Pacific oyster *Crassostrea gigas* control within the inter-tidal zone of the North East Kent Marine Protected Areas, UK

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SUMMARY

This study aimed to assess the effectiveness of control measures undertaken by volunteer labour to impede the spread of wild Pacific oysters *Crassostrea gigas* within the inter-tidal zone of the North East Kent Marine Protected Areas. This was achieved by conducting a one-year field trial during which a small group of volunteers physically reduced the number of oysters towards a pre-determined target. The site contained a large number of oysters and had high levels of annual recruitment, thus posing a threat to native species and biotopes. Comparison of pre- and post-trial data indicated that oyster numbers were considerably reduced at the trial site although they had increased at each of three control sites. The method used had minimal impact on native species and habitats but was labour-intensive, warranting the use of volunteers. This method of control could be used effectively in other similar situations.

BACKGROUND

The Pacific oyster is native to north-east Asia and has been extensively cultivated elsewhere in order to support shellfish industries where native oysters have declined. In 1964 they were imported to the UK from British Columbia, Canada as an alternative to the native oyster *Ostrea edulis*. Since then production has increased and in 2011 stood at 754 tonnes compared to 114 tonnes for the native oyster (Reese 2013). Pacific oysters were not considered capable of proliferation in northern European waters due to low sea temperatures. However in the 1990s wild populations were recorded in Devon (Couzens 2006). Further settlement has been recorded in Essex and Kent. Similar settlement has been seen in other European nations such as France, Ireland and the Netherlands (Fey *et al.* 2010).

In 2007, at Western Undercliff in Ramsgate, the Kent Wildlife Trust recorded Pacific oysters at levels not previously seen within the North East Kent Marine Protected Areas. No native oysters were recorded. In response to concerns about possible impact on the designated features of the sites such as common mussel *Mytilus edulis* beds, Ross worm *Sabellaria spinulosa* reefs and chalk reef communities, Natural England commissioned a survey to establish a baseline record of inter-tidal distribution and density of Pacific oysters. This was conducted across the 46 km expanse of the protected area during 2007–2008. The results of the survey were used as the baseline for a monitoring programme, which identified the Western Undercliff as a recruitment hotspot with a rapidly increasing oyster population. In 2010, based on monitoring data, the contracted researcher recommended to Natural England that a trial should take place to assess the feasibility of controlling wild Pacific oysters within the inter-tidal zone at this site using volunteer labour. We report the methods and outcome of this trial.

ACTION

Site Description: The trial site (Figure 1) at Western Undercliff in Ramsgate, is within the Sandwich and Pegwell Bay National Nature Reserve, Thanet Coast Special Area of Conservation, Thanet Coast Special Protection Area and the Thanet Coast Marine Conservation Zone. Collectively these sites are known as the North East Kent Marine Protected Areas (51°21'N, 1°3'E to 51°14'N, 1°24'E). The site consists of a 670 m length of inter-tidal area (approximately 5.4 ha). At the eastern boundary is the port of Ramsgate. To the west are the extensive mudflats and saltmarsh of the National Nature Reserve and the estuary of the River Stour. A typical shore profile across the trial site, measured across the inter-tidal area from upper to lower shore, consists of:

- a concrete sea wall
- 7 m band of bare chalk scoured by tidal rebound from the sea defences
- 44 m band of red turf algae *Gelidium pusillum* and *Laurencia pinnatifida* on chalk
- 24 m bed of common mussel on chalk
- 12 m bed of Pacific oyster on chalk
- 112 m mudflats

Figure 1. Aerial photograph of Western Undercliff

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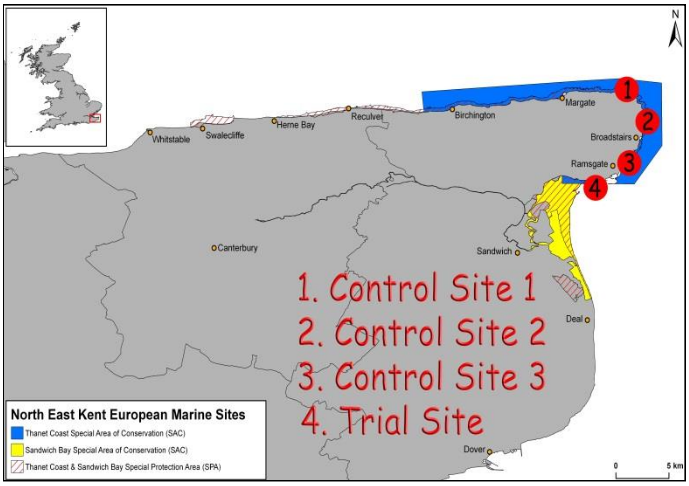

Figure 2. Location of trial site and control sites

Man-made structures include granite boulder armour, concrete sea wall, three concrete groynes and a concrete tidal bathing pool. Pacific oysters were present across the trial site but were most abundant on the boulder armour, concrete groynes and the band of chalk seaward of the mussel beds.

Pilot study: To ensure the methods used would be effective, a pre-trial pilot study was conducted at the proposed trial site between April 2011 and March 2012. The pilot consisted of a series of field events during which oysters were physically removed. A variety of tools and equipment were tested and from this best practices were established for the trial. Several types of hammer were tested, including club hammers, drywall hammers and ball pein hammers. Initially, whole oysters were removed but this resulted in a high rate of damage to the chalk reef substrate.

Trial: A team of eight volunteers was selected and trained in the following areas in order to take part in the trial:

- volunteering with Natural England
- the North East Kent Marine Protected Areas
- non-native species
- The North East Kent Marine Protected Areas Non-Native Species project
- Pacific oyster control methodology.

Table 1. Price and details of equipment purchased for each volunteer.

Item	Function	Cost
One Piece Dry Wall Hammer 22 oz	Break hinge and remove upper valve	£12.14
Edging Knife Carbon Steel 1000 mm	Reach & remove oysters high on groynes, walls etc	£4.90
Hand Tally Counter	Record specimens removed	£3.96
Large Tool Pouch	Hold hammer & other small items	£3.92
High Viz Waistcoat	Personal safety + public awareness	£3.32
Criss-Cross Gloves	Personal safety	£1.20
Eyeshields	Personal safety	£1.26
Total cost per Volunteer		£30.70

Table 2 Price and details of additional equipment purchased for the supervisor.

Item	Function	Cost
Demolition Crowbar 1500 mm	Remove oyster clumps from boulder armour	£18.39
First Aid Kit	Personal safety	£23.99
Face Masks x 150	Personal safety	£18.00
Total additional cost for volunteer supervisor		£60.38

It was anticipated that the work would present a range of operational challenges. To offset this, volunteers were recruited by invitation from known individuals who were considered capable of delivering the required levels of skill and effort. This resulted in a small team of enthusiastic and energetic volunteers who were committed to the success of the trial. Tools and equipment were purchased to equip a team of eight volunteers plus a supervisor (Tables 1 and 2).

Four transects were set out, one within the trial site and three as controls in similar habitat on the shore adjacent to the trial site (Figure 2). Each transect was 100 m long and 10 m wide and was randomly placed at intervals across the inter-tidal zone from the upper to the lower shore.

A schedule of work for oyster removal was produced covering the period July 2012 –July 2013 and focused around spring tides, when low water reached less than 0.9 m above chart datum. This was essential to access the lower shore zone where oysters were abundant and reef-forming. Field events were scheduled to start one hour before low water and to continue for 2.5 h. This allowed maximum time in the lower shore zone where oyster density was greatest. Each event targeted a physical area of the site e.g. the boulder armour, groynes or a section of chalk reef. This sequential approach allowed an even reduction in the population and prevented skewed progress data.

Where oysters were attached directly to the chalk reef they were removed by striking the upper valve at the hinge with a hammer resulting in a sheer along the longitudinal axis. This displaced the upper valve but left the lower valve in place ensuring that no damage occurred to the chalk which is a designated feature of the Special Area of Conservation. Lower valves were known to disintegrate over a period of approximately five years (W. McKnight, personal observation). Exposed tissue was readily consumed by herring gulls *Larus argentatus*, black headed gulls *Larus ridibundus*, turnstones *Arenaria interpres* and carrion crows *Corvus corone corone* which tracked the work party on each event. A one-metre long lawn-edging tool was used to reach specimens attached at height on groynes and other man made structures.

Table 3. Effectiveness and negative impacts from the oyster removal trial.

Total number of oysters removed	34,333
Total volunteer-hours on-site	234.5
Average oysters removed per volunteer-hour	146
Average volunteers per event	3.2
Total number of negative chalk reef impacts	14
Total number of health & safety incidents	0

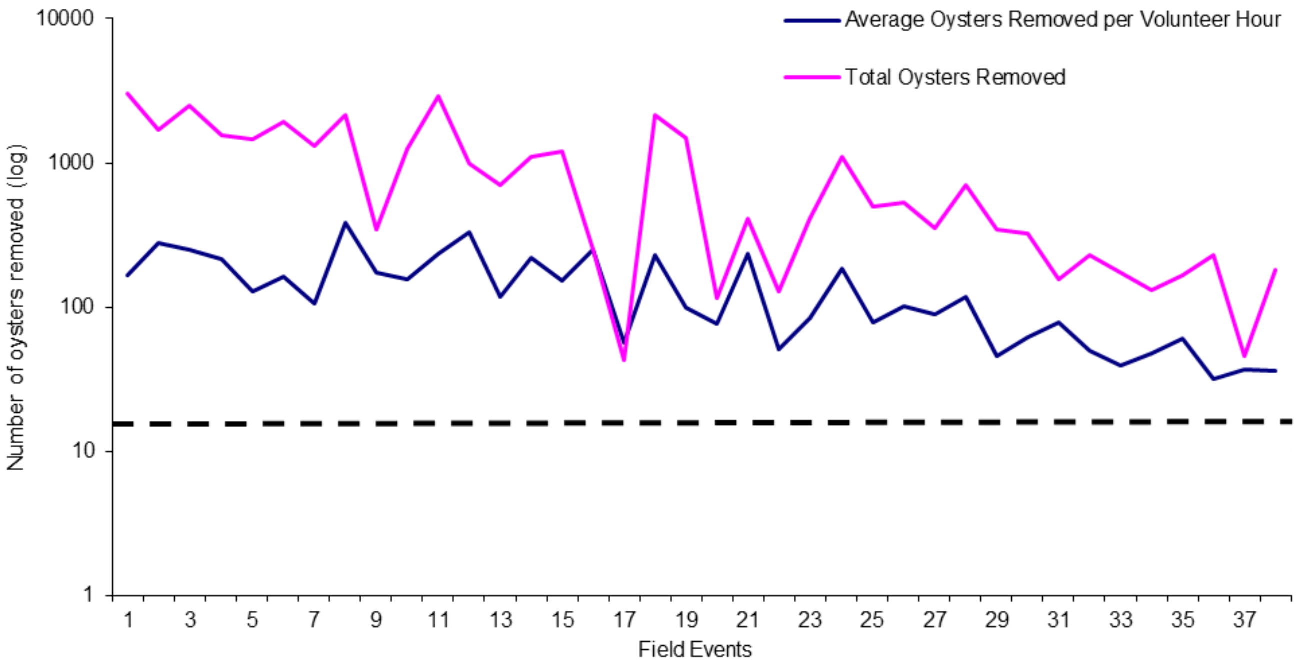

Figure 3. Rate and total number of oysters removed per field event during the trial period (July 2012 – June 2013). Dotted line represents the threshold of an average of 20 oysters removed per volunteer hour.

On non-chalk substrates both valves were removed. A hand tally counter was used to record the total number of oysters removed.

A threshold was set such that when volunteers were, on average, locating twenty or fewer oysters per hour then it would be unproductive to continue working. If this target was achieved for two consecutive sessions the site would be judged to be in favourable condition in terms of Pacific oyster impact on the designated features of the chalk reef. Prior to each event volunteers received joining instructions and a risk assessment for the site and task. Each event was pre-planned by the researcher who briefed the team, issued tools and personal safety equipment and supervised the event throughout.

As a designated feature, it was a requirement to safeguard the soft chalk when removing attached oysters. A minimum target of removal of 95% of the oysters with no physical damage to this feature was the target agreed by Natural England for the project.

Survey methodology: The total number of oysters and their individual shell lengths, measured from the hinge across the upper valve using callipers, were recorded within each transect. The initial survey was completed during June 2012, prior to both the trial launch and the 2012 spawning period. The survey was then repeated during June 2013 at the end of the trial period.

Additional monitoring took place within the trial site to record and compare annual oyster recruitment. This was carried out at four recruitment measuring sites created in March 2010, each consisting of a circle of 5 m radius and area 79 m^2. These were randomly placed at intervals on the chalk reef in the lower shore. Within each site all oysters were removed to establish a zero count baseline. The sites were then monitored annually, in April or May, after the spawning period, and the number of oysters was recorded to indicate recruitment from the previous summer's spawning period. All oysters were then removed to provide a zero start point for the following year.

CONSEQUENCES

Pilot study: During the pre-trial pilot period oysters were highly abundant and in places reef formation was at an advanced state, enabling the rapid removal of 40,196 oysters. This provided practical experience and allowed the various methods of the trial to be developed. The most effective methodology was found to be that described in the Action section above.

Table 4. Number of oysters at the control and trial sites before and after the oyster removal trial.

Transect	Total oysters		Mean density (oysters/m^2)		Total spats*	
(1000 m^2)	pre-trial	post-trial	pre-trial	post-trial	pre-trial	post-trial
Control 1	160	253	0.16	0.25	27	63
Control 2	220	284	0.22	0.28	25	61
Control 3	16	20	0.02	0.02	3	7
Trial Site	165	72	0.17	0.07	80	56

*'Spat' is defined as a juvenile oyster of less than 60 mm shell length.

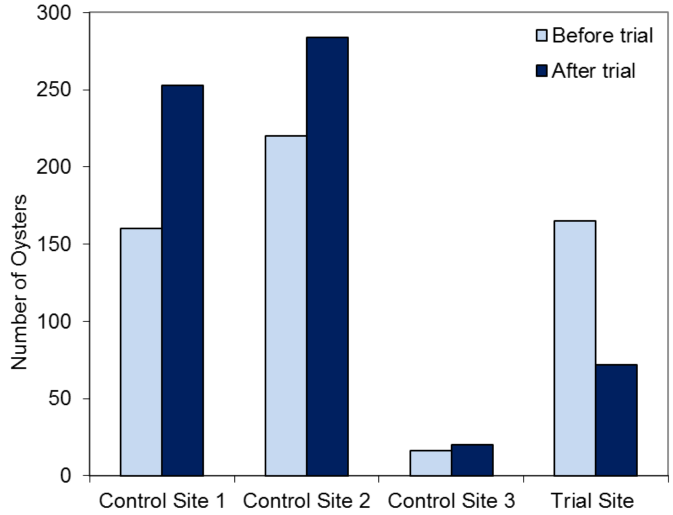

Figure 4. Total number of oysters at the control and trial sites before and after the oyster removal trial.

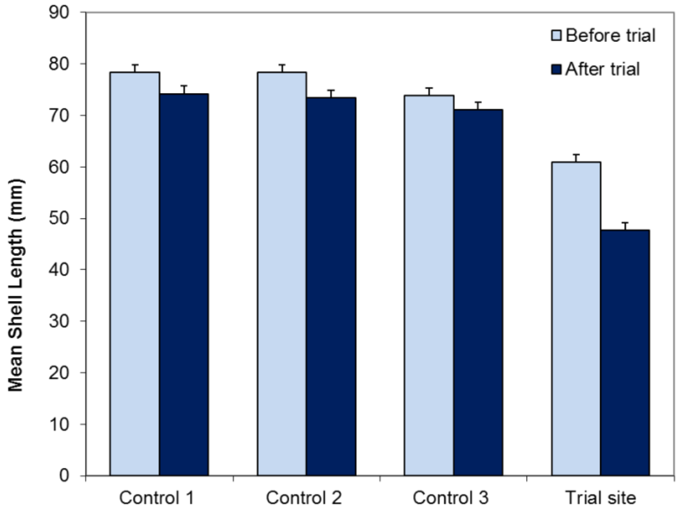

Figure 5. Mean shell lengths (± S.E.) at transects before and after the oyster removal trial.

Trial: During the one-year trial period 38 field events were completed. Over 34,300 oysters were removed over this period, at an average rate of 146 oysters per volunteer-hour (Table 3). The total number of oysters removed and the average number of oysters removed per volunteer hour for each field event declined slightly through the course of the trial, but remained above the threshold level at which removal became inefficient (Figure 3). The trial appeared to have been effective, as during the period of the trial, oyster numbers increased in the three control site transects but decreased in the trial site transect (Table 4, Figure 4).

There was little change in shell size at the three control sites between 2012 and 2013, but at the trial site oyster shells were significantly smaller after the trial than they had been before the removal experiment (Figure 5).

The number of recruits dropped significantly in all four recruitment sites after the pilot study and again after the main trial (paired one-tailed t-test: $t = 3.29$, d.f. = 3, $p = 0.023$, Figure 6). All recruitment sites were located within the trial site.

DISCUSSION

This trial has demonstrated that short-term control of Pacific oysters is possible using volunteer labour. This supports findings from a pilot cull that took place in Strangford Lough, Northern Ireland between 2008 and 2009 (Guy & Roberts 2010). The results of this study have led to recommendations to Natural England to continue control work at Western Undercliff and other targeted locations identified from the monitoring programme. This would provide long-term data to inform options for future management of wild Pacific oyster populations.

The trial was designed to match available resources against maximum achievable outcomes and was based on three guiding principles: containment not eradication, a targeted response based on the monitoring programme and a long-term commitment. A robust monitoring scheme was an essential prerequisite to the proposed control work and was an invaluable tool to identify priority work locations and to match volunteer resource to workload.

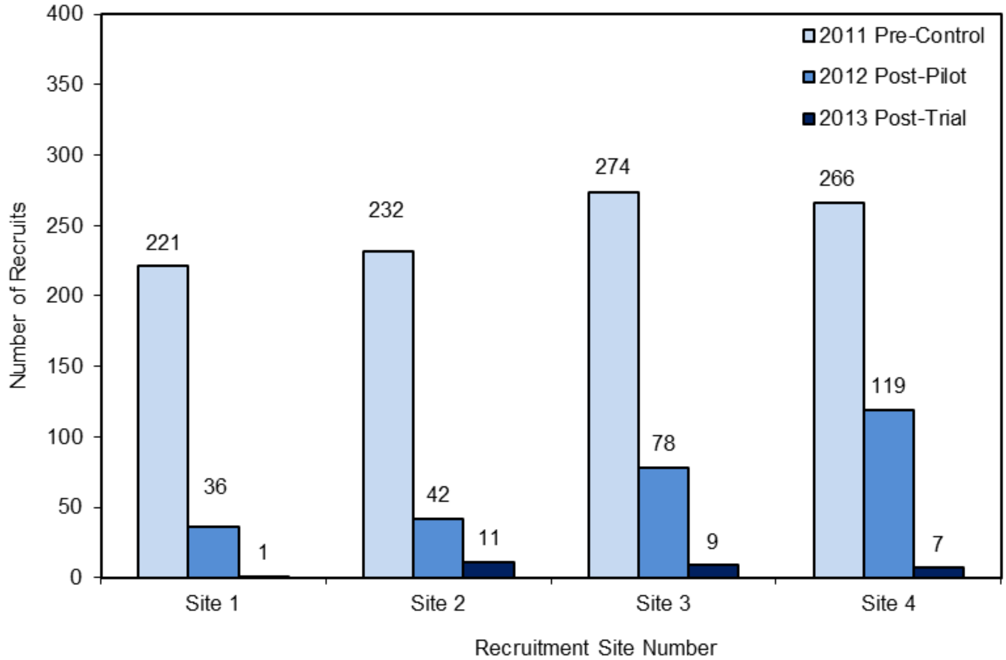

Figure 6. Number of recruits per recruitment site in the years before and after the trial removal of oysters.

Progress was impeded by several factors. Time on site per session was limited to two and a half hours around low tide. This was further restricted to spring tides which allowed access to the lower shore zone where oysters were most abundant. All field work was conducted within these time slots to maintain productivity, provide consistency and prevent distorted data. Control work was physically demanding, repetitive and very messy. Some volunteers found that constant bending and handling the 22 oz hammer became tiring. Protective clothing including eye-shields and face masks were needed to protect from the spraying contents of hammered oyster shells. Much care was needed working across the inter-tidal zone where gullies, deep sediment and slippery algae presented trip and slip hazards. Wellington boots or similar stout footwear was essential. Hand injuries, such as blisters and cuts from the razor sharp shells were prevented by wearing gloves. Working at exposed locations made the volunteers vulnerable to extreme weather conditions. The supervisor monitored the incoming tide to ensure escape routes were accessible.

By the end of the trial several benefits were noted. The oyster population had been considerably reduced and the lower shore had been visually transformed from oyster reef to scattered individual spat. The method used complies with DEFRA's three-stage hierarchical approach to non-native species policy (DEFRA 2008) and, although labour intensive, the methodology was highly selective, bio-secure and resulted in negligible impact on the chalk reef. The use of volunteer labour made the trial cost effective. An unexpected benefit came from the volume of public interest generated during field events. In response, a handout was produced which briefly described the trial and the wider non-native project. This was distributed by the researcher to members of the public who had engaged in conversation.

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