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# The European native oyster, *Ostrea edulis,* in Wales, a historical account of a forgotten fishery

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**Abstract –** The history of the European native oyster has been documented for numerous countries within its natural range. However, the history of *Ostrea edulis* in Wales remains conspicuously absent from current UK and European peer-reviewed publications. It was therefore deemed necessary to address this and as a result in-depth research of archival data was conducted including local trade directories, decennial census returns, collections from the National Museum Wales, annual government fisheries reports and grey literature from local historical societies. These historical reviews resulted in the construction of a timeline which documents all the significant historical dates related to *O. edulis* in Wales from the early 1500 s to present day. Fisheries statistics for England and Wales were also analysed for the western regional oyster fisheries in an attempt to understand the contribution which the Welsh landings made to the region. The review revealed that the Welsh fishery was the primary contributor of regional landings from the early 1600 s with maximum landings reported 1894, with the oyster beds at Mumbles producing more oysters than any other port until the fishery closed in 1937. A commercial native oyster fishery no longer exists in Wales but there remains a small native oyster population in South Wales. It is hoped that the historical accounts of bountiful catches, overexploitation, and restoration of *O. edulis* over the centuries in Wales may offer current conservation practitioners an insight into failures and mistakes of the past which could benefit the future of the European flat oyster in Wales.

**Keywords:** European flat oyster / *Ostrea edulis* / Wales / Historical fishery

## 1 Introduction

The European flat oyster, *Ostrea edulis,* is the only indigenous true Ostridea species found around the British Isles (Yonge, 1960). The historic geographical distribution of this oyster occurred naturally as far north as the fjords of Norway and as far south as Morocco (Alcaraz and Dominguez, 1985). It has been an important biogenic and economic component within estuarine, coastal, and offshore regions for centuries and has been supporting coastal communities as far back as the Mesolithic (Yonge, 1960; McErlean et al., 2002; Laing et al., 2006). Historical accounts of the *O. edulis* fishery in the UK show that the oyster was fished in a relatively sustainable manner up until the late 1700 s (Trimble et al., 2009; Thurstan et al., 2013; Smyth et al., 2020). However, by the mid-1800s, European wild stocks were showing signs of overexploitation (Eyton, 1858; Korringa, 1946; Pazó, 1987; Zu Ermgassen et al., 2012).

Boats from Denmark, Germany, the Netherlands, Norway, and the UK had continued to overfish oyster beds in the North Sea with advances in the fishing vessel and techniques used (Berghahn and Ruth, 2005). At the end of the 1800s, the Wadden Sea was one of the first oyster fisheries in Europe to be regulated (i.e. licenses, minimum landing size, fishery closures, stock assessment) however the management techniques were not successful as the beds were already in poor condition (Seaman and Ruth, 1997). Native oysters were once distributed throughout the German Bight covering an area of approximately 25,000 km$^2$ (Berghahn and Ruth, 2005) however overfishing from the late 1600 s had caused the species to be classed extinct in the 1950 s (Gercken and Schmidt, 2014; Pogoda, 2019). Coste (1861) considered the French oyster stocks in Cancale, Granville, Arcachon and La Rochelle over-fished to such an extent that successful spawning of the remaining populations was improbable. Indeed, by 1850 *O. edulis* beds at Oléron and Marennes had disappeared completely. In France by 1850 the harvesting of oysters had reached unsustainable levels, with annual landings regularly in the trillions (Breitburg et al., 2000).

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This intense overexploitation of wild oyster stocks was replicated in the UK with landings equalling that of France (Went, 1962). For example, fishers accounts in 1865–70 from the Firth of Forth fishery in Scotland documented landings of more than 0.5 million oysters per week to meet local demands (Thurstan et al., 2013). The immense pressure on stocks on once prolific grounds became unsustainable and associated fishery managers and stakeholders started to import from smaller fisheries in an attempt to address the reduction in landings (Owen, 1892; Matheson, 1929; Went, 1962). This in-turn led to the development of an export market from UK and Irish grounds which was a significant driver behind the increase in localised fishing pressure (McComb, 1861; Bromely et al., 2016).

The Port of Newhaven on the south coast of England became a primary export hub to France with approximately 20 million local oysters shipped between 1834 and 1836 (Edwards, 1997). In Northern Ireland small fisheries which primarily served local markets became supply points for dwindling Scottish and English stocks (McComb, 1861; Day and Mc Williams, 1991; Smyth et al., 2009).

The British Government recognised difficulties were developing within the oyster industry as early as 1833, and the House of Commons appointed a committee to assess the state of the amalgamated UK Fisheries (Yonge, 1960). The committee reported that fisheries operating in the British Channel had been in a state of decline since 1815 with a decrease in the number of boats, fishers, and productivity. However, in 1866, the Sea Fisheries Commission stated the fisheries had improved, with satisfactory increases in landings (Edwards, 1997).

However, the figures presented for the 1866 landings were misleading with increases more likely a result of increased fishing intensity and a release of imported oysters onto the market (Kennedy and Roberts, 2006; Jones et al., 2013). Indeed, the true state of the UK wild oyster stocks were reflected in the drop of tonnage which were landed. In 1887 the total landings for the entire UK and Ireland fishery were 3500 tonnes (equivalent to 50–55 million oysters). The UK stocks of *O. edulis* continued to collapse post-1866 with many fisheries closed or considered non-economically viable by 1901 (Went, 1962; Jones et al., 2013). This intensity of fishing led to the classic scenario whereby demand outweighed resource which culminated in the collapse of the majority of European and UK oyster stocks (Laing et al., 2006).

In the United Kingdom the plight of the English, Scottish and Irish *O. edulis* stocks have been well documented however, an accurate historical account of the Welsh fisheries demise has been absent from the current literature. Presently there is considerable interest throughout Europe and the UK in the restoration of the indigenous oyster (Helmer et al., 2019). Historical archives of *O. edulis* stocks have proved valuable in assisting restoration programmes in planning and implementing oyster reintroductions (Pogoda et al., 2019). It was therefore thought appropriate that the historical void in the Welsh *O. edulis* reference library be addressed.

## 2 Site description

The Welsh coastline spans 1400 km in length (Burek et al., 2013) and has a tidal range of 7 m in the North (Mudge and Norris, 1997) and 15 m in the South, the second highest tidal range in the world (Phillips and Crisp, 2010). Seawater temperatures range between 6 °C and 18 °C (Bohn et al., 2012; Cefas, 2019). Salinity can vary between 18 PSU in estuarine areas and up to 34 PSU in low flush marine bays (Bohn et al., 2012). The environment provides the ambient conditions required for *Ostrea edulis* (Hutchinson and Hawkins, 1992; Smyth et al., 2020), with suitable settlement substrates located at numerous regions around the coast (Fig. 1).

## 3 Materials and methods

### 3.1 Historical data collection

In an attempt to understand the growth and development of the *Ostrea edulis* fisheries in Wales and their subsequent demise archival data was collated and analysed. A search was conducted relating to the native oyster, oyster fisheries and aquaculture from: historical records reviewed from Bangor University's Archives and Special Collections, local trade directories, decennial census returns for employment and demographic data, collections from the National Museum Wales, annual government fisheries reports and grey literature from local historical societies. Any information from historical documentation of seabed lease applications and agreements relating to oyster lays was also examined, documented legal accounts and correspondence between fishermen, local councils and landowners was also analysed. Reports of early scientific experimentation and zoo archaeological remains were also included within the search criteria.

A comprehensive range of terminologies was used for oyster assemblages and habitats during archival searches as descriptive phrases for oyster stocks and fisheries differed greatly between region and timeline. Therefore, the location of historical oyster beds across the Welsh coast was extracted from data sources by searching for terms such as; 'oyster lays', 'oyster ground', 'oyster bed', 'oyster reef', 'oyster bank', 'oyster fishery', 'oyster perches', 'oyster plantation'.

This method of data collection is not often practiced in marine science. However, it can be a useful tool when trying to quantify historical baselines for habitats and species when trying to understand potential restoration feasibility. Records dated back to the Mesolithic and Roman empire, with the majority of information dating from the 19th and 20th centuries. The data related to oyster landings, catch value, fishing effort, location of oyster beds and description of the environment of fishing grounds.

### 3.2 Historical fisheries statistics

Prior to 1866, fisheries statistics were not collated systematically, landings were reported sporadically in log-books, customs revenue accounts, in port books or not at all. Information that was recorded was rarely organised or standardised. In 1863, commissioners were appointed to assess the status of UK and Irish fisheries; this data represented the most accurate accounts of stock status within pre-1900s archival material.

Railway reports from every fishing port in the UK recorded by the Board of Trade from 1886 until 1978 provided another important resource when reviewing oyster fishery landings information included; total quantity (cwts, individuals, tons)

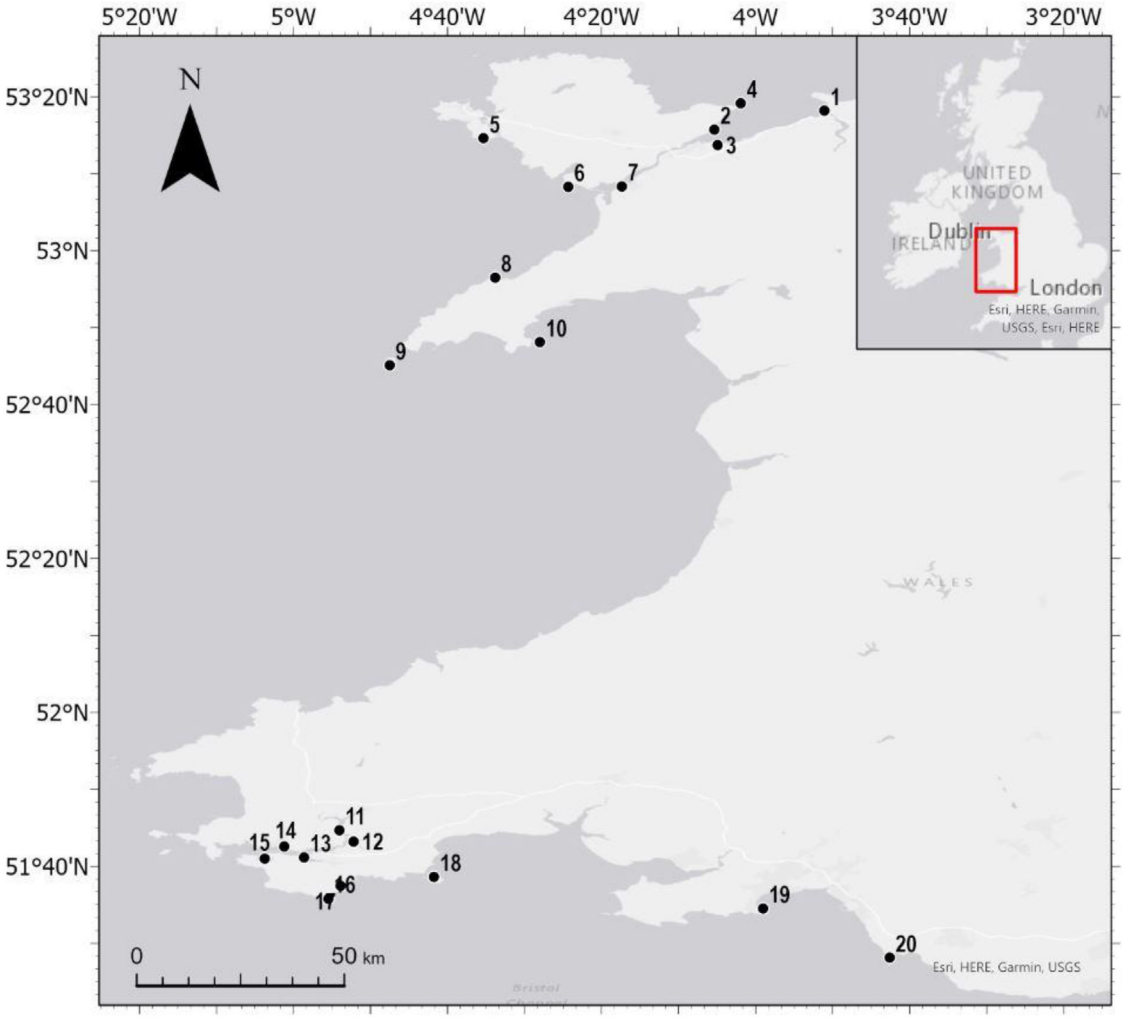


**Fig. 1.** Map of known historical native oyster culture sites in Wales- Conwy (1), Beaumaris (2), Ogwen River (3), Puffin Island (4), Rhoscolyn (5), Llanddwyn Island (6), Caernarfon (7), Porthdinllaen (8), Bardsey Island (9), Saint Tudwals Islands (10), Llangwm (11), Lawrenny (12), Pennar (13), Castle Pill (14), Angle (15), Saint Govan's Head (16), Stackpole (17), Caldey Island (18), The Mumbles (19), Porthcrawl (20). Esri Inc. (2021). ArcGIS Pro (Version 2.9.3).

and total value (GBP£) of fish types landed in England, Wales, Scotland and Ireland.

UK Sea Fisheries Statistics provided the most consistent datasets for analysis with; average monthly wholesale value (per dozen), the quantity and value of fish landed, and the number of fishing boats and crew members related to south, east and west coasts at each port documented. Records were also made of import returns and exports and comparisons of annual values of fisheries with other countries.

### 3.3 Statistical analysis

Meta-analysis of data was carried out to determine historical abundance, catch statistics, of *O. edulis*. Statistical analyse was undertaken using IBM SPSS Statistics, v27 (IBM Corp, 2020). The total oyster landings, imported oysters, value (£) of harvested and imported oysters, number of vessels were compared for ports on the west coast (Maryport, Cumbria to Sennen, Cornwall, including Isle of Man), Welsh ports (Rhyl in the North to Cardiff in the South) and highlighting Mumbles as the major oyster producer.

## 4 Results

### 4.1 Statistics and history of landings

A historical timeline was created using references related to the European native oyster in Wales. Searches relating to the socioeconomic history of the oyster from both scientific and anecdotal data was extracted and collated with key information summarised (Tab. 1).

Based on the UK sea fisheries annual statistics reports, oysters were imported as food, either fresh, prepared or preserved, but also for breeding purposes. Data was extracted from these annual reports, and from the Food and Agriculture Organization of the United Nations (FAO) Global Statistical

**Table 1.** Historical timeline of oyster fishery in Wales from 7000 BC to 1950 s.

| Year | Location | Anecdotal evidence | Source |
|---|---|---|---|
| *Historical remnants of oyster consumption* | | | |
| 7,000 BC | Caldey Island | Oyster part of diet based on Mesolithic archaeological remains | Schulting and Richards, 2002; Schulting et al., 2004 |
| 75–400 AD | Caerleon, Caerwent, Y Gaer Brecon | Large quantities of oyster shells excavated from Roman fortresses | Wheeler and Pryce, 1926; Matheson, 1929 |
| *First record of commercial oyster trade in Wales dating back to Tudor period* | | | |
| 1592 | Milford Haven* | Early record of oyster trade in Wales; 20,000 oysters | Lewis, 1927 |
| 1603–1850 | Milford Haven* and Tenby** | Oysters described as 'sweetest and fattest', 'most delicate of severall sortes' and were 'highly esteemed' 'sold by hundreds and by thousands, not by the bushel as in London'. | Jenkins, 1991; Owen, 1892 |
| *Early reports of depleting stocks but continued to overfish oyster beds* | | | |
| 1800–1820 | Milford Haven* and Tenby** | Stocks were 'nearly exhausted' and condition 'least estimable' | Fenton, 1810; Royal Commission, 1866; Wright, 1932; Lloyd, 1958; Davidson, 1976 |
| | Beaumaris | Native oyster fishery signs of exhaustion. | |
| 1836 | Milford Haven* and Swansea Bay | Oyster beds grew and production was substantial | Thorpe, 1896; Reid et al., 2000 |
| 1850 | Caernarfon Bay | Oysters fattened in Strait, sold in 'great quantities' to Manchester and Liverpool | Royal Commission, 1866 |
| 1854 | Pwllheli | Each boat landing 15-20,000 oysters daily | White, 1894 |
| *Oyster movements to replenish depleted oyster fisheries* | | | |
| 1854–1857 | Welsh coast | 'Exhaustive dredging', oysters sent to England and France to restock beds and sustain market demand. Fisheries closed as limited 'cultch' and breeding oysters | Bashford, 1891; White, 1894; Jenkins, 1974; Reid et al., 2000 |
| 1858 | Mumbles | Fishery recovered, began using 'smack' vessel, could fish further offshore | Wright, 1932; Lloyd, 1954 |
| *First regulations introduced in attempt to recover oyster populations* | | | |
| 1864 | Tenby | Regulations introduced to control minimum landing size | Royal Commission, 1866; Lloyd, 1958 |
| 1871 | Mumbles | Board of Trade Regulating Order; ground closed for 9 months. Maximum number of boats (>180), fishers (>540) reported landing over 9 million oysters | Anson and Willett, 1884; Royal Commission, 1866; Lloyd, 1954 |
| 1874 | Mumbles | Landings 'had greatly declined' by 58% since peak in 1871. | Holdsworth, 1874; Lloyd, 1954 |
| *First introduction of new oyster species in Wales* | | | |
| 1876–1902 | Conwy | First cultivated American oysters on artificial beds; 'fishers earned £5-7/8 per week' | Davidson, 1976; Llandudno, Colwyn Bay District Field Society, 1930 |
| 1894 | Menai Strait | American and foreign oysters introduced because of scarcity of natives | White, 1894 |
| 1894–1896 | Wales | Collecting oysters banned in hope to restore spat | White 1894 |
| 1919–1920 | Milford Haven* and Mumbles | Oyster disease causing 'oyster mortality', commercial fishing was no longer feasible | Orton, 1923; Cole, 1953; Jenkins, 1991 |
| *Fisheries experimental station opened to conduct research to support fisheries* | | | |
| 1919 | Conwy | MAFF fisheries station conducting experiments on oyster breeding showing 'some promise of success' | Laing et al., 2004; MMO, 2021 |
| 1933 | Milford Haven* | Portuguese oyster introduced but were unsuccessful | Cole, 1953 |
| 1937 | Mumbles | Closure of last commercial oyster fishery in Wales. | Laing et al., 2006; MMO, 2021 |
| 1950's | Menai Strait | MAFF native oyster spat settlement trials unsuccessful | Davidson, 1976 |

* Milford Haven describes oyster beds in Llangwm (11), Lawrenny (12), Pennar (13), Castle Pill (14).
** Tenby describing oyster beds at Stackpole (17) and Caldey Island (18). MAFF denotes the Ministry of Agriculture, Fisheries and Food, now known as the Department for Environment, Food and Rural Affairs (DEFRA). Historical records use term 'American oyster' to describe *Crassostrea virginica* and 'Portuguese oyster' to describe *Magallana angulata*.

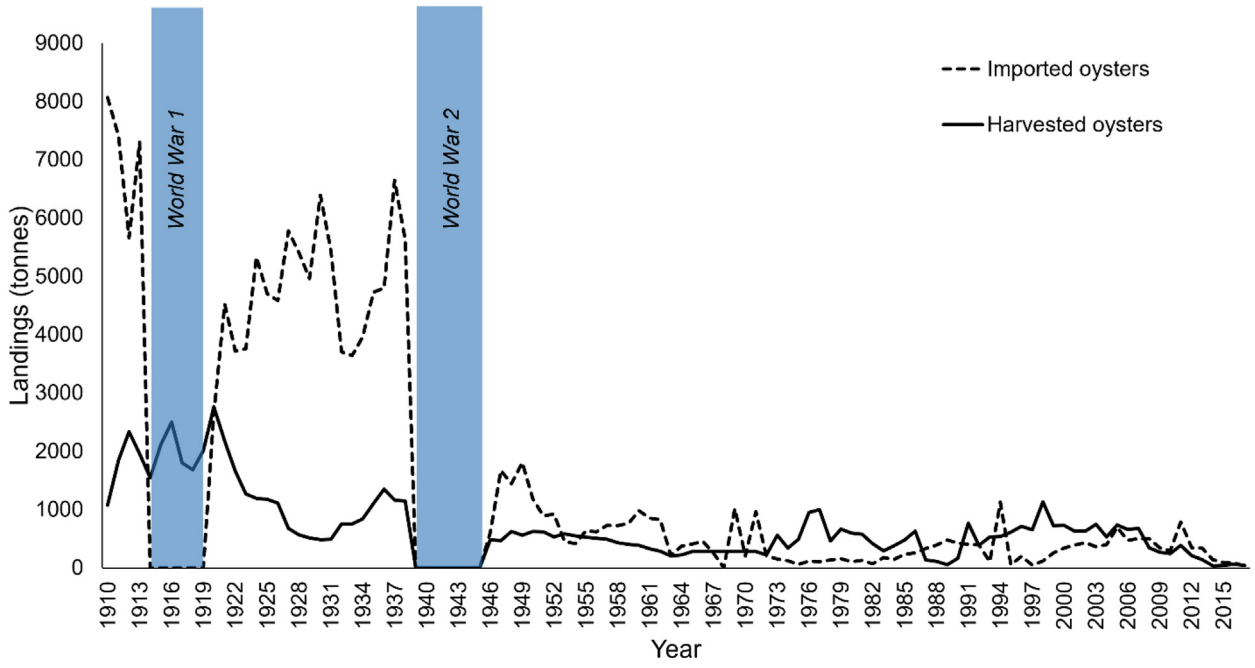


**Fig. 2.** Oyster landings for England and Wales from 1910 to 2017; black line denotes landings harvested within UK waters and dashed black line denotes landings of imported oysters. Note, blue regions when landings were not recorded reliably during WWI (1914–1918) and WWII (1939–1945).

Collections; 'Global Capture Production' and 'Global Fish Trade and Processed Products Statistics'. Documented information on oyster imports was available from 1910 onwards. However, the first introduction of new oyster species in Wales was in 1876 (Tab. 1). The 'American oyster', *Crassostrea virginica*, was introduced onto artificial oyster lays in Conwy (site 1 in Fig. 1). Further introductions were described in 1894 in the Menai Strait (sites 2, 3, 7 in Fig. 1), of both *Crassostrea virginica* and *Magallana angulata*, although quantitative data was unavailable. The total quantity of imported oysters was compared to the total oyster landings harvested in England and Wales between 1910 and 2017 (Fig. 2).

Oyster landings recorded in the UK sea fisheries annual statistics reports were reported for the east, south and west coasts of England and Wales from 1886. All Welsh stations (Aberdovey, Aberystwyth, Bangor, Caernarfon, Cardiff, Conwy, Ferryside, Holyhead, Laugharne, Llanelly, Milford, Mumbles, New Quay, Neyland, Penclawdd, Portmadog, Pwllheli, Red Wharf Bay, Rhyl, Swansea, Tenby) were included under the 'west coast' and accounted for 31–51% of the total stations in this west coast region, along the coast from Maryport, Cumbria to Sennen, Cornwall, and the Isle of Man. Oyster landing information was not available per station until 1911 with oyster landings reported at six stations in Wales: Aberystwyth, Milford, Mumbles, New Quay, Swansea, and Tenby (Fig. 3).

It is apparent that Mumbles was the only oyster fishery reporting landings on the 'west coast' of the UK after World War I, between 1919 to 1937 (Fig. 3). Univariant analysis was undertaken to examine the differences between total oyster landings recorded in UK sea fisheries annual statistics reports for the western region and that of the Mumbles between 1911 and 1914. Landings data was log transformed and satisfied the assumption of normality using a Shapiro-Wilk test. Once assumptions were met, a paired-samples *t*-test concluded that there was not a statistically significant difference in oyster landings between the total oyster landings of 'west coast' and Mumbles ($t(3) = 2.338$, $p = 0.101$). The Mumbles fishery produced an equivalent yield of oysters to that of the entire western region.

### 4.2 Oyster fishery from the Mesolithic to 1700 s

The historical timeline of the European native oyster *Ostrea edulis* in Wales reflects those documented within other regions of its natural range. The shells of *O. edulis* have been unearthed at archaeological digs in large quantities at a number of Welsh sites and dated back to the Mesolithic (Schulting et al., 2004). Similarly at Roman sites *O. edulis* shells have been excavated in high densities particularly at amphitheatre refuse heaps (Matheson, 1929).

Oysters remained a food source in Wales throughout the Middle Ages and were prevalent in Swansea Bay hence the name of the town 'Oystermouth' in Mumbles (RCAHMW, 2000). The species became heavily exploited in the post-medieval period and one of the earliest records of oyster trade in Wales was a consignment of 20,000 oysters from Milford which was listed in the Welsh Port Book of 1592 (Lewis, 1927; Sherman, 2009). George Owen of Henllys was a naturalist who described in 1603 the oysters of Milford Haven as having the "most delicate and of serverall sortes" (Owen, 1603). Owen (1603) also gives some insight into the fishing method and gear used at the time. It seems that oysters were fished by dredging using equipment described as; "a kind of Iron, made with bars, having a piece of horse or bullock skin sowed to it like a bag, in

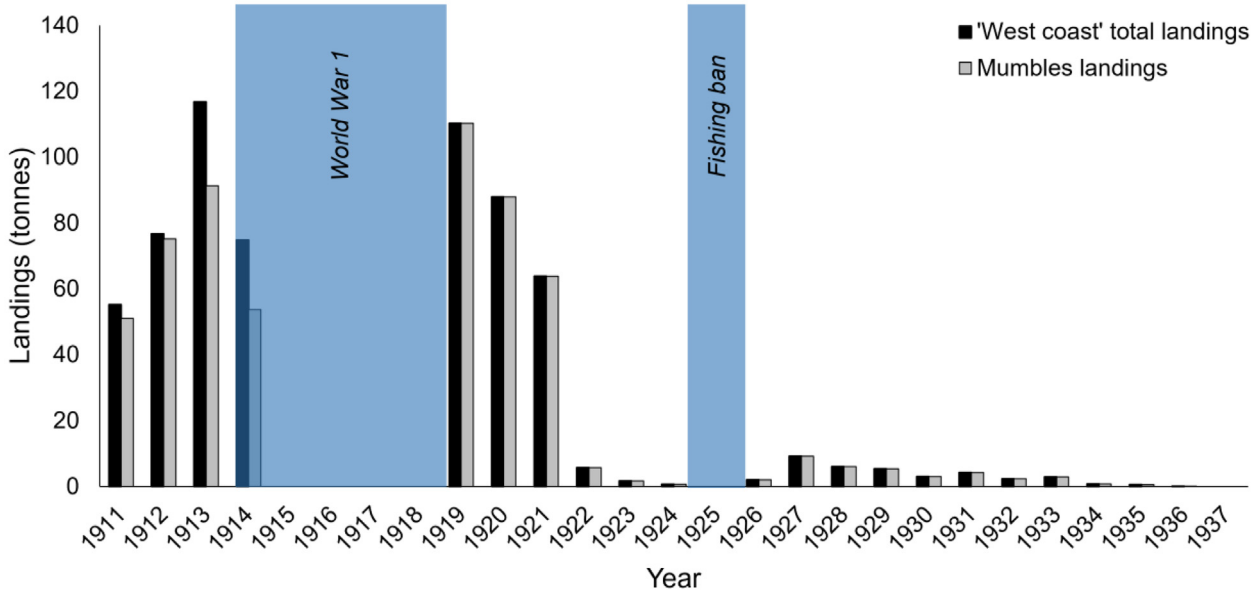


**Fig. 3.** Oyster landings for 'west coast' (including stations along the coast from Maryport, Cumbria to Sennen, Cornwall, and the Isle of Man) and for Mumbles from 1911 to 1937; black bar denotes total oyster landings recorded from ports on the 'west coast', grey bar denotes oyster landings recorded at Mumbles, South Wales. Note, blue regions when landings were not recorded because of WWI (1914–1918) and a fishing ban in Mumbles (1925). Landing information per station was not available prior to 1911 and Mumbles commercial oyster fishery closed in 1937.

such sort as that it being fastened to a ropes end and cast into the bottom of Milford at 8 or 10 fathom' (15–18 m) deep. It then being dragged at a boats end by two rowers which row up and down the channel, so the bag of leather, being made apt to scrape up all manner of things, lying in the bottom, gathereth up the oysters that breed there over certain known beds".

The archives reveal that oyster trade was commonplace in Wales in the 1600 s, with fresh and pickled oysters from Anglesey, Tenby and Milford (sites 2; 17 and 18; and 11 to 14 in Fig. 1), including Lawrenny (Fig. 4), being sent in vast quantities to Bristol, Somerset and Worcester in England (Morris, 1748; Davies, 1815; Dineley et al., 1888). In the 1600 s the Welsh oyster was held in high esteem and occupied vast beds in the southern region. The first Duke of Beaufort described the oysters "in view of the Harbour of Swansea and Oystermouth, to be the best bed of oysters in Great Britain" (Dineley et al., 1888). The Mumbles oysters from Oystermouth were described as the "most prolific in Britain" (Dineley et al., 1888).

Fisheries were also present in North Wales with prolific oyster beds situated around Puffin Island (Herdman, 1892), Red Wharf Bay (White, 1894), Rhoscolyn and Llanddwyn Island (Eyton, 1858), Caernarfon (Jenkins, 1974), Porthdinllaen, Bardsey Island, Saint Tudwal's Islands and in the Glaslyn River along the Llyn Peninsula, Gwynedd (sites 4–10 in Fig. 1).

Native oysters in Wales were harvested in a sustainable manner until the late 1700 s. Indeed, rival Welsh fisheries would boast among themselves of the great abundance and quality of their regional oysters in what could be considered as early marketing campaigns. During the mid-1700 s the fishers of the Pennar beds (site 13 in Fig. 1) in the west of Wales stated their oysters had superior taste and size to those from the neighbouring fishery of Llangwm (site 11 in Fig. 1) which they described as "bad of taste and small against our large delicious salty oysters of Pennar" (Fenton, 1810).

### 4.3 Oyster fishery from 1800 s to present day

In the early 1800 s the northern beds were still producing substantial landings, a dredger working the Pwllheli beds could regularly land between 15 and 20,000 oysters daily (White, 1894). However, catches of this size only lasted a decade and by 1810 the western fisheries of Tenby, Llangwm and Pennar were all considered in a serious state of decline with the beds at Caldey described as completely exhausted (Fenton, 1810). The demise of the Caldey beds was extremely distressing as more than 60 families were employed in the fishery (Fenton, 1810).

The same scenario was being played out at Menai Strait, Beaumaris and Gallows Point with reports of "worryingly decreased landings" (White, 1894). Oysters were still harvested from the northern sites up until the mid-1800 s but the catch was not destined for the English table market as the oysters were either too small or too large. Instead, the majority of oysters were exported to France in an attempt to replenish their depleted beds (White, 1894).

A British Government fisheries committee reported that fisheries including oysters, operating in the British Channel were in a state of decline since 1815. As smaller oyster beds became exhausted annual landings decreased 10-fold and the price of the native oyster trebled in 1863 (Royal Commission, 1866). An oyster fisher working the southern Welsh beds in the 1860 s could earn between £10 and £12 per week, the equivalent of £1200 and £1450 today (White, 1894). With higher wages and higher market prices more boats started fishing. In the Mumbles fishery in the south for example the number of oyster skiffs (Figs. 5a and 5b), rose from 90 in 1863

**Fig. 4.** Oyster shell buried in an estuary bank Lawrenny (site 12 in Fig. 1), from a historical oyster pickling station (2021). Pickled oysters were a valuable product in the 1700–1800's, and facilitated trade to other parts of Wales, England and outside the UK (Fenton, 1810).

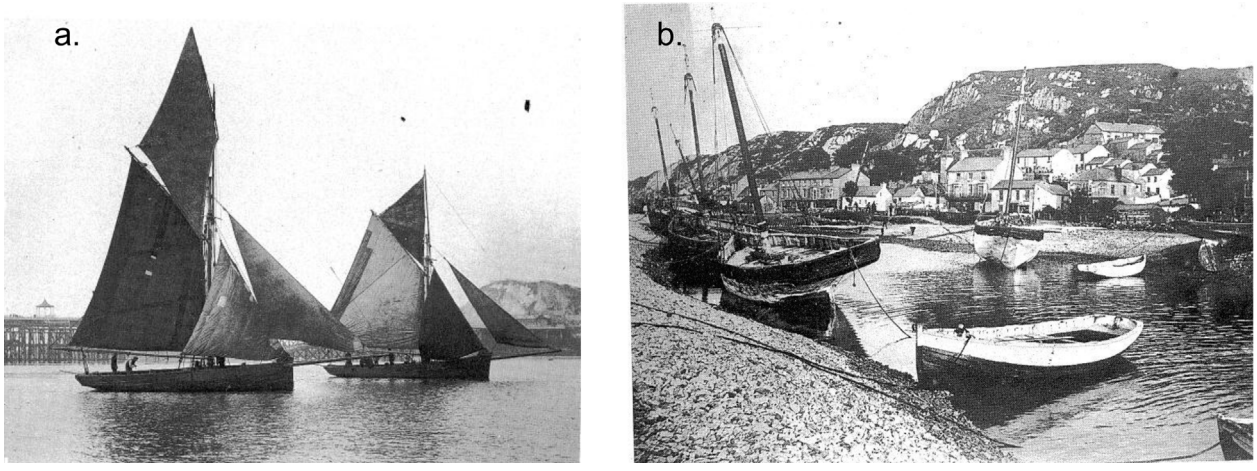


**Fig. 5.** (a) Photo of Mumbles oyster skiffs 'Snake' and 'Hawk' taken by R. J. H. Lloyd. (b) Photo of oyster skiffs in Oystermouth Harbour, Mumbles (both images sourced from Jenkins, 1974).

to >180 in 1870 (Lloyd, 1954). As a result, the Commission stated in 1864 that the Mumbles oyster fishery had improved (Royal Commission, 1866).

However, the reality in the mid-1800 s for the less productive fisheries in the north and west of Wales was one of despair as landings declined to a level whereby the catch per unit effort was no longer feasible (Appendix A). Attempts were made to restore the fisheries, oystermen at Bangor converted salmon weirs into spatting ponds in 1852 (Jenkins, 1974). However, after two years the venture was described as a failure due to the brood oysters being continually smothered in mud (White, 1894). In 1863, the Caldey oystermen tried to

**Fig. 6.** Large quantities of European flat oyster shell debris photographed in 2019 on the shores at Beaumaris in the Menai Strait, an area known as a historical oyster bed (site 2 in Fig. 1).

open their fishery by laying spat on shell. This was unsuccessful as the majority of the spat died during transport and those oysters that did survive were in densities too low to warrant reopening the beds (Lloyd, 1958).

The market demand for native oysters was still intense in the 1860 s, with 500 million oysters sold annually in Billingsgate, London (Mayhew, 1968). The high market prices and increase in demand for oysters put considerable pressure on the remaining active Welsh beds.

The southern oyster strongholds of Mumbles and Swansea saw a dramatic decrease in landings by the mid-1870 s (Lloyd, 1954). Holdsworth (1874) described the Swansea fishery as "declining in yield with oysters greatly decreased in numbers and size". The overexploitation of the southern fisheries was even more apparent when the landings for Mumbles were examined, as catches had decreased from 9 million oysters in 1873 to less than 4 million in 1875 (Lloyd, 1954). Furthermore, the number of oyster skiffs fishing the southern beds had decreased dramatically from >150 in 1871 to <20 in 1887 (Reid et al., 2000). Nonetheless, a few oystermen continued to dredge the southern beds during the 1890 s with the catch being sent to the Solway Firth in Scotland in an attempt to restore the western Scottish beds which were in a similar situation as those in Wales (Wade, 1914). This export to Scotland marked the end of the prolific South Wales fisheries, excluding Mumbles (Fig. 3), with the northern and western fisheries already considered closed (Jenkins, 1991).

In 1894, Beaumaris, Gallows Point and Goradygit in Bangor, attempted to rejuvenate the northern fishery in the Menai Strait. However, a shortage of native oysters meant new species were imported from America and France (*Crassostrea virginica* and *Crassostrea angulata*) to lay on intertidal sites (White, 1894) (Fig. 6). The venture proved unsuccessful with the imports succumbing to cold winter temperatures and disease (White, 1894). Further attempts to restore the Welsh beds were started by the Ministry of Agriculture, Fisheries and Food (MAFF), now known as the Department for Environment, Food and Rural Affairs (DEFRA), in the 1910 s with several oyster breeding experiments. Initially these were successful however, a year later the progeny underwent a mass mortality which was blamed on disease (Orton, 1923). A disease is not named in historical accounts. Oyster mortalities were likely caused by Hexamitiasis, based on reports of infections and mass-mortality events in Europe in the late 1800 s and early 1900 s (Mackin et al., 1951).

Up until the late 1970 s Welsh Government, fishery managers and oystermen cooperatives attempted several initiatives to kick start the oyster industry with no significant success (Jenkins, 1991). Small artisanal oyster fisheries are still in existence in the UK and have recorded landings in the

UK sea fisheries annual statistics report since 1886 until present day. The statistics take into account the import of oysters as well as fishery landings with no differentiation between species. The UK Sea fisheries annual statistics reports show that from 1910 to 1940 with breaks for the war years an average of 5000 tonnes of oysters (equivalent to 71–78 million oysters) were brought into the UK on an annual basis (Fig. 2). However, from 2000 to 2015 the UK market had all but ceased to exist (MMO, 2021).

## 5 Discussion

Oyster reefs have been classed as one of the most threatened marine habitats in the world with the species absent from much of its historical range and classed as functionally extinct (Beck et al., 2009; zu Ermgassen et al., 2020). As a result, the emphasis for the past decade on the European flat oyster has shifted from one of a fishery commodity to that of an environmental enhancing keystone species (Smyth et al., 2020). As a result, more than thirty *O. edulis* restoration projects are underway throughout the UK and Europe (NORA, 2022).

In Wales, two restoration programmes are currently in progress; "The Wales Native Oyster Restoration Project" led by Natural Resources Wales (NRW, 2021) and "The Wild Oysters Project" led by the Zoological Society of London, Blue Marine Foundation and British Marine (NORA, 2022). The Wales Native Oyster Restoration Project was established in 2019, in the Milford Haven Waterway, South Wales where there is a small remnant oyster population. The project has augmented the natural population with the addition of 25,000 native oysters onto cultch plots. The aim being to investigate oyster survivability, recruitment and, optimum density levels to effectively cope with the oyster disease (*Bonamia ostreae*) and non-native species (*Crepidula fornicata*) within the estuary. In the North of Wales, The Wild Oysters Project is a restoration initiative which is located in Conwy Bay. The significance of choosing Conwy was based on local history and the ecology of the area. Historical records and anecdotal conversations with retired fishers provided information about the location of once productive oyster beds in the region. The local marine environment continues to support a range of fisheries in Conwy, and as a designated Special Area of Conservation, the importance of conserving marine habitats and species such as *Ostrea edulis* has also been recognised. The project has installed oyster nurseries into marinas containing adult *O. edulis*, to use as a tool for educational outreach and engagement, and to act as a larval pump to support the development of an oyster reef in the Conwy estuary (The Wild Oysters Project, 2022).

These recent restoration efforts were not the first attempt to re-establish oyster populations in Wales. Fishers have endeavoured to revive the fishery since the mid-1800 s by setting oysters close together to promote reproductive success, oyster translocations to augment beds, introductions of non-native oyster species and enforcing fishing regulations as an attempt to conserve stocks (Royal Commission, 1866; White, 1894, Orton, 1923; Davidson, 1976). Based on the historical accounts, these attempts were unsuccessful because of overstocked lays which increased disease prevalence, continued fishing pressures, unsuitable seabed type, shortage of adult oysters, poor oyster condition, and irregular spawning (White, 1894; Orton, 1923; Davidson, 1976; Jenkins, 1991). Present restoration projects and future management should reflect on the historical findings to avoid the mistakes of the past and increase chances of successfully re-establishing *O. edulis* populations in Wales.

## 6 Conclusion

This research endeavour has emphasised how important an understanding of the local history and ecology is before oyster restoration commences. Hydrodynamic and biophysical models, and seabed habitat surveys can be useful tools to understand the environmental conditions and suitability of a proposed oyster restoration area (zu Ermgassen et al., 2021). The historical research has identified prior prolific oyster beds in Wales that warrant hydrodynamic and biophysical models and habitat surveys to identify potential restoration expansion. For example, in South Wales there are sparse native oyster populations found within the Milford Haven Waterway, Cleddau Ddu and Swansea Bay. Recent oyster surveys carried out by The Shellfish Centre identified a number of resident wild populations which could act as broodstock sources to initiate the formation of other oyster assemblages in the area (The Shellfish Centre, 2022).

The merits of restoring the native oyster, *O. edulis* to a functioning marine biotope have been recognised by the Welsh Government and they have recently invested in a research hatchery facility at Bangor University. Attempts are being made to develop hatchery protocols for the effective culture of native oysters within a small-scale set-up to help tackle the bottleneck individual projects face when scaling-up. It is hoped that these first attempts at reinstating the indigenous oyster species can lead to similar programmes. So that the iconic native oyster which was such a large part of Welsh life and culture for centuries can return to be a common feature within the marine environment of Wales once again.

## Authors contribution statement

Maria Hayden-Hughes: Concept, Data collection, Statistical analysis, GIS and map creation, Write up and review. Philippa Bayford: Statistical analysis, GIS and map creation, Manuscript edit. Jonathan King: Data collection. David Smyth: Concept, Data collection, Statistical analysis, Write up and review, Manuscript edit.

## Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix: A

Details for catch per unit effort for Welsh oyster fisheries from 1871 to 1928. Table includes details of the number of vessels and fishers, oyster landings (in tonnes and an estimated number of oysters), and an estimated value in 2021 (GBP) using the Bank of England inflation calculator which calculated inflation using Consumer Price Index (CPI) inflation data modelled based on data collected for the Retail Price Index (RPI). Employment was estimated based on local crewing records; an average of 3 fishers per vessel (Reid et al., 2000). Data was unavailable from 1876 to 1885 because of inconsistencies in record keeping. The Great Storm of January 1881 caused freezing temperatures, mass flooding and damage resulting in loss of several oyster vessels and oyster stocks (*The Cambria, Swansea* 21 January 1881 p. 8). No landings reported in 1895, 1896 and 1925 because of fishery closures.

| Year | No. of boats | No. of fishers | Landings (tonnes) | Landings (oysters) | Value in 2021 (GBP) |
|---|---|---|---|---|---|
| 1871 | 188 | 564 | 1,274.0 | 18,200,000 | NA |
| 1872 | 188 | 564 | NA | NA | NA |
| 1873 | NA | NA | 633.5 | 9,050,000 | £2,232,157.32 |
| 1874 | NA | NA | 462.0 | 6,600,000 | £1,823,805.30 |
| 1875 | NA | NA | 266.7 | 3,810,000 | £1,073,513.81 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 1886 | 21 | 63 | 80.4 | *1,148,000 | £264,718.12 |
| 1887 | 17 | 51 | 77.7 | *1,110,000 | £227,860.91 |
| 1888 | 24 | 72 | 40.5 | *578,000 | £139,664.45 |
| 1889 | 12 | 36 | 242.1 | *3,459,000 | £615,920.08 |
| 1890 | 20 | 60 | 397.4 | *5,677,000 | £1,183,033.09 |
| 1891 | 19 | 57 | 424.6 | *6,066,000 | £1,182,426.23 |
| 1892 | 22 | 66 | 330.8 | *4,725,000 | £910,882.48 |
| 1893 | 22 | 66 | 402.7 | *5,753,000 | £1,173,792.05 |
| 1894 | 24 | 72 | 466.4 | *6,663,000 | £1,341,740.63 |
| 1895 | 24 | 72 | 0 | 0 | £0.00 |
| 1896 | 23 | 69 | 0 | 0 | £0.00 |
| 1897 | 24 | 72 | 258.6 | *3,694,000 | £686,615.46 |
| 1898 | 25 | 75 | 240.7 | *3,438,000 | £640,060.65 |
| 1899 | 25 | 75 | 261.7 | *3,738,000 | £716,943.54 |
| 1900 | 27 | 81 | 322.4 | *4,605,000 | £831,576.95 |
| 1901 | 27 | 81 | 348.1 | *4,973,000 | £893,280.13 |
| 1902 | 23 | 69 | 357.0 | *5,100,000 | £870,967.44 |
| 1903 | 18 | 54 | 238.0 | *3,400,000 | £569,307.75 |
| 1904 | 15 | 45 | 92.6 | *1,323,000 | £152,811.50 |
| 1905 | 16 | 48 | 155.8 | *2,226,400 | £358,512.77 |
| 1906 | 19 | 57 | 112.2 | *1,603,368 | £239,829.17 |
| 1907 | 18 | 54 | 64.8 | *925,341 | £157,821.23 |
| 1908 | 18 | 54 | 220.3 | *3,147,537 | £397,618.79 |
| 1909 | 15 | 45 | 54.8 | *783,484 | £139,039.70 |
| 1910 | 14 | 42 | 46.2 | *660,382 | £105,187.91 |
| 1911 | 14 | 42 | 51.3 | 732,500 | £116,372.86 |
| 1912 | 14 | 42 | 75.1 | 1,072,800 | £169,708.24 |
| 1913 | 13 | 39 | 91.9 | 1,312,658 | £198,348.29 |
| 1914 | 9 | 27 | 54.1 | 773,300 | £112,306.06 |
| 1915 | 11 | 33 | 64.5 | 921,000 | £132,209.74 |
| 1916 | 9 | 27 | 76.3 | 1,090,000 | £133,612.11 |
| 1917 | 9 | 27 | 88.1 | 1,258,000 | £121,867.96 |
| 1918 | 9 | 27 | 91.3 | 1,304,000 | £103,471.56 |
| 1919 | 9 | 27 | 110.3 | 1,575,000 | £144,277.78 |
| 1920 | 10 | 30 | 87.9 | 1,256,000 | £119,583.56 |
| 1921 | 8 | 24 | 63.8 | 911,800 | £95,084.92 |

Appendix: A (continued).

| Year | No. of boats | No. of fishers | Landings (tonnes) | Landings (oysters) | Value in 2021 (GBP) |
|---|---|---|---|---|---|
| 1922 | 5 | 15 | 5.7 | 81,500 | £24,241.23 |
| 1923 | 2 | 6 | 1.7 | 23,900 | £8,444.13 |
| 1924 | 1 | 3 | 0.7 | 10,100 | £3,692.94 |
| 1925 | 4 | 12 | 0 | 0 | £0.00 |
| 1926 | 4 | 12 | 2.1 | 29,700 | £12,760.45 |
| 1927 | 8 | 24 | 9.2 | 131,800 | £60,398.75 |
| 1928 | 7 | 21 | 6.0 | 86,100 | £40,836.04 |

* Landings data from the annual fisheries statistics for England and Wales was reported for the 'west coast' region (Maryport, Cumbria to Sennen, Cornwall, including Isle of Man) from 1886 to 1910. It is presumed to be an estimate of the total landings for the Mumbles as it was the dominant fishery on the 'west coast'. Oyster landing information was not available by station until 1911 onwards. 'NA' denotes that data was not available. Data sources: Royal Commission 1866; White 1894; Matheson 1929; Lloyd 1954; Reid et al., 2000.

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