ZSL's Freshwater Mussel Survey in the Upper Tidal Thames

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Estuaries & Wetlands
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Introduction

Invasive Non-Native Species

The GB Non-Native Species Secretariat (GB NNSS) defines a non-native (or alien) species as one that has colonised outside of its natural distribution (past or present) as a result of human activity. A proportion of those non-native species are invasive (INNS) and are able to spread to such an extent that it causes harm to the environment, economy and sometimes human health (GB NNSS, 2017).

Estuaries such as the Tidal Thames are particularly vulnerable to invasions because they tend to be hubs for activities which facilitate the movement of INNS. Examples of vectors for aquatic INNS include ballast water, the hulls of ships to which INNS can attach, aquaculture and bait industries (Williams and Grosholz, 2008). Of the INNS known to have colonised UK freshwaters, 72% are present in the Tidal Thames, which could make it the source of many INNS around the rest of the UK (Jackson and Grey, 2012).

In response to the threats from INNS, the EU Invasive Alien Species (IAS) Regulation (1143/2014) came into force in January 2015. It details restrictions on the import, growth, sale, use and release of species considered to be of Union-wide concern. Following this, DEFRA published an updated Great Britain INNS Strategy (2015) which includes objectives for prevention, monitoring and management of INNS. The DEFRA Strategy also emphasises the need for coordinated management on a national and regional scale, which is supported by partnerships such as the London Invasive Species Initiative (LISI).

ZSL's freshwater bivalve survey in the upper Tidal Thames contributes towards the monitoring objectives of national and regional strategies including the DEFRA Strategy and the London Invasive Species Plan prepared by LISI.

Native Freshwater Mussels of the Tidal Thames

There are six species of freshwater mussel that are native to the UK, two of which (depressed river mussel *Pseudanodonta complanata* and pearl mussel *Margaritifera margaritifera*) have experienced large declines during the 20th century (University of Cambridge, 2011). Both species are now listed as species of principal importance in England under section 41 (England) of the Natural Environment and Rural Communities (NERC) Act 2006 (formerly UK Biodiversity Action Plan species).

Four native freshwater mussel species are present in the upper Tidal Thames, see **Figure 1**:

a. Depressed river mussel, *Pseudanodonta complanata*
b. Duck mussel, *Anodonta anatine*
c. Painter's mussel, *Unio pictorum*
d. Swollen river mussel, *Unio tumidus*

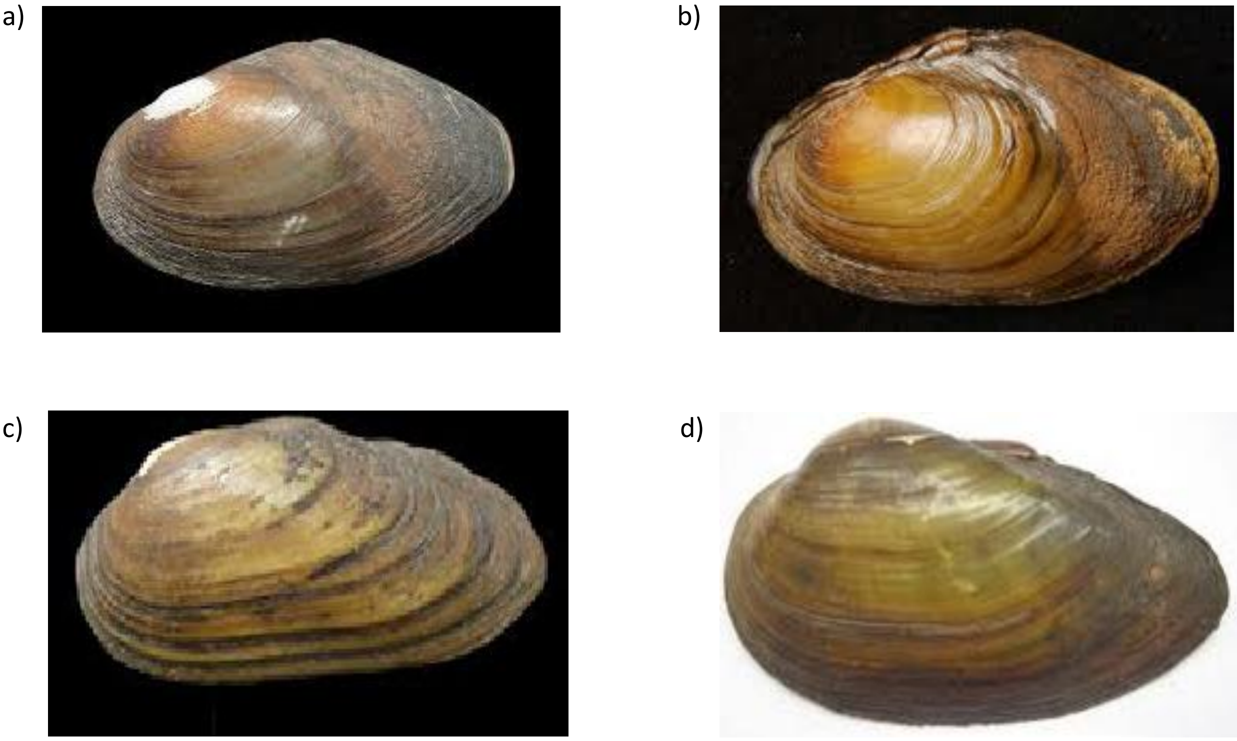

Figure 1: Native Freshwater Mussel Species Included in ZSL Survey – a) depressed river mussel, b) duck mussel, c) painter's mussel, and d) swollen river mussel

Bivalves play a key role providing vital ecosystems services such as nutrient cycling and water filtration (Vaughn *et al*., 2008). However, the UK's native freshwater mussels have slow growth rates, long life spans, and low fecundity, or 'k' selected strategists, meaning populations are often slow to recover following a decline (McMahon, 2002).

Non-Native Freshwater Mussels of the Tidal Thames

Bivalve mollusc INNS in the upper Tidal Thames include the zebra mussel (*Dreissena polymorpha*), Asiatic clam (*Corbicula fluminea*) and the recently introduced quagga mussel (*Dreissena bugensis*) (see **Figure 2**). All these species exhibit the typical traits of successful INNS; they adopt the 'r' life strategy characterised by high fecundity, high dispersal potential, rapid growth and maturation rates (Sousa *et al.*, 2014; McMahon, 2002). None of these species have particularly high physiological tolerance, but populations have the ability to recover numbers rapidly (McMahon, 2002). The quagga mussel is known to have similar invasive potential to the closely related zebra mussel, and has been found in areas that were initially invaded by the latter species (Beggel *et al*., 2015). As well as representing a direct threat to native mussels (Sousa *et al*., 2014 and Sousa *et al*., 2008), the high densities of both Asiatic clam and quagga mussel have the potential to significantly alter the entire ecosystem (Bodis *et al*., 2014).

a) b)

c)

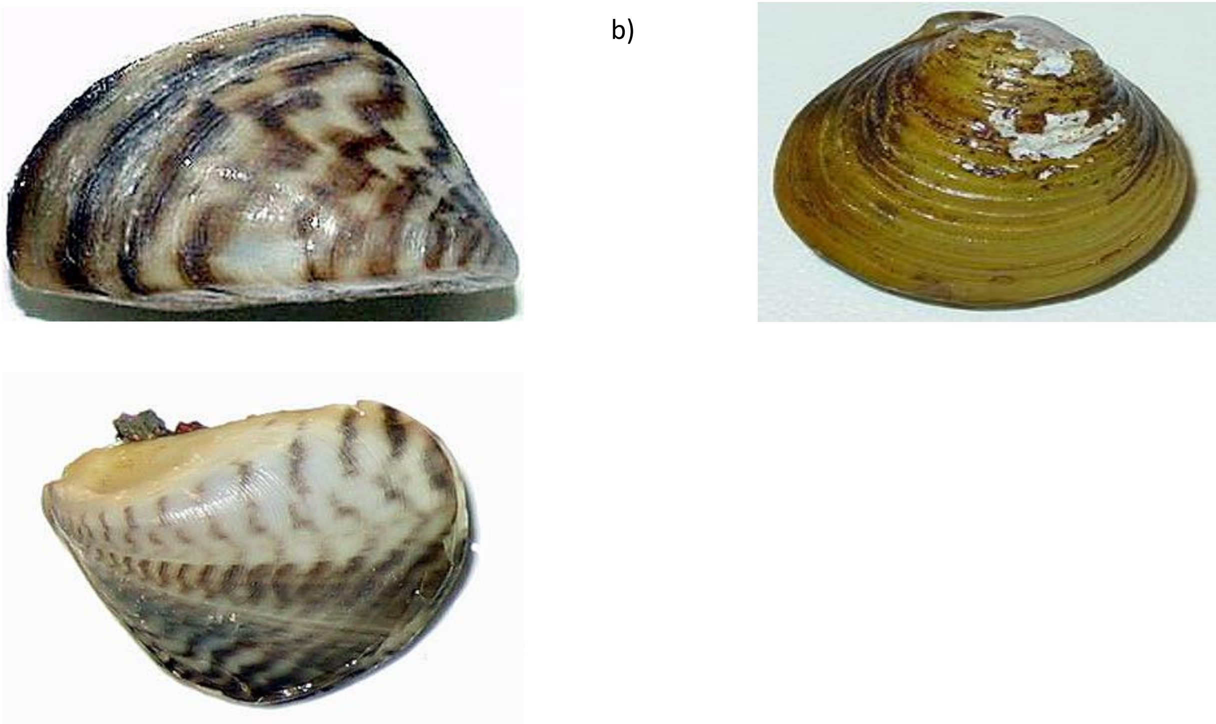

Figure 2: Bivalve Mollusc INNS in the Upper Tidal Thames – a) zebra mussel, b) Asiatic clam, and c) quagga mussel

Aims

The aims of the survey are to: a) assess the state of freshwater mussel populations in the upper Tidal Thames; b) enable early detection of new non-native species in the area; and c) gather a long-term dataset to help identify population trends.

Method

The annual ZSL survey is located on the Tidal Thames, in the Borough of Richmond upon Thames, in south-west London. The section of river surveyed lies upstream of Richmond half-lock and is usually semi tidal; however during November each year, the lock is opened for maintenance, allowing a full low tide. This exposes the benthic habitat, providing an opportunity to assess the bivalve community present.

A total of four sites (two on each bank) are surveyed (see **Table 1** and **Figure 3**) over two days. The 2017 survey only included the Glovers Island site on the Twickenham side of the river as the very low river levels experienced this year meant it took more time than usual to complete longer transects at the site. Leaving very little foreshore left by the time the survey team reached Orleans Gardens, which can get cut off by the rising tide.

Table 1: Site Locations for ZSL Upper Tidal Thames Freshwater Mussel Survey

Site Name	Latitude	Longitude
River Lane – Downstream, Petersham	51.449197	-0.305099
River Lane – Upstream, Petersham	51.448041	-0.307298
Glover's Island, Twickenham	51.448394	-0.309579
Orleans Garden, Twickenham	51.446403	-0.317349

Figure 3: Map of ZSL Freshwater Mussel Survey Locations on the Upper Tidal Thames

At each site, approximately 2 hours either side of low water, three transects are marked out from the riverbank to the water line at 5m intervals. A 0.25m^2 quadrat is laid at the riverbank end of each transect, and moved in 2m intervals down towards the waterline. The lengths of each transect, and therefore the number of quadrats analysed, is dependent on how much foreshore is exposed during the survey. In the 2017 survey, the transect lengths varied from 16 to 48 m. Each quadrat is examined by hand to a depth of 2cm, and all living individuals identified and counted. Surveys are carried out by ZSL conservation biologists and volunteer citizen scientists who are trained in the identification of bivalves at the beginning of the survey.

This report only present's data from the ZSL transects, which have followed the same methodology (as described above) since the surveys began in 2007. In 2017, ZSL were joined by Kings College London (KCL) student Daniel Mills who replicated the ZSL study and with volunteers examined an additional three transects. Data were also collected on percentage cover of different substrates (rock, gravel, sand, mud and shell), and measurements of pebble size and bivalve shell length were recorded. Further analysis of these data will be carried out by KCL separately and reported in Daniel Mills' PhD work.

Although the ZSL freshwater mussel survey in the upper Tidal Thames began in 2007, analysis for this report has focused on data collected after 2010 for which there is greater confidence in species-level identification.

Results

Overall, much higher average abundance and densities were recorded of invasive freshwater mollusc species in comparison to native species (see **Table 2** and **Figure 4**). The data indicates a decline in native freshwater mussels since ZSL surveys began in 2007, when recorded native freshwater mussel density was greatest. However, there have been some fluctuations over the years including in 2014 when the lowest densities during ZSL surveys were recorded.

Table 2: Mean Density (per 0.25m^2) of Native and Invasive Freshwater Mussels (2007-2010 and 2014-2017*)

	Mean Density (per 0.25m^2 ± S.E.M)							
	2007	**2008**	**2009**	**2010**	**2014**	**2015**	**2016**	**2017**
Native Freshwater Mussels	0.97 (± 0.27)	0.19 (± 0.07)	0.80 (± 0.21)	0.21 (± 0.07)	0.06 (± 0.03)	0.73 (± 0.14)	0.64 (± 0.15)	0.65 (± 0.34)
INNS Freshwater Mussels	17.39 (± 6.04)	11.02 (± 1.97)	157.31 (± 23.21)	68.02 (± 10.90)	9.76 (± 2.07)	32.91 (± 5.53)	18.14 (± 3.09)	20.54 (± 3.24)

***Note:** No 2011, 2012 or 2013 data available as surveys not conducted those years

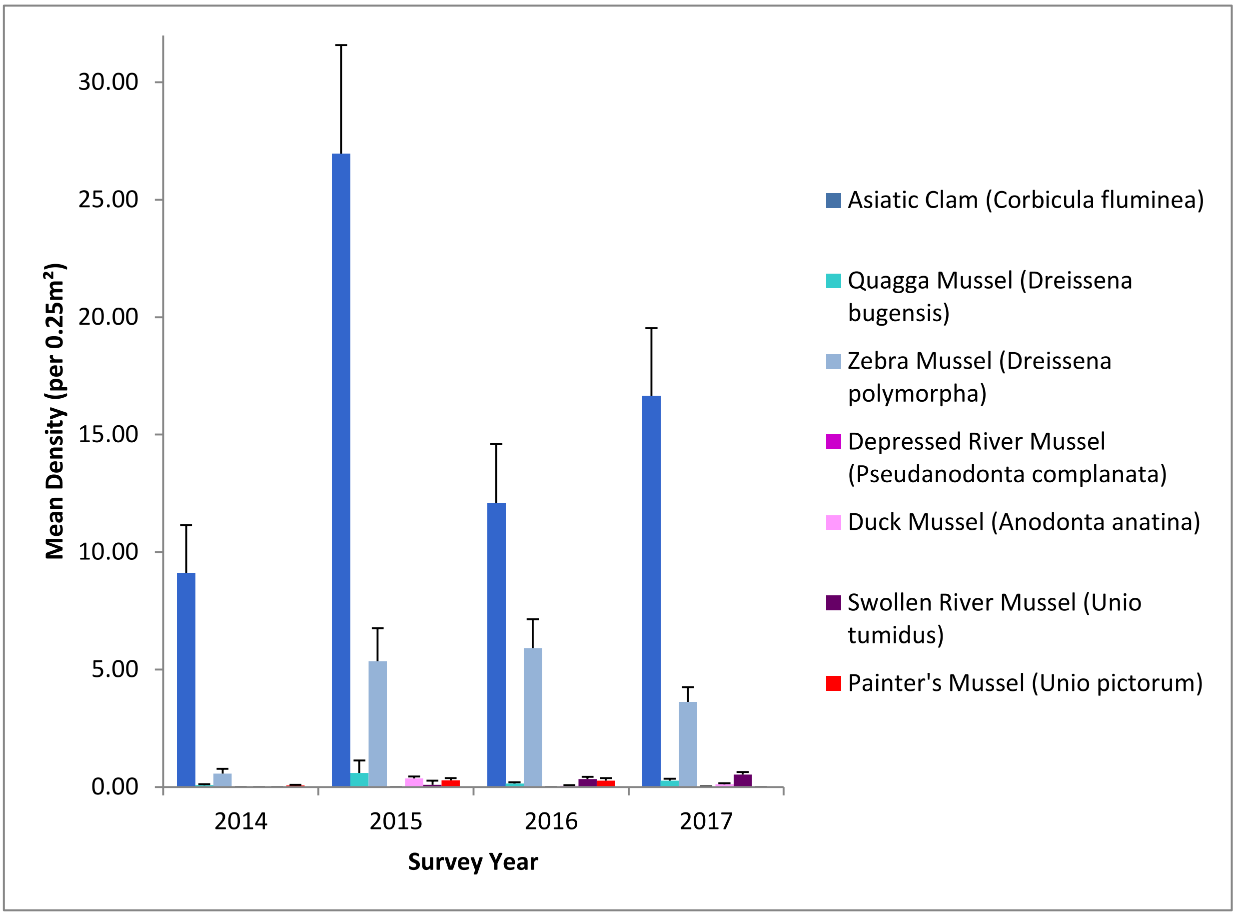

Figure 4: Mean Densities of Native and Invasive Freshwater Molluscs 2014-2017 (error bars indicate S.E.M.)

The density of both the Asiatic clam and quagga mussel has increased since 2016 (see **Table 3** and **Figure 5**). However, whilst an increase has been observed since 2016, the density of both species is still lower than the peaks observed in 2015. In contrast to the Asiatic clam and quagga mussel, the density of zebra mussel in has declined in comparison to 2015 and 2016 respectively.

Table 3: Mean Density (per 0.25m^2) of Asiatic Clam, Quagga Mussel and Zebra Mussel (2014-2017)

Species	**Mean Density (per 0.25m^2 ± S.E.M)**			
	2014	**2015**	**2016**	**2017**
Asiatic Clam	9.12 (± 2.02)	26.96 (± 4.62)	12.09 (± 2.50)	16.65 (± 2.88)
Quagga Mussel	0.08 (± 0.04)	0.60 (± 0.52)	0.14 (± 0.06)	0.26 (± 0.08)
Zebra Mussel	0.56 (± 0.21)	5.35 (± 1.40)	5.91 (± 1.23)	3.62 (± 0.63)

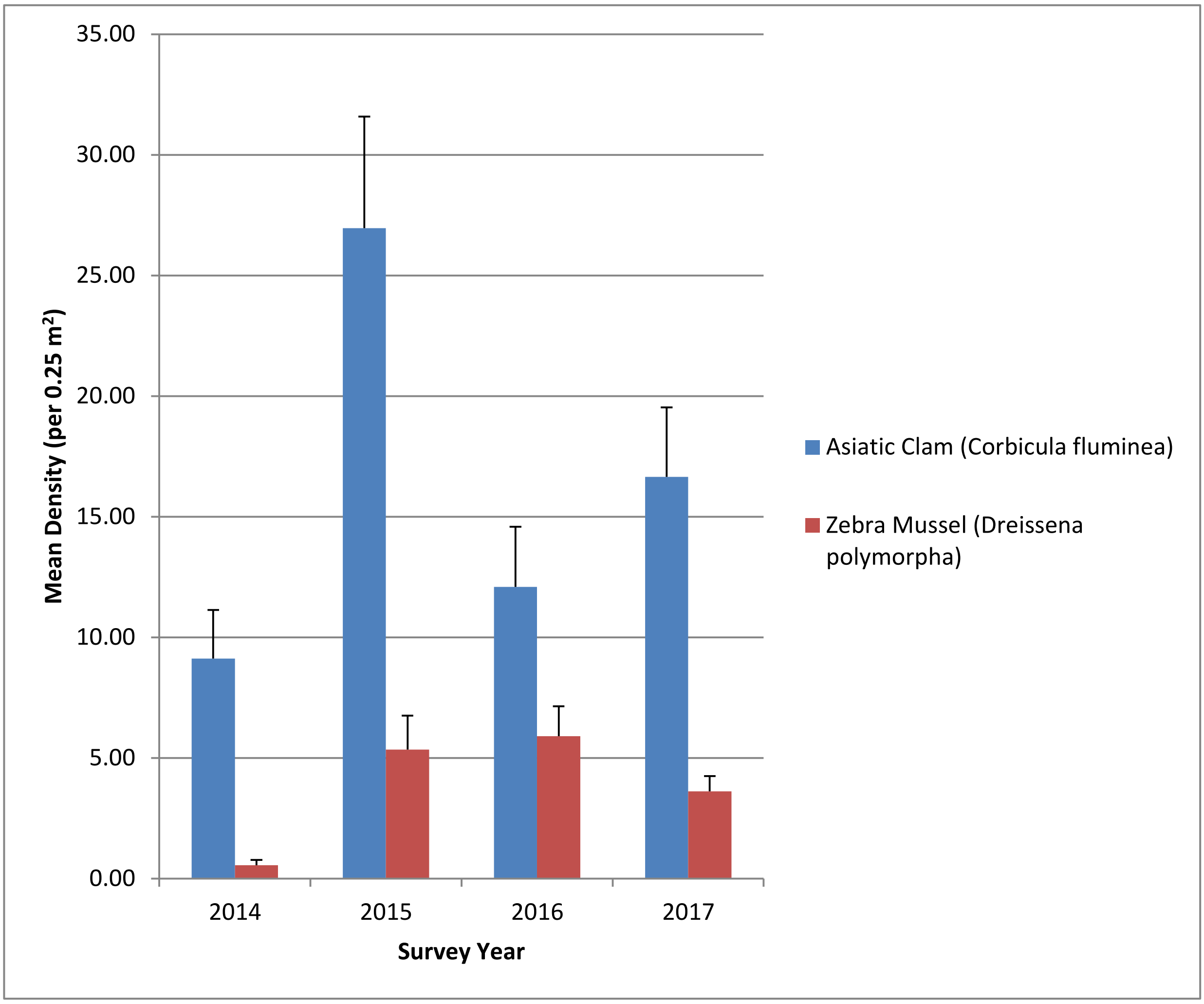

Figure 5: Mean Densities of the Asiatic Clam and the Zebra Mussel 2014-2017 (error bars indicate S.E.M.)

All native mollusc species, with the exception of the painter's mussel, have very slightly increased in density since 2016. However, the magnitude of increases in density is very small (see **Figure 6**), ranging only between 0.01 per $0.25m^2$ and 0.18 per $0.25m^2$. The painter's mussel, which was at a density of 0.26 (± 0.12) and 0.28 (±0.09) per $0.25m^2$ in 2016 and 2015 respectively, was not recorded during the 2017 survey.

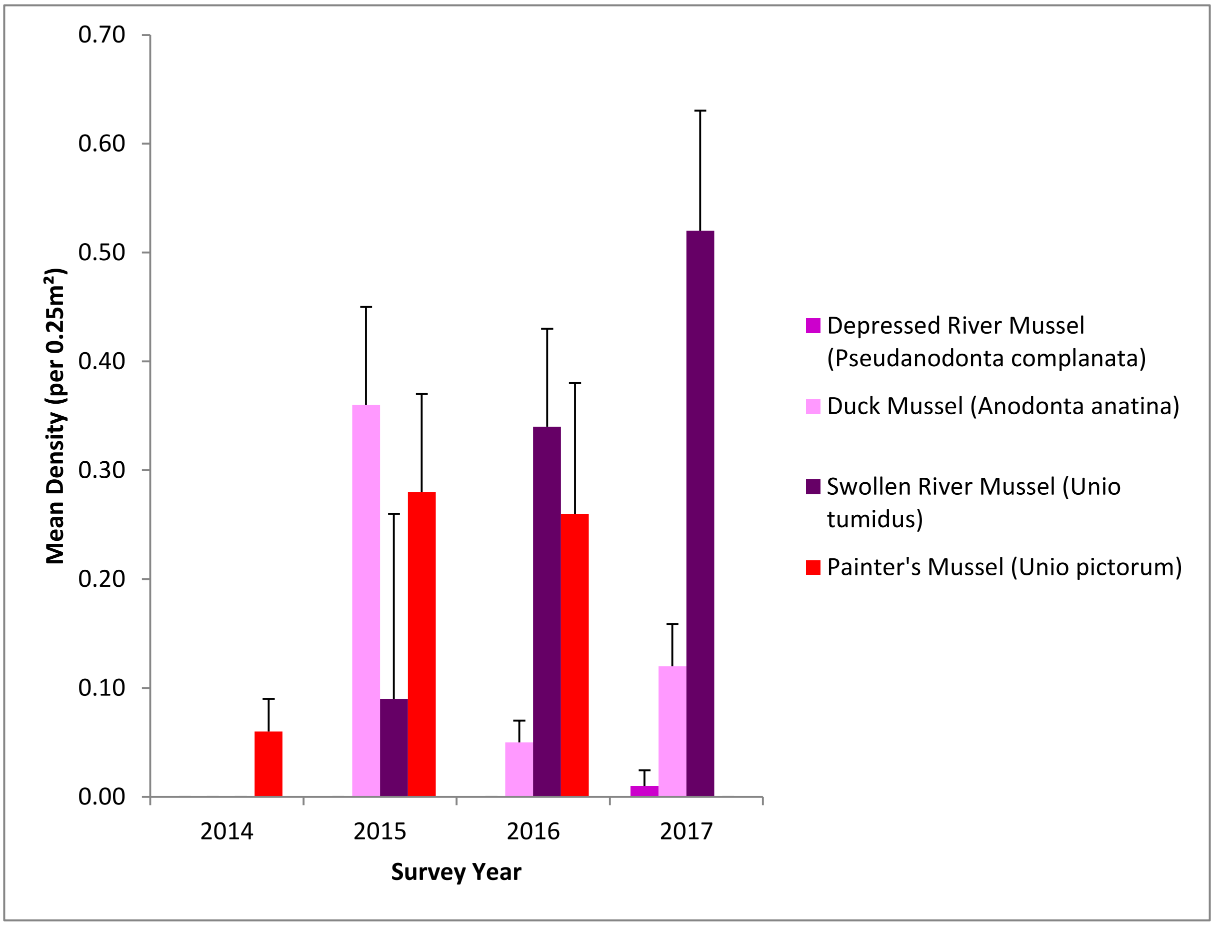

Figure 6: Mean Densities of Native Freshwater Molluscs 2014-2017 (error bars indicate S.E.M)

A general trend of increasing mean abundance of each species, both native and invasive non-native, with increasing distance from the foreshore was observed. This general trend was only observed across a distance of 0m to 10m from the foreshore and not beyond. However, it is worth noting that transects only extended beyond 10m from the foreshore at one site: Glover's Island.

The average shell length of each mussel species recorded during the 2017 survey has been calculated and is presented in **Table 4**.

Table 4: Mean Shell Length of Each Freshwater Mussel Species Recorded (2017)

Species	Mean Shell Length (mm) (to 2 d.p.)
Asiatic clam	16.37
Depressed river mussel	31.00
Duck mussel	49.38
Quagga mussel	29.83
Swollen mussel	43.43
Zebra mussel	22.80

Discussion

Throughout the last decade's survey work, native mussels have consistently only represented a small proportion of the total molluscs found. A key finding from the survey this year is that the painter's mussel was not recorded. This could indicate a decline in abundance of this species, to the point that individuals of this species were not captured within the sample, which could be an early warning about potential loss of this species in the area in the future. Or it could potentially indicate loss of this species already in this area. Given the relatively small scale of data collection over a two-day period only there is not yet enough information to determine the cause of this change. Further surveys would be required in order to come to firmer conclusions about the state of this species in the upper Tidal Thames. It is worth noting though that this species is thought to be susceptible to invasive bivalve infestations (Bauer and Wächtler, 2001); which could suggest that increases in INNS such as the Asiatic clam could have played a role in a decline. Asiatic clams can occupy the same niche as native bivalves (Phelps, 1994). The depressed river mussel has been recorded this year, with one individual being found at the Glover's Island site, 12m from the foreshore. This species was not recorded during the 2014-2016 surveys and therefore this is also a potentially interesting finding, but again further surveys with species identification not based on morphology alone would be required.

The identification of freshwater mussel species based on morphological characteristics alone is a recognised limitation of this survey. There is a large amount of morphological variability, particularly in relation to shell characteristics, which can make distinguishing species difficult (Zieritz and Aldridge, 2009; Zieritz *et al*., 2010; Zieritz and Aldridge, 2011) and using this in isolation can sometimes be unreliable (Zieritz *et al*., 2012). There is also some evidence that zebra mussels and quagga mussels are capable of natural hybridisation (Voroshilova *et al*., 2010), and hybrids have been detected in River Thames samples through molecular work (Laldin, 2016).

The most notable observation made over the 10 year survey period about INNS is the discovery of the quagga mussel in the 2014 Thames survey. There has also been a shift in the dominant INNS group. In 2007, the zebra mussel was the dominant INNS but the Asiatic clam took over as the dominant bivalve in 2008. Since the arrival of the Asiatic clam in the Tidal Thames in 2004 (Elliot and zu Ermgassen, 2008) numbers have grown to the extent that in the 2017 survey the Asiatic clam accounted for 79% of total molluscs counted.

A survey carried out at Ham, Richmond, in 2006 found high densities of Asiatic clam upstream of the survey site now used by ZSL (up to 648 individuals per m^2 (± 352)). The same study found lower densities at the ZSL survey site (approximately 300 individuals per m^2), but only in the intertidal channel; very low densities were in evidence 4m from the river bank, and none at 1 m (Elliott and zu Ermgassen, 2008). The population at the ZSL study sites has now become established higher up the river bank, and were found in large numbers at the top of the foreshore. Analysis of data from the 2017 survey has suggested that there is a general trend of increasing density of all species, not just the Asiatic clam, with increasing distance from the foreshore.

Initial introduction of INNS is followed by a 'lag period', during which the population is present at low densities, and this precedes a period of rapid expansion (Sakai *et al.* 2001). Eradication or management of non-native bivalves becomes more difficult once they have become established (Sousa *et al.* 2014); thus early detection and swift action are essential in the battle against INNS. The DEFRA INNS Strategy (2015) ranks early detection, monitoring and data sharing as a high priority for this reason. The data collected are shared with the Port of London Authority (PLA), Greenspace Information for Greater London (GiGL) and LISI and is available to those organisations responsible for making management decisions.

The probability of INNS introduction and spread can be greatly reduced by identifying vectors and through the establishment and implementation of biosecurity laws. Raising public awareness is also important in the fight against aquatic INNS. The most significant campaign for this is the Check, Clean, Dry campaign (see: http://www.nonnativespecies.org/checkcleandry/).

The data collected during the 2017 survey will also be shared with KCL PhD student, Daniel Mills, for further analysis. ZSL plan to repeat the upper Tidal Thames freshwater mussel survey next year. Continued monitoring is essential to identify any future population trends, and for the early detection of new INNS.

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References

Beggel S., Cerwenka A. F., Brandner J. and Geist J. (2015). Shell morphology verses genetic identification of quagga mussel (*Dreissena bugensis*) and zebra mussel (*Dreissena polymorpha*). *Aquatic Invasions* **10** (1): 93-99

Bodis, E., Toth, B., Szekeres, J., Borza, P. and Sousa, R. (2014) Empty native and invasive bivalve shells as benthic habitat modifiers in a large river. *Limnologica.* **49**: 1-9

DEFRA (2015). The Great Britain Invasive Non-native Species Strategy. *Department of Environment and Rural Affairs*, pp.42

Elliott, P. and Ermgassen, P. S. E. (2008). The Asian clam (*Corbicula fluminea*) in the River Thames, London, England. *Aquatic Invasions*, **3**: 1, 54-60.

Jackson, M. C. and Grey, J. 2012. Accelerating rates of freshwater invasions in the catchment of the River Thames. *Biological Invasions*, **15**: 5, 945-951.

Laldin, A. (2016). The development and application of molecular tools to differentiate *Dreissena* species. *MSc. Thesis.*

McMahon R. F. (2002). Evolutionary and physiological adaptations of aquatic invasive animals: “r” selection verses resistance. Can. *J. Fish. Aquat. Sci*. **59**: 1235 – 1244.

Phelps, H. L. (1994). The Asiatic clam (*Corbicula fluminea*) invasion and system-level ecological change in the Potomac River estuary near Washington, D.C. *Estuaries* **17**: 614–621

Sakai A.K., Allendorf F.W., Holt JS *et al* (2001) The population biology of invasive species. *Annu Rev Ecol Syst* **32**:305– 332

Sousa R., Antunes C. and Guilhermino L. (2008). Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. *Ann. Limnol. - Int. J. Lim* **44** (2): 85-94

Sousa, R., Novais, A. and Costa, R. (2014). Invasive bivalves in fresh waters: impacts from individuals to ecosystems and possible control strategies. *Hydrobiologia*, **735:** 233-251

Vaughn C.C., Nichols S.J. and Spooner D.E. (2008). Community and foodweb ecology of freshwater mussels. *Journal of the North American Benthological Society* **27**(2): 409-423

Voroshilova, I. S., Artamonova, V. S., Makhrov, A. A. and Slyn'ko, Yu. V. (2010) Natural hybridization of two mussel species *Dreissena polymorpha* (Pallas, 1771) and *Dreissena bugensis* (Andrusov, 1897) *Biol. Bull. Russ. Acad. Sci.* **37**: 542

Williams, S. L. and Grosholz, E. D. (2008) The Invasive Species Challenge in Estuarine and Coastal Environments: Marrying Management and Science. *Estuaries and Coasts*. **31**: 3-20

Zieritz, A. and Aldridge, D. C. (2009) Identification of ecophenotypic trends within three European freshwater mussel species (Bivalvia: Unionoida) using traditional and modern morphometric techniques. *Biol. J. Linnean Soc.* **98**: 814-825

Zieritz, A., Hoffman, J. I., Amos, W. and Aldridge, D. C. (2010) Phenotypic plasticity and genetic isolation-by-distance in the freshwater mussel *Unio pictorum* (Mollusca: Unionoida). *Evol. Ecol.* **24**: 923-938

Zieritz, A. and Aldridge, D. C. (2011) Sexual, habitat-constrained and parasite-induced dimorphism in the shell of a freshwater mussel (*Anodonta anatina,* Unionidae) *J. Morphol.* **272**: 1365-1375

Zieritz, A., Gum, B., Kuehn, R. and Geist, J. (2012) Identifying freshwater mussels (Unionoida) and parasitic glochidia larvae from host fish gills: a molecular key to the North and Central European species. *Ecology and Evolution* doi: 10.1002/ece3.220

Books

Bauer, G. & Wächtler, K. (2001). Ecology and evolution of the freshwaters mussels Unionidae. Springer-Verlag, Berlin Heidelberg, Germany.

Websites

Joint Nature Conservation Committee (2016) Priority Lists Spreadsheet http://jncc.defra.gov.uk/page-5717

GB Non-Native Species Secretariat (2017) http://www.nonnativespecies.org/index.cfm?sectionid=15

University of Cambridge Freshwater Mussel Ecology and Conservation (2011) http://www.museum.zoo.cam.ac.uk/bivalve.molluscs/bivalve.research/freshwater.mussels/