreline, where the complex grades into the littoral zone of the lake and thence into aquatic bed wetlands of the littoral zone. Because of their diversity, embayed wetlands provide habitat for breeding, migrating, and wintering waterfowl.

Shallow water sites on islands and shoals offer little protection from wave energy and wind, therefore wetland development is limited on those sites. Island and shoal wetlands are lacustrine aquatic bed wetlands (Geis 1985) that often provide important feeding habitat for some waterfowl species during migration and winter.

Delta wetlands form when sediments carried by a river are deposited and accumulate at the mouth. The resulting shallow water area allows extensive wetland development at the mouth of the river and out into the receiving body of water (Herdendorf *et al.* 1981a). Wetlands that are formed by this process are complexes of palustrine, riverine, and lacustrine wetland and deepwater habitats. Palustrine wetlands develop in the areas that become shallow enough to support emergent and scrub-shrub vegetation, grading into lacustrine habitats where the water deepens. If the receiving lake has a gradual slope, deltaic wetland complexes may include large lacustrine components of nonpersistent emergent wetlands in the littoral zone and aquatic bed wetlands in the limnetic zone. Riverine components of these complexes consist of channels that cut through the palustrine wetlands and empty into the receiving lake. Like embayed wetlands, deltas provide prime breeding, migration, and wintering habitats for many waterfowl species.

In contrast to deltas, freshwater estuaries occur where the lower reaches of rivers are influenced by the hydrologic regime of the receiving lake (Herdendorf *et al.* 1981a). They can extend several miles inland and are particularly extensive along streams that have low, wide floodplains. Palustrine forested, scrubshrub, emergent, and aquatic bed wetlands develop on the floodplains, thus dominating freshwater estuary complexes. Riverine components of these complexes are limited to the channels, and lacustrine components extend lakeward from the river mouths. Although they provide some breeding and wintering habitat, freshwater estuary wetlands are most extensive and important to migrating waterfowl based on habitat requirements (Fig. 2).

Plant Communities

Floristic descriptions of Great lakes wetlands are scant and only a few local areas have been well studied (Keddy and Reznicek 1985). About 400–450 species of vascular plants regularly occur, the most important genera ($\geq$ 10 spp. represented) are *Carex* (ca. 50 spp.), *Cyperus* (ca. 10 spp.), *Eleocharis* (ca. 12 spp.), *Juncus* (ca. 15 spp.), *Polygonum* (ca. 10 spp.), *Potamogeton* (ca. 22 spp.), and *Scirpus* (ca. 13 spp.).

Taxonomic descriptions of submersed and floating-leaved plants are limited. Many submersed species are widespread, but a few, such as *Ceratophyllum demersum,* are essentially cosmopolitan (Keddy and Reznicek 1985). Species distributions occur in regional patterns (Keddy and Reznicek 1985). Lake Erie has extensive wetlands rich in southern species. A rich, wet prairie element

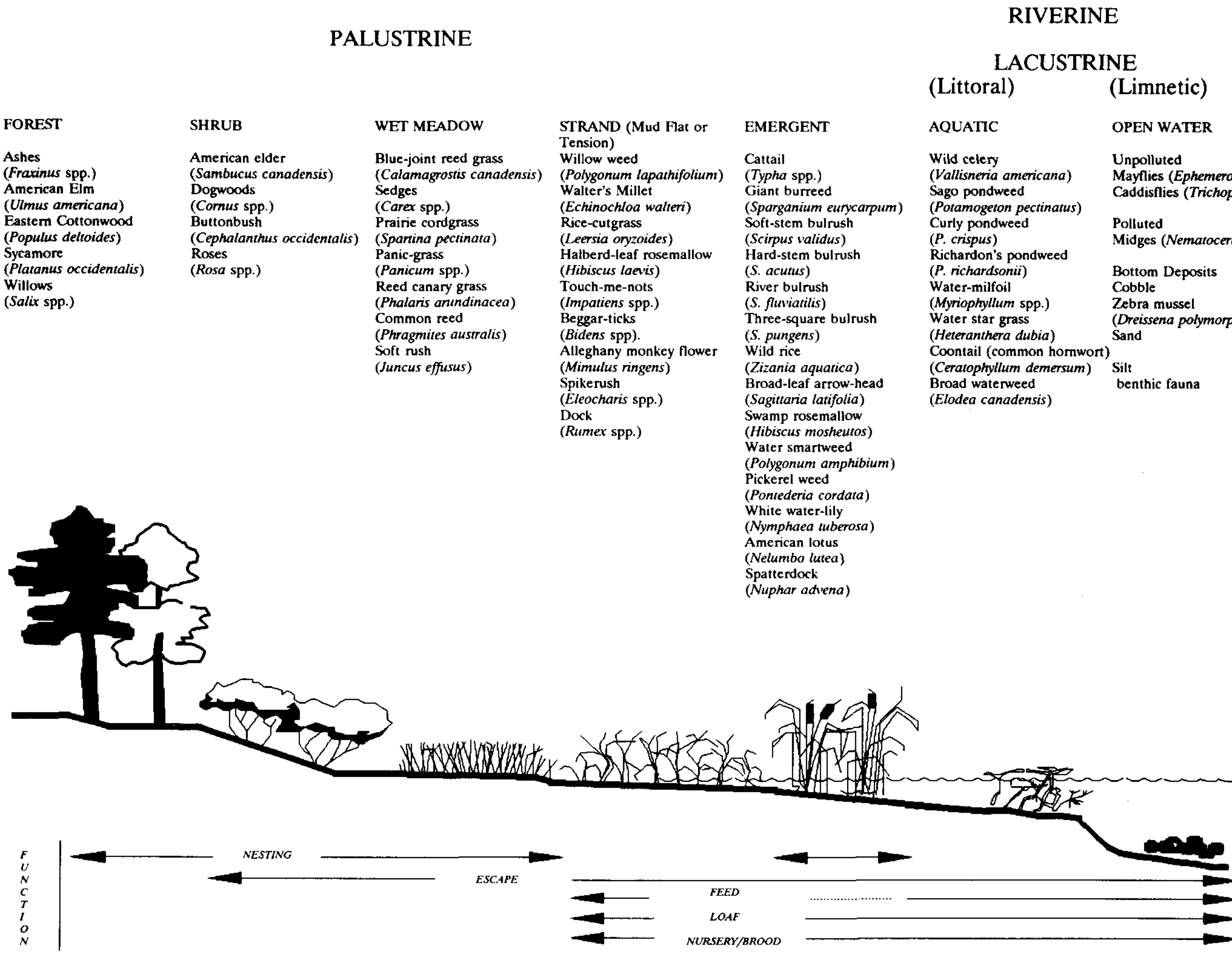

FIG. 2. A profile of habitats in the coastal zone area of the Laurentian Great lakes in reference to the Cowardin et al. (1979) wetland and deepwater classification scheme. Typical vegetative species and value to waterfowl are listed by habitat.

apparent in the flora of the southern Great Lakes is different from the boreal, subarctic, and arctic species in the northern portions of Lakes Huron, Michigan, and Superior.

Seven distinct vegetative zones can be identified in the coastal wetlands systems of the Great Lakes (Fig. 2). Each zone has a specific physiognomy, relationship to water levels, and life form of dominant species (Keddy and Reznicek 1985). The complexity of Great Lakes wetlands results in a large number of species capable of dominating local areas. A depositional and erosional shoreline area at the water line forms the strand, an area composed of short-lived ruderals, which is the zone in which many of the common vegetative food items used by dabbling ducks are found. Wet meadow, shrub, and forest zones form three broad shoreline vegetation types that occur above the mean water level in response to decreasing degrees of saturation. Waterfowl use of these zones is generally limited to species that utilize the vegetative structure as nest sites but migrant dabbling ducks may also use these areas in the early spring during the high water period for feeding. The greatest diversity of plant species often occurs in the emergent zone. The core of prime waterfowl habitat is formed by the emergent zone in combination with aquatic, open water, and strand zones. Emergent vegetation provides cover, and plant and animal foods are obtained by birds in adjacent zones.

Classification schemes of coastal wetland systems and deepwater habitats include all seven vegetative zones (Fig. 2) (Cowardin *et al.* 1979). Palustrine systems include all vegetative zones traditionally identified as wetlands. Deepwater habitats are lake (lacustrine) and river (riverine) areas that also include some of the traditional palustrine vegetative zones.

Short-term and long-term water level fluctuations constitute a factor that causes structural and functional changes in coastal wetland communities. Lagoon and diked coastal wetlands are closed systems in that they are protected from changes in the adjacent lake's water level. In contrast, embayed, delta, and freshwater estuary coastal wetlands are open systems that are directly subjected to the influence of the lake. Habitat structure in open system wetlands varies in relation to long-term changes in water levels. Emergent vegetation flourishes during low water years, whereas aquatic bed zones and open water dominate coastal wetlands in high water years (Herdendorf *et al.* 1981a). Impacts on waterfowl can be profound.

Successional patterns in glacial prairie marshes have received much more study (Johnsgard 1956; Harris and Marshall 1963; Weller and Spatcher 1965; Weller and Fredrickson 1974; van der Valk and Davis 1978, 1979; van der Valk 1981; Smith and Kadlec 1983) than have vegetation dynamics in Great Lakes coastal wetlands (Harris *et al.* 1977, 1981; Nicholson and Keddy 1983; Keddy and Reznicek 1982, 1985). The typical vegetative zonation as illustrated in Figure 2 is altered in response to fluctuating water levels. A plant community displacement model (Fig. 3) developed by Edsall *et al.* (1988) is based on field measurements on Dickinson Island associated with varied water levels in Lake St. Clair collected by Jaworski *et al.* (1979). At high water level, much of the emergent and wet meadow areas is converted to > 50% open water. Open water decreases to about 15% of the area during a low water level phase. Forest and shrub zones remain constant in size throughout the cycle. The tension zone or strand usually disappears during high water, thus reducing amounts of seed produced by annual plants used by migrant birds. Low water also will create a temporary shortage of optimum habitat for waterfowl because of the increase in wet meadow zones with the corresponding decrease of submersed aquatic and floating leaved macrophytes and emergents. Short-term water level fluctuations about the long-term mean create the best hydrological regime for the maintenance of productive wetland ecosystems beneficial to waterfowl.

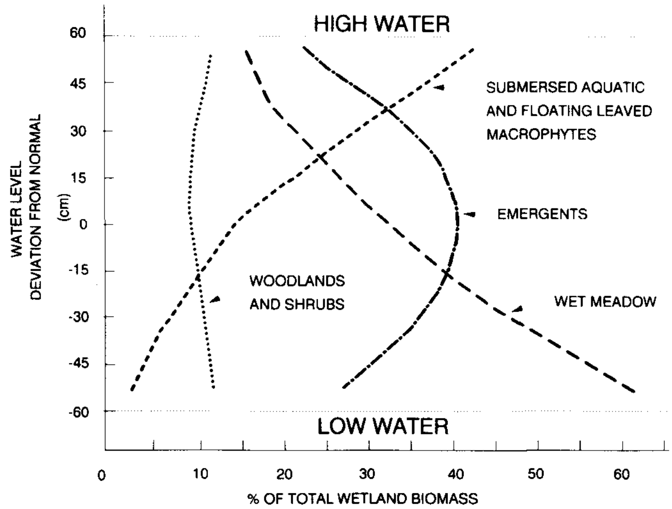

FIG. 3. Impact of lake level on habitats used by waterfowl (from Edsall et al. *1988).*

DISTRIBUTION OF COASTAL WATERFOWL HABITATS

The Great Lakes and their connecting waters have shorelines totaling >15,000 km in eight U. S. states and one Canadian province. Herdendorf et al. (1981a) identified 1,370 coastal wetlands totaling >120,000 ha along U. S. shores alone. Although waterfowl use all of the Great Lakes coastal wetlands to some extent, 15 areas can be identified as critical to waterfowl (Fig. 4). These areas are associated with embayed, deltaic, and freshwater estuarine wetland formations where productivity, structure, size, and proximity to other wetlands are major determinants of the specific value to waterfowl.

Lake Superior

The freshwater estuary wetlands of Chequamegon Bay and Portage Entry (Table 2) constitute about 25% of the total area of U. S. coastal wetlands of Lake Superior (Herdendorf *et al.* 1981f).

Chequamegon Bay

Although the palustrine floodplains of Chequamegon Wetland (3,850 ha) and Fish Creek Wetland (320 ha) are partially wooded (Herdendorf *et al.*

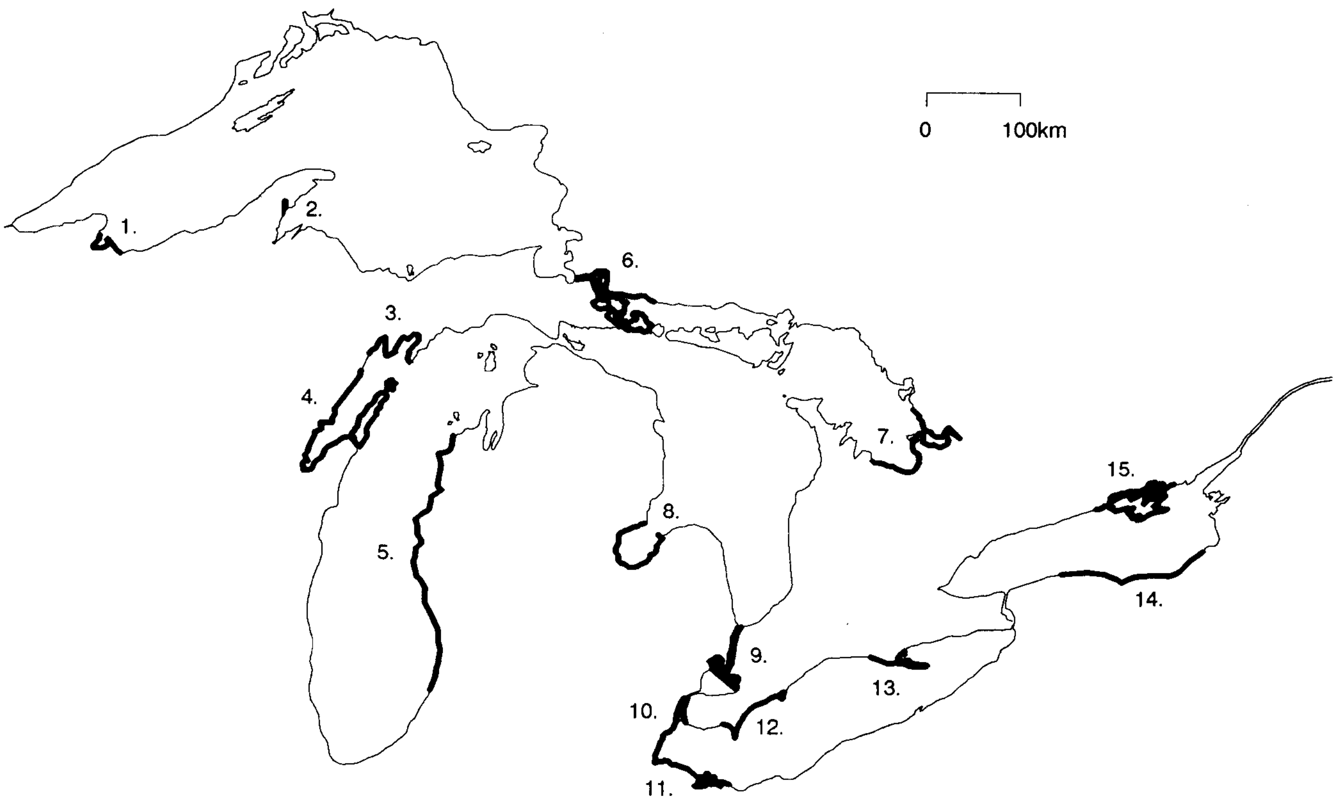

FIG. 4. Distribution of major waterfowl habitat complexes along Great Lakes coasts: 1. Chequamegon Bay. 2. Portage Entry. 3. Bay de Noc. 4. Green Bay. 5. West Michigan. 6. St. Marys River. 7. Georgian Bay. 8. Saginaw Bay. 9. St. Clair Delta. 10. Detroit River. 11. Southwest Lake Erie. 12. Point Pelee/Rondeau Bay. 13. Long Point. 14. Southcentral Lake Ontario. 15. Northeast Lake Ontario.

1981f), they are valuable to waterfowl because of large expanses of emergent wetlands (Bookhout *et al.* 1989).

Portage Entry

Portage Entry Marsh (3,300 ha), encompassing the lower reaches of the Sturgeon and Snake rivers, lies at the lower end of Portage Lake near Portage Entry, Michigan. It is dominated by a palustrine floodplain complex that includes forested, scrub-shrub, emergent, and aquatic bed wetlands (Herdendorf *et al.* 1981f).

Lake Michigan

Major coastal wetlands along Lake Michigan are concentrated along Green Bay, Little and Big Bay de Noc, and the west Michigan shoreline and make up about one-quarter of the important waterfowl habitat areas in the Great lakes (Table 2). They are primarily freshwater estuary wetlands in combination with large, embayed wetlands that have developed along the shores.

Bay de Noc

Portage Marsh (530 ha), Ogontz Bay Wetland (700 ha), the Upper Big Bay de Noc Wetland (3,780 ha), and the Sturgeon River Wetland (2,710 ha) contain most of the total wetland area in the Bay de Noc region. They are embayed and freshwater estuary complexes dominated by palustrine forested, emergent, and aquatic bed wetlands (Herdendorf *et al.* 1981e).

Green Bay

Coastal wetlands in the Green Bay area are located on Wisconsin's Door Peninsula and along the west shore of Green Bay. Two large, embayed wetlands are situated on the Lake Michigan side of Door

TABLE 2. Number, area, and estimated number of breeding pairs of dabbling ducks in major coastal wetland complexes of the Laurentian Great Lakes that are most heavily used by waterfowl.

Region-Location	(Number)	No. of major wetlands	Total area (ha)	%	Breeding pairs[a]	%
Lake Superior						
Chequamegon Bay	(1)	2	4,170	4	1,600	6
Portage Entry	(2)	1	3,300	3	1,300	5
Lake Michigan						
Bay de Noc	(3)	4	7,720	7	2,500	9
Green Bay	(4)	9	9,980	9	3,400	12
West Michigan	(5)	4	10,690	10	3,400	12
Lake Huron						
St. Marys River	(6)	10	3,970	4	400	1
Georgian Bay	(7)		12,600	11	2,100	7
Saginaw Bay	(8)	2	12,140	11	4,400	16
Lake St. Clair						
St. Clair River and Delta	(9)	5	17,500	16	4,400	16
Detroit River	(10)	0[b]	1,380	1	100	0
Lake Erie						
Southwest Lake Erie	(11)	7	5,890	5	1,000	3
Point Pelee/Rondeau Bay	(12)	5	3,580	3	150	2
Long Point	(13)	3	11,490	10	500	7
Lake Ontario						
SC Lake Ontario	(14)	4	1,340	1	200	1
NE Lake Ontario	(15)		6,000	5	1,000	3
Grand Total			111,750	100	26,450	100

[a]Estimates were derived directly from breeding pair survey data in specific coastal wetlands for the following areas: Portage Entry, Bay de Noc, west Michigan, Saginaw Bay and the St. Clair Delta (Jaworski and Raphael 1978; Herdendorf *et al.* 1981d,e); St. Marys River (Duffy *et al.* 1987); and southwest Lake Erie (Urban 1970, Hunt and Mickelson 1976, Herdendorf *et al.* 1981c). Estimates for Georgian Bay, Point Pelee/Rondeau Bay, Long Point and Northeast Lake Ontario are based on the average density of breeding pairs in southern Ontario (Dennis 1974). Estimates for Detroit River, Point Pelee/Rondeau Bay, and Long Point are based on Dennis, D.G., CWS, 1991, personal communication. Estimates presented for Chequamegon Bay, Green Bay, and southcentral Lake Ontario are approximations based on data from coastal wetlands that are located along the same lakes.

[b]No large wetlands remain in the Detroit River; total area of 31 small wetlands in and along the river and Canard River Marshes is reported.

Peninsula: Baileys Harbor-Ephraim Swamp (2,040 ha) and the North Bay Wetland (870 ha). Both of these palustrine complexes are forested wetlands interspersed with pockets of scrub-shrub, emergent, and aquatic bed wetlands (Herdendorf *et al.* 1981e).

The large coastal wetlands along the west shore of upper Green Bay are freshwater estuary complexes, whereas most coastal wetlands of lower Green Bay are embayed. Wisconsin's Oconto Marsh (3,790 ha) and Peshtigo River Wetland (2,040 ha) and Michigan's Cedar River Wetland (520 ha) consist primarily of palustrine forested and scrub-shrub wetlands but also encompass substantial areas of emergent and aquatic bed wetlands (Herdendorf *et al.* 1981e, Harris *et al.* 1983). Whitney Slough (180 ha), Atkinson Marsh (190 ha), Peter's Marsh (170 ha), and the Sensiba Wildlife Area (180 ha) are the principal coastal wetlands of lower Green Bay. They are predominantly palustrine emergent wetlands, some of which are diked (Herdendorf *et al.* 1981e, Harris *et al.* 1983).

West Michigan

Although 115 wetlands lie along the west Michigan shoreline from the Indiana–Michigan border to

Grand Traverse Bay, about 2/3 of the total coastal wetland area is confined to four major freshwater estuary wetlands (Herdendorf *et al.* 1981e). Two of these, the 3,700-ha Manistee River and 2,530-ha Pere Marquette River wetlands, have partially wooded floodplains that are palustrine complexes of forested, scrubshrub, emergent, and aquatic bed wetlands (Herdendorf *et al.* 1981e). Floodplains of the 1,580-ha White River and 2,880-ha Muskegon River wetlands have little woody vegetation and are composed mainly of emergent and aquatic bed wetlands (Herdendorf *et al.* 1981e).

Lake Huron

Embayed wetlands of the St. Marys River, Georgian Bay, and Saginaw Bay constitute about one-quarter of the area of the most important waterfowl habitats in the Great Lakes (Table 2).

St. Marys River

Coastal wetlands of the St. Marys River area occur in and along the river itself; along the shores of Lake George, Lake Nicolet, Munuscong Lake, and Potagannissing Bay; and on Sugar, Neebish, St. Joseph, and Drummond islands. Some beds of aquatic wetlands persist in the broad stretches of the river. However, most of the palustrine complexes of aquatic bed, emergent, scrub-shrub, and forested wetlands that are important to waterfowl are situated along the west shores and on the islands (Duffy *et al.* 1987). The largest of these occur on Sugar Island (n = 4, 1,270 ha), on Neebish Island (n = 2, 790 ha), and along the west shore of Munuscong Lake (n = 4, 1,910 ha) (Herdendorf *et al.* 1981f). Wetlands are restricted to smaller, freshwater estuaries along the Canadian shorelines of the area (Duffy *et al.* 1987).

Georgian Bay

Significant wetlands among the 12,600 ha of coastal wetlands (Bookhout *et al.* 1989) are the palustrine embayed marshes of Huronia District. These marshes are inlets off Georgian Bay and are characterized by dense stands of emergents, mostly *Typha* and *Scirpus*, interspersed with open water areas dominated by *Valisneria* and *Chara*. Wooded swamps occur along the shore of some marshes such as Sturgeon Bay (190 ha), and Matchedash Bay Marsh (810 ha) is considered a key wetland in southern Ontario by Ducks Unlimited.

Saginaw Bay

Most of the waterfowl habitat in Saginaw Bay occurs in a nearly continuous strip of embayed, lagoon, and diked wetlands along the perimeter of the bay. The east Saginaw Bay complex (6,770 ha) includes Wildfowl Bay, Fish Point, and Quanicassee coastal wetlands (Herdendorf *et al.* 1981d). The west Saginaw Bay complex (5,370 ha) includes the coastal wetlands of Tobico Marsh (a lagoon wetland), Nayanquing Point, Wigwam Bay, and Schnitzelbank Creek (Herdendorf *et al.* 1981d). Saginaw Bay's embayed complexes are predominantly palustrine emergent wetlands but also include lacustrine aquatic bed components (Herdendorf *et al.* 1981d).

Lake St. Clair

St. Clair Delta

The vast complex of lacustrine, riverine, and palustrine wetlands of the St. Clair Delta in the U.S. and Canada encompasses 17,500 ha, about 1/3 of which is diked (Bookhout *et al.* 1989) (Table 2). Approximately 16% of the area of coastal wetlands important to waterfowl is centered in Lake St. Clair. In the U. S., the coastal wetlands of St. John's Marsh, Dickinson Island, and Harsens Island total 3,520 ha (Bookhout *et al.* 1989). Mitchell Bay marshes and the Walpole Island wetland complex, which includes the marshes of Walpole, St. Anne, Squirrel, and Bassett islands, are the major coastal wetlands on the Canadian side of the St. Clair Delta (Herdendorf *et al.* 1986).

On the U. S. side of the complex, forested and scrub-shrub wetlands occur in the drier zones, emergent wetlands in the shallow water zones, and aquatic bed wetlands in the channels and lakeward from the emergent wetlands (Jaworski and Raphael 1976). Most of the total area is occupied by emergent and scrub-shrub wetlands (Raphael and Jaworski 1982). Canada's St. Clair Delta wetlands are similar, except that they are primarily emergent and aquatic bed wetlands with very few scrub-shrub zones (Raphael and Jaworski 1982, Herdendorf *et al.* 1986).

Detroit River

Coastal wetlands along most of the Detroit River have been lost to development. Although some large beds of submersed aquatic vegetation persist, most of the remaining 31 wetlands (1,380 ha) are located on islands in the river (Manny *et al.* 1988)

(Table 2). Canard River Marshes provide an additional 420 ha of wetlands. These are primarily aquatic bed wetlands and emergent—aquatic bed wetland complexes, but several include forested and scrub-shrub components (Manny *et al.* 1988).

Lake Erie

Southwestern Lake Erie

This area consists of the Lake Erie shoreline from the mouth of the Detroit River south and east to Sandusky Bay. Major coastal wetlands of southwestern Lake Erie include Mouillee Marsh (550 ha), the North Maumee Bay wetland complex (570 ha), Cedar Point National Wildlife Refuge (640 ha), the Ottawa wetland complex (Ottawa National Wildlife Refuge, Magee Marsh, and Metzger Marsh; 1,560 total ha), Toussaint River Wetland (1,050 ha), Muddy Creek Bay Wetland (1,260 ha), and Bay View Wetland (260 ha) (Herdendorf *et al.* 1981c). They consist of a variety of barrier and lagoon, embayed, and freshwater estuary complexes that are predominantly palustrine emergent and aquatic bed wetlands (Herdendorf 1987). Nearly all coastal wetlands of the area are diked to provide protection from the high energy wave action that occurs along Lake Erie shorelines, and to allow control of water levels (Bookhout *et al.* 1989).

Most of the diked wetlands are owned by sportsmen's clubs or administered by state and federal agencies and are managed primarily for waterfowl (Herdendorf *et al.* 1981c). As a consequence, the vegetative composition of those wetlands varies seasonally and annually, depending on the water regimes or other practices implemented by managers of individual wetland complexes. Managed palustrine wetlands in southwestern Lake Erie are primarily emergent wetlands in various stages of drawdown or reflooding.

Point Pelee and Rondeau Bay

Point Pelee Marsh (1,010 ha), Hillman Marsh (360 ha), and Big Creek Marsh (1,000 ha) are the largest coastal wetlands associated with the Point Pelee area (Glooschenko *et al.* 1987). The wetlands range from lagoon and freshwater estuary complexes dominated by palustrine emergents. The wetlands at Point Pelee lie within the boundaries of the national park; portions of the other marshes are in private ownership that ranges to 75% at Big Creek Marsh. Many of the wetlands are diked, like those along the southwestern Lake Erie shoreline, and for the same reasons.

The wetlands of Rondeau border an embayment enclosed between the mainland on the west and a large, cuspate sandspit to the east on the north shore of Lake Erie. About 800 ha of marsh and swamp occur in Rondeau Provincial Park; they are palustrine with intermittent or permanent outflow, and lacustrine in areas adjacent to Lake Erie (Glooschenko *et al.* 1987). The wetlands are a rich mixture of scrub-shrub wetland communities, wooded swamps, and dense stands of submerged and emergent macrophytes. The Rondeau Bay wetland complex of 271 ha is composed of 10 individual wetlands ranging in size from 2 to 71 ha. The wetland is exposed to Rondeau Bay, and is predominantly lacustrine.

Long Point Area

The Long Point Area, one of the most important wetland complexes in southern Canada, is a rich mixture of palustrine and lacustrine wetlands supporting dense stands of submersed and emergent macrophytes, deltaic wetlands at the mouths of Big and Dedrick creeks, wet meadows, wooded swamps, shrub-scrub wetland communities, a huge embayment, riverine wetlands, and lagoons behind sand dune barriers. The area is comprised of the Long Point peninsula (7,000 ha), Turkey Point Marsh (3,100 ha), marshes around the Inner Bay at Long Point (1,390 ha), and the Inner Bay itself (surface area 28 km^2) (Glooschenko *et al.* 1987).

The Long Point peninsula is a combination of sand dunes, wet meadows, coniferous and deciduous swamps, deep water *Typha* marshes, shallow water grass and sedge marshes and ponds, and intermediate successional stages. About half of the peninsula, primarily deep water marshes, is in private ownership; most of the other half is owned by federal and provincial government agencies and local government conservation authorities. Ninety-five per cent of Turkey Point Marsh is also privately owned; this marsh contains a high diversity of vegetational communities ranging from *Typha* marshes, grass and sedge marshes, and shrubscrub communities to deciduous swamps. Most marshes along the north shore of the Inner Bay are privately owned; they are mainly *Typha* marshes and act as a nutrient trap from the active deltaic wetlands of Big Creek, the main tributary of the Inner Bay (Berst and McCrimmon 1966). The Inner Bay is a large embayment formed by a shoal extending from Turkey Point to Pottohawk Point on Long Point. It is shallow, has a mean depth of about 2 m, and is about 90% covered with aquatic vegetation, primarily submerged macrophytes with species of *Chara, Valisneria, Najas*, and *Myriophyllum* predominating. The wetlands around the Inner Bay are dynamic, having developed in response to both long- and short-term fluctuations of Lake Erie water levels (Keddy and Reznicek 1985), and are subject to periodic flooding from storm surges and seiches. The only diked area is an impoundment in the Big Creek National Wildlife Area.

Lake Ontario

Northeast Lake Ontario

More than 6,000 ha of significant coastal wetlands are still present in this region (Glooschenko *et al.* 1987). Wetland types are diverse, ranging from extensive palustrine deciduous swamps such as Albury Swamp (440 ha) to riverine and lacustrine deep water *Typha* marshes such as Sawguin Creek Marsh (1,960 ha). The most important wetland complex in the region is Presqu'ile Bay Marsh, a lacustrine wetland on silty soils that support a high diversity of vegetation communities encompassing deep water and shallow water marshes, wooded swamps, and a fen, well interspersed with open water.

Southcentral Lake Ontario

Most of the total area of coastal wetland that persists along the southern shore of Lake Ontario extends from Braddock Bay east to Sunset Bay. Large marshes at Braddock Bay (160 ha), Sodus Bay (300 ha), and East Bay (510 ha) are embayed and/or diked wetlands that have extensive emergent and aquatic bed zones as well as some wooded components inland from the shore (Herdendorf *et al.* 1981b). Sterling Creek Wetland (370 ha) is a freshwater estuary with a nonwooded palustrine floodplain (Herdendorf *et al.* 1981b).

CHRONOLOGY, HABITAT REQUIREMENTS, AND STATUS OF WATERFOWL

Great Lakes coastal wetlands once formed a transition area between the eastern deciduous/coniferous forest complex and the prairie zones. Many of the waterfowl species common to the midcontinental prairies were absent or present in low numbers. Species adapted to forested upland habitats in combination with emergent and submersed palustrine and lacustrine wetlands were the most common. Black ducks were the most abundant species (Pirnie 1935).

Development of shorelines and the change to an agricultural—urban area from a forested area created a dramatic change in the waterfowl community. For instance, species common to the prairies such as mallard and blue-winged teal (*Anas discors*) began to be observed in the coastal wetlands coincidental with declines in species common during the predevelopment era (Pirnie 1935).

Breeding

Great Lakes coastal wetlands are of relatively minor importance in terms of continental waterfowl production. The region forms the periphery of the breeding range of many species. Furthermore, plant communities in the coastal wetlands change dramatically as a result of fluctuating water levels, causing the value of those habitats as breeding areas to be cyclic. Changes in water levels caused by wave action and seiches make coastal wetlands unpredictable for nesting within a season or in the short term as well. For waterfowl species that nest in emergent vegetation, even brief increases in water levels can result in nest failure.

Baseline data for assessment of the significance of Great Lakes coastal wetlands as waterfowl breeding habitat are limited. Most recent information on waterfowl production was collected in the 1970s by numerous agencies and individuals who used different methods of analysis and reporting. We used the available information to compute estimates of waterfowl production in the key coastal wetland habitat complexes.

Swans and Geese

Although the region is well south of the breeding range of native swan species, a population of >2,000 feral mute swans (*Cygnus olor*) resides in Michigan (G. F. Martz, MiDNR, 1991 personal communication). Up to 30% of them nest in emergent coastal wetlands (Koechlein 1971). Lake Erie's Long Point wetlands also support a small but apparently growing population of breeding mute swans (McCracken 1990).

Canada geese (*Branta canadensis*) commonly breed in the Great Lakes region. Interior Canada geese are most numerous as migrants, and giant Canada geese reside locally and breed. Although most breeding geese in the Great Lakes region use inland wetlands (G. F. Martz, MiDNR, 1991 personal communication), the importance of coastal wetlands as breeding habitat may be on the rise as local breeding populations increase. For example, at Long Point the resident population has increased steadily since the 1960s, and in some areas the density of breeding geese is as high as 92 pairs/km^2 (McCracken *et al.* 1981). Density estimates are not available for most other areas, but low numbers of Canada geese also breed regularly in the coastal wetlands of Green Bay (Scharf 1979), west Michigan (Prince 1985), the St. Marys River area (Duffy *et al.* 1987), and the St. Clair Delta (Edsall *et al.* 1988).

Dabbling Ducks and Perching Ducks

Although the Great Lakes region produces few dabbling ducks compared to the Prairie Pothole region of the northern Great Plains, significant numbers of mallards, black ducks, blue-winged teal, and wood ducks (*Aix sponsa*) breed in the region (Bellrose 1980). Breeding chronology is a function of latitude; nesting begins in late March in the southernmost Great Lakes coastal wetlands (e.g., Hunt and Mickelson 1976) and 2–4 weeks later in the northern marshes (e.g., Duffy *et al.* 1987).

The coastal wetlands complexes that provide both nesting and brood rearing habitats are most heavily used by dabbling ducks. Nesting mallards and blue-winged teal prefer upland sites with dense herbaceous vegetation (Bennett 1938, Sowls 1955), although mallards also frequently nest in emergent wetland vegetation (Krapu *et al.* 1979) and on muskrat (*Ondatra zibethicus*) houses (Bellrose 1980). Black duck females nest in lowland hardwoods and brush, wooded islands, upland herbaceous vegetation, and emergent wetland vegetation habitats located in wooded and nonwooded coastal wetlands (Bellrose 1980). Wood ducks nest in tree cavities but will readily accept man-made nest boxes. Nest boxes are extensively used throughout the Great Lakes region, therefore wood ducks nesting in coastal wetlands are not necessarily restricted to forested wetlands. Most of the larger coastal wetland complexes include zones that are >5% shallow (water depth 0.5–1 m) open water interspersed with dense emergent and/or woody vegetation that meet the requirements of dabbling duck broods (Ringelman and Longcore 1982, Cowardin *et al.* 1985).

Site specific information on the current status of breeding dabbling ducks in Great Lakes coastal wetlands is lacking for most regions. Michigan and Ohio have the most extensive information on breeding dabbling ducks in coastal wetlands. We used those data to estimate numbers of breeding pairs in the major coastal wetland areas (Table 2). Statewide surveys done in the 1960s by the Michigan Department of Natural Resources (DNR) provide estimates of densities of breeding pairs in most of Michigan's major coastal wetlands (Jaworski and Raphael 1978, Herdendorf *et al.* 1981d,e). About 80% of the breeding ducks using Michigan's coastal wetlands are mallards (40%), blue-winged teal (30%), and black ducks (10%). Greatest densities of breeding pairs occur in Portage Entry on Lake Superior; Portage Marsh on Lake Michigan; Saginaw Bay (primarily Tobico Marsh, Nayanquing Point, and Quanicassee) on Lake Huron; and the St. Clair Delta on Lake St. Clair. Lower densities of dabbling ducks, primarily mallards and wood ducks, are present on west Michigan's river deltas (Herdendorf *et al.* 1981e, Prince 1985). Other breeding areas of lesser importance include the lower St. Marys River on Lake Huron and southwestern Lake Erie (Hunt and Mickelson 1976, Duffy *et al.* 1987).

The large coastal wetlands along Ohio's southwestern Lake Erie shoreline also consistently support small populations of breeding mallards, wood ducks, blue-winged teal, and black ducks (Table 2). Managed wetlands such as Magee Marsh, the Cedar Point National Wildlife Refuge, and the Winous Point Club Marsh probably support several hundred pairs annually (data from several sources summarized by Herdendorf *et al.* 1981c). However, low nest success due to predation results in low overall productivity in some wetlands (e.g., Urban 1970).

Although no density estimates are available for Wisconsin's coastal wetlands, breeding dabbling ducks have been documented in many wetlands at Door Peninsula and Green Bay (Scharf 1979, Herdendorf *et al.* 1981e). Mallards, blue-winged teal, and gadwall (*Anas strepera*) are the most common species. Because Green Bay's coastal wetlands are similar to those of west Michigan and the Bay de Noc area, we used data for those areas to derive an estimate of breeding pairs in the Green Bay area (Table 2). We found no data on breeding waterfowl in Chequamegon Bay wetlands, so data from Portage Entry were used to derive estimates of dabbling duck breeding pairs in the Chequamegon Bay area (Table 2).

Ontario's coastal wetlands do not appear to produce significant numbers of dabbling ducks. The two most common nesting species at Long Point are mallard and blue-winged teal, both of which are relatively recent colonists of the region (McCracken *et al.* 1981). Both species have low productivity; intense predation on eggs and young has been proposed as the major cause of low reproductive success (Munroe 1965). The black duck evidently was once the most common nesting duck at Long Point (Snyder 1931), but has become increasingly rare in recent years and probably no longer breeds in the area.

Although estimates of waterfowl production have not been reported for specific coastal wetlands of Ontario, breeding waterfowl were surveyed throughout southern Ontario in 1972 (Dennis 1974, Ross *et al. 1984*). Densities of breeding dabbling ducks averaged 16.4 pairs/km^2 in a survey stratum that included wetlands of Long Point, Point Pelee/Rondeau Bay, Northeast Lake Ontario, and much of Georgian Bay. We used that average to derive estimates of breeding pairs on Ontario's coastal wetlands (Table 2).

Mallards and blue-winged teal commonly breed in the southcentral Lake Ontario area, particularly in the vicinity of the Braddock Bay Wildlife Management Area (Andrle and Carroll 1988). We used the average density of breeding pairs for southern Ontario (Dennis 1974, Ross *et al.* 1984) to estimate the breeding effort of dabbling ducks in southcentral Lake Ontario coastal wetlands (Table 2).

We estimate that 25,000–30,000 pairs of dabbling ducks attempt to breed in the major coastal wetland complexes of the Great Lakes (Table 2). This probably represents >75% of the total effort of dabbling ducks in Great Lakes coastal wetlands.

Diving Ducks

Redheads (*Aythya americana*) are the only species of diving duck breeding regularly in Great Lakes coastal wetlands (Reeves 1991a). In the 1970s, Jaworski and Raphael (1978) recognized the St. Clair Delta (primarily Walpole and Harsens islands) as an important breeding area for redheads. The area remains important, producing up to 4,000 redheads annually (G. F. Martz, MiDNR, 1991 personal communication).

Although many ring-necked ducks (*Aythya collaris*) breed in the Great Lakes region (Bellrose 1980), they prefer inland palustrine wetlands for nesting (Mendall 1958). The species does not commonly breed in coastal wetlands (Jaworski and Raphael 1978, Reeves 1991b).

Sea Ducks and Stiff-tailed Ducks

The Great Lakes region is at the southern periphery of the breeding ranges of common goldeneye (*Bucephala clangula*), bufflehead (*B. albeola*), ruddy duck (*Oxyura jamaicensis*), and hooded (*Lophodytes cucullatus*), red-breasted (*Mergus serrator*), and common (*M. merganser*) merganser (Bellrose 1980). However, these species are primarily inland nesting species and seldom use coastal wetlands as nesting or brood rearing habitats (Jaworski and Raphael 1978). Green Bay, St. Marys River, Georgian Bay, and Lake Superior region are exceptions; red-breasted mergansers regularly breed on Door Peninsula and the nearby islands and several wetlands along the Wisconsin, Michigan, and Ontario coasts (Scharf 1979; Ludwig 1991, Padding 1991a,b; Prince 1991,). Ruddy ducks breed regularly in the Lake St. Clair delta area (Eastman 1991).

Postbreeding

Dispersal from breeding to molting areas, where different food and habitats are used, occurs in all anatids (Weller 1975, Fredrickson and Drobney 1979). Waterfowl annually undergo a complete wing molt, during which they are flightless for 3–5 weeks while the prebasic molt proceeds. In geese, both sexes molt their wing feathers during the summer brood rearing period. Male ducks molt soon after the breeding season ends in late spring and early summer, whereas females molt in late summer and early autumn, after rearing their broods (Palmer 1972).

Most Great Lakes coastal wetlands do not have large stands of emergent vegetation interspersed with open areas of submersed aquatics characteristically used by molting male mallards (Gordon 1985). Waterfowl that breed in the Great Lakes region probably molt in small groups on or near their breeding grounds, as commonly occurs in much of western Europe (Salomonsen 1968). Although flocks of 100–200 Canada geese molt at some of the islands associated with Door Peninsula in the Green Bay area (Scharf 1979), larger groups of molting waterfowl have not been reported in the Great Lakes region (McNicholl 1985) except for large numbers of molting wood ducks, especially males. at Long Point, Point Pelee/Rondeau Bay, and Lake St. Clair delta (D. Dennis, CWS, 1992 personal communication).

After molting, waterfowl congregate (stage) in large wetlands during late summer and early fall, prior to migration. During this period, waterfowl require an abundant supply of foods that have high carbohydrate content, as well as secure resting sites.

Postbreeding Canada geese feed mainly on green browse and cultivated crops, primarily corn and small grains, and rest in emergent wetlands. Postbreeding dabbling ducks feed in agricultural fields as well but also rely heavily on natural foods that develop in the strand zone during the summer. In Lake St. Clair, the Detroit River, and southwestern Lake Erie, the primary fall foods of dabbling ducks are seeds of strand plant species such as rice, cutgrass, and smartweed and seeds of emergent species such as sedge and softstem bulrush (Ford 1975, Hoffman and Bookhout 1985).

Aquatic invertebrates are also an important food during this period, particularly for black ducks and blue-winged teal (Bellrose 1980). Emergent and aquatic bed wetlands of palustrine, riverine, and lacustrine systems provide an abundance of these food resources, as well as secure resting habitat.

Although many waterfowl that breed in the Great Lakes region gather on inland wetlands managed by state and federal agencies, coastal wetlands in agricultural areas also attract flocks of postbreeding ducks and geese. Areas that are used heavily by postbreeding Canada geese and/or dabbling ducks include the large coastal wetlands of Green Bay (Scharf 1979), Saginaw Bay (Jaworski and Raphael 1978), the St. Clair Delta (Dennis and North 1984, Edsall *et al.* 1988), and southwestern Lake Erie (Herdendorf *et al.* 1981c; G. M. Tori, OhDNR, 1991 personal communication). In early and midfall, these birds are joined by migrants.

Migration

By far the greatest use of Great Lakes coastal wetlands by waterfowl occurs during migration. About 3–4 million swans, geese, and ducks travel along migration corridors that cross the Great Lakes region (Bellrose 1980). Chronology and patterns of waterfowl use differ greatly between fall and spring migration periods.

Fall migration is a leisurely trip for most waterfowl species compared with spring migration. Thousands of geese and ducks congregate on traditional staging areas each fall to rest and feed until the next movement to another staging area or a wintering location. Because the chronology of fall migration varies widely among species, use of staging areas in the Great Lakes region extends over 3 months from early fall through early winter, depending on local temperature, water conditions, food availability, and hunting pressure.

In contrast, most waterfowl species spend little time on major staging areas en route to their breeding grounds during spring migration. Stops along the migration routes are brief, thus areas of intense and extended use by spring migrants are few. Birds are widely distributed and usually present on areas seldom used during the fall such as embayed, open shoreline, and lagoon areas. The chronology of spring migration is similar for most species, and most of the movement through the Great Lakes region is restricted to 1 month from late March through April.

Data on migrating waterfowl in Great Lakes coastal wetlands are limited for some areas. A variety of techniques used to document waterfowl use has been employed by several individuals and agencies. The most comprehensive data on fall and spring migration was collected by the Canadian Wildlife Service and reported in terms of waterfowl use-days (Dennis *et al.* 1984). Some data are available for most Michigan (Jaworski and Raphael 1978; Herdendorf *et al.* 1981d,e; Herdendorf *et al.* 1986; Duffy *et al.* 1987) and Ohio (Bookhout *et al.* 1989) coastal wetlands that permit conversion to waterfowl use-day estimates. Total numbers of waterfowl for Wisconsin (Herdendorf *et al.* 1981e,f; Bookhout *et al.* 1989), New York (Bookhout *et al.* 1989), and some Michigan (Unpubl. data, Michigan DNR) coastal wetlands were converted to use-days by assuming an average stopover of 4 weeks during fall and 2 weeks during spring to estimate waterfowl use-days on coastal wetlands in those states (Table 3).

Swans and Geese

Each fall, 50,000–100,000 tundra swans, about 25% of the North American population (Gillespie *et al.* 1991), migrate nonstop through the Great Lakes region en route to their wintering grounds in Chesapeake Bay. Most swans that pass through the Great Lakes during spring migration stop to rest and feed in coastal wetlands (Bellrose 1980). This is reflected by greater use-day estimates for spring (Table 3). In addition to the St. Clair Delta and

TABLE 3. Average number of waterfowl use-days (× 1,000) in Great Lakes coastal wetlands during spring (S) and fall (F) migration.

Region-Location	(Number)	Year(s) of Survey	Swans	Geese	Dabbling ducks	Diving ducks	Sea ducks	Total ducks	Total Waterfowl
Lake Superior									
Chequamegon Bay[a]	(1)	1970 S	0	0	1	59	0	60	60
		1970 F	0	0	1	1	0	2	2
Portage Entry	(2)	No data							
Lake Michigan									
Bay de Noc[b]	(3)	1984–86 F	0	51	20	4	58	82	133
Green Bay[c]	(4)	1977 F				414	414		828
West Michigan[d]	(5)	1974 F	1	12	450	60	4	514	527
Lake Huron									
St. Marys River[e]	(6)	1979–84 F	0	25	105	357	57	519	544
Georgian Bay	(7)	No data							
Saginaw Bay[f,g]	(8)	1967–77 S	44	413	621	57	186	864	1,321
		1974 F	42	708	1,859	149	22	2,030	2,780
Lake St. Clair									
St. Clair Delta (Can.)[h]	(9)	1977 S	135	378	532	508	108	1,148	1,661
		1976 F	12	673	5,127	1,194	81	6,402	7,087
St. Clair Delta (U.S.)[f,i]	(9)	1974 S	55	0	179	171	36	386	441
		1974 F	21	0	791	606	128	1,525	1,546
Detroit River[h]	(10)	1980 S	1	49	27	259	38	324	374
		1979 F	0	160	718	480	1	1,199	1,359
Lake Erie									
Southwest Lake Erie[b,d,j]	(11)	1980–90 F	1	1,120	6,591	879	930	8,400	9,521
Point Pelee/Rondeau Bay[h]	(12)	1973 S	16	34	246	92	144	482	532
		1972 F	2	4	169	242	215	626	632
Long Point[h]	(13)	1978–79 S	10	147	373	1,162	1,367	2,902	3,059
		1977–78 F	24	328	3,732	3,199	1,055	7,986	8,338
Lake Ontario									
SC Lake Ontario[d]	(14)	1986–87 F	0	154	302	277	87	666	820
NE Lake Ontario[h]	(15)	1976 S	0	113	15	884	399	1,298	1,141
		1970–71 F	0	9	193	1,878	592	2,663	2,672

[a]Herdendorf *et al.* (1981f).
[b]Unpubl. data, Michigan DNR files.
[c]Bookhout *et al.* (1989).
[d]Herdendorf *et al.* (1981e).
[e]Duffy *et al.* (1987).
[f]Jaworski and Raphael (1978).
[g]Herdendorf *et al.* (1981d).
[h]Dennis *et al.* (1984).
[i]Herdendorf *et al.* (1986).
[j]G.M. Tori, Oh DNR, 1991 personal communication.

Saginaw Bay, thousands of tundra swans stop annually in southwestern Lake Erie and Green Bay (Herdendorf *et al.* 1981c,e), and lesser numbers visit Long Point and Point Pelee/Rondeau Bay (Dennis *et al.* 1984). Most migrants feed in corn and winter wheat fields (Dennis and North In Press).

More than 1,500,000 migrating Canada geese pass through the Great Lakes during fall migration, most of which visit wetlands in the region for extended periods. Migrating Canada geese feed primarily on corn, winter wheat, and small grains. Like postbreeding geese, they favor emergent wetlands in agricultural areas. Large, managed, inland wetlands such as Horicon Marsh in Wisconsin, Shiawassee National Wildlife Refuge in Michigan, and Jack Miner's Sanctuary in Ontario attract many of these birds. However, thousands of Canada geese also congregate in managed coastal wetlands, especially where flooded crops are used to attract geese and ducks to hunting areas. The coastal wetlands that are most heavily used by Canada geese during fall migration are those in southwestern Lake Erie, the St. Clair Delta (primarily on the Canadian side), Saginaw Bay, and Long Point (Table 3). Green Bay wetlands are also important during fall migration (Scharf 1979, Herdendorf *et al.* 1981e). Although overall use is lower in spring due to abbreviated stopovers en route to the breeding grounds, the same areas attract large numbers of geese during spring migration.

Although 300,000 lesser snow geese (*Chen caerulescens*) fly through the Great Lakes region during fall migration, <5,000 of them pause along the way (Bellrose 1980). Many of these stop at managed inland wetlands, but 500–1,000 snow geese annually visit coastal wetlands in Saginaw Bay and Green Bay (Herdendorf *et al.* 1981d,e). The migration corridors that these snow geese travel during spring migration do not cross the Great Lakes (Bellrose 1980).

Dabbling Ducks and Perching Ducks

A conservative estimate of 2,000,000 dabbling ducks, most of which are blue-winged and green-winged teal (*Anas crecca*), mallards, black ducks, and American wigeon, migrate through the Great Lakes region annually (Bellrose 1980). Chronology of fall migration varies widely among species. Periods of peak movement through the Great Lakes region are: blue-winged teal, early September; wood duck, early, mid/ and late September; green-winged teal, mid October; American wigeon (*Anas americana*), late October; mallard and northern pintail (*Anas acuta*), early November; and black duck, gadwall, and northern shoveler (*Anas clypeata*), mid November (Bellrose 1980).

Although most of the large Great Lakes coastal wetland complexes provide abundant food and secure resting habitats for postbreeding and migrating waterfowl, wetlands with uncontrolled water levels do not consistently attract as many staging dabbling ducks as do those wetlands in which water levels are controlled.

Of the Great Lakes coastal wetlands that are controlled and managed for wildlife, most are designed to attract migrating dabbling ducks during fall hunting seasons. The most effective configuration consists of a large area of emergent wetland (resting habitat) adjacent to agricultural fields, flooded strand vegetation, or flooded crops (feeding habitat). Such situations occur in much of the total wetland area of the St. Clair Delta, southwest Lake Erie, and Long Point, and in some Saginaw Bay wetlands. Thus these areas are the most heavily used during fall (Table 3).

Coastal wetlands of southwestern Lake Erie are particularly important to migrating black ducks. A 1-day peak of 76,020 black ducks was counted along Lake Erie's Ohio shoreline during fall 1981 (G. M. Tori, OhDNR, 1991 personal communication). Ohio DNR surveys done in the 1980s indicate that most of the black ducks in the Mississippi Flyway stop there during fall migration (Bookhout *et al.* 1989).

Information on use of coastal wetlands during spring migration is limited (Table 3). The available data reflect an accelerated pattern of movement through the Great Lakes region. Furthermore, the total number of dabbling ducks that use controlled coastal wetlands during spring is greatly reduced compared to fall use. The wide distribution of surface water in the spring allows for greater distribution of dabbling ducks throughout coastal and inland wetlands.

Diving Ducks

Great Lakes coastal wetlands are important to all species of diving ducks during migration. At least 500,000–600,000 diving ducks, primarily canvasbacks (*Aythya valisineria*), redheads, greater scaup (*Aythya marila*), and lesser scaup (*Aythya affinis*), use migration corridors that include the Great Lakes (Bellrose 1980). Redheads are the first to arrive in early October, and chronology is fairly uniform among the scaup and canvasbacks; peak numbers arrive in the Great Lakes region in late October and early November (Bellrose 1980). Significant numbers of canvasbacks, redheads, and scaup remain in the Great Lakes well into early winter during most years.

Migrating and wintering canvasbacks and redheads feed in relatively shallow water, eating the tubers, seeds, stems, and leaves of aquatic plants and animal foods. These species find their preferred foods in nonpersistent emergent and aquatic bed wetlands of lacustrine and riverine systems. In contrast, greater and lesser scaup rely more heavily on animal foods, especially mollusks, that are found in aquatic bed and unconsolidated bottom wetlands of lacustrine systems. They typically feed farther off shore and in deeper water than the other diving duck species.

Long Point and the St. Clair Delta are two of the major fall staging areas in North America for canvasbacks and redheads (Dennis and Chandler 1974) (Table 3). This is primarily due to the extensive beds of submerged vegetation, especially wild celery, that provide the preferred fall foods of those species (Martz *et al.* 1976). Saginaw Bay was formerly a fall concentration area, but excessive sediment and nutrient input has resulted in the virtual disappearance of submerged vegetation (Martz *et al.* 1976). As a consequence, Saginaw Bay now has little importance as a fall staging area for diving ducks (Table 3).

Northeast Lake Ontario shorelines are also visited by numerous diving ducks (Table 3), >90% of which are greater and lesser scaup (Dennis *et al.* 1984). Other key areas for diving ducks include the Detroit River, Green Bay, the St. Marys River, and southcentral Lake Ontario (Table 3).

Fall staging areas also attract diving ducks during spring, but use-days are reduced compared to fall. Habitats used by diving ducks are not managed for waterfowl hunting, therefore habitat quality does not change from fall to spring. Thus decreased use of coastal wetlands is probably a result of reduced durations of visits rather than fewer diving ducks visiting coastal wetlands during spring migration.

Sea Ducks and Stiff-tailed Ducks

The Great Lakes are a major stopover area for about 250,000 migrating buffleheads, common goldeneyes, ruddy ducks, and red-breasted and common mergansers (Bellrose 1980). Current impressions of numbers based on field observations is the 1980 estimate is low since more than 250,000 can be counted at one time in Lake Erie (D.G. Dennis, CWS, 1992 personal communication). These ducks arrive in the Great Lakes in early November, and many remain in the Great Lakes throughout the winter.

Foods of migrating ruddy ducks are located in areas similar to those used by diving ducks but they tend to use small coastal wetlands more frequently than do canvasbacks, redheads, and scaup (Bellrose 1980). Buffleheads and goldeneyes feed primarily on crustaceans, mollusks, and fish, and to a lesser extent on leaves, tubers, and seeds of aquatic plants (Bellrose 1980). Thus migrating and wintering goldeneyes congregate in aquatic bed and unconsolidated bottom wetlands in the littoral and limnetic zones of the lakes and in lower perennial riverine systems at the mouths of rivers. Red-breasted and common mergansers feed almost exclusively on fish. Wetland habitats preferred by migrating and wintering mergansers are similar to those used by goldeneyes and buffleheads.

Long Point, southwestern Lake Erie, northeastern Lake Onatrio, and Green Bay shorelines are the primary coastal areas used by sea ducks during fall and spring migrations (Table 3). Secondary areas include Saginaw Bay, Point Pelee/Rondeau Bay, the St. Clair Delta, southcentral Lake Ontario, and the St. Marys River (Table 3).

Winter

One consequence of technological and industrial development in the 20th century has been the creation of numerous artificial environments, including permanent open water zones in areas north of traditional waterfowl wintering grounds. Individuals of several waterfowl species have responded to this newly available winter habitat. In the Great Lakes, significant numbers of waterfowl currently winter in open water zones created by thermal discharges from power generating plants (e.g., Reed 1971, Haymes and Sheehan 1982, McCullough 1984) and other municipal and industrial operations (e.g., Freedman and McKay 1977, Manny *et al.* 1988).

Facultative migrants (i.e., birds that remain in northern areas as long as those areas provide their winter requirements) derive the greatest benefits from man-made winter habitats along the Great Lakes. Individuals of several waterfowl species have adopted the facultative migrant strategy, including black ducks (Brodsky and Weatherhead 1984), mallards (Nichols *et al.* 1983), common goldeneyes (Sayler and Afton 1981), and common mergansers (Bellrose 1980).

Numbers and distribution of waterfowl that winter in the Great Lakes vary annually, depending largely on ice cover and winter severity in general. Most of the available data on wintering waterfowl come from annual aerial surveys done in early January. Although changes in numbers and distribution probably occur frequently later in winter, the surveys provide an indication of the importance of the Great Lakes to wintering waterfowl.

Swans and Geese

Prior to the 1980s, Michigan's flock of mute swans wintered annually in Traverse Bay, Michigan (Gelston and Wood 1982). Curtailment of artificial feeding forced wintering swans to relocate farther south to areas that provided access to natural foods (G. F. Martz, MiDNR, 1991 personal communication). About 800 of Michigan's mute swans still winter in the northern half of the state, but most (1,400) now reside in southern Michigan (G. F. Martz, MiDNR, personal communication). During winter, they move to the river mouths with aquatic bed vegetation that occur along Lakes Michigan, Huron, St. Clair, and Erie.

Up to 100,000 Canada geese, predominantly of the giant race (*B. c. maxima*), winter in the southern Great Lakes region annually. Many giant Canada geese migrate only as far south as is necessary to find open water and accessible food. Their main food during winter is waste grains in harvested croplands, but excessive snow cover can limit the availability of this food source for extended periods. Thus annual variation in the number and distribution of geese that winter in coastal wetlands is determined largely by winter severity.

Coastal wetlands support few wintering Canada geese. Whitney Slough in the Green Bay region is one exception; ice cover is prevented mechanically, allowing hundreds of geese to remain there throughout the winter (Herdendorf *et al.* 1981e).

Dabbling Ducks

Among the dabbling ducks, black ducks tend to winter farthest north in large numbers. A much smaller proportion of the continental mallard population also adopts this wintering strategy. These birds migrate only as far south as is necessary to find open water, and feed primarily on waste grains in agricultural fields and on animal foods in open water zones of wetlands.

Thousands of mallards and black ducks winter annually at Whitney Slough, where open water is maintained mechanically (Herdendorf *et al.* 1981e). The coastal wetlands of the St. Clair Delta, the Detroit River, and southwestern Lake Erie also support wintering dabbling ducks. An average of 3,000 mallards and 600 black ducks wintered in those areas in 1986–90 (Michigan DNR, unpubl. data). Small areas of open water resulting from river currents and thermal discharges from power plants on the St. Marys River, west Michigan shoreline, and Saginaw Bay each support up to 500 wintering mallards and black ducks (Herdendorf *et al.* 1981d,e; Duffy *et al.* 1987).

Diving Ducks

Although flocks of several species consistently winter in the Great Lakes, the region generally is a minor wintering area for diving ducks. During most years, <20,000 canvasbacks and redheads remain into early winter, primarily in Lakes St. Clair and Erie, and the St. Clair and Detroit rivers (Bellrose 1980). However, aerial surveys by the Michigan DNR in 1988 (unpubl. data) indicated that 32,500 canvasbacks and 4,050 redheads were present in those areas in early January. Up to 30,000 each of greater and lesser scaup were present during early winter surveys in Lake St. Clair and along the shores of Lakes Michigan, Erie and Ontario (Bellrose 1980, Root 1988). Most diving ducks probably leave the Great Lakes in early to mid/January, after the winter surveys have been completed.

Sea Ducks

Red-breasted and common mergansers that spend the entire winter in the Great Lakes probably number more than 40,000. Large numbers of them are found in all of the lakes except Lake Superior (Root 1988). Thousands more mergansers, mostly female and immature birds, remain in the Great Lakes for part of the winter, often delaying further southward migration until mid/ to late January.

The Great Lakes also provide important wintering grounds for oldsquaws. Oldsquaws (*Clangula hyemalis*) can dive to depths of >30 m and feed primarily on crustaceans (Bellrose 1980). They usually stay well away from shorelines, preferring the nonvegetated limnetic zones of the Great Lakes. About 20,000 oldsquaws winter in the Great Lakes (Bellrose 1980), most of them in southern Lake Michigan and northern Lake Ontario (Root 1988, Bookhout *et al.* 1989).

Mergansers and common goldeneyes are the primary beneficiaries of the numerous artificial winter habitats created by warm water discharges from power plants, water treatment plants, and other industrial operations. For example, 10,000–15,000 common mergansers congregate each fall in Saginaw Bay at Consumers Power's Karn-Weadock power generating plant in Essexville, Michigan. Many of the females and immature birds leave the area in late January, but 3,000–5,000, mostly adults and immature males, remain through the winter. A similar situation occurs at the Ontario Hydro Nanticoke Generating Station near Long

Point, where 1,000–2,000 mergansers wintered in 1978 and 1979 (McCullough 1984).

Only the Atlantic and Pacific coasts are used by more wintering common goldeneyes than coastal wetlands of the Great Lakes. More than 20,000 goldeneyes winter in the Great Lakes, mainly in Lakes Michigan, Erie, and Ontario (Bellrose 1980, Root 1988).

POTENTIAL LIMITING FACTORS

Proximate factors affecting waterfowl use of Great Lakes coastal wetlands and deepwater habitats revolve about energy and nutrient demands and space. Although Great Lakes coastal wetlands are not currently of major importance as waterfowl breeding habitat in North America, areas with suitable nesting habitat and strand, emergent, and aquatic vegetative zones are attractive to breeding pairs. Nonbreeding birds respond dramatically during migration and winter periods to abundant supplies of food in the strand or its agricultural equivalent, aquatic bed, and open water areas.

Fluctuating water levels clearly have a strong influence on breeding waterfowl on both a short- and long-term basis. Short-term extreme fluctuations due to a combination of storm surges and seiches, as high as 3 m in Lake Erie (Crowder and Bristow 1988), can result in nest loss caused by "wash-out" or flooding. In the longterm, succession in aquatic plant communities as a result of changing water levels creates an unpredictable environment for breeding waterfowl in terms of, for example, nesting sites, food (both vegetation and invertebrates), and vulnerability to nest predators. The high water cycle in the early 1970s resulted in a huge but short-lived increase in productivity of ducks associated with appearence of invertebrates used by young ducklings. High water has reduced the quantity of waterfowl breeding habitat in the Great Lakes, but current trends are showing some improvement of quality wetland habitats (D. G. Dennis, CWS, 1991 personal communication).

Competitive interaction may be another factor limiting or influencing the breeding populations of some waterfowl species. Black ducks, for example, have experienced declines throughout the Great Lakes basin, and this decline has coincided with a concomitant increase in mallards. Habitat loss and overhunting have been identified as potential factors contributing to the decline of black ducks (Conroy *et al.* 1989). The black duck was once the most common nesting duck in some areas of the lower Great Lakes where it is now rare or absent, for example at Long Point (Snyder 1931, McCracken *et al.* 1981). Indeed, trend analysis indicates that the breeding population of black ducks in southern Ontario is decreasing by one-half in 11-year increments; mallards are showing a corresponding population doubling in 43 years (Dennis *et al.* 1989). Ankney *et al.* (1987, 1989) suggested that increased mallards in an area cause a decline in black ducks through introgressive hybridization and/or competitive exclusion.

Development of waterfowl populations in urban areas is recent and expanding. This process of domestication as described by Price (1984) is due to genetic changes and urban environments. Hand-reared mallards have responded to unique combinations of food, protection, and habitat (Heusmann 1991). Small populations develop and become isolated, in part, from wild populations, which is coincidental with the spread of the mallard eastward to the Great Lake region. Isolation is promoted by response to year around open water areas due to municipal and/or industrial discharges of heated water, and to dependable supplies of food from feeding by the public and/or nearby agricultural activities during the winter (Figley and VanDruff 1982). Nonmigratory populations of Canada geese have become reestablished in many urban and suburban areas over the past 50 years and are a nuisance to people because of artificial feeding and a propensity to graze on lawns and gardens (Conover and Kania 1991). The mute swan, an exotic species from Europe, became established in the Grand Traverse Bay region of Lake Michigan due primarily to a winter feeding program and an ability to use natural wetlands for breeding (Gelston and Wood 1982).

Waterfowl need nutrients and energy continuously; specific requirements vary as a function of the physical and biotic surroundings. King (1974) suggested that energy flow can be partitioned into the requirements of self-maintenance and reproduction. Energetic and nutritional requirements of waterfowl outlined by Holm and Scott (1954) and Scott (1973) show that breeding requires a high quality diet that includes $>18\%$ protein. In the span of several days a female lays a clutch of eggs that can amount to nearly one-half of her body weight. This is followed by additional energetic demands during an incubation period of nearly four weeks. Young ducklings up to four weeks old use invertebrates as a main source of food (Chura 1961). This critical link, presence of appropriate invertebrate communities in coastal wetlands, may be one of the major factors limiting waterfowl productivity (D.G. Dennis, CWS, 1992 personal communication).

Migration is an adaptation that assures an adequate food supply for self-maintenance during winter and reserves to meet the nutritional and energetic costs of reproduction. Species such as mallards (Krapu 1981) and geese (Ankney and MacInnes 1978, Raveling 1979) store endogenous supplies of lipids and protein during winter and at staging areas during spring migration. Females utilize these reserves to produce eggs, so that reproductive success is influenced by the ability to store nutrients (Newton 1977, Afton and Ankney 1991). Although few waterfowl actually breed in Great Lakes coastal wetlands, use of these habitats by millions of migrating waterfowl makes them critical to waterfowl production.

Factors affecting migrating and wintering waterfowl in Great Lakes coastal wetlands are numerous. Waterfowl management practices, other human activities, pollution, and invasions by exotic plants and animals have significant impacts on waterfowl use of and distribution in the Great Lakes.

Bookhout *et al.* (1989) reviewed extensively the habitat management of Great Lakes marshes and its impacts on waterfowl. Nearly all current management practices are aimed at increasing hunting opportunities by providing abundant fall foods for migrating waterfowl, thereby attracting them to hunting areas. Effective techniques include moist-soil management to provide natural, seed-producing plants; flooding of crops; and artificial feeding (baiting) (Bookhout *et al.* 1989). Unfortunately, such practices do not address the needs of waterfowl during spring migration, when food supply is more critical.

Other recreational, water-based human activities such as boating, windsurfing, and swimming can also have major impacts on populations of waterfowl during the time when waterfowl are staging. Such activities can be particularly damaging if they cause species to curtail feeding or in some way stress the birds involved, and hence influence survival. The use of power boats during the fall at a wetland complex such as Long Point reduces the number of diving ducks using the Inner Bay during the day, and formerly safe havens for waterfowl in channels and backwaters are now threatened with disturbance from currently popular recreational equipment such as Sea-Doos. Recreational human activities have also contributed to losses of submersed vegetation in the Great Lakes (Stuckey 1978), accelerating losses of critical feeding habitat for migrating and wintering diving ducks. Information on the effect of such direct human disturbance on waterfowl and their habitats is lacking for Great Lakes wetlands.

In addition to directly causing irretrievable losses of coastal wetlands, agricultural, industrial, and urban development along the coasts has led to an infusion of pollution into the Great Lakes. Although thermal and petroleum inputs are the most common pollutants, heavy metals and toxic organic compounds pose a more serious problem because they persist in the sediments for long periods. Organochlorines contained in pesticides and industrial chemicals are currently of primary concern because they are known to adversely affect avian reproduction and survival, and are a potential threat to human health. Green Bay, Saginaw Bay, and the Detroit River are among the waterfowl concentration areas on the Great Lakes that are heavily contaminated.

Organochlorines bioaccumulate in the food chain (Hamelink and Spacie 1977), and ducks that feed on fish (mergansers) and molluscs (e.g., goldeneyes, buffleheads, scaup, and oldsquaw) are at highest risk among the waterfowl. Comparisons of organochlorine levels in tissues of waterfowl in the Great Lakes indicate that mergansers have higher levels of contaminants than dabbling ducks (Haseltine *et al.* 1981, Kim *et al.* 1984). Although reproductive success of resident red-breasted mergansers in Green Bay did not appear to be impaired despite elevated levels of organochlorines (Haseltine *et al.* 1981), the impacts of contaminants on diving and sea ducks that migrate through or winter in the Great Lakes are unknown.

Human activities also have resulted in the introduction of numerous exotic species, some of which could significantly alter Great Lakes ecosystems. The spread of purple loosestrife (*Lythrum salicaria*) in the last 30 years has posed a major problem for wetlands in eastern North America, including the coastal wetlands of the lower Great Lakes. A highly competitive species, purple loosestrife develops rapidly in new areas, essentially displacing native flora (Thompson *et al.* 1987). Disappearance of native plants leads to the elimination of essential natural food and cover of many wetland fauna, including waterfowl (Hight and Drea 1991). No part of the plant is eaten by waterfowl, and the dense, monotypic stands hold no attraction as nesting sites. The problem will increase as the plant spreads and becomes consolidated in wetlands; research into biological control appears to hold the best prospects for effective control of the species (Hight and Drea 1991).

Another exotic species, the zebra mussel (*Dreissena polymorpha*), first appeared in the Great Lakes about 1985 (Hebert *et al.* 1989). This species has spread rapidly through Lakes St. Clair and Erie, and parts of Lakes Huron and Ontario, partly because of its high reproductive rate (one female can produce up to 30,000 eggs per year). Mussel aggregations of tens of thousands per square meter have been recorded in Europe (Stanczykowska 1977), and such densities are probably being reached in the lower Great Lakes.

The potential for major changes in the coastal wetlands community is great due to the zebra mussel invasion. The filtering of about a liter of water per day by each mussel could lead to an increase in water clarity and associated changes in distribution of submerged macrophytes. Depredation of phytoplankton by mussels has potential for changing the benthic community, which could trigger associated perturbations of the ecosystem. The mussels themselves are potential prey for mollusc-feeding waterfowl; Pedroli (1981) documented a 10-fold increase in duck populations (primarily *Aythya* spp.) on some Swiss lakes after a mussel invasion into those lakes. Van Eerden and Bij de Vaate (1984) documented a response to zebra mussels by wintering pochard (*A. ferina*), tufted duck (*A. fuligula*), greater scaup, and common goldeneye on Lake IJsselmeer area (the Netherlands). They reported a decrease in zebra mussel densities where an estimated 10 to 30% of the annual zebra mussel production is eaten by predators, mostly ducks. Walz (1974) observed that overwintering ducks consumed most of the zebra mussel production on Lake Constance.

An increase in numbers of lesser scaup in response to zebra mussel concentrations in autumn off Point Pelee, Ontario, in 1988–1989 appears to have occurred (A. Wormington, Ont MNR, 1990 personal communication), similar to the magnitude of response observed in Europe by other species of *Aythya* spp. There appears to be a potential for major shifts from traditional staging grounds to areas of high zebra mussel densities in the lower Great Lakes for several species of diving ducks, primarily scaups, goldeneyes, scoters, and buffleheads, and possibly redheads and canvasbacks.

The distribution of migrating and wintering waterfowl in the Great Lakes, and their use of coastal wetlands, are in a state of constant flux. Continued wetland destruction and alteration have caused habitat fragmentation and further losses of waterfowl habitat. Consequently, waterfowl are currently limited to relatively few habitat complexes that meet their requirements, and those remaining wetland habitats are increasingly important. This has resulted in large concentrations of birds in a few areas, increasing the danger of disease and resource limitations. There is also the potential for loss of biodiversity if waterfowl are forced to alter traditional migration routes and wintering areas. Mingling of distinct subpopulations during migration or wintering may result in loss of intraspecific genetic diversity. Thus the issues facing waterfowl and wetlands managers and researchers are many and varied, as are areas that require further research.

RESEARCH NEEDS

We have only a vague notion of the magnitude of coastal wetland losses and waterfowl population declines in the Great Lakes since presettlement times. Furthermore, we cannot show how and to what extent the two phenomena are linked. We do know that Great Lakes coastal wetlands are critically important to the life cycles of millions of waterfowl. Detailed documentation of current conditions is the first necessity if downward trends are to be halted or reversed.

At present, inventories of coastal wetlands appear to be fairly complete, but detailed community descriptions of even the largest are lacking in most instances. In addition to documenting wetland losses, we must be able to detect significant alterations of wetland ecosystems and determine the causes and impacts of those changes.

A shift in waterfowl use is one indicator of such changes, but comprehensive, baseline data on waterfowl are also lacking for much of the Great Lakes. Lack of standardized data collection, analysis, and reporting methodology among the various federal, state, and provincial agencies further complicates attempts to assess various trends. As a result, our evaluation of the current status of waterfowl in coastal wetlands provides only general comparisons of the relative importance of various wetland complexes. Comprehensive and directly comparable baseline data on wetland structure and waterfowl use are currently probably the most pressing research need.

There are large gaps in our knowledge of basic information on breeding populations of waterfowl in Great Lakes wetlands. Density estimates and measures of productivity are lacking for much of the lower Great Lakes. Little in-depth research in specific wetlands on factors influencing reproductive success has been carried out. Hence, the relative effects of abiotic factors such as water level fluctuations and of biotic factors such as food as a limiting resource, competitive interactions, and predation pressure have not been determined. The growing body of information indicating that there is competition for food between fish and nesting waterfowl (e.g. Eadie and Keast 1982, Eriksson 1983) is a field of research that should be applied to coastal wetlands.

Migration and wintering strategies of waterfowl should also be investigated. Ketterson and Nolan (1976, 1979) noted that energetic costs of migration are reduced for individuals that winter farther north than other conspecifics. Furthermore, wintering closer to the breeding grounds may enhance their timing of arrival on breeding grounds (Ketterson and Nolan 1976, 1979). Thus the strategy may result in increased survival and/or reproductive success. Populations of several waterfowl species winter along Great Lakes coasts, but we do not know how their survival and reproductive success compare with birds that winter farther south on more traditional wintering grounds.

The direct role played by Great Lakes coastal wetland and deep water habitats relative to energetic and nutritional requirements of waterfowl remains to be identified in future studies. Hoffman and Bookhout (1985) demonstrated that some plant species provided higher TME values than other species and proposed that marshes could be managed to provide greater amounts of these higher value species for use by autumn migrating ducks. Much recent work has focused on storage of endogenous nutrients, how nutrient reserves are used, and which nutrients are in limited supply during reproduction. Afton and Ankney (1991) tested three competing hypotheses. The protein-limitation hypothesis (Drobney 1980, Krapu 1981, Drobney and Fredrickson 1985) proposes that clutch sizes of female ducks vary as a function of availability of protein-rich foods during spring, and lipid reserves are primarily needed to provide energy for foraging. In direct contrast, the lipid-limitation hypothesis (Ankney and Afton 1988; Alisauskas *et al.* in press) asserts that protein is readily available in spring, therefore clutch size varies largely as a function of endogenous lipid reserves. The migrational uncertainty hypothesis (Rohwer in press) proposes that reserves are primarily for migration, and are useful on the breeding grounds only when inclement weather delays nest initiation; excess reserves serve as insurance against delays in the reproductive process.

Afton and Ankney's (1991) results supported the lipidlimitation hypothesis, suggesting that lipid reserve is a primary determinant of reproductive success. Riley and Bookhout (1990) demonstrated that early drawdown of diked marshes provides increased biomass of aquatic macroinvertebrates for use by spring migrating waterfowl. Such work could provide the basis and the impetus for development of management techniques that are designed to meet the needs of waterfowl during spring migration through the Great Lakes region.

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