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Summer diet analysis of the invasive rainbow smelt (*Osmerus mordax*) in Lake Winnipeg, Manitoba

Katie T. Sheppard [1], Andrew J. Olynyk [1], Gail K. Davoren, Brenda J. Hann *

Department of Biological Sciences, Duff Roblin Building, University of Manitoba, Winnipeg, Canada Manitoba R3T 2N2

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ABSTRACT

Invasive species can have both negative and positive impacts on the trophic structure of aquatic systems. Rainbow smelt were first observed in Lake Winnipeg during late 1990 and their impact on upper and lower trophic levels is unclear. To begin to understand the impact of this invasive species in this large, shallow lake, dietary composition of smelt was described. During mid-summer 2008 and 2009, we simultaneously quantified the stomach contents of smelt and characterized the zooplankton community in the North Basin of Lake Winnipeg. Zooplankton and rainbow smelt (total length: 70–130 mm) were collected from ten stations in 2008 and six in 2009 on the M.V. *Namao*. The relative abundance of four zooplankton prey types (copepods, *Daphnia* spp., *Eubosmina coregoni* and *Bosmina longirostris*) was determined from the zooplankton samples and the smelt stomach contents. Using electivity indices, we found that rainbow smelt preferred *Daphnia* spp., as well as larger individuals of *Daphnia* spp., in both years. Preference for larger *Daphnia* spp. is likely due to conspicuousness (size, movement patterns) and slow swimming speeds relative to the other prey types. With detailed knowledge of the trophic linkage between rainbow smelt and the zooplankton community, we can begin to quantify the effects of invasive rainbow smelt on the food web structure of the lake.

Introduction

Rainbow smelt (*Osmerus mordax*) are a non-indigenous fish species in Lake Winnipeg (Franzin et al., 1994), originally found as anadromous populations off the coast of northeastern North America (Franzin et al., 1994). In the 1920s, rainbow smelt invaded the Laurentian Great Lakes, subsequently expanding its range into smaller isolated lakes within the Great Lakes watershed, and in late 1990, was first observed in Lake Winnipeg (Campbell et al., 1991; Franzin et al., 1994). These introductions were likely a mixture of intentional and accidental release, perhaps as bait from anglers, along with dispersal via drainage systems (Franzin et al., 1994; Mercado-Silva et al., 2006).

In other landlocked freshwater populations, schools of rainbow smelt are generally found in the pelagic zone, with feeding commonly occurring at mid-water depths (Scott and Crossman, 1973). Rainbow smelt are predominantly zooplanktivorous at sizes <150 mm total length, but consume benthic macroinvertebrates and small fish as length and gape size increase beyond the 150 mm threshold (Urban and Brandt, 1993; Hrabik et al., 1998; Stewart and Watkinson, 2004). The diet of freshwater populations of rainbow smelt is generally composed of copepods and cladocerans (including *Daphnia* spp., *Eubosmina* and *Bosmina*) (Urban and Brandt, 1993; Hrabik et al., 1998; Beisner et al., 2003; Johnson et al., 2004). Large cladocerans possess a relatively conspicuous pattern of movement and a slow swimming speed (O'Brien, 1987; Amundsen et al., 2009), making these prey items less likely to escape smelt predation. In contrast, similar-sized copepods have a streamlined body, sleek movement in the water and much faster swimming speeds (O'Brien, 1987; Amundsen et al., 2009). As smelt tend to show dietary preference for larger zooplankton taxa, species composition of zooplankton prey communities has changed in response to invasion in other systems (Beisner et al., 2003; Johnson et al., 2004). As with other zooplanktivorous, non-indigenous fishes, decreased density and species richness of the prey community, and dominance of small zooplankton species can occur in a matter of decades after smelt invade (Wells, 1970, Mills et al., 1995; Amundsen et al., 2009). These alterations in zooplankton communities are more obvious where smelt populations have been established for a long period of time, such as in the Great Lakes, and have far-reaching impacts on the energetic pathways and food web structure of invaded lakes (Johnson et al., 2004). Currently, there is no published literature on diets of rainbow smelt in Lake Winnipeg.

Lake Winnipeg is the tenth largest freshwater body in the world based on surface area; however, it is unique to the Laurentian Great Lakes in that it is relatively shallow. It is composed of two distinct basins, the deeper North Basin (mean depth 13.3 m) and the shallower South Basin (mean depth 9.7 m), connected by a short

* Corresponding author at: Department of Biological Sciences Duff Roblin Building, 190 Dysart Rd University of Manitoba Winnipeg, MB R3T 2N2 Canada. Tel.: +1 204 474 7450.

E-mail addresses: katietsheppard@gmail.com (K.T. Sheppard), umolynya@cc.umanitoba.ca (A.J. Olynyk), davoreng@cc.umanitoba.ca (G.K. Davoren), hann@cc.umanitoba.ca (B.J. Hann).

[1] Sheppard and Olynyk contributed equally to the study.

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passage known as the Narrows (Patalas and Salki, 1992). Thermal stratification is rarely observed (Hann et al., 2005). The shallow depth and large fetch make the waters of Lake Winnipeg consistently turbid, where Secchi transparencies are low (2008: 0.80 ± 0.52 m, 2009: 1.06 ± 0.28 m). These characteristics lead to a well-mixed water column, rare for a lake of its size.

Pre-invasion information on the zooplankton and fish communities in Lake Winnipeg is limited. A 1969 study on the crustacean plankton community showed that copepods, *Bosmina*, and *Daphnia* spp. were fairly abundant, in rank order, in the North Basin of Lake Winnipeg (Patalas and Salki, 1992). *Eubosmina* had not yet invaded the lake; it is possible that rainbow smelt and *Eubosmina* invaded concurrently (Suchy et al., 2009). The South Basin to the northern part of the Narrows was known to have three major forage fish species during 1976–1983, in rank order: emerald shiner (*Notropis atherinoides*), yellow perch (*Perca flavescens*) and cisco (*Coregonus artedii*) (Kristofferson, 1985). Standardized sampling on the lake since 2002 has shown that this region is currently dominated by emerald shiner and to a lesser extent by cisco, whereas the community in the North Basin is predominantly rainbow smelt, with fewer cisco and emerald shiner (Lumb et al., 2010).

The goal of this study (2008–09) was to provide the first insight into the diet of rainbow smelt in the North Basin. To do this, we simultaneously quantified the stomach contents of smelt and characterized the zooplankton community in the North Basin of Lake Winnipeg in the summer. Based on previous studies, we predicted that smelt would consume larger prey (e.g. *Daphnia* spp.) relative to other available prey. Describing the diet of this non-indigenous species is a first important step in our understanding of its potential impact on food web interactions in this large, unique, economically important lake.

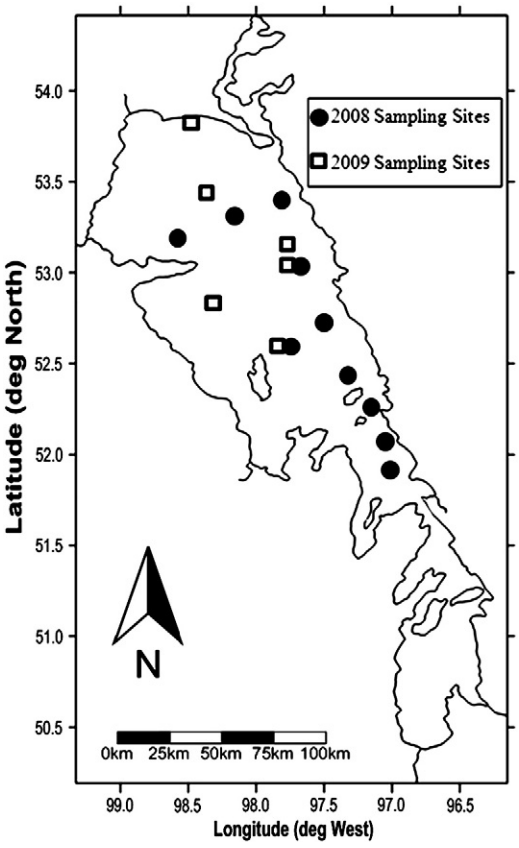

Fig. 1. Map of Lake Winnipeg showing zooplankton and rainbow smelt sample sites in 2008 (black circles, $n = 10$) and 2009 (white boxes, $n = 6$).

Materials and methods

Field collection

Rainbow smelt from the North Basin of Lake Winnipeg were collected by Manitoba Water Stewardship, Fisheries Branch by trawling from the M.V. *Namao* during the summer surveys of 2008 (July 22–28) and 2009 (July 25–31). Trawls were conducted at pre-determined stations (2008: $n = 19$; 2009: $n = 30$) distributed throughout the lake (mean station depth—2008: 13.99 ± 2.85 m; 2009: 15.15 ± 3.15 m; Fig. 1). Trawling occurred at one of three randomly assigned relative depths (surface, middle or deep) by towing a 3 m beam trawl with 6 mm mesh size at the cod-end for 30 minutes. At each station, the net was hauled on board and the catch sorted by species. In 2008 and 2009, one subsample of 30 rainbow smelt between 70–130 mm was collected per station. Thirty fish were collected to ensure a minimum of 10 full stomachs for gut content analysis, as with previous planktivore diet studies (Darbyson et al., 2003; Parker Stetter et al., 2005). The entire digestive tract of each individual was immediately excised and placed in a 20 mL vial half-filled with 70% ethanol. This halted digestion and preserved the ingested organisms to facilitate later identification and quantification in the laboratory.

The zooplankton (i.e. prey) community was sampled at every trawl station where smelt were collected to quantitatively compare the prey community composition in the water column with prey composition of smelt guts. A Wisconsin zooplankton net with a mesh size of 73 μm and a diameter of 25 cm was hauled at a speed of 0.2 m/s from 1 m above the sediment to the surface. Each zooplankton sample was placed in a 125 mL container and preserved with 70% ethanol as per gut contents. Vertically integrated tows pooled the zooplankton community from the entire water column. This shallow lake does not typically stratify during the summer (Hann et al., 2005), suggesting that the zooplankton community is well-mixed vertically. This, together with the ability of smelt to move, and potentially feed, throughout the water column, suggests that vertically pooled zooplankton samples are representative of the prey available to the sampled rainbow smelt (Appenzeller and Leggett, 1995; Alajärvi and Horppila, 2004).

Laboratory analysis

Zooplankton samples

Using a dissecting microscope at 10× magnification, the zooplankton community was classified into four prey types: copepods (which included cyclopoids, calanoids, nauplius larvae and copepodids), *Eubosmina coregoni*, *Bosmina longirostris* and *Daphnia* spp. (which included *Daphnia mendotae*, *Daphnia retrocurva* and *Daphnia longiremis*). Each zooplankton sample was thoroughly mixed and a subsample taken by removing a measured aliquot and placing it in a square petri dish. The mean density of each prey type in the water column was determined as follows: the number of individuals of each prey type in a sub-sample was counted and divided by the sub-sample volume and multiplied by the total volume of the sample. This provided an estimate of the total number of individuals within the sample. This value was then divided by the volume of water that was filtered through the Wisconsin net, determined by multiplying the sample depth by the area of the mouth of the net (0.049 m^2), resulting in the density of individuals in the water column (individuals/L).

Zooplankton length was measured using a digitizing tablet and microscope equipped with a *camera lucida*. Copepods were measured from the most anterior point on the cephalosome, medial to the eyespot, to the end of the abdomen. *Daphnia* spp. were measured from the middle of the compound eye to the base of the caudal spine. *Eubosmina* and *Bosmina* were measured from a point on the head shield, anterior to the eye, to the base of the mucrone.

To establish mean sizes of each prey type, the first 100 intact individuals of each prey type from three stations with the highest zooplankton densities in 2008 were measured. A subsample of 50