The Pacific Oyster

Why we should love them

Contributions and services of the Pacific oyster to the UK's marine environment and coastal economy.

Pacific oyster aquaculture

A cultivation species with tremendous potential in the UK.

Requiring no fertilizer or feed inputs, the cultivation of the Pacific oyster *Magallana (Crassostrea) gigas* is one of the most sustainable forms of food production. Nowadays, this species is the world's most globalised shellfish, farmed in over 50 countries.

In Europe, Pacific oyster production in Ireland, France and Spain far outstrips that in the UK, with France alone producing about 100 times more than Britain. In these countries, the species is recognised as naturally resident, including in areas of importance to marine conservation, and Pacific oyster farming is backed by strong support from government.

Why the confusion in Britain?

In the absence of clear policy, fear of doing the wrong thing clouds decision making.

In England and Wales, the Pacific oyster is currently classified as an invasive, non-native species under the Wildlife and Countryside Act 1981, and there are concerns among conservation organisations that the species may impact negatively on indigenous ecosystems.

These well voiced concerns, combined with a uniquely stringent application of EU marine conservation legislation and lack of settled national policy, have meant that quite different approaches have been adopted towards Pacific oyster aquaculture in different areas around the country.

If the UK is to rise to meet ambitions to produce more sustainable healthy food, including those targets set out in the English Aquaculture Strategy (Huntington and Cappell 2020) and the Blue New Deal action plan (New Economics Foundation 2016), then clarification of the legality and status of farming Pacific oysters must be provided to enable investment and provide security for existing businesses. Alternatively, if the UK seeks to retire its oyster industry, then clear guidance must be given to ease the exit of existing businesses and a pragmatic management strategy put in place to account for the ongoing presence of the species in British waters.

A brief history

An ancient industry with a new species that is here to stay.

Wild native oyster beds have been an important part of the British marine ecosystem and have been harvested for food for millennia, and, at least since Roman times, oysters have been included as a regular part of the British diet. For centuries dredge fisheries for the native oyster *(Ostrea edulis)* were the only source, but in 1890 the "non-native" Pacific oyster was introduced to be farmed. The demise of the wild native oyster fisheries in the latter 20th Century due to dredging, pollution, changing habitats, and disease brought about the development of oyster aquaculture, and the Pacific oyster was adopted as the only viable species to farm.

The 1960's saw the species approved under licence for aquaculture on the assumption that British waters were too cold for the Pacific oyster to settle in wild populations, but by 1982 a General Licence to "release or allow to escape into the wild" was issued on the basis that it was "already resident" here, with UK oyster growers operating their farms on this basis. Warming seas have since enabled wild populations to become established around the south coasts of England and Wales. It is accepted that, once present, there is no way to remove or any means to stop their gradual advance northwards as our seas continue to warm, and currents from neighbouring countries bring Pacific oyster larvae to our shores.

The environment

Carbon, nitrogen, pollution, biodiversity, birds, native oysters.

Oyster farming provides a number of key ecosystem services important for a healthy marine environment. Unlike other forms of food production, oysters and other shellfish farming have a very low carbon footprint, and can even be a carbon sink, locking carbon away in shells.

By filtering all their food from the surrounding seawater, oysters actually cleans up excess algae and other particles that result from high nutrient agricultural inputs. Clearer water enhances the growth of seagrass and larger seaweeds, in turn sheltering and feeding wide ecological communities.

Wild Pacific oyster reef habitats themselves have higher biodiversity than alternative cleared or natural mudflats, with many native animals, including various birds, feeding in, on, and around the reefs. Best evidence suggests that a mosaic of different habitats that includes oyster reefs provides the optimum conservation outcomes for threatened water bird populations.

Europe has lost vast swathes of native oyster beds, and despite huge restoration efforts, disease and other pressures remain, and so it is unlikely that the native species will ever return to historical levels. Farming the alternative, more robust Pacific species, can fulfil many of the important ecosystem functions that have been lost with the decline of the native oyster. This doesn't imply that one simply replaces the other, and evidence from both Poole Harbour and the Dutch North Sea shows that native oysters will settle amongst the Pacific oysters, actually aiding the restoration of the native species.

Neighbouring approaches to Pacific oysters

Our European neighbours recognise that Pacific oysters can provide valuable ecosystem services as well as providing local economic opportunities.

Due to the presence of locally self-sustaining populations, Pacific oysters are considered naturalised in all other European countries where they are farmed. Pacific oyster farms are permitted within conservation areas (i.e. Natura 2000 sites) and are often recognised as supporting wildlife and increasing overall biodiversity where they occur.

The Netherlands
After comprehensive study, Pacific oyster farms now accepted as part of local culture and economy.

Republic of Ireland
On the back of appropriate assessments, Pacific oyster aquaculture supported as the species is naturalised.

France
Naturalised and considered a valuable contributor to the environment and local economies, with production 100x UK volumes.

Spain
Galicia and Catalonia produce 50x UK volumes in Natura 2000 sites, with strong support from local government.

Italy
With unmanaged Pacific oyster beds widespread, there are no regulatory concerns about farming.

Denmark
Large populations of wild settled oysters, and farmed in Natura 2000 sites with no issues.

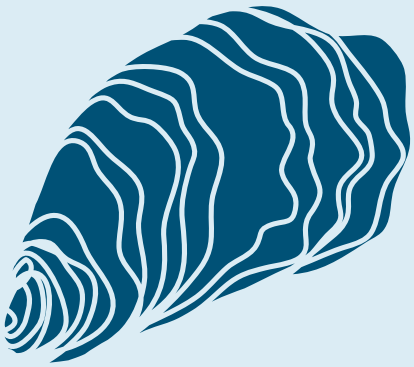
The economic potential for the UK

A chance to grow the sustainable blue economy.

Pacific oyster farming is an integral part of the local economy and culture supporting jobs and economic activity in many coastal communities in England and Wales.

In 2018, England and Wales produced only 1,000 tonnes of Pacific oysters, compared to 100,000 + tonnes in France. Nevertheless, the English industry supported 142 Full Time Equivalents in 2017, and in Poole Harbour, where 25-35% of English Pacific oysters are grown, this equated to a total economic activity of £2.6m when both direct economic turnover and supply chain expenditure were taken into account.

Still modest compared to neighbouring countries, the ambition of the English Aquaculture Strategy to grow Pacific oyster production to 5,000 tonnes by 2040 suggests the potential for an additional £10m of turnover in our coastal economies.



The alternative?

For an oyster industry in Britain, there isn't one.

Although the subject of many restoration projects, native European oyster beds and their associated dredge fisheries are unlikely to return. Difficult to farm and with significant disease risks, the native oyster can no longer provide the ecosystem functions that it's large reefs historically played.

The Pacific oyster is already resident in the south of Britain and across Europe. A faster growing species with higher survival than the sensitive and disease prone native oyster, the Pacific oyster will remain the mainstay of European oyster production and should do so here too.

We should learn to love the Pacific oyster which brings a range of environmental and socio-economic benefits to our coasts.

Why we **should** love the Pacific oyster

- Pacific oyster farming delivers a range of ecosystem services, locking up carbon and excess nutrients in our estuaries, cleaning the water and providing a habitat for many other species.
- One of the lowest carbon footprint forms of high quality food production worldwide.
- Supports much needed jobs and economic activity in our deprived coastal communities.
- Wild beds are biodiversity hotspots that support threatened waders and waterbirds.

Photos by Dai Williams

The Value of Pacific Oyster Aquaculture

Pacific Oyster Aquaculture Overview

With a low carbon footprint and with no requirement for external inputs, the cultivation of the Pacific oyster *Magallana (Crassostrea) gigas* represents a sustainable method of producing high quality marine protein whilst providing employment and economic activity in coastal communities. The species is indigenous to western Pacific coasts but nowadays is the world's most globalised shellfish with cultivation occurring in over 50 countries (King et al. 2020). It provides high value crops in all continents. In Europe, production in France, Ireland and Spain dwarfs that of the UK. In France, production is in the region of 100 times that of Britain on the basis of significant government support (Humphreys et al. 2014).

Non-native oysters were first introduced into British waters for cultivation in 1890 as the "Portuguese Oyster" which is genetically very similar and thought by some taxonomists to be the same species as the Pacific oyster (Humphreys et al. 2014). But in any event, as the "Pacific Oyster" there is good evidence that it has been locally naturalised on NW Atlantic coasts, including Britain, for over 60 years. The fact that the species was known to live and spawn in Essex waters in the 1950s led biologists of that time to consider it as part of the British marine fauna (Yonge 1960).

Such categorisations are not insignificant: The future of British Pacific oyster cultivation could have been threatened by the Wildlife and Countryside Act 1981, which included clauses on the introduction of non-indigenous species. In particular, the Act could have prevented release of juvenile Pacific oysters for cultivation. However, in 1982 a General Licence to "release or allow to escape into the wild" was issued (London Gazette 30th November 1982) under the terms of the Act on the basis that the Pacific oyster was "already resident" in British waters (Humphreys et al. 2014).

It might be supposed that this legal recognition of the species would have resolved the status of the Pacific oyster in Britain, but in fact this was not the case. Whilst previous reviews have assessed the ecological risks and benefits posed by this species (e.g. Syvret et al. 2008; Herbert et al. 2012, 2016), these have not yet resulted in a settled policy position. In contrast to neighbouring states where oyster production has flourished over the last 20 years, this extended period of uncertainty has attenuated investment in British oyster production and exports into an undersupplied worldwide market, which since 1980, has consistently exceeded 500,000 tonnes (FAO 2021).

Throughout NW Europe the context and rationale for the introduction of the Pacific oyster as an aquaculture species has been the decline of dredge fisheries for the native European oyster *(Ostrea edulis)* which today is widely regarded as functionally extinct in many regions (Dame 2021) in terms of both ecology and economics. While overfishing undoubtedly contributed to this problem, especially in the 19th century, it is clear that the arrival of a new disease into British waters around the 1980s was and is a serious problem for the species, despite a number of significant but as yet largely unsuccessful restoration projects (Humphreys 2021).

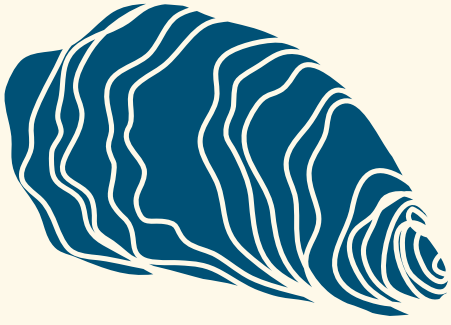
Native oysters are less suited to mainstream aquaculture cultivation practises, are slower growing and have higher mortality rates. As a consequence, the Pacific oyster will remain the mainstay of the British oyster industry indefinitely. As such, in the English Aquaculture Strategy (Huntington and Cappell 2020) it is targeted with annual production growth from around 1000 tonnes in 2020 to 5000+ tonnes by 2040. In the context of the extensive British coastline this target is entirely feasible. Conversely, without the Pacific oyster the UK would have no significant oyster production and no prospect of such growth. In terms of potential for sustainable English shellfish production, the species is considerably under-developed in comparison to immediate neighbouring states.

Natural Dispersal & Climate Change

The 1960's introduction for aquaculture under UK Government licence was approved on the basis that the species, although capable of fattening when introduced as seed oysters, would find British water temperatures too cold for successful reproduction and naturalisation. In recent years however warming seas have contributed to local naturalisations, especially on southern and south-east coasts. On a strict cause and effect basis the current issue can more accurately be attributed to global warming rather than the Pacific oyster *per se*.

Wild settlement of Pacific oysters has led to concerns among conservation organisations that the species may impact indigenous ecosystems to the detriment of native fauna, especially estuarine birds of conservation importance. These concerns typically anticipate changes in ecosystem function (especially bird food availability) and reflect more general worries about conserving British biodiversity. These are reasonable concerns, but for reasons outlined as follows they have triggered spurious arguments for no further aquaculture development, or even cessation of current activities.

The Pacific oyster, which is a "broadcast spawner" with a planktonic larval stage, needs a sustained period of sufficient spring and summer conditions to allow successful recruitment. However, naturalisation of non-native bivalves does not necessarily follow conducive physical conditions: A range of biotic factors are also important. For example, predator pressure can prevent successful bivalve recruitment even in areas where a species is widespread and/or farmed (Deane et al. 2013; Humphreys et al. 2015). While this can make the spread of non-native bivalves opportunistic and gradual, this should not be taken to suggest that spread can be prevented by management.



Climate Change and the Inevitability of Spread

There is no longer any serious doubt that warming sea temperatures combined with globalised anthropogenic vectors from fisheries to shipping have extended the range within which this species can successfully naturalise. Moreover, gradual and continued northerly range expansion is now consistently predicted by independent modelling studies. Using IPCC climate predictions combined with hydrodynamic modelling and suitable habitat mapping, British range expansion along the south-east, south and west coasts of England is predicted (King et al. 2020; Wood et al. 2021). Similar work in Scandinavia suggests that the Pacific oyster, already found in the cold waters around Bergen, could achieve naturalisation on Norwegian Arctic coasts by 2050 (Laugen et al. 2015).

In this context, modelling of possible Pacific oyster management approaches at Cefas has indicated that, in the absence of external recruitment, annual removal of a large proportion of the population is required for eradication from a site within 20 years (Tidbury and Alves 2020). Leaving aside the environmental impacts of large-scale removal, ostensibly this work could be taken to imply that eradication is feasible. However, by showing such a strategy would necessitate an absence of external recruitment and annual removal of around 90% of the population, it effectively demonstrates the opposite.

Inevitability of spread and the impossibility of eradication is implicit in all predictive estimates of range expansion and is now manifest in emergent policy as far north as the cold waters of the Nordic countries, whose intergovernmental Council of Ministers, while recognising the need for informed management, welcomes the species as "a new Nordic food resource and a basis for tourism" (Mortensen et al. 2019).

Recently published Cefas research indicates that restricting further aquaculture and undertaking management of wild Pacific oyster populations on the south coast of England is unlikely to reduce its long-term distribution dramatically (Wood et al. 2021). Essentially, in areas where water temperature is now warm enough, the further spread of the Pacific oyster is unpreventable, whereas in more northern parts of Britain temperatures are not yet sufficient for significant naturalisation (Teixeira Alves et al. 2021) (although this latter conclusion may need to be tested further in relation to the Nordic naturalisations).

All this brings into question the legitimacy of efforts to prevent aquaculture development whilst also bringing into focus the purpose of management. In order to answer these questions further attention is given in the next section to the risks and benefits of local Pacific oyster naturalisation events.

The Ecological Impacts of Pacific Oysters

Ecological Risks and Benefits

Pacific oyster aquaculture in Britain requires no fertiliser or feeding, a fact that distinguishes this from many other types of aquaculture. Conservation concerns focus to a large extent on the fact that, in optimal conditions, feral Pacific oysters can over time form biogenic reefs covering the underlying sediment, which it should be noted is the primary aim for Native oyster restoration projects. In Britain, concerns relate particularly to the possibility that any substantial accumulation of such reefs may prevent protected estuarine bird species from feeding on the underlying sediment for interstitial prey species, and/or that the oyster may competitively exclude indigenous species such as the mussel *Mytilus edulis*. These will be considered in turn before outlining the general ecological benefits and services delivered by the Pacific oyster.

It is long established that the biodiversity and biomass associated with Pacific oyster reefs is greater than that of the surrounding sediment. In the Colne Estuary, Essex, areas of Pacific oyster reef have become established on what would otherwise be intertidal mudflats. Comparisons of areas of oyster reef, cleared oyster reef, and natural mudflat have shown that oyster reefs score highest in terms of both species' richness and biomass (even excluding the oysters themselves). Cleared oyster reefs come second.

In fact, various bird species do feed on Pacific oyster reefs with some eating the oysters themselves. But even those which do not can benefit in a properly managed habitat.

Behaviour-based modelling in relation to all relevant bird feeding behaviours suggests a conservation strategy in which a mosaic of these three area types is optimal for bird populations. In research carried out in Essex, the clearance of oyster reefs was done by collaborating commercial fishers using oyster dredges, whereby a virtuous co-management circle of both economic and environmental benefit is implied (Herbert et al. 2018).

On the possible displacement of the indigenous blue mussel *(Mytilus edulis)*, evidence from the Wadden Sea and Scandinavia shows that, due to niche differences, neither competition for space nor food prevents the two species from coexisting (Diederich 2005; Nehls et al. 2006). In fact, the two species are capable of forming combined reefs of greater ecological complexity and diversity than either produce alone. Moreover, the acknowledged risk that the blue mussel may decline due to climate change (Laugen et al. 2015) suggests that the ecological benefits of the Pacific oyster outlined below will become increasingly important in British waters.

Ecosystem Services

The ecological functions and processes, which shellfish provide, contribute to human well-being, and these ecosystem services are recognised by the Millennium Ecosystem Assessment (MEA 2005). Despite this recognition, the management of shellfish and shellfish habitats for objectives beyond commercial and recreational fisheries is not yet widespread (Brumbaugh and Toropova 2008). The common / public good nature of fisheries resources, including shellfish, risk a *tragedy of the unmanaged commons* as many of the non-market benefits (un-priced) accrue to society as a positive externality and society-at-large remains unaware of their contribution to wellbeing and healthy ecosystems and therefore cannot value them (Costanza et al. 1997). The only directly priced ecosystem service provision by shellfish is that once they are harvested and sold for human consumption or other purposes, but this by no means comprises a fair quantification of their total value to society and the ecosystem as a whole.

By way of an example, Pacific oysters make significant contributions to the **mitigation of human induced water quality issues**. Many of these services relate to sewage effluent and agricultural runoff which enter estuaries both directly and indirectly via river catchments. This creates chronic and sometimes acute water quality issues in many British estuaries due to an overabundance of nitrogen, phosphorus and particulates. These in turn can cause severe ecological detriment, resulting from oxygen depletion, water turbidity, toxic phytoplankton blooms and the development of large areas of macro-algal "mat" on what otherwise would be natural bird feeding sediment flats.

These **"eutrophic" impacts are mitigated by Pacific oyster aquaculture through the filtering out by oysters (as food) of phytoplanktonic algae** whose own growth has taken nitrates etc. from the water column. Essentially, these pollutants are assimilated first by the phytoplankton, which in turn are incorporated into oyster tissues, which is then removed from the system at harvest. Oysters also **reduce turbidity** directly by filtering out both the phytoplankton and non-living organic particulates released in effluents, which in turn, through **clearer water, enhances seagrass and more natural macroalgal growth**.

Furthermore, Pacific oyster cultivation could play an important role in **carbon sequestration** operating as a carbon sink in terms of the production of shell (Moore 2020). In addition, bivalve cultivation is known to have a low carbon footprint in comparison to terrestrial protein production with examples of Life Cycle Assessments showing bivalve aquaculture can even operate as a net carbon sink (Turolla et al. 2020).

Overall, a strong consensus exists that, with the plateauing of wild fishery production, the main additional contribution to high quality protein food production worldwide should preferentially be by non-artificially fed aquaculture species, a category in which the Pacific oyster is pre-eminent worldwide.

These ecological services are of particular importance in the context of the decline of the native oyster *Ostrea edulis* whose absence is compensated for through Pacific oyster aquaculture beds. Furthermore, the benefits are substantial. Studies in Chesapeake Bay (USA) have shown the related species *Crassostrea virginica* to be capable of removing up to 23-40% by mass of phytoplankton production. Work in the UK by Gravestock et al. (2020) examined the significance of this benefit in Poole Harbour by calculating the filtration rates of Pacific oysters under conditions typical of the Harbour environment. They concluded that the total volume of water filtered by Pacific oysters on the Harbour's aquaculture beds ranges up to $1.9x10^6$ m^{-3} per day, during the peak growth season. When combined with other commercial aquaculture bivalve species this represents over 61% of the Harbour's total high-water volume on a neap tide, just when the water quality issues are most acute. Approximate and localised as they are, such estimates substantiate an important water purification role for cultured Pacific oysters.

Finally, it is noteworthy that the presence of Pacific oysters facilitates the settlement and growth of the native oyster *Ostrea edulis*. In both Poole Harbour (Humphreys 2021) and the Voordelta area of the Dutch North Sea (Christianen et al. 2018), native oysters successfully settle and grow on living and dead Pacific oyster shells. In the latter case, native oysters have re-established in areas where they have been ecologically extinct for almost a century (Christianen et al. 2018).

Ecosystem Service Valuation of Oyster Reefs

In US research, high density oyster bed ecosystem services (excluding harvest, i.e. the non-market ecosystem services) were valued between $5,500 and $99,000 per Hectare per annum. This case study from the USA showed the avoided-cost concerning Nitrogen removal to meet the Clean Water Act (1972) from 1 hectare of oyster-bed habitat was estimated at $1,385–$6,716 per year. In addition, the replacement costs in terms of providing the rocky sea defences provided by oyster reefs was substantial, as were the benefits in terms of habitat enhancement and the resulting fish and crustacean productivity enhancement (Grabowski et al. 2012).

Some of these ecological services have been valued through the Ecosystem Services Valuation Database (ESVD 2020) and available literature, which means it has been possible to estimate the total value per hectare of oyster reefs at £17,376 – as shown in Table 1 below.

Table 1: Ecosystem oyster reef values per hectare per year where monetary value is shown. Source: Calculations based on ESVD values and available valuations (Grabowski et al. 2012; Watson et al. 2020).

Cluster	ES category	ES sub-category	Ecosystem service	£/ha/yr. (2017 prices)
Marine resources	Provisioning services	Provision of food	Shellfish landings	£399.85
Coastal health & quality	Regulating services	Nutrient removal (N&P)	Nitrogen removal	£15,257.00
Coastal health & quality	Regulating services	Pollutant removal	Carbon sequestration	£5.04
Habitat modification	Regulating services	Sediment/ Shoreline stabilization	Shoreline protection	£685.16
Biological structuring	Habitat & supporting services	Habitat provision	Submerged aquatic vegetation enhancement	£1,029.34
Total £/ha/yr.				**£17,376.39**

The Value of Pacific Oyster Aquaculture to Local Economies

Poole Harbour Case Study

The UK Marine Strategy (HM Government 2019) sets out a vision for, 'clean, healthy, safe, productive and biologically diverse oceans and seas'. To deliver healthy oceans and more prosperous coastal communities, the local economic contribution of different sectors of the maritime economy, and their respective impacts on the natural resource base that underpins their economic activity, needs to be understood.

Bivalve Shellfish Aquaculture (including Pacific and native oysters, mussels, clams and cockles) supports coastal jobs and revenues in the UK with the shellfish sector contributing nearly 21,000 tonnes worth over £28 million at first sale in 2018. Despite the potential for oyster aquaculture in England, the sector is underdeveloped in comparison to France. English aquaculture bivalve shellfish production is mainly comprised of mussels and Pacific oysters – and was around 2,700 tonnes in 2018 of which 1,700 tonnes were mussels and 1,000 tonnes were Pacific oysters (Huntington and Cappell 2020). Pacific oyster aquaculture supported 142 FTE jobs in England in 2017 (Pye Tait 2020). The growth of bivalve shellfish aquaculture is important for marine planning and is a key area promoted in the Blue New Deal action plan (New Economics Foundation 2016).

Poole Harbour: Local Context and Environment

As described in a New Economics Foundation study (2018), Poole is a major conurbation and a tourism hot spot in Dorset, with some of the UK's finest 'blue flag' beaches and home to the second largest natural harbour in the world. The harbour is of ecological, recreational and commercial importance to residents and visitors alike, with Ramsar (wetland), SSSI, EU Special Protection Area (SPA) and Special Area of Conservation (SAC) designations.

Employment

Poole is characterised by a high proportion of small and medium enterprises (SMEs), with the majority having a turnover of less than £250k and/or employing fewer than five employees. Poole has a slightly lower than UK average percentage of employees working in low-paid sectors, including agriculture, forestry and fishing; distribution; accommodation and food service; health and social care; some manufacturing sectors; culture and recreation, among others. In 2011 the Environmental Goods and Services (EGS, latest data) sector contributed 1.5% of employment in Poole (Borough of Poole 2014). Pacific oyster aquaculture in Poole employed 6 FTE people and 2 PTE people in 2018. The post-harvest purification process to remove low level microbial contamination (also known as depuration) is undertaken in Scotland for these oysters where further local jobs are reliant on Poole's oyster production.

Aquaculture in Poole Harbour

Managed under the Poole Harbour Fishery Order 2015, aquaculture is a major activity in Poole Harbour. The main species grown are oysters (both Pacific and native), clams (both *Mercenaria* and *Manila*), mussels and cockles. Less than one quarter of this Several Order is currently under production and so there is significant scope for increasing shellfish production (Southern IFCA). Poole Harbour is the largest Pacific oyster production area in England with annual production levels of between 250 and 350 tonnes per year.

Recent research showed that 67% of UK Pacific oyster production is exported from the UK (Humphreys et al. 2014). Pacific oysters now have an economic significance UK-wide, represented by Gross Output and Gross Value Added (GVA) through all stages of the value chain. Using 2011/12 market prices, the value was estimated at £13 million (Annual Gross Output, being 5 times the first sale value), and over £10 million Gross Value Added (GVA) for total UK production.

Economic Impact of Pacific Oysters to the Economy of Poole

To estimate the economic activity for Pacific oyster aquaculture in Poole Harbour, a model was used that had been previously developed in the context of harvesting shellfish in the Solent (Williams and Davies 2018). This model estimated Gross Output, defined as the direct economic turnover generated from shellfish aquaculture. Here, Gross Output relates to the turnover received by aquaculturists, when selling their catch upon landing. Indirect Output represents the measure of economic impact of bivalve shellfish harvesting on supply chain expenditure. Total economic activity equals the sum of Gross Output and Indirect Output. Table 2 shows a total economic activity associated with Pacific oyster aquaculture for Poole Harbour of £2.6 million (*at 2018 £*).

Table 2: Total economic activity for Pacific oysters in Poole Harbour

Gross Output	Indirect Output	Total Economic Activity
£1,590,000	£1,025,250	£2,615,250

The full 2018 NEF Consulting report informing this summary is available here.

Pacific Oysters as a Non-Native Species in Other European Countries

Legal and Management Perspectives

Introduction

The Pacific oyster is currently classified as an invasive, non-native species under the Wildlife and Countryside Act 1981. A lack of settled national policy regarding the status of this species has meant that regulators, often at local level, will often seek to impose their own subjective interpretation on industry of what is permissible and this results in quite different, often precautionary, approaches being adopted in different geographic areas. These precautionary policies are being imposed not only on potential new businesses but also onto existing lawfully operating businesses, deterring not only new entrants and but also further investment into this sector. The Shellfish Association of Great Britain (SAGB) has been calling for a policy review to establish a settled position for the cultivation of Pacific oysters so that business can have a certainty about the future in order to allow planning, development and investment to take place.

The current drive by Government to examine the position of the Pacific oyster in our UK waters is primarily legislative with the main areas of concern being Marine Protected Areas (MPAs) such as Special Protection Areas for birds (SPAs) or Special Areas of Conservation (SACs). Those areas are widespread around the coast of England and Wales and cover the areas of operation for the vast majority of existing businesses as well as the most suitable areas for new farms. Differences exist between countries in the UK with Scotland having a different, less restrictive policy where Pacific oyster farming is generally permitted in European marine sites. It should be noted that in many of our European neighbours' documentation with regard to Natura 2000 sites, there is no mention of Pacific oysters as the species is considered naturalised.

Whilst the legislation which regulators are using to restrict the cultivation of Pacific oysters originates from the EU, in Member States this legislation is implemented in a more pragmatic manner with a more reasonable, industry supportive approach which affords their Pacific oyster cultivation industry significant advantages over our own. To illustrate the different approaches, this section will describe the policy towards Pacific oysters in various EU countries who follow exactly the same legislation as exists in the UK.

France

France is our closest European neighbour and has very similar geographical and hydrological conditions to the UK. It has however a Pacific oyster cultivation industry which is more than one hundred times larger than the UK's with **virtually all Pacific oyster farms located within European marine sites where Natura 2000 legislation is considered to be fully implemented**. The French guidance on Natura 2000 sites at sea is there to help each steering committee for individual Natura sites to define their "document of objectives" for planning the various activities to be authorised and managed in the designated sites. The main paragraph in the guidance for Pacific oysters expresses that this species is not a concern of the provisions, except for articles 3 and 4 which address the level of risk and thus the compatibility of the species with Natura 2000 sites. In the case of Pacific oysters the risk is assessed as low and as a consequence Pacific oysters are considered fully compatible with all Natura 2000 sites. In fact the French go further and assert that the Pacific oyster farming activities are an integral part of the features of the marine sites and the species is described as supporting wildlife and increasing biodiversity.

There have been attempts in the past in France to have targeted removal programmes for Pacific oysters but these have been to support the farming activities by trying to limit wild settlement which had become a problem for the farmers There has never been an attempt to remove Pacific oysters from any area in France due to them being a non-native species as they are regarded as being naturalised and a valuable contributor to the environment and the local economies. The approach to the management of the species is based on the principle that reefs of Pacific oysters have ecological, environmental and economic benefits i.e. they provide significant ecosystem services.

The Netherlands

In the Netherlands, Pacific oysters are located and farmed in an area called the Oosterschelde. In 2006 an investigation was undertaken in this area to explore whether the Pacific oysters could be controlled or removed from the site. The project cleared an area of approximately 50 hectares, which at that time was estimated to be about a twentieth of the total area of Pacific oyster reef in the Oosterschelde. During the project, which cost in excess of £250,000, the oysters were removed and put into piles on the sea-bed in the expectation that they would die. This however had limited success as about 16% of the oysters survived. The project in the Netherlands reached a number of conclusions;

- Whilst the trial reduced spatfall levels, the high fecundity of this species meant that it was estimated that the population would be back to original levels within 6 years. Thus without considerable expansion of the scope of the project, and repeating it every year, it was concluded that removal of the species would be impossible.

- That the Pacific oysters play a role in filtration of the waters.

- That the Pacific oyster reefs have more mud sediment than exposed areas and that this sediment is rich in organic carbon with a higher biomass of macrobenthos.

- There are some wading birds that feed more readily on the oyster beds, a few of these actually feed on the oysters themselves, whilst others feed on the food sources found amongst the oysters.

- Pacific oyster reefs can provide an effective means to prevent erosion of the seabed.

Following this study the **attitude and approach taken to Pacific oyster farming in the Netherlands has changed and the farms are now recognised and accepted as part of the local culture and economy**. In fact, when the producer organisation for aquaculture in the Netherlands was asked about the attitude of their government to cultivation of Pacific oysters in Natura 2000 sites they said:

"An invasive non-native always remains a non-native. However, when you can draw the conclusion that it is impossible to eliminate them, and also if you conclude that our oyster sector is 90% Pacific oysters in volume, our Ministry cannot imagine to restricting the farming of Pacific oysters. There is not a 'scientific' argument why or why not. More practical argument. They are just here, so we live with it and take the advantages that farming them has to offer"

In the Netherlands therefore they have concluded that the species will remain and they accept that farming them is not an activity which should be restricted.

Republic of Ireland

The Pacific oyster was introduced into the Republic of Ireland in the mid-20th century as an aquaculture species, and by the early 21st century it has established wild populations in many locations. Following a legal ruling by the Court of Justice of the European Union against Ireland in 2007, all shellfish farming activities in Natura 2000 sites are now subject to an appropriate assessment. **Pacific oyster aquaculture is permitted on the basis that Pacific oyster populations in their oyster growing bays have become naturalised with clear evidence of spat-fall**. This is now documented in appropriate assessments, where the only concern is other non-native species that the Pacific oyster may bring with it.

An example from an appropriate assessment is: "Oyster culture poses a risk in terms of the introduction of non-native species as the Pacific oyster (*Crassostrea gigas*) itself is a non-native species. Recruitment of *C. gigas* has been documented in a number of Bays in Ireland and appears to have become naturalised (i.e. establishment of a breeding population) in many locations".

So again, this time in Ireland, the species is now considered naturalised and aquaculture is supported, including new cultivation operations.

Spain

In Spain, the position is not as clear as there is a different system of government. They have a national Government, but they also operate a federalised system which allows the various regions a great deal of autonomy. The Pacific oyster is produced by aquaculture primarily in the regions of Galicia and Catalonia, there is little culture outside of these regions, but these two together easily produce fifty times the volume of Pacific oysters grown in the UK. It is also the case that the **vast majority of Spanish Pacific oyster production is carried out in Natura 2000 sites**.

It is therefore not surprising that, whilst there seems to be an ambivalence at national level regarding the aquaculture of Pacific oysters in the Natura 2000 sites, at a local level in Galicia and Catalonia there is strong support for the continued cultivation and expansion of the species. As the licensing and management of aquaculture is the responsibility of the local government, then there is no problem with Pacific oyster farming in these places.

Italy

In Italy, Pacific oyster farming is not very developed and the volumes produced only slightly exceed the production in the UK. However, most of the farms that do exist are located in Natura 2000 sites, with some in Veneto, the Po Delta Park area, in Sardinia, and in the San Teodoro lagoon.

Requests for information regarding any issues posed by the cultivation of the non-native Pacific oyster in Natura 2000 sites in Italy are met with some consternation. It appears that this has never been raised as a regulatory problem in Italy and hence is not considered when licensing and management decisions are made. When questioning this position we were told that this is because **the Pacific oyster was imported into Italy in the 1960s and is now naturalised with natural beds of oysters being widespread. They also consider that the Pacific oysters breed and spread naturally anyway and hence there is no concern about the economic activity of farming them**.

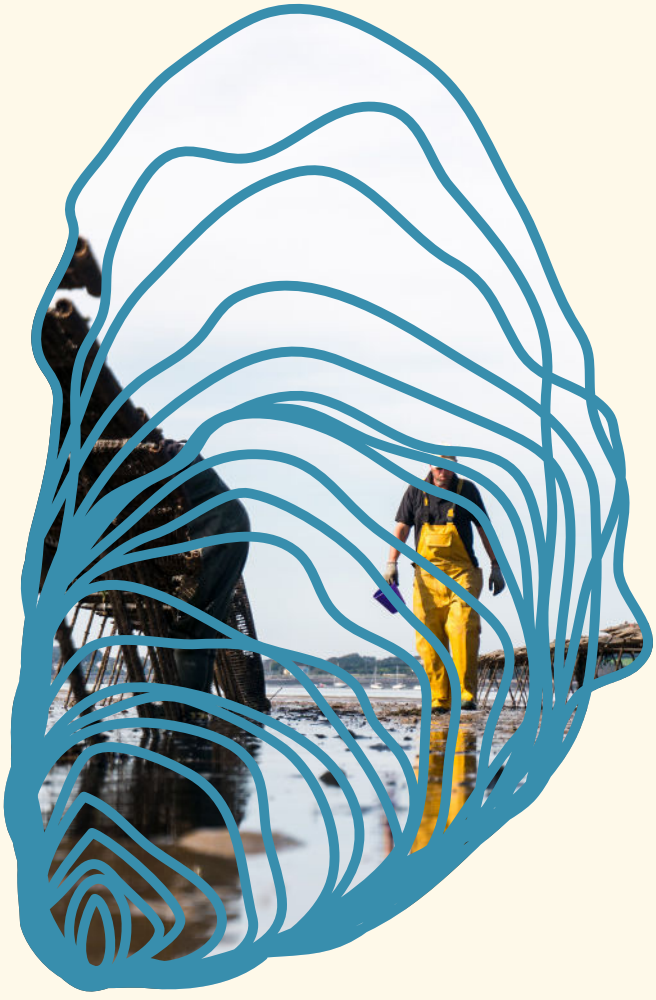
Denmark

Like many of the other countries, the Pacific oyster was introduced into Denmark in the mid-20th century. It **now has large populations of wild settled oysters, despite a sea temperature which would appear to be incompatible with spawning**. Pacific oysters are farmed in Denmark in designated Natura 2000 sites and there have been no issues with licensing or management of the aquaculture operations.

Conclusions

As with the classification system of waters for shellfish harvesting, it seems that **England has a far more restrictive system for licensing shellfish aquaculture than exists anywhere else in Europe and this has been a significant factor in limiting the expansion of this sector**. There are some things which we can conclude from the information from other European countries;

- Due to the presence of locally sustaining populations, Pacific oysters are considered naturalised in all other European countries where they are farmed.
- All other European countries take a far more pragmatic view towards the management of Pacific oysters than the UK. They accept that it is present and that farming it will not add to the spread of the species given the high numbers of larvae that the wild populations produce.
- Pacific oysters are breeding in our waters and there is no practical way to eradicate them, and so any restrictions in certain areas will not be effective.
- Rising seawater temperatures associated with Global Warming will allow the geographic spread of the Pacific oyster to new areas of the UK coastline.
- Our European neighbours recognise that Pacific oysters can provide valuable ecosystem services as well as providing local economic opportunities.
- Even if it were somehow possible to totally eradicate Pacific oysters from the UK, research has shown that recolonisation of the UK coastline would occur due to larval drift from neighbouring European countries.



The Nature and Purpose of Effective Management

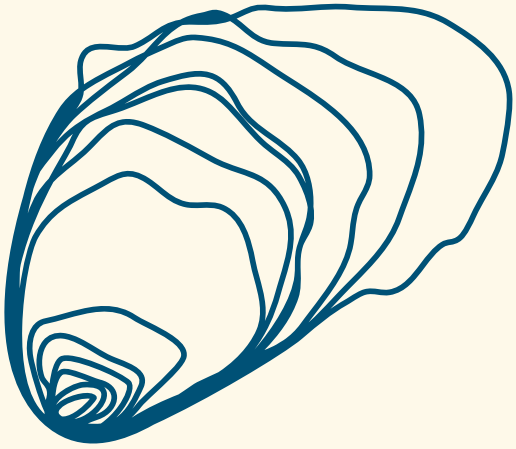
It is evident that the Pacific oyster will not disappear from British waters by natural mortality events and no plausible eradication method is available. In light of the "lack of feasible management solutions" to the inevitable gradual spread of the Pacific oyster in England (King et al. 2020) what should be the British policy on Pacific oyster aquaculture and the goals of management?

It seems reasonable to expect that conservation concerns about the Pacific oyster must be balanced against their ecological and socio-economic benefits. Most British estuaries have long been highly anthropogenically altered environments which can benefit from the ecological services Pacific oysters provide, not least in the absence of the native species. The answer lies in achieving a feasible and cost-effective balance between ecological and economic benefits and mitigating any emergent overabundance impacts by considered, proportionate and locally appropriate management responses. Such evidenced-based management approaches are now widely advocated in Europe, including in the UK (Herbert et al. 2016). Persistent reluctance to accept this is becoming a peculiarity of the UK among European governments.

As Herbert et al. (2016) concluded in their extensive and much cited review, what is needed is locally responsive management regimes that balance protection of biodiversity with exploitation of the resource and the socio-economics of coastal aquaculture and fishing communities.

It is clear from this review paper that general calls for the prohibition of new Pacific oyster aquaculture sites are spurious in the context of any balanced assessment of the scientific literature. Moreover, cessation of existing sites would almost certainly be ecologically detrimental in the estuaries concerned, to an extent that, ironically, would be precluded by a precautionary approach.

For some conservation organisations, calling for the expenditure of considerable amounts of public funding to protect indigenous ecosystems, in areas already temperature-compatible with Pacific oysters, might be considered legitimate and appropriate. However, globalisation, with the consequent movement of species, as well as climate change have resulted in few, if any, such extant systems, and all the science indicates that preventing the gradual spread of the Pacific oyster is no longer feasible. This is the reality which demands the adoption of more sophisticated conservation solutions of the sort which recognise not only the risks but also the benefits of the Pacific oyster in Britain.



Nevertheless, a number of issues should be addressed in the further development of responsible and sustainable Pacific oyster aquaculture. Scientifically and dispassionately informed impact assessments in relation to new sites are important; laying of exclusively triploid (sterile) seed oysters to moderate naturalisation where wild settled Pacific oysters do not already occur; in parallel with this there should the development and application of adaptive management plans specifying responsibilities for growers in terms of disease, hygiene and ecologically acceptable practices akin to Habitats Regulation Assessments carried out in SACs and SPAs, perhaps as an extension to existing Biosecurity Management Plans.

Finally, the adoption of best practice co-management approaches will be essential in seeking to manage the Pacific oyster and thereby ensuring a sustainable estuarine ecology is maintained. Notable in this respect is the case of the Netherlands' commercial bottom-cultured Pacific oyster production which received Marine Stewardship Council certification in 2012 (Dolmer et al. 2014; Mortensen et al. 2017). Here the species has been cultivated in an ecologically and economically sustainable way, demonstrating the value of co-management approaches.

Such measures are consistent with the UN FAO Code of Conduct for Responsible Fisheries (FAO 2021), and with them in place, the potential exists in Britain to continue the sustainable and responsible production of Pacific oysters and even to develop production in areas where the species has not previously been grown.

It's time for a sophisticated and clear approach to this species in Britain.

References

Borough of Poole (2014). *Poole economic development strategy and action plan 2014-2019.* http://ha2.boroughofpoole.com/akspoole/images/att22796.pdf

Brumbaugh, R.D. and Toropova, C. (2008). Economic valuation of ecosystem services: A new impetus for shellfish restoration? *Basins and Coasts News 2* (2): 8-15.

Christianen, M. J. A., Lengkeek, W., Bergsma, J.H., Coolen, J.W.P., Didderen, K., Dorenbosch, M., Driessen, F.M.F., Kamermans, P., Reuchlin-Hugenholtz, E., Sas, H., Smaal, A., van den Wijngaard, K.A. and van der Have, T.M. (2018). Return of the native facilitated by the invasive? Population composition, substrate preferences and epibenthic species richness of a recently discovered shellfish reef with native European flat oysters *(Ostrea edulis)* in the North Sea. *Marine Biology Research*, 14:6: 590-597, DOI: 10.1080/17451000.2018.1498520

Costanza, R., d'Arge, R., de Groot, R., Farbeck, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260. https://doi.org/10.1038/387253a0

Dame, R.F. (2012). *The Ecology of Marine Bivalves: An Ecosystem Approach* (2nd Edition) CRC Press. Marine Science Series.

Deane, S., Jensen, A. and Collins, J. (2013). D*istribution, abundance and temporal variation of the Pacific oyster, Crassostrea gigas in Poole Harbour.* Southampton University: Ocean and Earth Science FES 287.

Diederich, S. (2005). Differential recruitment of introduced Pacific oysters and native mussels at the North Sea coast: coexistence possible? *Journal of Sea Research*, 53 (4): 269-281.

ESVD (2020). Ecosystem Service Valuation Database https://www.es-partnership.org/

FAO (2021). *Crassostrea gigas* (Thunberg,1793). Food and Agriculture Organisation of the United Nations. Fisheries Division, Cultured Aquatic Species Information Programme. Downloaded 2021.

Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.H., Powers, S.P. and Smyth, A.R. (2012). Economic Valuation of Ecosystem Services Provided by Oyster Reefs. *BioScience, 62, Issue 10*: 900–909, https://doi.org/10.1525/bio.2012.62.10.10

Gravestock, V.J., Nicoll, R., Clark, R.W.E. and Humphreys, J. (2020). Assessing the benefits of shellfish aquaculture in improving water quality in Poole Harbour, an estuarine Marine Protected Area. In Humphreys, J., Clark, R.G. (Editors) *Marine Protected Areas: Science, Policy and Management.* Amsterdam: Elsevier.

Herbert, R.J.H., Roberts, C., Humphreys, J. and Fletcher, S. (2012). *The Pacific oyster in the UK: Economic, legal and environmental issues associated with its cultivation, wild establishment and exploitation.* For: Shellfish Association of Great Britain, London.

Herbert, R.J.H., Humphreys, J., Robert, C., Fletcher, S. and Crowe, T. (2016). Ecological impacts of non-native Pacific oysters *(Crassostrea gigas)* and management measures for protected areas in Europe. *Biodiversity and Conservation 25:* 2835-2865.

Herbert, R.J.H., Davies, C.J., Katharine, M., Bowgen, K.M., Hatton, J. and Stillman, R.A. (2018). The importance of non-native Pacific oyster reefs as supplementary feeding areas for coastal birds on estuary mudflats. *Aquatic Conserv: Mar Freshw Ecosyst.* 28:1294–1307.

HM Government (2019). *Marine strategy part one: UK updated assessment and Good Environmental Status.* The Stationary Office, London. Crown Copyright. https://www.gov.uk/government/publications/marine-strategy-part-one-uk-updated-assessment-and-good-environmental-status

Humphreys, J. (2021). The Poole Harbour Oyster Industry. In Humphreys, J. and Hall, A. (Editors), *Poole Harbour: Aspects of environment and Industry.* Poole Harbour Study Group (In press).

Humphreys, J., Herbert, R.J.H., Roberts, C. and Fletcher, S. (2014). A reappraisal of the history and economics of the Pacific Oyster in Britain. *Aquaculture 428-429:* 117-124.

Humphreys, J., Harris, M.C.R., Herbert, R.J.H., Farrell, P., Jensen, A. and Cragg, S.M. (2015). Introduction naturalisation and dispersal of the Manila clam *Ruditapes philippinarum* in British estuaries 1980-2010. *Journal of the Marine Biological Association of the UK 95(6): 1163-1172.*

Huntington, T. and Cappell, R. (2020). *English Aquaculture Strategy. Final Report.* Produced by Poseidon Aquatic Resources Management Ltd. For: The Sea Fish Industry Authority. 80p + appendices.

King, N.G., Wilmes, S.B., Smyth, D., Tinker, J., Robins, P.E., Thorpe, J., Jones, L. and Malham, S.K. (2020). Climate change accelerates range expansion of the invasive non-native species, the Pacific oyster, *Crassostrea gigas. ICES Journal of Marine Science DOI:10.1093/icesjms/fsaa189.*

Laugen, A.T., Hollander, J., Obst, M. and Strand, A. (2015). The Pacific Oyster *(Crassostrea gigas)* Invasion in Scandinavian Coastal Waters: Impact on Local Ecosystem Services Chapter 10. In: Canning-Clode, J. (Editor) *Biological Invasions in Changing Ecosystems Vectors, Ecological Impacts, Management and Predictions* pp. 230-253 De Gruyter Open Ltd, Warsaw/Berlin.

Millennium Ecosystem Assessment (2005). http://millenniumassessment.org/en/Condition.html

Moore, D. (2020). A biotechnological expansion of shellfish cultivation could permanently remove carbon dioxide from the atmosphere. *Mexican Journal of Biotechnology 5(1):* 1-10.

Mortensen, S., Bodvin, T., Strand, A., Holm, M.W. and Dolmer, P. (2017). Effects of a bio-invasion of the Pacific oyster, *Crassostrea gigas* (Thunberg, 1793) in five shallow water habitats in Scandinavia. *Management of Biological Invasions 8.*

Mortensen, S., Dolmer, P., Strand, A., Naustvoll, L-J. and Laugen, A.T. (2019). *Policy Brief: The Pacific Oyster- a new Nordic food resource and a basis for tourism.* Nordic Council of Ministers ISBN 978-92-893-6122-4 (PDF). http://dx.doi.org/10.6027/Nord2019-015

Nehls, G., Diederich, S., Thieltges, D.W. and Strasser, M. (2006). Wadden Sea mussel beds invaded by oysters and slipper limpets: competition or climate control? *Helgoland Marine Research, 60 (2):* 135-143.

New Economics Foundation (2016). T*urning Back to The Sea: A Blue New Deal To Revitaliase Coastal Communities, 116p.* https://neweconomics.org/uploads/files/NEF-Blue-New-Deal-AP-HighRes.pdf

New Economics Foundation (2018). *A Tale of Three Fisheries: The value of the small scale commercial fishing fleet, aquaculture and the recreational charter boat fleet, to the local economy of Poole,* 41p. For: Southern IFCA. https://nefconsulting.com/wp-content/uploads/2018/09/A-TALE-OF-THREE-FISHERIES_FINAL_VERSION_.pdf

Pye Tait (2020). *Skills, Recruitment and Retention in England's Seafood Industry, 142p.* For: Seafood 2040.

Southern IFCA http://www.southern-ifca.gov.uk/the-poole-fishery-order extent of the Order map. https://secure.toolkitfiles.co.uk/clients/25364/sitedata/files/Poole_Order2015_Map.pdf

Syvret, M., FitzGerald, A. and Hoare, P. (2008). FIFG Project No: 07/Eng/46/04 - *Development of a Pacific Oyster Aquaculture Protocol for the UK – Technical Report, 195p.*

Teixeira Alves, M., Taylor, N.G.H. and Tidbury, H.J. (2021). Understanding drivers of wild oyster population persistence. *Sci Rep 11:* Article 7837. https://doi.org/10.1038/s41598-021-87418-1

Tidbury, H.J. and Teixeira Alves, M. (2020). *Pacific oyster population modelling.* Presentation - 22nd September 2020, Cefas.

Turolla, E., Castaldelli, G., Fano, E.A. and Tamburini, E. (2020). "Life Cycle Assessment (LCA) Proves that Manila Clam Farming *(Ruditapes Philippinarum)* is a Fully Sustainable Aquaculture Practice and a Carbon Sink". *Sustainability* 12, no. 13: 5252. https://doi.org/10.3390/su12135252

Watson, W., Watson, G. and Preston, J. (2020). *Valuing the Solent Marine Sites Habitats and Species: A Natural Capital Study of Benthic Ecosystem Services and how they Contribute to Water Quality Regulation.* Environment Agency R&D Technical Report ENV6003066R.

Williams, C, and Davies, W. (2018). *A valuation of the Provisioning Ecosystem Services provided by shellfish for priority waters in the Solent.* For: Southern Inshore Fisheries and Conservation Authority (SIFCA) / Environment Agency. NEF Consulting, London. https://bit.ly/2jNB5QL

Wood, L.E., Tiago, A.M., Silva, R.H., Kennerley, A., Stebbing, P., Fernand, L. and Tidbury, H.J. (2021). Unaided dispersal risk of *Magallana gigas* into and around the UK: combining particle tracking modelling and environmental suitability scoring. Biological Invasions. https://doi.org/10.1007/s10530-021-02467-x

Yonge, C.M. (1960). *Oysters* London: Collins New Naturalist Series.

Citation

Syvret, M., Horsfall, S., Humphreys, J., Williams, C., Woolmer, A. and Adamson, E. (2021). The Pacific Oyster: Why we should love them. For: Shellfish Association of Great Britain.

Authorship and Contributions

Listed in order using PCI (percentage-contribution–indicated) approach to author sequencing except for last corresponding author. Where section contributions are numerically equal then Authors are placed in alphabetical order by surname. No differentiation is made between primary or contributory authorship.

Authors' Note and Disclaimer

This study has been undertaken on behalf of the Shellfish Association of Great Britain (SAGB) and is funded by The Fishmongers' Company's Fisheries Charitable Trust. This study is intended to assist in the formulation of a policy towards the cultivation of the Pacific oyster in England and Wales. The views expressed in this report are those of the Authors and are not therefore necessarily representative of the SAGB or The Fishmongers' Company. The Authors cannot be held responsible for any consequences arising from the use of this Report.

V1.0
June 2021