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Research Article

Non-native amphipod, *Apocorophium lacustre* (Vanhoffen, 1911), in the Illinois River and Chicago Area Waterway System

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Editor's note:
This study was first presented at the 19th International Conference on Aquatic Invasive Species held in Winnipeg, Canada, April 10–14, 2016 (http://www.icais.org/html/previous19.html). This conference has provided a venue for the exchange of information on various aspects of aquatic invasive species since its inception in 1990. The conference continues to provide an opportunity for dialog between academia, industry and environmental regulators.

Abstract

Apocorophium lacustre (Vanhoffen, 1911) is a recent colonizer of freshwater ecosystems in the United States of America and Europe. This species is native primarily to estuarine environments on both sides of the North Atlantic, but in the US it has been established in the Gulf of Mexico since at least 1982 and more recently in the Mississippi River Basin. In 2005 it was found in the Dresden Island Pool of the Upper Illinois River, placing it within 100 river kilometers of Lake Michigan, and it is considered a high risk for continuing its spread into the Laurentian Great Lakes. During summer 2015 we conducted what we believe is the only sampling for this species to have taken place upstream of the Dresden Island Pool since 2005. We sampled at 25 sites from the Dresden Island Pool upstream to Lake Michigan, including six Lake Michigan harbors. *A. lacustre* was found at a single site in the Dresden Island Pool, indicating that the species has not spread over the last decade. This result could occur because of a physical or chemical barrier to further movement, or because our sampling was not sufficient to locate the population. Further sampling, and tests of *A. lacustre* tolerance to water from different sources, will be required to determine if spread has truly stopped, and if so, the reason for this.

Key words: scud, invasive species, Great Lakes, Mississippi River

Introduction

Apocorophium lacustre (Vanhoffen, 1911) (Figure 1) is a filter feeding amphipod crustacean with a North American native range extending along the Atlantic coast, from the Bay of Fundy in Canada to Florida (Shoemaker 1934; Bousefield 1973; Nelson 1995). It is also native to Atlantic coastal regions of Europe, including the Netherlands (Faasse and van Moorsel 2003; Noordhuis et al. 2009) and the Baltic Sea (Ezhova et al. 2005; Jażdżewski et al. 2005). *A. lacustre* is generally found in estuarine environments and may extend up the estuary into fully fresh water (Shoemaker 1934; LeCroy 2004). It has been found on a range of substrates, from vegetation to large woody debris to sandy and muddy bottoms, at depths ranging from < 1 to 10 m (Heard 1982; Payne et al. 1989; LeCroy 2004).

Over recent decades *A. lacustre* has spread into new ecosystems in both North America and Europe. In Germany, its spread into the Werra River has been associated with anthropogenically increased salinity (Szöcs et al. 2014). In North America, *A. lacustre* is considered non-native to the Gulf of Mexico where it has been established at least since 1982 (Heard 1982). It was subsequently first sampled in the Lower Mississippi River in 1987 by which time it was already 510 miles upstream from the mouth, and was recorded at densities up to 38,937/m^2 (Payne et al. 1989). Since then it has shown rapid spread throughout much of the Mississippi River Basin, reaching the Ohio River by 1996 (Grigorovich et al. 2008) and the Illinois River by 2003 (Benson 2017). *A. lacustre* is known to attach to boat hulls, and the movement of such boats through the Mississippi River Basin is the most likely vector for this rapid spread (Grigorovich et al. 2008; Llansó and Sillett 2009).

There is particular concern about the spread of *A. lacustre* in the Illinois River because the Chicago Area Water System (CAWS) provides a direct canal link into the Laurentian Great Lakes (USACE 2014). The CAWS is a largely artificial system that connects Lake Michigan to the Illinois River via the Chicago River, Calumet River, Cal-Sag Channel, the Chicago Sanitary and Ship Canal (CSSC), and the Des Plaines River. Water flows from Lake Michigan towards the Illinois River, and there is currently discussion about re-engineering the CAWS, including the option of inserting a permanent physical barrier, to reduce the risk of species spread (USACE 2014). This risk is illustrated by the previous movement of zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels from the Great Lakes into the Mississippi River, and the current threat that silver (*Hypophthalmichthys molitrix*) and bighead (*H. nobilis*) carps may enter the Great Lakes (Veraldi et al. 2011).

The closest to Lake Michigan that *A. lacustre* has been recorded is at the Dresden Island Pool of the Illinois River in 2005 (Grigorovich et al. 2008; USGS 2016; Figure 2). To get from the Dresden Island Pool to Lake Michigan *A. lacustre* would need to move upstream through less than 100 km of connected waterways. Based on this location *A. lacustre* was classified as a *High Risk Invasive Species* for entering the Great Lakes as part of the US Army Corps of Engineers' Great Lakes and Mississippi River Interbasin Study (Veraldi et al. 2011). This study also concluded that the species has the potential to alter food-webs if it becomes established (Veraldi et al. 2011). A more recent risk assessment concurred that based on its known location and its range *A. lacustre* has a high likelihood of being introduced to Lake Michigan and establishing there (Fusaro et al. 2016). Although the impacts of this species as an invader have never been studied (Fusaro et al. 2016), it is a filter feeder that can reach high densities. It is speculated that *A. lacustre* may compete with native filter feeders, such as mussels and other benthic species, for space and food (Grigorovich et al. 2008; USACE 2016). Despite concern about the potential for this species to spread, we are not aware of any sampling efforts upstream of the Dresden Island Pool since 2005. To address this, we report here on our work sampling *A. lacustre* at 25 sites in the Upper Illinois River, CAWS, and Lake Michigan, during 2015.

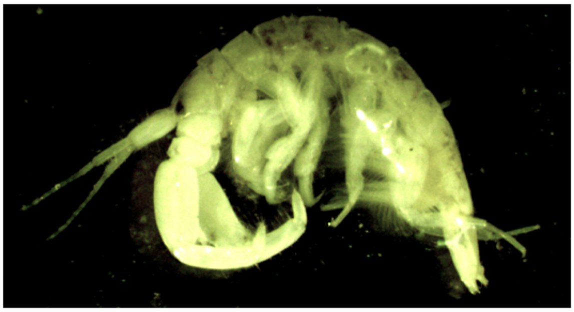

Figure 1. *Apocorophium lacustre*. This individual was 5 mm long. Note the large pediform second antennae that makes this species distinctive among amphipods in the Mississippi River Basin. Photo credit: the authors.

Methods

During June–August 2015 we sampled for *A. lacustre* at 25 sites (Table 1; Figure 2). The furthest sites from Lake Michigan were in the Dresden Island Pool of the Illinois River. Other sites were in the Brandon Road Pool of the Des Plaines River, the CSSC, the Chicago River and North Shore Channel, the Cal-Sag Channel and Calumet River, six Lake Michigan harbors, and one site along a Lake Michigan pier (Figure 2). Sites were selected to span the range of habitats in the system, and to span the distance from the Dresden Island Pool to Lake Michigan.

At each site we set three clusters of Hester Dendy (HD) samplers, with roughly 100 m between each cluster. Each HD cluster consisted of a brick anchor, two HDs tied off ~20 cm above the brick and two HDs tied off ~40 cm above the brick. Approximately 60 cm above the brick we tied off a small float that kept the HDs suspended above the bottom. This HD cluster design is based on that used by the Ohio River Valley Water Sanitation Commission (ORSANCO) which frequently captures large numbers of *A. lacustre* (Jeff Thomas, ORSANCO, personal communication).

HD clusters were set in 1–8 m water depth on substrates ranging from muck and sand to gravel and boulders. A total of 300 HDs were deployed (25 sites, three clusters/site, four HDs/cluster). Our goal was to leave each cluster in the water for 7–10 weeks.

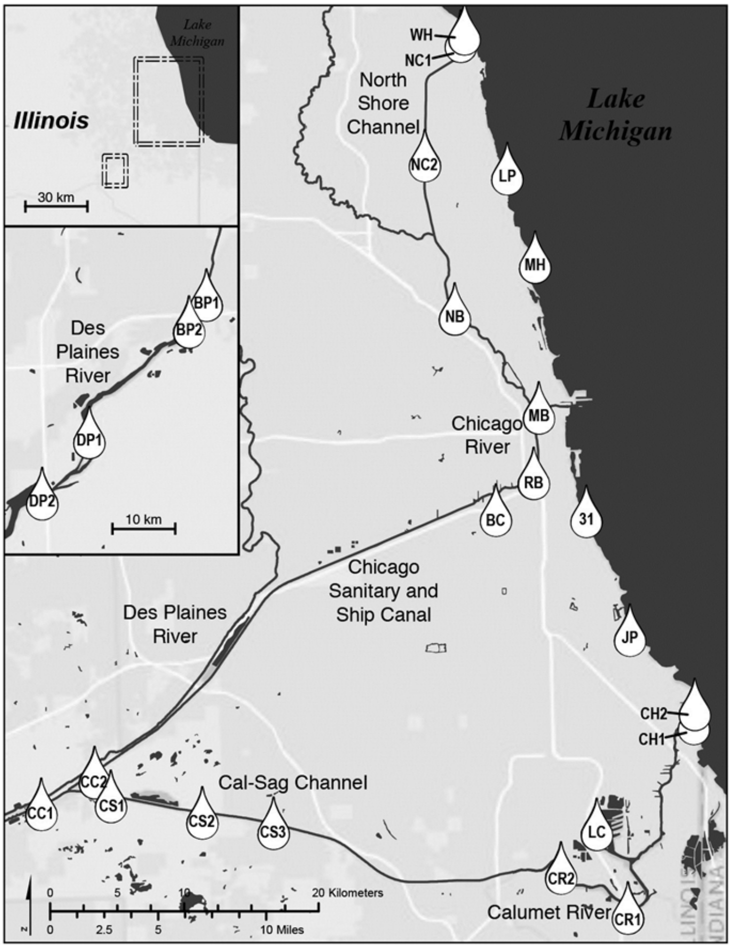

Figure 2. Map of sites sampled for *Apocorophium lacustre* during 2015. *A. lacustre* was found only at site DP1. See Table 1 for site descriptions.

We were mostly able to achieve this, but flooding at some sites during June slowed our deployment and meant that at a small number of sites HD clusters were only in the water for six weeks (Table 1). This still falls within the standard time-frame for HD use (Meier et al. 1979). After each HD cluster was collected it was disassembled and all plates scraped to remove organisms. All material removed from the plates was preserved in ethanol for future sorting.

To supplement the HD samplers we endeavored to collect samples at each site through one additional sampling technique. This was through taking a Ponar grab (15 cm × 15 cm; http://wildco.com) sample of sediment, a kick-net sample from shallow water, or by scraping a kick-net net across a submerged surface and collecting the material that came off. When we could take these samples we did so in the vicinity of a HD cluster, and the combination of material from three Ponar grabs or three kick-net/scrape samples was considered one sample. Table 1 lists the number and type of these additional samples taken. Many of our sites were in deep artificial canals with steep sides and heavy boat traffic that made these additional samples difficult to collect, and at some sites the substrate was not appropriate for Ponar or kicknet sampling. We took 25 of these additional samples across 14 sites (Table 1).

Samples were returned to the lab for sorting. Samples containing large amounts of sediment were elutriated to remove organic matter and organisms. We searched specifically for *A. lacustre*, which are the only known members of the Corophiidae family in the region. This family has prominently enlarged second antennae that are distinctive compared to other similar sized organisms (see Figure 1).

Results

At all but six sites we recovered all HD clusters (Table 1). At our most downstream site (DP2) we recovered only one HD cluster, with ropes to the other two having been cut. No more than one cluster

Table 1. Sites sampled for *Apocorophium lacustre* during 2015.

Site ID	Set	Recovered	Latitude	Longitude	HDs Rec	Ponar	Kicknet	Site Description
DP1	6/23/15	7/30/15	41.45237	-88.1654	3			Dresden Pool, Des Plaines River
DP2	6/23/15	7/30/15	41.42174	-88.1971	1			Dresden Pool, Des Plaines River
BP1	6/23/15	7/30/15	41.52119	-88.0871	3	1		Brandon Road Pool, Des Plaines River
BP2	6/23/15	7/30/15	41.50772	-88.0988	3	1		Brandon Road Pool, Des Plaines River
CC1	6/24/15	8/10/15	41.69013	-87.967	3			Chicago Sanitary and Ship Canal
CC2	6/24/15	8/10/15	41.70606	-87.9314	2.5			Chicago Sanitary and Ship Canal
CS1	6/24/15	8/10/15	41.69413	-87.9204	2.5			Cal-Sag Channel
CS2	6/24/15	7/29/15	41.68593	-87.8592	3			Cal-Sag Channel
CS3	6/24/15	7/29/15	41.68067	-87.8114	3			Cal-Sag Channel
CR1	7/1/15	8/11/15	41.63832	-87.5743	3	1	1	Little Calumet River
CR2	7/1/15	8/11/15	41.65841	-87.6192	3	1	1	Little Calumet River
LC	7/1/15	8/11/15	41.68015	-87.5952	3	2		Lake Calumet
BC	7/2/15	8/20/15	41.84086	-87.6645	3	2		Bubbly Creek
RB	7/2/15	8/20/15	41.86721	-87.63440	3	2		Main Branch, Chicago River
MB	7/2/15	8/20/15	41.88783	-87.634	2			Main Branch, Chicago River
NB1	6/30/15	9/3/15	41.93703	-87.6902	3			North Branch, Chicago River
NC1	6/29/15	8/17/15	42.07255	-87.6863	3	2		North Shore Channel
NC2	6/29/15	8/6/15	42.01322	-87.7103	3	1	1	North Shore Channel
CH1	7/6/15	8/14/15	41.7331	-87.5303	3		2	Calumet Harbor
CH2	7/6/15	8/14/15	41.74003	-87.5297	3		2	Calumet Harbor
WH	7/7/15	8/17/15	42.07616	-87.684	2		1	Wilmette Harbor
JP	7/8/15	8/18/15	41.7771	-87.5731	2			Jackson Park Harbor
LP	7/20/15	9/1/15	42.00681	-87.6552	3			Pier just North of Loyola University
MH	7/8/15	8/18/15	41.96284	-87.6366	3	1	1	Montrose Harbor
31	7/8/15	8/18/15	41.83628	-87.6021	3	2		31st Street Harbor

HD =Dester Dendy cluster (see *Methods* for full description). Set=date HD was set, Recovered = date HD removed, HDs Rec = # (/3) recovered, Ponar/Kicknet = # of Ponar/Kicknet samples taken at each site.

was lost at any other site. It is not surprising to lose some samplers given that these waterways have a lot of commercial and recreational boat traffic.

Organisms collected from all recovered HD samplers were sorted, along with organisms from the supplementary samples. In a majority of samples we found large numbers of small crustaceans (e.g., *Corophium,* Isopoda), indicating that the HD samplers and other approaches were capable of finding organisms that are similar in size to *A. lacustre*. From the whole study a total of three *A. lacustre* individuals were found at site DP1 in the Dresden Pool (Figure 2). None of the other sites yielded this species, although we note that at site DP2, which was downstream of DP1, we only recovered one HD cluster. *A. lacustre* is visually distinctive (Figure 1) and we are confident that we did not overlook it in any of our samples.

Discussion

This study did not find evidence that *A. lacustre* has expanded its range in Illinois towards Lake Michigan over the last decade. This is a surprising result given that previous sampling indicates that its range through the Mississippi River Basin expanded by many hundreds of miles during the decade prior (Grigorovich et al. 2008). Taking the known location of the species in 1987 when we believe it was first recorded in the Mississippi River (Payne et al. 1989) and its location in the Dresden Island Pool by 2005 (USGS 2016) gives a rate of spread of 87 km/year. We stress that this is an approximation and that the species may have already spread further by 1987 and may have been in the Dresden Island Pool earlier than 2005. Despite these caveats, this represents rapid spread that almost definitely occurred through boat fouling (Grigorovich et al. 2008; Llansó and Sillett 2009). Extensive boat traffic from the Dresden Island Pool towards Lake Michigan means that there is likely adequate vector activity for additional spread.

Two scenarios could have caused our results. First, it is possible that *A. lacustre* has spread further and that our sampling density and/or methods were insufficient to detect it. Our total sampling effort, consisting of 25 sites, was spread across more than 130 km of waterway and 20 km of lakeshore (Figure 2). It is possible that *A. lacustre* is present upstream of the Dresden Island Pool but that we selected sites where the species was not present during summer 2015. Although we utilized a range of sampling approaches, it is also possible that our sampling methods were not optimal. Previous sampling methods that have found this species include HDs, kicknets in shallow water, and scrapes of large woody debris (Grigorovich et al. 2008; USGS 2016). Unfortunately the methods used during 2005 when *A. lacustre* was found in the Dresden Pool are not included with the record (https://nas.er.usgs.gov specimen ID 237724), although it does state that a total of 179 individuals were captured. Our samplers captured many crustaceans of a similar size to *A. lacustre* and we know that similar designs are effective for catching the species in the Ohio River. Thus, while we are confident in our design, it would also be useful to compare different sampling methods in regions known to contain the species. Determining the best methods and using them for additional sampling, preferably with more sites and at sites where we did not sample during 2015, would help to determine whether the species has spread further towards Lake Michigan.

The second scenario is that our results are a true indication that the species has not spread. This could come about from a physical or chemical barrier to dispersal that exists upstream of the Dresden Pool. There are no physical barriers between Dresden Island Pool and Lake Michigan that pose a different challenge to the barriers *A. lacustre* passed through to get to the Dresden Island Pool. In particular, *A. lacustre* is known to travel as a fouling organism of boats (Grigorovich et al. 2008; Llansó and Sillett 2009), and many boats continue upstream from the Dresden Island Pool and into Lake Michigan. *A. lacustre* are usually found associated with hard substrates, including large woody debris, but may also colonize sand and softer substrates (Angradi et al. 2009; LeCroy 2004; Way et al. 1995). Upstream of the Dresden Island Pool the river is channelized with vertical steel, concrete, or rock walls and soft substrate on the bottom. If *A. lacustre* are unable to utilize the firm substrate on the channel sides then they may not find extensive appropriate habitat through the CSSC.

Alternatively, water quality may pose a barrier to *A. lacustre* spread. The existing distribution of the species, from estuarine to freshwater, and from systems both warmer and cooler than the Chicago Region, indicates that temperature and salinity do not pose immediate barriers to spread (Bousefield 1973; LeCroy 2004; Nelson 1995). The tolerance of *A. lacustre* to other water quality metrics, such as turbidity and nutrients, is unknown. Given the lack of information about tolerances it is difficult to speculate on any water quality factors that may limit the spread of *A. lacustre*, but we note that water quality in the CSSC and CAWS is highly variable and strongly influenced by urban runoff and treated wastewater. One way to directly address the effect of water quality would be to expose live *A. lacustre* to water from the river systems between the Dresden Island Pool and Lake Michigan. We do not know of anyone who has tried to keep this species in aquaria, but if a protocol could be devised it could help to address questions about potential for further spread. Such work could be expanded to determine whether *A. lacustre* can survive in water from Lake Michigan.

Further research and sampling would be helpful to better understand the dynamics of *A. lacustre* spread and the risk posed of establishment in the Great Lakes. We recommend additional and more intensive sampling upstream of Dresden Island Pool, in the Des Plaines River, CAWS, and Lake Michigan. Such sampling should ideally be stratified across depth, substrate, and sampling technology so that the most effective sampling methods can be determined. Finally, samples of organisms from the hulls of boats passing through the area could help to determine if there is active movement of the species. If there is, this could lead to management through cleaning hulls and/or restricting the movement of boats. Apart from these approaches, which have not been implemented, there are no other known ways to manage the spread of the species through connected waterways (Fusaro et al. 2016).

Given the current discussion and debate about how the CAWS should be managed in the future (USACE 2014), detailed information about *A. lacustre* may be important for helping to guide the type of changes made to the CAWS and the urgency with which they should be pursued. Although the impacts of *A. lacustre* have not been studied, the high densities at which they have been found (Payne et al. 1989; Grigorovich et al. 2008), their proximity to the Great Lakes, and the strong desire to prevent further spread (USACE 2014), all support further work to determine and manage the threat of this species.

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