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Status of Asian Clam

in the mid-River Shannon and recommendations for its management

October 2014

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1 Scope of report

This preliminary report was produced for an inter-agency meeting on the 17/10/2014 as part of a rapid reaction response to the recent discovery of a sizeable population of the highly invasive Asian clam in the hotwater stretch at Lanesborough, Co. Longford. It details the work undertaken to establish the distribution and population status of the Asian clam in the mid-River Shannon (from Termonbarry *via* Lanesborough-Ballyleague to its inflow in Lough Ree), presents the preliminary results of the survey and provides management recommendations to mitigate the threat from this highly invasive aquatic species. A more complete technical and scientific document will be produced in due course.

2 Introduction

2.1 Asian Clam in Ireland

The Asian clam was first recorded in Ireland from the lower section of the River Barrow at St Mullin's in April 2010 (Sweeney 2019). A subsequent investigation by Inland Fisheries Ireland (IFI) to investigate the status of the find revealed the presence of a large and sustainable population in the immediate downstream vicinity of St Mullin's. Further investigations using scuba divers reported that the Asian clam populations in the River Barrow extended downstream to the saline waters at New Ross and upstream to Inistioge in the connected River Nore (Caffrey *et al*. 2011).

In September 2010 the presence of small but sustainable populations of Asian clam was reported from Carrick on Shannon, in the upper reaches of the River Shannon catchment (Hayden and Caffrey 2013). Later this year another sighting of the invasive Asian clam was made in Lough Derg, where two small and discrete populations were present.

Through 2011 to 2014 further detailed surveys were conducted by IFI staff and others to determine the extent of the Asian clam populations in Ireland, but primarily in the Rivers Barrow, Nore and Shannon catchment. Small populations were reported from Portumna on the lower River Shannon (Minchin pers. comm.) and a single Asian clam was recorded from the Lanesborough area in 2013 (Sheehan pers. comm.). In March 2014 an extensive benthic survey of Lough Ree, which is located immediately downstream of Lanesborough-Ballyleague, produced no specimens at all. During this investigation in excess of 200 sites were specifically examined to determine the presence or otherwise of Asian clam.

2.2 Asian Clam at Lanesborough

In September 2014 a large population of Asian clam was located in the hotwater stretch of the River Shannon, below the hot water discharge from the ESB electricity generating station at Lanesborough. Initial observations revealed large numbers of live Asian clams inhabiting the coarse substrate in this shallow (to 2 metres) and warm water habitat. As a consequence of the threat that an infestation of Asian clam in this mid-Shannon area might have on angling and tourism in general, IFI temporarily closed the fishery at the hotwater stretch in Lanesborough and erected signage alerting anglers and others of the presence of this invasive organism in the water.

Angling in Ireland is worth €755 million per annum and up to10,000 job equivalents (IFI, 2013). The threat posed by Asian clam populations to angling, resident fishes and the aquatic habitat is recognised (Caffrey *et al*. 2011) and necessitated this rapid response. Anglers and local community groups were informed that the fishery would be reopened as soon as effective biosecurity measures were put in place to minimise the risk of anglers

inadvertently moving juvenile clams on their keep or landing nets from the Lanesborough stretch to other, as yet, uninfested waters.

2.3 Survey objectives

Following meetings convened by IFI with local angling interests, community groups and relevant agencies (ESB, Waterways Ireland, OPW, Bord na Mona, NPWS, County Councils) it was agreed that no further action would be taken until a detailed scientific survey of the area was undertaken by IFI. The objectives of this survey would be:

- to accurately determine the status (presence or absence and relative abundance) of Asian clam populations in the mid-Shannon area, from Termonbarry (10 km upstream of Lanesborough-Ballyleague) to the mouth of Lough Ree;
- to focus survey efforts on the River Shannon in the immediate vicinity of Lanesborough-Ballyleague to determine if the Asian clams were concentrated in the hotwater stretch or were more evenly distributed in the main river; and
- to cursorily examine the spawning status of live Asian clams recorded throughout the survey.

This report details the work undertaken to establish the distribution and population status of Asian clam in the mid-River Shannon (from Termonbarry *via* Lanesborough-Ballyleague to its inflow in Lough Ree) in response to the discovery of a substantial population in the hotwater stretch at Lanesborough, Co. Longford. The report presents the results of the survey and provides management recommendations to mitigate the threat from this highly invasive aquatic species.

Plate 1 Asian clams in the hotwater stretch in Lanesborough

3 Methods

3.1 Study area

The distribution and abundance of Asian clam was assessed in a 14 km-long section of the River Shannon from Termonbarry on the Longford-Roscommon border downstream *via* Lanesborough-Ballyleague to its inflow at the northernmost part of Lough Ree (Figure 1). Particular attention was given to the *c.* 400 m-long 'hotwater stretch' which discharges from the ESB Power Station at Lanesborough (Figure 2) where preliminary observations suggested an abundant clam population was present. Sampling effort was also focused in the adjacent main River Shannon channel which runs parallel to the hotwater stretch in Lanesborough-Ballyleague (Figure 2). Further sampling was undertaken in the River Shannon directly downstream of Lanesborough-Ballyleague and in the navigation cut which links the River Shannon to Lough Ree (Figure 3).

Lough Ree is designated as a Special Area of Conservation (Site Code: 000440) and Special Protection Area (004064) under the European Community Birds or Habitats Directive (European Community 1992).

3.2 Field sampling

Three sampling methods were used during the course of the field investigations in order to detect the presence, establish the distribution and determine the abundance of Asian clam in the study area as follows:

- Benthic hand-dredge (50m-long tows)
- Van Ween grab (area sampled = 0.05 m^2)
- Surber sampler (area sampled = 0.25 m^2)

Benthic hand-dredges provided a means of rapidly surveying sites to detect the presence of Asian clam over a much larger area than the other two point sampling methods employed. This sampling method also facilitated a comparison of the relative abundance of clams between sites. The Van Ween grab and surber samplers enabled the quantitative assessment of Asian clam density and wet weight (per m^2) in areas known from preliminary observations to be abundant in clams (i.e. hot water flow at Lanesborough).

Sixty-two sites were examined for the presence of Asian clams using a benthic hand-dredge from **Termonbarry downstream to the input point of the hotwater stretch at Lanesborough-Ballyleague** (Figure 1). Working downstream, sites were sampled at 200m intervals until 1 km above the input point of the hotwater stretch where sampling intensity was increased to 100m intervals (site code: **TL**). At each sampling site, the hand-dredge was deployed from a boat and slowly towed a distance of 50m. Three replicate samples were taken per site.

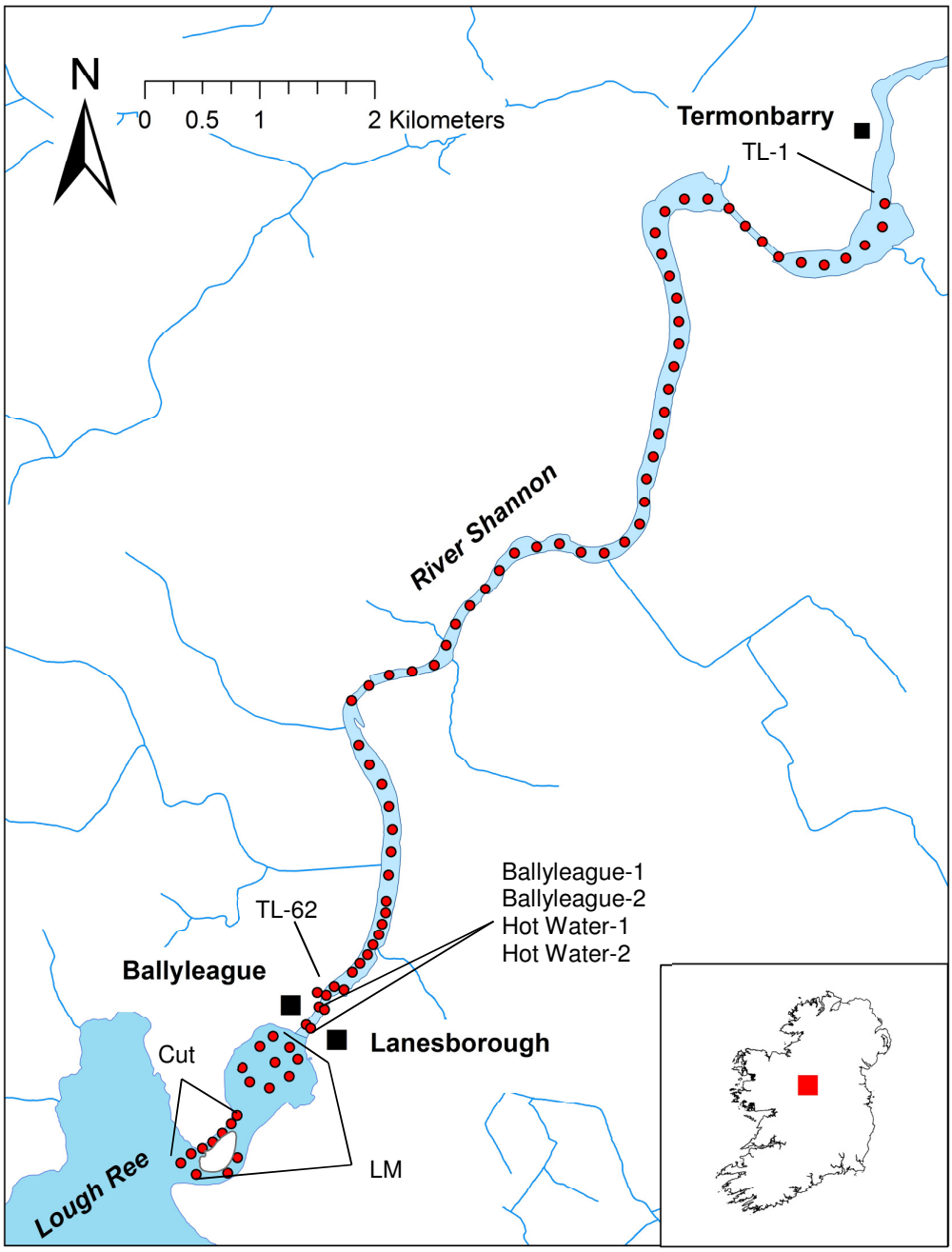

Figure 1 Section of the River Shannon from Termonbarry to the Lough Ree inflow sampled for Asian clam in September / October 2014. (•= sampling sites).

In Lanesborough-Ballyleague, as preliminary observations indicated that Asian clams were abundant in the hotwater stretch, four *c.* 200m-long sections were intensively sampled as follows (Figure 2):

- **main river channel** upstream of the road bridge (site code: **Ballyleague-1**);
- **hotwater stretch** upstream of the road bridge (site code: **Hot Water-1)**;
- **main river channel** downstream of the road bridge (site code: **Ballyleague-2**); and
- **hotwater stretch** downstream of the road bridge (site code: **Hot Water-2**).

In each of the four sections, 10 hand-dredges (of 50m length each) and 10 benthic grab samples were taken. Grab sampling enabled a direct comparison to be made of clam density between the four sections. Further to this, 10 surber samples were taken in each hotwater section to provide an additional assessment of clam density (Plate 2). It was not possible to take surber samples in the main river channel due to prohibitive depths.

Three replicate hand-dredges were additionally taken in the public harbour upstream of Ballyleague (site code: Harbour).

Plate 2 Sampling apparatus used during the study (Van Ween grab; surber sampler and benthic hand-dredge).

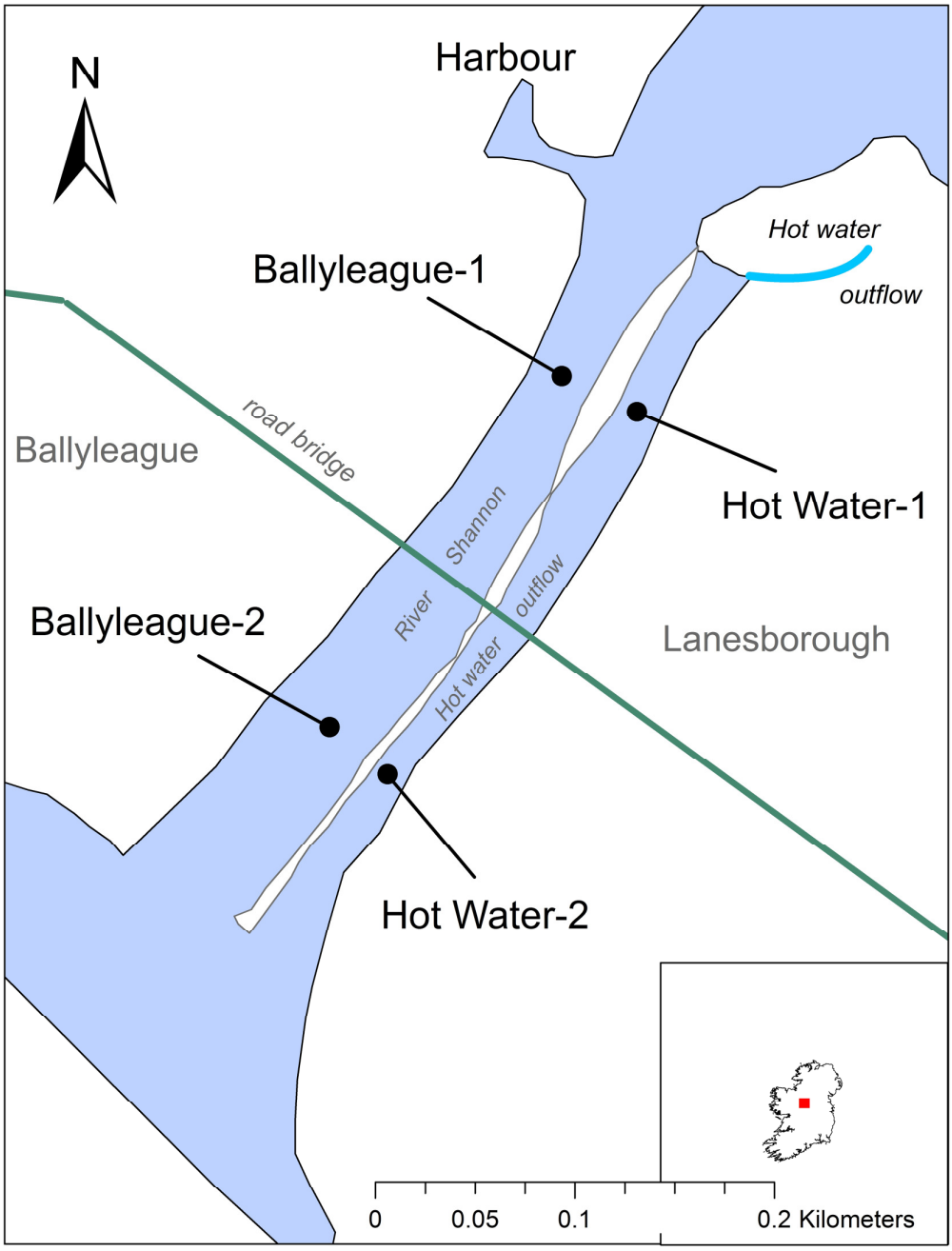

Figure 2 Areas in the main River Shannon channel and adjacent hotwater stretch of the ESB power station in Lanesborough-Ballyleague sampled for Asian clam in September / October 2014 (site codes: Ballyleague-1, Ballyleague-2, Hot Water-1 and Hot Water-2).

Downstream of Lanesborough-Ballyleague to Lough Ree, 19 locations were sampled for the presence of Asian clam using a hand-dredge (Figure 3). This included 12 sites in the main channel (site code: **LM**) and a further seven sites located at 100m intervals in the navigation cut (site code**: Cut**).

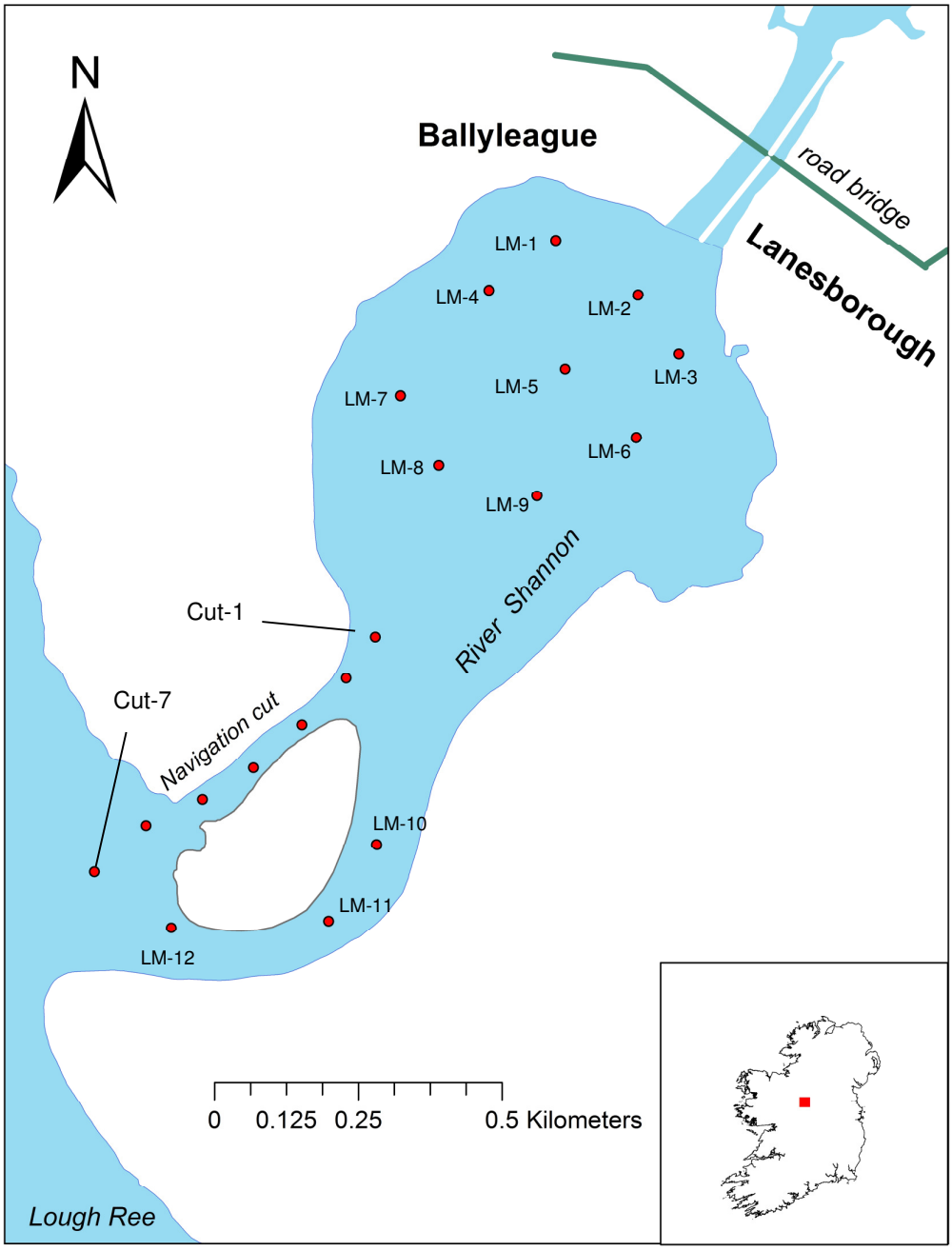

Figure 3 Section of the River Shannon downstream of Lanesborough-Ballyleague to the Lough Ree inflow sampled for Asian clam in September / October 2014 (•= sampling sites).

3.3 Sample processing and data analyses

Each sample was washed through 16 mm^2 sieve and the remaining contents were carefully examined in a white tray for the presence of clams. Counts were made of the number of Asian clams present in each sample and these were averaged per site and per study section.

The density of Asian clams per square metre was determined at sites where grab and / or surber samples were taken (i.e. main River Shannon [sites Ballyleague-1 & Ballyleague-2 and adjacent hotwater stretch in Lanesborough-Ballyleague [sites Hot Water-1 and Hot Water-2]). The shell height (umbo to gape) of up to 200 randomly selected clams per study section, if available, were measured to the nearest 1 mm using electronic calipers in order to generate length-frequency analyses (i.e. number of clams in each mm size class), examine the size distribution of clams in each study section and potentially identify any age-cohorts present.

Further to the above, a preliminary assessment of the spawning status of the Asian Clam in four sections of the study area (sites: Hot Water-1; Hot Water-2; Ballyleague (1 & 2); and CUT) was undertaken by Prof Jim Wilson (Trinity College Dublin - TCD).

4 Results

4.1 Overview

Asian clam populations were found to be occasionally present in very low abundance in the River Shannon from Termonbarry downstream to the input point of the hotwater stretch at Lanesborough-Ballyleague. In the hotwater stretch, a highly abundant clam population has established. This is not reflected in the adjacent main River Shannon channel where a very low abundance of clams was recorded. Downstream of Lanesborough-Ballyleague, where the River Shannon widens, Asian clam populations were again recorded in very low abundance. However, a moderately abundant population of relatively small-sized clams, compared to the hotwater stretch, was found to be present in the navigation cut which enters Lough Ree.

4.2 Distribution and abundance of Asian clams in study area

Asian clams were recorded at 28 of the 86 sites examined in the study area (Figure 5). From Termonbarry downstream to the input point of the hotwater stretch at Lanesborough-Ballyleague (TL), clams were detected in low abundance at only seven of the 62 sites examined (Figure 4 and Figure 5). At five of these sites (TL-7, TL-8, TL-33, TL-57 and TL-58) only single clams were recovered in the hand-dredge. At a further two sites, TL-55 and UL-60, only 3 and 5 clams, respectively, were found (Figure 5).

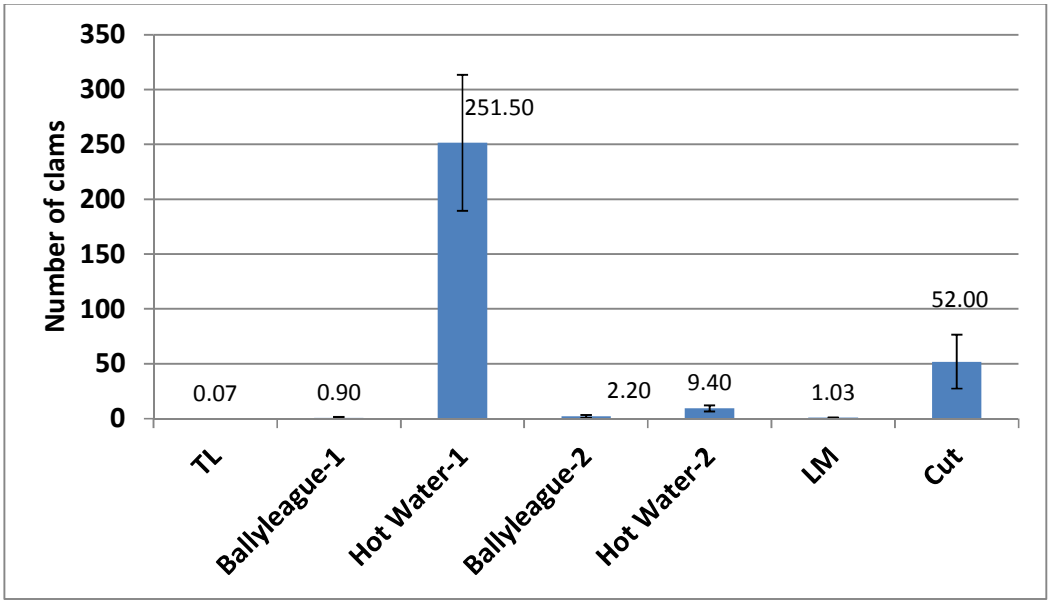

Figure 4 Mean number of Asian clams in hand-dredge samples per section of study area (TL= Termonbarry downstream to the input point of the hotwater stretch at Lanesborough; Ballyleague-1 and Ballyleague-2 = main River Shannon channel in Lanesborough-Ballyleague upstream and downstream of the road bridge, respectively; Hot Water-1 and Hot Water-1 = hotwater stretch in Lanesborough-Ballyleague, upstream and downstream of the road bridge, respectively; LM = River Shannon downstream of Lanesborough-Ballyleague; and Cut = Lough Ree cut).

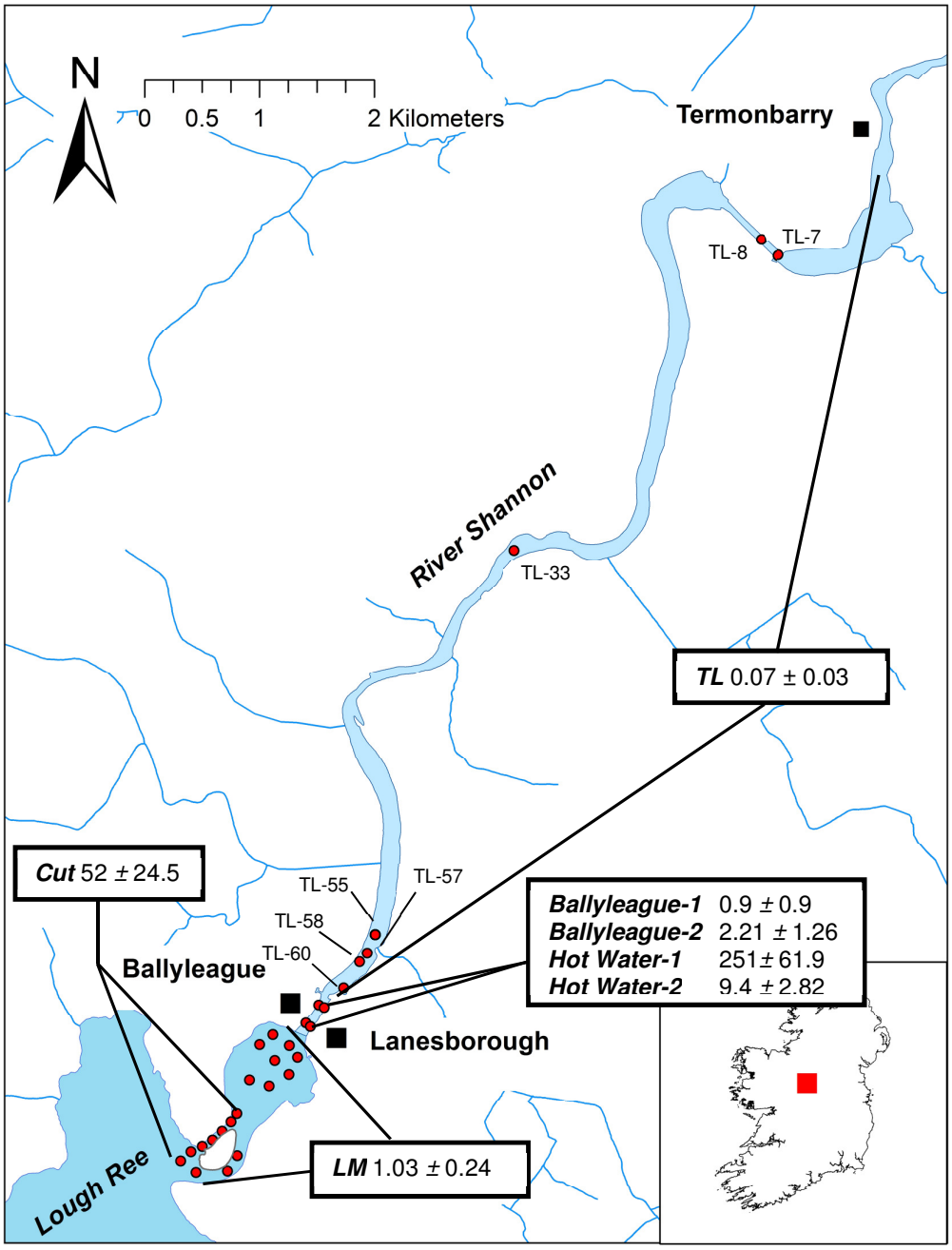

Figure 5 Distribution of Asian clam in the River Shannon from Termonbarry to the Lough Ree inflow sampled in September / October 2014. The mean number of clams ± standard error recorded from the hand-dredge samples per section of the study area is indicated (•= Asian clam present).

In the Lanesborough-Ballyleague area, Asian clams were recorded at all four sites examined (sites Ballyleague-1, Ballyleague-2, Hot Water-1 and Hot Water-2). The clams were significantly more abundant in both the hand-dredge and grab samples from both sites in the hotwater stretch than at the two corresponding sites in the adjacent main River Shannon (Figure 4 and Figure 7). In the hotwater stretch, a mean clam count of 251 ± 61.9 individuals was retrieved in the hand-dredge samples taken upstream of the bridge (Hot Water-1) and 9.4 ± 2.8 clams were recorded in this section downstream of the bridge (Hot Water-2; dredge sampling at this site was somewhat hampered by aquatic weeds). However, in the corresponding sites in the main River Shannon channel, very low mean numbers of clams were recorded (maximum mean of 2.2 ± 1.3 clams at site Ballyleague-2). Grab sampling indicated that the mean density of the Asian clam population per square metre was 92 – 193 times greater in the hotwater stretch than in the adjacent main River Shannon (Figure 7 and Figure 6). Mean densities of Asian clam were 3098 ± 515 individuals m^{-2} and 1486 ± 139 individuals m^{-2} upstream and downstream of the bridge, respectively. In comparison, mean densities of Asian clam upstream and downstream of the bridge in the main river channel were only 16 ± 16 individuals m^{-2} and 14 ± 5.2 individuals m^{-2}, respectively (Figure 7 and Figure 6).

Surber sampling confirmed the trend observed from the grab sampling which indicated the section of hotwater stretch upstream of the bridge (Hot Water-1) which was nearer the input point, had a greater abundance of clams present than the hotwater section sampled (Hot Water-2) downstream of the bridge (5109 ± 814 and 1370 ± 241, respectively) (Figure 7 and Figure 8).

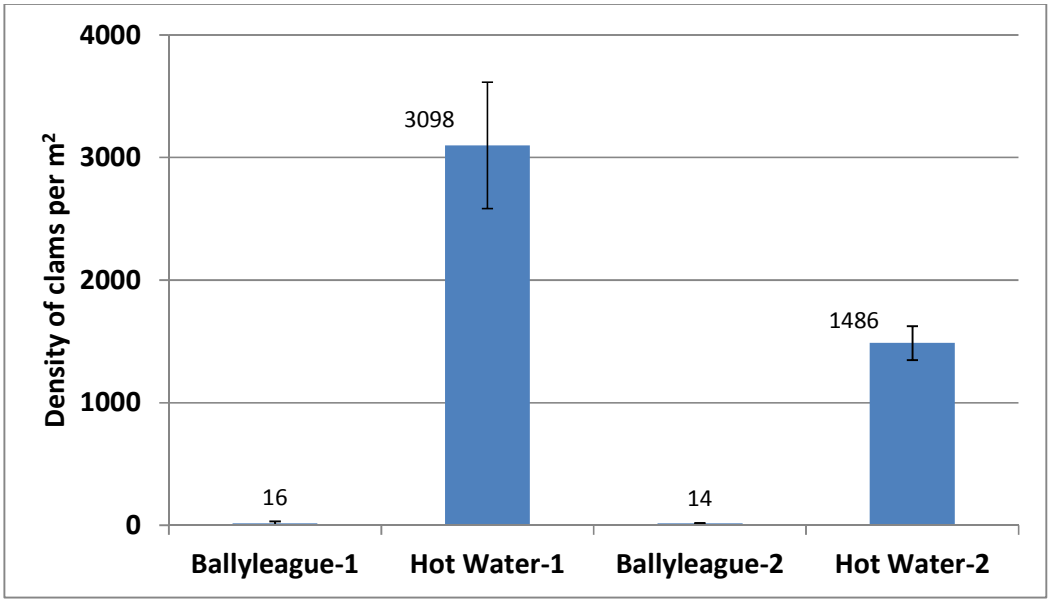

Figure 6 Density of Asian clam population per m^2 in Lanesborough-Ballyleague from Van Ween grab samples (Ballyleague-1 and Ballyleague-2 = main River Shannon channel in Lanesborough-Ballyleague above and below the road bridge, respectively; Hot Water-1 and Hot Water-2 = hotwater stretch in Lanesborough-Ballyleague, upstream and downstream of the road bridge, respectively).

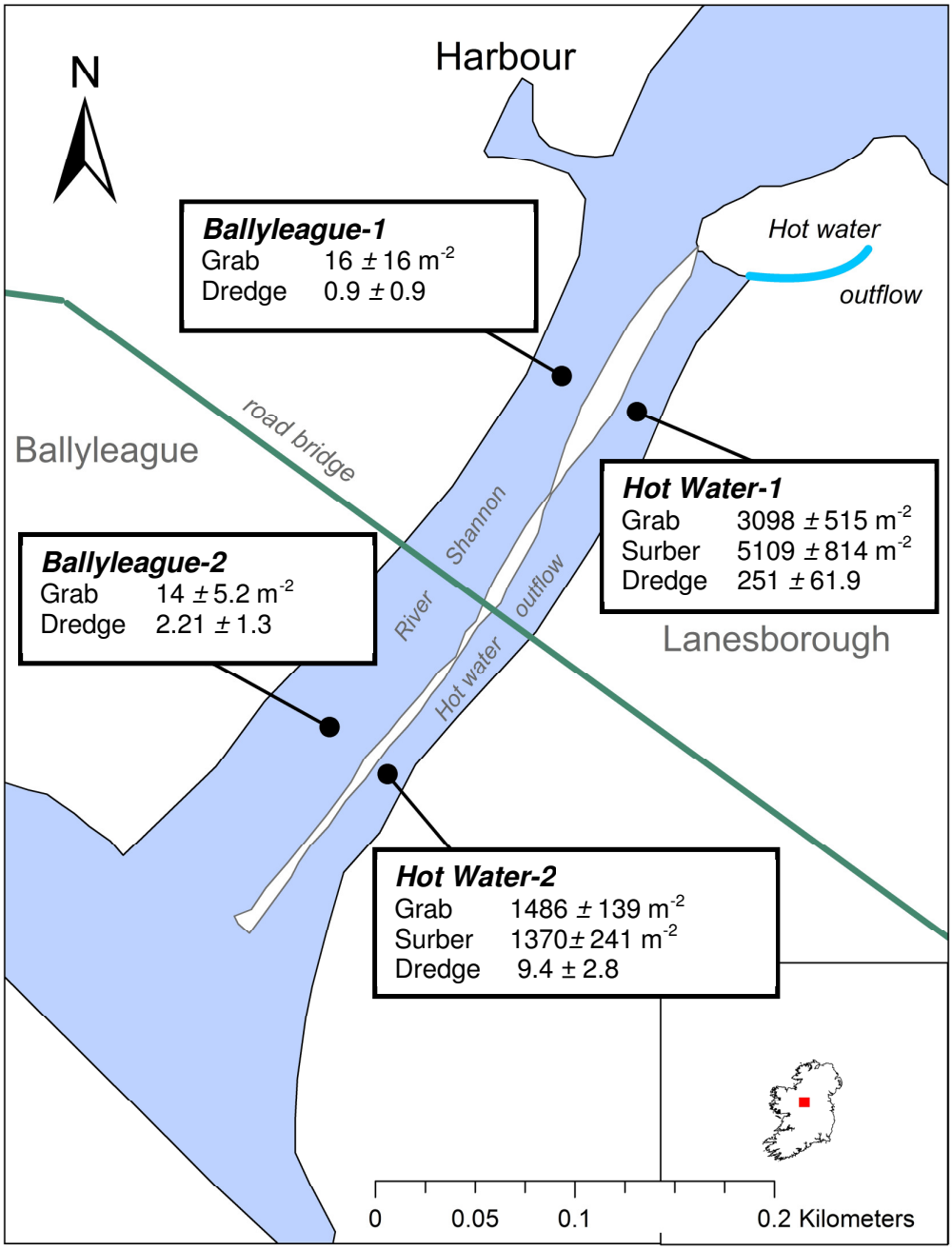

Figure 7 Map of Ballyleague-Lanesborough showing 1) respective mean densities of Asian clams recorded per square metre from Van Ween grab and surber samples; and 2) mean numbers of clams recorded in hand-dredge samples; at each sampling site.

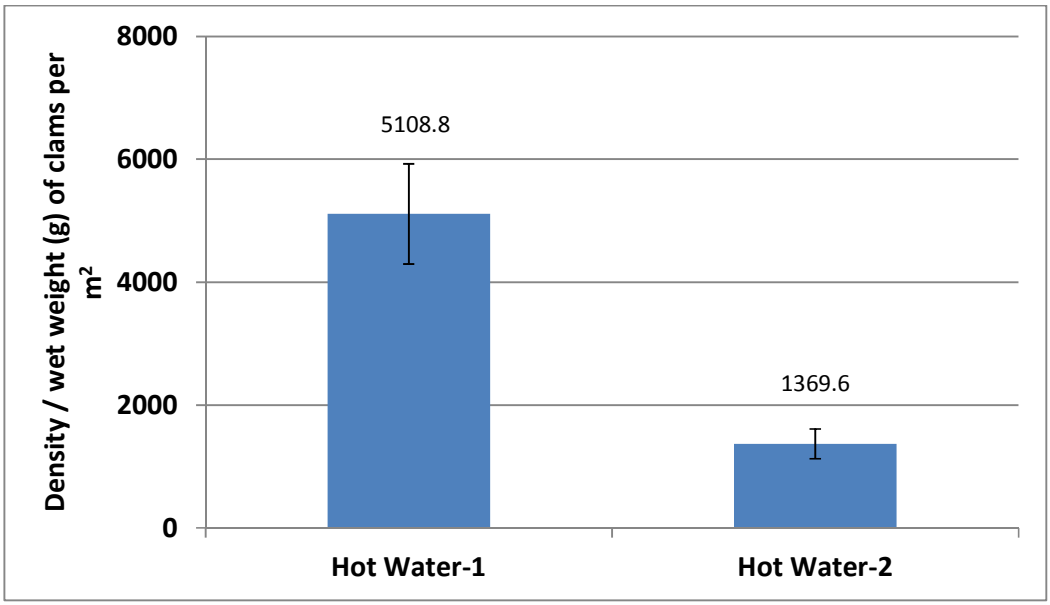

Figure 8 Mean density per m^2 of Asian clam population in Lanesborough-Ballyleague from surber samples (Hot Water-1 and Hot Water-2 = hotwater stretch in Lanesborough-Ballyleague, upstream and downstream of the road bridge, respectively).

Downstream of Lanesborough-Ballyleague, where the River Shannon widens, Asian clam populations were recorded in very low abundance with an average number of 1.03 ± 0.24 clams retrieved in the hand-dredges (Figure 4 and Figure 5). The highest number of clams was recorded at site LM-9 (9 clams in total), followed by sites LM-1, LM-5 and LM-12 (6 clams at each site). In the navigation cut which leads to Lough Ree, a moderately abundant population of relatively small-sized Asian clams was recorded (Figure 4 and Figure 5). In this section, an average number of 52 ± 24.5 clams were retrieved in the hand-dredges (maximum mean was at site CUT-1 of 167 ± 27.9 clams).

4.3 Length-frequencies of clams in study area

The Asian clam population in both hotwater stretch sites (sites: Hot Water-1 and Hot Water-2) had a much higher relative frequency of larger clams present than all other sampling sections in the study area (Figure 9 - Figure 15). Clear age-cohorts are not obviously identifiable in the length-frequency plots at these two sites but probably consist of a number of age cohorts (Figure 9 and Figure 10). The difficulty in determining distinct age-cohorts in the hotwater stretch reflects the fact that the clams are immersed in warm water throughout the year, enabling them to actively feed during all 12 months. As a consequence, the clams will probably exhibit faster growth rates than their equivalent in cold water situations. The Asian clam population in the Lough Ree navigation cut (site: Cut) was dominated by small clams in the 5-10 mm size range and probably represent a single age-cohort, likely to be from this year's spawning event (Figure 11). The low numbers of clams in other study sections in the main channel of the River Shannon

precluded any attempt to identify age cohorts. However, such sites appear to be predominated by smaller-sized clams.

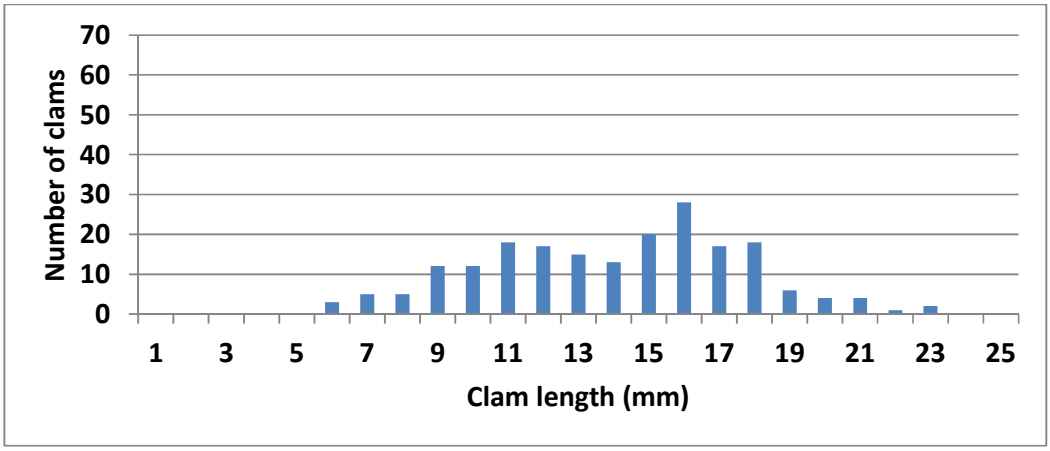

Figure 9 Length-frequency of Asian clam population in the hotwater stretch upstream of the road bridge in Ballyleague-Lanesborough (site: Hot Water-1; n= 200).

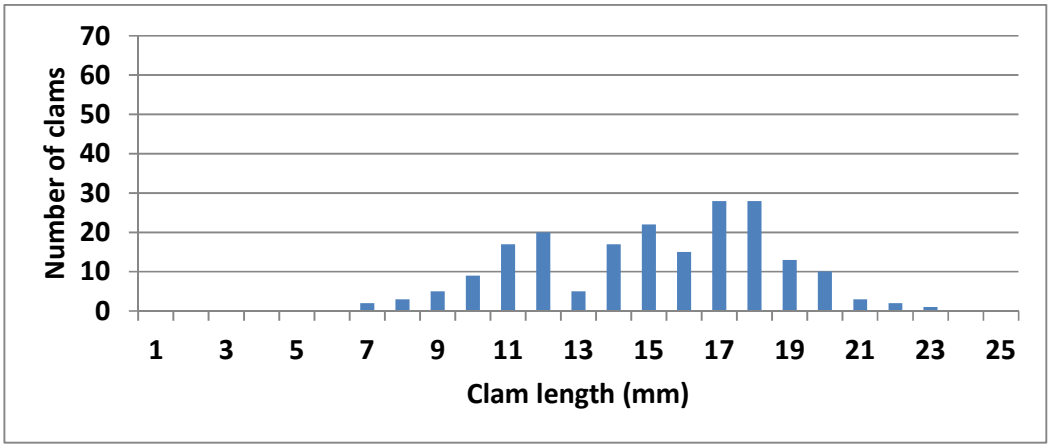

Figure 10 Length-frequency of Asian clam population in the hotwater stretch downstream of the road bridge in Ballyleague-Lanesborough (site: Hot Water-2; n= 200).

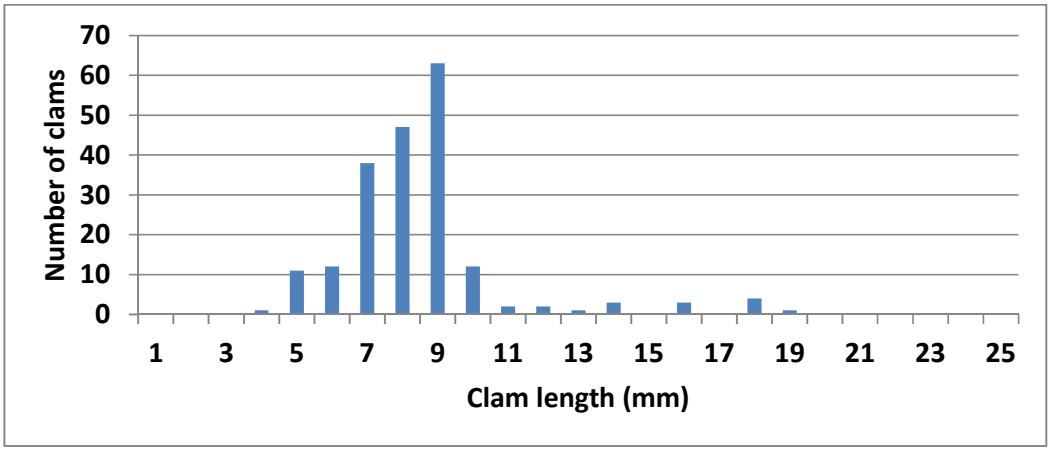

Figure 11 Length-frequency of Asian clam population in the navigation cut entering Lough Ree (site: CUT; n=200).

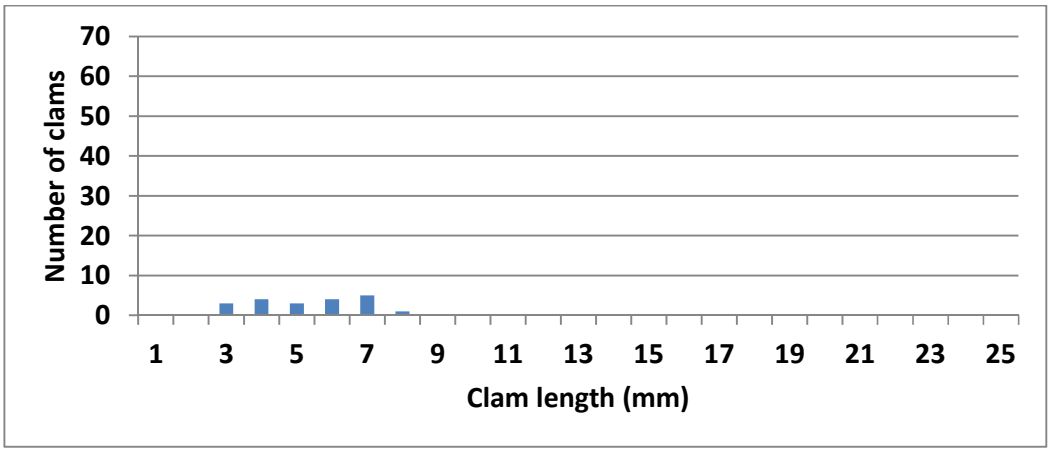

Figure 12 Length-frequency of Asian clam population in the River Shannon main channel upstream of the road bridge in Ballyleague-Lanesborough (site: Ballyleague-1; n=17).

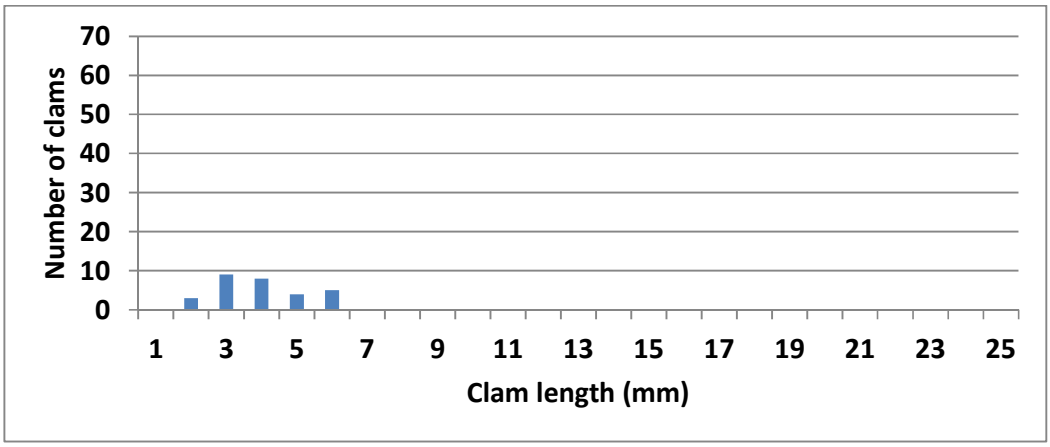

Figure 13 Length-frequency of Asian clam population in the River Shannon main channel downstream of the road bridge in Ballyleague-Lanesborough (site: Ballyleague-2; n= 29).

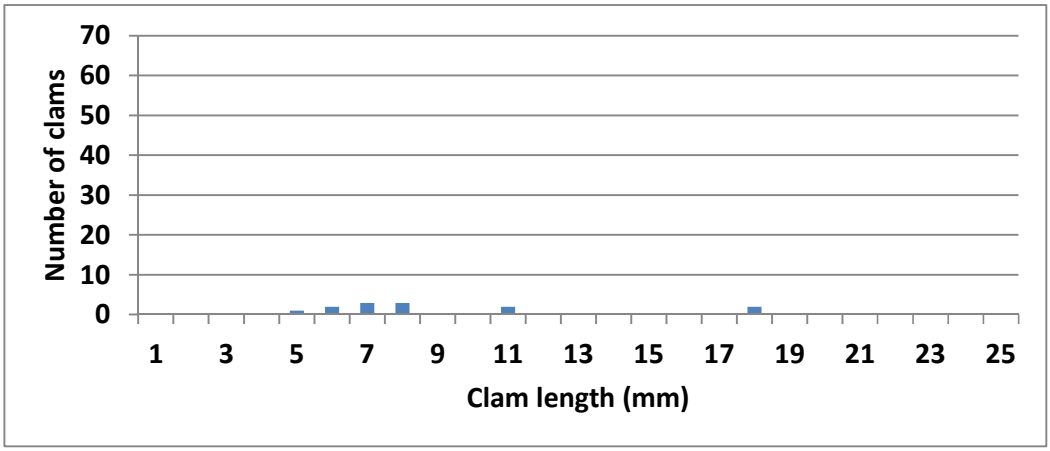

Figure 14 Length-frequency of Asian clam population in the River Shannon at sites from Termonbarry downstream to the input point of the hotwater stretch in Lanesborough-Ballyleague (site: TL; n=13).

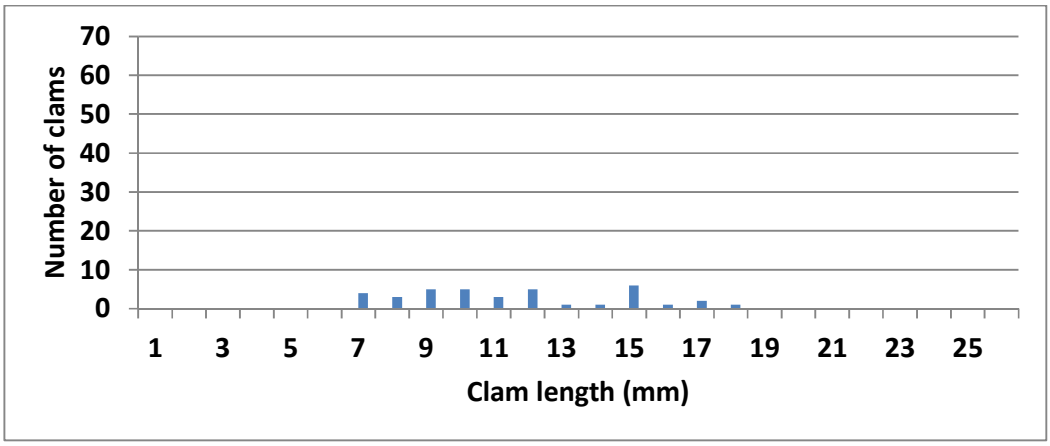

Figure 15 Length-frequency of Asian clam population in the River Shannon at sites downstream from Lanesborough-Ballyleague to Lough Ree (site: LM; n= 37).

4.4 Asian clam spawning

Preliminary results suggest that some Asian clams were spawning at all four study sections examined (sites: Hot Water-1; Hot Water-2; Ballyleague (1 & 2); and CUT) as identified by the presence of shelled larvae (D-hinge at release stage) in the parent gill. All spawning specimens were found to be well spent with little gonad tissue remaining. In contrast, River Barrow clam samples examined in the same period had no larvae present and had finished spawning (personal communication, Prof Jim Wilson, TCD).

5 Discussion

The Asian clam is a most unwelcome recent addition to the fauna of Irish rivers and lakes. It is regarded as one of the most notorious aquatic invasive species in the world. In the USA, the clam causes millions of dollars worth of damage to intake pipes used in the water and power industries. Large numbers can clog water intake pipes and the cost of removing them is estimated at about $1 billion US dollars each year (Global Invasive Species Database 2005; CABI 2012).

The majority of freshwaters in Ireland are considered suitable for the establishment of Asian clam with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters. It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005).

The inadvertent introduction and transfer of Asian clam to uninfested waterways represent a major threat to Ireland's habitats, native species and internationally renowned fisheries. The ecology of invaded watercourses can become dramatically altered and may become unsuitable for water-based amenity and recreational pursuits. Asian clam infestations also have the potential to clog up brown trout and Atlantic salmon spawning grounds (Millane and Caffrey 2014). According to Lucy *et al*. (2012), "potential economic damage in Ireland may include interference with power plant operation, drinking water abstraction from lakes and other industries using raw water". There may also be financial implications if conservations goals such as those specified in the EC Habitats Directive and the EU Water Framework Directive are under threat. Further to the above, if Asian clam has a detrimental effect on the abundance of important angling species such as Atlantic salmon or brown trout, this has the potential to incur economic costs due to reduced angling revenue and related income (Millane and Caffrey 2014). Both the economic and ecological impacts of Asian clam will depend on their population density in a given waterbody. When high densities are attained over large areas, the clams can filter large volumes of water in short periods of time, in turn depositing vast quantities of organic matter on the bottom. This can ultimately upset normal function and natural processes in an aquatic ecosystem with detrimental consequences for a range of resident native flora and fauna (reviewed Karatayev *et al*. 2005, 2007).

There are a number of key biological characteristics of Asian clam that facilitate its establishment. The species has a high reproductive capacity (including the ability to self-fertilise and early sexual maturity), high natural dispersal ability and rapid growth rate. (reviewed in Sousa *et al*. 2008; Caffrey *et al*. 2011 and Lucy *et al*. 2012). In the River Barrow, Asian clam has attained staggering densities of up to 13,667 clams per square metre (Sheehan *et al*. 2012). Considering that each clam can produce up to 70,000 juveniles each year, the potential for the enormous expansion of a large resident

population is apparent. When reproducing, adult clams release vast quantities of planktonic juveniles into the water.

Once the species is introduced into a waterway, natural spread can occur passively downstream with the water currents, and also upstream, although much more slowly (reviewed in Lucy *et al*. 2012). The clams are able to move locally by pedal locomotion. Pediveliger larvae or small juveniles (<2 mm), released by the adults, can remain suspended in the water column and be transported long distances on water currents prior to settlement (reviewed in Lucy *et al*. 2012, Barbour *et al*. 2013 and Minchin 2014). Sticky byssal threads also allow pediveliger and juvenile Asian clam to spread by attachment to equipment used in water such as boats, trailers, engines or angling gear (reviewed in Lucy *et al* . 2012, Barbour *et al*. 2013 and Minchin 2014). As Asian clam is a hermaphrodite and can self-fertilise, a single clam has the potential to start a new population after it spreads away from the parent population (Sousa *et al*. 2008). This further enhances its capacity for successful establishment after spread.

Asian clams are known to have established in sections of three river systems in Ireland thus far; the River Shannon, River Barrow and River Nore. However, the majority of habitat suitable for colonisation in Ireland has not been colonised to date (Lucy *et al*. 2012). The implementation of and adherence to strict biosecurity measures may slow the spread of Asian clam within presently colonised catchments and between catchments which are geographically isolated from infested areas. In addition, the implementation of control and containments measures in relatively confined areas already colonised by abundant localised, populations of Asian clam (e.g. the hotwater stretch at Lanesborough) can play an important role in contributing to this.

6 Management recommendations

The results from the survey conducted in September/October 2014 by IFI demonstrate that the primary breeding population of Asian clam in the mid-Shannon area immediately north of Lough Ree is concentrated in the hotwater stretch of the river, below the hot water discharge from the ESB electricity generating station. A secondary population was present in the navigation cut at the entrance to Lough Ree, although the vast majority of the Asian clam specimens recorded were ≤ 10 mm and were probably spawned only this year.

As very few Asian clams were present in the river upstream of or adjacent to the hotwater stretch, it is reasonable to assume that propagule pressure to infest Lough Ree, its tributary rivers and habitats, and ultimately the lower River Shannon will arise primarily from this short hotwater stretch of river. This provides an opportunity to intervene with a realistic expectation of significantly slowing the expansion rate of this breeding population and dramatically reducing the abundance of breeding individuals. The killing or removal of the majority of this relatively confined Asian clam population will restrict the spread of newly spawned juveniles from this area downstream to Lough Ree and further south in the River Shannon catchment.

It must be accepted that no intervention method will eradicate the Asian clam population from this section of river. However, the situation as it exists in the Lanesborough area is peculiar in that the clam population is relatively confined and can be easily accessed from land. Intensive intervention now will seriously impact the abundance and spawning potential of this population and, at least temporarily, reduce the infestation pressure on the Lough Ree catchment. For this reason, IFI is recommending that every endeavour is made to kill or remove as many clams as possible from the hotwater stretch of river and from the navigation cut at the entrance to Lough Ree.

Below are a number of management recommendations informed by the recent survey that could fill knowledge gaps pertaining to the Asian clam population in this section of the River Shannon and significantly reduce the abundance of the current resident populations.

6.1 Further studies

Research Programme

To understand how the ecology of this anthropogenically altered hotwater stretch of the River Shannon is affecting the performance, levels of abundance and growth, spawning potential and ultimate expansion of the Asian clam, further scientific investigation is required. Studies to elicit the required level of scientific information must be both field- and laboratory-based and should focus attention on the impact that the hot water

discharge from the ESB generating station has on all facets of the life cycle of resident Asian clams.

The objectives of this research programme would involve studies to determine:

- the influence of the hot water from the ESB electricity generating station on the life cycle features (see below) of the Asian clam in the Lanesborough area of the River Shannon;
- the effects of dredging (if conducted) on the population dynamics and life cycle features of the Asian clam in the hot water channel and in the lake downstream;
- recruitment of Asian clam (and associated communities) in the treated channel in the aftermath of dredging;
- alternative Asian clam control methods (e.g. temperature manipulation (increasing ex power plant or decreasing e.g. liquid N), benthic barriers, biobullet…); and
- biosecurity and pathways (anglers, boats, cruisers, etc.).

Life cycle/population features for 'hot water' and 'cold water' populations

IFI recommends that a scientific study should be conducted in partnership with a third level institute with a view to investigate factors such as the following:

- differential growth rates and feeding patterns;
- feeding activity throughout a 12 month cycle;
- age structure;
- density (overall and per age group);
- survival of all life stages (including smallest juveniles);
- dispersal from hotwater stretch (natural *via* mucilaginous threads/byssal threads);
- gonad development; age at maturity; spawning frequency, timing and success;
- condition factors in hotwater stretch and in the main river or lake;
- recruitment potential from spawned juveniles (*versus* new introductions); and
- impact of Asian clams, water temperature and dredging on indigenous invertebrate communities;

and following dredging:

- recruitment rate to dredged stretch; and
- growth rate and spawning potential in new habitat.

An approximate cost for a study of this nature would be in the region of €24k per annum with the potential for matching funding and support provided by the third level institute.

Survey of Lough Ree

While no Asian clam specimens were recorded in Lough Ree when it was surveyed in March 2014 by IFI, it is probable that some individuals have accessed the lake and that small, localised populations have become established. Indeed, small numbers of Asian clams have been recorded at the entrance to Lough Ree during this study. It will be important to conduct detailed surveys, probably annually, to determine the status of Asian clam populations in this prestigious angling and navigation watercourse.

6.2 Biosecurity

Lanesborough- Ballyleague

Four purpose-built disinfection stations have been purchased for both sides of the main road bridge at Lanesborough and Ballyleague, funded by ESB, for use by anglers fishing this stretch of river. One of the disinfection stations has been located adjacent to the slipway at Lanesborough and will be used by boating anglers to clean their nets and gear before leaving the fishery. Appropriate instructional signage will be erected and the stations will be operated by the local Tidy Towns Committee and angling club, with assistance from IFI.

Lough Ree

Lough Ree is an important mixed fishery and navigable waterway. As it is probable that sustainable populations are already present in the lake, though currently at very low levels, it will be necessary to ensure that effective biosecurity is in place around the lake to minimise the spread of this invasive species to other fisheries in the country. Anglers will be requested by IFI (and their clubs and Federations) to adhere strictly to IFI's biosecurity protocols for boaters - *The Disinfection of Boats and Boating Equipment* (http://www.fisheriesireland.ie/Biosecurity/biosecurity-for-boaters-and-anglers.html) and to ensure that their boat and engine is cleaned before moving it to another water.

All agencies that use the River Shannon must be biosecuruty aware and likewise adopt the above protocls. All recreational water users (e.g paddle sports enthusiasts, scuba divers, jet skiers and others) must also be included in this. Information literature should be produced to advise all water-based recreational users of the hazards posed by Asian clams and the biosecurity protocols that must be implemented to mininise their spread within the wider catchnment and indeed other catchments.

6.3 Dredging

Hotwater stretch

Dredging using long-reach, land-based machinery (as appropriate) should be used to remove the top 30 cm of substrate, plus Asian clams, from the entire length of the

hotwater stretch. It will be important to erect silt screens at the end of the dredging area and at any locations where water and disturbed material (possibly including clams) can discharge to the main river to stop disturbed clams being carried downstream.

In order to render this operation more effective it may also be necessary or beneficial to divert the hot water discharge from the existing 'canal' to the main river. This would allow for more efficient and targetted dredging and further increase the percentage of clams removed from the target area.

Spoil from the dredging will be removed in biosecure trucks (to avoid spillage while travelling) to landfill, where they will be buried beneath a shallow layer (50 cm) of soil. The designated disposal area should be located within the local catchment to minimise the risk of further inadvertent spread during transit.

IFI staff will be on hand to monitor the efficacy of the dredging operation by conducting sampling of the substrate in the immediate aftermath of the treatment. This will inform the machine operator of the appropriate depth to dredge and of areas that may need to be retreated. As eradication of the Asian clam in this stretch of river, even in the aftermath of dredging, is highly improbable, monitoring of the status of the organism in this area will be conducted annually and the need for retreatment will be relayed to the relevant agency. This may require the periodic dredging of the hot water stretch to prevent it becoming an established inoculum due to the opportunity for rapid growth.

Navigation Cut at Entrance to Lough Ree

The presence of a small population of juvenile Asian clams in the navigation cut at the entrance to Lough Ree is of concern and will need to be addressed to safeguard the lake and its tributary rivers from possible infestion. In order to remove or kill clams in this relatively wide and deep channel, consideration should be given to a number of options, which could include: the use of a conventional dredger on a pontoon, the use of a suction dredger (as employed by Waterways Ireland for some instream operations) or the use of benthic barriers, such as heavy plastic or jute. The latter operations would be very costly and would involve the use of a team of scuba divers over a prolonged period to ensure that the materials would be properly secured on the river bed. All spoil removed from the navigation cut would need to be brought to landfill and buried.

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8 Appendix 1 Summary of costs incurred to date

Item	**Cost (€)**
IFI ShRBD staff cost	2,900.42
IFI ShRBD non-staff survey costs	390
IFI Citywest staff costs	4981.96
IFI Citywest non-staff survey costs	500
Disinfection stations (ESB)	2,000
Total cost	**10772.38**

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