Portland Harbour – A High Level Review of Aquaculture Opportunities

Report for Portland Harbour Authority Limited

IMPORTANT NOTE

This review considers the potential aquaculture opportunities only. Future aquaculture opportunities will require much broader consideration taking account of the harbour's existing users and the environment.

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1. Introduction

This report has been completed by MacAlister Elliott and Partners Ltd (MEP) on behalf of the client, the Portland Harbour Authority Ltd (PHA).

PHA is a privately owned UK registered company which owns the commercial port operating out of the Portland peninsula close to Weymouth. The company was founded in 1977 with the purchase of the harbour from the Royal Navy by its parent company, Langham Industries.

Recently, the port has seen individuals taking an active interest in the potential for aquaculture development. This has led PHA to consider what opportunities may actually exist in the harbour and surrounding zone. The outcome of this may lead to PHA applying for a several order for part or parts of the area for future aquaculture development. It is with this consideration in mind that a request for a high level review of aquaculture opportunities has been made. This review will consider the whole area currently under the control of PHA (inside and outside the port).

The aim of this piece of work is to assess the potential which does or does not exist in the area controlled by the PHA for aquaculture development now and in to the future. This work is based on both a visual inspection of the port (completed on the 7th February 2018) followed by a desk based review. It is important to note that this review does not explicitly consider issues such as other stakeholder interaction or port harbour activities. It considers the potential for aquaculture development based purely on the feasibility of the activity (i.e. environmental, physical and regulatory considerations). Future aquaculture opportunities will clearly require a much broader consideration of all external and internal issues before commencing.

For each species, a SWOT analysis has been completed if an opportunity is thought to exist for the species production in the Portland Area. This is not considered the case for Lobster, Crab, Finfish and Macro algae production (and hence no SWOT analysis is provided).

This report was submitted to the client on the 16th March 2018 for comment.

2. Aquaculture Species & Gear Review

In this section, MEP will cover a variety of species and the current techniques used for production. The review starts by considering Molluscs, then moves on to crustaceans, finfish and finally macro-algae.

2.1 Molluscs

2.1.1 Blue Mussels *(Mytilus edulis)*

Species Overview and UK Production

The blue mussel or common mussel, Mytilus edulis, it the most commonly produced species in aquaculture in Europe. The species is naturally occurring in intertidal and subtidal areas (1 to 10 metre) along the whole of the UK coast line. The species has a relatively complex life cycle but in summary it consists of a number of larval stages (trocophore and veliger) during which they float on prevailing currents and commence filter feeding before settling on a primary settlement location. They will remain here for a number of weeks usually doubling in size before detaching and finding a permanent settlement point (often attaching to each other to form large mussel beds). This settlement can be on the seabed or on suitable vertical or horizontal structures. A visual representation of this process is provided in Figure 2 below.

Figure 1: Mussel *(Mytilus edulis)*

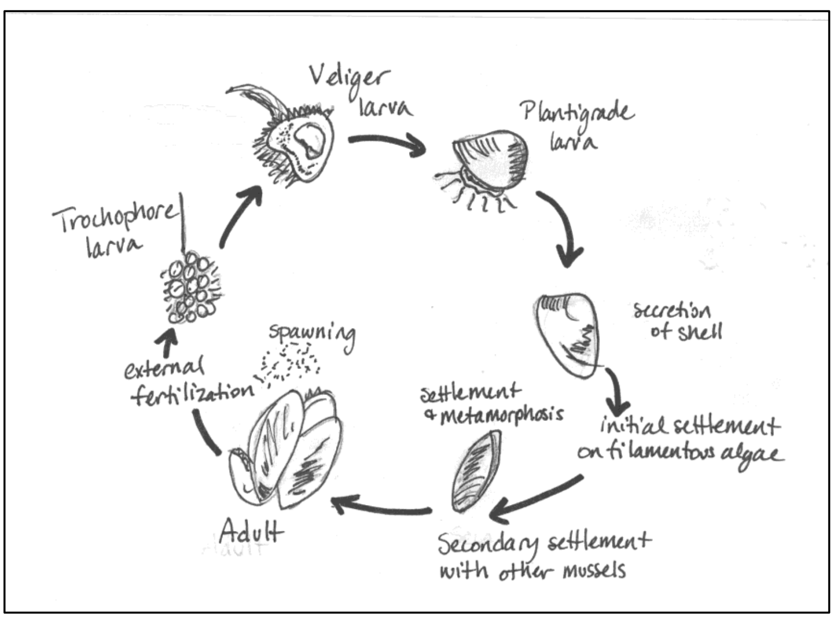

Figure 2: Visual representation of Mussel lifecycle

A blue mussel can survive for up to twenty-four years but in reality, predation or other factors will limit most survival to around four.

Production of mussels in the UK currently totals 15,000 Tonnes annually (2016, wet weight). Production totals for the UK between 2008 and 2016 are shown in Figure 3 below and show a steady decline over this period.

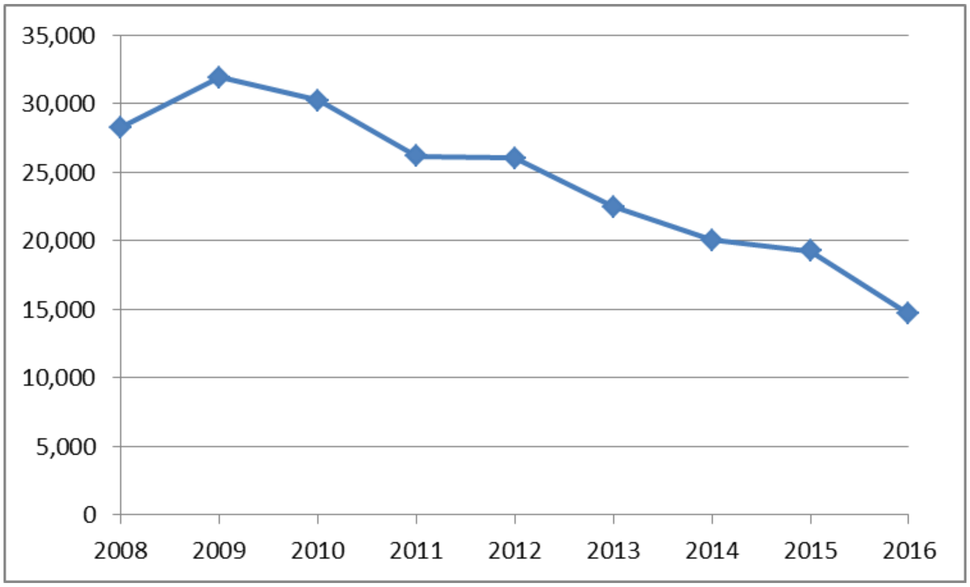

Figure 3: UK mussel production figures (Tonnes) between 2008 and 2016)

The reasons for this decline are thought to be linked to reduction in spat falls, increase disease issues and increased competition from other EU producers (mainly, Holland, France, Spain).

Mussel production is currently dominated by Scottish producers (around 40-50% of production) with Shetland being a major site for the production of rope grown mussels. Wales also has a major mussel relaying activities located in the Menai Straits capable of producing 6,000 Tonnes alone every year. In England, 25 producers are active with the biggest farm located in Exmouth (relaying activity of 2,000 Tonnes per year). A potential Offshore farm is also being planned for Lyme bay (Offshore Shellfish Ltd) aiming to produce 10,000 Tonnes of rope grown mussels yearly.

Production Techniques

The production of *Mytilus edulis* in the UK and Europe is completed either by relaying or the use of longlines (often referred to as ‘rope grown’).

Relaying

In essence, relaying is actually a form of ranching and can have more of an association with wild fisheries than aquaculture. It is though generally included in the aquaculture bracket.

The aim of relaying is to take captured spat and relay it to areas which will allow it to be dredged up once fully grown. As an example, we will look at the Menai Strait mussel fishery. The fishery operates by collecting seed mussels (recently settled mussels usually of around 20 mm shell length or less) from several specific areas and relaying them on lays in the northern Menai Strait. These lays can be up to 400 M^2 and often 40cm thick with mussels by the time they are fully grown. An example of one lay on a low tide is shown in Figure 4 below.

Figure 4: Mussel lay in the Menai Strait at low tide

They are grown on these lays for up to two years before being harvest by dredge vessels and sold as adult mussels, generally on to the Dutch market. An example of a current vessel being used in the Menai Strait fishery is shown below in Figure 5.

Figure 5: Dredging vessel in the Menai Strait mussel fishery

Longline (or 'rope grown')

The second method of production involves the use of suspended rope systems to hold mussels off the seabed. An example of a system is shown in Figure 6 and Figure 7 below.

Figure 6: Rope grown mussel farming operation[1]

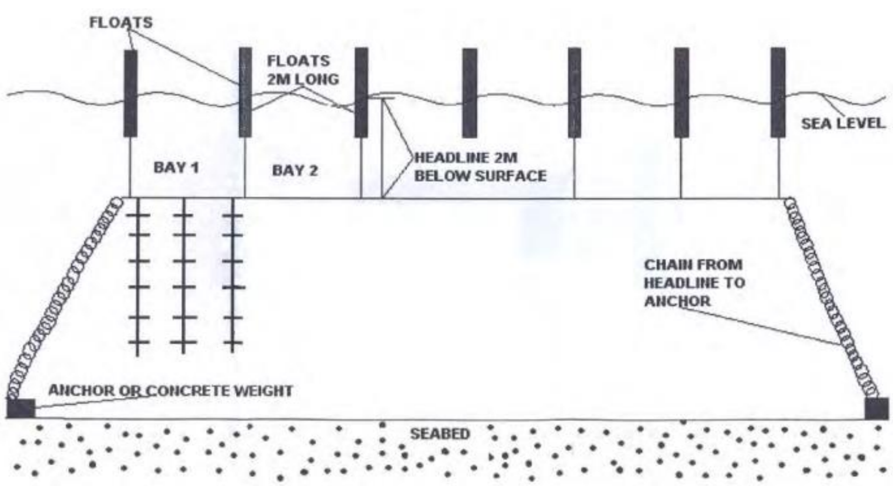

Figure 7: Diagram of a typical rope grown mussel system

Rope grown mussel farming will start with the collection of spat. This is often done by the placement of old ropes (or similar) in area of known spat fall. Here the spat will naturally settle on to the ropes and after time form a dense covering on the ropes. Most operations will then take the rope and place it through a rubberised ring to remove and collect the spat. A separate rope is then taken and a breathable bag placed over it (and tied off at one end). The bag is then

[1] *Photo courtesy of Coromandel Aquaculture (www.coromandela quaculutre.co.nz)*

filled with mussel spat and then tied at the top. Once attached to the float and mooring system this bag or sock disintegrates over time during which period the spat will attach to each other and the rope. An example of this sock system is shown in Figure 8 below.

Figure 8: Mussel attachment system using disintegrating sock system

A number of other technologies can be used to achieve this desired effect (so called ‘hairy rope’ is becoming popular) but the aim is to provide as larger density of mussels as is possible in order to maximise production.

The relaying and rope grown activities described above have inherent advantages and disadvantages. In essence the relaying activities tend to operate on a relatively large scale and require major investment in vessels only. Rope grown activities require more operational labour and require the purchase of the systems and vessels to monitor and harvest the rope systems. In general though they are thought to result in a higher meat content than re-laid mussels (better water movement and access to microalgae), have lower predation rates (starfish are less likely to attack rope grown mussels), and do not suffer from grit build up to the same degree. As a result, prices can generally be a little higher for rope grown mussels.

Requirements for Production

Mussel production requires a number of key environmental and physical conditions to ensure successful production. These are summarised in Table 1 below.

Table 1: Mussel production requirements (Environmental and Physical)

Factor	Relaying	Rope Grown
Environmental Factors		
Water Temperature	Can survive from 5 - 20 °C	No difference
Salinity	Full strength seawater but can tolerate relatively large fluctuations (i.e. estuarine run-off)	No difference
Physical Factors		
Wave Action	Moderate. Large seas can result in damage to beds and inhibit vessel activity	Low. Systems require limited wave action and well sheltered areas of operation (although new offshore systems are now being designed).
Water Depth	10m Mean Water Depth. Many relaying activities prefer a period of dry out to improve mussel quality	10-20m water depth on average but can go deeper. Requires enough water to maintain the suspension of the ropes.
Current	High currents can create gritty mussels (due to sedimentation). Medium flow is recommended.	High currents can create problems with the mooring system. Medium flow is recommended.
Seabed Characteristics	A flat and relatively mundane seabed is needed for dredge harvesting. Significant silt depth can create gritty mussels.	Less of a concern than for relaying but significant changes in topography or bottom type is not recommended.

Mussel relaying activities tend to be significant in terms of space and size requirements. Since mussels are only being laid on the bottom a relatively small amount are actually produced per m^3 of water column (hence they can spread quite far). As an example, the Menai strait mussel producers operate within an approved several order area of 14 km^2 and can produce up to 10,000 Tonnes a year. A relaying farm in Portland harbour would be very small in comparison to other operations in the UK.

Rope grown mussel facilities vary greatly size but it is roughly considered possible to produce between 5 and 10 Tonnes per Hectare. The average size of rope grown mussel farms in the UK is between 50 and 100 Tonnes meaning an average size requirement of between 5 and 10 Hectares. Again, the space available to allow mussel farming in Portland harbour means any farm would be relatively small.

Offshore Mussel farming

The farming of mussels in offshore locations has gained recent traction in the UK with the development of the Offshore Shellfish Ltd company, based in Lyme Bay, Dorset (http://www.offshoreshellfish.com). Until relatively recently, the process of offshore mussel farming was seen as un-economic and technically difficult although the possible benefits (reduced pollution threats, availability of space, wild seed and phytoplankton) were also well acknowledged.

Offshore Shellfish Ltd has been developing a pilot farm which is located around 5 miles of the coast and consists of a series of 4 mussel rope lines, each 2 kilometres long. Trials here have proven successful and the farm has now received licensing permission to increase the farms size to a total area of 15.4 Km^2, capable of producing 10,000 Tonnes annually. This would represent one of the largest farms in the world and would significantly increase the UKs mussel production capacity (by around 40-50%).

Offshore projects of this type do have a number of disadvantages in that they require specialised production equipment (screw anchors, specialist ropes), they must be outside of shipping channels and well-marked (due to collision risks) and can often compete with fishermen's natural trawling grounds.

In the project area of Portland, the space is not available for an offshore farm development. The PHA area is not considered offshore and should a farm be located in the areas outside the harbour they would be limited by space and likely be a major hazard to the harbours shipping.

Harvesting and Processing Requirements

With rope based operations, once fully grown the mussels are harvested often using a specially converted barge. Here the ropes are pulled to the surface and often placed into a special chute which separates the mussels from the rope directly. An example is provided in Figure 9 below.

Figure 9: Showing harvesting process of rope grown mussels

Depending on the classification of water within the region of cultivation a period of depuration may be required. This classification system is determined by the Food Standards Agency (FSA) using a set testing process and basically provides the following classification levels;

Class A – Contains less that 230 *E. coli* per 100 grams of flesh and may be used for direct human consumption.

Class B - Contains less that 4,600 *E. coli* per 100 grams of flesh and may be used for human consumption after depuration (usually for a period of 48 hours), relaying in Class A area or an EC approved heat treatment process.

Class C - Contains less that 46,000 *E. coli* per 100 grams of flesh and can go for human consumption only after relaying for at least two months in approved relaying area followed, where necessary, by treatment in a purification centres or after an EC approved heat treatment process

Prohibited Area – Contains more that 46,000 *E coli* per 100 grams of flesh and may not be used for human consumption

LT - A new category of 'Long term classification' was added to the FSA system in 2006 with the aim of reducing costs associated with the testing process. In essence an LT classification can be provided for sites with 5 years of compliance data. It allows Local Action Groups and Local Action Plans to provide an immediate response mechanism for investigating *E. coli* sample results that exceed the regulatory levels[2].

A list of all classifications in England and Wales can be found at the following link (https://www.food.gov.uk/sites/default/files/classification-list-05-feb-18.pdf). This also makes it clear that the area of Portland harbour (or more specifically the Fleet) is classified as Class B LT meaning that depuration would be required. This would require an FSA and EU approved depuration unit to be used for a period of 48 hours[3]. An example of a basic depuration unit is provided in Figure 10 below.

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Figure 10: Basic shellfish depuration unit

[2] *In essence this make it easier for LT classified areas to deal with issues quickly rather than go through a protracted FSA system*

[3] *Recent changes in legislation have actually provided the option for approved depuration units to reduce this time period in line with their own HACCP based procedures. Most have chosen to maintain the 48 hour rule.*

Once depuration is completed, mussels are usually sold whole and live in bags. These bags can vary in size from large 1 Tonne carriers to small net bags (1kg) to be placed on supermarket shelves. Some processing of mussels does also occur (vacuum packing) but this remains a niche market.

SWOT Analysis

Strengths

- Species is suitable for production in Portland Bay
- Species has a track record of successful production in the UK
- Species is relatively robust to disease
- Species is a native of UK waters

Weaknesses

- A relatively low priced product and so is generally grown in large quantities.
- Rope grown mussels require areas which cannot be used by surface based marine traffic
- Seabed production often requires intensive harvesting and requires vessels to be on site for sustained periods of time.
- Depuration site is required

Opportunities

- Offshore farming techniques are growing in prominence

Threats

- New diseases and predators for the mussel continue to be found
- Toxic algal blooms in Portland Harbour

Suitability of species for Portland Harbour

The mussel is the most commonly cultivated shellfish in UK waters and would be quite capable of being produced in Portland harbour (environmental conditions are considered suitable).

Growing methods for the species are well known and they are successfully produced around the UK coast both by relaying and rope grown techniques.

The species is a relatively low value species and so tends to be grown in relatively large quantities. For rope grown culture this can lead to large areas which are no longer accessible to vessels (as they would hit the mussel culture system). Similarly relaying activities tend to be extensive and require regular sorting and harvesting, usually by suction and mussel trawl.

If produced, mussels would also need to be depurated in a facility within the current *Bonamia* Designated Area as export outside of this area is forbidden by DEFRA (See Section 2.1.3.). The production of blue mussels (*Mytilus edulis*) cannot be ruled out in Portland harbour but suitable sites which would not interfere with the operation of the harbour (and are large enough for economic production) are limited.

A possible opportunity for the product of mussels in offshore systems has also been considered but is not suitable for the project area due to space limitations and likely impact on shipping.

2.1.2 Pacific Oysters *(Crassostrea gigas)*

Species Overview & UK Production

The pacific or cupped oyster, Crassostrea gigas, is, as the name suggests, not a native species to the shores of the UK. Its native range sits in Japan and Northeast Asia and is thought to of been first introduced at the end of the 19th century in response to declining production rates in the native oyster (*Ostrea edulis*). In the first part of the 20th century the rate of introduction increased markedly.

Figure 11: Pacific Oyster *(Crassostrea gigas)*

The species inhabits the intertidal and subtidal zones of estuaries or coastal waters (1 to 10 metres) and will attach themselves to solid substrates such as rocks or indeed to each other (often forming dense oyster beds). It feeds primarily on phytoplankton and protists and on average reach a size of 15-20 cm in length (although specimens up to 40 cm have been recorded in Europe). The species has a relatively simple reproductive cycle with each specimen being hermaphroditic and normally starting life as male. Spawning is highly temperature dependant with a water temperature of 18°C required to trigger the process. Fertilisation is then external and larvae are planktonic, drifting for three to four weeks before they settle and begin to grow.

The species is hardy to changes in environment and can tolerate high salinities, although favouring 20-35 PPT. It can also tolerate large temperature variations (although spawning is inhibited outside the optimum range).

As mentioned, the species was introduced to the UK (and Europe) to replace dwindling native oyster stocks which had suffered high mortality due both to overfishing and disease. The pacific oyster was seen to grow quicker, was more tolerant to environmental conditions and had better disease resistance. Initially the water temperatures of the UK were seen as too cold to allow the species to spawn. In recent years it has become clear that warming temperatures have resulted in wild populations establishing themselves in Europe[4]. This has led many to raise concerns over the spread of what is effectively an invasive species to these waters.

One response to this problem has been the development of so-called triploid strains. An oyster, like a human is a diploid species (i.e. it has two sets of chromosomes, one from each of its parents). In the late 1970's, a technique was developed which created an oyster that had three sets of chromosomes (a triploid). The process by which this occurs is relatively complex but involves the use of Cytochalasin to inhibit the process of meiosis. The advantage is that the triploid oyster that is produced by the process is infertile. Also, since it does not require the use

[4] https://hmr.biomedcentral.com/articles/10.1007/s10152-004-0195-1

of energy to produce gametes or sexual organs it will grow faster than normal diploid specimens. As a result, the majority of hatchery production is now of triploid juveniles.

The species is considered to be relatively hardy and resistant to most diseases which are known to affect the native oyster. A relatively recent exception to this though was seen in 2010 with the outbreak of a herpes strain in Europe (OsHV-1). This disease attacked juvenile pacific oysters resulting in up to 90% mortality in some cases. Again the industry has responded by producing disease resistance strains which are produced by exposing young oysters to small amounts of the disease (vaccination). These are costly however and still not widely used by growers.

Production of pacific oysters in the UK currently totals 2,160 Tonnes annually (2016, wet weight). Production totals for the UK between 2008 and 2016 are shown in Figure 12 below and show a steady increase since 2011. This increase is a reflection of a generally increasing market for the pacific oyster in the UK. The reduction seen during 2011 can be directly attributed to the outbreak of OsHV-1.

The greatest production of farmed Pacific oysters comes out of England, with the highest concentration of aquaculture beds occurring in the South East and the South West. This is mainly due to the more conducive water temperatures in the South. A large production is also centred in the Channel Islands, particularly Jersey.

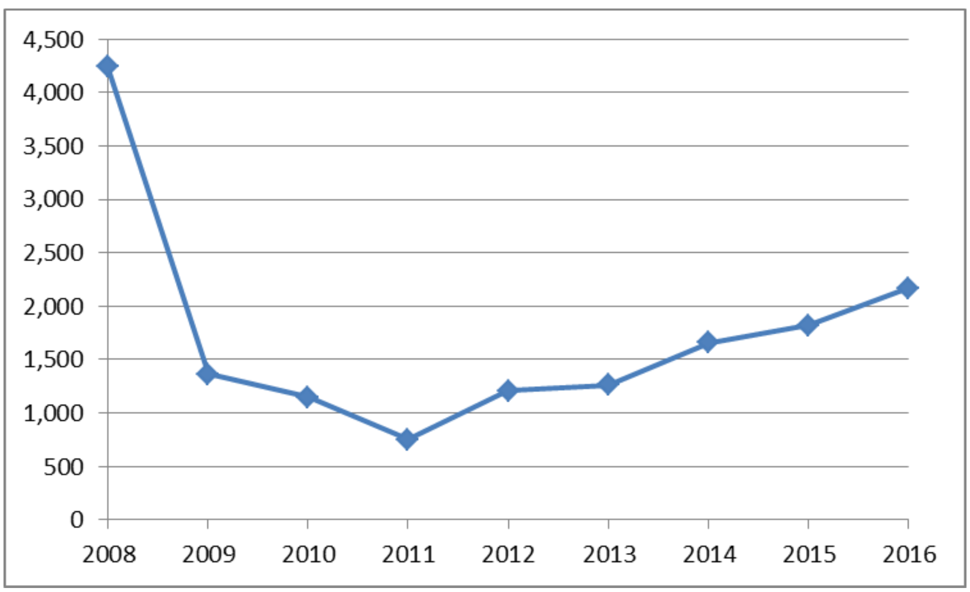

Figure 12: UK pacific oyster production figures (Tonnes) between 2008 and 2016)

Some of the major farmers of pacific oysters in Great Britain are as follows;

- Othniel Oysters – Poole Harbour – 400 Tonnes per year
- Maldon Oysters – River Blackwater – Not known
- Jersey Oysters – Jersey – 700 Tonnes per year

Requirements for Production

Pacific Oyster production requires a number of key environmental and physical conditions to ensure successful production. These are summarised in Table 2 below.

Table 2: Pacific Oyster production requirements (Environmental and Physical)

Factor	Relaying	Trestle Tables
Environmental Factors		
Water Temperature	10-20 °C (with spawning triggered at around 18 °C)	No difference
Salinity	20-35 PPT although it is relatively hardy to changes	No difference
Physical Factors		
Wave Action	Surface wave action should be Medium-Low to allow for easy surface operations and avoid excessive sedimentation of the seabed.	Very limited. Trestle and net systems are easily damage by wave action. For this reason they are usually located in highly protected areas such as estuaries.
Water Depth	5-10 Metre Mean Water Depth. Many relaying activities prefer a period of dry out to improve Oyster quality	Trestles must be uncovered on a mean spring tide cycle to allow the farmer to service them and help improve the quality of the taste
Current	High currents can create gritty Oysters (due to sedimentation) if not relaid on trestles before harvest. Medium flow is recommended. 1-2 knots)	No difference
Seabed Characteristics	A flat and relatively mundane seabed is needed for dredge harvesting. Significant silt depth can create gritty mussels.	Less need for mundane seabed due to trestle table system but major rocky outcrops would reduce space for trestles

The size of an oyster farm can vary greatly depending on site availability and business strategy. Finding average space usage requirements for oyster production in the UK is challenging but in terms of trestle table coverage it will only exceed 2 hectares for very large farms. Even at levels below 2 Hectares, it is clear that space availability in Portland harbour will be limiting.

Techniques

Pacific oysters are grown by a variety of methods and techniques which vary depending on the location of the farm and the period of production (juvenile or adult). The methods can generally be split between relaying and off-bottom production (of which the use of trestle tables is by far the most common).

Relaying

Relaying techniques do not differ greatly from those described for mussels previously although they do tend to be completed on a much smaller scale (due to the higher price of the product).

A system though is required for the storage and maintenance of juvenile oysters prior to relaying as they are simply too small to survive relaying this early. Generally oysters are received from the hatchery at around 2mm in size.

Off-bottom

The use of trestle tables for the production of oysters is a common system in use in the UK. Often this is used as a final hardening stage for product before it is sold (although they can be grown on trestle from a relatively early stage).

Essentially a trestle table is a simple metal frame on which 'oyster bags' can be attached. They sit up to a metre off the seabed which allows good water movement around the bags and avoids the inclusion of silt in the oysters. An example of a trestle system is shown in Figure 13 below.

Figure 13: Example of Oyster trestles[5]

The bags placed on the trestles are usually made of plastic or more rarely wire mesh. The size of the mesh varies depending on the size of the oysters in the bag. Oyster seed of between 4-8 mm in length are usually purchased directly from a hatchery and placed in 2mm mesh bags. Once 8-15mm in size a 4mm mesh is used, followed by a 8mm mesh for 15-25 mm oysters, a 14 mm mesh for 18-25 mm oysters, right up to a 25 mm mesh for fully grown oysters (around 70 mm).

Trestles are always located in the intertidal zone which allows them to be uncovered on a regular basis (often once a day for around 1-2 hours or longer on spring tides). This is for a number of reasons. Firstly it is thought to improve the taste of the oysters (toughening them).

[5] *Photo courtesy of RPS Group Ltd*

Secondly it allows the farmer to access the oysters. Indeed, trestle farming of oysters can be a very labour intensive business with farmers required to perform a number of tasks;

1. Turn the bags to ensure even growth and remove any build-up of algae
2. Grade the bags to ensure even growth, maintain densities (as the oysters grown) and change the mesh sizes accordingly
3. Remove predators as required
4. Remove dead shells

On average an oyster farmer with need to access his trestles a minimum of every two weeks in summer with this decreasing to once every month in winter.

In some farms the use of trestles is only employed for the final few weeks of the oyster's production to act as a toughening process before harvest and sale.

Harvesting and Processing Requirements

Harvesting of pacific oyster is either completed by vessel based dredge gear (bottom grown) or by hand (trestle grown systems). From here products will require the same depuration treatment as has already been described for mussels.

The majority of oysters are sold live within a few days of capture.

SWOT Analysis

Strengths

- Species is suitable for production in Portland Bay
- Species has a track record of successful production in the UK
- Species is robust to most diseases and changes in environmental conditions

Weaknesses

- Recent susceptibility to herpes virus (OsHV-1) has resulted in major losses to farmers in the UK.
- The species is classed as an invasive species
- A suitable depuration unit would be required
- Lack of suitable shoreline available for the species in the project area

Opportunities

- Use of triploid based strains through hatchery production
- Use of Disease Resistant Strains (DRS)

Threats

- Growing criticism of non-indigenous status and concerns over its ability to reproduce in UK waters with increasing water temperatures

Suitability of species for Portland Harbour

Pacific oysters are physically capable of growing in Portland harbour, with the physical and environmental conditions being suitable for its production requirements.

Production can be seabed based but for optimum production a trestle table and bag system would need to be employed. This would need to be located in the intertidal zone (uncovering at mean spring low tides). Access to a suitable length of shore line would therefore be required for the species production.

The species is relatively hardy and resistant to diseases with the exception of the recent herpes virus (OsHV-1). This disease is not currently known to occur in Portland Harbour and the area currently sits outside the DEFRA control area (which is limited to Poole Harbour only)[6].

A successful industry has developed in the UK although concern is growing over its position as an introduced species.

MEP is of the opinion that a lack of shore based sites (with easy shore access) will be an issue for its production but that it would be well suited in many other ways. We would though recommend the use of triploid hatchery juveniles only to mitigate concerns over the introduced nature of the species.

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/545855/Poole_Harbour.pdf

2.1.3 Atlantic Oysters *(Ostrea edulis)*

Species Overview and UK Production

The European flat oyster or Atlantic oyster *(Ostrea edulis)* represents the native species found around the UK shores (although the species can also be found throughout Europe and on the East coast of the USA).

The species differs in appearance to the pacific oyster being more oval in shape and generally flatter. Its biology is however very similar inhabiting the intertidal and subtidal zones of estuaries or coastal waters (1 to 10 metre) and it can reach up to 11 centimetres across.

Figure 14: Atlantic Oyster *(Ostrea edulis)*

The native oyster represented a major food source for the people of the UK which can be traced right back to the period of the Roman occupation. In the 1920s however the species was hit by a mass mortality event. The reasons for this are not clear but it was followed by a gradual increase in the population (although never back to the levels seen in the 18th century). In the 1960's, a further mass mortality event occurred due in the main to the proliferation of two separate diseases (*Marteilia refringens* and *Bonamia ostrea*).

Bonamia spp. is a form of protozoa which can cause lethal infection of the haemocytes of European oysters. Infection rarely results in clinical signs of disease, and the only visual cue is often increased mortality or reduced growth. The disease can occur at any time of the year, although the prevalence and intensity of infection is known to increase during the warmer months. In the UK, prevalence is highest in September with significant mortality occurring at water temperatures of 12°-20°C. The disease can have very high infection and mortality rates (up to 80%) which have had a dramatic effect on wild stocks of the species in the UK. In an attempt to control the spread of the disease, DEFRA have set up designation areas for known infection spots. The area of Portland harbour falls inside one of these 'Confirmed Designation Areas' meaning the disease is confirmed as prevalent in the area. This places a restriction on the movement of *Ostrea edulis* (and indeed *Mytilus edulis*) in and out of the designated area unless with express consent of DEFRA or if it is going for direct human consumption. This includes movements to depuration facilities that do not discharge into the area.

In practice this restriction does not necessarily limit the production of native oysters in Portland harbour but it does mean that;

1. A hatchery in the designated area must be used for stocking purposes unless permission is first granted
2. A depuration unit in the area must also be used unless permission is first granted

Of more concern to a grower however is the presence of the designation in the first place, as it confirms the region to be a known *Bonamia* prevalent area. This means it is more likely that the disease will occur in native oysters grown in the area.

Further information on the Confirmed Designation Area can be found at the following link; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/545851/Dorset_Hampshire_Bonamia_Ostreae_CD02.pdf

Marteilia refringens is a parasite which is known to attack the native oyster[7] and often causes a lethal disease, provoking mass mortality. Death occurs during the second year after initial infection and infection prevalence can reach 80–100%. Clinical signs can include emaciation, discolouration of the digestive gland and cessation of growth (although these are not specific to *Marteilia*). The disease is often also associated with stress conditions similar to *Bonamia* above (indeed both diseases can often occur simultaneously). Although prevalent in the UK, the disease is not considered as destructive as *Bonamia*.

Portland harbour is not located in a Confirmed Designation Area for *Marteilia refringens* meaning no restrictions on the species movement (for this reason) exist and it is not considered a prevalent disease in the area.

It is ironic that the most likely reason for the introduction of these diseases is linked to the import of the pacific oyster (which is less affected by the diseases and does not suffer heavy mortality).

A further problem has occurred for wile native oyster populations in the form of the invasive species, the slipper limpet *(Crepidula fornicata)*. Indigenous to the East coast of the USA, the species is thought to of come to Europe through a variety of paths (attached to vessels and with other imported species). The species has become well established in the South of the UK and forms particularly dense beds. These grow in areas also favoured by native oysters resulting in increased competition between the two species. Due to the faster growth rates and higher reproductive capacity of *Crepidula*, native oysters have struggled to compete resulting in reductions in populations.

The result of the above has seen the farming of native oysters drop to very small levels with only 25 Tonnes being currently produced in the UK (See Figure 15).

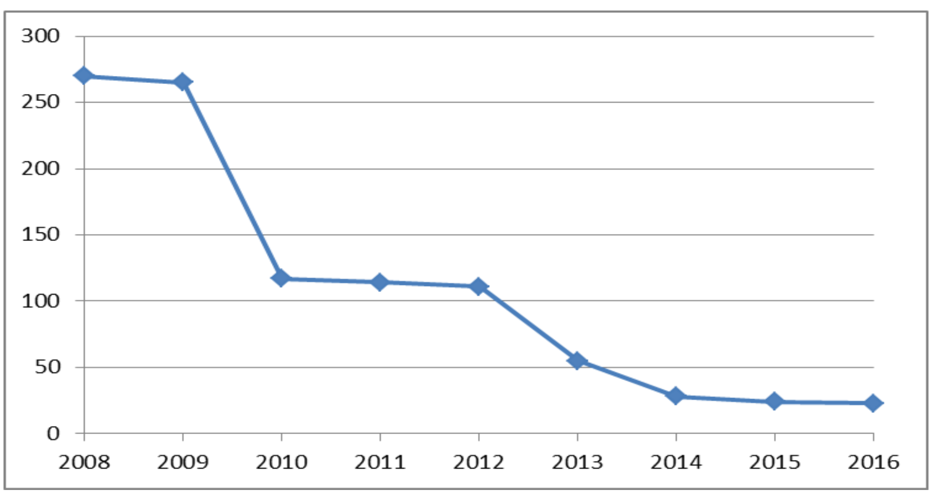

Figure 15: UK Atlantic oyster production figures (Tonnes) between 2008 and 2016)

[7] *Although mussels are also known to be infected by M. refringens in Europe, they are usually not adversely affected by marteilioisis*

Simply put, the native oyster is far less robust or quick growing than its pacific relative and so presents a much less attractive proposition to farmers. The species is susceptible to large variations in temperature and salinity and is more prone to a number of diseases (which can lead to high mortality rates). Since little interest has been seen by the consumer in distinguishing the species it is understandable why the production of native oysters has reduced to such small levels. Pacific oysters can be grown at lower cost with better survival and growth all year round.

In 2009 and 2010, a slight reversal in fortunes for the native oyster was seen with a large mortality outbreak in the pacific species of a herpes virus. This virus (referred to as OsHV-1) was new to Europe and was thought to have been triggered by particularly high water temperatures that year. The virus is similar in effect to the human version in that it is present in most oysters but lays dormant unless triggered by a specific change (in this case temperature). The disease resulted in 90% mortality rates in juvenile pacific oysters and was devastating to the European pacific oyster industry at the time. In the UK alone, over eight million pacific oysters were estimated to of died in 2010.

However the disease had no effect on the native oyster populations which appeared to have natural immunity. As a result, a number of companies showed renewed interest in culturing the species although to date this has not materialised into large increases in commercial production.

The reintroduction of wild native populations has received far greater attention with projects being planned in the Solent and Essex. The Solent project alone aims to reintroduce what was one of the largest natural populations in Europe after a succession of crashes over the last decade. The plan, which is supported by the UK based, Blue Marine Foundation, is to introduce a million juvenile oysters into the water in 2017 which will be sourced from a variety of hatcheries around the country. The hope is that this population will then form new dense oyster beds which in turn will help to fight off slipper limpet populations by reaching a critical mass. Further information on the project can be read at the following link, https://www.theguardian.com/environment/2017/apr/20/millions-of-native-oysters-to-be-returned-to-the-solent

Some evidence also exists that consumers actually prefer the taste of the European native oyster over the pacific variety, with the flesh often described as firmer. To date, little marketing or promotion of the native oyster has taken place but this is beginning to change with programs such as that described above.

Requirements for Production

The production requirements for native oysters are identical to that of the pacific oyster with the exception of reduced growth rates (native oysters requiring on average 6-12 months longer to reach marketable size) and generally increase mortality rates (which can be up to 40% higher in native production systems).

Techniques

The techniques for native oyster production are identical to that of the pacific oyster.

Harvesting and Processing Requirements

The harvesting and processing requirements for native oysters are identical to that of the pacific oyster.

SWOT Analysis

Strengths

- The species is resistant to the Herpes virus (OsHV-1)
- It is a native species and hence popular with NGOs etc…

Weaknesses

- The species is slower growing than the Pacific strain
- The species is highly susceptible to a number of diseases
- Requires intertidal zone for trestle production (which can be location limiting)

Opportunities

- Its position as a native species presents a marketing opportunity
- Many consumers find the species taste better than the Pacific oyster

Threats

- *Bonamia* is prevalent in Portland harbour area and could result in high mortality
- Other disease issues

Suitability of species for Portland Harbour

Ostrea edulis is physically capable of growing in Portland harbour, with the physical and environmental conditions being suitable for its production requirements.

The species is a native species to UK waters and presents no threat to other marine life.

Production can be seabed based but for optimum production a trestle table and bag system would need to be employed. This would need to be located in the intertidal zone (uncovering at mean spring low tides). Access to a suitable length of shore line would therefore be required for the species production.

The species is not produced in large quantities in the UK anymore due to the greater suitability of the pacific oyster variety for aquaculture production. The species is particularly susceptible to the *Bonamia* protozoa and Portland harbour is located in a 'Confirmed Designation Area' for the disease.

MEP is of the opinion that despite the species having a certain resurgence in recent years and environmental conditions being within required tolerances, a lack of shore based sites (with easy shore access) and more importantly its location in the Confirmed Designation Area (CDA) means the species is unlikely to be grown successfully within the designated area of this study. A site outside a *Bonamia* CDA would represent a much reduced risk for production.

2.1.4 Atlantic Scallops *(Pecten maximus)*

Species Overview & UK prodution

Scallop is a common name provided to a variety of marine bivalve molluscs which belong to the *Pectinidae* family. Two types of scallop are currently cultivated/caught in the UK, the king scallop (*Pecten maximus*) and the queen scallop (*Aequipecten opercularis*).Both species represent valuable fisheries in the UK but it is the King scallop which has shown most potential for aquaculture development due, in most, to its higher prices and longer growth periods.

King scallops live on the seabed, preferring substrates of clean firm sand, fine or sandy gravel. The species will bury itself into the sediment to a level with the upper shell or to the point of partial covering. The species takes around four years to reach marketable sizes (wild and aquaculture). In UK waters, king scallops become sexually mature at approximately 2-3 years old and 80-90 mm in shell length, but may live for over 20 years and grow to over 200 mm in undisturbed populations.

The scallop does not like to be uncovered at low tide and so inhabits slightly deeper water than many of the other molluscs described here, typically 15-30 metres. They are also considered to be particularly sensitive to light, current, wave movement and changes in temperature and salinity meaning careful management and site selection is required to produce them successfully.

The scallop is also able to propel itself short distances by opening and closing it shells (so propelling water out). This allows them to spread out and avoid areas of overcrowding (unlike other species, they do not form dense beds but prefer to maintain some space).

The UK production of king scallops is dominated by the wild fishery which consists of both industrial dredging (trawling) and also a much smaller sector of hand diving. Figures for 2016 report a total scallop landing in the UK (by UK registered vessels) of 38,400 Tonnes representing a value of £74 Million[8]. This is a reduction on a high of 53,000 Tonnes recorded in 2012.

With regards to aquaculture, production is relatively small and currently sits at around 10 Tonnes. Figure 16 below provides the reported UK figures for King scallop aquaculture production..

[8] https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2016

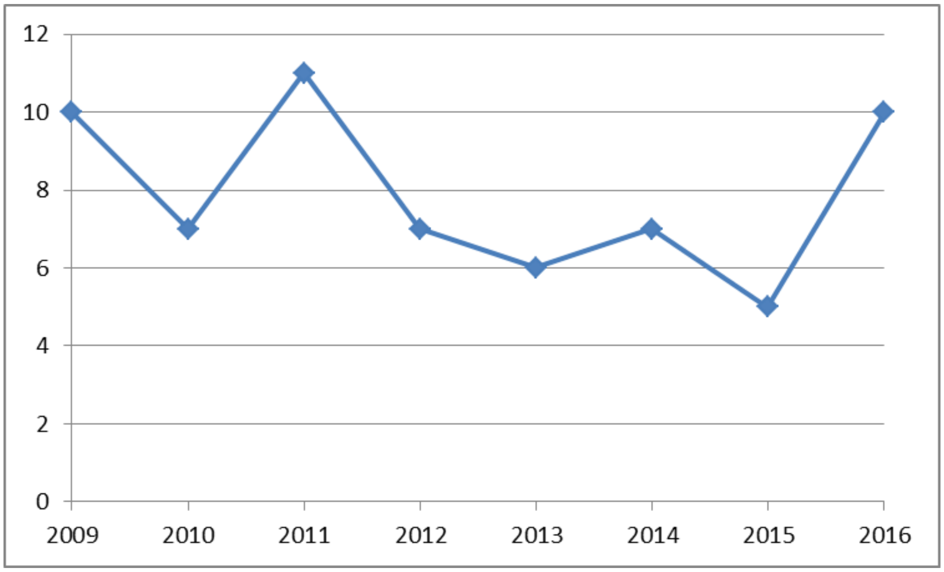

Figure 16: King scallop production (Tonnes) in the UK between 2009 & 2016

Requirements for Production

Compared to other molluscs, king scallops can be considered relatively difficult to produce as they are somewhat more sensitive to environmental conditions.

Scallops require the correct substrate (sand or gravel) and will not tolerate deep dense layers of silt. They also require limited current and subsequently do not like agitation of the sea bed (silt suspension for prolonged periods will result in high mortality). Areas of fine sediment are only likely to be suitable if accompanied by very low currents and no external influences on sediment suspension.

Temperature averages of 17-18 °C are considered ideal for scallop production meaning that southern and western waters of the UK are often considered more suitable for production than those of the East coast.

Full strength seawater is preferred by scallops but they will tolerate occasional reductions for small periods of time (i.e. high freshwater run off for a few days). Longer periods will lead to mortality and is another reason that deeper waters are favoured (where salinity stability tends to be greater).

Scallops require a well-protected site for production and will not tolerate prolonged wave action.

Scallops feed on phytoplankton and so an area with good primary productivity is needed to ensure growth is optimised. However very high particle concentrations can result in feeding being inhibited and for this reason sites where there are regular and intense blooms of algae, perhaps as a result of very high nutrient loading of the seawater coupled with low exchange, are best avoided.

It should also be noted that scallops do not like regular handling. Indeed it is recommended that they are not touched at all during the winter months and that in summer it is kept to around once every month at a maximum.

The major requirements for production are summarised in Table 3 below.

Table 3: Scallop production requirements (Environmental and Physical)

Factor	Relaying	Lantern and Pearl Nets
Environmental Factors		
Water Temperature	17-18 °C is considered ideal. Fast changes are not tolerated	No difference
Salinity	Full strength seawater. Occasional changes are tolerated but species is more susceptible than most other molluscs.	No difference
Physical Factors		
Wave Action	Low. Scallops do not tolerate wave action or movement well compared to other bivalve species.	No difference
Water Depth	10 to 15 metres with a minimum of 5 metres at low water (to avoid excessive water movement on the sea bed). Scallops cannot tolerate periods of exposure (30 minutes or more) and will experience high mortality if this occurs.	No change
Current	1-2 knots ideal	No change
Seabed Characteristics	Sand or gravel and will not tolerate deep dense layers of silt.	Not relevant

Aquaculture of scallops is currently very limited, with little information on production sizes available. Currently, few farms are thought to produce more than 2-3 Tonnes annually in the UK. Globally however, a large industry exists in China and Japan for the production of the Yesso scallop (*Pecten yessoensis*) which is thought to be close to 1 Million Tonnes per year (although some care is required here due to a large proportion of the production coming from China). As a comparison, farms in China and Japan may produce up to 1,000 Tonnes of scallop a year in what is a multi-million dollar business.

It is noted that the relatively high price of scallops is likely to make the production of the species at smaller quantities more economically viable than for other mollusc species.

Techniques

King scallops are nearly always produced through a combination of production methods to reflect the changing vulnerability of the species as they grow. Often this process involves the combination of suspended pearl and lantern nets followed by sea bed based production. A description of the key steps for a typical king scallop farm is resented below.

Seed supply

The supply of king scallop seed in the UK remains heavily dependent on wild-caught seed which is obtained by deploying collectors (often a mesh onion bag full of monofilament). The deployment of these collectors needs to be completed during a very small window (often a few days) and requires local knowledge to ensure it is successful. Some UK based spat collectors also operate and collect spat which is sent to the buyer as requested (usually at around 20-30mm in size).

Hatchery techniques are also well developed for scallops but due to a lack of market in the UK, they are currently uncommon.

Juvenile production

To avoid excessive predation and mortality, juvenile scallops are virtually always raised in pearl or lantern nets. At a very early stage a pearl net (as shown in Figure 17) is used. These can be stocked at 50-80 scallops per net, reducing to 20-30 as they grow.

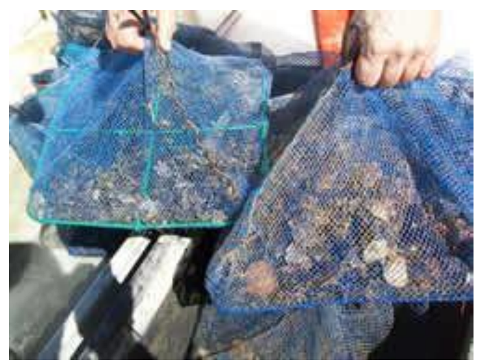

Figure 17: Pearl net for Scallop farming

Once the scallops reach a size of 30-40 mm they are then transferred to the lantern nets with 30-60 placed in each compartment. Again this is reduced to no more than 10-15 per compartment when they reach 60-80 mm.

Examples of lantern nets are shown in Figure 18.

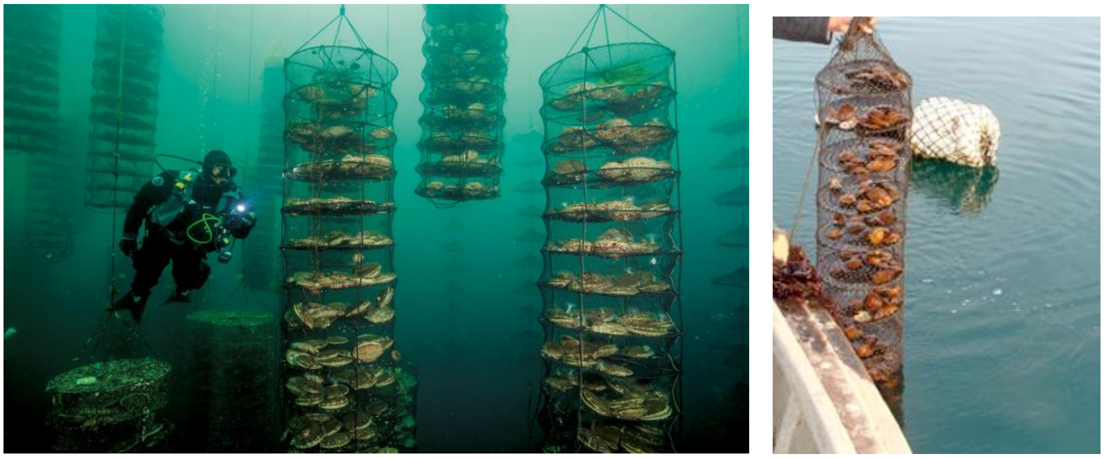

Figure 18: Scallop lantern nets as seen in the water in Japan[9]

Both pearl and lantern nets are suspended from a system similar to that already described for rope grown mussel culture (a series of ropes, floats and anchors)

On-growing to market size

To remain economic it is common practice to remove the scallops at 60mm and place them on the seabed for grow out. This should happen as soon as practical as evidence suggests scallops left for more prolonged periods in suspension have weaker shells and are more susceptible to predation. Scallops seeded onto the seabed will disperse naturally finding a density of less than one scallop per square metre.

Harvesting and Processing Requirements

King scallops grown on the seabed (as described above) are generally harvested by divers when they reach a market size of around 100 to 150 mm.

Scallops are normally sold alive and whole. The depuration requirements, as described for mussels also apply to scallop production.

[9] *Courtesy of National Geographic*

SWOT Analysis

Strengths

- Relatively disease resistant
- Commands a good price
- Conditions in Portland Bay area are very suitable for production
- Does not like or need regular attention (once of a month) meaning less interaction in the harbour

Weaknesses

- Lack of suitable hatchery source
- Sensitive to changes in environmental conditions (compared to other molluscs)
- Requires bottom laying and space limitations for this may exist in the harbour
- Collection is by diver (and this may have limitations in the harbour)
- Requires a depuration unit in the area

Opportunities

- Little production in the UK currently
- Popular among UK consumers

Threats

- High levels of freshwater run off in the bay
- Toxic Algal Blooms

Suitability of species for Portland Harbour

Scallops represent a very suitable species for production in Portland Harbour. They are well suited to the environmental conditions and require strong protection from wave action which the harbour can offer. Scallops are selective about sea bed conditions and these would need to be confirmed as suitable first. The species commands a good price and has potential for the UK market.

Little scallop is currently grown in the UK and as a result hatchery production is limited. Wild collection is difficult and requires expert local understanding. Production methods will also require the installation of hanging lanterns and pearl nets (using similar systems as for rope grown mussels). Final harvesting will be on the seabed and also requires the use of divers.

Scallops present the most sensitive of mollusc species to varying environmental changes. They cannot tolerate large or prolonged variations in temperature or salinity.

In summary, scallops would seem to present the most suitable opportunity for aquaculture production in Portland Harbour.

2.1.5 Abalone *(Haliotis tuberculata)*

Species Overview

The term Abalone is used to describe a variety of marine gastropod molluscs which belong to the family, *Haliotidae*. The species can vary greatly but of interest to the UK is the species *Haliotis tuberculata*, which is commonly referred to as the European Abalone or Ormer.

The Ormer is found within the Northeast Atlantic and Mediterranean and can grow to around 10cms in length. The species inhabits rocky shore areas and will move under its own propulsion to locate algae (especially sea lettuce) which are its primary food source. The meat of the Ormer is highly priced both in Europe (France in particular) and in some Asian countries (Japan and China). The meat of the Ormer can be sold for up to £150 per kg.

Until relatively recently, the species was not thought to be found any further North than the Channel Islands with waters considered too cold to support the species. Although no evidence of existing Ormer populations have been found on the UK mainland, increasing water temperatures have bought about the very real possibility that the species can be produced commercially in the region.

In 1992, the then MAFF were asked to clarify their position on Ormer production in UK mainland waters. They confirmed that the species would not require licensing under the Wildlife and Countryside Act meaning that it could be produced in open systems within coastal waters[10]. Following this confirmation a trial was completed on the Isle of Scilly and other locations around the South West coast, including it appears Portland[11]. These proved successful with good growth rates and in 2002 it was announced that the first hatchery for Ormer would be opened in Cornwall[12]. This has since failed to materialise.

Abalone can be produced in a number of different systems but all fall into one of two categories, land based tanks and sea based cage systems.

Land based production

Worldwide a large amount of Abalone production is completed in land based tank systems. The methods for production can vary considerably but generally abalone is kept in relatively shallow water in large outdoor tanks and in high densities. An example of such a system from Australia is provided in Figure 19 below. These systems are not used extensively in Europe due to natural weather conditions meaning covering for the tanks would be required (to avoid influx of rainwater and large temperature variations).

Abalone can be fed either through the introduction of harvested wild seaweed (*Laminaria spp*. particularly) or the use of formulated feeds. A number of feed manufacturers now produce a

[10] http://www.seafish.org/media/Publications/B40_biotope_comparison.pdf

[11] https://www.theguardian.com/environment/2002/dec/10/food.fish

[12] http://news.bbc.co.uk/2/hi/uk_news/england/cornwall/2944554.stm

commercial pelleted feed for Abalone production (e.g. Halo from Skretting) and these are particularly popular for land based farmers in New Zealand, Australia and the USA.

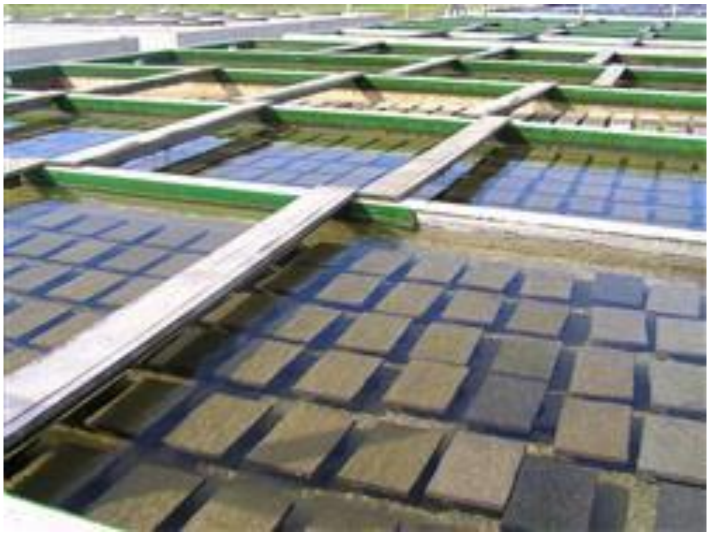

Figure 19: Land based tank production of Abalone (Australia)

Sea based cage production

The majority of European Ormer farmers use some form of cage system to grow the species. These systems vary greatly from farm to farm (most are custom made) but are based on the principal of metal or plastic cages which are placed on the seabed in which Ormer are placed. An example of a system used in France can be seen below in Figure 20.

Figure 20: Cage system for Ormer culture in France[13]

[13] *Image courtesy of France Haliotis*

One relatively new system which is showing potential is the so-called Abblox system, developed and patented by Mr Tony Legg (owner of Jersey sea farms). The system consists of 1m^3 precision plastic moulded cubes with mesh based sides. The units have an opening into which the Abalone can be placed. They are then either sat directly on the sea bed or suspended from a raft system (depending on depth). An image of the raft system with one cube out of the water for inspection is shown below in Figure 21. This system has been developed in cooperation with Fusion marine and opens up the possibility of ormer culture in deeper waters.

Figure 21: Raft and Abblox system for Ormer production in Jersey[14]

Little information is currently available on the success of this system other than anecdotal reports of good growth rates.

[14] *Image courtesy of Fusion Marrine*

SWOT Analysis

Strengths

- High priced species
- Can be grown in relatively small quantities
- Can be grown in the UK with no regulatory barriers (introduced species).

Weaknesses

- Not known how well the species will perform in UK mainland waters and definitely not in Portland
- No hatchery in the UK
- Requires surface based infrastructure

Opportunities

- No production in the UK currently

Threats

- Threat of theft on abalone farms can be high and often requires close monitoring
- Risks of starting a business without further pilots would be high

Suitability of species for Portland Harbour

Currently, Abalone is not being produced commercially around the UK waters and no evidence exists of its survival in the wild. It does appear that the species can survive in the waters of the South West and could be conceivably produced on a commercial scale. Portland sits at the outer edge of the 'anticipated range' and it is currently unclear how well Abalone would grow here.

The production of abalone using raft or seabed cage systems does have potential in Portland harbour which offers good shelter and general conditions. However a large amount of research is likely to be required into the production of the species in UK coastal waters before anything more than trial based projects are likely. Furthermore, the production is reliant on sourcing suitable juveniles for stocking. Since no hatchery currently exists on the UK mainland one would either need to be built or they would need to be sourced from the Channel Islands or France.

2.2 Crustaceans

2.2.1 Lobster *(Homarus gammarus)*

The European lobster (*Homarus gammarus*) is a highly prized edible lobster in the UK. The species is found throughout the North Sea, Mediterranean and into the Black Sea.

European lobsters can grow to a size of 60 cm in length and live amongst rocky outcrops in coastal areas. They are non-migratory and will inhabit the same areas through there life. The species is part of a highly profitable wild capture fishery which operates around the coast of the UK.

Aquaculture development for the European lobster has been the source of much funding over the past four decades. This has taken two major forms, namely hatchery development for wild release and possible on-growing to marketable size.

Hatchery Production

The production of juvenile lobsters in hatcheries has become relatively successful in the UK, led by the work of the National Lobster Hatchery in Padstow. This facility was developed on the back of EU funds, opening in 2000, and had the objective of producing juvenile lobster for re-stocking into the local environment. This activity is essentially a process of stock enhancement which provides a method of increasing juvenile survival rates and increasing local lobster stocks which had been in terminal decline due in part to over fishing.

Lobsters are bred in confinement and the juveniles supported through the planktonic stage until they are around 1cm in length. From here they are released back into the wild to continue to grow.

After early troubles, the hatchery has grown into a successful operation, rearing large numbers of lobsters and becoming self-funding, mainly through local tourist based charitable donations. The idea has also begun to be copied around the UK coast with other lobster hatcheries now present in Orkney and Shetland.

Lobster on-growing

The on-growing of lobsters in aquaculture systems has been attempted since the early 1970s.

The majority of lobster farming has concentrated on the use of land based recirculating systems. Here one major issue was identified early on with lobster showing highly aggressive tendencies to each other when held in confined captivity together. Mortality levels were so high that systems of maintaining lobsters in individual units were soon developed. An example of such a system is shown below in Figure 22. This shows lobster being grown in individual trays at the Norwegian Lobster Farm (https://www.norwegian-lobster-farm.com/). These are stacked high in a centrally controlled water column to optimise space usage. The column can be seen in the second picture below (Figure 23).

Figure 22: Lobster trays for land based system

Figure 23: Land based lobster farm facility

To date few systems are considered to be a commercial success with the space, capital and labour requirements being high for such systems. The improvement of natural lobster stocks (often as a direct result of the hatcheries already described) have also made the need for such aquaculture systems unnecessary as the wild fishery can meet demand[15].

Recently a number of Sea-Based Container Culture (SBCC) systems have been trialled for the production of lobster. These systems use a variety of container systems (with oyster spat settlers being popular) which are either placed directly on the sea bed or hung on vertical rope systems. Each has a number of trays inside it with a single lobster in each. In this system they are able to grow naturally (albeit in captivity). Figure 24 below shows an example of one of these containers

Figure 24: Example of Se a-Based Container Culture (SBCC) system for Lobster culture

[15] http://aquaticcommons.org/9793/

The following link also shows a video of a system being used in the UK, https://www.youtube.com/watch?v=4HqRWX0Nd7c .

These systems are currently only being used for trials and none have yet been proven as commercially successful. Further work is required before this can be seen as a viable method of producing farmed European lobster.

Suitability of species for Portland Harbour

Aquaculture production of European lobster in Portland harbour is seen as limitedas most requires land based facilities.

Although the possibility of stock enhancement from a hatchery is an option for the area it would require a land based facility to be built (no specific interaction with the harbour is required).

The only possibility is the development of SBCC systems within the Harbour area. These would most likely be positioned within the harbour walls and would be rope based systems. Locations would be similar to those already discussed for mussels and scallops. These techniques are currently in the trial stage only but may be an option for future development in the harbour areas.

2.2.1 Crabs

In the UK, the Brown crab (*Cancer pagurus)*, Spider crab *(Maia squinado)* and velvet swimming crab *(Liocarcinus puber),* are species available and caught commercially for consumption. Images of these three species are provided in Figure 25 below.

Figure 25: Images of the Brown crab, Spider Crab and Velvet Swimming Crab

Currently no aquaculture production for any of these species is practised in the UK or Europe with the wild fishery meeting all current demand requirements.

MEP is not aware of any current projects in Europe considering the production of crabs under farming conditions. Some suggestions of restocking programs (similar to those mentioned for lobster above) have been discussed but no projects are yet in operation.

2.3 Finfish

A number of marine finfish are currently cultivated in UK waters including salmon (*Salmo salar*), Sea Trout, halibut, turbot and until recently European sea bass (Dicentrax labrax).

Salmon and Trout

The majority of this production consists of salmon production in cages all of which is produced either in Scotland or to a much lesser extent Northern Ireland. A picture of a typical Salmon farm is provided in Figure 26 below showing the production cages and feeding barge (which holds feed and pumps it via pipes into each cage individually).

Figure 26: Salmon cage farm located in Scotland

The cage farming of salmon or sea trout is not considered in more detail for this study for the simple reason that production of the species in Portland is not commercially viable. Both species grow most productively in water temperatures of 12-14°C. As the water warms up growth begins to be reduced until at 20°C the physiological break down of the species occurs[16]. To emphasis the lack of suitability of Portland water temperatures for salmon and sea trout production, Figure 27 below shows the average monthly water temperatures (°C) for both Portland and Shetland (a major centre of salmon production in Scotland). The temperature can be seen to be quite dramatically different with Portland reaching levels which would seriously impede the species growth.

[16] *https://munin.uit.no/bitstream/handle/10037/7184/article.pdf?sequence=1*

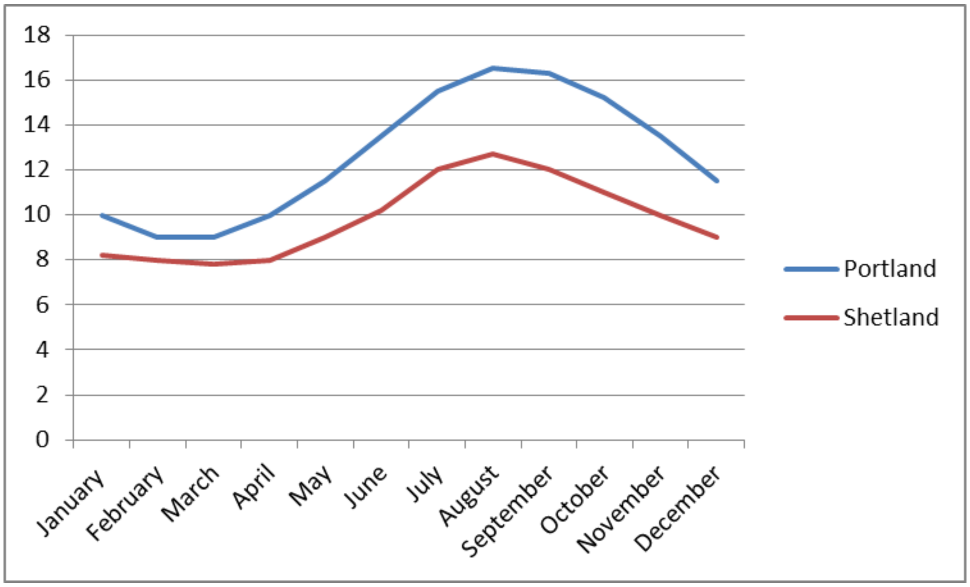

Figure 27: Average monthly water temperatures in Portland and Shetland

Sea bass

The production of sea bass was until recently completed in Wales by the company Anglesey Aquaculture Ltd. This used a highly modern and sophisticated land based recirculating system to produce plate sized bass for the UK market. Unfortunately the company went into receivership in 2015 and was subsequently bought by Marine Harvest who intend to use if the production of Wrasse.

Land based production struggles to compete with the vast production systems of Greece and Turkey which use extensive cage culture systems. The waters in Portland however are too cold for this with both species needing an optimal temperature of around 30°C. Production of cage farmed sea bass and/or sea bream is not considered suitable for Portland.

Halibut

The production of Halibut is currently completed at one site in the UK, namely Gigha Halibut. Here fish are produced in large land based tanks. Cage culture was originally attempted for Halibut but has proven unsuccessful in multiple trials. Furthermore optimum temperatures for Halibut productions vary from 13 to 9 °C (size dependant) making the waters of Portland too warm for optimal production.

Turbot

The production of Turbot has been relatively successful in the past decade with Spain now leading the way. Again, though virtually all production is completed in shore based tank systems. Production in cages has been attempted but results have been mixed with mortality high (turbot can be very sensitive to environmental changes and difficult to maintain healthy populations in cages). Although water temepratures may be more suitable in Portland for turbot production, growth would suffer in the winter months with the drop in sea temperatures.

Suitability of species for Portland Harbour

In summary, MEP does not see any viable opportunities for the production of finfish in cage farms in the Portland area. Water temperatures do not lend themselves to the production of any currently commercial species.

Furthermore, the shelter provided outside of the harbour is not considered sufficient for cage culture. Inside the harbour the space required for cage culture would be limiting on other users and is not considered an option.

2.4 Macroalgae

Species Overview and UK Production

Macroalgae or seaweeds to give it is more commonly used name, is a large group of marine based algae which are multicellular and often plant like in nature. The group is vast, covering a great range of species and taxa all of which have different environmental requirements.

Seaweed globally is harvested on a massive scale for four separate uses;

1. Food (human consumption as sea vegetables and premium condiments) and animal feeds and supplements;

2. Chemicals production (hydrocolloids, organic fertilisers, ethanol etc.);

3. Bio-actives used in the cosmeceuticals and nutraceuticals industries;

4. Bioenergy and biofuels (e.g. bio-methane production);

In the UK, limited data is available on the harvested quantities of seaweed although CEFAS have previously estimated the figure at around 2 to 3,000 Tonnes per annum. It is clear that seaweeds have been harvested for centuries around the British coastline for a variety of reasons.

Currently in the UK around fifteen companies are estimated as using seaweed from UK waters to produce a variety of products[17]. All of this though is currently taken from wild growing productions and no one is known to be specifically farming seaweed in the UK, beyond what could be considered a pilot scale.

In terms of species which have interest for commercial reasons the following are considered the most important.

***Laminaria saccharina* (or *Saccharina latissimi*):** Commonly referred to as kelp is a brown seaweed capable of growing up to 5 metres long. It attaches to the seabed by a 'holdfast' as is found throughout the intertidal and sublittoral zones.

Laminaria has a variety of uses including the harvesting of iodine, use as a food source and as a potential biofuel.

Palmaria palmate: Often referred to as dulse is a red algae which grows in a similar method as luminaria but not to the same sizes (blades rarely exceed 50cms in length).

Palmaria has been used as a food source and has been used in Ireland for centuries to make white larva bread. It is also often dried and sold in health shops.

17 *https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/546679/FC002I__Cefas_Seaweed_industry_report_2016_Capuzzo_and_McKie.pdf*

Ulva lactuca: Commonly referred to as sea lettuce, this green seaweed is found around the UK coast and is somewhat thin and flat in appearance (hence the reference to lettuce).

It has been used for centuries in Scotland and is found is salad products and health stores.

Undaria pinnatifida: Often referred to as Wakame or Japanese kelp, Undaria is an invasive species to the shores of the UK. It was first found in the Hamble, Southampton in 1994 and has since spread to cover virtually the whole Southern coast.

In Japan, the species is an important productions species and is used in soups (particularly miso soup) and salads.

Production

The productions techniques for seaweed worldwide are wide ranging and to cover them all would be beyond the scope of this study. Production thought can be roughly split between rope culture (used for the long stranded species (kelp or kelp like) or bottom rope culture (for the smaller more delicate bottom dwelling species such as *Ulva* or *Palmaria*).

Figure 28: Surface rope culture of Seaweed

The surface rope grown techniques employ a very similar system to that already described for rope grown mussels except the seaweed is attached to the near surface rope and allowed to grow vertically down towards the seabed (See Figure 28).

Figure 29: Bottom rope culture of seaweed

For bottom rope culture, ropes are secured along the seabed (often close to the shore) and seaweed attached at set points along it (See Figure 29). Seaweed can often be uncovered at low tide to aid with collection.

Suitability of species for Portland Harbour

Since product is not currently grown using farming techniques in the UK, let alone near Portland, it is not possible to say with any certainty if any of the species can be grown in the project area commercially now or in the future.

However, MEP considers it highly likely that Portland harbour would offer suitable production conditions for some of these species to be produced. It is also likely that a rope based production system would be used and this would have the same limitations and drawbacks as already mentioned elsewhere in this report (i.e. space competition, risk of collisions etc.).

Seaweed production in Portland Harbour is not considered likely in the near to medium term future (or at least until further commercial trials have proven successful elsewhere in the UK).

3. Annotated Aquaculture Map

In Figure 30 below we have presented an annotated map which provides some high end site analysis for possible aquaculture operations in the Portland Harbour area.

In summary, the map shows four separate generic areas namely;

Raft/Rope Culture Areas: The breakwaters of the harbour present by far the best opportunities for aquaculture production in the Portland harbour area. They offer good protection from waves and decent water depths. There suitability is reinforced by current and previous attempts of rope grown production in these areas.

In essence three possible areas exist within the harbour. The possibility of a further site to the very north on the rear side of the breakwater is also considered plausible. It is exposed to certain wind directions but may be able to offer enough protection to support some rope grown production systems.

These areas of the most potential for aquaculture production in Portland harbour.

Relaying Areas: In essence, the whole of Portland harbour (inside the breakwaters) offers the opportunity for relaying of shellfish. The depths are suitable for the production of all the species discussed in this report. The exception to this is the areas directly around the breakwaters and shoreline. These are considered too shallow and close to obstructions to be suitable for relaying activities.

However, the limiting factor is likely to focus on the interaction of other stakeholders, particularly the port itself. A number of activities are going to make areas of the harbour unsuitable for relaying activities.

The area available for relaying is expected to be greatly reduced once other stakeholder activities are fully considered.

Trestle Areas: The Northern and Western shore of Portland harbour offer the only possible locations for trestle production of oysters. In practice, the sites are suitable with a gently sloping bank and relatively clear sub-tidal sea bed.

In practice however, it is likely that access to these sites and interests of other stakeholders will make these sites relatively difficult for trestle oyster production. We would be surprised if a major opportunity for the farming of oysters in trestles exists on this basis in Portland Harbour.

Over Exposed Area: The majority of the area outside of the harbour is considered to be too exposed for the majority of aquaculture operations. Although protection is offered by Portland Bill from a Westerly direction, the area becomes highly exposed to an Easterly wind which would result in high wave activity. As a result, we do not believe that this area is suitable for the majority of production systems discussed in this report (with the possible exception of the newly developed offshore mussel raft systems although with these the site would not offer enough space to make the technology economically viable).

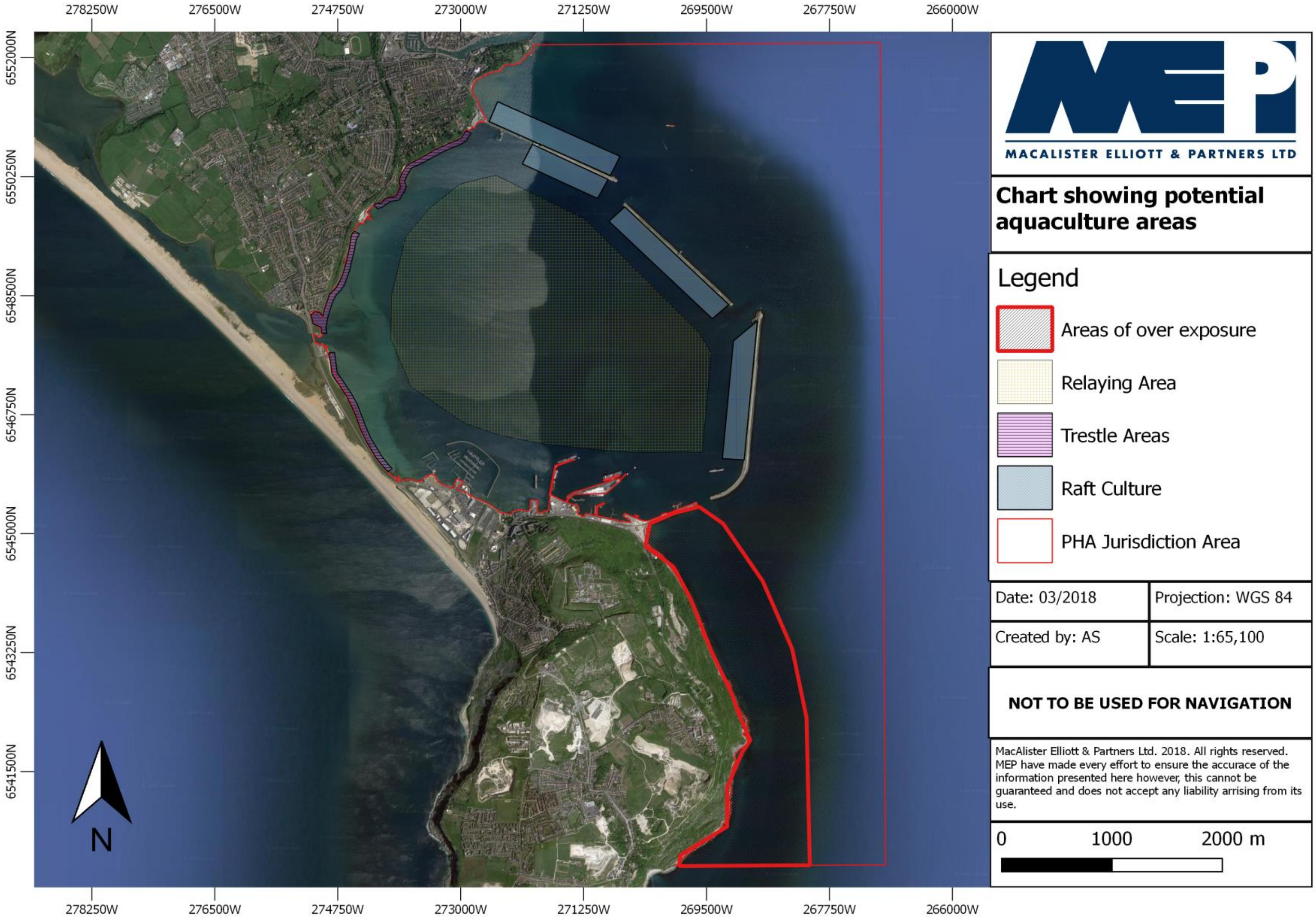

Figure 30: Possible High level aquaculture locations in the Portland Harbour Area

4. Aquaculture Preferences for Portland Harbour

The below table provides a top 5 ranking of MEPs suggested preferences for aquaculture production in the Portland Harbour project area.

Table 4: Top 5 aquaculture production options for Portland Harbour site

Rank	Production Method	Justification
1	Scallop production (lanterns and relaying)	Environmental conditions are good for scallop production. Scallops are a native species with good market potential and are likely to grow well. They do not required major interaction with the farmer and can be grown in smaller quantities than other molluscs. Further study required to ensure seabed is suitable and the availability of spat in the region. A hatchery may well be a requirement for successful production.
2	Pacific oyster production (seabed and trestles)	Pacific oysters are currently produced in the area and would be suitable for production. They are also resistant to *Bonamia* and hardy in growth. A lack of space for trestle systems is seen as an issue. Triploid hatchery sourced juveniles are recommended
3	Abalone production (cage and raft)	Although not currently produced in the UK, trials have shown success for production of the species. They require relatively little space and can be grown in small numbers (due to high price). Production would need to be piloted first to ensure success. Supply of hatchery juveniles is also a major problems and would probably need to come from Jersey..
4	Mussels production (rope grown)	Mussels would grow well in Portland harbour and are relatively easy to produce and tolerant to disease. The product is relatively cheap though and needs large farming areas to produce economically. Space in the harbour is considered limited for production on the scale required.
5	Native oyster production (seabed and trestles)	Would be suitable for production and perception of native production is positive. Space for trestles is considered limiting but more worryingly is the location of Portland in a *Bonamia* management zone. This is considered a high risk for production of native oysters.