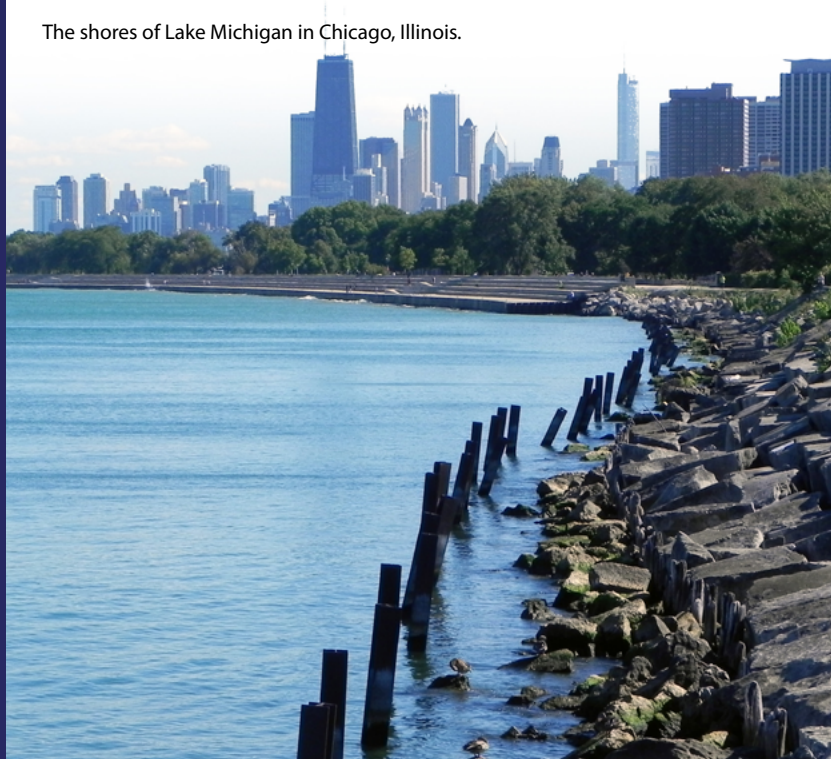
PURDUE UNIVERSITY | Forestry and Natural Resources
COLLEGE OF AGRICULTURE

Sea Grant ILLINOIS-INDIANA

IISG18-LWD-RLA-009 • FNR-565

What's on the menu for salmon and trout in Lake Michigan?

Benjamin Leonhardt, Harvey Bootsma, Charles Bronte, Serguisz Czesny, Austin Happel, Matt Kornis, Jacques Rinchard, Ben Turschak, Mitchell Zischke, and Tomas Höök.



The shores of Lake Michigan in Chicago, Illinois.

Lake Michigan is a changing ecosystem

In the 1990s, two important types of invasive species were accidentally introduced into Lake Michigan via the ballast water of ships: 1) dreissenid mussels (zebra and quagga mussels) and 2) round gobies. Dreissenid mussels are voracious filter feeders of phytoplankton (i.e., microscopic plants). Phytoplankton form the base of the food web, providing important food for zooplankton (i.e., microscopic animals), which in turn serve as an important food source for small fishes. High numbers of dreissenid mussels, coupled with reduced nutrient (e.g., phosphorus) input from tributaries, have reduced the abundance and diversity of phytoplankton and zooplankton, and have been linked to declines of some benthic invertebrates (e.g., *Diporeia* or mud scuds) in Lake Michigan, particularly in offshore areas[1,2,3]. As a result, populations of some offshore forage fish species that rely on planktonic and invertebrate food, such as alewife and bloater, have also declined. Offshore forage fish populations have also been reduced through predation from salmon and trout, whose populations are supplemented by stocking[4]. In contrast

Two important types of invasive species in Lake Michigan: round goby (top) and dreissenid mussels (bottom).

Photo credit: USGS.

Zebra mussel

Quagga mussel

to offshore areas, nearshore areas have not seen declines in plankton populations[5] and have seen huge increases in populations of the invasive round goby. Round gobies are an invasive species that compete for food and habitat with other small, bottom fishes, such as sculpin[6]. However, round goby may serve as an increasingly important food source for larger fish[7]. Since the 1990s, invasive species have drastically changed the Lake Michigan food web, which has likely led to changes in the diets of large predators, such as salmon and trout.

Salmon and trout in Lake Michigan

Five primary species of salmon and trout (known as salmonines) live in Lake Michigan: one native species (lake trout) and four introduced species (brown trout, Chinook salmon, coho salmon, and steelhead). Lake trout were once the primary offshore predator in Lake Michigan, but sea lamprey predation and overfishing caused lake trout populations to collapse in the 1950s. Declining populations of lake trout allowed nonnative alewife populations to rapidly increase to nuisance levels. Widespread salmonine stocking began in the late 1960s to help control the overabundant alewife populations and to promote what has become a highly valuable recreational fishery. Through much of the 1970s, 1980s, and 1990s, salmonines almost exclusively ate alewife, while occasionally consuming other prey like bloater, sculpin, rainbow smelt, insects, and other prey[8,9]. The decline in populations of some forage fishes, such as bloater and alewife, in recent years have led to changes in management strategies (e.g., numbers stocked) of some predators like salmonines, but may have also changed the types of prey that these predators eat in Lake Michigan.

Fishery managers in Lake Michigan use a predator-prey ratio to monitor changes in the abundance of Chinook salmon (predator) and alewife (prey). A predator-prey ratio calculates the proportion of a predator compared to the available prey to ensure that fish populations remain balanced, with not too many predators for the amount of food available. Over the past 10-15 years, predator-prey ratios in Lake Michigan have increased due to both the decline of alewife and increases in salmonine biomass[10]. To try and bring populations back to balance, fisheries management agencies have reduced stocking levels of Chinook salmon by 50% since 2012 (numbers stocked: 3.24 million in 2012; 1.37 million in 2017)[11].

The decline in forage fish in Lake Michigan has also likely led to changes in the diet composition of some salmonine species. To understand how salmonines are adjusting to a changed ecosystem, we collected 1,380 stomachs from five salmonine species in 2016. Most fish were caught by Lake Michigan anglers surveyed by the Great Lakes Mass Marking Program, a multi-agency project coordinated by the U.S. Fish and Wildlife Service. Stomachs were collected from fish in the main basin of Lake Michigan (excluding Green Bay) at ports ranging from Gary, Indiana, north to Manistique, Michigan, on the west coast and Michigan City, Indiana, north to Charlevoix, Michigan, on the east coast (Figure 1). From these stomachs, we calculated the average weight of each prey category, expressed as a proportion of all stomachs of that particular species. This allowed us to describe the diet composition of brown trout, Chinook salmon, coho salmon, lake trout, and steelhead in Lake Michigan.

A catch of multiple salmonine species from a charter fishing trip in Lake Michigan.

An angler on Lake Michigan.

Figure 1. Salmonines were collected from ports along eastern and western Lake Michigan (division shown by center line). Eastern salmonines were collected from Michigan City, Indiana, north to Charlevoix, Michigan, while western salmonines were collected from Gary, Indiana, north to Manistique, Michigan. No salmonines were collected from Green Bay (grey area on map).

A steelhead stomach full of terrestrial insects.

Photo credit: B. Leonhardt

Salmonine diet composition

The most common prey consumed by all five salmonine species across all of Lake Michigan was alewife (Figure 2). Alewife contributed most to the diets of Chinook and coho salmon. Chinook salmon consumed almost exclusively alewife (97% of weight in stomach) and rarely consumed other prey types. Similar to Chinook salmon, coho salmon primarily consumed alewife (90%), but incorporated a larger diversity of prey into their diet, including such aquatic invertebrates as mysid shrimp and spiny waterfleas. Steelhead primarily consumed alewife (76%); however, they ate a substantial amount of terrestrial insects (16%). Round goby was primarily consumed by brown trout (52%) and lake trout (25%), though alewife still contributed significantly to their diets (brown trout: 35%; lake trout: 70%).

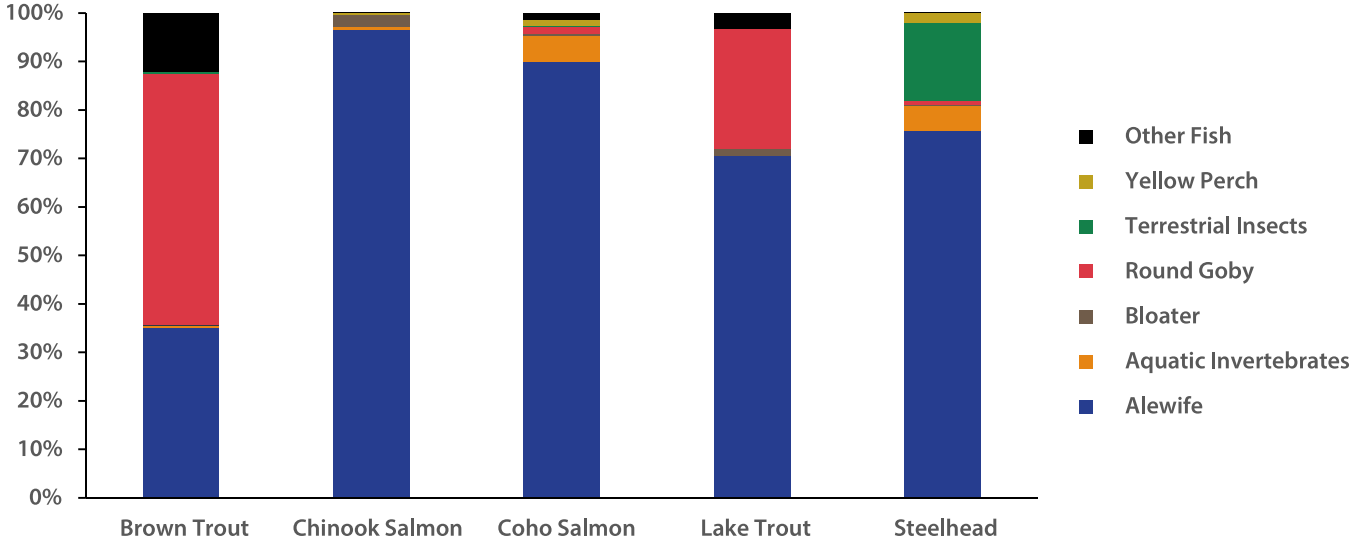


Figure 2. Average weight of each prey type expressed as proportions for each salmonine species collected from Lake Michigan waters.

Spatial variation in salmonine diets

In 2016, the diet compositions of salmonines varied depending where fish were caught; there were large differences in diet between the east and west sides of Lake Michigan (Figure 3). For all five salmonine species, more alewife were consumed on the west side compared to the east side of Lake Michigan. This may be attributed to higher numbers of alewife on the west side of the lake, especially in the spring. Coho salmon and steelhead had more diverse diets on the east side of Lake Michigan – commonly eating aquatic invertebrates, terrestrial insects, and juvenile yellow perch, in addition to alewife – which could be related to differences in alewife availability across Lake Michigan. More round gobies were consumed by brown trout and lake trout on the east side of Lake Michigan. The east side of the lake is mostly sandy habitat, which may make it easier for predators to capture round gobies. In contrast, the west side of the lake has rockier habitat with crevices that provide hiding places for round gobies, which may make it more difficult for brown trout and lake trout to catch them.

An example of some terrestrial insects, including stink bugs, lady-bugs, bees, and beetles, found in steelhead stomachs.

Photo credit: B. Leonhardt

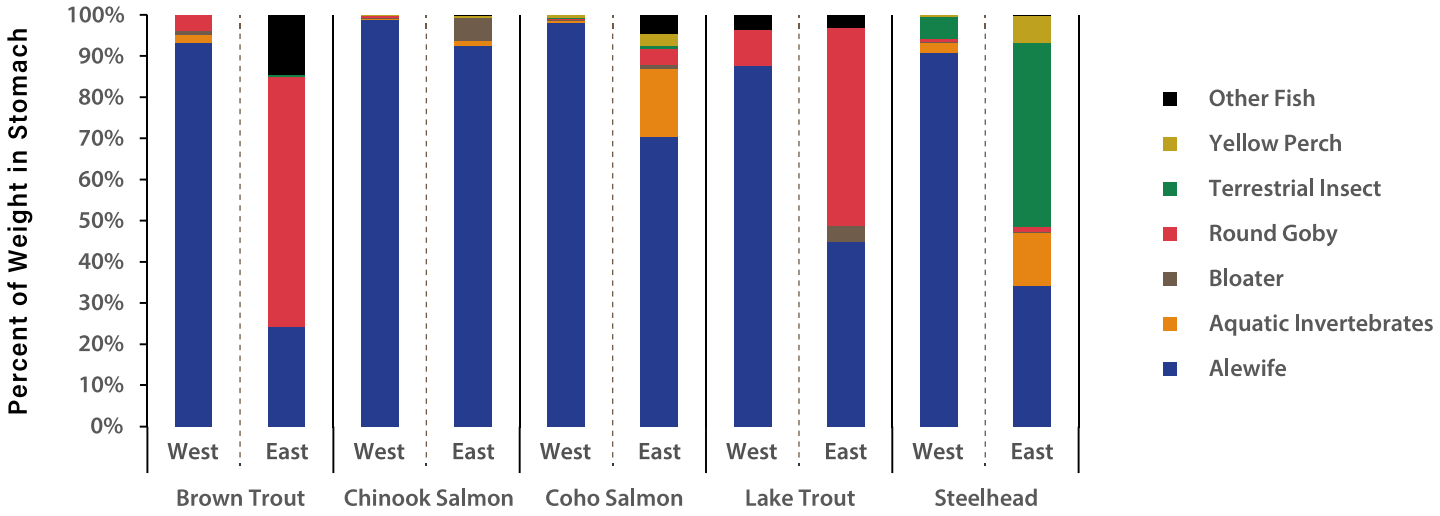


Figure 3. Average weight of each prey type expressed as proportions for each salmonine species collected from the east and west halves of Lake Michigan.

Sizes of alewife that were typically found in the stomachs of salmonines.

Photo credit: B. Leonhardt

Size of alewife in salmonine diets

The five salmonine species not only differed in what they ate, but also in the size of fish they ate–specifically, alewife (Figure 4). Brown trout, Chinook salmon, coho salmon, and lake trout ate alewife that were on average 4 ½–5 inches long, whereas steelhead ate smaller alewife that were on average 3 ¾ inches long. Steelhead tend to feed higher in the water column compared to the other species, which likely restricts them from interacting with large alewife that are deeper in the water column.

Take-home message

Diets of some salmonine species have changed since the introduction of dreissenid mussels and round goby into Lake Michigan. Some species – brown trout, lake trout, and steelhead – have changed from eating mainly alewife to now eating a mixture of alewife and other prey items. However, other species, particularly Chinook salmon, continue to rely almost exclusively on alewife despite declines in alewife abundance. This reliance of Chinook salmon on alewife means that fishery managers will continue to closely monitor the predator-prey ratio in Lake Michigan and make changes to Chinook salmon stocking to match alewife population levels. As the Lake Michigan ecosystem continues to change, salmonine species that have a more flexible and diverse diet, such as brown trout, lake trout, and steelhead, may be better prepared to deal with these changes, whereas species that rely heavily on alewife, such as Chinook salmon and coho salmon, may have a more uncertain future.

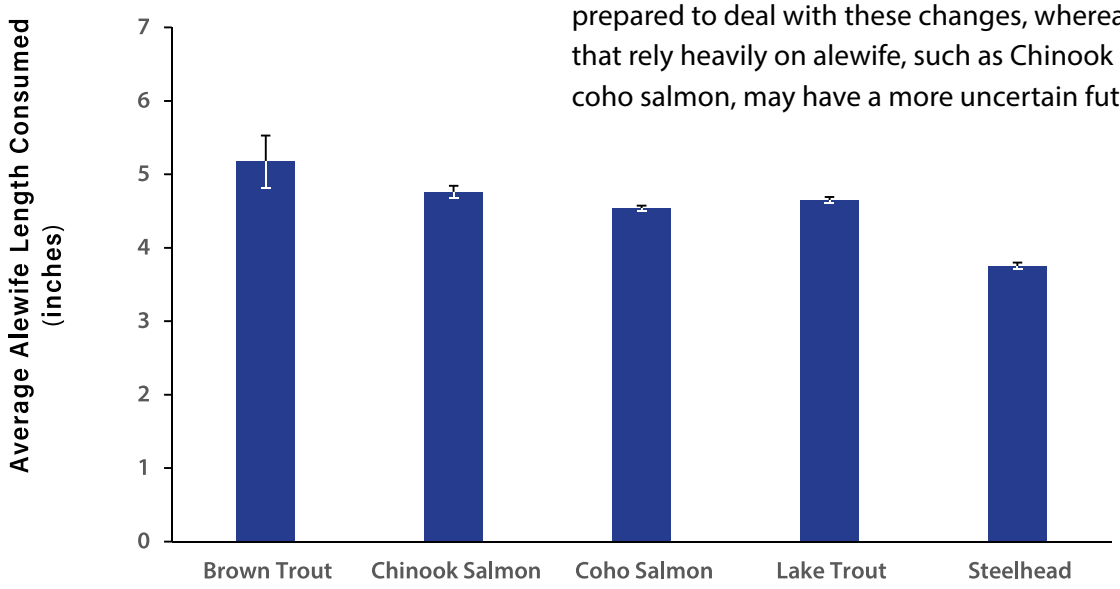


Figure 4. Average length (inches) of alewife consumed by each species of salmon and trout. Error bars represent standard error.

Literature Cited

[1]Hecky, R.E., Smith, R.E., Barton, D.R., Guildford, S.J., Taylor, W.D., Charlton, M.N., & Howell, T. 2004. The nearshore phosphorus shunt : a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. *Can. J. Fish. Aquat. Sci, 61*(7), 1285–1293. https://doi.org/10.1139/F04-065.

[2]Vanderploeg, H.A., Liebig, J.R., Nalepa, T.F., Fahnenstiel, G.L., & Pothoven, S.A. 2010. Dreissena and the disappearance of the spring phytoplankton bloom in Lake Michigan. *Journal of Great Lakes Research*, 36 (3), 50–59. https://doi.org/10.1016/j.jglr.2010.04.005.

[3]Nalepa, T.F., Fanslow, D.L., & Lang, G.A. 2009. Transformation of the offshore benthic community in Lake Michigan: Recent shift from the native amphipod *Diporeia* spp. to the invasive mussel Dreissena r*ostriformis bugensis. Freshwater Biology, 54*(3), 466–479. https://doi.org/10.1111/j.1365-2427.2008.02123.x.

[4]Tsehaye, I., Jones, M.L., Brenden, T.O., Bence, J.R., Randall, M., & Claramunt, R.M. 2014. Changes in the salmonine community of Lake Michigan and their implications for predator – prey balance. *Transactions of the American Fisheries Society, 143*(October), 420–437. https://doi.org/10.1080/00028487.2013.862176.

[5]Hutton-Stadiq, M. 2016. Lower food web dynamics of Lakes Michigan and Huron: spatial and temporal responses to recent oligotrophication. Purdue University, West Lafayette, Indiana, USA. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2041&context=open_access_theses.

[6]Janssen, J., & Jude, D.J. 2001. Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus. Journal of Great Lakes Research, 27*(3), 319–328. https://doi.org/10.1016/S0380-1330(01)70647-8.

[7]Happel, A., Jonas, J.L., McKenna, P.R., Rinchard, J., He, J.X., & Czesny, S.J. 2017. Spatial variability of lake trout diets in Lakes Huron and Michigan revealed by stomach content and fatty acid profiles. *Canadian Journal of Fisheries and Aquatic Sciences, 1–11*. https://doi.org/10.1139/cjfas-2016-0202.

[8]Jude, D.J., Tesar, F.J., Deboe, S.F., & Miller, T.J. 1987. Diet and selection of major prey species by Lake Michigan USA salmonines 1973-1982. *Transactions of the American Fisheries Society, 116*(5), 677–691. https://doi.org/10.1577/1548-8659(1987)116<677.

[9]Rybicki, R.W., & Clapp, D.F. 1996. Diet of Chinook salmon in Eastern Lake Michigan, 1991-93. *Michigan Department of Natural Resources, Fisheries Research Report No. 2027*. https://www.michigan.gov/documents/dnr/2027rr_537046_7.PDF.

[10]Great Lakes Fishery Commission. 2017. Summary of the Predator/Prey Ratio Analysis for Chinook Salmon and Alewife in Lake Michigan. http://www.glfc.org/pubs/lake_committees/michigan/PPR%20Summary%20for%20Outreach_Final%20draft_LMC%20approved%205-15.pdf.

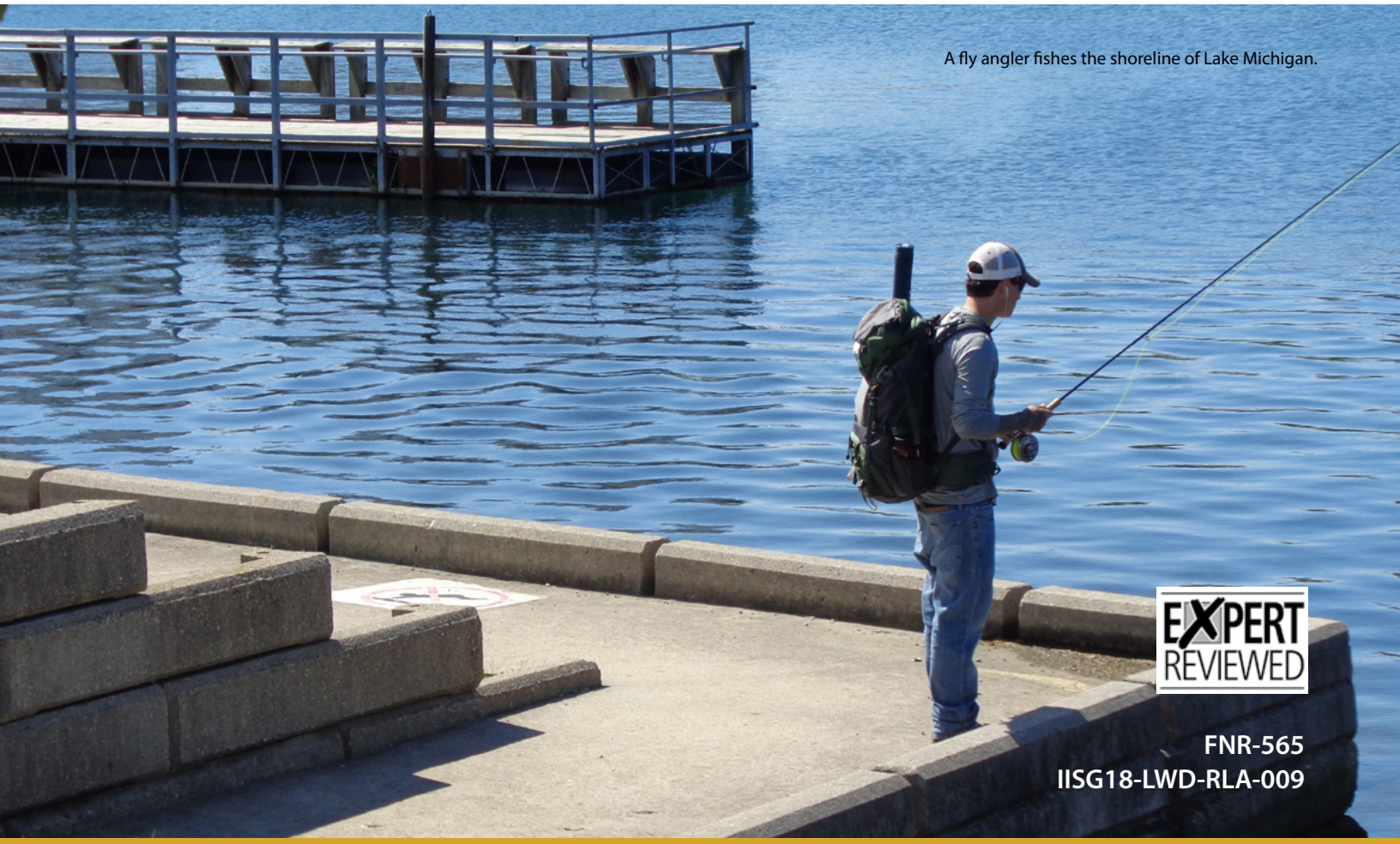
[11]R. Wehse, D. Hanson, T. Treska, M. Holey. 2017. Summary of 2016 Lake Trout and Salmonid Stocking in Lake Michigan. U.S. Fish and Wildlife Service. Green Bay Fish and Wildlife Conservation Office Report number: 2017-02. http://www.glfc.org/pubs/lake_committees/michigan/LTWG_docs/Lake%20Michigan%20Stocking%20Report%202016.pdf. 2017 numbers can be accessed at http://www.glfc.org/fishstocking.

[12]Leonhardt, B. 2018. Evaluating Methods to Describe Dietary Patterns of Lake Michigan Salmonids. Purdue University, West Lafayette, Indiana, USA.

Acknowledgements

First and foremost, thank you to all the anglers that provided fish samples for this research. We'd also like to acknowledge agency partners who assisted in collecting fish samples: Michigan, Indiana, Illinois and Wisconsin Departments of Natural Resources, Illinois Natural History Survey, and U.S. Fish and Wildlife Service. We also acknowledge undergraduate student technicians at Purdue University who assisted in stomach content analyses, and our funding agency–Great Lakes Fishery Trust. Methods, data, and results discussed in this publication formed part of a Master's thesis completed by Ben Leonhardt in 2018[12]. Additionally, thank you to Chuck Wineland, Jade Layman, and the Illinois-Indiana Sea Grant communication team for their work to pull this publication together.

PURDUE UNIVERSITY | Extension



A fly angler fishes the shoreline of Lake Michigan.

EXPERT REVIEWED

FNR-565
IISG18-LWD-RLA-009