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# The most northerly record of feral Pacific oyster *Crassostrea gigas* (Thunberg, 1793) in the British Isles

Richard L. Shelmerdine*, Beth Mouat, and Rachel J. Shucksmith
*NAFC Marine Centre, Port Arthur, Scalloway, Shetland, ZE1 0UN, UK*
**Corresponding author*
*E-mail: richard.shelmerdine@uhi.ac.uk*

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## Abstract

The Pacific oyster *Crassostrea gigas* (Thunberg, 1793) is an invasive non-native species to Europe, introduced as an aquaculture alternative in 1890. In recent years, *C. gigas* have expanded their range past 60ºN on the east side of the North Sea along the Norwegian coast, consistent with range-expansion predictions. However, the northwest North Sea around the Scottish coast has not shown an equivalent expansion. Here we report collection of two *C. gigas* specimens north of 60ºN in Shetland, corresponding to an increase in the species northwest range of 471 km. These finds have implications for local shellfish aquaculture industries and in the conservation of priority marine habitats that are located in the near vicinity. The findings suggest that the species can spawn and survive at much lower temperatures than those used in current models.

**Key words:** biosecurity, invasive non-native species, range expansion, priority habitats, species distribution

## Introduction

The Pacific oyster, *Crassostrea gigas* (Thunberg, 1793) is native to Japan and northeast Asia. During 1890, the species (as synonymous to *C. angulata* (Lamark, 1819)) was introduced to Atlantic European countries for shellfish farming in response to the collapse of the native European oyster *Ostrea edulis* Linnaeus, 1758 fishery (Humphreys et al. 2014). Introductions to European countries have a complex history (see Lallias et al. 2015 for a review) with the main source of *C. gigas* to the United Kingdom being British Columbia, Canada (McKnight and Chudleigh 2015).

Countries in southern Europe started to record populations of *C. gigas* establishing in the wild within twenty years of initial introduction (see Ruesink et al. 2005 for a review) but it was thought that the more northerly introductions in and around Scotland and Scandinavia would pose less of a threat to the natural environment due to the lower sea temperatures of these regions (Humphreys et al. 2014). The most northerly record of *C. gigas* was estimated, by the authors of this manuscript, at 60º16′N in Norway (Dolmer et al. 2014, latitude was estimated from one of the authors' published maps within the manuscript) with the northern most record in the British Isles at 56ºN in the Firth of Forth (Smith et al. 2015).

Historically, *O. edulis* thrived in Shetland waters and supported a commercial fishery up to 1897 when the stocks collapsed (see Shelmerdine and Leslie 2009 for a review). *Crassostrea gigas* farming was introduced to northern Europe in the 1960s with the most northerly farm site in Shetland located in Basta Voe, Unst (60º45′18″N; 000º51′26″W). Although attempts were made to farm *O. edulis*, *C. gigas* was found to have a faster growth to market size and became the preferred farm choice.

According to information obtained through the Scottish Shellfish Production Surveys carried out by Marine Scotland, the farmed production of *C. gigas* in Shetland, since 1996, peaked in 2010 at 30,000 individuals from one business and the last recorded production was in 2012 (Figure 1). The total number of businesses registered for *C. gigas* production peaked at nine during 2005 and 2006, although at most only two actually produced any oysters during

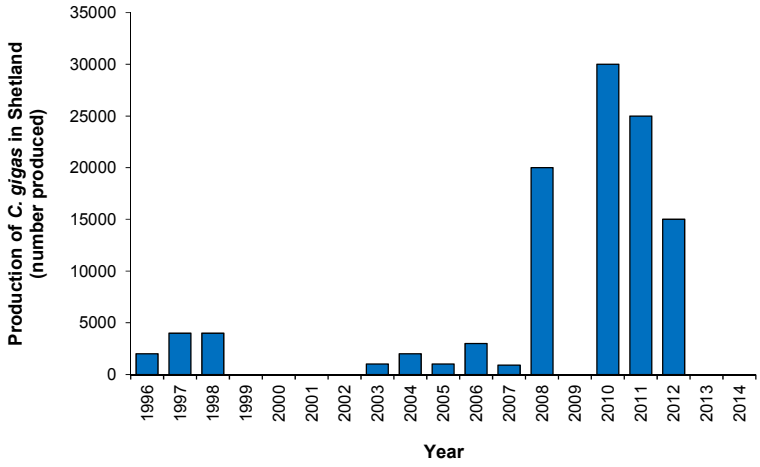


**Figure 1.** Annual production of farmed *Crassostrea gigas* in Shetland from 1996 to 2014. Data obtained from Scottish Shellfish Production Surveys carried out by Marine Scotland.

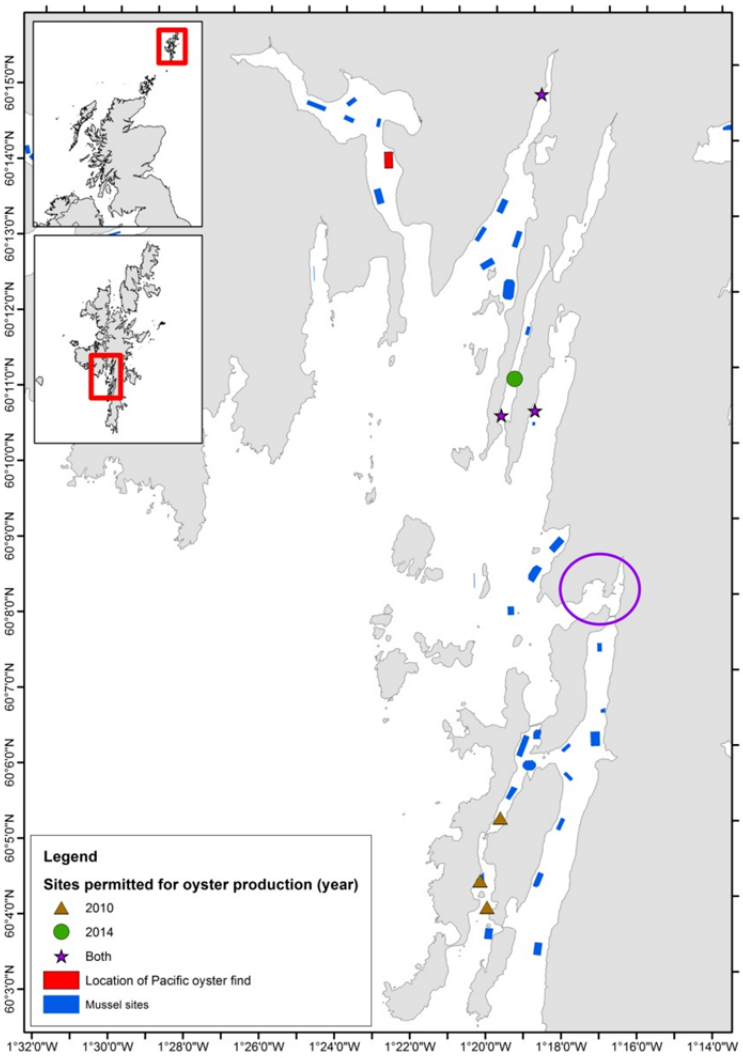


**Figure 2.** Collection location of the two *Crassostrea gigas* specimens (red box) and the corresponding mussel farm sites (blue areas) as well as permitted oyster sites (*C. gigas* and *O. edulis*) for 2010 (brown triangle), 2014 (green circle), and both years (purple star). Large open circle depicts the location of Scalloway harbour. The inserts show the location of Shetland to the British Isles (upper) and the location within Shetland (lower).

a year. No businesses registered for *C. gigas* production in Shetland from 2013 onwards, although some sites did retain planning permission into 2014 (see Figure 2).

## Updated status

In February 2016, two specimens of the Pacific oyster *Crassostrea gigas* were found attached to mussel lines on a mussel farm on the west coast of Shetland. The location where specimens were collected is 60º13′58.1″N; 001º21′59.3″W (Figure 2). The largest specimen measured 73 mm by 61 mm and was no more than three years old (the mussel lines which the specimens were recorded on were deployed, clean, in 2013, Figure 3).

## Discussion

These are the most northerly recorded specimens of *C. gigas* for the British Isles (see also Supplementary material Table S1 for published locations of *C. gigas* in Scotland) and represent a 471 km northerly range expansion from the previous northern limit reported by Smith et al. (2015). As the mussel lines were new prior to deployment, it would imply that these specimens settled as spat on the lines. It is likely that the source locations of these Shetland specimens were either from sites farming *C. gigas* (see Figure 2) or hull fouling from visiting marine vessels (Shucksmith and Shelmerdine 2015). Although a number of aquaculture sites on the west coast of Shetland still have a license to farm oysters, *C. gigas* was last harvested in Shetland in 2012 from one business (Munro et al. 2013), in Unst in the northeast of the Isles. It is highly unlikely that these specimens originated from this particular source in Unst given the geographic and temporal separation as well as the prevailing tidal flow from the west of Shetland moving north and then northeast around the north of Unst. As there has been no concurrent farming of oysters since the deployment of the mussel lines at this site and, if the original source of *C. gigas* in Shetland were aquaculture, it would imply that *C. gigas* has either established in the wild and are now spawning or are spawning from previously licensed sites in the local vicinity. It is known that, due to the economic challenges of farming *C. gigas*, a number of sites more local to the find were abandoned, equipment was not removed, and the oysters were not harvested from the sites, leaving potential breeding populations in nearby inlets. Modelling the local hydrodynamics of the area has proved challenging due to the complex nature of the coastline and the numerous surrounding islands


**Figure 3.** One of the two *Crassostrea gigas* specimens collected in Shetland. Vertical and horizontal hatchings are in centimetres. Photograph by Richard L. Shelmerdine.

(Halliday 2011). New models would have to be run and tested in order to better estimate the potential distribution of *C. gigas* larvae.

Alternatively, hull fouling remains a route of introduction, with the main port of Scalloway Harbour (see purple circle of Figure 2) servicing a variety of vessels, mainly fishing vessels, but also including offshore supply ships, accommodation barges, aquaculture vessels, and pleasure craft. However, no oysters have been detected within the harbour area despite a non-native species monitoring programme comprising both settlement panels and rapid assessment (see Collin et al. 2015).

The occurrence of these two *C. gigas* specimens has implications for the current understanding of the species distribution at its northern limit, especially in the northwest North Sea and northeast Atlantic where the species has previously been predicted to be absent (Thomas et al. 2016). Sea temperature in the area of the present find did not exceed 14 °C during three separate years of recording between 1997 and 2015 (NAFC Marine Centre unpublished data) suggesting that the 18 °C temperature threshold, the lower limit of the spawning temperature range, used in some of the distribution models may be set too high (for examples see Humphreys et al. 2014; Thomas et al. 2016). Thomas et al. (2016) demonstrated simulated spawning events as far north as Norway at 60ºN and referred to this expansion as a "drastic shift of the northern boundary". Interestingly, the authors' simulations did not show spawning events around any of the Scottish coast, including

Shetland (Thomas et al. 2016), probably due to higher summer surface water temperatures in Norway (Dolmer et al. 2014) compared to those found in Shetland.

Shetland has a thriving shellfish aquaculture industry with farmed blue mussels *Mytilus edulis* Linnaeus, 1758 accounting for 77% of total Scottish production in 2014 (Munro and Wallace 2015). The introduction of *C. gigas* to the natural population has potential financial costs to the mussel industry through interspecies competition, carrying capacity of the environment, and trophic competition resulting in reduction of natural *M. edulis* spat fall, which the industry rely on, as well as increased competition for space on the mussel lines.

It is unclear what the environmental impact of an established *C. gigas* population in Shetland would be for the conservation of priority habitats. At the entrance to Sandsound Voe, where the *C. gigas* specimens were recorded, there is an established horse mussel *Modiolus modiolus* Linnaeus, 1758 bed with additional *M. modiolus* and maerl beds mapped around Shetland (Shelmerdine et al. 2014). The inlet to the east of Sandsound Voe contains large quantities of *M. modiolus* shells (Shelmerdine et al. 2013) and soft sediment providing a suitable substrate for the settlement of *C. gigas*. The interactions between *C. gigas* and *M. modiolus* (and possibly maerl) need to be investigated further in order to determine if *C. gigas* pose a significant risk to these habitats, concerns also noted by Humphreys et al. (2014). Indirect risks to habitats from changes in the localised environmental dynamics would be highly likely in certain scenarios (see Ruesink et al. 2005 for a review). In addition, the establishment of *C. gigas* could hamper any potential recovery of the native oyster *O. edulis* in Shetland. To date, all *C. gigas* records for Scotland have been recorded in the intertidal (see Table S1 and Cook et al. 2014; Smith et al. 2015) but this may be more an artefact of the type of survey, rather than an accurate representation of the species' habitat.

Despite the previously held belief that *C. gigas* would be unable to reproduce at the temperatures found in Shetland, this record has implications for marine management and incorporating adequate decommissioning protocols with licence conditions, with abandoned bivalve aquaculture sites potentially providing spat long after the sites have been abandoned.

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Location of the Pacific oyster, *Crassosterea gigas*, in western Shetland, U.K, from the present study and locations of published sightings in Scotland.

This material is available as part of online article from:

http://www.reabic.net/journals/bir/2017/Supplements/BIR_2017_Shelmerdine_etal_Supplement.xls