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Asian Carp in the Diet of River Otters in Illinois

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NOTES AND DISCUSSION

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ABSTRACT. — Populations of invasive silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*), collectively known as "Asian carp," are growing rapidly in Illinois and may make up a large fraction of available prey for river otters (*Lontra canadensis*) in larger waterbodies. Our goals were to assess the frequency of Asian carp in otter diets and compare the frequency of occurrence of prey groups (fish, crayfish, and amphibians) in otter diets between land cover types and seasons. We searched for Asian carp otoliths and pharyngeal teeth, as well as parts of other fishes, crayfish, and amphibians in 155 otter scats collected from 43 stream sites in central and southern Illinois during January–April 2013 and 2014. Consistent with previous studies, fish and crayfish were primary prey items for otters, followed by amphibians. Frequency of occurrence of crayfish increased from January–February to March–April, but frequency of occurrence of the other prey types remained similar between those periods. Land cover type did not seem to influence frequency of occurrence of prey types. Asian carp pharyngeal teeth and otoliths occurred in four (2.6%) scat samples, two from sites were Asian carp were not previously confirmed to be present. This is the first direct confirmation of Asian carp in the diet of wild river otters. Otoliths and pharyngeal teeth provided effective structures for identifying fish species in otter diet.

INTRODUCTION

North American river otters (*Lontra canadensis*; hereafter, otters) are opportunistic aquatic predators that primarily consume fish, followed by crayfish and then amphibians (Lagler and Ostenson, 1942; Greer, 1955; Knudsen and Hale, 1968; Swimley *et al.*, 1998; Stearns and Serfass, 2005; Crait and Ben-David, 2006; Barding and Lacki, 2012). Fish are consumed in the greatest proportion during winter (Stearns and Serfass, 2005; Crait and Ben-David, 2006; Crimmins *et al*., 2009; Barding and Lacki, 2012). Fish families typically identified in the scat and gut contents of otters include centrarchids, cyprinids, and catostomids (Lagler and Ostenson, 1942; Stearns and Serfass, 2005; Crait and Ben-David, 2006; Barding and Lacki, 2012). Centrarchids have appeared in 11–36% of otter scats and cyprinids have appeared in 11–86% of otter scats (Lagler and Ostenson, 1942; Stearns and Serfass, 2005; Wengeler *et al*., 2010; Barding and Lacki, 2012). Crayfish, where readily available, typically are consumed in greater proportion than fish during summer (Route and Peterson, 1988; Roberts *et al*., 2008). However, crayfish are composed of a greater proportion of hard parts than other prey items, so the dietary predominance of crayfish can be overestimated by scat analysis (Cottrell *et al*., 1996; Tollit *et al*., 1997; Marcus *et al*., 1998; van Dijk *et al*., 2007).

Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*), often recognized as "Asian carp," have become abundant in many Illinois waterbodies (Chick and Pegg, 2001; McClelland *et al*., 2012) and may influence available prey resources for otters. The effect of Asian carp on native fish and plankton communities are subjects of intense study, particularly in the Mississippi River basin (Williamson, 2004; Kolar *et al*., 2007; Sampson *et al*., 2009; Chapman and Hoff, 2011). Despite the many diet studies of otters, no published studies confirm otters consume Asian carp outside of aquaculture ponds (Lanszki *et al*., 2001; Lanszki and Molnár, 2003; Kortan *et al*., 2007). Additionally, most diet studies in North America occurred before Asian carp arrived or occurred in areas without Asian carp (Ryder, 1955; Knudsen and Hale, 1968; Chabreck *et al*., 1982; Roberts *et al*., 2008; Crimmins *et al*., 2009; Barding and Lacki, 2012). Determining the extent to which otters prey on Asian carp is crucial to further understanding the influence these invasive species have on otters and vice versa.

Our primary objective was to estimate the presence of Asian carp in the diet of otters using scat analysis. We used frequency of occurrence to compare scat collected from waterbodies with Asian carp present to waterbodies with Asian carp absent and predicted otters would consume Asian carp when present. We also compared the difference in diet between seasons and land cover types and predicted there would be seasonal differences in the diet for crayfish and amphibians but no difference in the diet between land cover types.

METHODS

We analyzed otter scat collected along waterbodies throughout central and southern Illinois (Fig. 1). Sign surveys for river otters were conducted at 120 bridge sites, selected from the Illinois Department of Natural Resources and Illinois Environmental Protection Agency stream database (A. M. Holtrop, Illinois Department of Natural Resources, pers.comm.). The sites captured a diverse array of freshwater habitats both with and without Asian carp present. Nineteen percent (n = 23) of sites occurred at 1–3 order headwater streams, 72% (n = 86) at 4–6 order streams, and 9% (n = 11) of sites at larger rivers such as the Saline, Little Wabash, Big Muddy, and Cache rivers. Thirty-nine percent (n = 47) of sites occurred in agriculturally dominated landscapes (>70% agriculture land cover), and remaining sites were located in forest (27.5%, n = 33), urban (2.5%, n = 3), and other cover types (31%, n = 37) (Luman *et al*., 1996).

Otter scats were collected opportunistically along 400 m and 800 m stream transects, which began at road bridges, during January–April 2013 and 2014. A team of two technicians visited each site four times per season. The scat was stored in a Whirl-Pak bag, placed on ice as soon as possible in the field, and stored at –20 C (Mowry *et al*., 2011; Barding and Lacki, 2012). We dried the scat samples at 60 C for 48 h and then sifted the scat using a no. 18 (1.00 mm) long-handled sieve (Mowry *et al*., 2011; Barding and Lacki, 2012).

We recorded the presence of fish by identifying scales, otoliths, and pharyngeal teeth in the sample. We acknowledge that this approach is may miss scaleless fishes, but expect any resulting bias to be similar across seasons and landcover types. Crayfish were identified by their exoskeleton. Herptiles (which we presumed to be amphibians on the basis of their importance in prior studies of otter diet) have more robust bones than fish and were discerned from small mammals by a lack of hair found in the scat sample. Prey types were identified using reference collections, taxonomic keys (Duellman and Trueb, 1986; Daniels, 1996), and photo references.

We examined scats for presence of Asian carp otoliths and pharyngeal teeth and calculated their percentage occurrence in the otter's diet. Fish otoliths and pharyngeal teeth have commonly been used as identifying structures in earlier studies of otter diets(Greer, 1955; Trites and Joy, 2005; Cote *et al*., 2008a; Wengeler *et al*., 2010). Ruiz-Olmo *et al*. (1998) found European otters (*Lutra lutra*) prefer to begin fish consumption by eating the heads, but heads from larger fish (>30 cm) were less frequently consumed. We used physical references of Asian carp sagittal and lapilli otoliths and pharyngeal teeth in addition to photo references. It is not possible to visually distinguish silver carp from bighead carp by examining their otoliths. However, silver carp have fine horizontal striations on the interior side of their pharyngeal teeth, whereas bighead carp teeth are smooth (Chu, 1935; Yokote, 1956; Spataru *et al*., 1983). Fish scales were used in previous diet studies to differentiate species (Knudsen and Hale, 1968; Crait and Ben-David, 2006; Barding and Lacki, 2012). However, differentiating Asian carp from other cyprinids, especially juveniles, using visual scale identification is difficult and therefore not attempted in this study.

To categorize Asian carp presence at the survey sites, we compiled all fish sampling data from Illinois Department of Natural Resources for the stream sites where scat was collected and also referenced the online state stream database (http://dnr.illinois.gov/IBICalculation/Select SamplesForm.aspx, accessed 02 Aug 2014). Geographic Information Systems (GIS) was used to map Asian carp distribution because Asian carp were not present at all survey sites. We determined the occurrence of Asian carp in otter scat collected from sites with Asian carp present (Fig. 1).

We used 2 x 2 contingency tables and Fisher's exact test to compare the frequency of occurrence of each prey type (fish, crayfish, and amphibians) in otter diet between late winter and early spring seasons (January–February, March–April). Given the average temperature from January–February was 3.1 C and from March–April was 10.3 C during the study period (www.wunderground.com, 2015), we predicted consumption of crayfish and amphibians would be higher during March–April than January–February. We used 2 x 3 contingency tables and Fisher's exact test to compare the frequency of occurrence of each prey type in otter diet among three land cover types: forest, agriculture, and mixed. Sites were classified based on dominant land cover type (>50% cover) within a 400 m buffer around the survey location in a GIS. Mixed land cover was defined as not having a dominant land cover type (<50% cover). All statistical tests were considered significant at $P \leq 0.05$ and were conducted with SPSS 19 (IBM Corp., Armonk, NY).

RESULTS

We analyzed 155 otter scat samples from 43 sites: 56 (36.1%) samples from 2013 and 99 (63.9%) samples from 2014. Of these 43 sites, 14 were classified as forested, 15 were agricultural, and 14 had mixed landcover. Forty (25.8%) samples were collected as a solitary spraint and 115 (74.2%) samples were collected from 32 latrines. Asian carp were known to be present in 18 (15%) of the 120 surveyed sites. Otter scat was collected from six of those sites but only one site had otter scat (n = 2) containing Asian carp remains. Evidence of Asian carp was found in otter scat from two additional sites (n = 1 each) where there were no database records of Asian carp being present. Therefore, Asian carp pharyngeal teeth or otoliths occurred in four (2.6%) scat samples.

Fish and crayfish were consumed in the greatest proportion, occurring in 140 (90.3%) and 87 (56.1%) scat samples, respectively. Amphibians occurred in 19 (12.3%) scat samples with 12 (63.2%) of those samples collected during January–February and seven (36.8%) during March–April. We found hair (unknown species) in four (2.6%) scat samples, but the samples did not contain additional evidence of mammal consumption so the hair potentially could be from grooming. We found 220 otoliths in 48 (31.0%) scat samples and pharyngeal teeth in six (3.9%) scat samples from fish other than Asian carp. We found centrarchid otoliths in 26 (16.8%) scat samples.

Frequency of occurrence of amphibians in the scat was similar between seasons (Table 1). However, frequency of occurrence of crayfish increased from January–February to March–April. We found suggestive evidence that frequency of occurrence of fish was higher in January–February than in March–April (Table 1). Frequency of occurrence was similar among land cover types for each prey type (Table 2).

DISCUSSION

We provide the first definitive evidence of North American river otters consuming Asian carp. The lack of Asian carp remains in scat collected from sites with Asian carp present could be the result of a limited number of samples or heads from larger fish (>30 cm) being less frequently consumed (Ruiz-Olmo *et al*., 1998). Also, otters consume prey in relation to abundance (Melquist *et al*., 2003, Kruuk, 2006; Penland and Black, 2009). So, Asian carp abundance could have been low, potentially due to the downstream movement of Asian carp in the winter (Coulter *et al*., 2012), at the sites where we did not find evidence of Asian carp in the scat samples. We found evidence of Asian carp in scat samples from areas with no previous confirmation of Asian carp being present. Monitoring and sampling of Asian carp in Illinois are ongoing because they are prolific dispersers (Sampson *et al*., 2009; Freedman *et al*., 2012). Therefore, discovery of new sites containing Asian carp is not unexpected. Additionally, otters could have been foraging in nearby waterbodies containing Asian carp.

Our findings are consistent with previous studies confirming fish and crayfish as primary prey items of river otters, followed by amphibians (Greer, 1955; Knudsen and Hale, 1968; Serfass *et al*., 1990; Stearns and Serfass, 2005; Barding and Lacki, 2012). The high proportion of fish present in the diet corresponds with previous studies indicating a high reliance on fish as prey during winter (Stearns and Serfass, 2005; Crait and Ben-David, 2006; Crimmins *et al*., 2009; Barding and Lacki, 2012). Frequency of crayfish occurrence increased during March−April. We expected crayfish consumption would increase in the summer potentially due to the increased crayfish availability and possibly a decreased ability of otters to capture fish due to their increased swimming speeds with warmer water temperatures (Erlinge, 1968; Flint, 1977; Wardle, 1980). The frequency of occurrence for amphibians in otter diets did not appear to differ seasonally. Although amphibians typically are more available in warmer months, their proportion in the diet was similar between seasons and with reported frequencies (Ryder, 1955; Knudsen and Hale, 1968; Stearns and Serfass, 2005; Roberts *et al*., 2008). Frequency of occurrence did not differ statistically between seasons for amphibians and fish, although we cannot rule out a biologically significant difference. However, the time frames we set for the seasons were a fairly short range and could have been too short to detect differences in diet.

Furthermore, the difference in proportions of crayfish could be attributed to greater seasonal fluctuations in abundance (Jędrzejewska *et al*., 2001).

Fish species are highly influenced by the surrounding land cover and size of waterbody (Gorman and Karr, 1978; Lammert and Allan, 1999). However, we did not find evidence that land cover types influenced the frequency of occurrence of prey types at the sampled sites. Prey availability seemed to be the primary factor that influenced the diet composition of otters as opposed to different habitats (Kemenes and Nechay, 1990). Jędrzejewska *et al*. (2001) found otter diets depended on habitat types. However, habitat types were defined by waterbody size and type and likely are not comparable to the habitat types we had in this study.

Our study suggests otoliths and pharyngeal teeth enable efficient identification of fish species in otter diet; either in addition to fish scale identification or used solely when searching for a particular species of interest. We found a considerable number of fish otoliths in the otter scat samples. Otoliths are characteristic for many species of fish and can easily be identified (Cote *et al*., 2008a, b; Crimmins *et al*., 2009). Although Asian carp otoliths can be exceptionally small (<2 mm) and difficult to discover in scat, otoliths can be a feasible option for identifying fish species in otter diets (Cote *et al*., 2008b) and can provide ancillary information. For instance, we found centrarchid otoliths in each sample containing Asian carp otoliths, so our scat analysis does not suggest that Asian carp have supplanted other commonly identified prey in otter diets. We suggest future otter dietary studies involving Asian carp use pharyngeal teeth as a distinguishing structure to differentiate silver carp from bighead carp. Asian carp populations are expected to continue to expand and increase in abundance, so future studies also may focus on the effect of the Asian carp invasion on otter diets in other portions of otter range.

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Table 1.— Frequencies of occurrence (%) of prey items for otter (*Lontra canadensis*) scat samples (n = 155) collected in southern Illinois during 2013–14. We used 2 x 2 contingency tables and Fisher's exact test (*df* = 1) to compare prey occurrence between seasons (*a* = 0.05)

	Season				
	January–February (n = 108 scat)		March–April (n = 47 scat)		P-value
Prey items	n with prey	%	n with prey	%	
Fish	101	93.5	39	83.0	0.07
Crayfish	54	50.0	33	70.2	0.02
Amphibian	12	11.1	7	14.9	0.56

Table 2.— Frequencies of occurrence (%) of prey items by land cover types for otter (*Lontra canadensis*) scat samples (n = 155) in southern Illinois during 2013–14. We used 2 x 3 contingency tables and Fisher's exact test (*df* = 2) to compare prey occurrence between land cover types (*a* = 0.05)

	Land cover						
	Forest (n = 47 scat)		Agriculture (n = 51 scat)		Mixed (n = 57 scat)		P-value
Prey items	n with prey	%	n with prey	%	n with prey	%	
Fish	44	93.6	40	78.4	56	98.2	0.11
Crayfish	30	63.8	31	60.8	26	51.0	0.70
Amphibian	9	19.1	4	7.8	6	10.5	0.27

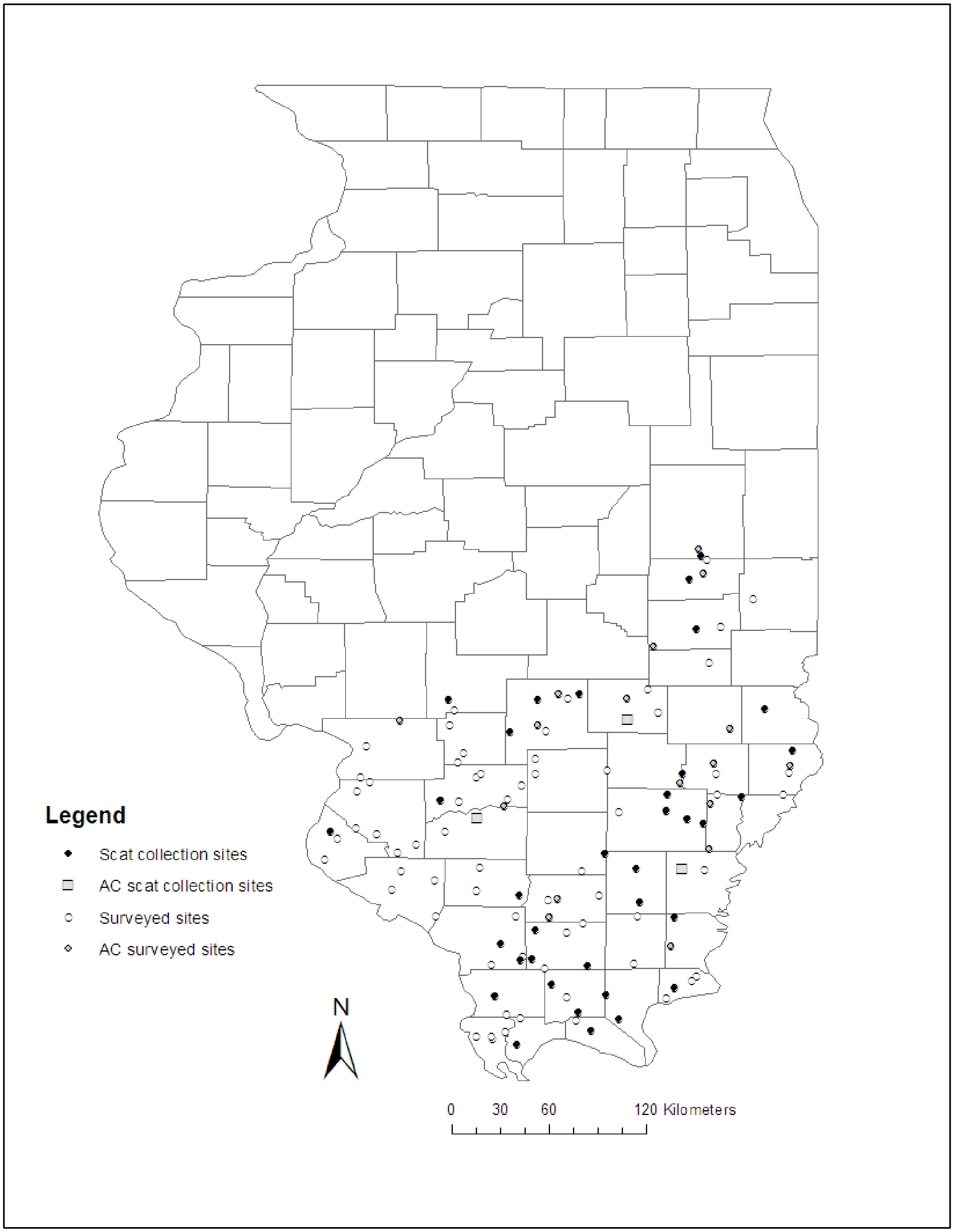

Fig 1.— Otter (*Lontra canadensis*) scat collection sites (n = 43), sites with Asian carp (AC) evidence in the scat (n = 3), total sites surveyed (n = 120), and surveyed sites with Asian carp (AC) present (n = 18) in southern Illinois, January–April 2013–14