Waterfowl Responses to Zebra Mussels on the Lower Great Lakes

Scott Petrie[1] and Michael L. Schummer[2]

MIKE DANZENBAKER

Long-tailed Ducks are annual on the lower Great Lakes. They are uncommon at most times and at most places, but large concentrations are sometimes noted both on migration and during the winter months. It is unknown whether Long-tailed Duck populations on the lower Great Lakes are being affected by the zebra mussel invasion in the region.

[1,2] Long Point Waterfowl and Wetlands Research Fund Bird Studies Canada
P.O. Box 160
Port Rowan ON N0E 1M0
[1] spetrie@bsc-eoc.org
[2] mschumme@uwo.ca

SP is the research director of the Long Point Waterfowl and Wetlands Research Fund. His work has focused primarily on the ecology of waterfowl in semi-arid environments and the staging ecology of waterfowl in north-temperate regions.

MLS is a Ph.D. candidate in Zoology at the University of Western Ontario, where he specializes in waterbird research and the advancement of wetland conservation. His areas of interest include waterfowl population dynamics, socio-economic impacts on wetland conservation, and landscape ecology.

Greater Scaup, Buffleheads, Long-tailed Ducks, and other waterfowl species that concentrate in large numbers on the Great Lakes each winter are in danger of being poisoned by a novel food source. The problem is presented by a small creature with a remarkable ability to concentrate toxic substances found in lake water—the zebra mussel.

The Great Lakes are widely acknowledged to be one of the most beleaguered ecosystems in North America. Water pollution and shoreline development are two of the better- known affronts on this ecosystem, but some ecologists consider exotic plants and animals to be an even greater threat. For better or for worse, virtually every native species in the Great Lakes has been impacted by exotics, and waterfowl are no exception.

The introduction of the zebra mussel (*Dreissena polymorpha*) and closely related Quagga Mussel (*D. bugensis*)—hereafter referred to collectively as zebra mussels—is a fairly recent phenomeon, but it has already had dramatic impacts on plants, animals, and ecosystem processes of the Great Lakes. It is tempting to view this mussel invasion as a positive development for waterfowl. Zebra mussels provide a novel food source easily exploited by certain species of waterfowl. But the short-term benefits of an increased food supply may be outweighed by the threat of food contamination: as zebra mussels feed, they accumulate in their tissues toxins that may be passed up the food chain.

Exotic Introductions

From the common carp (late 1800s), to the Eurasian watermilfoil (1952), and to one of the newest introductions, the round goby (about 1990), the Great Lakes have endured their share of exotic invasions over the past 200 years. Over 140 non-indigenous species have invaded the Great Lakes since the early 1800s. Some introduced species compete strongly with native fauna and flora, often resulting in changes in community structure. This competition ultimately can influence food web interactions and ecosystem functioning. Few introductions, however, have had a greater effect on the lower Great Lakes ecosystem than has the zebra mussel.

Zebra mussels are small (less than one inch) clam-like invertebrates native to European lakes. They were introduced into Lake St. Claire, east of Detroit, in 1986, apparently a result of the discharge of larvae in ship ballast water. Faced with limited competition, zebra mussels rapidly increased in numbers, expanding their range throughout the lower Great Lakes. They occur at densities from a few hundred to ten thousand per square meter on sandy, loamy, and vegetative surfaces. In rocky areas, where the mussels preferentially settle, densities have reached 750,000 per square meter.

The ability to expand rapidly and colonize new areas (via free-swimming larvae called veligers), coupled with the extremely high densities at which they can occur (they can adhere to most surfaces, including each other), has enabled zebra mussels to change the entire dynamic of the lower Great Lakes lake-bottom community. Previously slow-growing, with limited influence on ecosystem interactions, that community now is dominated by a single species that has transcendent effects on the ecology of the lower Great Lakes and their inhabitants. Native mussels, which averaged ten individuals per square meter prior to zebra mussel colonization, have been almost completely displaced by this highly competitive, exotic species.

Influence on Diet and Distribution

In Europe, zebra mussels provide a readily available source of food used by certain species of waterfowl. These waterfowl species are known to alter movement patterns to take advantage of zebra mussels, particularly in recently invaded lakes. It is not surprising that certain species of North American waterfowl also have shifted their dietary choices, as well as their distributions, to take advantage of this novel, yet easy-to-find, food source. When a prey item becomes superabundant and is easily exploited, waterfowl tend to concentrate their foraging efforts on that food source. Zebra mussels certainly fit this bill (no pun intended). They now are much more readily available than any other invertebrate food source, their consumption generally requires limited search, and they are easy to eat.

From 1991 to 1995, the diets of 552 ducks of twelve species were sampled from the Long Point, Lake Erie, waterfowl check station to identify food habits. Five of the twelve species analyzed had consumed zebra mussels, but only Lesser Scaup, Greater Scaup, and Buffleheads consistently incorporated zebra mussels in their diet.

Other species of diving ducks have been reported to consume zebra mussels: Common Goldeneye, Long-tailed Duck, and White-winged Scoter, according to research by D.J. Hamilton and C.D. Ankney. Given their inability

MICHAEL L. SCHUMMER

Exotic zebra mussels can reach astonishingly high densities in suitable environments in the lower Great Lakes. On sandy, loamy, or vegetative substrates, they occur at densities of a few hundred to ten thousand per square meter. On rocky substrates, densities as high as three-quarters of a million per square meter have been recorded. In contrast, native mussels average only ten individuals per square meter.

to forage in deep water, and a normal diet of vegetation during the non-breeding period, it is not surprising that dabbling ducks generally do not consume zebra mussels.

At Long Point, there was a three-fold increase in the number of waterfowl staging there between 1986 (prior to zebra mussel colonization) and 1997 (six years after colonization). Most of this gain can be attributed to increased numbers of Lesser and Greater Scaup (Figure 1). In fact, the use of Long Point by Lesser and Greater Scaup together increased 92-fold between 1986 and 1997 (based on day-use calculations), despite a substantial decline in the North American population of scaup during that time. Similar increases in scaup use have been reported for Lake St. Clair, as well as for Points Pelee and Rondeau on Lake Erie.

MIKE DANZENBAKER

Numbers of Common Goldeneyes wintering on the lower Great Lakes have increased appreciably in recent years. These recent population increases are probably tied to the fact that the species is a known consumer of zebra mussels—which are a potentially major food resource for wintering waterfowl.

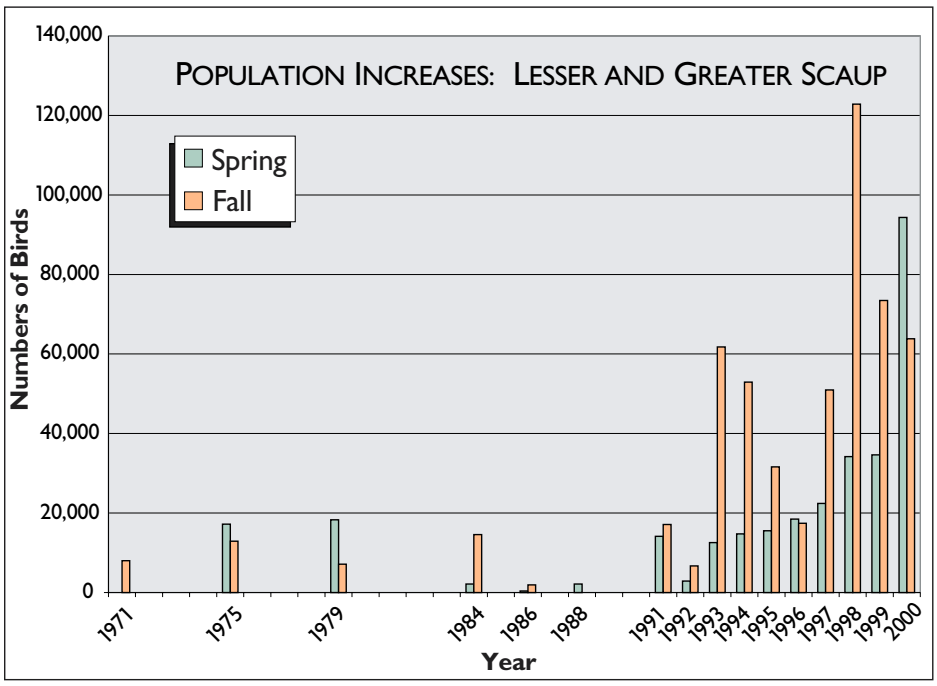

Figure 1. This chart shows a steep rise in Lesser and Greater Scaup populations at Long Point, which is on the northern shore of Lake Erie. Similar increases have been reported for Lake St. Clair, as well as for Points Pelee and Rondeau on Lake Erie.

These increases in scaup numbers are most likely a consequence of more birds gathering in these areas during migration and of those birds then remaining longer to consume zebra mussels. Not only has the presence of the mussels influenced the diets of certain species of diving ducks on the lower Great Lakes, but it also has caused dramatic shifts in their distributions and relative abundance during migration.

Although no dietary studies have been performed on diving ducks wintering on the lower Great Lakes since the arrival of zebra mussels, we do know that there have been major changes in the wintering populations of waterfowl since zebra mussel colonization. One of the better long-term sources of information on wintering Great Lakes waterfowl numbers is an extensive ground-based midwinter survey of the Canadian shoreline of Lake Ontario, compiled by Bill Edmunds of the Toronto Ornithological Club.

Numbers of Canada Goose and dabbling ducks (all species combined) increased by 2.8- and two-fold, respectively, between 1980 and 2000. But numbers of diving ducks (all species) increased nine-fold (Figure 2). Actually, wintering diving duck numbers have been increasing exponentially since 1991, around the time zebra mussels arrived on Lake Ontario. This substantial increase in overwintering diving ducks can be attributed for the most part to increased numbers of Lesser Scaup, Greater Scaup, Long-tailed Ducks, Common Goldeneye, Buffleheads, White-winged Scoters, and Common Mergansers, all of which—with the exception of Common Mergansers—are known to consume zebra mussels. Higher winter temperatures and reduced ice cover associated with the recent warming trend have in all likelihood contributed to increased use of the lower Great Lakes by these birds. However, substantial increases in numbers of staging and overwintering birds have been primarily limited to those species which consume zebra mussels, which suggests that mussel availability is quite possibly a primary factor influencing these changes in distribution and abundance.

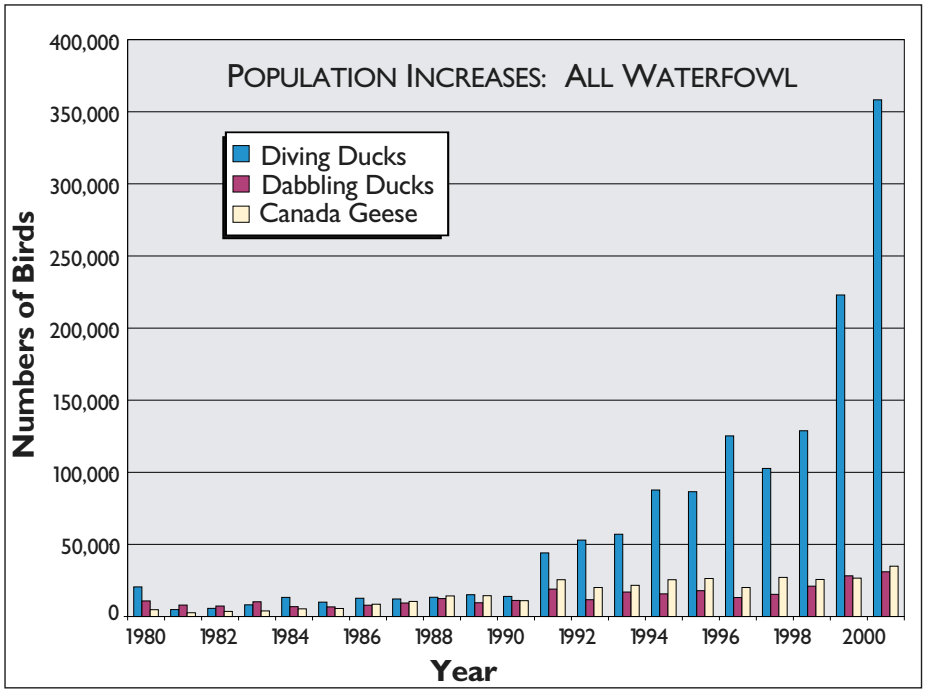

Figure 2. This chart shows across-the-board increases in waterfowl populations on the Canadian shoreline of Lake Ontario. Note that numbers of diving ducks have been increasing especially rapidly.

Possible Adverse Impacts

Rather than consuming algae and other food items that adhere to rocks and plants on the lake bottom, zebra mussels acquire their nutrition by filtering suspended matter from the water. Each zebra mussel filters several quarts of water per day. It is this prolific filtering capacity, combined with the fact that the animals occur at such high densities, that has enabled zebra mussels to have such a profound effect on lake ecology. This species has increased water clarity on the lower Great Lakes, diverted organic matter from the water column to the bottom,

BRIAN E. SMALL

The Lesser Scaup, like other diving duck species, appears to have been a beneficiary of the recent zebra mussel invasion of the lower Great Lakes. But the species may suffer in the long run from eating too many zebra mussels. This hazard arises because of the fact that zebra mussels bioaccumulate toxins that are passed up the food chain to predators such as the Lesser Scaup. In particular, Lesser Scaup may be in danger of eating zebra mussels that have been contaminated with cadmium, selenium, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons.

LARRY SANSONE

It is difficult to speculate at the present time about the eventual impacts of the zebra mussel on waterfowl populations that winter on the Great Lakes. Zebra mussels present a superabundant resource for Buffleheads and other species. But zebra mussels have greatly destabilized foodweb dynamics and contaminant cycling in the lower Great Lakes, with potentially harmful long-term effects on waterfowl populations.

altered foodweb interactions, and influenced contaminant and nutrient cycling. The uptake and subsequent transfer of contaminants through the food chain by these creatures is an area of continuing research and concern.

Because they filter particles indiscriminately, zebra mussels incorporate and accumulate into their tissues water-associated contaminants—polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and heavy metals (*e.g.*, cadmium). They do this much more readily than do native Great Lakes bivalves. These contaminants can subsequently be passed up the food chain to waterfowl that consume the mussels. This ultimately could compromise waterfowl reproductive output or survival. For instance, reproductive success in captive Tufted Ducks fed contaminated zebra mussels was 60 percent less than that of individuals fed less-contaminated mussels, according to research by W.C. de Kock and C.T. Bowmer.

Waterfowl surveys on the breeding grounds indicate that the continental population of Lesser and Greater Scaup declined from a high of eight million birds in 1972 to 3.7 million in 2001. However, the bulk of this decline has occurred since the mid-1980s, around the time zebra mussels began colonizing the Great Lakes. United States harvest data also suggest that the proportion of juveniles and adult females in the Lesser Scaup population has declined over the last two decades. This implies that both female survival and breeding or fledgling success have declined. Furthermore, there has not been an increase in the number of scaup taken by hunters, and populations of most other species of diving ducks have been increasing during the period of scaup decline.

Considering the increased use of the Great Lakes by scaup, plus a diet shift toward zebra mussels, scaup could be acquiring unhealthy contaminant burdens.

Studies to date have indicated that PCB and DDE burdens in staging and wintering Lesser and Greater Scaup on the Great Lakes are below the known effect levels for waterfowl. However, selenium has been detected in the elevated-to-potentially-harmful range in most birds collected from Lakes Ontario, Erie, St. Clair, and Michigan. Elevated selenium levels (more than ten parts per million, dry weight) can impair reproduction; yet higher levels (more than 33 parts per million) actually can cause mortality, according to a 1996 study by G.H. Heinz. Selenium is a semi-metallic trace element occurring naturally in some soils; it is also a byproduct of smelting operations and other industrial activities. Although selenium is nutritionally required by birds in very small amounts, it is highly toxic in greater quantities.

Selenium can rapidly increase in aquatic organisms, particularly in filter feeders such as zebra mussels. Field studies show that bottom-zone invertebrates can accumulate 20 to 370 parts per million of selenium and still maintain stable, reproducing populations. These levels are somewhat alarming as reproduction in Mallards is impaired at a dietary concentration of just nine parts per million. It has been recommended by A.D. Lemly that three parts per million is the toxic threshold for selenium in aquatic food-chain organisms consumed by fish and wildlife. Selenium concentrations quickly build up in tissues when birds are introduced to a selenium-contaminated diet. Selenium is also quickly excreted from the body when birds are removed from a selenium source. Females use the egg as a route of selenium excretion, and high selenium burdens can impair reproduction.

Because of the rapid rate of uptake and excretion, birds collected on the Great Lakes that show elevated selenium burdens quite possibly acquired those burdens while foraging on the Great Lakes. Even if selenium inputs to the lower Great Lakes have not increased substantially over the past fifteen years, zebra mussels—through filter feeding and bioaccumulation—may have concentrated selenium in their tissues, thereby increasing the availability of this trace element to waterfowl that consume them. Due to the large numbers of scaup staging on the lower Great Lakes and Mississippi River, where zebra mussels are readily available, selenium intake may be a factor in the decline of these species.

For these reasons, the Long Point Waterfowl and Wetlands Research Fund began an intensive study of dietary intake, contaminant burdens, and body condition of spring and fall staging Lesser and Greater Scaup on Lakes Ontario, Erie, and St. Clair in 1999. Birds collected by the Canadian Wildlife Service in 1985 (prior to zebra mussel colonization), as well as birds collected throughout the fall of 1999 and spring of 2000, plus the zebra mussels themselves, are being analyzed for burdens of heavy metals and trace elements, including selenium. This study will enable us to determine conclusively if Lesser and Greater Scaup are acquiring unhealthy burdens of selenium (or any other heavy metals or trace elements) while staging on the lower Great Lakes, and if contaminants are in fact acquired through zebra mussel consumption.

We know that zebra mussels provide a readily available, easily exploitable food source, and that certain species of waterfowl will change their movement patterns to exploit it. But we are as yet uncertain if this novel food item is in fact toxic to its dinner guests.

Further Reading

For further details on some of the studies mentioned in the article, along with additional information on zebra mussels, we recommend the following resources:

Brieger, G. and R.D. Hunter. 1993. Uptake and depuration of PCB 77, PCB 169, and hexachlorobenzene by zebra mussels (*Dreissena polymorpha*). Ecotoxicology and Environmental Safety 26:153–165.

Custer, C.M. and T.W. Custer. 1996. Food habits of diving ducks in the Great Lakes after the zebra mussel invasion. Journal of Field Ornithology 67:86–99.

de Kock, W.C. and C.T. Bowmer. 1993. Bioaccumulation, biological effects, and foodchain transfer of contaminants in the zebra mussel (*Dreissena polymorpha*). pp. 503–533 *in*: T.F. Nalepa and D.W. Schloesser, eds. Zebra Mussels: Biology, Impacts, and Controls. Lewis Publishers, Boca Raton.

Fisher, S.W., D.C. Gossiaux, K.A. Bruner, and P.F. Landrum. 1993. Investigations of the toxicokinetics of hydrophobic contaminants in the zebra mussel (*Dreissena polymorpha*). pp. 465–490 *in*: T.F. Nalepa and D.W. Schloesser, eds. Zebra Mussels: Biology, Impacts, and Controls. Lewis Publishers, Boca Raton.

Gillis, P.L. and G.L. Mackie. 1994. Impact of the zebra mussel, *Dreissena polymorpha*, on populations of Unionidae (Bivalvia) in Lake St. Clair. Canadian Journal of Zoology 72:1260–1271.

Griffiths, R.W., D.W. Schloesser, J.H. Leach, and W.P. Kovalak. 1991. Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes region. Canadian Journal of Fisheries and Aquatic Sciences. 48:1381–1388.

Hamilton, D.J. and C.D. Ankney. 1994. Consumption of zebra mussels *Dreissena polymorpha* by diving ducks in Lakes Erie and St. Clair. Wildfowl 45:159–166.

Heinz, G.H. 1996. Selenium in birds. pp. 447–458 *in*: W.N Beyer, G.H. Heinz, and A.W. Redmond-Norwood, eds. Environmental Contaminants in Wildlife: Interpreting Tissue Concentration. SETAC Special Publication Series. Lewis Publishers, Boca Raton.

Herbert, P.D.N., B.W. Muncaster, and G.L. Mackie. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 46:1587–1591.

Lemly, A.D. 1996. Selenium in aquatic organisms. pp. 427–445 *in*: W.N. Beyer, G.H. Heinz, and A.W. Redmond-Norwood, eds. Environmental Contaminants in Wildlife: Interpreting Tissue Concentration. SETAC Special Publication Series. Lewis Publishers, Boca Raton.

Mitchell, C.A. and J. Carlson. 1993. Lesser Scaup forage on zebra mussels at Cook Nuclear Plant, Michigan. Journal of Field Ornithology 64:219–222.

Petrie, S.A. and R.W. Knapton. 1999. Rapid increase and subsequent decline of zebra and quagga mussels in Long Point Bay, Lake Erie: possible influence of waterfowl predation. Journal of Great Lakes Research 25:772–782.

Prince, H.H., P.I. Padding, and R.W. Knapton. 1992. Waterfowl use of the Laurentian Great Lakes. Journal of Great Lakes Research 18:673–699.

Wormington, A. and J.H. Leech. 1992. Concentrations of diving ducks at Point Pelee, Ontario, in response to invasion of zebra mussels, *Dreissena polymorpha*. Canadian Field Naturalist 106:376–380.