Catching invasive Chinese mitten crabs whilst releasing the endangered European eel and other fish by-catch: the implications of fyke net design

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Running header: CATCHING CRABS BUT RELEASING EELS P.F. CLARK *ET AL*.

ABSTRACT

1. Modifications of a traditional fyke net design were trialled in 42 hauls over 5 months at 42 locations in the Thames estuary, London. These trials were to determine whether the modified nets could be used to catch invasive mitten crabs whilst at the same time releasing endangered eels, back into the river.

2. The modifications included rings of different diameters fixed into the netting to provide escape apertures and also a variation in mesh size. A standard, unmodified net was included as a control.

3. Captured mitten crabs, eels and other fish by-catch were measured and recorded for all deployed nets. Mitten crabs and eels were caught in all nets except those of the largest mesh size (70mm) which caught no eels. This may have been the combined effect of the mesh size and it being set on the square, versus the normal diagonal netting which may become increasingly constricted in one axis, under tension. Such a square mesh net could be used to trap crabs of carapace width > 65mm, whilst releasing all eels.

4. The smallest rings, 22mm internal diameter, inserted into the mesh may have allowed the escape of eels < 35cm length, but retained larger, market legal, individuals. This suggests that a slightly smaller escape ring could potentially be used to release eels of ≤ 30cm in length, in line with current regulations.

KEY WORDS: non-native species; commercial exploitation; Chinese mitten crab; fyke nets; European eel; River Thames

INTRODUCTION

The numbers of the invasive Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1853 in the River Thames have increased since the end of the 1980s (Clark and Rainbow, 1997; Clark *et al*., 1998) and the species continues to disperse westwards upstream (Morritt *et al*., 2013). The Natural History Museum (NHM) completed a feasibility study into the commercial exploitation of *E. sinensis* in the River Thames (Clark *et al*., 2008; Clark, 2011). Such fishing of mitten crabs could provide benefits to local fishermen as *Eriocheir* is considered to be a delicacy in many Far Eastern countries including China, Japan, Korea, Taiwan, Thailand and Singapore. During the autumnal months crabs become sexually mature and consumption of the ripening gonads is regarded as a luxury. Exploitation could therefore reduce the mitten crab population in the Thames and possibly alleviate some of the environmental damage, e.g. collapsed river banks (Zucco, 1999; Rauxloh, 2000) and blocked water intakes (Morritt *et al*., 2013), caused by this invasive species. The NHM study compared *E. sinensis* captures using baited pots versus fyke nets, and the latter proved to be the most effective method to trap these crabs. During this feasibility study, however, ca. 1,400 European eels, *Anguilla anguilla* (Linnaeus, 1758) were captured as by-catch while fishing for *Eriocheir*.

Concern over the decline in population of eels across Europe has led to the European Commission initiating an Eel Recovery Plan (Council Regulation, 2007) in an attempt to return the European eel stock to more sustainable levels of adult abundance and glass eel recruitment. Each Member State is required to establish regional Eel Management Plans. A key target for recovery is to restore successful migration of spawning stock to 40% of historical levels pre-dating anthropogenic interference. The Council Regulation defines various methods of determining historic escapement including; use of data prior to 1980; habitat based assessment of potential eel production; or with reference to the ecology and hydrography of similar river systems. The date of 1980 is important because it is believed that the long term data on European glass eel recruitment suggests that populations were stable (with some fluctuations) until around 1984, when the recruitment crashed. This is critical as it is thought that insufficient spawning stock may be the primary reason for the population decline (see Dekker, 2003a, b). *Anguilla anguilla* has also recently been listed in Appendix II of the Convention on International Trade on Endangered Species (Jacoby and Gollock, 2014). The main problem with a mitten crab fishery using a traditional fyke net is that the by-catch of eels has a commercial value and therefore would probably not be released, but sold on. This would potentially deplete the Thames population further.

In the Netherlands, different fyke net designs have been proposed to allow the exploitation of mitten crabs during the closed seasons for eels. Furthermore, a scheme is operated by the Dutch fishermen to release undersized eels (28cm minimum length in Holland). Eel escape outlets are not required in any net where the mesh size is > 20mm. If the mesh size is < 20mm, however, then escape holes of 13mm internal diameter, must be fitted in the cod end; the number of these is dependent on size of hoop. Two escape rings are required if there are < 300 squares of mesh in the diameter of the net, four escape holes if there are > 300. These 13mm rings are claimed to allow undersized eels to escape so that they can be recaptured at a larger size.

In Great Britain, the main yellow and silver eel fisheries are in southern and eastern England within the Humber, Anglian, Thames and South West River Basin Districts. Fyke nets are the preferred method for capturing eels and there is a standard condition on authorizations for fyke nets that any eels caught less than 30cm in length must be returned to the same water they were taken from and with as little injury as possible. Nets, however, are sorted manually and eel size is estimated, so in fact many undersized eels are retained.

Indeed, there is a market for undersized eels. There is no current requirement in England and Wales to fit eel escape rings in fyke nets to release undersized eels of < 30 cm.

The aim of this project was to carry out trials with different types of fyke net to collect data that would address two key issues; 1) to improve design of commercial fyke nets to allow the release of undersized eels; 2) to identify an optimal fyke net design that could be used to capture invasive Chinese mitten crabs with minimal fish by-catch, especially *A. anguilla*. A fyke net that releases more undersized eels back into the environment via an escape mechanism will help UK compliance with the EU Eel Recovery Plan (Council Regulation, 2007). Furthermore, an efficient crab net would assist in the establishment of a temporary fishery for marketable sexually mature mitten crabs. The emphasis is, however, on a temporary fishery in an attempt to deplete/eradicate *Eriocheir* and not an implied acceptance of this invasive species in our catchments for economic benefit.

MATERIALS AND METHODS

<u>The fishing boat</u>: MV *Billy Boy*, a passenger boat licensed by the Port of London Authority to operate in Category C Waters, River Thames from Teddington to Denton Wharf, under the Inland Waters Small Passenger Boat Code, was hired for the duration of this project.

<u>Mesh size</u>: The all important factor for any net is the dimension of the mesh as this governs the size of the fish caught (Garner, 1962). The dimensions of the mesh are taken from the centre of one knot to the centre of the next diagonally opposite knot. This is a stretched diagonal measurement. UK mesh (and ring) sizes are normally old imperial measurements rounded up to metric.

<u>Fyke nets</u>: The standard fyke net used in the UK to trap eels comprises a cylindrical 20mm mesh net that tapers to the holding end (cod end) and is ca. 2m in length. It is held open by a

“D” ring, followed by a series of hoops. The trapping of eels is accomplished by several internal “non-return valves” made of netting. These “valves” taper towards the cod end, are held in position by being tied to the next hoop in line and they prevent the eels from escaping back through the net opening. For the present investigation, fyke nets were fished in pairs joined together by a “leader”; a fence like barrier made of netting which hangs vertically in the water and guides the eels into the net openings. Otter guards were fitted at the opening of the net to prevent entrapment and drowning of this protected species.

Fyke net fishing: Each fleet of nets consisted of three double fykes (or six fyke net ends) tied together at their cod ends. Nets were fixed firmly to the river bed by anchors at both free cod ends of the fleet to keep it taught and upright. The anchors were tied to the cod end by a 10m line and a 2m length of 6mm short link chain. This type of fishing is sometimes referred to as using “fixed engines”. Attached to the end of one anchor was another 10m leading line weighted at one end with a ball of chain. This line was initially picked up by a grapple when hauling the nets.

Buoys were not used to mark the position of the nets in the river as this attracts attention and the potential for unwanted net disturbance. Nets were set, and their positions recorded on a GPS navigational plotter in the wheel house of the boat. The nets were always set in the same methodical way and orientation so that the position of each leading line with the ball of chain was known. Each fleet of nets was set parallel to the shore and in line with the tidal direction. Fyke nets set at angles from the shore and into the strong tidal flow, although anchored at both ends, tended to be washed away. The nets were set sub-tidally in shallow water so as not to become exposed low tide. They were not set in the deep water navigational channel. Retrieval was a relatively straightforward matter of returning to each net using the GPS guidance system. The position of the leading line with the ball of chain was then crossed by the boat trailing a grapple. In this way the leading line was hooked with the prongs of the grapple eventually becoming embedded into the ball chain. The leading line was then man-handled into the boat followed by the anchors, lines and nets. This was an extremely efficient and simple method of retrieval which, above all, does not damage the nets. The time that the nets were set and hauled, was noted. The intervening period represents the soak time for each net.

Stations: The area fished was between Crossness and Broadness Point, Greenhithe, in the upper Thames Estuary (Figure 1). After the nets were hauled they were re-set at a different locality. The same station was not immediately fished again and allowed to "rest" for at least five days before fishing the same area again. For locality data see Additional supporting information.

Net trials: Two separate trials were undertaken. The first started on the 17 September 2012 and continued thereafter every third day until the13 December 2012 and the second started on the 15 May 2013 and continued thereafter every third day until 23 June 2013 (for dates and exact localities see supporting information). The first trial comprised four types of fyke net and the second only three.

First trial: Net 1: comprised a standard (traditional) fyke net with a 20mm (actually 19.7mm) mesh cod end as currently deployed on the Thames, and nationally, for eel fishing. Past experience indicates that this net traps undersized (< 30cm) eels. This net was effectively the control for the trial (Figure 2a). Net 2: comprised a standard 20mm mesh fyke net with 2×22mm internal diameter (actually 21.83mm) brass rings inserted into the cod end (Figure 2b). The two rings were placed in the top of the cod end, close to the hoop at the origin of the last non-return valve. The ring had a smooth internal surface so that escaping eels would not be injured. This net was designed to release undersized eels. Net 3: comprised a traditional 20mm mesh fyke net with a 50mm internal diameter (actually 51.86mm) stainless steel ring inserted into the cod end (Figure 2c). The ring was placed into the upper part the cod end, close to the hoop at the origin of the last non-return valve and its internal diameter was also smooth in order to prevent injury to escaping eels. This net was designed to release eels, minimise the by-catch and retain marketable sexually mature, mitten crabs. Net 4: comprised a traditional 20mm mesh fyke net with a separate holding end made from 50mm (actually 53mm) pot netting mesh set on the diagonal and kept open with plastic hoops (Figure 3). This holding end was then tied into the cod end of a traditional 20 mm mesh fyke net and additionally held in place with cable ties. Pot netting was considered strong enough to retain mitten crabs in the light of observations that *E. sinensis* damage standard 20mm fyke mesh nets (D. Pearce pers. obs.). This net was designed to release eels and smaller fish caught as by-catch, but retain marketable sexually mature, mitten crabs.

Second trial: Net 1and 2 as above Net 3: comprised, distally, a traditional 20mm mesh fyke net with a separate holding end made from 70mm (40mm square) "cricket" netting mesh kept open with plastic hoops (Figure 4). This holding end was then tied into the cod end of a traditional 20 mm mesh fyke net and additionally held in place with cable ties. The square cricket netting was considered strong, much more flexible than the 50mm pot diagonal netting as used in Trial 1 above and was designed to release eels and smaller fish caught as by-catch, but retain marketable sized mitten crabs.

Eel data: For each eel captured, the total body length (to the nearest cm) and eye dimensions (height and width to nearest mm) were measured. Eye measurements to the nearest mm were taken safely, without damage to the eel, with a 100mm plastic ruler. In addition, the weight of individual eels, numbers trapped in each net end and total weight caught in each set of nets was recorded.

Maturing 'silver' eels: Eye measurements were used to calculate the eye index, I_E (Pankhurst 1982) to help establish the sexual maturity of the individuals trapped in the fyke nets. Eels with an eye index > 6.5 were classed as maturing adults.

Equation: Eye Index, $I_E = [(A+B/4)2\ \pi\ / L] \times 100$

Where A and B = horizontal and vertical eye diameters (in mm) respectively and L = eel body length in mm.

All captured eels were released back into the Thames at the place of capture.

Mitten crab data: The size of all mitten crabs captured was measured across the carapace width between the fourth pair of lateral spines, and each individual was weighed, sexed and, if female, its egg-bearing status noted. The number of mitten crabs in each holding end of each fyke net was noted. Most mitten crabs were retained for various student projects at Royal Holloway University of London and the NHM, but, with authorised permission, the remainder were returned to the river at point of capture. Furthermore, the return of a small number of specimens back into the Thames would have little effect on an already well-established population of mitten crabs.

Fish by-catch: The fish captured were identified and measured. The standard length, from tip of upper jaw to posterior edge of the hypural bones, was recorded. Other information taken included the number of fish captured in each net end and the total weight of fish by-catch for each set (fleet) of nets.

Data analyses: Catch per unit effort (CPUE) for total fish by-catch data (kg/end/day) were log transformed and, after checking for homogeneity of variance, compared using Welch ANOVA with post-hoc Tukey multiple comparisons. Total crab catches (CPUE: crabs/end/day), eel catch weights (CPUE: kg/end/day) and eel numbers (numbers/end/day) were analysed using Kruskal-Wallis H test with subsequent comparisons as data were, in all cases, non-normally distributed even following logarithmic transformation. The significance level was set at $P = 0.05$.

RESULTS

During these two net trials, 42 localities were fished between Crossness and Broadness Point, Greenhithe in the upper Thames Estuary, resulting in the capture of 545 *A. anguilla*, 634 *E. sinensis* and 3206 fish (excluding eels) as by-catch.

Catch per Unit Effort analyses

20 September to 13 December 2012

Eels: There was a significant difference in eel catch weights (CPUE: kg/end/day) between different net types (Kruskal-Wallis: $\chi2 = 48.18$, df = 3, $P < 0.01$) and multiple comparisons identified significant differences between the catch weights of all nets apart from between the standard net and 2×22mm ring net ($P > 0.05$; Figure 5). The latter two had significantly higher catches than the 50mm ring and 50mm mesh nets ($P < 0.01$ in all cases). This was also reflected in the numbers of eels caught (CPUE: numbers/end/day) where there was also a statistically ~~important~~ significant difference between net types ($\chi2 = 54.4$, df = 3, $P < 0.01$) with a significant difference between all net types except between standard and 2×22mm ring net ($P > 0.05$). The latter two nets caught significantly more eels than both the 50mm ring and the 50mm mesh nets ($P < 0.01$ in all cases; Figure 6). The 50mm ring net caught significantly fewer eels ($\chi2 = 6.63$, df = 1, $P = 0.01$) with lower catch weights ($\chi2 = 8.76$, df = 1, $P < 0.01$)

than the 50mm mesh net. On the basis of IE values, a total of 23 eels caught in Trial 1 could have been described as maturing (Table 1).

Mitten crabs and by-catch: There was a significant difference in Chinese mitten crab numbers (CPUE: numbers/end/day) between net types ($\chi2 = 9.89$, df = 3, P = 0.02) with the CPUEs for the standard net and 22mm ring net being higher than for the net with the 50mm ring ($\chi2 = 8.72$, df = 1, P = 0.02 and $\chi2 = 3.87$, df = 1, P = 0.049 respectively; there was no difference between the 50mm ring and 50mm mesh; Figure 7). There was a significant difference in total fish by-catch weights (CPUE: kg/end/day) between net types (Welch ANOVA, $F_{3, 61.38} = 3.634$, P = 0.018) with multiple comparisons demonstrating that the by-catch in the 50mm ring nets was significantly greater than the 2×22mm ring net and 50mm mesh nets (Tukey HSD multiple comparisons, $P < 0.05$ in all cases; Figure 8). There were no other significant differences between the net types.

15 May to 23 June 2013

Eels: The standard net and 22 mm ring net showed similar efficiency in terms of both eel catch weights (CPUE: kg/end/day) and number of eels caught (CPUE: numbers/end/day), showed no significant differences (One-Way-ANOVA: $P > 0.05$ in all cases; Figures 9, 10). No eels were caught in 40mm square mesh nets so these were excluded from analyses. On the basis of IE values a total of 25 eels were caught in Trial 2 that could be described as maturing eels (Table 2).

Mitten crabs and by-catch: There were significant differences in Chinese mitten crab numbers (CPUE: numbers/end/day) between net types (Kruskal-Wallis: $\chi2 = 11.48$, df = 2, P = 0.03) and multiple comparisons identified a significant difference between the catch weights of the standard net and 40mm square mesh net ($\chi2 = 9.8$, df = 1, P = 0.02; Figure 11). Regarding total fish by-catch weights (CPUE: kg/end/day) there were no significant differences between the three net types (Kruskal-Wallis: $P > 0.05$; Figure 12).

Catch details

In order to clarify the efficiency of each net type used in both trials, the measurement data for eels, mitten crabs and by-catch were organized into size classes vs. number of individuals.

20 September to 13 December 2012

Twenty-nine Thames visits were made during the first trial capturing 345 *A. anguilla*, 427 *E. sinensis* and 2,894 fish as by-catch (excluding eels). Twenty species were identified in the by-catch (Table 3).

The standard fyke net: Total catches were 177 eels (mean length, 53.9 ± 10.1cm; median length 54cm; mean weight 0.3 ± 0.2kg; median weight 0.3kg; Figure 13a); 142 mitten crabs (mean carapace width, 47.8 ± 9.3mm; median carapace width, 46.9mm; Figure 13b) and 1,008 fish as by-catch (mean standard length, 10.5 ± 5.8cm; median standard length 7.7cm; Figure 13c).

2×22 mm ring in cod end: Total catches were 146 eels (mean length, 54.1 ± 8.3cm; median length 53.5cm; mean weight 0.3 ± 0.2kg; median 0.3kg; Figure 14a); 125 mitten crabs (mean carapace width, 47.9 ± 9.3mm; median carapace width, 46.6mm; Figure 14b); 944 fish as by-catch (mean standard length, 10.7 ± 5.9cm; median standard length 8.0cm; Figure 14c).

50mm ring in cod end: Total catches were 5 eels (mean length, 50.0 ± 10.4cm; median length 51.0cm; mean weight 0.3 ± 0.2kg; median weight 0.3kg; Figure 15a); 64 mitten crabs (mean carapace width, 58.7 ± 9.8mm; median carapace width, 60.9mm; Figure 15b) and 638 fish as by-catch (mean standard length, 15 ± 8.0cm; median standard length 15.0cm; Figure 15c). <u>50mm diagonal mesh cod end</u>: Total catches were 17 eels (mean length, 71.1 ± 5.7cm; median length 73.0cm; mean weight 0.8 ± 0.2kg; median weight 0.8kg; Figure 16a); 96 mitten crabs (mean carapace width, 53.7 ± 10mm; median carapace width, 52.6mm; Figure 16b) and 304 fish caught as by-catch (mean standard length, 17.8 ± 5.3cm; median standard length 18.0cm; Figure 16c).

In general, the standard net and the 22 mm ring net (Figures 13c, 14c) retained smaller fish than the 50mm ring and 50 mesh cod end nets (Figures 15c, 16c). This is further illustrated by considering the total number of smaller fish, standard length size class 5.1–10cm, captured by the different nets which show that 633 fish in this size class were caught in standard nets compared to 615 in 20mm ring nets, 254 in 50mm ring nets and only 33 in 50 mm mesh nets (Figure 17). The top 3 species collected in standard length size class 5.1–10cm comprised 681 common sole (*Solea solea*), commercially valuable; 403 European flounder (*Platichthys flesus*) and 154 European sea bass (*Dicentrarchus labrax*) commercially valuable.

15 May to 23 June 2013

Thirteen Thames visits were made during the second trial capturing 200 *A. anguilla*, 207 *E. sinensis*, and 312 fish as by-catch (excluding eels). From the by-catch, 8 species of fish were identified (Table 3). The greater pipe fish (*Syngnathus acus*) was the only species not recorded in the first trial. Whilst fewer net types were used than in trial 1 a similar approach is taken below in considering the results.

The standard fyke net: Total catches were 125 eels (mean length, 51.4 ± 9.3cm; median length 51cm; mean weight 0.29 ± 0.17kg; median weight 0.26kg; Figure 18a); 110 mitten crabs (mean carapace width, 45.33 ± 9.16mm; median carapace width, 45.33mm; Figure 18b) and 657 fish caught as by-catch (mean standard length, 11.1 ± 4.6cm; median standard length 9.5cm; Figure 18c).

2×22 mm rings in cod end: Total catches were 75 eels (mean length, 56.3 ± 7.9cm; median length 55cm; mean weight 0.35 ± 0.17kg; median weight 0.3kg; Figure 19a); 86 mitten crabs (mean carapace width, 44.57 ± 8.73mm; median carapace width, 42.16mm; Figure 19b) and 525 fish caught as by-catch (mean standard length, 11.1 ±4.3cm; median standard length 9.5cm; Figure 19c).

70mm square mesh cod end: No eels were trapped in this modified cod end. A total of 11 mitten crabs was caught (mean carapace width, 54.24 ± 15.14mm; median carapace width, 50.6mm; Figure 20a) and 130 fish caught as by-catch (mean standard length, 16.7 ± 5.6cm; median standard length 18.3cm; Figure 20b).

In general, the standard and the 22mm ring fyke nets (Figures 18c, 19c) retained smaller fish than the 40mm square mesh cod end fyke net (Figure 20b). The total numbers of fish in standard length size class 5.1–10cm, captured by the different net designs were: standard net = 395 (Figure 21a); 20mm ring net = 306 (Figure 21b) and 40mm square mesh net = 32 (Figure 21c).

The standard fyke net trapped three small (< 35cm) eels during trial 1 (e.g. 1×31cm, 2×34cm) and two undersized (< 30cm) during trial 2 (e.g. 1×24cm and 1×29cm). In comparison, no undersized eels were captured with the 22 mm ring net and only some small eels were captured during trial 1 (1×35cm and 2×37cm) and trial 2 (1×40cm, 1×43cm, 1×44cm and 3×45cm).

Of the 270 mitten crabs caught during the spring of 2013, only four were females. Three of these were ovigerous with one captured on 8 June (carapace width = 55.92mm) and two on 11 June (carapace width = 52.93, 55.58mm). They were, however, all carrying only small numbers of eggs.

DISCUSSION

Eels

The latest UK report (Defra, 2015) to the European Commission on progress with the Eel Regulation (Council Regulation, 2007), estimates silver eel escapement from the Thames River Basin District (Thames RBD) was 51,581kg in 2013 and pre-anthropogenic mortality escapement of 251,699kg. This is well below the 40% of pre-anthropogenic escapement target set by the European Regulation (Council Regulation, 2007). The estimated biomass of silver eel equivalents caught by the commercial fyke net fishery in the Thames RBD in 2013 was 4,300kg, which would not contribute significantly to meeting the escapement target. The commercial fishery for eels on the River Thames is already restricted by capping the number of licensed nets and limiting fishing seasons. Allowing the escape of undersized eels from nets could assist with developing a more sustainable fishery, and make eel sorting easier for fishermen. The initiation of a commercial fishery for mitten crabs, in which eels were a considerable by-catch, would not be commensurate with good management since this would constitute an additional burden on *Anguilla* stocks.

Eel captures: In terms of maintaining an active commercial fishery for eels, installing a 22mm ring into the cod end will not lead to a significant change in biomass of eel caught compared to a standard fyke net. The 50mm ring, 50mm diagonal mesh and 70mm mesh do lead to a significant reduction in eel catches, presumably because of escapes from the cod end.

The 70mm soft, square mesh, cricket netting did not catch any eels and thus appears to be more effective at releasing eels compared to the 50mm ring and 50mm diagonal mesh nets, both of which captured a small numbers of eels (5 and 17, respectively). Moreover, eel escapes from the 50mm mesh net (see Figure 22) may have been compromised by the diagonal mesh closing under tension, i.e. larger eels may not have been able to wriggle out of the net. In fact they may have damaged themselves judging by the mucus left on the mesh openings. In comparison, the 70mm soft square mesh appeared to be more flexible than the 50mm cod end net, that is the mesh of the net did not close under tension leaving the perpendicular lines stress-free (see Figure 23) and allowing eel escape.

The insertion of 2×20mm rings into the 20mm mesh cod end was proposed in order to release under sized eels (< 30cm). The smallest *Anguilla* trapped by this net was 35cm in length. Consequently, this fyke net trial cannot confirm the size class of eel actually released, however, it may be inferred that that the 22mm rings may release eels < 35cm. In terms of allowing undersized eels to escape from the nets only two eels that were < 30cm in length and both were caught in the standard fyke net (comprising < 1% of the total catch by that instrument). There are some data from the Thames to suggest that eels < 30cm in length can be caught by standard fyke nets. In a study by the Environment Agency (EA) between 30 June and 4 August 2009 using a standard fyke net set in the Crossness area, which is contiguous with that of the present study, seven of the 278 (2.5%) eels collected were < 30cm long (unpublished data). Similarly, Naismith (1992) reported that of 2,356 eels caught in September and October 1985 by a standard fyke net in the Middle Thames Estuary (between Tower Bridge and Gravesend), 7.3% were smaller than 30cm.

Eel data collected during Trial 1 by the standard and 22mm ring fyke nets were compared to captures reported in an EA sponsored study (Lundberg, 2009). Lundburg collected 278 eels using a standard fyke net compared to 213 eels trapped in 2012 with the standard and 22mm ring nets. There appears to be a considerable difference in the length frequency distribution of the two data sets (Figure 24). This could be due to seasonal abundance patterns (June-July 2009 vs. September-October 2012) or it could be that the Thames population is in decline, with almost no recruitment of juveniles and the remaining eels growing on. If true, then this would be of concern.

Maturing eels: According to Pankhurst (1982), eels with an eye index (I_E) of ≤ 6.5 are considered to be sexually immature in comparison with an index > 6.5 which he referred to as "sexually maturing adults" i.e. "silver" eels. Pankhurst (1982) accepts that "the onset of maturation is signalled by the beginning of seaward spawning migration". Consideration of the eye index scores suggests that there may have been 23 silver eels caught in 2012 (6.67% of the total eel catch) and 25 in the 2013 trial (12.5% of the total eel catch). This implies that fyke nets do not specifically target migrating silver eels, but instead tend to take resident yellow eels. This appears to be the same for all methods of capture apart from the 50mm mesh in 2012, which appeared to catch a high proportion of silver eels.

Mitten crabs

Mitten crab capture: The largest haul of mitten crabs (89) occurred on the 29 October 2012 followed by 46 on 1 November 2012. During autumn 2012, 126 female mitten crabs were caught, of which 22 were ovigerous (egg carrying), indicating that the annual breeding cycle migration (see Robbins *et al*., 2000; Morritt *et al*., 2013) had reached the upper Thames Estuary. In addition, four mitten crabs caught on 26 and 29 September and 2 October 2012

had barnacles attached to the carapace which suggested that these specimens had been in the estuary for some time (see Clark, 2011; Naser *et al*., 2015). In addition, three ovigerous crabs were caught in June and provide an indication of fecundity for this species. Females in the Thames Estuary are bearing eggs for ca. 8 months with the first ovigerous crab being recorded by the initial net trial on the 29 October 2012 at Littlebrook and the last one during the subsequent trial on 8 June 2013 at Johnston's Jetty just downstream of Littlebrook (Andrews *et al*., 1981: Table 1; Ingle, 1986; Attrill and Thomas, 1996; Clark, 2011: Table 2).
<u>Commercial exploitation</u>: Of interest from the present study is the fact that the 70mm square mesh net trialled throughout spring 2013 did not trap any eels. This is significant with respect to the potential for a commercial mitten crab fishery in England and North Wales as it does not impact on the protected eel populations. But while it is apparent that the square mesh cod end is releasing eels, mitten crabs below the 65–69.9mm carapace class size may also be escaping. Moreover, those mitten crabs that were retained by this net in carapace class size 30–54.9mm (6 in total) were trapped in the proximal end of the fyke net where the mesh is 22mm. Overall, although the 70mm square mesh net is working, a further square mesh net trial may be required with a view to obtaining an optimum square mesh net size that will trap a slightly lower carapace class size of crab, but still release eels.

By-catch

Wheeler (1979) and Colclough *et al*. (2002) summarise the history of tidal Thames River Surveys. These accounts indicate that current information with regards to the fish life of the Thames has been obtained piecemeal and have come from such diverse sources as angling club records, examination of power station intake screens, fishing competition results, seine and small trawl netting experiments, trap surveys, commercial fishing returns and individual fieldwork initiatives. The present experimental netting series was not intended to provide a comprehensive picture of the Thames ichthyofauna, but to provide information on the possible impact on catch results of the adapted nets.

In terms of CPUE, the weight of by-catch was significantly higher in the 50mm ring and 70mm square mesh nets than for the other net types. The explanation being that they tended to retain smaller numbers of relatively large fish compared to the other nets that retained higher numbers of smaller fish (lower total weight). In terms of catch numbers, sole, a commercially valuable fish (Gibson *et al*., 2015), and flounder were the top two species of fish caught. The standard fyke net and the 22mm ring trapped more small fish for the standard length size classes 0–5cm and 5.1–10cm, but although sole and flounder of this standard length class survived net capture to be returned to the Thames alive, a number of fish species in this size category did not. These included; sand goby (*Pomatoschistus minutus*), European sea bass (*Dicentrarchus labrax*), sprat (*Sprattus sprattus*), whiting (*Merlangius merlangus*), pouting (*Trisopterus luscus*), and common goby (*Pomatoschistus microps*). No class size of pogge (*Agonus cataphractus*) or European smelt (*Osmerus eperlanus*) survived being trapped in the fyke nets.

Net design

<u>Releasing undersized eels</u>: The insertion of 2×22mm rings into the 20mm mesh cod end was proposed in order to release under sized eels (< 30cm). All eels then retained in such a net could be considered of legal size and be marketed without further delays in sorting through the catch. The two separate net trials undertaken in 2012 and 2013, demonstrated by inference that the 22mm rings apparently allow the escape of eels < 35cm. If 22mm escape rings were made compulsory for the holding end of the traditional fyke net, then the

minimum size for eel capture would be increased to ca. 35cm, alternatively a slightly smaller escape ring could potentially be used to release eels of ≤30cm in length, in line with current regulations.

Catching crabs whist releasing eels: *Eriocheir sinensis* populations continue to increase in number and disperse throughout water catchments in England and North Wales (visit www.mittencrabs.org.uk; 20 February 2017). Commercial exploitation using a traditional fyke net could be used as a method of controlling these invasive crabs, but although these nets are extremely efficient at trapping *E. sinensis*, they also capture eels. *Anguilla anguilla* is considered by the EU to be overfished and critically endangered (Jacoby and Gollock, 2014). Therefore trapping mitten crabs using fyke nets would not be acceptable unless the release of captured eels can be clearly demonstrated.

The 70mm square mesh holding (cod) end appeared to be environmentally friendly because it trapped Chinese mitten crabs yet allowed the escape of eels and indeed the majority of fish normally caught as by-catch in traditional fyke nets. Ultimately this could permit the licensing of a commercial mitten crab fishery in the Thames and other English and Welsh river catchments infested by this highly invasive and potentially economically damaging species. Such a fishery may help control *E. sinensis*. The sourcing and testing, however, of 35mm and or 30mm square mesh net holding ends with a view catching small class sizes of mitten crab but still releasing all eels would be required if commercial exploitation of *Eriocheir* was to be profitable. This would also serve to increase removal of the breeding population of mitten crabs from the Thames.

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Table 1. Trial 1: captured sexually mature females that fall within the body lengths as suggested by Sinha & Jones (1975), Tesch (1977) and Durif *et al.* (2005) for silver eels and an eye index greater than 6.5 (Pankhurst 1982).

#	**Length in mm**	**Index (IE)**	**Net type**	**Date 2012**
1	630	7.01	22mm rings	26 Sept
2	680	6.50	Standard	26 Sept
3	750	6.70	50mm mesh	29 Sept
4	610	8.24	Standard	29 Sept
5	770	6.53	50mm mesh	17 Oct
6	740	6.79	50mm mesh	17 Oct
7	570	6.75	22mm rings	17 Oct
8	770	7.37	50mm mesh	23 Oct
9	640	6.90	Standard	23 Oct
10	670	8.47	50mm mesh	29 Oct
11	650	8.73	22mm rings	29 Oct
12	570	8.82	22mm rings	29 Oct
13	520	7.40	22mm rings	29 Oct
14	610	7.24	22mm rings	29 Oct
15	870	9.95	22mm rings	01 Nov
16	760	6.61	50mm mesh	04 Nov
17	780	12.19	50mm mesh	13 Nov
18	710	7.99	Standard	16 Nov
19	690	9.22	Standard	16 Nov
20	790	7.18	Standard	19 Nov
21	740	6.79	Standard	22 Nov
22	810	8.75	Standard	22 Nov
23	690	8.22	22mm rings	07 Dec

Table 2. Trial 2: captured sexually mature females that fall within the body lengths as suggested by Sinha & Jones (1975), Tesch (1977) and Durif *et al.* (2005) for silver eels and an eye index greater than 6.5 (Pankhurst 1982).

#	Stn	Length in mm	Index (I_E)	Net type	Date 2013
1	1	570	6.75	Standard	18 May
2	1	600	7.36	Standard	18 May
3	1	720	6.98	Standard	18 May
4	1	700	7.18	Standard	18 May
5	1	720	6.98	22mm rings	18 May
6	2	670	7.50	Standard	21 May
7	3	500	6.64	Standard	24 May
8	6	500	6.64	Standard	02 Jun
9	7	690	7.29	Standard	05 Jun
10	8	750	6.70	Standard	08 Jun
11	8	490	6.77	Standard	08 Jun
12	9	660	7.62	22mm rings	11 Jun
13	10	590	6.52	Standard	14 Jun
14	10	540	7.13	Standard	14 Jun
15	10	520	13.63	Standard	14 Jun
16	10	610	8.24	Standard	14 Jun
17	10	580	12.22	22mm rings	14 Jun
18	10	660	7.62	22mm rings	14 Jun
19	10	570	9.96	22mm rings	14 Jun
20	11	640	7.86	22mm rings	17 Jun
21	11	640	7.86	22mm rings	17 Jun
22	12	760	7.47	22mm rings	20 Jun
23	12	730	8.72	22mm rings	20 Jun
24	12	570	6.75	22mm rings	20 Jun
25	12	730	8.72	22mm rings	20 Jun

Table 3. List of fish species caught as by-catch during the nets trials of 2012 and 2013.

	Fish species	**Vernacular name**	**Number trapped 2012**	**Number trapped 2013**
1	*Platichthys flesus* (Linnaeus, 1758)	European flounder	1284	467
2	*Solea solea* (Linnaeus, 1758)	common sole	740	789
3	*Pomatoschistus minutus* (Pallas, 1770)	sand goby	202	0
4	*Dicentrarchus labrax* (Linnaeus, 1758)	European sea bass	168	7
5	*Sprattus sprattus* (Linnaeus, 1758)	sprat	162	0
6	*Osmerus eperlanus* (Linnaeus, 1758)	European smelt	161	43
7	*Merlangius merlangus* (Linnaeus, 1758)	whiting	104	0
8	*Trisopterus luscus* (Linnaeus, 1758)	pouting	20	2
9	*Pomatoschistus microps* (Krøyer, 1838)	common goby	16	0
10	*Agonus cataphractus* (Linnaeus, 1758)	pogge	16	0
11	*Chelidonichthys lucerna* (Linnaeus, 1758)	tub gurnard	9	0
12	*Chelidonichthys cuculus* (Linnaeus, 1758)	red gurnard	3	0
13	*Clupea harengus* Linnaeus, 1758	Atlantic herring	2	0
14	*Liza ramada* (Risso, 1827)	thin-lipped grey mullet	1	0
15	*Aphia minuta* (Risso, 1810)	transparent goby	1	0
16	*Gasterosteus aculeatus* Linnaeus, 1758	three-spined stickleback	1	0
17	*Labrus bergylta* Ascanius, 1767	ballan wrasse	1	0
18	*Perca fluviatilis* Linnaeus, 1758	perch	1	1
19	*Gadus morhua* Linnaeus, 1758	Atlantic cod	1	1
20	*Rutilus rutilus* (Linnaeus, 1758)	common roach	1	0
21	*Syngnathus acus* Linnaeus, 1758	greater pipe fish	0	2

Table 4. Entrapment of silver eels during the 2012 & 2013 trials.

	2012				2013		
	Standard	22mm	50mm ring	50mm mesh	Standard	22mm	40mm
Silver eels	8/177	8/146	0/5	7/17	14/125	11/75	0
Percentage	4.52	5.48	0	41.18	11.20	14.67	0

Figure legends

Figure 1. Fyke net trials were undertaken in the Thames Estuary between Crossness and Broadness Point, Greenhithe comprising 29 visits from 17 September to 13 December 2012 and 13 visits from 18 May to 23 June 2013.

Figure 2. Fyke nets deployed in the Thames during this present survey: (a) Standard (traditional) fyke net, (b) Standard fyke net with 2×22mm (actually 21.83mm) brass rings inserted into the cod end, (c) Standard 20mm fyke net with a 50mm stainless steel ring inserted into cod end. Photographs by Harry Taylor, NHM Photo Unit.

Figure 3. Modified holding end: (a) Standard fyke net, (b) Holding end made from 50mm pot netting kept open with two plastic hoops, (c) Modified holding end tied into the cod end of a traditional fyke net. Photographs by Harry Taylor, NHM Photo Unit.

Figure 4. Fyke nets deployed in the Thames during this present survey: (a) Standard (traditional) fyke net, (b) Standard fyke net with 2×22mm (actually 21.83mm) brass rings inserted into the cod end, (c) Holding end (cod end) made from 70mm (40mm square) net set on the square and not the diagonal. Photographs by Harry Taylor, NHM Photo Unit.

Figure 5. Mean (± S.D.) CPUE for eel weights (kg/end/day) vs. type of net trialled for 2012.

Figure 6. Mean (± S.D.) CPUE for eel numbers (numbers/end/day) vs. type of net trialled for 2012.

Figure 7. Mean (± S.D.) CPUE for mitten crab numbers (numbers/end/day) vs. type of net trialled for 2012.

Figure 8. Mean (± S.D.) CPUE for by-catch weights (kg/end/day) vs. type of net trialled for 2012.

Figure 9. Mean (± S.D.) CPUE for eel weights (kg/end/day) vs. type of net trialled for 2013.

Figure 10. Mean (± S.D.) CPUE for eel numbers (numbers/end/day) vs. type of net trialled for 2013.

Figure 11. Mean (± S.D.) CPUE for mitten crab numbers (numbers/end/day) vs. type of net trialled for 2013.

Figure 12. Mean (± S.D.) CPUE for by-catch weights (kg/end/day) vs. type of net trialled for 2013.

Figure 13. Standard fyke net set in 2012: (a) Total length distribution of 177 eels caught, (b) Carapace width distribution of 142 *Eriocheir sinensis* caught, (c) Standard length distribution of 1008 fish caught.

Figure 14. 22 mm ring fyke net set in 2012: (a) Total length distribution of 146 eels caught, (b) Carapace width distribution of 125 *Eriocheir sinensis* caught, (c) Standard length distribution of 944 fish caught.

Figure 15. 50mm ring fyke net set in 2012: (a) Total length distribution of 5 eels caught, (b) Carapace width distribution of 64 *Eriocheir sinensis* caught, (c) Standard length distribution of 638 fish caught.

Figure 16. 50mm diagonal mesh cod end fyke net set in 2012: (a) Total length distribution of 17 eels caught, (b) Carapace width distribution of 96 *Eriocheir sinensis* caught, (c) Standard length distribution of 304 fish caught.

Figure 17. The total number of fish caught during 2012: (a) Standard length size class 5.1–10cm captured by the standard fyke net, (b) Standard length size class 5.1–10cm captured by the 20mm ring net, (c) Standard length size class 5.1–10cm captured by the 50mm ring net, (d) Standard length size class 5.1–10cm, captured by the 50mm mesh net set on the diagonal.

Figure 18. Standard fyke net set in 2013: (a) Total length distribution of 125 eels caught, (b) Carapace width distribution of 110 *Eriocheir sinensis* caught, (c) Standard length distribution of 657 fish caught.

Figure 19. 22mm ring fyke net set in 2013: (a) Total length distribution of 75 eels caught, (b) Carapace width distribution of 86 *Eriocheir sinensis* caught, (c) Standard length distribution of 525 fish caught.

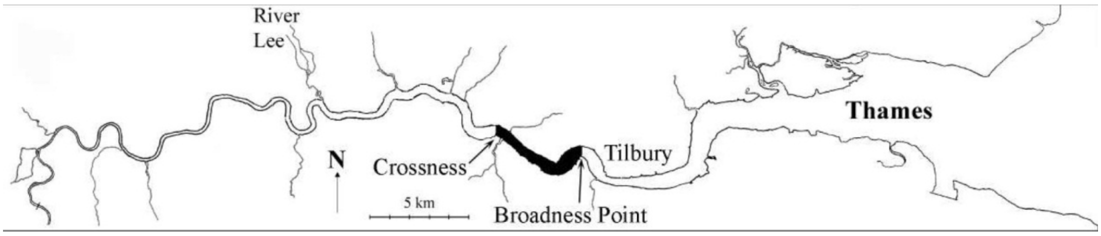
Figure 20. 40mm square mesh cod end fyke net set in 2013: no eels were trapped, (a) Carapace width distribution of 11 *Eriocheir sinensis*, (b) Standard length distribution of 130 fish caught.

Figure 21. (a) Standard net set in 2013: total number of fish captured, standard length size class 5.1–10cm; (b) 22mm ring net set in 2013: total number of fish captured, standard length size class 5.1–10cm; (c) 40mm square mesh net in 2013: total number of fish captured, standard length size class 5.1–10cm.

Figure 22. When this 50mm diagonal mesh is tensioned the net closes and does not provide an easy escape mechanism for trapped eels.

Figure 23. 70mm soft cricket net with the square mesh does not close under tension leaving the lines perpendicular to “tensioned” sides, stress-free and open, therefore providing eels with an effortless escape mechanism.

Figure 24. Thames eel capture data: Environment Agency 2009 vs. standard and 22 ring fyke net from 2012 and 2013 of the present study.



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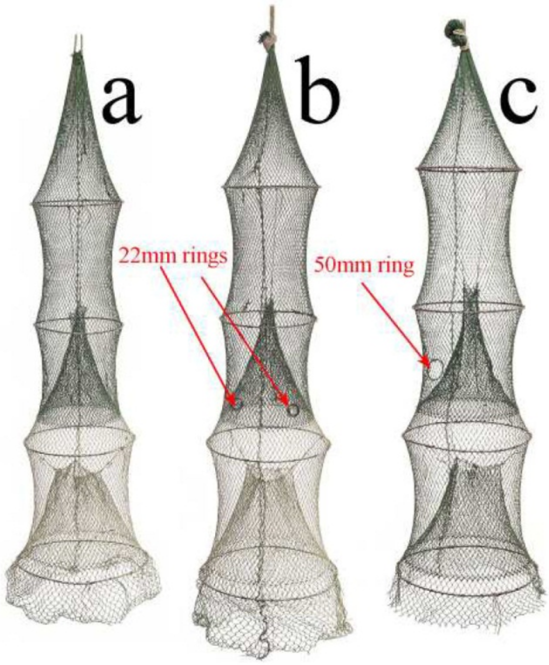

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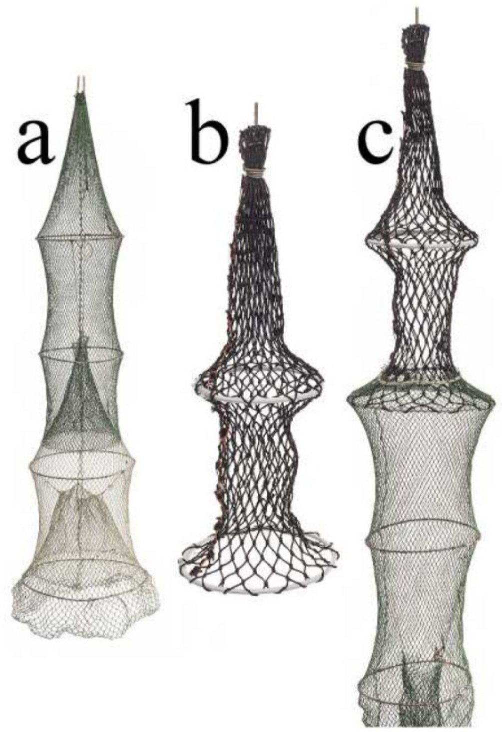

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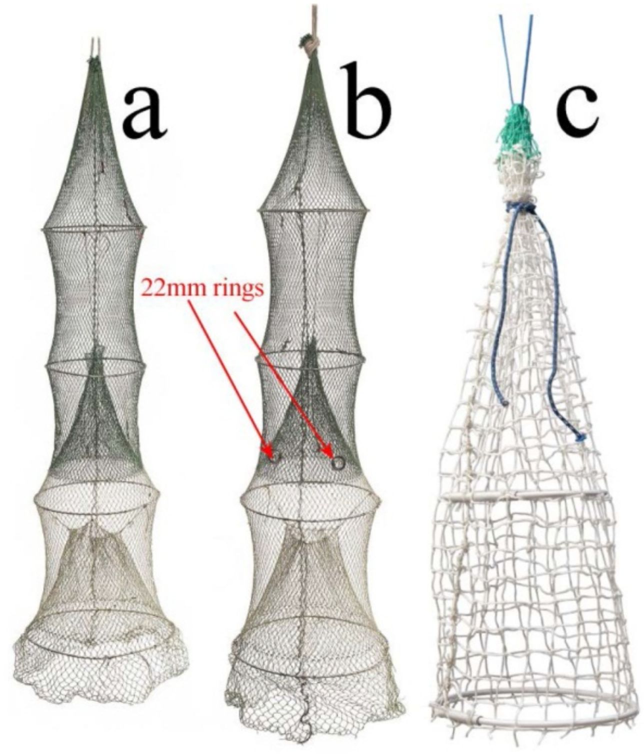

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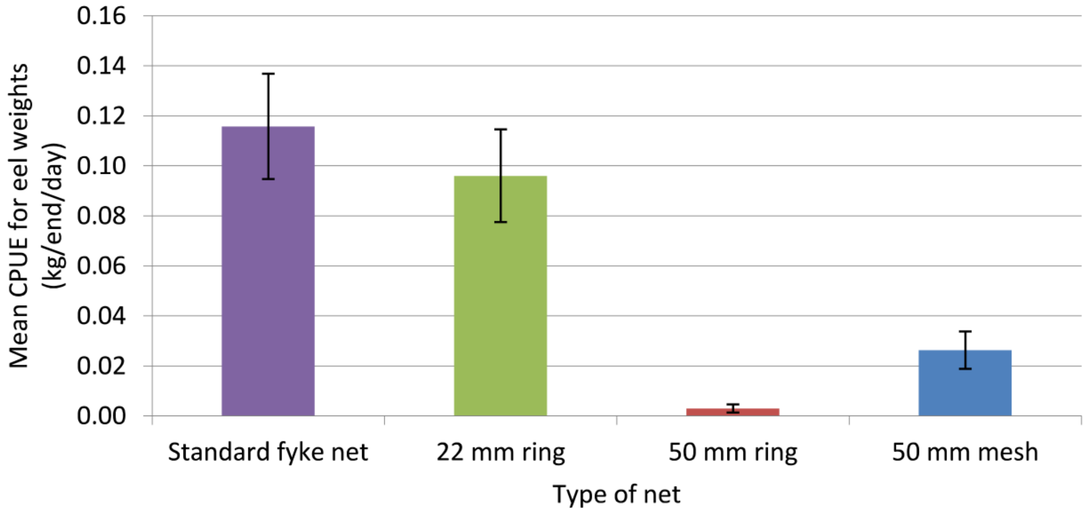

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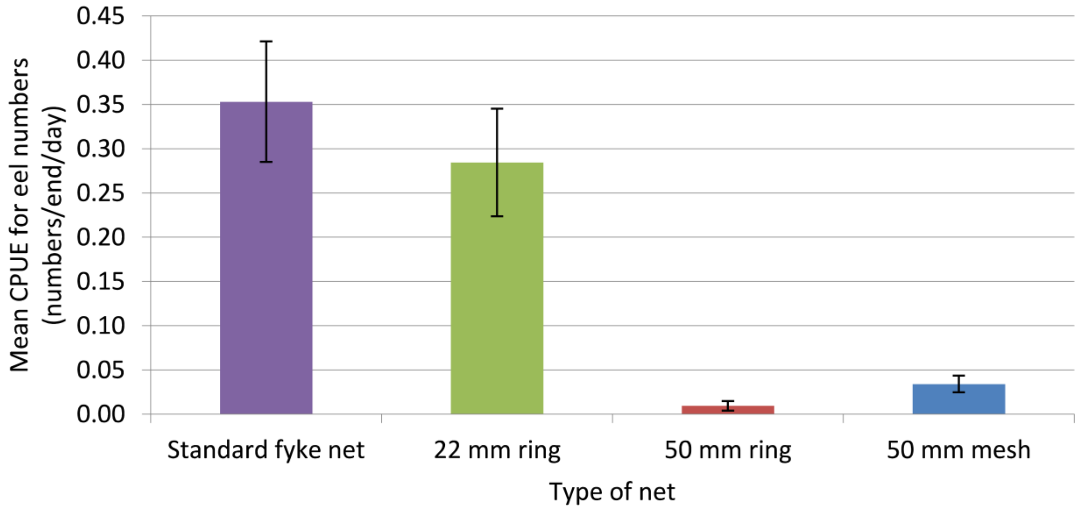


Figure 6. Mean (± S.D.) CPUE for eel numbers (numbers/end/day) vs. type of net trialled for 2012.

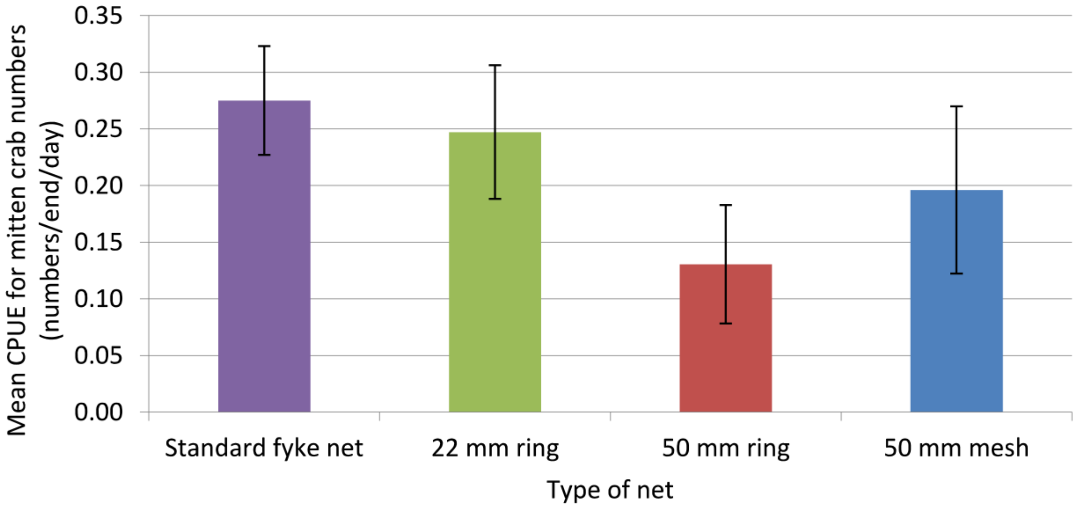


Figure 7. Mean (± S.D.) CPUE for mitten crab numbers (numbers/end/day) vs. type of net trialled for 2012.

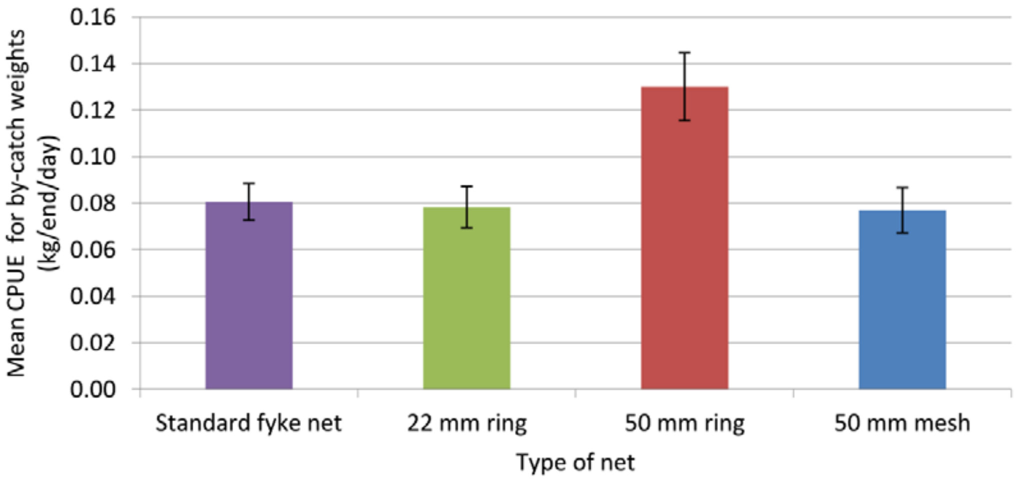


Figure 8. Mean (± S.D.) CPUE for by-catch weights (kg/end/day) vs. type of net trialled for 2012.

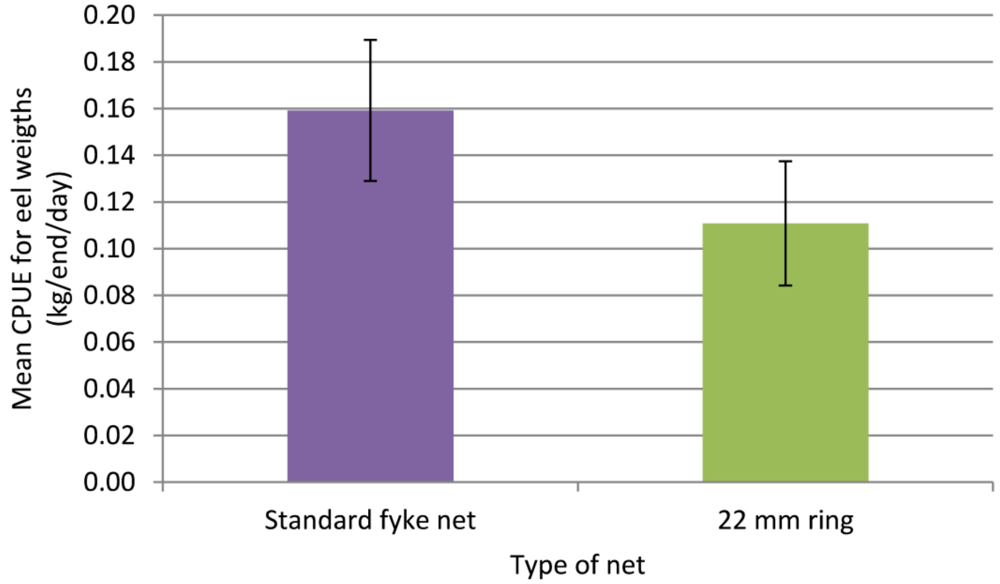


Figure 9. Mean (± S.D.) CPUE for eel weights (kg/end/day) vs. type of net trialled for 2013.

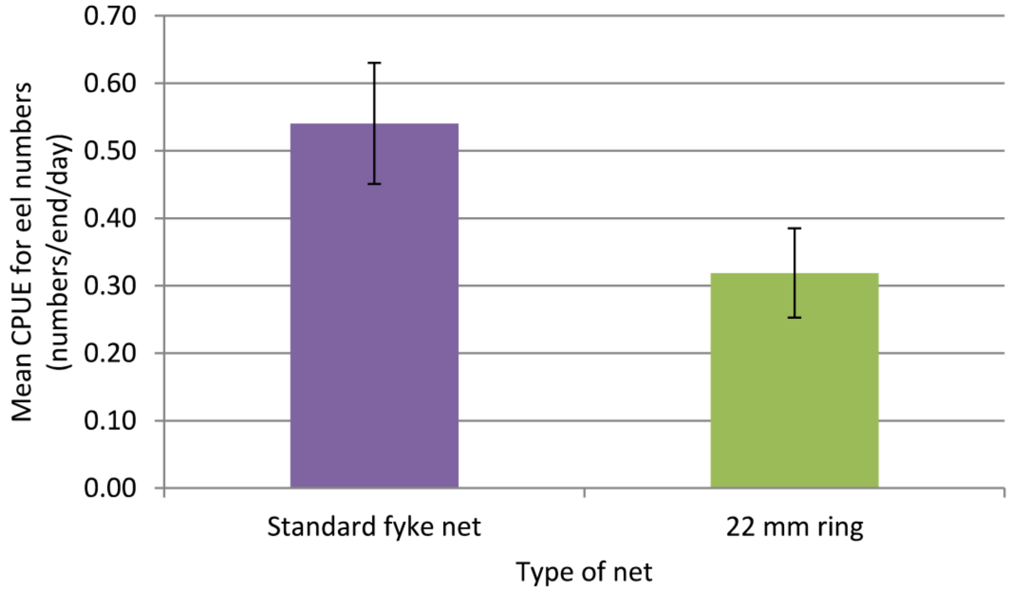
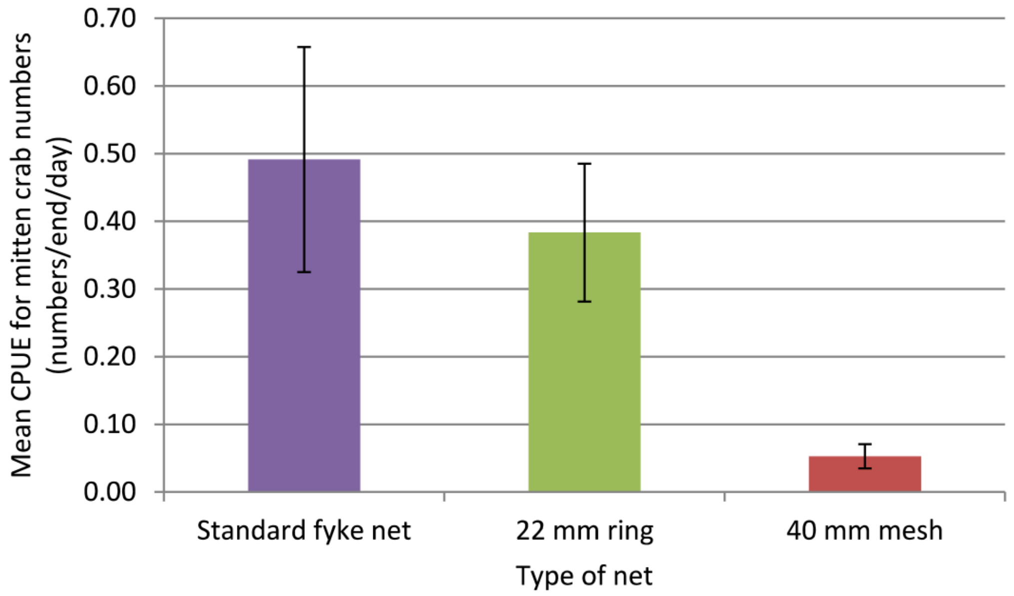


Figure 10. Mean (± S.D.) CPUE for eel numbers (numbers/end/day) vs. type of net trialled for 2013.



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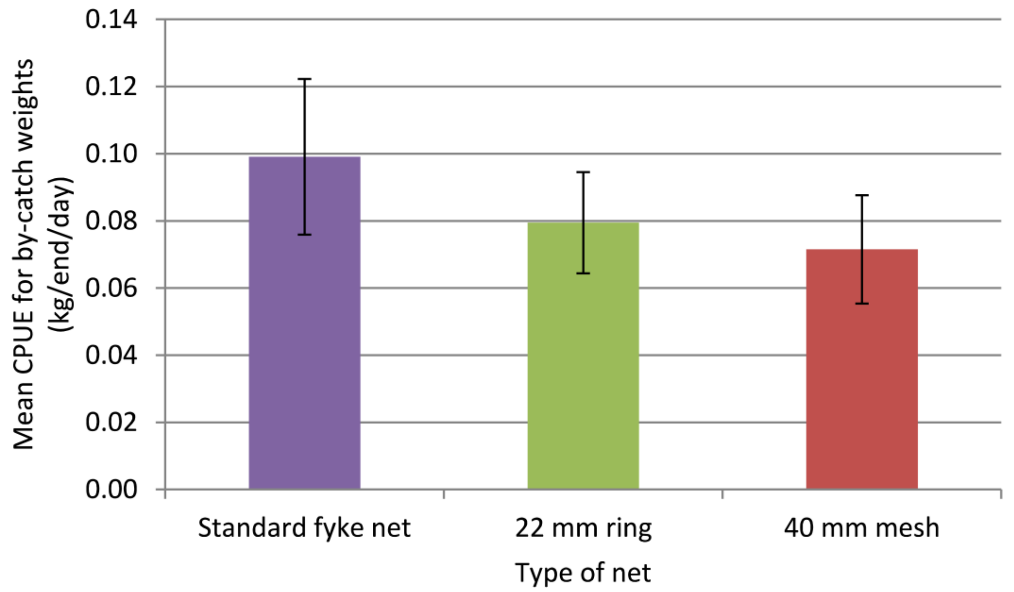

Figure 12. Mean (± S.D.) CPUE for by-catch weights (kg/end/day) vs. type of net trialled for 2013.

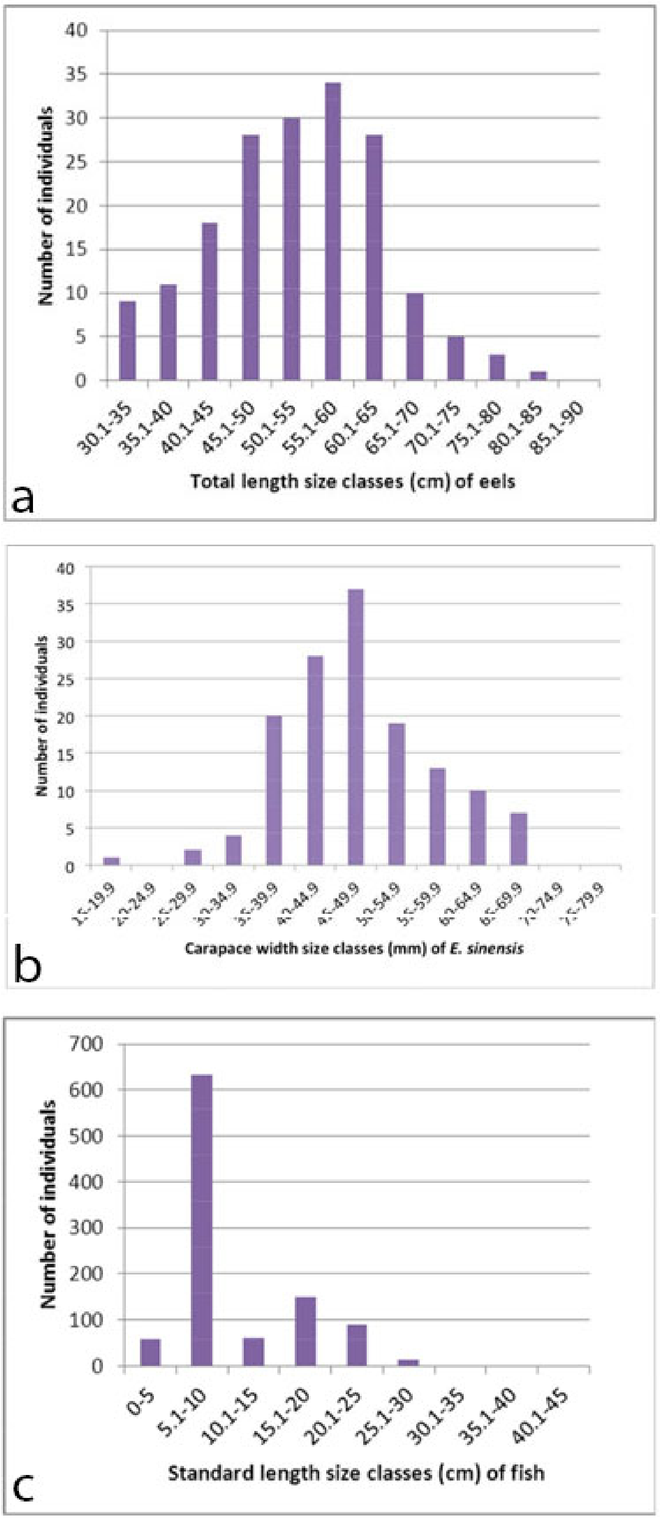

Figure 13. Standard fyke net set in 2012: (a) Total length distribution of 177 eels caught, (b) Carapace width distribution of 142 *Eriocheir sinensis* caught, (c) Standard length distribution of 1008 fish caught.

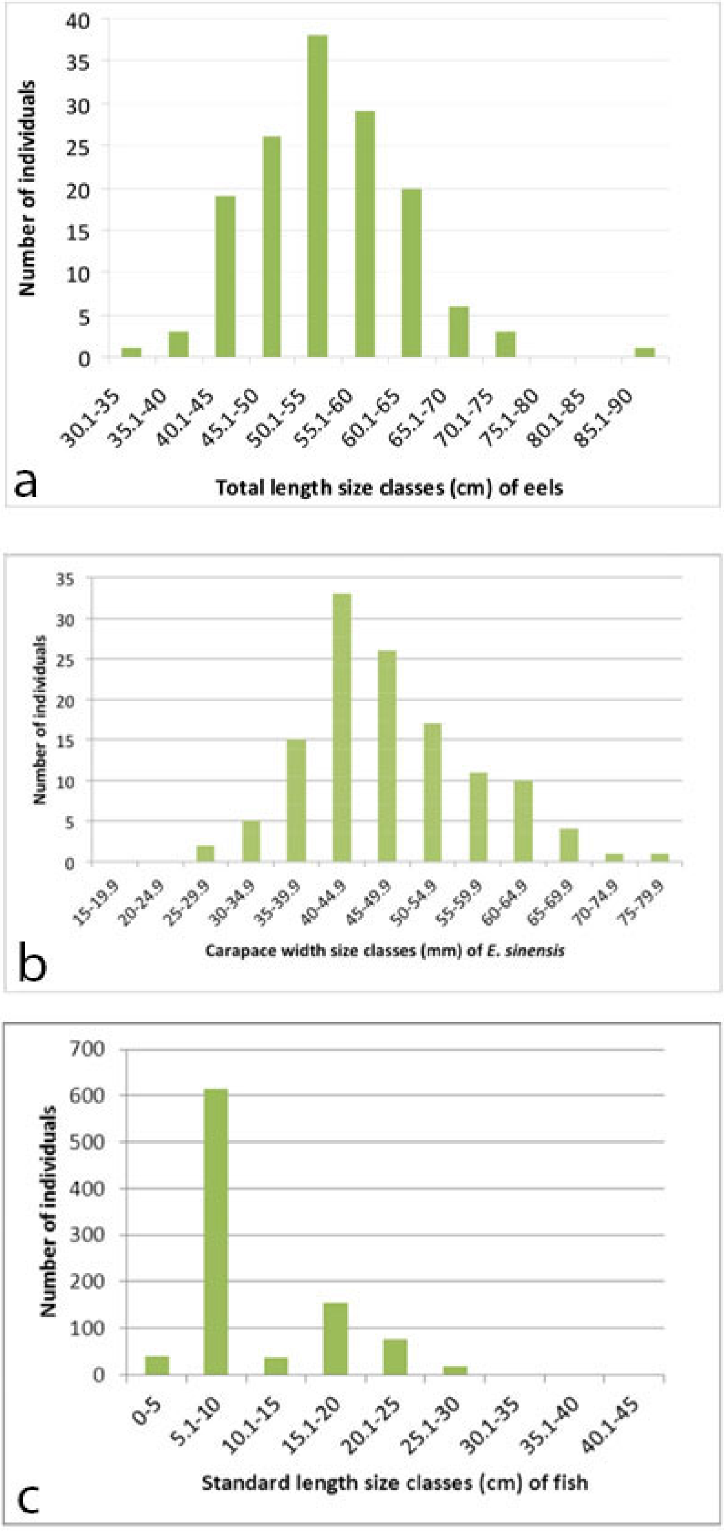

Figure 14. 22 mm ring fyke net set in 2012: (a) Total length distribution of 146 eels caught, (b) Carapace width distribution of 125 *Eriocheir sinensis* caught, (c) Standard length distribution of 944 fish caught.

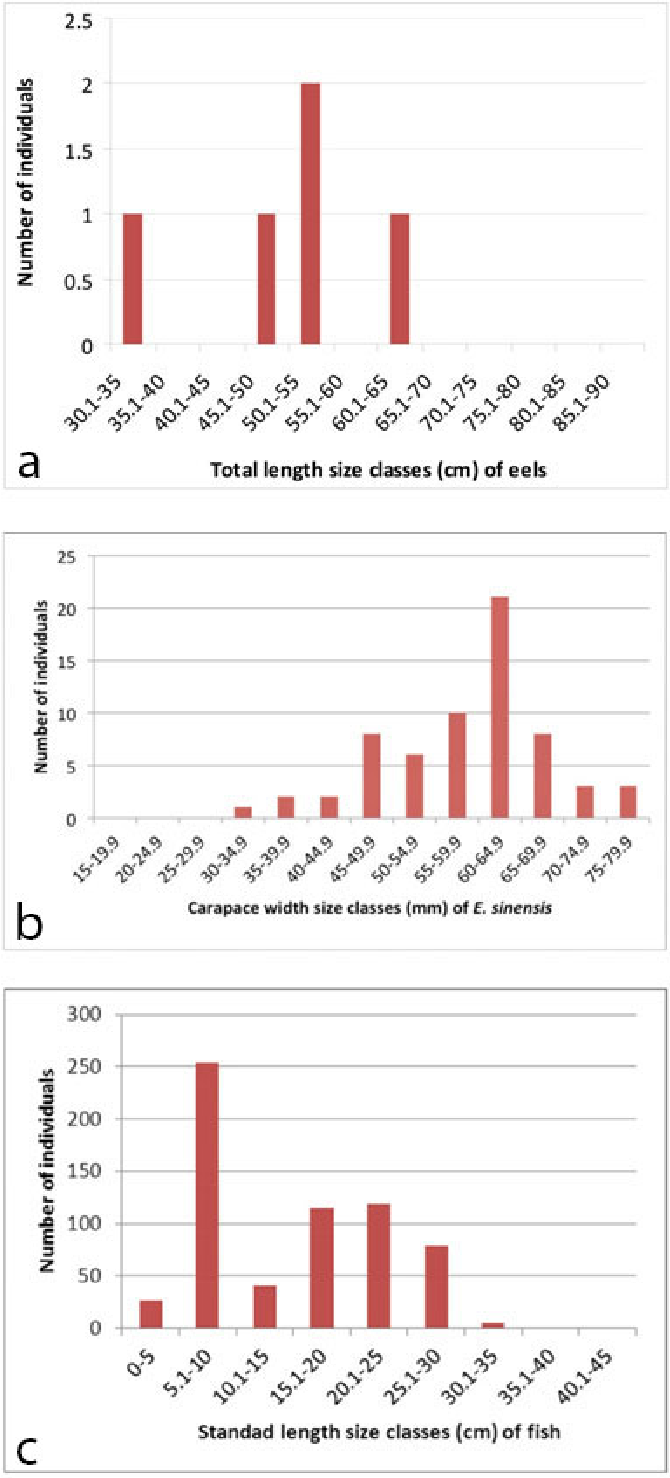

Figure 15. 50mm ring fyke net set in 2012: (a) Total length distribution of 5 eels caught, (b) Carapace width distribution of 64 *Eriocheir sinensis* caught, (c) Standard length distribution of 638 fish caught.

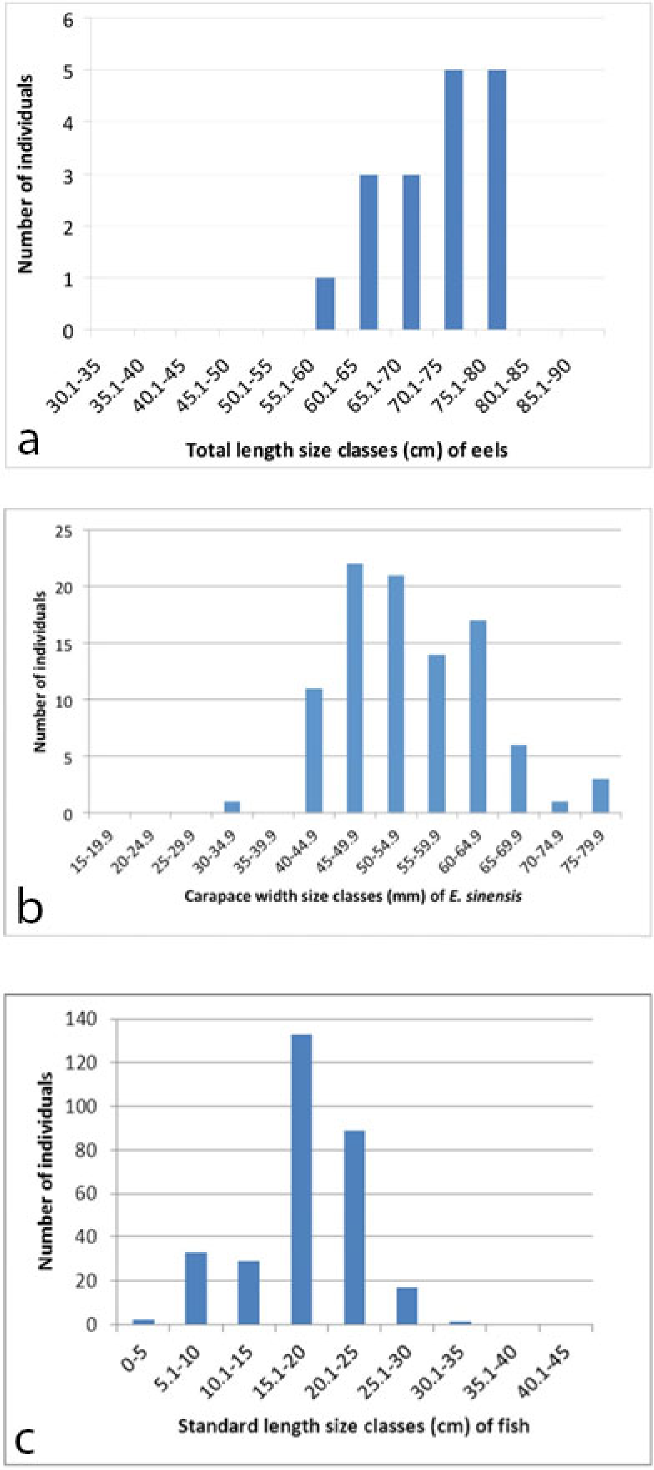

Figure 16. 50mm diagonal mesh cod end fyke net set in 2012: (a) Total length distribution of 17 eels caught, (b) Carapace width distribution of 96 *Eriocheir sinensis* caught, (c) Standard length distribution of 304 fish caught.

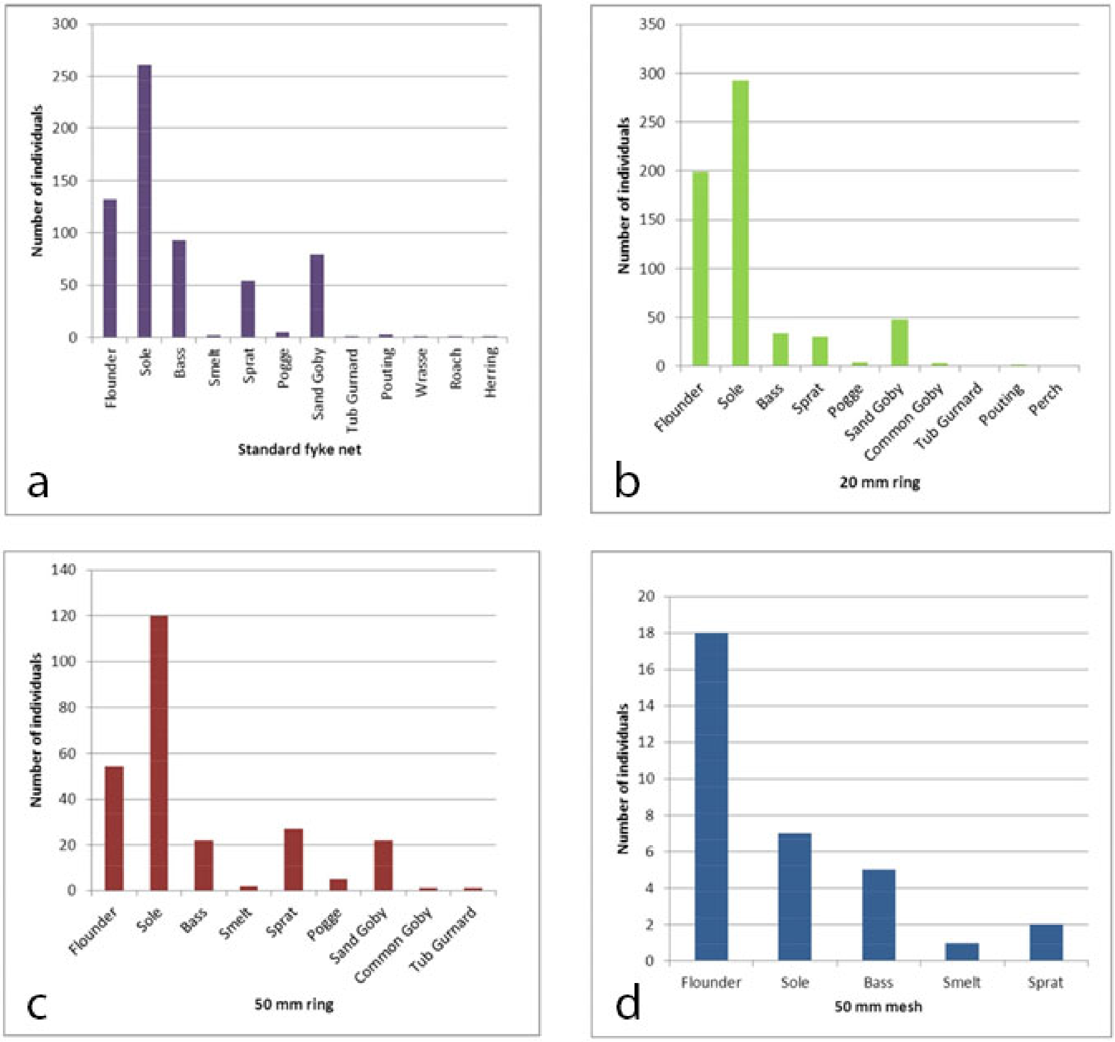

Figure 17. The total number of fish caught during 2012: (a) Standard length size class 5.1–10cm captured by the standard fyke net, (b) Standard length size class 5.1–10cm captured by the 20mm ring net, (c) Standard length size class 5.1–10cm captured by the 50mm ring net, (d) Standard length size class 5.1–10cm, captured by the 50mm mesh net set on the diagonal.

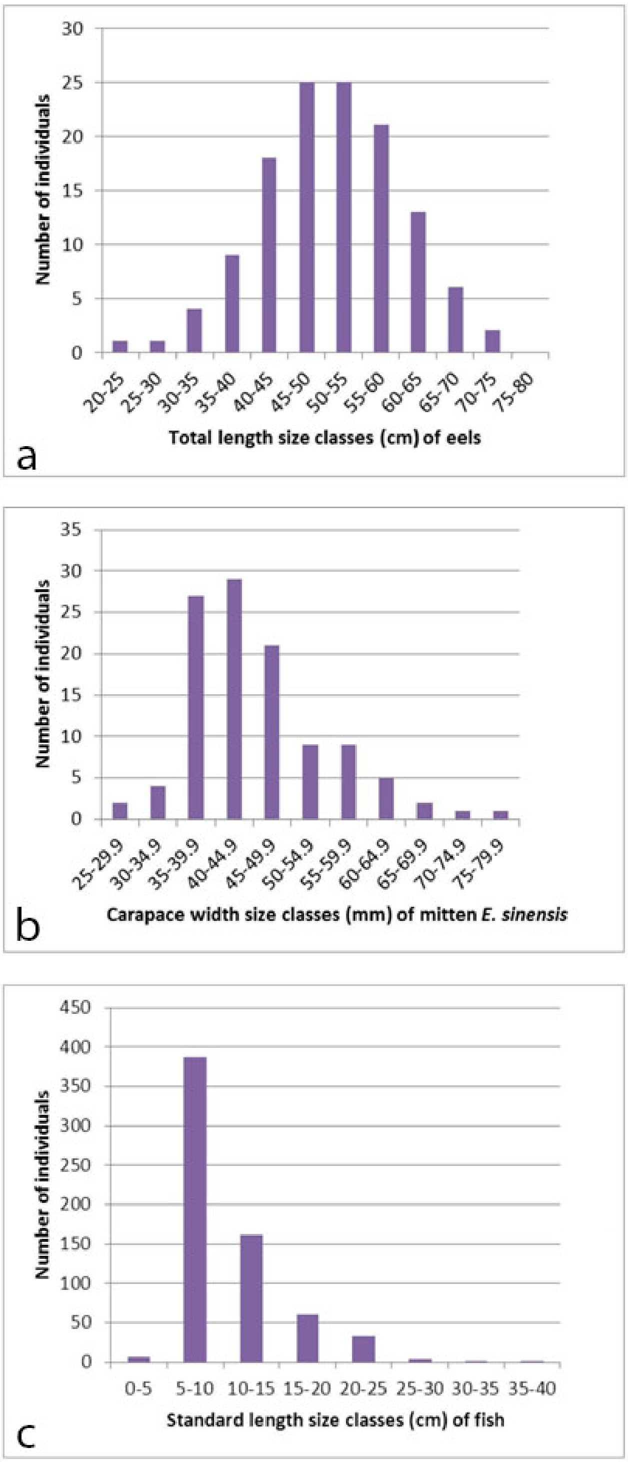

Figure 18. Standard fyke net set in 2013: (a) Total length distribution of 125 eels caught, (b) Carapace width distribution of 110 *Eriocheir sinensis* caught, (c) Standard length distribution of 657 fish caught.

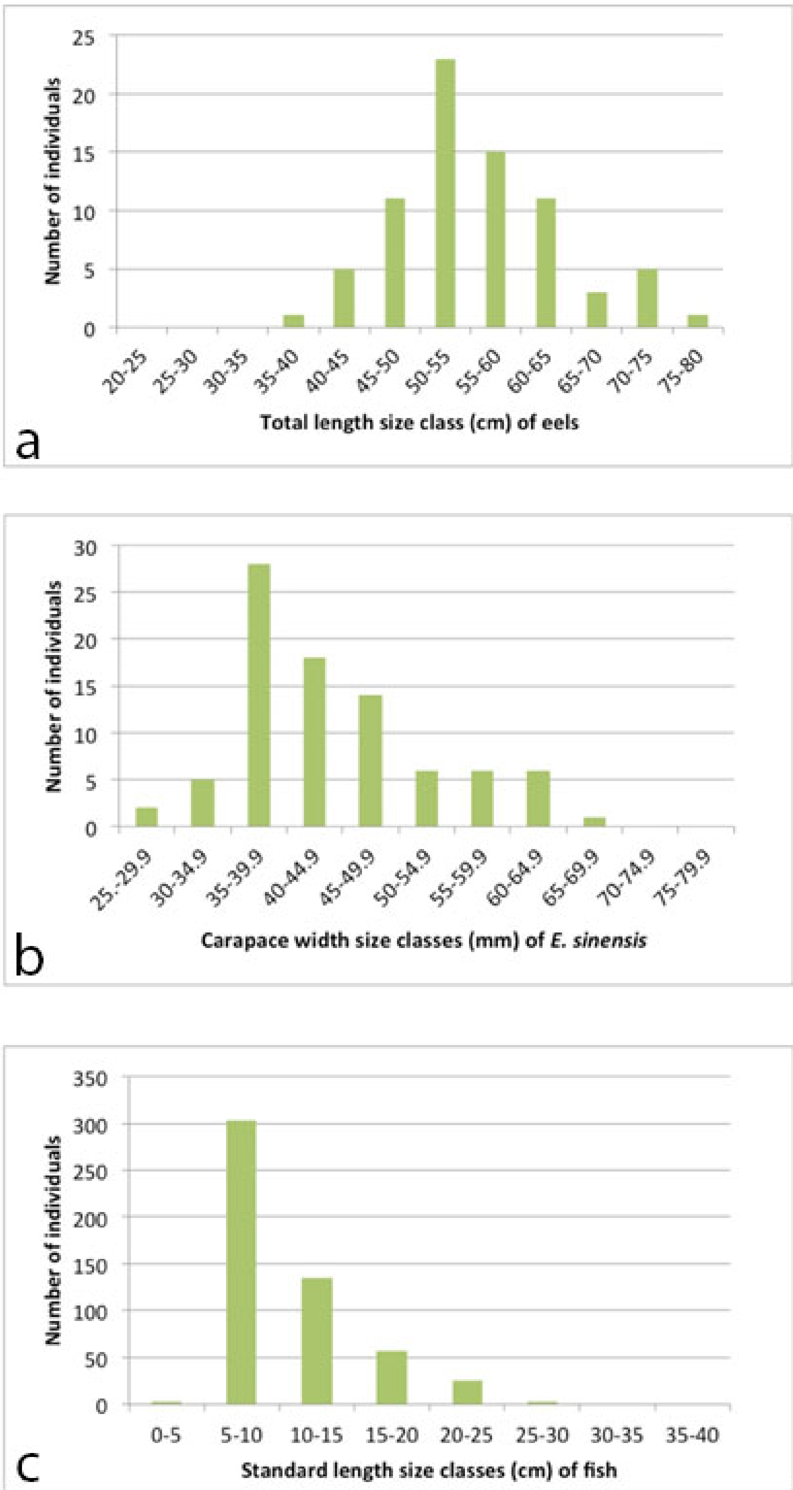

Figure 19. 22mm ring fyke net set in 2013: (a) Total length distribution of 75 eels caught, (b) Carapace width distribution of 86 *Eriocheir sinensis* caught, (c) Standard length distribution of 525 fish caught.

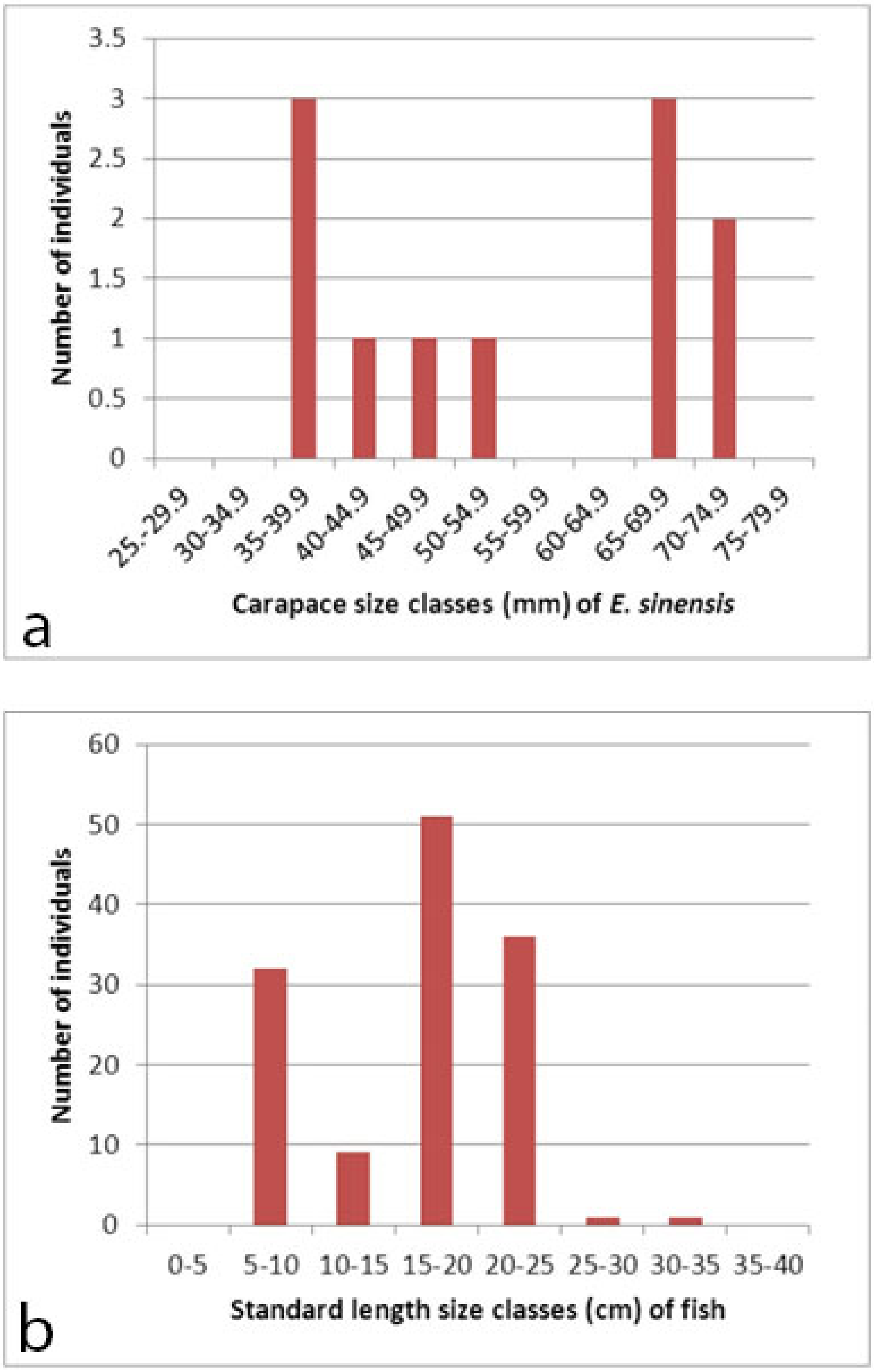

Figure 20. 40mm square mesh cod end fyke net set in 2013: no eels were trapped, (a) Carapace width distribution of 11 *Eriocheir sinensis*, (b) Standard length distribution of 130 fish caught.

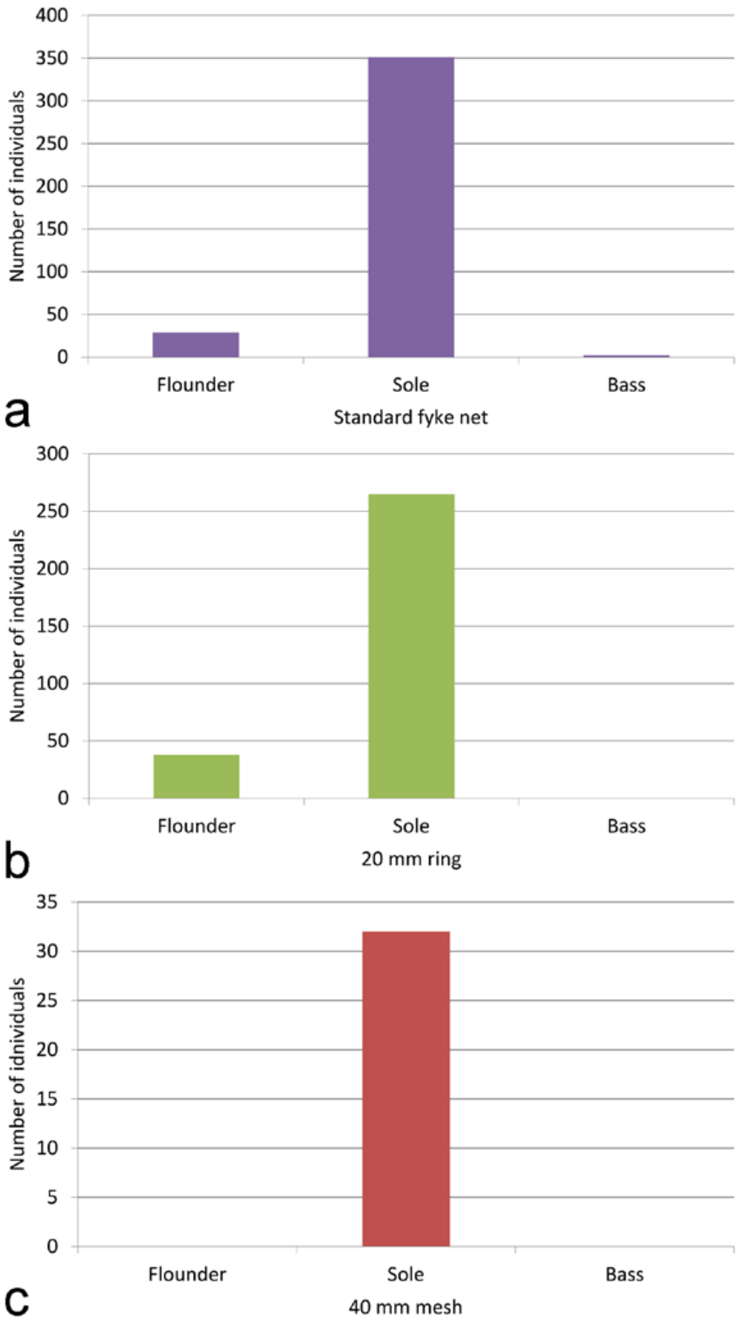

Figure 21. (a) Standard net set in 2013: total number of fish captured, standard length size class 5.1–10cm; (b) 22mm ring net set in 2013: total number of fish captured, standard length size class 5.1–10cm; (c) 40mm square mesh net in 2013: total number of fish captured, standard length size class 5.1–10cm.

Figure 22. When this 50mm diagonal mesh is tensioned the net closes and does not provide an easy escape mechanism for trapped eels.

Figure 23. 70mm soft cricket net with the square mesh does not close under tension leaving the lines perpendicular to “tensioned” sides, stress-free and open, therefore providing eels with an effortless escape mechanism.

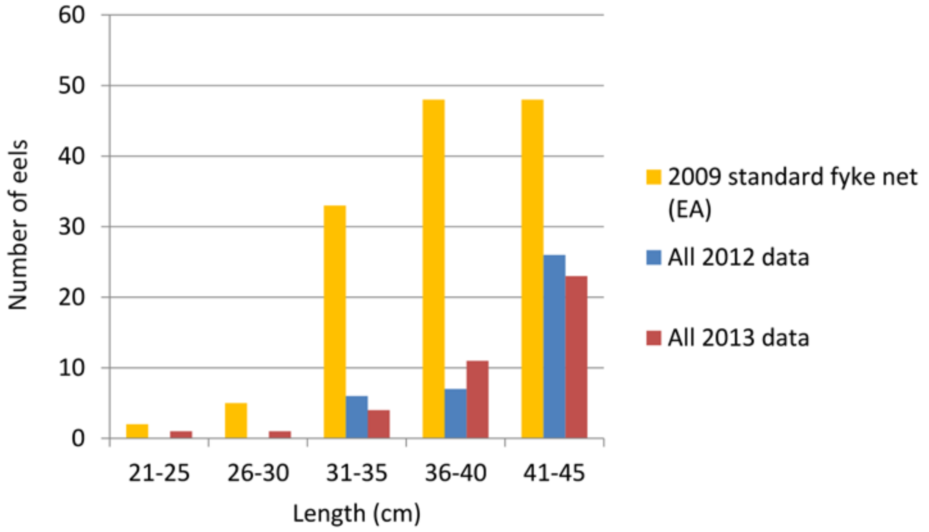

Figure 24. Thames eel capture data: Environment Agency 2009 vs. standard and 22 ring fyke net from 2012 and 2013 of the present study.

Supporting Information

Additional Supporting Information may be found in the online version of this article:
Appendix S1. Twenty-nine Upper Thames Estuary localities were fished from 17 September to 13 December 2012.

Station 1 North bank of Erith Rands 17–20 September 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.282'N 000° 12.571'E	0905	1135	7430
2	22 mm ring	51° 29.296'N 000° 12.445'E	0855	1030	7335
3	50mm ring	51° 29.293'N 000° 12.237'E	0840	0945	7305
4	50mm mesh	51° 29.270'N 000° 12.195'E	0830	0915	7245

Station 2 West of Littlebrook Power Station 20–23 September 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.041'N 000° 14.686'E	1313	1342	7229
2	22 mm ring	51° 28.234'N 000° 14.302'E	1305	1330	7225
3	50mm ring	51° 28.338'N 000° 14.164'E	1256	1245	7149
4	50mm mesh	51° 28.501'N 000° 13.908'E	1249	1235	7146

Station 3 Long Reach, Greenhithe 23–26 September 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.281'N 000° 17.050'E	1530	1617	7247
2	22 mm ring	51° 27.324'N 000° 16.365'E	1520	1605	7245
3	50mm ring	51° 27.393'N 000° 16.134'E	1510	1537	7227
4	50mm mesh	51° 27.532'N 000° 15.868'E	1500	1530	7230

Station 4 Broadness, Lower Greenhithe 26–29 September 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.603'N 000° 18.007'E	1719	0904	6345
2	22 mm ring	51° 27.507'N 000° 17.816'E	1713	0858	6345
3	50mm ring	51° 27.416'N 000° 17.637'E	1707	0818	6311
4	50mm mesh	51° 27.364'N 000° 17.468'E	1704	0807	6303

Station 5 Phoenix Jetty 29 September – 02 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.409'N 000° 10.421 'E	1029	0934	7105
2	22 mm ring	51° 30.515'N 000° 10.176'E	1020	0926	7106
3	50mm ring	51° 30.608'N 000° 09.822'E	1013	0901	7048
4	50mm mesh	51° 30.640'N 000° 19.597'E	1005	0825	7020

Station 6 Crossness 02–05 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.366'N 000° 08.611'E	1112	1132	7220
2	22 mm ring	51° 30.511'N 000° 08.912'E	1103	1210	7307
3	50mm ring	51° 30.600'N 000° 08.610'E	1055	1025	7130
4	50mm mesh	51° 30.634'N 000° 09.528'E	1049	1016	7127

Station 7 Rainham Marshes 05–08 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.690'N 000° 10.909'E	1336	1242	7106
2	22 mm ring	51° 29.807'N 000° 10.878'E	1328	1230	7123
3	50mm ring	51° 29.612'N 000° 10.943'E	1323	1210	7041
4	50mm mesh	51° 29.566'N 000° 10.971'E	1315	1200	7022

Station 8 Erith Yacht Club 08–11 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.953'N 000° 12.396'E	1318	1523	7220
2	22 mm ring	51° 28.846'N 000° 11.871'E	1313	1514	7307
3	50mm ring	51° 28.844'N 000° 11.656'E	1307	1442	7130
4	50mm mesh	51° 28.868'N 000° 11.514'E	1303	1435	7127

Station 9 North bank of Erith Rands 11–14 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.296'N 000° 12.445'E	1635	1228	6753
2	22 mm ring	51° 29.293'N 000° 12.330'E	1630	1222	6752
3	50mm ring	51° 29.290'N 000° 12.218'E	1624	1150	6726
4	50mm mesh	51° 29.285'N 000° 12.211'E	1618	1141	6723

Station 10 Upper Littlebrook 14–17 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.198'N 000° 14.381'E	1357	0750	6553
2	22 mm ring	51° 28.355'N 000° 14.120'E	1352	0758	6606
3	50mm ring	51° 28.549'N 000° 13.967'E	1343	0917	6729
4	50mm mesh	51° 28.505'N 000° 13.881'E	1335	0926	6751

Station 11 Greenhithe-Dartford International Ferry Terminal 17–20 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.325'N 000° 16.366'E	1106	1008	7123
2	22 mm ring	51° 27.427'N 000° 16.064'E	1052	1000	7108
3	50mm ring	51° 27.349'N 000° 16.283'E	1059	0931	7032
4	50mm mesh	51° 27.516'N 000° 15.896'E	1043	0920	7037

Station 12 Greenhithe 20–23 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.316'N 000° 17.310'E	1130	1211	7241
2	22 mm ring	51° 27.301'N 000° 12.142'E	1125	1205	7240
3	50mm ring	51° 27.276'N 000° 16.953'E	1115	1142	7227
4	50mm mesh	51° 27.275'N 000° 16.695'E	1109	1133	7037

Station 13 Broadness Point 23–26 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.372'N 000° 17.470'E	1316	1508	7352
2	22 mm ring	51° 27.432'N 000° 17.666'E	1310	1502	7352
3	50mm ring	51° 27.514'N 000° 17.839'E	1305	1438	7333
4	50mm mesh	51° 27.625'N 000° 18.031'E	1301	1430	7329

Station 14 Littlebrook Power Station 26–29 October 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.209'N 000° 14.366'E	1639	1300	6821
2	22 mm ring	51° 28.254'N 000° 14.283'E	1634	1249	6815
3	50mm ring	51° 28.357'N 000° 14.122'E	1629	1145	6716
4	50mm mesh	51° 28.413'N 000° 14.019'E	1624	1122	6658

Station 15 North bank of Erith Rands 29 October – 01 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.292'N 000° 12.891'E	1455	0810	6515
2	22 mm ring	51° 29.302'N 000° 12.610'E	1449	0801	6512
3	50mm ring	51° 29.301'N 000° 12.305'E	1443	0725	6442
4	50mm mesh	51° 29.293'N 000° 12.190'E	1438	0719	6441

Station 16 Erith Causeway 01–04 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.128'N 000° 10.728'E	0913	1001	7248
2	22 mm ring	51° 29.058'N 000° 10.823'E	0917	0955	7238
3	50mm ring	51° 29.000'N 000° 10.977'E	0922	0907	7145
4	50mm mesh	51° 28.896'N 000° 11.316'E	0929	0901	7132

Station 17 Phoenix Jetty 04–07 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.523'N 000° 10.188'E	1146	1115	7129
2	22 mm ring	51° 30.431'N 000° 10.384'E	1140	1109	7129
3	50mm ring	51° 30.379'N 000° 10.474'E	1135	1041	7129
4	50mm mesh	51° 30.331'N 000° 10.532'E	1130	1034	7104

Station 18 Upper Crossness 07–10 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.793'N 000° 08.100'E	1226	1510	7444
2	22 mm ring	51° 30.732'N 000° 08.189'E	1231	1503	7432
3	50mm ring	51° 30.702'N 000° 08.242'E	1237	1430	7353
4	50mm mesh	51° 30.644'N 000° 08.434'E	1244	1423	7339

Station 19 Erith Causeway 10–13 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.320'N 000° 10.508'E	1607	1138	6731
2	22 mm ring	51° 29.183'N 000° 10.640'E	1613	1129	6716
3	50mm ring	51° 29.110'N 000° 10.739'E	1618	1055	6637
4	50mm mesh	51° 29.039'N 000° 10.861'E	1625	1044	6619

Station 20 Phoenix Wharf 13–16 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.522'N 000° 10.190'E	1256	0858	6802
2	22 mm ring	51° 30.434'N 000° 10.397'E	1251	0851	6800
3	50mm ring	51° 30.220'N 000° 10.643'E	1244	0823	6739
4	50mm mesh	51° 30.066'N 000° 10.736'E	1239	0815	6736

Station 21 Greenhithe 16–19 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.327'N 000° 16.347'E	1058	1010	7112
2	22 mm ring	51° 37.266'N 000° 16.734'E	1053	1022	7129
3	50mm ring	51° 27.319'N 000° 17.222'E	1046	1110	7224
4	50mm mesh	51° 37.351'N 000° 17.464'E	1041	1103	7222

Station 22 Littlebrook Power Station 19–22 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.536'N 000° 15.915'E	1144	1325	7341
2	22 mm ring	51° 28.212'N 000° 14.362'E	1206	1226	7220
3	50mm ring	51° 27.643'N 000° 15.710'E	1150	1316	7326
4	50mm mesh	51° 27.911'N 000° 15.012'E	1158	1238	7326

Station 23 Erith Yacht Club 22–25 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.980'N 000° 12.575'E	1435	0835	6618
2	22 mm ring	51° 28.848'N 000° 11.844'E	1444	0756	6512
3	50mm ring	51° 28.850'N 000° 11.624'E	1450	0750	6500
4	50mm mesh	51° 28.965'N 000° 12.484'E	1430	0841	6611

Station 24 Erith Causeway 25–28 November 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.170'N 000° 10.651'E	0945	0834	7049
2	22 mm ring	51° 29.070'N 000° 10.802'E	0940	0822	7042
3	50mm ring	51° 29.031'N 000° 10.887'E	0934	0753	7019
4	50mm mesh	51° 28.989'N 000° 10.989'E	0929	0746	7017

Station 25 Phoenix Wharf 28 November – 01 December 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.524'N 000° 10.195'E	0937	0928	7151
2	22 mm ring	51° 30.491'N 000° 10.271'E	0934	0920	7146
3	50mm ring	51° 30.421'N 000° 10.405'E	0929	0855	7123
4	50mm mesh	51° 29.980'N 000° 10.795'E	0921	0841	7120

Station 26 Crossness 01–04 December 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.371'N 000° 08.488'E	1007	1210	7403
2	22 mm ring	51° 30.384'N 000° 09.133'E	1012	1216	7404
3	50mm ring	51° 30.457'N 000° 09.565'E	1016	1250	7434
4	50mm mesh	51° 30.375'N 000° 09.641'E	1023	1305	7442

Station 27 Littlebrook Power Station 04–07 December 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.216'N 000° 14.366'E	1441	1200	6919
2	22 mm ring	51° 28.260'N 000° 14.264'E	1436	1153	6917
3	50mm ring	51° 28.336'N 000° 14.149'E	1431	1116	6845
4	50mm mesh	51° 28.414'N 000° 14.018'E	1425	1110	6845

Station 28 Greenhithe-Dartford International Ferry Terminal 07–10 December 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.540'N 000° 15.909'E	1305	1441	7340
2	22 mm ring	51° 27.585'N 000° 15.799'E	1301	1448	7347
3	50mm ring	51° 27.402'N 000° 16.126'E	1312	1508	7356
4	50mm mesh	51° 27.335'N 000° 16.313'E	1317	1517	7400

Station 29 Erith Yacht Club 10–13December 2012					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.871'N 000° 12.043'E	1639	0939	6500
2	22 mm ring	51° 28.844'N 000° 11.851'E	1644	0944	6517
3	50mm ring	51° 28.963'N 000° 12.501'E	1636	0907	6431
4	50mm mesh	51° 28.979'N 000° 12.599'E	1625	0901	6436

Appendix S2. Thirteen Upper Thames Estuary localities were fished from 15 May to 23 June 2013.

Station 1 Phoenix Jetty 15–18 May 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.523´N 000° 10.180´E	0858	1152	7454
2	22 mm ring	51° 30.595´N 000° 09.949´E	0905	1232	7527
3	40 mm mesh	51° 30.423´N 000° 10.399´E	0914	1140	7426

Station 2 Crossness-Barking Power Station outfall 18–21 May 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.794´N 000° 08.105´E	1318	1425	7307
2	22 mm ring	51° 30.812´N 000° 08.590´E	1330	1343	7213
3	40 mm mesh	51° 30.959´N 000° 08.348´E	1326	1447	7321

Station 3 North Thamesmead 21–24 May 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 30.772´N 000° 07.397´E	1523	0630	6307
2	22 mm ring	51° 30.734´N 000° 07.287´E	1529	0700	6331
3	40 mm mesh	51° 30.694´N 000° 07.101´E	1534	0711	6337

Station 4 Erith Causeway 24–27 May 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.042´N 000° 10.855´E	0834	0820	7146
2	22 mm ring	51° 29.331´N 000° 10.723´E	0821	0900	7239
3	40 mm mesh	51° 29.098´N 000° 10.773´E	0829	0844	7215

Station 5 North Rands 27–30 May 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 29.300´N 000° 12.536´E	0947	1129	7342
2	22 mm ring	51° 29.268´N 000° 12.278´E	0942	1030	7248
3	40 mm mesh	51° 29.255´N 000° 12.077´E	0938	1010	7232

Station 6 Littlebrook Power Station 30 May – 2 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.212´N 000° 14.369´E	1240	1359	7319
2	22 mm ring	51° 28.262´N 000° 14.289´E	1229	1327	7258
3	40 mm mesh	51° 28.293´N 000° 14.225´E	1223	1307	7304

Station 7 Dartford Ferry Terminal, Lower Littlebrook 2–5 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.467´N 000° 16.016´E	1502	1733	7431
2	22 mm ring	51° 27.527´N 000° 15.922´E	1456	1700	7404
3	40 mm mesh	51° 27.556´N 000° 15.845´E	1452	1625	7333

Station 8 Johnson’s Jetty 5–8 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.328´N 000° 16.366´E	1823	0718	6055
2	22 mm ring	51° 27.361´N 000° 16.261´E	1818	0652	6034
3	40 mm mesh	51° 27.392´N 000° 16.184´E	1814	0636	6022

Station 9 Greenhithe 8–11 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.370´N 000° 17.473´E	0807	0816	7209
2	22 mm ring	51° 27.324´N 000° 17. 304´E	0803	0855	7252
3	40 mm mesh	51° 27.315´N 000° 17.230´E	0758	0919	7357

Station 10 White’s Jetty, Broadness 11–14 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.620´N 000° 18.040´E	0958	1106	7308
2	22 mm ring	51° 27.553´N 000° 17. 913´E	0954	1011	7217
3	40 mm mesh	51° 27.470´N 000° 17.718´E	0945	0950	7205

Station 11 Littlebrook Power Station 14–17 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 28.290´N 000° 14.021´E	1250	1253	7203
2	22 mm ring	51° 28.239´N 000° 14.316´E	1245	1220	7135
3	40 mm mesh	51° 28.199´N 000° 14.389´E	1237	1200	7123

Station 12 Dartford Ferry Terminal, Lower Littlebrook 17–20 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.471´N 000° 16.019´E	1356	1619	7424
2	22 mm ring	51° 27.532´N 000° 15.903´E	1352	1540	7348
3	40 mm mesh	51° 27.533´N 000° 15.868´E	1348	1527	7339

Station 13 Johnson’s Jetty 20–23 June 2013					
Net	Type	Position	Time set	Time hauled	Soak time
1	Standard	51° 27.316´N 000° 16.412´E	1706	0641	6135
2	22 mm ring	51° 27.337´N 000° 16.316´E	1701	0617	6116
3	40 mm mesh	51° 27.379´N 000° 16.201´E	1656	0601	6105