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Dry-weight energy density of prey fishes from nearshore waters of the upper Niagara River and Buffalo Harbor, New York

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ABSTRACT

Energy density of prey fishes can affect the survival, growth, and fitness of piscivorous fishes, and these vital rates may change – for better or worse – after fish communities are altered by the establishment of new species. Invasive round goby (*Neogobius melanostomus*) and rudd (*Scardinius erythrophthalmus*) are highly abundant in the upper Niagara River and Buffalo Harbor and serve as alternative food for piscivores. However, there is a paucity of information on the energy density of native and invasive prey fishes in these waters. To better understand the energy density of available prey fishes in nearshore areas of the upper Niagara River and Buffalo Harbor, we compared the energy densities of: (1) native fishes and invasive fishes, (2) age-0 and yearling-and-older conspecific fishes, and (3) upper Niagara River and Buffalo Harbor conspecific fishes. Fishes were collected from New York waters of the upper Niagara River and Buffalo Harbor during early August through mid-September 2013. We combusted fishes in a bomb calorimeter to determine dry-weight energy densities (J/g) for two invasive and eight native species. Energy densities were dependent on an interaction between fish species and age group, and did not differ between the upper Niagara River and Buffalo Harbor. Yearling-and-older spottail shiner (*Notropis hudsonius*) had a significantly higher energy density than all other species examined and was the only species with a significant difference in energy density between age classes. Rudd had an energy density similar to most native fishes; and, although not significantly lower, round goby energy density was lower than most native fishes. Our energy density estimates can be used to better understand mechanisms affecting growth and condition of piscivorous fishes in the upper Niagara River and Buffalo Harbor.

Introduction

The survival, growth, and fitness of piscivorous fishes is in part dependent on the abundance, quality, and accessibility of prey fishes (Bryan et al., 1996). Energy density is one aspect of prey fish quality and is frequently used in bioenergetics models to better understand the contribution of specific prey fishes to the energy budget of predatory fishes. Species, reproductive status, geographic location, season, size, and age of prey fishes may vary, and result in differing levels of prey fish quality (Bryan et al., 1996; Glover et al., 2010). Also, additions of invasive fishes into receptor habitats can disrupt trophic interactions, thereby altering native prey fish population characteristics and energy content of native prey (Kornis et al., 2012).

The round goby (*Neogobius melanostomus*) is a pervasive aquatic invasive species in the Great Lakes and has reached high abundances in many locations (Chotkowski and Marsden, 1999; Johnson et al., 2005a; Ray and Corkum, 2001). Round goby are vectors for transfer of contaminants and disease (Dietrich et al., 2006; Kornis et al., 2012), displace native prey fishes (Janssen and Jude, 2001), restructure energy pathways, and have become an important food source for many Great Lakes fishes (Crane and Einhouse, 2016; Dietrich et al., 2006; Hensler et al., 2008; Johnson et al., 2005a). In some locations, round goby may serve as an alternative food source, while in other locations round goby have replaced native benthic prey fishes. For example, localized declines or extirpations of mottled sculpin (*Cottus bairdii*; Hares et al., 2015; Janssen and Jude, 2001; Lauer et al., 2004), johnny darter (*Etheostoma nigrum*; Lauer et al., 2004), and tessellated darter (*Etheostoma olmstedi*; J. M. Farrell, SUNY-ESF, unpublished data) in the Great Lakes corresponded with invasion of round goby.

The distribution of rudd (*Scardinius erythrophthalmus*) is more limited in the Great Lakes compared to round goby (U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, Florida, accessed 5/23/2016, available at: http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=648), and the importance of rudd as a food source for native fishes has garnered little attention. However, rudd are highly abundant in the upper Niagara River and Buffalo Harbor. Kapuscinski et al. (2015) estimated a biomass of 100.21 mt (0.022 mt/ha) of rudd in the upper

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Niagara River and 1.89 mt (0.004 mt/ha) in Buffalo Harbor. Due to their abundance in the upper Niagara River and Buffalo Harbor, rudd may be an important food source for native fishes. In their native environments in Europe and Asia, rudd are consumed by northern pike (*Esox lucius;* Eklöv and Hamrin, 1989), which are also present in the upper Niagara River and Buffalo Harbor.

Energy density data for nearshore prey fishes in the Great Lakes are lacking compared to pelagic prey fishes such as alewife (*Alosa pseudoharengus*). Studies comparing energy density among different age groups of prey fishes are also lacking, despite surveys of Great Lakes prey fishes commonly classifying fish as age-0 or yearling-and-older (YAO). Energy density of round goby was quantified for Lake Erie (Johnson et al., 2005a) and a tributary of Lake Michigan (Ruetz et al., 2009), but energy density estimates for a North American population of rudd are non-existent. To better understand the quality of available prey in nearshore areas of the upper Niagara River and Buffalo Harbor, we compared the energy densities of (1) native fishes and invasive fishes, (2) age-0 and YAO conspecific fishes, and (3) upper Niagara River and Buffalo Harbor conspecific fishes.

Methods

Field collection

Prey fishes were collected with seines and by electrofishing during early August through mid-September 2013 in nearshore areas of the upper Niagara River and Buffalo Harbor, Lake Erie. Two invasive species (rudd and round goby) and eight native species were collected (Table 1). Target fish species were selected based on their relative abundance in annual index sampling of nearshore fish communities in the upper Niagara River and Buffalo Harbor (7 years). All fishes were classified as age-0 or YAO upon capture based on species-specific literature values for total lengths of age-0 fishes. When literature values were not available, age-0 and YAO were distinguished based on obvious differences in size classes. The age-0 and YAO age classification system was used because it is the most common forage fish classification method used in the Great Lakes (Bunnell et al., 2013; Lake Erie Forage Task Group, 2013). We are confident that we were able to correctly assign fishes to these two age groups because we intensively seined the upper Niagara River and Buffalo Harbor throughout the summer of 2013 and observed growth of age-0 fishes beginning with the larval stage. Upon capture, fishes were sorted by species and age group, and then immediately placed in a bag of water on ice to minimize water loss (Hartman and Brandt, 1995). Fishes were frozen in water at −20 °C until processing for combustion in a bomb calorimeter (Hartman and Brandt, 1995). All samples were processed within two months of collection.

Lab procedure

Prior to combustion, fishes were thawed in tubs of cool water. Upon thawing, total length was measured for all YAO fish using digital calipers to the nearest mm and wet-weight was measured to the nearest 0.0001 g after patting fish dry. To eliminate the potential for affecting energy density estimates by handling and damaging fragile age-0 fishes, we measured individual total length and wet-weight for a sub-sample of 60–75 age-0 fishes (for each species and location) that were not used to estimate energy densities. Because at least 1 g of dry-weight fish tissue was needed for combustion in the bomb calorimeter and we wanted at least three sub-samples available for each species, water body, and age-specific replicate we used at least 30 g (wet-weight) of fish for each replicate. If an individual did not weigh >30 g, multiple individuals were pooled to obtain 30 g wet-weight samples (Table 1). Wet-weight was recorded to the nearest 0.0001 g for each sample (Ruetz et al., 2009; Table 1). After measuring wet-weight, samples were dried at 70 °C in an oven (Lantry and O'Gorman, 2007) and a final dry-weight was recorded after a mass of ±0.01 g was maintained for two consecutive days (Glover et al., 2010). After drying, samples were homogenized using a coffee grinder. If the dry-weight of a sample did not exceed 3 g, multiple individuals were combined to ensure that three 1 g sub-samples were available to combust in the bomb calorimeter for each biological replicate. Homogenized samples were returned to the oven for a minimum of 1 h to dry to a constant weight (Rand et al., 1994) and then allowed to cool for a minimum of 30 min in a desiccator.

After cooling, about 1 g of homogenized fish tissue was weighed to the nearest 0.0001 g and immediately combusted in a Parr 1356 isoperibol bomb calorimeter (Parr Instrument Co., Moline, IL) to estimate dry-weight energy densities (J/g). Two sub-samples of each biological replicate were combusted, and a third sub-sample was combusted if the gross heat of the first two samples differed by >3% of the minimum value (Tirelli et al., 2006). Three sub-samples were required for 4 of 188 samples and the maximum difference between sub-samples was 5.2% (age-0 yellow perch collected in the Buffalo Harbor). A fuse wire correction was applied to the gross energy of each sub-sample (Parr Instrument Co., 1999; Glover et al., 2010). Estimates for sub-samples were averaged in order to estimate the energy density of each biological replicate, and these energy density estimates were used in all statistical tests. The calorimeter was tested using a benzoic acid standard about every 20 runs throughout the duration of the study. Because all gross heat estimates were within ±0.3% of the

Table 1

Descriptive statistics for fishes used in energy density analyses of yearling-and-older (YAO) and age-0 nearshore fishes from the upper Niagara River (UNR) and Buffalo Harbor (BH). Fishes were collected during August and September 2013.

Common name	Scientific name	Age group	Collection location	*n*	Mean *n* of fish per sample	Mean length ± SD (mm)	Mean dry weight ± SD (g)	Mean wet weight ± SD (g)	Mean dry-weight energy density ± SD (J/g)	Mean wet-weight energy density ± SD (J/g)
Banded killifish	*Fundulus diaphanous*	YAO	BH, UNR	10	5	60 ± 14	0.53 ± 0.38	2.5 ± 1.6	20,514 ± 780	4495 ± 284
		Age-0	UNR	5	115	31 ± 4	0.05 ± 0.01	0.3 ± 0.1	20,782 ± 147	3328 ± 232
Bluntnose minnow	*Pimephales notatus*	YAO	BH, UNR	10	8	58 ± 10	0.46 ± 0.39	2.1 ± 1.5	22,955 ± 1042	5117 ± 788
		Age-0	BH, UNR	9	94	33 ± 6	0.06 ± 0.02	0.4 ± 0.2	21,353 ± 631	3258 ± 263
Emerald shiner	*Notropis atherinoides*	YAO	UNR	5	11	65 ± 7	0.36 ± 0.13	1.8 ± 0.5	22,596 ± 426	4368 ± 451
Largemouth bass	*Micropterus salmoides*	Age-0	BH, UNR	10	16	55 ± 11	0.38 ± 0.12	2.3 ± 1.3	20,636 ± 701	3582 ± 106
Lepomis spp.	*Lepomis spp.*	Age-0	UNR	5	87	31 ± 4	0.07 ± 0.04	0.5 ± 0.2	21,072 ± 283	3318 ± 453
Rock bass	*Ambloplites rupestris*	Age-0	UNR	5	60	30 ± 5	0.09 ± 0.02	0.6 ± 0.3	22,219 ± 392	3929 ± 355
Round goby	*Neogobius melanostomus*	YAO	BH, UNR	10	4	71 ± 9	1.2 ± 0.60	5.5 ± 2.8	20,713 ± 711	4527 ± 264
		Age-0	BH, UNR	9	63	39 ± 9	0.15 ± 0.11	0.9 ± 0.6	20,314 ± 384	3493 ± 326
Rudd	*Scardinius erythrophthalmus*	YAO	UNR	20	1	154 ± 45	21 ± 31	77 ± 107	22,394 ± 1177	5799 ± 648
		Age-0	UNR	5	41	44 ± 8	0.18 ± 0.08	1.0 ± 0.5	21,234 ± 462	3771 ± 359
Spottail shiner	*Notropis hudsonius*	YAO	UNR	5	2	104 ± 8	3.4 ± 0.86	12 ± 3.0	25,823 ± 406	7307 ± 251
		Age-0	UNR	5	61	39 ± 5	0.08 ± 0.02	0.6 ± 0.2	20,594 ± 212	3043 ± 176
Yellow perch	*Perca flavescens*	Age-0	BH	5	11	66 ± 5	0.61 ± 0.12	2.9 ± 0.7	20,938 ± 307	4389 ± 178