The feasibility of aquaculture, aquaponics and a lobster hatchery in Amble

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Produced for the Amble Development Trust
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1. Executive summary

1.1 Introduction
- This study investigated the feasibility of developing aquaculture, aquaponics and a lobster hatchery in Amble.
- Aquaculture is the farming of aquatic species whilst aquaponics is combining farming aquatic species with plants. A lobster hatchery grows lobsters from eggs to juveniles, which are then released in the sea to increase the local lobster population.
- In England rainbow trout and mussels dominate aquaculture production whilst in Scotland salmon dominates and in Ireland more shellfish are produced. Production using a recirculation aquaculture system (RAS) also occurs although less than 40 sites were operational in England and Wales in 2010.
- Three lobster hatcheries currently exist in the UK: The Padstow National Lobster Hatchery in Cornwall, the Orkney Lobster Hatchery and the Firth of Forth hatchery in North Berwick. The Orkney hatchery releases 60,000 juveniles per year and the Padstow hatchery releases 30,000 juveniles per year and attracts 40,000 visitors per year.
- UK production of cultivated blue mussels was 26,000 tonnes in 2011. In Scotland, mussels are mainly rope-grown whilst in England and Wales they are mostly cultivated from bottom dredging.
- There are few current operations running in the north-east of England although the viability of a lobster hatchery in Scarborough or Bridlington was investigated in 2008.

1.2 Systems
- A recirculating aquaculture system (RAS) can be used for aquaculture and aquaponics. This requires less than 5% of the total water volume to be replaced per day, substantially reducing costs. They are also flexible where they can be placed and can be used to farm either tropical or temperate species all year round. However, it also requires high start-up costs and experienced technicians to ensure the system runs smoothly.
- A lobster hatchery system can either use RAS or a flow-through to waste system. For both systems the quality of water is paramount and it is recommended that a water quality survey is undertaken. As the juveniles become cannibalistic, individual rearing cages are also needed and either a shallow tray system or an aquahive system can be used. In order to increase the survivorship of juveniles being released in the sea, an outdoor caging system can be used to rear lobsters for 6-8 months.
- A suspended culture method can be used to rear mussels outdoors. Either longline, pole or raft cultivation can be used and requires either ropes, poles or wooden rafts to be used to attach the mussels onto where they grow before harvesting 18-24 months later.

1.3 Site suitability
- There are three suggested sites in Amble which can be developed: One in the estuary which can be used for suspended mussel development; one small site based next to the harbour; and one large site based on the industrial estate which is about one mile from the seafront. To assess the suitability of these sites water quality tests for all sites need to occur and for the mussel development site an assessment of a suitable depth and nutrient availability needs to occur.
- Amble has close access to good transport links such as road (A1 less than 15 minute drive), rail (Almout train station is 6 miles from Amble), plane (Newcastle Upon Tyne International Airport is 45 minute drive) and ferry (North Shields ferry terminal is 45 minute drive). Public transport links by bus and rail also exist.
- Currently, Amble receives 121,000 visitors per year with the majority of visitors being loyal but low spending. The number of visitors may increase to over 400,000 visits per year due to the development of an aquaculture, aquaponics or lobster hatchery centre as well as other developments.
1.4 New developments

- It may be viable for longline or raft cultivation to occur for mussel development. For example, it can be estimated that one 120m longline or one 10m² raft produces 2300-4500kg of mussels in 18-24 months. An initial cost of £3000 for a longline or £2100 for a raft exists and there is a subsequent annual cost of £1000 per year. This would create a profit of £1300-3500 in year two excluding the initial cost.

- The development of aquaponics would be deemed more economically viable than aquaculture. For a warm water system it may be most suitable to grow carp or tilapia and in a cold water system rainbow trout or arctic char. Growing a variety of plants may be the most suitable to test which grow best in the environment and to ensure market saturation does not occur.

- It may be viable to have aquaponics development occur on a large scale and growing cold or warm water species based on the large site in the industrial estate. For example, using estimates for RAS development of tilapia, rainbow trout and lettuce initial costs for equipment may be £6385 for a small-scale development and £40,000-50,000 for a large-scale development. On a small-scale a loss of £403-1187 may be made annually but on a large scale a profit from £-19,786 to 49,293.5 can be made for Tilapia and lettuce annually and a profit of £-175 to 43,825 for rainbow trout and lettuce. Therefore if development were to take place it is necessary to conduct detailed cost analysis to ensure the development will be profitable.

- It is viable to create a demonstration unit of a lobster hatchery and visitors centre based on the small site next to the harbour. It is estimated based on the Firth of Forth lobster hatchery demonstration unit and it may cost around £10,000. Estimated revenue from ticket sales may be £21,054, possibly increasing to £69,600 in the future. Part of this revenue can be used together with a large grant to create a large lobster hatchery based on the large site on the industrial estate. It is estimated to cost between £175,950-182,700 and will produce between 34,000-104,000 juveniles per year if the stacking tray system were to be used. If the aquahive system were to be used this could increase the number of juveniles by a factor of 6-10 at an additional cost of £750-1125 per tank. The running costs of the facility may be £5637-6337 per year. If juveniles were to be held in an outdoor caging system than an additional relatively small cost must also be included. Financing for the large-scale hatchery may be obtained from donations, sale of juvenile lobsters to third parties, revenue from a souvenir shop, sponsorship and an industrial levy.

1.5 Environmental issues, local benefits and limitations

- Mussel aquaculture, RAS and a lobster hatchery produce little waste which limits environmental issues. However, any waste produced needs to be disposed of or reused appropriately and needs to follow EU regulations. Also, as mussels can produce biodeposits care must be taken to ensure this does not change the sediment characteristics of the sea bed.

- The creation of a lobster hatchery is likely to benefit the fishery and it is likely that the fishermen will support the hatchery. The hatchery can also provide short-term benefits through increasing awareness of the fishery through the visitors’ centre and conducting educational outreach programmes.

- The creation of an aquaponics centre and mussel aquaculture can support the local area through increased employment and can potentially also have educational outreach programmes. Mussels and products produced from aquaponics can also be sold to the local and regional economy.

- A number of limitations were found in the study such as: the unknown quality of the water; the unknown rate of survivorship of juvenile lobsters being released into the sea; the high costs of RAS and steep learning curve potentially causing losses particularly at the beginning of the project; estimating costs based on desk-based research which may not be accurate.
2. Introduction

2.1 Introduction to aquaculture, aquaponics and a lobster hatchery

With the UK population estimated to grow to almost 71 million by 2035 the total seafood requirement would grow from 1.1 to 1.9 million tonnes (James and Slaski, 2009). However, capture fisheries are declining with most wild fisheries being either fully or over exploited (James and Slaski, 2009). Therefore, in the coming decades it is likely that aquaculture will be the greatest source of increased fish and shellfish production.

Aquaculture can be defined as the farming of aquatic species (Blidariu and Grozea, 2011) whilst aquaponics is the combination of aquaculture and hydroponics, the production of plants in water (Diver, 2006). A lobster hatchery is used to grow lobsters from eggs to juveniles where they are then released in the sea in order to boost the local population (Rodmell and Todd, 2008).

2.1.1 Aquaculture

Aquaculture is the rearing of aquatic species under controlled conditions. These include finfish, shellfish, algae and crustaceans. The rearing of the species is normally split into two sections: 1. Hatchery stage where the species produce eggs/seed which are grown out into juveniles 2. Fattening stage where the juveniles are fed and grown out.

There are many different types of aquaculture, from the production of warm or cold water, fresh water, salt water or brackish water species, to how they are produced in different systems such as a pond, running water or a closed system (figure 1). However, because of time restraints this report will focus only on aquaculture which could be produced in Amble.

2.1.2 Aquaponics

The main principle of aquaponics is to have the waste products of one biological system serve as nutrients for a second biological system (Diver, 2006). For example, in one system, fish are fed and produce a nutrient-rich effluent. This is used to fertilise plants in another system and as the plants remove the nutrients from the water (which start to build up and become toxic to the fish) and add oxygen to the water, this water can be re-circulated back to the fish (figure 2). The benefit of this, as opposed to just having aquaculture, is that the plants and fish have a complementary relationship and reduce the need for...
flushing out toxins. Furthermore, it produces a polyculture, increasing the diversity and yields multiple produce (Diver, 2006).

Aquaponics mostly takes place indoors in a closed system due to the need to regulate the water quality and temperature. The selection of the species for aquaponics needs to be chosen carefully to ensure an efficient relationship exists. Some plant species adapted to hydroponic culture include lettuce, flowers, herbs and specialty greens (spinach, chives, basil, watercress) as they have low nutritional requirements although plants yielding fruits such as tomatoes, bell peppers and cucumbers can still be grown in a well-established aquaponic system. Coldwater and warm water fish species can also be grown such as trout, perch, arctic char, bass and tilapia (Diver, 2006).

2.1.3 Lobster Hatchery
With the value of lobster landings in 2008 in the Northumberland Region estimated to be £2.9 million, lobster is seen as an economically important species in the district (Turner et al., 2009). However, the 2011 stock assessment of the European Lobster in Durham and Northumberland found that the stock might be declining (Cefas, 2011). A lobster hatchery may be used as a conservation measure to increase the local population of lobsters as the juveniles grown in the hatchery are released into the sea where they grow out and reproduce (figure 3). A hatchery can also play an educational role for the public, improving better understanding of the basis upon which the fishery depends (Rodmell and Todd, 2008)
2.2 Amble
Amble is a small port town situated in north-east England. A small fishing fleet exists, employing 60-70 people and with an annual catch worth close to £2 million (Ellis, 2013). However, it is an area which has been affected badly by industrial downsizing, with 17% of the population being income-deprived (Ellis, 2013).

Amble is currently trying to redevelop itself through the work of the Amble Development Trust which was set up in 1994 to regenerate the town. This is partly being achieved through Amble 2020, a document created to identify potential areas of economic growth. Tourism was identified as one of the best opportunities and this may be developed through creating a seafood centre (Ellis, 2013). If this is developed then aquaculture, aquaponics or a lobster hatchery would complement the seafood centre and could further increase employment and tourism.

2.3 Aims and objectives
The aim of this report is to investigate the viability and financial implications of setting up aquaculture, aquaponics and a lobster hatchery in Amble.

The objectives are to:

- Investigate operations already occurring in the UK and in north-east England
- Discuss potential aquaculture, aquaponics and lobster hatchery systems
- Review the site suitability and existing infrastructure available including aquaculture specific infrastructure
- Consider new developments which could be built and the cost implications of setting these up
- Investigate possible environmental implications of introducing these new developments
- Consider stakeholders views and support in creating new developments
- Review some of the major limitations of constructing the new developments

3. Area specific operations

3.1 UK operations

3.1.1 Aquaculture and aquaponics
Aquaculture production in England is dominated by rainbow trout and mussels whilst Scotland mainly cultivates Atlantic salmon and Ireland produces more shellfish than finfish (Callaway et al., 2012). The UK also accounts for about a quarter (by value and volume) of all EU imports of ornamental fish (Jeffery et al., 2011). The number of aquaculture sites and amount produced in the UK can be seen in table 1. Aquaponics is more of a fledgling sector and no published data is available for the amount of sites existing in the UK.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of aquaculture sites</th>
<th>Tonnes production</th>
</tr>
</thead>
<tbody>
<tr>
<td>England and Wales</td>
<td>399</td>
<td>20317</td>
</tr>
<tr>
<td>Scotland</td>
<td>758</td>
<td>170062</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>67</td>
<td>8863</td>
</tr>
<tr>
<td>UK Total</td>
<td>1224</td>
<td>199243</td>
</tr>
</tbody>
</table>

However, although no data exists for cold water RAS sites, the number and type of species farmed using warm water RAS can be seen in table 2.
Table 2 (Jeffery et al., 2011): Numbers of warm water recirculation fish farm sites registered between 2000 and 2010, and the number of sites operational in 2010 NB: Data contains one hatchery that moved location.

<table>
<thead>
<tr>
<th>Species held</th>
<th>Number of sites registered between 2000 and 2010</th>
<th>Sites operational in 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilapia</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Tilapia &amp; catfish</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Barramundi</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Hybrid striped bass</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Prawns</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Turbot</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Grass carp</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>26</strong></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td>Wales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole, bass, prawns &amp; turbot</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Turbot &amp; bass</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bass</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>3</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>29</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>

3.1.2 Lobster Hatchery

There are two main lobster hatcheries in the UK: the Padstow National Lobster Hatchery in Cornwall and the Orkney Lobster Hatchery. Another hatchery in North Berwick exists, the Firth of Forth Lobster Hatchery although it is still in the early stages of development.

The Orkney Lobster Hatchery is the oldest hatchery in the UK. It began in 1985 and now releases 60,000 juveniles per year. The Padstow National Lobster Hatchery opened in 2000 and releases about 30,000 juveniles per year. It also has a strong visitor centre, attracting over 40,000 people per year.

3.1.3 Mussels

The total UK production of cultivated blue mussel was around 26,000 tonnes in 2011 although consumption in the UK was only 4,000 tonnes (Seafish, 2011). In Scotland, mussels are mainly rope-grown whilst in England and Wales they are cultivated from bottom dredging (Epsilon and Seafish, 2002). England and Wales produces the most blue mussels (figure 4).
3.2 North-east England operations
There are few operations running in the north-east. The viability of a lobster hatchery in either Scarborough or Bridlington was investigated in 2008 but although it was thought to be viable it was never constructed (Rodmell and Todd, 2008). Some aquaculture and aquaponic operations exist although less than 20 businesses may be operating. There is no known data on cultivated blue mussel occurring in the north-east although this is not due to it being an unsuitable location for cultivating mussels.

4. Systems

A number of systems are discussed for the development of indoor aquaculture and aquaponics using a recirculation aquaculture system (section 4.1), a lobster hatchery system (section 4.2) and outdoor mussel aquaculture (section 4.3). These systems were chosen because they best suited the location and species which may be grown.

4.1 Recirculation Aquaculture System

4.1.1 Introduction
A recirculation aquaculture system (RAS) can be defined as a system which incorporates the treatment and reuse of water, with less than 5% of total water volume being replaced per day (Blidariu and Grozea, 2011). This is conducted through technology maintaining oxygen levels and removing waste (Jeffery et al., 2011). In general, a RAS consists of mechanical and biological filtration components, pumps and holding tanks and may also include additional water treatment elements which improve water quality and reduce disease (Blidariu and Grozea, 2011). They can be designed around indoor or outdoor culture tanks or ponds (Klinger and Naylor, 2012).

Most perform the following key wastewater treatment functions: solid waste removal, carbon dioxide removal, bacteria and pathogen sterilization, nutrient removal and dissolved oxygen supplementation (Klinger and Naylor, 2012).

4.1.2 Fundamentals of RAS
The main processes occurring in a RAS is shown in figure 5. Filtration of the water from production units is carried out by two main processes (Jeffery et al., 2011):

- Mechanical filtration- where suspended solids such as uneaten food and faeces are removed
- Biological filtration- where dissolved chemical wastes and gasses such as ammonia, nitrate and CO$_2$ are converted to less toxic substances an oxygen levels are also increased.

Additional processes can also occur such as oxygenation, sterilisation (to remove pathogens and undesirable bacteria), chemical buffering (of water quality parameters), etc. which depends on the requirements and ‘loading’ (which depends on the rate of waste production and fish biomass which is held in the system) of the system (Jeffery et al., 2011).
4.1.3 Advantages

There are a number of advantages RASs offers over conventional aquaculture systems (Jeffery et al., 2011; Klinger and Naylor, 2012):

- Recycling water reduces water-use substantially: In freshwater RASs as little water as 50 litres/kilogram of produced seafood can be used and in saltwater RASs as low as 16 litres/kilogram of fish. In contrast, in conventional aquaculture systems as much water as 3,000-45,000 litres/kilogram of seafood can be used.
- RASs are flexible where they can be placed: Because of the little amount of water they use, RASs can operate close to markets, reducing transport emissions.
- RASs can be used to farm either tropical or temperate species
- Waste from RASs can be used as agricultural fertilizers, in vermicomposting, polychaete production and methane production. Also RASs can be used for the production of aquaponics.
- Year-round production and a control of the fishes’ environment which allows consistent and predictable production
- Improved biosecurity in closed systems reduces the risk of pathogen ingress and disease outbreaks

4.1.4 Constraints

The main constraints for developing a RAS at a commercial scale are (Jeffery et al., 2011; Klinger and Naylor, 2012):

- High costs of feed: Due to the high cost of building and operating RASs it is more favourable to produce high-value carnivorous fish that require large amounts of feed
- Labour: Experienced technicians and good management is needed to ensure the system runs smoothly
- Energy intensity: Electricity is required to run the RAS and it requires much more operational energy than most other types of aquaculture systems. For example, a carnivorous finfish RAS facility requires 16-98 kilowatt hours/kilogram (kWh/kg) of fish produced compared to 7.4 kWh/kg for a net pen and 27 kWh/kg for a flow-through farm of similar species.
- Large setup and investment costs needed and there are high running costs

Improving energy efficiency and finding alternative energy sources may help to overcome some of these barriers.
4.2 Lobster Hatchery system

Lobster hatcheries may be operated on two bases: a recirculation system or a flow-through to waste system (Rodmell and Todd, 2008). For both cases, the quality of seawater is paramount. The source of water can either be pumped from a clean source adjacent to the hatchery or artificial seawater can be created. It is recommended that if seawater abstraction will occur that a water quality survey is undertaken at any site intended to supply to a hatchery (Rodmell and Todd, 2008).

The lobster hatchery consists of four rearing systems (Burton, 2003; Rodmell and Todd, 2008):
- Broodstock, holding and manipulation tanks to house mature females
- Larval rearing tanks
- Juvenile on-growing tanks
- Live food stock production

Because of large growth variation and high losses due to cannibalism and injuries when kept communally, juveniles have to be kept in individual containers (Drengstig and Bergheim, 2013). There are a number of designs and two of these are described in section 4.2.1 and 4.2.2.

All culture systems require individual filtration systems which have the following major components (Rodmell and Todd, 2008):
- Biological Filtration
- Ultraviolet sterilisation (unless using live algae in the larval system)
- Temperature control chillers/heaters
- Mechanical filtration
- Protein skimming (may not be needed on larval system)
- Pumps
- Controlled alarm system
- Isolated sump

A potential design of a hatchery used for a Norwegian Lobster Farm is shown in figure 6.

Figure 6 (Drengstig and Bergheim, 2013): A flow diagram and design of the RAS facilities at Norwegian Lobster Farm, Kvitsøy including the hatchery, broodstock and grow-out sections with water treatment units
This uses a RAS to conserve water which is more efficient than the flow-through to waste system.

Some major constraints of lobster hatcheries have been high labour costs, the need for individual rearing cages to avoid cannibalism, lack of high quality dry food, need of heated water, inadequate technological solutions and high investment costs (Drengstig and Bergheim, 2013).

4.2.1 Shallow Tray system
Once larval lobsters begin their benthic lifestyle after four larval stage moults they are transferred into a juvenile rearing system (Rodmell and Todd, 2008). The container for the on-growing juveniles may be one of the most problematic items of equipment to obtain as currently there are no ready available containers to buy (Burton, 2003).

The main requirement for the container is to keep each individual juvenile separate whilst it grows to the release size. The container should allow them to be inspected, cleaned and fed easily. It must be possible to remove the containers from the on-growing tank so that the juveniles can be removed and the cells cleaned and sterilised between uses (Burton, 2003).

One possible design is a shallow tray design. These can have either plastic slot-together cells such as shown in figure 7A or individual plastic cells with a perforated base that slot together to form an array as shown in figure 7B which is used in the Orkney Lobster Hatchery (Burton, 2003). As the lobsters grow the size of the cell should increase and therefore fewer lobsters can be held per unit of area. Suggested container sizes for 5-10mm long lobsters is 25cm², for 11-25mm long are 115cm² and for 26-40mm are 310cm². This increase in size occurs between 1,4 and 12 months (Rodmell and Todd, 2008). The trays can potentially be stacked vertically in tanks as shown in figure 7.

Figure 7 adapted from (Burton, 2003): A.) A plan view of a lobster tray B.) A plan view of a Orkney lobster tray C.) Potential design for siphon and overflow arrangements in a stacked tray on-growing system
4.2.2 Aquahive system

Developed by the Orkney Lobster Hatchery and also being used at the National Lobster hatchery the ‘aquahive’ system can hold between 6-10 times more juvenile lobster per square metre than the equivalent shallow tray system (Rodmell and Todd, 2008). The trays are designed to have a shape similar to a honeycomb and can be stacked to create 6-10 layers which are then fully submerged (figure 8).

Main benefits on the ‘aquahive’ system include an increase in juvenile production for the available floor space. It also requires far less labour input to feed the lobsters because the lobsters can be fed as an entire system rather than needing to feed every individual lobster compartment daily. Furthermore, cleaning and maintenance is only required every few days although it is not easy to observe any lobster mortalities until maintenance occurs.

Although the cost of an ‘aquahive’ system is greater than a shallow tray system and it is important to fully consider the ‘aquahive’ system for an experimental or main production technique.

Figure 8 (http://aquahive.co.uk/): The lobster ‘aquahive’ design (right) and how the aquahive system is stacked on top of each other to minimise the space needed to grow the lobsters (left)

4.2.3 Outdoor system

Currently, either large numbers of lobsters are being released when they are small (5-7mm) or a small number of lobsters are being grown out (to 12-16mm) in a land-based facility and then released. There are little attempts to release a large number of relatively large juveniles because of lack of space, time and the finances to rear the animals to a larger size (Beal et al., 2002). However, it may be possible to have a low-cost, low-maintenance, outdoor-based nursery caging system (figure 9).

This is beneficial because post-larval lobsters are extremely vulnerable to predation when released directly into the sea and so increasing the size of the lobsters before release will increase their chances of survival (Perez Benavente et al., 2010).

Figure 9 (Perez Benavente et al., 2010): A sketch showing the design and methodology of an outdoor system using custom-made single containers and commercial oyster baskets
The outdoor caging system is experimental but uses the basic idea that natural occurring zooplankton and organisms growing on the surfaces of culture structures will provide a sufficient source of food for high growth rates for 6-8 months (Perez Benavente et al., 2010).

A number of different containers have been developed to hold the lobsters with varying results. Plastic netting, plastic petri dishes and commercial oyster baskets have been used with the oyster baskets achieving the highest survival (82-89%) and growth rate (4–5 cm total length over 190–250 days) (Beal et al., 2002; Perez Benavente et al., 2010).

Although this system is still at an experimental stage and it may not be possible to create a system which will be able to include all of the lobsters grown in the hatchery, it may be worth considering adopting once the hatchery is established to improve the chance of survival for some lobsters.

4.3 Suspended mussels system

4.3.1 Introduction
The main mollusc species cultivated in the UK is the blue mussel (Mytilus edulis) (Epsilon and Seafish, 2002). An advantage of cultivating mussels is that their natural environmental ranges suggest they can survive high levels of physical stress in a high energy environment such as underneath breaking waves and currents (Lado-Insua et al., 2009). They also do not require daily maintenance. Mussels can be cultivated either on the seabed or using ropes ('Responsible Sourcing Guide: Mussels,' 2011). Due to space restrictions, this report will focus on suspended mussel cultivation.

In a suspended culture, the majority of seed mussel is located and fished from offshore beds, although some hatchery produced spat is available ('Shellfish Industry Development Strategy: A Case for Considering MSC Certification for Shellfish Cultivation Operations,' 2008). It is relayed to a more productive and protected location and attached to ropes to on-grow until harvested 18-24 months later (Seafish, 2011). The growth of the mussels is dependent on natural plankton present in the water and so no additional food is added.

The advantages of suspended culture methods are increased exposure to water currents, which increases the ability of the mussels to reach plankton and the reduction of predation on the cultured population from benthic (seabed) predators ('Shellfish Industry Development Strategy: A Case for Considering MSC Certification for Shellfish Cultivation Operations,' 2008). Furthermore, mussels produced in suspended cultivation tend to have thinner shells than seabed mussels which consequently results in a high meat-to-shell weight ratio. They also may be less prone to certain biofouling organisms (Seafish, 2011).

4.3.2 Different suspended culture techniques
There are three main types of suspended mussel culture techniques: Longline, pole and rafts ('Shellfish Industry Development Strategy: A Case for Considering MSC Certification for Shellfish Cultivation Operations,' 2008).

Longline cultivation: It is the method of choice in more exposed waters due to the flexibility of the structures. Typically there will be a series of horizontal ropes that are held in the top 3m of the water column using buoys (figure 10). From these ropes there are a series of dropper ropes which carry the mussels and tend to be 4-6m in length and spaced a 50cm intervals. Additional floats may be necessary to support the mussels as they grow.
Figure 10 (Lado-Insua et al., 2009): A longline system based on several lines where the mussels are attached hanging from a mother line which floats from buoys.

Pole cultivation: Also known as the bouchot method it consists of vertical poles being driven into the seabed and is essentially a shallow water technique, with access to the poles at low tide or by diving (figure 11). Poles are typically 4-7m long (with 2-3m rising above the seabed) and 25-30cm in diameter. They can be made from hardwoods or aluminium. They are placed in parallel rows at right angles to the shoreline.

Figure 11 (Epsilon and Seafish, 2002): An image of a typical ‘bouchot’ operation taking place

Raft cultivation: This uses a framework of timber supported by floats which have a series of ropes attached (figure 12). The rafts require a water depth several metres deeper than the length of the ropes to prevent the grounding of the mussels during low tides. Water quality, current speed and shelter are also important in the siting of mussel rafts. Rafts can have a carrying capacity of over 10t each, equating to 6kg of mussel per metre of rope.

Figure 12 (Epsilon and Seafish, 2002): An image of a typical raft structure
5. Site suitability and existing infrastructure

5.1 Location of sites

There are two sites which are available for development (figure 13). The smaller site next to the quayside will be within a new development area which aims to enhance the harbour and waterfront area by creating a ‘seafood hub’ attracting tourists (Ellis, 2013). The larger site is based approximately one mile from the seafront in an industrial estate.

The available site in the industrial estate is shown in figure 14. The site is approximately 3.4 hectares and will have access to electricity. Water may have to be pumped from an available source, as it may be too far to pump water directly from the sea.

The available site on the quayside is shown in figure 15. The site is approximately 20x12m with an internal floor area of 146m\(^2\). The roof height is 5.5m in the centre, with eaves heights of 2.8m on the southern side and 4m on the northern side (Darbyshire and Kendall, 2013). The site will sit in close proximity to a restaurant and ‘incubator units’ which will provide start-up businesses which are directly related to seafood or which serve associated or separate markets accommodation.

Additionally, there is a site available in the estuary which may be suitable to grow mussels (figure 13). Mussels currently grow inside of the harbour and these may be relocated to a site north along the jetty. This will be a larger site and will allow for more undisturbed growth.

Figure 13: A google map displaying the approximate areas of potential aquaculture development
Figure 14: The site available for aquaculture development is shown in blue and the companies surrounding the site are also named.
Figure 15 (Darbyshire and Kendall, 2013): The potential development site at the Quayside. Site 2 is the building where potential aquaculture/aquaponics/lobster hatchery development may occur. Site 3 displays a space or ‘incubator units’ which provides accommodation for businesses. Route 4 displays an access route for service vehicles.
5.2 Existing infrastructure

5.2.1 Transport links
Amble has close access to good transport links (figure 16). The A1, A1068 and A19 are close, with access to Newcastle Upon Tyne International Airport by car in 45 minutes, North Shields ferry terminal in 45 minutes and Edinburgh approximately 2 hours away. This will also create easy transport of produce to other areas although it is imagined that the majority of produce will be consumed locally.

It is also relatively easy to reach Amble by public transport. Two bus services run through Amble hourly to Berwick upon Tweed (on the border of Scotland) and Newcastle upon Tyne as well as more local towns such as Alnwick, Morpeth, Widdrington and Ashington. Alnmouth rail station is a short car journey (15 minutes) from Amble and both local and mainline trains stop there.

Amble is also quite close to international travel routes by sea and air. The North Shields Ferry terminal offers a number of services including ferries to Holland and Scandinavia. Newcastle upon Tyne International airport offers holiday and charter flights from lots of major tour operators to the rest of the UK, Europe, Africa and North America.

Figure 16: A google map displaying the transport links available from Amble
5.2.2 Labour
The current population of Amble is around 6000 people, with approximately 38% of people economically inactive (Northumberland County Council, 2008). Labour will be needed for the building and setting up of the sites and for the operation of the sites. Most of the labour can be sourced from the town and surrounding local areas although an aquaculture/aquaponics technician may have to be brought from a different area due to their specialist knowledge (Burton, 2003).

5.2.3 Tourism
In 2011 9.1 million people visited Northumberland, with 1.7 million overnight visitors and 7.4 day visitors (Thomas, 2012). Amble currently receives an estimated 121,000 visitors per year, with many loyal but low spending visitors, with a dominance in self-catering accommodation (Ellis, 2013).

An aquaculture, aquaponics or lobster hatchery centre will attract more visitors and may increase spend among existing visitors through an entry fee or shop merchandise. The majority of visitors may be local (less than 1 hour away) and together with other developments, over 400,000 visitors may be attracted per year in the long term (Ellis, 2013).

5.2.4 Facilities
Currently the seafood centre has not been built, but once completed will have access to electricity and water. If water is to be used from the sea then thorough water quality tests need to take place to ensure that the water quality is adequate for aquaculture or aquaponics or a lobster hatchery.

The site based on the industrial estate will also have access to electricity and is approximately one mile from the sea. This may be deemed too far to pump water from the sea to the site and it may be possible to receive water from a nearby site on the industrial estate (Northumbria Water). This will require negotiations with Northumbria Water and water quality tests to ensure water quality is adequate.

The site based in the estuary can be accessed by road and boat. The water quality will need to be tested before relocation of the mussels takes place.

5.3 Suitability of sites
The key considerations to contemplate in order to assess the site suitability are established in table 3.

| Table 3 †: Physical, social and mussel specific considerations for site suitability |
|--------------------------------------------------|-----------------|--------------------------------------------------|
| Considerations for site suitability             | Adequate         | Further details                                  |
|                                                  | suitability      |                                                  |
| **Physical considerations**                     |                  |                                                  |
| Land- flat, not prone to flooding               | ✓                | Land sculpting may be needed to ensure land is flat when construction takes place |
| Water supply and quality                        | ?                | Need to test water quality for all sites         |
| **Considerations specifically for mussels**     |                  |                                                  |
| Suitable climate                                | ✓                | Mussels are grown within the estuary and so the climate is suitable |
| Suitable depth                                  | ?                | When relocating mussels ensure the depth is suitable |
| Nutrient availability                            | ?                | Test to see if there is appropriate nutrients available |
| **Social considerations**                       |                  |                                                  |
| Development plans for the project area          | ✓                | Project area available for specific aquaculture/aquaponics/lobster hatchery development |
This illustrates that the three sites are satisfactory for the development of aquaculture, aquaponics or a lobster hatchery if the water quality is adequate and if a suitable depth and nutrients are available for mussels.

6. New Developments

6.1. Mussel outdoor aquaculture

From the three options explained in section 3.3.2 used for suspended mussel aquaculture, it was thought that longline suspension and raft cultivation may be best suited to the site. This is due to both techniques being more flexible than pole cultivation as structures do not need to be placed permanently in the seabed. Therefore the costs and viability of both methods are discussed below.

6.1.1 Longline cultivation

If mussel spat is needed then spat collectors, which are ‘fuzzy’ lengths of rope are deployed on the longlines (Hoagland et al., 2003). Mussel larvae naturally settle on the rope, often in huge numbers (10,000 to 1000,000 per collector) and can be left on the ropes for 3-12 months (Brown et al., 2000; Hoagland et al., 2003). Once the seed has grown to 15-20mm it is stripped from the collector, graded according to size and ‘socked’ (Hoagland et al., 2003). This involves placing the seed into disposable mesh tubes called socks which are then placed on the growout ropes for 13-24 months until harvest where they reach around 50mm (Brown et al., 2000; Hoagland et al., 2003).

The spacing and different equipment needed for longline suspension can be seen in figure 17. The most common ropes to use is a 13 -14mm polypropylene rope. A number of different anchors and floats can be used. For example, eyebolts can be drilled into large rocks (500-2000kg) or concrete or Dor mor anchors can be used. A concrete or Dor mor anchor may be the best to use as expensive equipment is needed to drill into rock and suitable rocks need to be found. Furthermore, the weight for a concrete or Dor mor anchor can be split into two, using two anchors connected with a rope which means that the anchors can be moved by a small boat rather than one with hydraulic equipment (Brown et al., 2000). A variety of floats can also be used such as 45 gallon aquaculture barrels, hard plastic spherical buoys, Styrofoam lobster floats, soft drink contains, buckets and plastic bottles (figure 18). These vary in the number of outgrow ropes they can hold (as shown in figure 17) and their cost (Brown et al., 2000).
The costs of the equipment needed for longline suspension is shown in table 4. However, these costs are only estimates as the only costs available were in US dollars. Therefore, before conducting longline suspension detailed costs need to be established.
Assuming that one 120m longline harness is used with 200 ropes, two anchors and eight barrel floats the total cost for one year is £3000 not including installation or manpower. After this initial cost, there will only be a cost of £1000 per year per longline not including manpower.

It is also estimated that one 3m length rope can produce between 11.5-22.61kg of mussels. Assuming that the cost of 1kg of mussels is £1 (Epsilon and Seafish, 2002) this suggests that between £4500-2300 can be made per longline. As the mussels will only reach harvest size after year two this means that there will be a loss for year one and a profit of £3500-1300 for year two excluding the initial cost.

6.1.2 Raft cultivation
Raft cultivation uses a similar process of spat collection and socking to longline cultivation although the ropes are attached to a raft instead of a longline (figure 19). The raft is a rectangular floating frame which has suspended culture ropes and is anchored to one point tied to the side, which allows the raft to move to face into the direction of the current (Fuentes et al., 2000).

The potential costs for raft cultivation are shown in table 5. However, these costs are only estimates and therefore a full cost plan needs to be developed if raft cultivation were considered.
Table 5 (Brown et al., 2000; Sallih, 2005): The costs of the equipment needed for raft cultivation

<table>
<thead>
<tr>
<th>Equipment needed</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raft (7-10m²)</td>
<td>£500</td>
</tr>
<tr>
<td>Anchor (Dor mor)</td>
<td>£600</td>
</tr>
<tr>
<td>Seed collector, outgrow ropes and mesh tubes (for 200-600 ropes)</td>
<td>£1000-3000 (per raft per year)</td>
</tr>
</tbody>
</table>

Assuming that one raft is 10m² and uses 200 ropes the total cost for one year is £2100 not including installation or manpower. After this initial cost, there will only be a cost of £1000 per year per raft not including manpower. Using similar assumptions with the longline suspension for mussel production it can be estimated that one raft can also produce between £4500-2300. This suggests that in year one there will be a loss and in year two there will be a profit of £3500-1300 excluding the initial cost. Therefore excluding the initial cost of setting up both techniques, it is seems that outdoor mussel aquaculture is a viable option in the area.

6.2. Indoor aquaculture and aquaponics

6.2.1 Species

A number of fish species can be grown using RAS (figure 19).

![Figure 19: Fish species which can be grown in RAS. They are either temperate or tropical (grow in temperatures above 20°C) and live in freshwater or saltwater.](image)

A number of plants can also be grown dependent on space such as:

- Salad varieties- tomato, lettuce, cucumbers, red salad onions, snow peas, shallots
- Vegetables- beans, cauliflower, cabbage, broccoli, aubergine, okra
- Herbs- watercress, basil, coriander, parsley, lemongrass, sage etc.
- Flowering plants- e.g. roses

For a warm water system it may be best to grow carp or tilapia as they are very hardy, grow fast, are easy to grow and are sustainable. For a cold water system it may be best to grow either rainbow trout or arctic char as they are relatively hardy and fast growing although they do require good water quality. Growing a variety of plants may be best to test which plants will be the most suitable for the environment although beginning with salad varieties or herbs may be best as they are fast growing plants.
6.2.1 Costs of RAS
Due to the higher costs of RAS compared to other aquaculture systems and the nature of aquaponics creating a diversity of products and reducing the need for waste disposal (Diver, 2006) it makes economic sense to set up an aquaponics system rather than an aquaculture system. However, this requires two different management systems to ensure both the aquaculture and hydroponics system remain healthy and these need to be closely monitored.

The species suggested for aquaponics are all freshwater species. However, if saltwater species were to be grown then either saltwater would need to be pumped from the sea to the facilities or artificial saltwater would need to be created, which would both increase the costs of the RAS.

In order to fully understand the estimated costs needed for a RAS, examples of a tropical and temperate RAS raising Tilapia and Rainbow Trout will be used in conjunction with growing lettuce. Tilapia is the most popular species to grow in aquaculture due to its hardiness, ability to cope with crowding and resistance to disease. Nile Tilapia live in conditions between 24-32°C and grow to harvest size (500g) within 6 months\(^9\). Rainbow Trout are also relatively hardy although they require better water quality than Tilapia. They live in conditions between 12-16°C and so are more suited to the UK climate and reach harvest size (280-400g) after 12-18 months\(^9\). Lettuce is also an easy plant to grow and has had proven success of growing in aquaponics conditions (Sikawa and Yakupitiyage, 2010).

To estimate the costs a number of assumptions have been made such as salaries, maintenance, marketing, building infrastructure, cost of building and transport not being included in the costs. Also it is assumed that all lettuce and fish species survive to market which is unlikely to occur. Furthermore, these costs have been devised through desk-based research and therefore may not be accurate. It would be advised that if an aquaculture facility were to be established, detailed costing would be established.

The costing of three different sized facilities were used to give estimates for the amount of Tilapia, Rainbow Trout and lettuce which can be produced (table 6). This shows that at a small scale (Miller, 1995) it may not be viable to have aquaponics as the cost of producing the fish is greater than the profit produced by selling the fish. This is partly due to the expensiveness of feed, fingerlings, water and electricity in the UK compared to other countries such as they USA. However, at a larger scale it has been shown that aquaponics can be profitable. Although rainbow trout takes longer to grow than tilapia and command more high quality water than tilapia, due to the lower cost of heating and higher wholesale price it may be recommended to grow rainbow trout if the conditions are correct. Furthermore, once the correct conditions are met for growing lettuce it can become a good source of income for supplementing the cost of the aquaculture. Different plant species can also be grown to ensure market saturation does not occur. Therefore on a larger scale and excluding an initial investment cost it may be deemed that aquaponics can be viable on the larger site in Amble.
6.3 Lobster Hatchery

6.3.1 Costs of a lobster hatchery
A lobster hatchery can either be small scale, such as the Firth of Forth lobster hatchery, or large scale such as the Orkney or Padstow hatchery. A small-scale hatchery can be used as a demonstration for the public and can be used as a visitor’s centre and can cost under £10,000.

A large scale hatchery based on the following floor space requirements can cost £175,950-£182,700 (table 7; (Rodmell and Todd, 2008)):

- Juvenile system: 100m²
- Larval system: 30m²
- Live food production (Artemia only): 12m²
- Brookstock (Berried Hens): 20m²
- Storage Tank and Plant room: 40m²
This could produce 16,000 juveniles at any one time and the maximum production of juveniles could be 104,000 per year if held for 4 weeks, 52,000 per year if held for 8 weeks and 34,000 per year if held for 12 weeks (Rodmell and Todd, 2008). This could be increased by a factor of 6-10 using the aquahive design.

Table 7 (Rodmell and Todd, 2008): Estimated costs for a large scale lobster hatchery

<table>
<thead>
<tr>
<th>System</th>
<th>Insulated</th>
<th>Un-insulated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Larval system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Larval Cones</td>
<td>£5,400</td>
<td>£3,600</td>
</tr>
<tr>
<td>Fiberglass Framework supports</td>
<td>£3,750</td>
<td>£3,750</td>
</tr>
<tr>
<td>ABS Pipework</td>
<td>£2,700</td>
<td>£2,700</td>
</tr>
<tr>
<td>Filtration</td>
<td>£6,750</td>
<td>£6,750</td>
</tr>
<tr>
<td><strong>Juvenile system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 juvenile trays (3m<em>0.6m</em>0.3m)</td>
<td>£18,000</td>
<td>£14,400</td>
</tr>
<tr>
<td>Fiberglass Framework supports</td>
<td>£27,000</td>
<td>£27,000</td>
</tr>
<tr>
<td>ABS Pipework</td>
<td>£3,750</td>
<td>£3,750</td>
</tr>
<tr>
<td>Filtration</td>
<td>£45,000</td>
<td>£45,000</td>
</tr>
<tr>
<td><strong>Broodstock system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 broodstock tanks (1.6m<em>1m</em>0.3m)</td>
<td>£4,050</td>
<td>£2,700</td>
</tr>
<tr>
<td>Fiberglass Framework supports</td>
<td>£2,280</td>
<td>£2,280</td>
</tr>
<tr>
<td>ABS Pipework</td>
<td>£1,500</td>
<td>£1,500</td>
</tr>
<tr>
<td>Filtration</td>
<td>£6,750</td>
<td>£6,750</td>
</tr>
<tr>
<td><strong>Live food</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 conical Artemia bins</td>
<td>£2,288</td>
<td>£2,288</td>
</tr>
<tr>
<td>Pipework</td>
<td>£900</td>
<td>£900</td>
</tr>
<tr>
<td><strong>Refrigeration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensing unit and pipework</td>
<td>£15,000</td>
<td>£15,000</td>
</tr>
<tr>
<td><strong>Intake system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake pump and system</td>
<td>£11,160</td>
<td>£11,160</td>
</tr>
<tr>
<td>Storage tank filtration</td>
<td>£14,422</td>
<td>£14,422</td>
</tr>
<tr>
<td>Storage tank</td>
<td>£12,000</td>
<td>£12,000</td>
</tr>
<tr>
<td><strong>Sub totals</strong></td>
<td>£182,700</td>
<td>£175,950</td>
</tr>
</tbody>
</table>

Installation and delivery would also warrant additional costs. If the aquahive system was used instead of the tray stacking system then it was estimated it would cost £750 for each uninsulated tank or £1125 for each insulated tank compared to £400 for the stacking trays. However, the aquahive system would hold 3120 juveniles in approximately 1.2m² whereas the stacking tray system would only hold 1360 juveniles in 3.5m² (Rodmell and Todd, 2008).

Estimated running costs for the facility have also been estimated to be £3,037 per year for an insulated system and £3,737.60 per year for an uninsulated system (Rodmell and Todd, 2008). Additionally, £600-800 should be allowed for maintenance fees and £1,800 for live feed each year (Rodmell and Todd, 2008). If juveniles were to be held in submerged cages or oyster baskets for 6-8 months then additional costs must be included for buying the oyster baskets although this would be a relatively small, initial cost.

6.3.2 Financing options
For a small-scale hatchery used as a visitor centre it may be possible to obtain the initial capital investment using a small grant or loan. Once completed it may be estimated that between £21,054-69,600 revenue can
be obtained from ticket prices (table 8) based on current and future projections of visitor numbers to Amble and that 0.06% of those visitors would visit the hatchery.

**Table 8 (Rodmell and Todd, 2008; Ellis, 2013): The estimated amount of revenue generated from tourists visiting a lobster hatchery visitor centre per year (based on ticket prices of £2.90 per person)**

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Short term estimated</th>
<th>Long term estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amble tourists</strong></td>
<td>121,000</td>
<td>135,000</td>
<td>400,000</td>
</tr>
<tr>
<td><strong>Lobster hatchery visitors</strong></td>
<td>7,260</td>
<td>8,100</td>
<td>24,000</td>
</tr>
<tr>
<td><strong>Revenue from tickets</strong></td>
<td>£21,054</td>
<td>£23,490</td>
<td>£69,600</td>
</tr>
</tbody>
</table>

For a large-scale hatchery it is anticipated that grant financing would be required to obtain the initial capital investment (Rodmell and Todd, 2008). If this is combined with a visitor centre then revenue obtained can be used to supplement the large-scale hatchery. Other possible financial options are shown below (Rodmell and Todd, 2008):

- Revenue obtained from a souvenir shop
- Donations- such as sponsor a lobster as used in the Padstow hatchery and customers at local restaurants agreeing for a small fee (such as 10p per meal) to be donated to the hatchery which is used at the Firth of Forth hatchery
- Sale of juvenile lobsters to third parties
- Sponsorship
- Industrial Levy- the Orkney Lobster Hatchery is primarily funded through an industry agreed levy on landings collected through landing merchants. This would need to be discussed first with the industry.

Therefore it is viable to have a demonstration unit and visitors centre held on the small site in Amble if a small grant or loan could be obtained. This could be used to help secure a larger investment for a large-scale hatchery which would be based on the larger site in Amble.

### 7. The environmental impact and stakeholder analysis of new developments

#### 7.1 Environmental issues

As RAS reuses water in the system there is a reduction in the amount of water used and waste being produced (Martins et al., 2010) which limits environmental issues. However, any waste which does need to be disposed of or reused will have to be properly treated, be environmentally appropriate and follow EU regulations at all time. A lobster hatchery will also have similar although potentially more waste than RAS and will need to follow the same regulations when disposing of or reusing waste.

Mussel aquaculture needs a clean water supply and natural food sources and therefore will produce little waste. Furthermore, as the mussel aquaculture is likely to be small scale it is unlikely that there will be a large impact on the environment. However, it may be astute to test the water quality regularly to ensure biodeposits are not accumulating as accumulated biodeposits can change sediment characteristics and cause benthic enrichment.
7.2 Stakeholder analysis
The creation of a lobster hatchery is likely to benefit the fishery as an increase in lobster juveniles will increase the lobster population. However, as it takes more than 5-6 years for a lobster to grow to be large enough to be caught by the fishery (Duffill Telsnig, 2014), there will be no immediate benefit. As the majority of the Pot Fishermen in the district believe that lobster v-notching, where berried hens are v-notched and then banned from landing whilst the v-notch exists, is an effective measure at increasing the lobster population (Duffill Telsnig, 2014), it may be likely that they will support a lobster hatchery. However, it may be less likely that the fishermen will voluntarily pay towards the hatchery without first seeing how effective it is.

In addition to the long-term benefits to the fishery, the hatchery can provide short-term benefits by increasing awareness of the fishery through a visitor’s centre. Educational outreach programmes could also be conducted to further increase this awareness (Rodmell and Todd, 2008).

Mussels and products produced from aquaponics such as a variety of plants and rainbow trout could be sold to the local and regional economy. However, if products were to be sold then a licence from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) would need to be obtained. It may also be possible to have educational outreach programmes for the aquaponics centre to increase awareness about this business.

8. Limitations
A number of limitations exist when considering the new developments:

- Water quality needs to be tested where it will be used for development. If the water quality is inadequate then costs will be higher as it will need to be treated or alternative water sources will be used.
- The survivorship of juvenile lobsters is relatively unknown and therefore the scale of the direct benefit to the fishery is likely to be unknown. The survivorship of juveniles is also likely to be influence how they are released into the sea and where. This is because the highest survivorship exists when the juveniles are released on the seabed by divers and also in areas of hard substratum (Burton, 2003) although the cost of this is likely to be the highest compared to releasing the juveniles from the beach or at the sea surface.
- RAS also has high capital costs, a steep learning curve and in the past system design problems (Jeffery et al., 2011) which could cause losses, particularly in the beginning of the project as techniques are perfected.
- The estimated costs of the new developments were based on desk-based research and were often based on costs in different countries and therefore may not be accurate. Therefore before fully undertaking a new development, detailed costing need to be established.

9. Conclusions and Recommendations

- This study has considered the feasibility of developing aquaculture, aquaponics and a lobster hatchery in Amble.
- It has been suggested that a RAS is used on land for aquaculture and aquaponics development and a suspended mussel culture is used in the estuary. Choices between a tray system and aquahive system are also available for juvenile development for the lobster hatchery.
• Three sites were available for development: One based in the estuary available for mussel development, one small site based next to the harbour and one large site based on the industrial estate which are available for aquaculture, aquaponics and lobster hatchery development.
• In order to fully assess whether the sites will be suitable for development water quality tests need to occur for all three sites and a suitable depth and test for nutrient availability need to occur for the mussel development site.
• If the sites are deemed suitable then it has been shown that mussel development may be viable using longline suspension or raft cultivation provided a small loan can be obtained to buy the initial equipment.
• Aquaponics was deemed as a more viable option than aquaculture and may be viable on a large-scale based on the industrial site. If development were to occur then detailed cost analysis must be conducted first.
• It may also be viable to place a demonstration unit of a lobster hatchery and visitors centre in the small site based next to the harbour if a small grant can be obtained. This may provide sufficient knowledge to obtain a large grant for a large-scale lobster hatchery to be based on the industrial site.
• Therefore it has been shown that aquaculture, aquaponics and a lobster hatchery are viable in Amble at different scales and if a development were to take place then detailed costing must occur before to ensure financial feasibility.

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3 http://www.nationallobsterhatchery.co.uk/
4 http://orkneylobsterhatchery.co.uk/
5 http://firthofforthlobsterhatchery.org.uk/
7 http://www.fao.org/docrep/x5744e/x5744e02.htm
10 http://www.aquaponics.org.uk/
11 http://www.mwg.utvinternet.com/iss_ma_impacts_shellfish.html