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THE ASIATIC CLAM, *CORBICULA FLUMINEA*, IN BRITAIN: CURRENT STATUS AND POTENTIAL IMPACTS

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Abstract *The distribution and population structure of* C. fluminea *in Britain was investigated during February 2000. The presence of large individuals (32 mm length) and absence of any dead shells suggests that* C. fluminea *arrived in 1997. It now occurs in East Anglia at four sites within a 12 km radius. The greatest densities are in the River Chet, Norfolk, (up to 2500 individuals m^{-2}) where the population is dominated by small individuals (2 to 9 mm in length). The potential impacts that* C. fluminea *may have on Britain's economy and ecology are discussed.*

Key words Corbicula fluminea, *Britain, impacts, River Chet, non-native bivalve*

INTRODUCTION

The Asiatic clam, *Corbicula fluminea* (Müller) is an invasive bivalve which was discovered in Britain in 1998 (Baker *et al.*, 1999; Howlett & Baker, 1999). It is native and widespread throughout Southeast Asia but its range has extended remarkably over the last century. It was first discovered in North America in 1924 (Counts, 1981) and by 1957 was abundant in many catchments within eastern and western USA (McMahon, 1983). In Europe, *C. fluminea* was first recorded from Portugal and the River Garonne in France in 1980/1981. In 1983 it was recorded in Germany's River Weser, and in 1987 the first specimens of *C. fluminea* and *C. fluviatilis* (Müller) were collected from the River Rhine. By 1991 both species were common throughout the lower and middle Rhine system (den Hartog *et al.*, 1992).

C. fluminea is of particular interest not only because of its ability to spread rapidly, but also because of the major impacts it can have both on aquatic ecosystems and industrial installations. Indeed, prior to the invasion of the zebra mussel, *Dreissena polymorpha* (Pallas), in North America, McMahon (1983) described *C. fluminea* as 'one of the most important molluscan pest species ever introduced into the United States'.

The aim of this paper is to document the current distribution and abundance of *C. fluminea* in Britain and to review the potential impacts that the clam's spread may have on British industry and aquatic ecosystems.

METHODS

LARGE SCALE DISTRIBUTION

During February 2000, rivers were sampled to record the presence or absence of *Corbicula*. At each site visited, a standard sampling technique was used: at least three *c.* 3m-long dredges were done by throwing from the bank a hand dredge with a 46x21 cm front aperture and 15 mm mesh size. Where access from the river bank was restricted dredging was done from a boat. After each dredge, the mud was washed through a 2 mm sieve and all *Corbicula* were counted. While this standard sampling technique does not allow a quantitative assessment of absolute densities of clams and is size selective with regard to the dredge mesh, it allows rapid assessment of populations and enables abundance comparisons to be made between sites.

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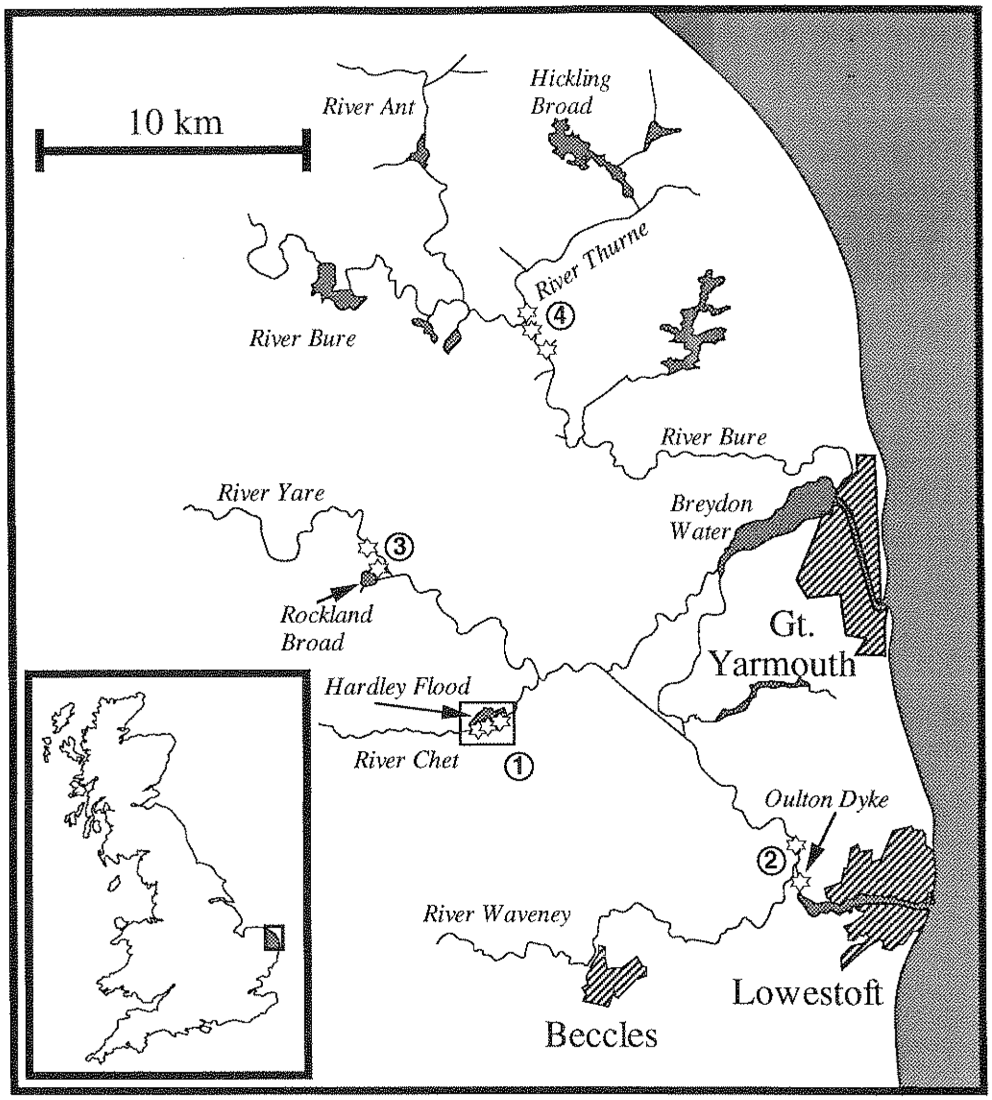

Fig. 1 Distribution of *Corbicula fluminea* in East Anglia in February 2000. Sites where clams have been collected are represented by stars. Numbers represent the historical order in which clams were found.
1. River Chet population located by D. Howlett & R. Baker in October 1998 (Howlett & Baker, 1999).
2. Clams found in the River Waveney and Oulton Dyke by D. Aldridge & S. Müller in April 1999.
3. Clams found in the River Yare by S. Müller in December 1999 and Fleet Dyke by R. Baker in summer 1999 (R. Baker, pers. comm.).
4. Clams found in the Rivers Thurne and Bure by the Environment Agency in January 2000 (J. Stansfield, pers. comm.).

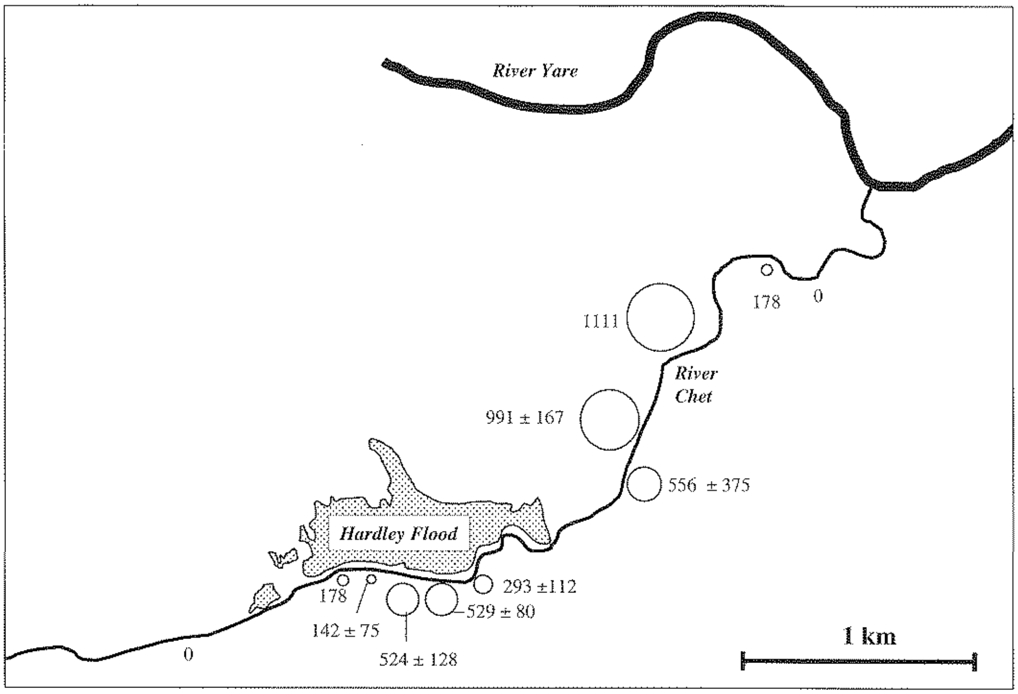

Fig. 2 Distribution of *Corbicula fluminea* in the River Chet, Norfolk, in February 2000. Mean densities per m^2 are denoted by numbers in the proportionately sized circles. Standard error of the mean is given where 5 grab samples were taken at the site.

Additional data on distributions were supplied by the Environment Agency and taken from Baker *et al.* (1999).

POPULATION SURVEYS

During February 2000 detailed population surveys were undertaken in the River Chet, which contains the greatest numbers of *Corbicula*. A total of 11 cross-channel transects were done using a van Veen grab ($0.045m^2$) from a boat. Up to 5 grabs were taken within each transect. The sediment was washed through a 2 mm sieve and the posterior-anterior length of all *Corbicula* was measured with Vernier callipers.

RESULTS

DISTRIBUTION OF *C. FLUMINEA* IN BRITAIN

C. fluminea has been recorded in four discrete regions of the Norfolk Broads, but all sites fall within a small radius of 12 km (Fig. 1). The locations range from shallow (<1 m), essentially lentic environments (e.g. Hardley Flood adjacent to the River Chet), to relatively wide (*c.* 30 m), deep (>3 m), flowing channels (e.g. River Waveney). The population in the River Chet contains the greatest densities with a mean catch per unit effort (CPUE) of 29.5 (SE ± 17.5) clams per dredge, compared with a CPUE of <1 at all the other sites.

POPULATION STRUCTURE IN THE RIVER CHET

C. fluminea is distributed along a 3 km stretch of the River Chet and clams were also found in Hardley Flood in regions that connect it to the river (Fig. 2). No clams have been collected downstream of Norton Marshes or upstream of Redgrave Common. A total of 752 live *Corbicula* were collected but no dead shells were found. The population density is highest 1 km downriver of Hardley flood, where a single grab gave an estimate of 2500 individuals m^{-2}. The population is dominated by small (2–9 mm) individuals which appear to belong to a discrete cohort (Fig. 3). Despite the large sample size, it is unclear how many cohorts are present amongst the larger size classes.

DISCUSSION

C. FLUMINEA IN BRITAIN

The absence of dead shells in any of the sites studied suggests that *C. fluminea* is a relatively new arrival to Britain. The longest lived populations have a lifespan of 3 years in both Asia (Morton, 1977) and North America (Eng, 1979), suggesting that the species cannot have arrived in East Anglia much before 1997. It is unclear what mechanisms are important in the dispersal of *Corbicula*. It has been suggested that juvenile clams may be transported in boat bilge water or in bait buckets, while adults may be transferred by the aquarium trade or in river gravel shipped in barges (Thompson & Sparks, 1977 & references therein). Within East Anglia it is likely that pleasure boats will function as important agents of transport, especially where the anchor is dropped into sediments containing *Corbicula*. Asiatic clams can form an important part of the diet of waterfowl (Phelps, 1994) and fish such as common carp, *Cyprinus carpio* (Rinne, 1974; Morton, 1979) and these organisms may serve as important vectors. Thompson & Sparks (1977) showed that while *C. fluminea* could not survive passage through the digestive tract of lesser scaup ducks, *Aythya affinis*, the clam would survive regurgitation from the gizzard; this may enable the clams to be transported short distances over land and sea. Furthermore, Oka *et al.* (1999) found that in Japanese lakes *Corbicula japonica* could survive within the gizzards of tufted ducks, *Aythya fuligula*, and that two thirds of the ducks studied fed solely on *Corbicula*.

POTENTIAL IMPACTS

Economic

C. fluminea has become a major pest in much of North America and Europe because of its high reproductive output, rapid growth rate, free-living juvenile stage and great powers of dispersal. All these characteristics enable *C. fluminea* to quickly invade disturbed and poorly colonised sites. *C. fluminea* has caused major problems in North America because live animals and dead shells block irrigation systems; such systems must be perenially dewatered and the clams physically removed. Of even greater concern is the ability of juvenile clams to be carried into condensers of electrical generating facilities where they attach to the walls by their mucilagenous byssus threads and ultimately grow and impede the flow of water. A number of nuclear reactors have had to be closed down temporarily in the United States so that *Corbicula* can be removed mechanically from the emergency cooling systems (Isom, 1986).

High densities of Asian clams have devastated industries in Ohio and Tennessee where river beds are dredged for sand and gravel for use as aggregation material in cement (Sinclair & Isom, 1961 in McMahon, 1983). The clams become incorporated in the cement and burrow to the surface as the cement begins to set, thus structurally weakening it.

Ecological

The massive densities that Asiatic clam populations can reach (up to 131,000 clams m^{-2}; Eng, 1977) can have a major impact on freshwater ecosystems. Numerous studies have shown that the filter feeding of *C. fluminea* has led to a significant removal of suspended particulate matter from the water column. For example, Cohen *et al.* (1984) found that *Corbicula* was responsible for a major decline in phytoplankton in the Potomac River and Leff *et al.* (1990) recorded a decline in seston which was attributable to *Corbicula*. Such a decline in suspended particles has an important knock-on effect to the rest of the biota. Such system-level changes are exemplified by Phelps (1994) who showed that arrival of *Corbicula* in the Potomac River estuary led to a decline in phytoplankton, but an increase in submerged aquatic vegetation, fish populations and bird populations (particularly diving ducks that feed on molluscs).

There has been some concern in North America that *Corbicula* could lead to the decline of threatened native unionid mussels by outcompeting the unionids for habitat and food. This issue is of particular concern in Britain because rivers in Eastern England, including the River Waveney, contain internationally important populations of the depressed river mussel, *Pseudanodonta complanata* (Rossmässler) (Müller, 1999), which is a priority species for conservation on the UK Biodiversity Action Plan (BAP) (HMSO, 1996). However, no studies in North America have yet shown *Corbicula* to be directly responsible for declines in unionids (Leff *et al.*, 1990; Miller & Payne, 1994).

As well as impacting on the cycling of nutrients and organic carbon in the water column, *Corbicula* has a marked effect on organic matter dynamics in streambed sediments (Hakenkamp & Palmer, 1999). It is able to pedal-feed and thus deplete sediments of their organic content, and produces vast quantities of pseudofaeces that increase the

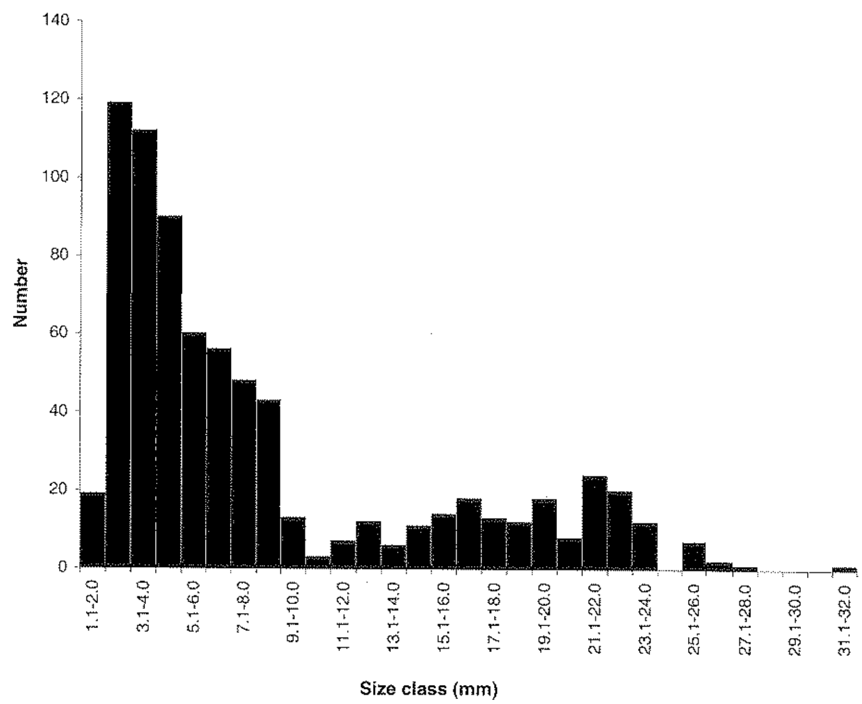

Fig. 3 Size-frequency distribution of *Corbicula fluminea* in the River Chet in Februray 2000. Data are combined from a total of 34 grab samples along 3 km of river.

rate of sedimentation. If sedimentation rates increase in the Norfolk Broads we would predict a requirement for more regular dredging programmes to maintain flows and navigability; this would be costly and have further deleterious impacts on the river ecosystem (Aldridge, in press).

CONCLUSIONS

Given the huge densities already recorded in the Rivers Chet, it is likely that *Corbicula* will have a major economic and ecological effect in Britain. The rapid spread of *Corbicula* in East Anglia suggests that there is little possibility that the species can be eradicated, particularly if the separate populations in Britain represent different invasion events. No species-specific techniques are available for the eradication of *Corbicula*, although biological control using crayfish (Covich *et al.*, 1981) or benthic-foraging fish (Robinson & Wellborn, 1988) may serve to control population densities. The best that can be done is to investigate ways of controlling and containing as much as possible the spread of *Corbicula*.

It is important that every effort should be made to minimise human-mediated transport of *Corbicula*. This should include efforts to wash-down boats used in research and barges used in transporting river sediments in sites known to contain *Corbicula*. Washing-down should be undertaken upstream of the lowest limit of the known *Corbicula* distribution to prevent accidental dispersal. Where equipment such as hand dredges and nets are used in surveys it is appropriate that the equipment should be thoroughly cleaned. Whilst more information is needed on appropriate methods for cleaning equipment, hot (> 50°C), chlorinated water appears to be effective (Thompson & Sparks, 1977 & pers. observ.).

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