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Consumption of New Zealand mudsnail by native benthivorous fishes in the Pere Marquette River, Michigan

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Abstract

New Zealand mudsnails *Potamopyrgus antipodarum* are a relatively new invader (first confirmed observation in 2015) to the state of Michigan. Their density has not yet reached the high levels observed in other newly invaded areas, so we sought to determine the extent to which native benthivorous fishes consume them, potentially limiting population growth, in the Pere Marquette River, Michigan. Based on gut content analysis, we found that Mottled Sculpin *Cottus bairdii* and two sucker species (White Sucker *Catastomus commersonii*, and Shorthead Redhorse *Moxostoma macrolepidotum)* all consumed New Zealand mudsnails, but at relatively low rates. Given the expansion of New Zealand mudsnail in the Pere Marquette River and the low consumption rate, it appears unlikely that these fish exert strong biological control on this invasive species.

INTRODUCTION

New Zealand mudsnails *Potamopyrgus antipodarum*, NZMS hereafter, are invasive to many parts of the world having established populations in Asia, Europe, Australia, and North America (Bowler 1991). Outside of its native range, this species can form very dense populations, reaching more than 500,000 individuals per square meter (Hall et al. 2006). Such high populations have been shown to lead to reductions in other benthic invertebrates (Kerans et al. 2005). Although NZMS have been shown to be consumed by Rainbow Trout *Oncorhynchus mykiss* (Bruce and Moffitt 2010), they have been observed to be able to survive passage through their digestive tract (Vinson and Baker 2008, Bruce et al. 2009), negatively impacting overall fish health (Vinson and Baker 2008). Thus, NZMS are a poor food source for trout, and reductions in other more energetically valuable invertebrates is thought to lead to reductions in the growth and survival of valued game fishes.

The NZMS was found in the Pere Marquette River near Baldwin, Michigan, in 2015 (Tank 2020). Subsequently, they have been found in four other rivers in Michigan, including the Au Sable River, the Manistee River, the Boardman River, and the Pine River (Tank 2020). These rivers support coldwater fisheries and contribute to the ecotourism economy of northern Michigan. Although the density of NZMS has not yet reached the high abundances observed elsewhere, there is concern that they will have a negative impact on these valued stream resources.

Within their native range, the population of NZMS is thought to be limited through parasitism by castrating trematodes that limit their reproductive success (Hechinger 2012, Larson and Krist 2020). Predation by shorebirds (Fredensborg et al. 2006) and waterfowl (Levri and Lively 1996) has been documented, also potentially limiting NZMS populations. Given that the density of NZMS in Michigan rivers has not yet reached densities observed elsewhere, we sought to determine if native predators are potentially limiting their abundance. Based on evidence that NZMS are preyed upon by fish, we wanted to examine whether native benthivorous fishes could serve as a biological control in the Pere Marquette River. White Sucker *Catastomus commersonii* and Shorthead Redhorse *Moxostoma macrolepidotum* (both in family Catastomidae) and Mottled Sculpin *Cottus bairdii* are abundant in these rivers, and we hypothesized that their adaptation to a benthic feeding strategy make them likely candidates for preying on NZMS. Thus, our goal was to determine whether NZMS are present in the diet of these fishes in a natural setting.

MATERIALS AND METHODS

STUDY AREA

Our study focused on the Pere Marquette River, near Baldwin, MI. Qualitative visual surveys were performed at 11 access sites to determine whether a site was infested with NZMS. Sites were located between 43.89463°N, 85.95831°W and 43.86240°N, 85.88072°W (Figure 1). Standardized visual surveys consisted of 20-minute timed searches, involving two individuals searching independently 50 meters upstream and downstream of the designated start point of the site. These surveys have been shown to be highly effective at detecting the presence of NZMS. For more details on the survey methods, please refer to Tank et al. 2021. Fish sampling occurred at three sites with NZMS infestation and two sites outside of the infested area. One site was uninfested at the beginning of our study, but one snail was detected at the end of our sampling period. We considered this site to be uninfested for the purposes of data analysis, due to the timing of detection of this single mudsnail.

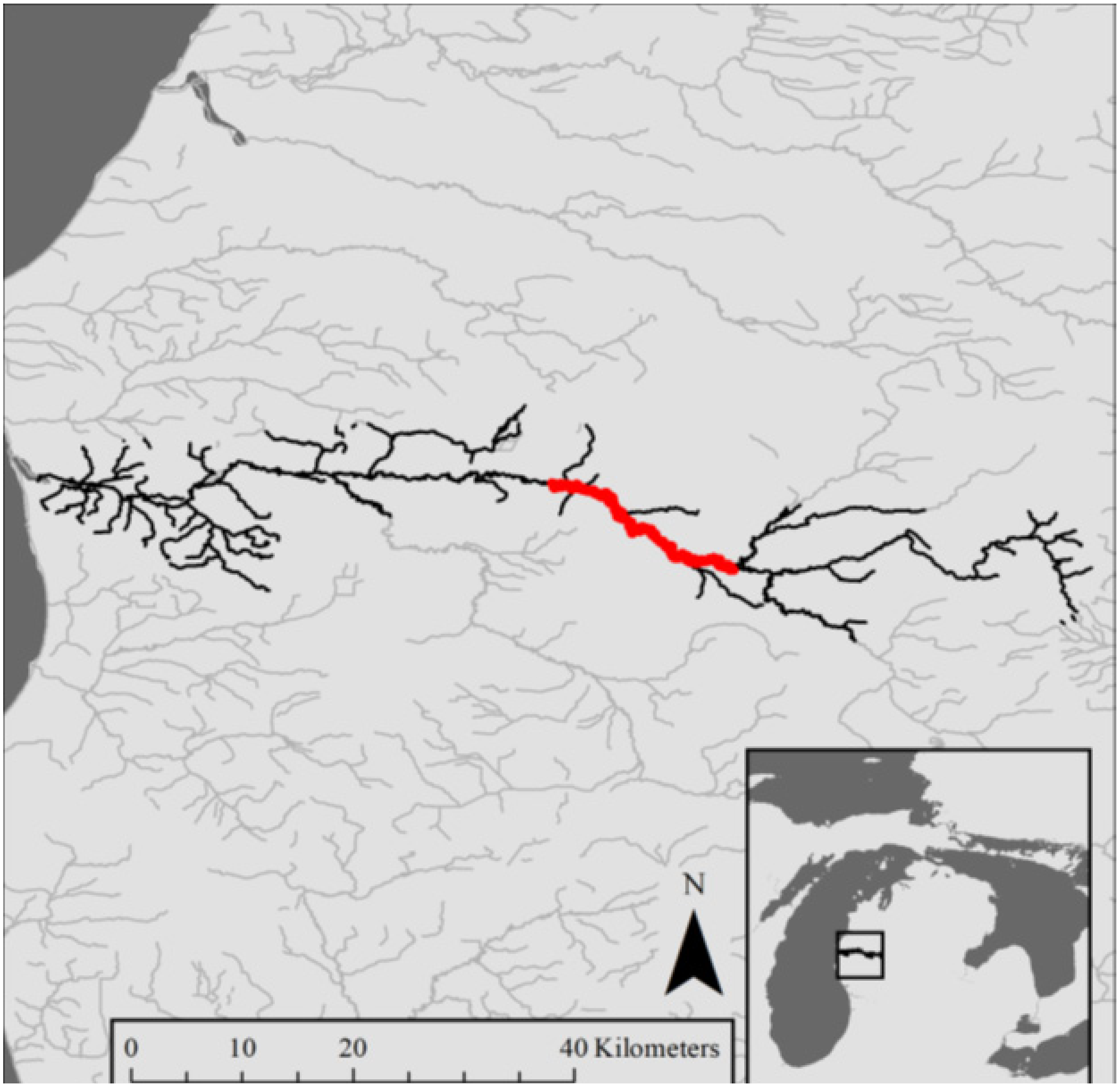

FIGURE 1. Map of the survey range on the Pere Marquette River. Red indicates extent of survey locations.

FISH COLLECTION AND DIET ASSESSMENT

White Sucker and Shorthead Redhorse, hereafter suckers, and Mottled Sculpin, hereafter sculpin, were collected monthly from May to August in 2016 and 2017 with a Smith-Root electrofishing barge. At each site, electrofishing started 50m downstream from the access point and continued until the river was no longer wadable, or our limit of fish was collected for that day. We were permitted to collect nine individuals from each of our fish species group per site in 2016 and up to 25 individuals of each species group per sampling event in 2017. In the field, collected suckers and sculpin appearing less than 250 mm were preserved whole in a 95% ethanol solution whereas, those over 250 mm were measured to the nearest mm and their GI tracts were removed and preserved in 95% ethanol solution. In the laboratory, the whole fish were measured to the nearest mm and their GI tracts were removed. The contents of the

GI tracts were emptied into a dissecting tray containing 95% ethanol solution and each diet item was identified to Order using a dissecting microscope.

DATA ANALYSIS

For each fish sample, we recorded the fish species, the date and location of collection, their total length in mm, and gave each fish a unique identification number. Too few individuals of the sucker species were captured within each sampling event to allow for analysis by individual species. We focused on descriptive statistics (i.e., percent composition by number) for diet composition, and evaluated differences in the mean number of items consumed per fish between infested and uninfested sites and years using a general linear model.

RESULTS

During the study period, we collected a total of 310 fish for diet analysis. We sampled 145 Mottled Sculpin and 97 suckers from sites known to be infested with NZMS and 57 Mottled Sculpin and 11 suckers from sites where NZMS were not detected (Table 1). The sample size of Mottled Sculpin containing diet items was 123 in NZMS infested sites and 52 in uninfested sites. The sample size of suckers containing diet items was 84 and 10 in NZMS infested and uninfested sites, respectively.

TABLE 1. Diet composition of Mottled Sculpin and White Sucker and Shorthead Redhorse (Sucker spp.) in the Pere Marquette River, 2016 and 2017 combined. Sample size N is represented for all fish and for fish that were empty. Diet taxa are arranged in descending order of overall contribution.

	Sculpin Diet		Sucker spp. Diet	
	NZMS Infested	NZMS Uninfested	NZMS Infested	NZMS Uninfested
N (N empty)	145 (22)	57 (5)	97 (13)	11 (1)
Diet composition				
Diptera	42.8%	32.3%	52.0%	57.6%
Ephemeroptera	15.0%	20.1%	20.2%	25.9%
Amphipoda	16.6%	24.4%	3.3%	1.7%
Other	12.9%	16.7%	2.2%	5.2%
Trichoptera	10.2%	3.4%	2.8%	3.0%
Gastropoda	1.0%	1.9%	8.8%	0.2%
Coleoptera	1.0%	1.0%	3.5%	6.1%
Bivalvia	0.3%	0.2%	3.4%	0.3%
New Zealand Mud Snail	0.2%	0.0%	3.7%	0.0%

The diet of Mottled Sculpin was similar across sites with and without NZMS. The mean number of items in the diet of Mottled Sculpins that contained diet contents averaged 11.9 ± 1.2 items per fish. The number of items in the diet did not vary significantly across infestation status of sites (t-test; P=0.82). The dominant diet items of Mottled Sculpin were larval dipterans, ephemeropterans, amphipods, and trichopterans (Table 1) in sites with and without NZMS. Items in the "Other" category combined also made up a substantial percentage of the diet and contained a diversity of taxa such as annelids, megalopterans, odonates, ostracods, isopods, juvenile fish, decapods, and hymenopterans. Native gastropods were found at sites with and without NZMS and comprised 1–2% of their diet. NZMS were observed in the diet of Mottled Sculpin at infested sites, but only as single individuals consumed and only comprising 0.2% of the diet. Other taxa were found in the diet sporadically and generally made up less than 5% of the diet.

The diet of suckers was also similar across sites with and without NZMS. The mean number of items in the diet of suckers across all samples averaged 150.2 ± 27.6 items per fish. The number of items in the diet did not vary significantly across infestation status of sites (t-test; P=0.64). The dominant diet items of suckers were also larval Diptera and Ephemeroptera (Table 1). Items in the "Other" category comprised 2–5% of the diet (Table 1) and contained a diversity of taxa as seen in Mottled Sculpin. Native gastropods were found at sites with and without NZMS, making up 8.8% of their diet at infested sites and 0.2% at sites not infested with NZMS. NZMS were observed in the diet of suckers only at infested sites, comprising about 3.7% of their diet. Several suckers contained only a single NZMS, but over 100 NZMS were observed in one of the fish examined. Other taxa were found in the diet sporadically and generally made up less than 5% of the diet.

DISCUSSION

The overall diet composition of both Mottled Sculpin and suckers consisted primarily of Diptera and Ephemeroptera. The diet of Mottled Sculpin is not well documented in the primary literature, however McGinley (2013) also found that Mottled Sculpin feed primarily on these insect orders. The diet of the White Sucker is somewhat more well documented, but much of this work has focused on lake-dwelling populations. Nonetheless, other studies of sucker diet have shown these Orders contribute strongly to sucker diets. For example, Hayes et al. (1992) found that White Sucker in lakes consumed primarily Diptera and Ephemeroptera in addition to occasional large numbers of microcrustaceans (*Chydorus* and *Bosmina*). Eder and Carlson (1977) report that chironomid larvae and pupae were the predominant prey item of White Sucker in a Colorado Stream.

Interestingly, we observed that native gastropods made up a higher proportion of the diet of suckers at sites infested with NZMS than at sites where NZMS were absent. We speculate that this could be due to these habitats being more conducive for gastropods in general. An alternate hypothesis is that this difference in diet could also be due to suckers showing a preference for gastropods where the overall density (including NZMS) is high.

We found positive evidence that native benthivores do consume NZMS, albeit at a low rate. Suckers consumed NZMS to a greater extent than sculpins; as such, native sucker species may exert some control on the population of NZMS. The limited number of fish examined within each site/month/year sampling block did not allow us to evaluate the potential effects of fish size or seasonal factors on consumption rates of NZMS. Also, we did not have a quantitative measure of the abundance of NZMS, which precluded determining how consumption rate would vary with their abundance. Despite these limitations of our sampling, the observed rate of NZMS population expansion in the Pere Marquette River (Tank 2020) indicates that this predation is insufficient to fully prevent NZMS invasion or range expansion.

Previous studies have shown that NZMS are capable of surviving passage through the digestive tract of Rainbow Trout (Vinson and Baker 2008; Bruce et al. 2009). In contrast, we found evidence that mechanical digestion was occurring in suckers, as fragmented NZMS shells were detected in the diets we sampled. As such, consumption rates by suckers may be underestimated given that some NZMS may have been crushed to an unidentifiable state. Unlike sucker predation, all NZMS shells observed in the diet of Mottled Sculpin were intact. However, we are uncertain whether NZMS survived the passage through Mottled Sculpin digestion. More research is needed to assess the degree to which NZMS can successfully survive digestion by native benthic predator species. Although suckers are a highly mobile group, particularly during the spawning season (Scott and Crossman 1973), none of the fish sampled in uninfested areas contained NZMS. This could be due to mechanical digestion occurring in suckers, or due to the lack of movement extensive enough to lead to detection of consumption by suckers resident in areas lacking NZMS. In either case, it suggests that movement of NZMS by suckers while they are within the digestive tract is not likely a strong contributor to dispersal of NZMS within a river system.

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