Journal of Great Lakes Research xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Diet and relative weight in migratory walleye (*Sander vitreus*) of the Bay of Quinte and eastern Lake Ontario, 1992–2015

James A. Hoyle *, Jeremy P. Holden, Michael J. Yuille

Ontario Ministry of Natural Resources and Forestry, Lake Ontario Management Unit, Glenora Fisheries Station 41 Hatchery Lane, Picton, Ontario K0K 2T0, Canada

ARTICLE INFO

Article history:
Received 18 August 2016
7 December 2016
Accepted 14 January 2017
Available online xxxx

Keywords:
Walleye
Alewife
Bay of Quinte
Lake Ontario
Diet
Relative weight (*Wr*)
Migration

ABSTRACT

Diet and relative weight were examined for Bay of Quinte-eastern Lake Ontario walleye (*Sander vitreum*) from 1992 to 2015. After spawning in the Bay of Quinte, mature walleye migrate to eastern Lake Ontario to spend the late-spring and summer; immature walleye remain in the Bay of Quinte year-round. Summer walleye diet was dominated by alewife which made up one-half the diet in the Bay of Quinte and nearly the entire diet in eastern Lake Ontario. The Bay of Quinte walleye diet was more diverse than that for Lake Ontario, particularly in the post-goby (round goby, *Neogobius melanostomus*) time-period. In addition to alewife, the Bay of Quinte walleye diet included yellow perch (*Perca flavescens*), white perch (*Morone americana*), gizzard shad (*Dorosoma cepedianum*), and johnny darter (*Etheostoma nigrum*). Goby appeared in the walleye diet in 2003, and thereafter made up an average frequency of occurrence (FO) of 18%. Focusing on the large, migratory walleye and their alewife prey in eastern Lake Ontario, we found significant positive relationships among walleye relative weight (*Wr*), the size of alewife in the walleye diet, various measures of alewife prey availability, and spring water temperature. Based on the high prevalence of alewife in the walleye diet, we concluded that walleye migration to Lake Ontario and the availability of alewife present there is key to maintaining a large and productive Bay of Quinte walleye population.

Introduction

The walleye (*Sander vitreus*) is the dominant piscivorous fish in the Bay of Quinte (Hoyle et al., 2012) and throughout eastern Lake Ontario's nearshore waters (Hoyle, 2015). As such, walleye exert a strong top-down influence on fish community and aquatic ecosystem structure (Hurley and Christie, 1977; Hurley, 1986a; Ridgway et al., 1990; Bowlby et al., 1991). Bay of Quinte and eastern Lake Ontario (Fig. 1) walleye support important recreational, commercial, and First Nations fisheries whose collective harvest ranged from 75,000 to 200,000 fish from 1984 to 2000 (Morrison and LaPan, 2007). Other, much smaller, populations of walleye are associated with the larger tributaries and embayments of Lake Ontario (Hoyle et al., 2007).

The Bay of Quinte and eastern Lake Ontario walleye are highly migratory and largely one genetic stock (Wilson and Mathers, 2003). Walleye spawn during April along the shoreline and in the major rivers of the Bay of Quinte. Juvenile walleye (mostly less than age-5 years old) inhabit the Bay of Quinte year-round. Soon after spawning, adult walleye, unlike other Bay of Quinte piscivores, migrate to the lower Bay of Quinte and eastern Lake Ontario where they reside during summer (Payne, 1963; Hurley, 1986a). The annual migration pattern is thought to be related to avoiding warm temperatures in the upper Bay of Quinte, foraging on abundant alewife (*Alosa pseudoharengus*) prey in the lower bay and eastern Lake Ontario during summer, and returning to the Bay of Quinte in the fall to prey on young-of-the-year fishes such as gizzard shad (*Dorosoma cepedianum*) (Bowlby and Hoyle, 2011). A similar migration pattern to capitalize on seasonally available prey was observed for western basin Lake Erie walleye (Wang et al., 2007).

Predator-prey interactions and our understanding of them are considered critical to restore (Hurley, 1986b) and maintain (Hoyle et al., 2012) healthy ecosystem function in the Bay of Quinte. Our objective in this paper was to add to the understanding of these predator-prey interactions, especially walleye (predator)-alewife (prey) interactions. Specifically, we updated and summarized long-term walleye diets in the Bay of Quinte and eastern Lake Ontario and examined annual variation and trends in walleye relative weight (*Wr*) using an equation developed for walleye by Murphy et al. (1990). *Wr* is a commonly used measure of fish health and well-being (Blackwell et al., 2000) and has been correlated with prey availability in other aquatic systems (Rennie and Verdon, 2008; Liao et al., 1995). In particular, we focused on walleye-alewife relationships in eastern Lake Ontario because a significant component of the Bay of Quinte walleye population's production may come from feeding and growth during summer in the lake,

* Corresponding author.
E-mail address: jim.hoyle@ontario.ca (J.A. Hoyle).

http://dx.doi.org/10.1016/j.jglr.2017.01.013

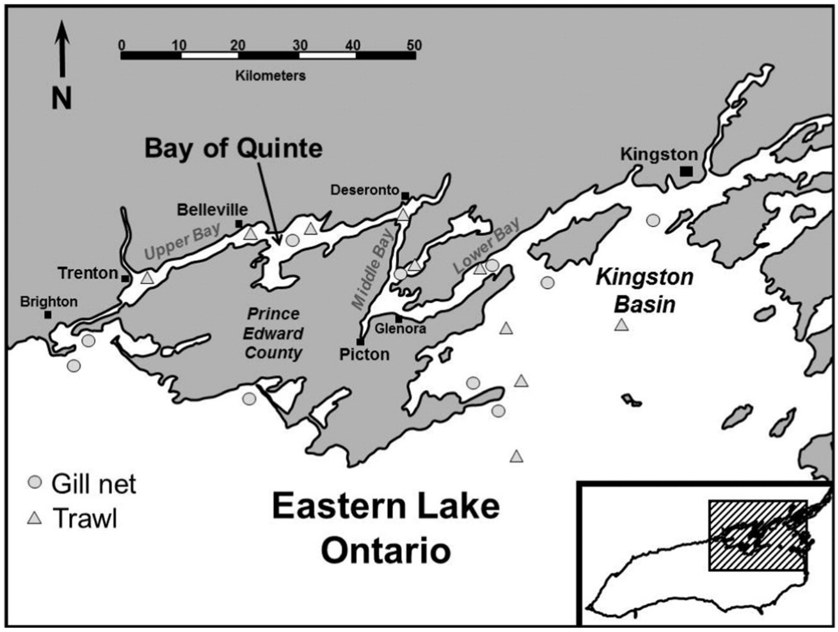

Fig. 1. Map of northeastern Lake Ontario showing gill net (circles) and bottom trawl (triangles) locations in the Bay of Quinte and eastern Lake Ontario from which walleye and alewife samples were collected (see text for details).

and these relationships have not previously been examined in detail. We hypothesized that variation in walleye *Wr* would be related to the availability of alewife prey.

Methods

Study area and fish sampling

In this study, we draw upon data collected during the intensive, fish community sampling conducted by the Ontario Ministry of Natural Resources and Forestry in the Bay of Quinte and eastern Lake Ontario (gill nets and bottom trawls) from 1992 to 2015 (Fig. 1). The Bay of Quinte is a long (64 km), narrow and productive embayment extending from Trenton in the west to Kingston and the Kingston Basin of eastern Lake Ontario in the east (Fig. 1). The Trent, Moira, Salmon and Napanee Rivers and numerous smaller warm-water tributaries enter the bay. Physical and biological gradients span shallow and eutrophic conditions in the upper bay and deep and mesotrophic conditions in the lower bay near Lake Ontario. Fish movements are unrestricted in and out of the bay and include annual spawning migrations of walleye, alewife, and lake whitefish (*Coregonus clupeaformis*). In the context of the present study, eastern Lake Ontario encompasses Canadian waters west of Brighton, south and east around Prince Edward County, and the Kingston Basin to the mouth of the St. Lawrence River (Fig. 1). This area, and the contiguous Bay of Quinte, historically produced the highest fish yields of the entire lake, supporting important commercial and recreational fisheries. The area's high productivity relates to the relatively shallow depths and high degree of shoreline irregularity (Christie et al., 1987).

Details of the field sampling protocols for the long-term annual sampling were recently described by Hoyle et al. (2012) for gill netting and bottom trawling in the Bay of Quinte and Hoyle (2015) for eastern Lake Ontario gill netting. Briefly, gill nets consisted of a graded series of mesh sizes measuring from 38 to 152 mm (stretched mesh measure) in 13 mm increments for a total of 10 panels in a single gill net gang. Each panel was 15.2 m in length except for the smallest mesh size (38 mm) which was either 4.6 (eastern Lake Ontario gill nets) or 15.2 m (Bay of Quinte gill nets). Gill net set duration ranged from 18 to 24 h. Bay of Quinte trawling was conducted using a ¾ Western bottom trawl with a 13 mm mesh cod-end. Trawl duration was 6 min, covering approximately 400 m linear distance. Eastern Lake Ontario bottom trawling was conducted using a Yankee trawl with a 13 mm cod end, towed for 12 min and covering a distance of about 800 m. Here, our analyses are restricted to the summer months (July and August for Bay of Quinte gill nets, August and September for Bay of Quinte trawls, and late-June through early August for eastern Lake Ontario gill nets and bottom trawls) from 1992 to 2015.

All fish were routinely processed within a day of capture. Biological information collected on walleye included length (mm), weight (g), sex and state of maturity, age (otoliths and scales collected), and diet. Routinely, fork length (FL) was measured but occasionally total length (TL) was also measured to develop a FL to TL conversion equation as follows: walleye TL (mm) $= 1.0385 * \mathrm{FL}$ (mm) $+ 8.9142$ ($n = 252$; $r = 0.999$; $p < 0.001$). Age determination methodology varied by walleye size. Generally, walleye <150 mm fork length were classified as young of the year. Age of some walleye between 140 and 250 mm was interpreted by examining walleye scale impressions on acetate slides under a dissecting microscope. Age was interpreted for all other walleye using otoliths. Otoliths were mounted in epoxy, thinly cross-sectioned through the origin and examined under a dissecting microscope. Diet information included total stomach contents weight, individual prey species identification and counts, and individual prey TL for intact fish prey. We employed a rapid assessment approach to our diet sampling. Walleye stomach contents were visually inspected and processed at the same time as other biological attributes were collected. This approach facilitated the sampling of maximum numbers of walleye and their stomachs because no attempt was made to identify significantly digested prey items (for example, from the shape of bony structures); however, this resulted in large numbers of unidentified prey fish remains. Our working assumption was that the proportion of each identified fish prey type was the same as that for unidentified fish prey types.

For eastern Lake Ontario gill nets and bottom trawls, alewife were counted and weighed in bulk for each net. Either all alewife or a random sub-sample of approximately 200 fish in each catch were routinely measured for FL or occasionally for TL to develop a FL to TL conversion equation as follows: alewife TL (mm) $= 1.183 * \mathrm{FL}$ (mm) $- 3.896$ ($n = 909$; $r = 0.995$; $p < 0.001$). For bottom trawls only, individual alewife lengths and weights were taken for a random sample of fish.

Please cite this article as: Hoyle, J.A., et al., Diet and relative weight in migratory walleye (*Sander vitreus*) of the Bay of Quinte and eastern Lake Ontario, 1992–2015, J. Great Lakes Res. (2017), http://dx.doi.org/10.1016/j.jglr.2017.01.013