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Rapid Communication

First record of the Asian clam *Corbicula fluminea* (Müller, 1774) (Bivalvia, Cyrenidae) in Northern Ireland

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Abstract

Since its first detection on the island of Ireland in April 2010, the invasive Asian clam *Corbicula fluminea* (Müller, 1774) has been confirmed present at five sites within the Republic of Ireland (RoI). In March 2016, specimens of *C. fluminea* were first discovered in Northern Ireland (NI) within the River Foyle, which delineates the border between RoI and NI. In a subsequent survey in June 2016 an established population was confirmed to be present within the River Foyle, where densities of clams attained 384 individuals m^{-2}. This highly invasive species can potentially represent a significant threat to freshwater environments. Therefore, increased biosecurity awareness and enforcement of existing legislation is needed to prevent further spread.

Key words: invasive alien species, Asian clam, *Corbicula fluminea*, Corbiculidae, spread, Ireland, biosecurity

Introduction

Native to southern and eastern Asia, Australia and Africa, the Asian clam *Corbicula fluminea* (Müller, 1774) (Bivalvia, Cyrenidae; formerly Corbiculidae) is regarded as one of the most notorious aquatic invasive species in the world (Sousa et al. 2008). Specimens of this highly invasive species were first recorded on the island of Ireland in April 2010 in the River Barrow (Sweeney 2009). Subsequent detailed examinations revealed that the population extended upstream from the brackish waters at New Ross for *circa* 29.7 km and into the connected River Nore (Caffrey et al. 2011). In total, since its initial discovery, five separate populations of *C. fluminea* have been identified in the Republic of Ireland (Hayden and Caffrey 2013; Minchin 2014). Four of these sites are located on the River Shannon, the most extensive river system on the island of Ireland (see Figure 1).

The inadvertent dispersal of *C. fluminea* represents a biosecurity concern for Irish freshwaters (Lucy et al. 2012; Minchin 2014). For example, recreational activities predominate the Shannon River, which is further connected to several other major waterways *via* canal systems (Hayden and Caffrey 2013; Minchin 2014). However, extensive benthic surveys of other "at risk" sites on the River Shannon have not yet detected further infestations. In addition, while several dead specimens were recovered from a sixth location at Cornalour Lock on the Grand Canal, a survey of the site did not detect the presence of further individuals (Minchin 2014). Similarly, in September 2015, three juvenile *C. fluminea* were detected in the River Erne at Belturbet. However, subsequent surveys of the site detected no further specimens.

The River Foyle, and its source the River Finn, form part of the border between the Republic of Ireland and Northern Ireland. The rivers are managed

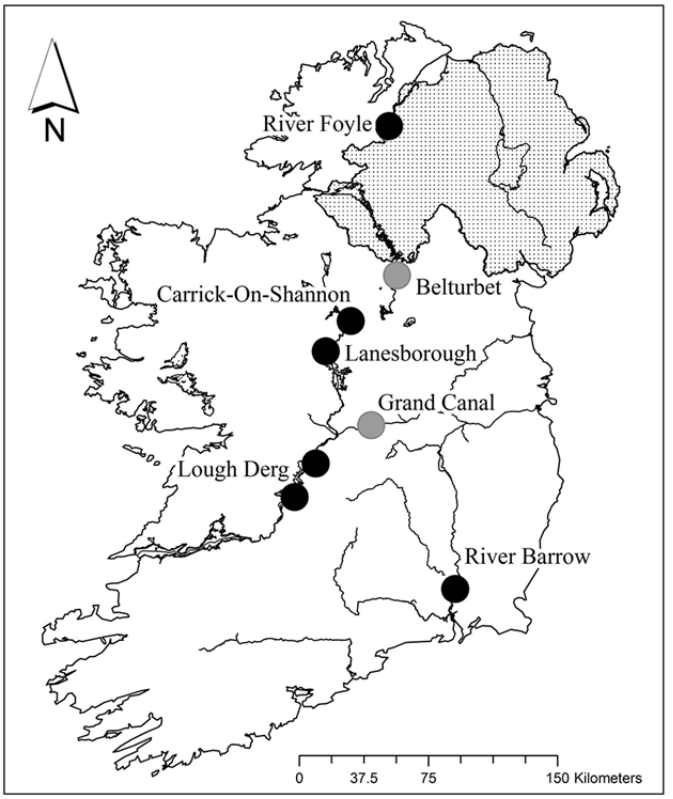

Figure 1. Current known distribution of *Corbicula fluminea* on the island of Ireland. Black dots indicate confirmed populations. Grey dots indicate sites where live and/or dead specimens were found but follow-up surveys failed to detect further presence. The shaded region of the island designates the jurisdiction of Northern Ireland. For details see Supplementary material Table S1.

by the Loughs Agency, a cross-border body responsible for, *inter alia*, the management, conservation, protection, improvement and development of the inland fisheries in the Foyle and Carlingford areas. In March 2016, live *C. fluminea* specimens were recovered from fyke nets deployed during a Loughs Agency smelt survey of the River Foyle. Our subsequent benthic survey reported here was undertaken in June 2016 to determine the presence or absence, current distribution and relative abundances of *C. fluminea* in the River Foyle, Northern Ireland.

Material and methods

Study area

Sampling of the River Foyle commenced at Lifford Bridge, *circa* 3.5 km upstream of the site at which specimens of *C. fluminea* were originally recorded, and continued downstream for a total of 11 km to a bankside area known as "The Gribbon".

Sampling methods

Three sampling techniques were used during the survey: 1) visual line transects, 2) Surber samplers, and 3) benthic hand-dredging. In addition, we attempted to use a Van Veen grab sampler; however, the jaws of the device continuously jammed with gravel or stones and failed to successfully retain samples.

Visual observation along line transects was conducted by a three-man team while walking at exposed shallow bankside shoals and shallow water sites—including backwaters located behind shoals. All exposed sites in the study area were examined for evidence of *C. fluminea*. Moreover, as *C. fluminea* can burrow into sand and gravel, the walking surveys involved systematic scraping of the surface substrate (to *circa* 15 cm deep) every 2–3 m. Transect lengths were dependent on the size of the exposed area but, where possible, a ≥ 50 m length was examined. In addition, 5–10 Surber samples were taken at sites where *C. fluminea* specimens were discovered. The area of substrate demarcated by the Surber frame (0.25 m^2) was removed, to a depth of 15 cm, into the attached net using a hand trowel and washed through a sieve (4 mm × 4 mm). *Corbicula fluminea* specimens ≥ 5 mm in height (umbo to gape) would not be able to pass through this mesh. All *C. fluminea* specimens retained by the sieve were counted and returned to the Queen's University Marine Laboratory (QML) for processing.

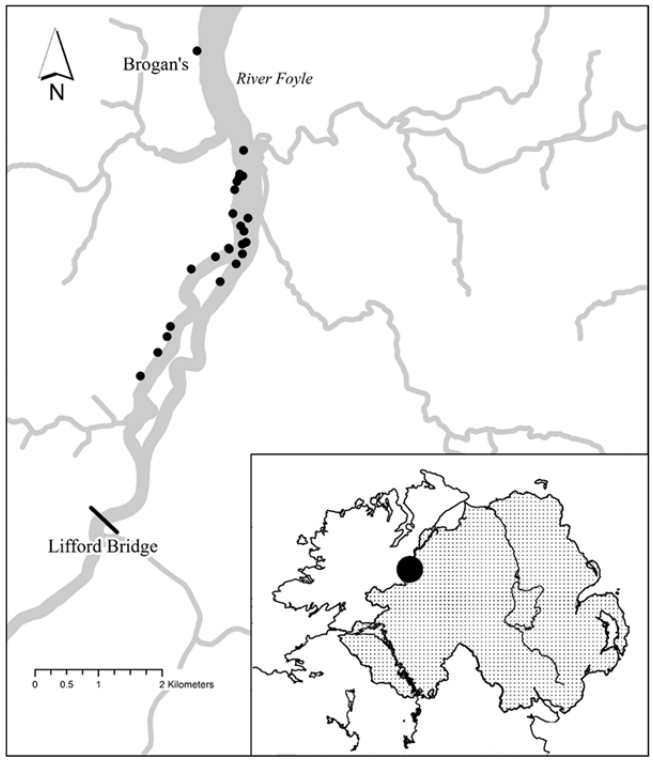

Figure 2. Section of the River Foyle between Lifford Bridge and Brogan's. Black dots designate locations where *C. fluminea* was present. Mean densities (± SE) varied between 5 ± 2 and 283 ± 18 individuals m^{-2}. The shaded region within the inset of the island designates the jurisdiction of Northern Ireland. For details see Supplementary material Table S2.

The criteria used to identify the specimens were those described by Korniushin (2004).

A benthic hand-dredge was used to sample for *C. fluminea* in water deeper than wading depth. The device consisted of a stainless steel wire-meshed (5 mm × 5 mm) basket that was 300 mm in height, 260 mm in open diameter and 180 mm in bottom diameter. A lead plate was attached to one side of the wire-mesh frame. The weight of the lead plate and a one metre chain attached to the leading section of the bridle ensured correct positioning of the dredge during sampling (Minchin 2014). The device provides for relatively rapid surveying of sites over a larger area than can be achieved with the other sampling methods employed during this survey. Commonly, three benthic hand-dredge tows were taken at suitable locations in the channel. The substrate collected from each tow was washed through a sieve (4 mm × 4 mm) and all *C. fluminea* specimens retained with the sieve were counted and returned to QML.

The density of *C. fluminea* individuals (ind.) m^{-2}, ± standard error, was determined at sites where Surber samples were taken. In addition, the shell heights (umbo to gape) of 207 randomly selected specimens were measured to the nearest 0.1 mm using digital callipers for height-frequency analyses and as an indicator of population age.

Results

Distribution of C. fluminea

The presence or absence of *C. fluminea* was assessed at 100 sampling sites for a distance of 11 km downstream of Lifford Bridge (Figure 2). Live *C. fluminea* were detected at 24 of these sites (Supplementary material Table S2). The farthest upstream point of detection was situated *circa* 2.9 km downstream of Lifford Bridge (Figure 2), while a bankside area known as Brogan's, *circa* 8.6 km north of Lifford Bridge, was the farthest point of detection in the downstream direction (Figure 2). The greatest *C. fluminea* densities, of up to 384 ind. m^{-2}, were recorded in the shallow water situated at the northern end of the main island (Figure 2). Here, an extensive area (*circa* 12000 m^2) of sand and fine gravel is present. The results of this survey suggest that this is the primary breeding population within the River Foyle. However, smaller breeding populations are present along the shallow margins and gravel/sand shoals both upstream and downstream of this location. The mean number of *C. fluminea* specimens recovered from dredge samples (3 per site) ranged from 0.33 ± 0 to 148 ± 26 ind. m^{-2}. The maximum number of individuals recovered per site *via* dredge sampling

was 296. Mean Surber sample densities ranged from 5 ± 2 to 283 ± 18 ind. m^{-2}. A maximum density of 384 ind. m^{-2} was recorded. In some instances, small numbers (normally fewer than five) of live *C. fluminea* specimens or shells were visually observed at sites where Surber sampling failed to detect any further live individuals.

Height frequency of C. fluminea

Height frequencies of a randomly chosen sub-sample of specimens (n = 207) would suggest a maximum population age of 3 years (Figure 3). No specimens of <8 mm were detected during sampling, although it is likely that specimens <5 mm would have passed through the sieve.

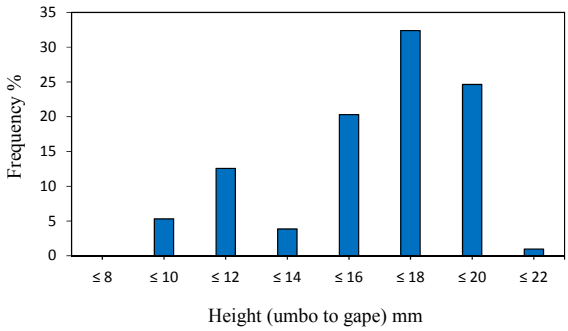

Figure 3. Size distribution of a selection of *Corbicula fluminea* (n = 207) found at sampling sites on the River Foyle in June 2016. Mean (± SE) = 15.8 ± 0.2 mm; Min. = 9.2 mm; Max. = 20.6 mm.

Discussion

Corbicula fluminea is a most unwelcome recent addition to the fauna of Ireland's rivers and lakes. According to Lucy et al. (2012), potential economic damage on the island of Ireland may include interference with power plant operation, drinking water abstraction, and other industries using raw water. Worryingly, the vast majority of freshwaters on the island of Ireland are considered to be suitable habitats for *C. fluminea* (Lucy et al. 2012). In addition, when high densities (*circa* > 1,000 ind. m^{-2}) are attained over large areas, *C. fluminea* can filter large volumes of water in short periods of time and deposit significant quantities of organic matter on the lake or river bed. This process can negatively impact the normal processes in an aquatic ecosystem (Karatayev et al. 2007). Moreover, *C. fluminea* infestations have the potential to clog and adversely alter brown trout and Atlantic salmon spawning grounds *via* increased sedimentation and disturbance of deposited salmonid eggs by burrowing activity (Caffrey et al. 2011). While densities recorded in the River Foyle are not high in comparison with other infested waters on the island of Ireland and elsewhere, current densities indicate that this highly invasive species has established a sustainable population and is now poised to expand its frequency and spread throughout this catchment.

The current distribution and mean densities of *C. fluminea* in the River Foyle appear be relatively confined and low, respectively. This is likely to be due, in part, to the age of the infestation and habitat availability. For example, in the River Barrow, a maximum density of 17,872 ind. m^{-2} was recorded in 2011 (Sheehan et al. 2014). This exceptionally high density was recorded from a section of river where *C. fluminea* was first recorded and where habitat conditions were deemed to be optimal. Elsewhere, mean densities varied from 8 to 1,196 ind. m^{-2} (Caffrey et al. 2011). Within the River Foyle, *C. fluminea* densities were noted to vary with habitat. Generally, few or no individuals were retrieved from large, coarse gravel, stone and rock deposits or heavily compacted areas – such as the bed of the main channel between Lifford Bridge and the main island. However, there is little doubt that the population will proliferate and expand both up- and downstream of its current location, *via* tidal flows and currents.

Further spread and biosecurity

While the cooler temporal conditions of Irish rivers are likely to reduce growth rates of *C. fluminea* (Lucy et al. 2012), based on growth rate curves reported by Cataldo and Boltovskoy (1998) from warmer waters, and the shell lengths observed by Mouthon (2003) (mean height/length ratio for *C. fluminea* ranges between *circa* 0.8–0.95; Bödis et al. 2011) it appears that the majority of specimens recorded in our sampling were likely 1–3 years of age. Moreover, the bimodal size distribution of the clams, similar to the distribution observed by Elliott and zu Ermgassen (2008) in the Thames River, England, implies that there have been only a few years of annual recruitment. Therefore, it is likely that the infestation is relatively recent and may have occurred within the previous two to three years. Interestingly, the frequency of the first cohort (i.e., individuals 16–20 mm) is higher than that of the second cohort (< 16 mm). This may, in part, be attributed to the recentness of the invasion. However, it also suggests a deficiency in recruitment that may be due, for example, to reduced spawning or to a high mortality rate of larvae and/or juveniles (see Sousa et al. 2006 for discussion).

Although it is not known how *C. fluminea* was first introduced to the River Foyle, there is the potential for its further spread to many other freshwater systems on the island of Ireland. Potential dispersal vectors of concern include the use of contaminated equipment (nets, boots, boats, trailers and engines) used by anglers and other recreational water users (Caffrey et al. 2011; Lucy et al. 2012; Barbour et al. 2013; Minchin 2014). While most anglers and recreational water users are generally keen to limit the spread of invasive species, the problem is further compounded by possible transfer of *C. fluminea* on poachers' equipment. In addition, commercial gravel and sand extraction from the River Foyle in the downstream vicinity of Lifford Bridge is a cause for concern, as movement of sediment and equipment could potentially facilitate the spread of *C. fluminea* to uninvaded waterways.

Biosecurity is an integral aspect of invasive species management and mitigation (Simberloff et al. 2013). The implementation of strict biosecurity measures will help to slow, and possibly even prevent, the spread of *C. fluminea* to uninvaded catchments that are geographically isolated from infested areas. However, biosecurity awareness and stakeholder engagement remains problematic, as until recently there has been no legal requirement for stakeholders (e.g. recreational, professional, commercial, and government groups) to implement biosecurity protocols at invaded sites (Caffrey et al. 2014). Furthermore, the lack of a unified, strategic approach in the development of efficient biosecurity protocols, and the adequate enforcement of existing legislation concerning the release of invasive species, is a continuing cause for concern (Caffrey et al. 2014). However, the recent enactment of the European Union Invasive Alien Species Regulation (1143/2014) will require Member States to prevent the introduction and spread of invasive species within and between their territories. In order to address the spread of *C. fluminea* in Ireland's waters, it will be necessary to alert the widest diversity of water users to the presence of this invader, and its potential impacts. This may be achieved through biosecurity and advisory signage at invaded sites, the use of social and traditional media or public meetings. Without doubt, appropriate biosecurity protocols and participation from all responsible agencies will be required to reduce the spread of this highly invasive species. Moreover, the discovery of *C. fluminea* at the cross-border site of the River Foyle signifies that the challenge of prevention, control and eradication of this invasive species on the island of Ireland has increased.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Records of *Corbicula fluminea* in Ireland from 2011–2016.

Table S2. Records of *Corbicula fluminea* in Northern Ireland in 2016.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2016/Supplements/BIR_2016_Caffrey_etal_Supplement.xls