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Status and trends of the Asian clam (*Corbicula fluminea*) in the lower Fox River and Green Bay

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ABSTRACT

In the upper Great Lakes region, survival and population growth of the non-indigenous Asian clam *Corbicula fluminea* has been limited by cold climates that cause severe overwinter mortality. At these northern latitudes, Asian clam populations are often limited to thermal refugia – particularly warmwater discharges from industrial facilities. Several such facilities exist in the lower Fox River in Green Bay. Asian clams were first documented in the lower Fox River in 1999 and were extensively surveyed near the river mouth in 2011, but the few individuals found were restricted to the warmwater discharge from the Pulliam Power Plant. We performed a follow-up survey during 2017 to re-assess the population status of Asian clams in the lower Fox River at four industrial discharges, including the Pulliam Power Plant. We found more widespread evidence of Asian clams throughout the lower Fox River than previous surveys, but only one live individual was captured. We suspect that the back-to-back severe winters of 2013–2014 and 2014–2015 caused widespread overwinter mortality. Our investigation highlights the significant challenges for establishment of Asian clam populations in the upper Great Lakes region, and provides an example of a potential invasive species struggling to establish a viable population in a hostile climate.

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Introduction

The Asian clam *Corbicula fluminea* is a prolific and increasingly ubiquitous aquatic invader in North America (Sousa et al., 2008). Due to its diverse life-history characteristics, reproductive habits, and dispersal by humans, they will continue to expand to new waters. However, their northward expansion is limited by overwinter survival (French and Schloesser, 1996). Water temperatures < 2 °C for extended durations (weeks-months) are known to cause mass mortality (Mattice and Dye, 1976), though more recent experimental evidence suggests 0 °C may be a more accurate lower thermal tolerance (Müller and Baur, 2011). Younger (Age-0), smaller individuals (<5 mm) are usually more vulnerable to this form of mortality (Werner and Rothhaupt, 2008). For this reason, Asian clam populations in the upper Great Lakes region are few, and often spatially limited to thermal refugia, particularly warmwater discharges from industrial facilities (Clarke, 1981; Scott-Wasilk et al., 1983; French and Schloesser, 1991; Simard et al., 2012). This appears to be the case for Asian clams in the Fox River, which drains most of northeastern Wisconsin and empties into Green Bay on Lake Michigan.

Asian clams were first documented in the Fox River near the river mouth during a benthic survey in 1999 (Integrated Paper Services Inc., 2000). They were reported again in 2011 by a fisherman and a subsequent survey by the Wisconsin Department of Natural Resources (WDNR) found eight live individuals and fewer than a dozen relic shells or shell fragments (Wisconsin Department of Natural Resources, 2011, unpublished data). Several years later in 2016, we collected an Asian clam shell during an early detection and monitoring survey for invasive species. During a follow-up survey around the river mouth, we found additional relic shells, but no live individuals. The timeline of events indicates that Asian clams have been in the lower Fox River for at least 18 years (Fig. 1).

The Fox River and lower Green Bay provide ideal physical habitat for Asian clams. Most authors have reported that Asian clams prefer shallow (<3 m), well oxygenated, sandy substrates in rivers and reservoirs (Matthews and McMahon, 1999; Sousa et al., 2008) – these conditions are found throughout the Fox River and its river mouth in Green Bay. Low overwinter temperature is likely the largest impediment to survival (Müller and Baur, 2011). However, the industrialized lower stretch of the Fox River from the De Pere Dam downstream to the river mouth (11.7 km) has at least four warmwater discharges that may provide thermal refuge during winter.

The Pulliam Power Plant (PPP) is one such facility at the mouth of the Fox River. During a survey by the WDNR in 2011, the few live individuals found were restricted to the warmwater discharge from the PPP. During the 2011 survey, WDNR set up a survey grid that included the Fox River from upstream of the PPP out into lower Green Bay. This grid provided an opportunity to re-sample the PPP area to look for

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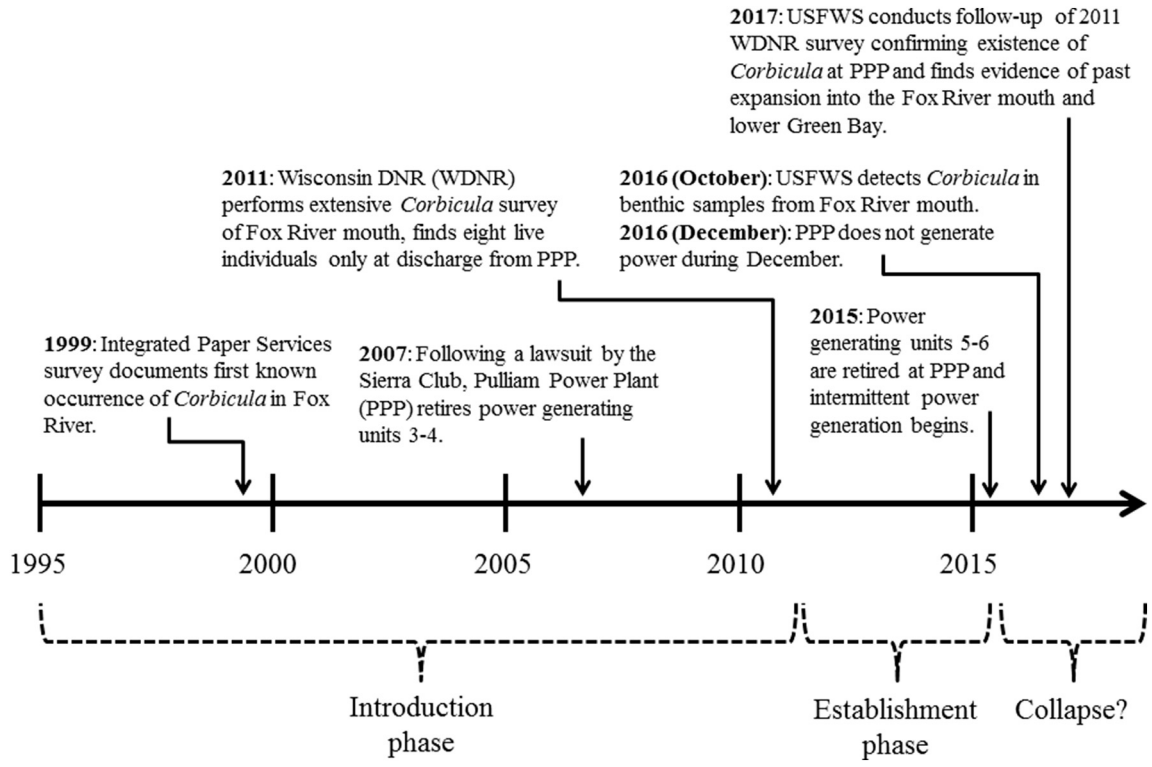

Fig. 1. Timeline of events relevant to the Asian clam (*Corbicula fluminea*) in the lower Fox River and lower Green Bay.

trends in the Asian clam population at the river mouth. In addition to the PPP, we wanted to survey the three additional discharges in the Fox River for Asian clams including the NEW Water – De Pere wastewater treatment facility, Green Bay Paper Mill, and NEW Water – Green Bay wastewater treatment facility. Our objectives in this study were to: 1) survey the four known warmwater discharges and record presence, relative abundance, and size structure of Asian clams, 2) resample the river mouth area using the survey grid used by the WDNR to look for expansion of Asian clams from the Fox River into lower Green Bay, and 3) assess the status of the Asian clam population in the lower Fox River and Green Bay and identify any population trends (i.e., expansion, contraction).

Methods

Study area

The Fox River is one of the largest tributaries to Lake Michigan; it drains 16,651 km^2, is 322 km long, and discharges an average 117 m^3/s of water into Green Bay. The lowest stretch of the river, which flows from the De Pere dam through the city of Green Bay, Wisconsin, will be referred to as the lower Fox River (Fig. 2). This stretch of river is heavily industrialized and is being actively remediated through dredging and capping of PCB-contaminated (PCB; Polychlorinated biphenyl) sediments. Lower Green Bay (southernmost portion of Green Bay), which receives the discharge of the Fox River, is shallow (<4 m) and eutrophic-hypereutrophic with predominantly sand, silt, and muck (organic matter) substrates. The four discharges surveyed are known by direct observation to release water warmer than the ambient river temperature during winter, and thus, we hypothesized that these areas may serve as thermal refuges.

Experimental design

At each of the four warmwater discharges we established a 5 × 5 sampling grid (25 cells) that was either 50 or 75 m on a side, depending on the size of the discharge. At each site, the grid was centered on the discharge and 10 cells within the grid were randomly assigned to be sampled. Surface water temperature and depth were recorded for each sample. Benthic sediments were collected using a petite PONAR grab (volume = 2.4 L; area = 0.024 m^2). Composition of sediments (e.g., gravel, sand, silt, clay) was noted in the field; then sediments were washed through a 500 micron sieve bucket and all collected materials were placed in a labeled bottle and fixed with 95% ethanol. Sorting through collected material and identification of Asian clams was performed in the laboratory. All shells were enumerated and measured for total length (TL; mm) if they were intact, and live specimens were also weighed (g). Sampling at the PPP was performed during April and the other three discharges were sampled during July 2017.

We repeated the 2011 WDNR survey by re-sampling approximately half of their sample points during June 2017 using our petite PONAR grab, the same gear used during the 2011 survey. The WDNR only sampled 39 of their original 109 sample points during their survey, plus six additional grabs directly at the discharge of the PPP. Some of the points could not be revisited because of shoreline changes and inaccessibility. Similar to sampling at the discharges, water temperature and depth were recorded and sediment composition was classified for each sample site.

To collect live individuals for genetic analysis, and to further investigate the likelihood of Asian clams persisting at the PPP, we obtained permission from Wisconsin Public Service (WPS) to sample the cooling pond at the PPP. Warmwater from the generating units was released into the cooling pond before being discharged into the river but was not influenced by the flow of the Fox River, making it an ideal thermal refuge for Asian clams. No target level of effort or a sample design were established because the primary purpose of this effort was to collect live individuals for genetic analysis; we sampled haphazardly throughout the cooling pond until live organisms were obtained or until it was deemed unrealistic that live organisms were present (i.e. >50 samples without detecting a live individual). We sampled from shore during June 2017 using a petite PONAR and from a small boat during August 2017 using a petite PONAR and an Ekman dredge. Results of

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