Scottish Shellfish Development
Critical Mass Model

Mussel production, Shetland: R. Cappell

REPORT

SUBMITTED TO

CROWN ESTATE SCOTLAND

&

ASSOCIATION OF SCOTTISH SHELLFISH GROWERS (ASSG)

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EXECUTIVE SUMMARY

The overall objective of this research commissioned by the Crown Estate Scotland is to support growth of the Scottish shellfish sector, particularly where development constraints are identified.

While there is continued growth in Shetland mussel production (now accounting for 74% of total Scottish production), mainland production has stagnated at between 1,500 and 2,500 tonnes for the last 15 years.

This research applies economic analysis to identify where collaborative working could contribute to the growth of shellfish operations. The team undertook background research, data collection and consultation to inform an economic model of mussel production.

Those consulted suggested that the factors that have contributed to the growth of Shetland's mussel sector (good growing conditions and supporting infrastructure plus council & community support) are absent or weaker in Scottish mainland sites.

Many of the constraints identified point to the benefit of public-sector assistance in (a) providing the planning & exploratory groundwork to remove some of the regulatory and biological uncertainties of site development and (b) reducing capital costs/risk through financial instruments and facilitating more collaborative working.

Farm scale viability

An economic production model was developed to explore the viability of various scales.

The model considers mussel production as a stand-alone venture. The model identifies scale-related capital investment and operating costs. It does not include development costs, which although site-specific (depending on survey & planning requirements), can be considerable and represent a further constraint to development.

The smallest scale presented is a 150t per annum farm, which is more than many Scottish farms currently produce. Very small-scale operations (<50t p.a.) are often within a lifestyle/crofting set-up. These are not viable as a separate enterprise, but mussel production can contribute to overall earnings where general equipment (fishing vessels) can be used and/or producers seek assistance from larger producers for some tasks such as at harvest.

The table below summarises model runs at a range of scales. The values and assumptions used are described in more detail in the main report. The results indicate that while gross earnings (EBIT[1]) are positive for all scales, the smallest scale presented (150t) results in a negative internal rate of return (IRR) and Net Present Value (NPV) over 10 years. The results also illustrate the production 'plateau' that can be experienced by operators seeking to increase the scale of their business. The 450t farm shows a marginal IRR and negative NPV due to the high cost of a second workboat. In practice, many operators look to reduce the investment required by purchasing second-hand or modified vessels.

Only 27.5% of Scottish mussel sites currently produce more than 200 tonnes. The financial model developed indicates that only marginal gross earnings are achieved from mussel farms producing 150 tonnes. Low mainland production may be a consequence of the sites not achieving the scale required to be viable stand-alone enterprises. Significant capital investment is needed to increase in scale, which can also be a barrier to growth.

The growth of mussel production throughout Scotland will require increased scales of production. This can be achieved through the re-structuring of existing licenced sites (not necessarily increasing total licenced tonnage within a loch) to establish farm units that are viable.

[1] Earnings Before Interest and Tax

Table 1 Farm production scale characteristics and financial performance

Farm scale	Farm 150	Farm 250	Farm 450	Farm 750
Scale				
total annual production (tonnes)	150	250	450	750
total length of grow-out line (m)	37,500	62500	112,500	187,500
no. lines	16.00	27	46.00	76
spat lines	2.00	3	5.00	8
Total seed required (Nos)	8.9 million	14.9 million	26.8 million	44.6 million
production lines harvested/yr	4	7	12	20
no workers	1	2	3	4
no managers	1	1	2	2
Cost & earnings				
labour cost	£ 80,000	£ 110,000	£ 190,000	£ 220,000
Total Cap Ex	£ 331,136	£ 486,696	£ 975,979	£ 2,056,571
Total Op Ex*	108,631	154,691	287,153	412,682
Revenue	£ 142,500	£ 237,500	£ 427,500	£ 712,500
earnings @ yr 7	£ 6,267	£ 43,056	£ 69,741	£ 152,119
EBIT ratio** @ yr 7	4%	18%	16%	21%
EBIT/tonne	£ 41.78	£ 172.22	£ 154.98	£ 202.83
Net Present Value	(£115,830.76)	£26,022.83	(£26,077.59)	£504,394.50
Internal Rate of Return	-6%	5%	3%	12%

*Operational expenditure = total expenditure - depreciation of capex (in year 7)

**Earnings Before Interest and Tax (EBIT) as a % of turnover

Loch-scale production

The mussel production model was then used to explore loch-scale scenarios to identify potential collaborative arrangements to increase scale and efficiencies. It identifies some of the development constraints and how some of these could be addressed, including community involvement and agency support.

Collaborative purchasing can over-come some investment hurdles, but this does present practical difficulties, particularly with shared equipment. The rental of vessel services (from larger-scale producers) can enable small-scale producers to increase production without the large capital expenditure required. Shared labour presents more collaborative benefit, reducing a significant operating cost.

The model illustrates that economies of scale can be achieved if resources are collectively pooled in various ways. However, only the closest collaborative arrangement of shared capital investment and labour results in a loch-wide performance that is close to that of a single large operator.

Collaboration outside of production may be more practical and beneficial, namely:

- Collaborative marketing (already evident for SSMG members);
- Start-up assistance (e.g. by establishing development areas or extending this to the aquaculture parks model where infrastructure and services are provided); and
- Collective decision-making (e.g. the Loch Roag Working Group and the CLAMS model in Ireland)

Greater involvement of the local community, particularly through some form of collaboration with an established producer could address some of the problems encountered at start-up of new sites.

Spat collection is a major production uncertainty in terms of quantity and quality of spat. For small scale operations, spat collection is cheaper than buying in all the spat required. At larger scales this speculative approach is counter-productive. If spat settlement is not as expected, a top-up with bought-in wild spat is needed and the comparative benefit of spat collection is quickly lost.

The uncertainty over the amount and also the quality of spat at many sites points to the potential need for a mussel hatchery that can deliver known volumes and quality controlled spat to producers.

RECOMMENDATIONS

- **Further model development**

The farm-level production model was used to identify development constraints and to inform loch-scale scenarios. It could be developed as a business planning tool for producers by creating a more user-friendly interface that enables more flexibility with different production assumptions & scales.

- **Hatchery feasibility**

The constraint of depending on unknown amounts of wild spat of variable quality (due to lack of genetic selection) points to the benefit of hatchery supply. The Shetland hatchery project is not configured to supply spat, but to test the feasibility of such a hatchery approach. Further work will be required to determine the viability and optimal location of a mainland hatchery for mussel and the potential to supply a growing industry.

- **Financial assistance**

The model illustrates that, even with 50% grant funding, other forms of financial support may be needed (bank guarantees etc.) to encourage investments in mussel production at smaller scales. Only larger tonnage operations appear to show the potential for expansion through re-investment.

- **Community involvement**

Consultation identified that uncertainties over planning approval and set-up costs represent further barriers to development that could be addressed through collaborative working and community involvement to promote preferred areas of development at a loch scale. The benefits of various enabling approaches (e.g. area of permitted development, aquaculture park, community interest group, etc.) should be explored in more detail to determine appropriate business structures.

- **Market study**

The model uses a constant, current price. It does not take into account price elasticity whereby increased supply of mussel into the current market could reduce prices without an equivalent increased in demand. A market study could explore how increased supply will fit with the demand side of the market. This should result in an industry conceived and producer supported marketing strategy to best ensure increases in production can maintain or improve the prices being achieved.

1 INTRODUCTION

This report by Poseidon Aquatic Resource Management Ltd (**Poseidon**) presents the outputs from research commissioned by **Crown Estate Scotland** to explore:

"Scottish Shellfish Development Critical Mass"

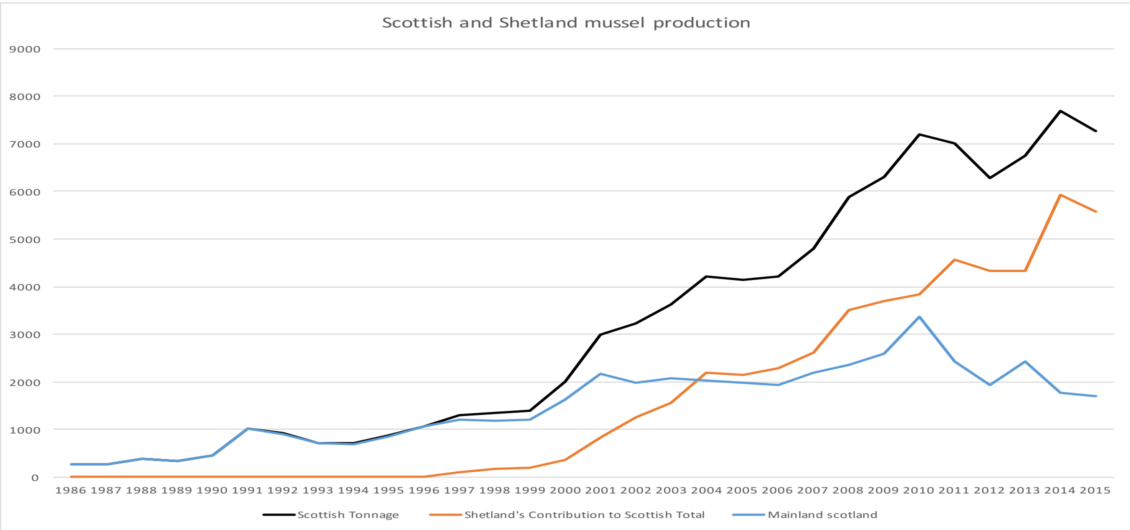
1.1 STUDY BACKGROUND AND OBJECTIVES

Scotland Food and Drink's 'Aquaculture Growth to 2030' gives a vision for the shellfish sector in 2030:

"Production will be more balanced across the regions, with current low-volume production areas gaining critical mass to support new infrastructure in these locations… Highly efficient farming practices will be the norm and costs of farming will be well understood and competitive."

Figure 1-1 below illustrates that, while there is a growth trend for Shetland production (albeit with dips in some years), mainland production has stagnated at between 1,500 and 2,500 tonnes for the last 15 years. Shetland now accounts for 74% of total Scottish production (Marine Scotland, 2017).

Figure 1-1 Scottish mussel production over the last 30 years



source: SSMG, 2016

The reasons for this disparity in development are varied, but are suggested to include Shetland's ability for rapid expansion through the uptake of unwanted salmon sites and more efficient operations with co-operation between Shetland producers. This research explores this premise through consultation and the economic modelling of production costs.

1.2 OBJECTIVES

The overall objective is to support growth of the Scottish shellfish sector, particularly where development constraints are identified. This research applies economic analysis to identify where collaborative working could contribute to the growth of shellfish operations.

1.3 APPROACH

The team used a combination of background research, data collection and consultation to inform an economic model that explores the viability of mussel production at various scales. The mussel production model was then used to explore loch-scale scenarios to identify potential collaborative arrangements to increase scale and efficiencies. It identifies some of the development constraints and how some of these could be addressed, including community involvement and agency support.

2 SCOTTISH SHELLFISH DEVELOPMENT

2.1 TRENDS IN THE SCOTTISH SHELLFISH SECTOR

The latest Scottish shellfish production survey reports 7,732 tonnes of mussel was produced for the table, representing a 6% growth in production in 2016 compared to 2015 (Marine Scotland, 2017). 11 companies accounted for 79% of the total mussel production in Scotland.

Shetland accounted for 5,686 tonnes (74% of the total), representing annual growth at around 3%, less than the Scotland total. However, the activity levels per region still differ significantly: in Shetland 74% of active sites produced mussel in 2016, compared to only 38% in Highland, 40% in Western Isles and 46% in Strathclyde.

Table 2 Business production levels by species, 2016

Species	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-200	>200	Total
Pacific oyster (000s)	11	1	1	0	2	2	2	0	0	1	2	6	**28**
Native oyster (000s)	1	0	0	0	0	0	0	0	0	0	1	0	**2**
Scallop (000s)	2	2	0	0	0	0	0	0	0	0	0	0	**4**
Queen (000s)	2	0	0	0	0	0	0	0	0	0	1	0	**3**
Mussel (tonnes)	4	1	5	4	0	2	4	1	2	2	4	11	**40**
Total	**20**	**4**	**6**	**4**	**2**	**4**	**6**	**1**	**2**	**3**	**8**	**17**	**77**

source: Marine Scotland, 2017

Table 2 illustrates the relatively small-scale production seen at many Scottish shellfish sites. Only 27.5% of mussel sites produce more than 200 tonnes.

Production for on-growing grew substantially again in 2016, rising to 2,619 tonnes from a relatively low base of 309 tonnes in 2012. This is dominated by Shetland, which accounted for 15 of 19 on-growing sites.

The number of people employed by the shellfish farming industry in Scotland was 315, an 8% decrease from the 2015 total.

Recent price rises for mussel indicates positive current market conditions, particularly for the premium MSC-certified Scottish production. These trends illustrate continued modest growth in the Scottish shellfish sector, despite national strategic plans for significant increases in production. The following section explore some of the reasons for this development trajectory.

2.2 THE SHETLAND MODEL

Consultees suggest that the production growth seen in Shetland results from (in no particular order of priority):

- Better sites: colder temps and more Grade A waters (and so no need to depurate)
- Better toxin profiles (Shetland sites are normally capable of year-round harvests)
- Seafaring & fishing community: Shetlanders generally have a natural affinity for marine based activities and historically have made a living from the sea
- Entrepreneurial spirit: there is more of a ‘can do’ attitude

- Council support: SIC has a positive outlook on aquaculture in general and support applications and provide funding through soft loans.
- Good infrastructure: many bays in Shetland have a marina or jetty for launching/basing support vessels whereas in Scotland there is often a need to build a jetty or look for suitable sites close to existing harbours.

2.3 CHALLENGES FACING THE MAINLAND SECTOR

Those consulted suggest that the factors that have facilitated growth in Shetland are absent or weaker for Scottish mainland areas. Other aspects include:

- Finance: access to finance is an issue for smaller companies further exasperated by cash flow issues with the long lead in time (3 years) before a company starts getting revenues.
- Competition for water space and infrastructure access with the yachting and tourism sectors.
- Mainland Scotland can suffer from NIMBYism whereas places like the Western Isles (which are keen to attract employment opportunities) are far more positive/welcoming.
- Regulatory constraints: Obtaining Planning permission, Marine Licence, Marine Scotland FHI Consent, Crown Estate Lease etc. It remains expensive, complex and with uncertain outcomes.
- Technical knowledge of farming location - It takes 4-5 years to learn each sites different farming needs due to environmental conditions such as: spat quantity and quality; spat-fall timing; fouling levels; current speeds; salinity, etc.
- Biological events. Most mussel farming companies that have ceased production have predominantly failed due to biological related issues or unexpected costs. For a new and growing business, the costs resulting from predation (e.g. the need for eider predation deterrence), fouling, biotoxin presence or poor spat collection can quickly make businesses unviable.
- Markets: as growth in the domestic market is slow (around 1% per year), the predicted growth in Shetland production capacity appears to cover this demand. There is a need to ensure a demand driver for the additional production proposed is clearly identified (e.g. the market growth seen in value-added convenience products). Large scale operations could feed into the European mussel market. However, wholesale markets typically exhibit low prices and instability.
- Employment: In some mainland areas there are many other employment options. Due to the nature of cultivation activities and uncertain returns, producers cannot compete with many of these industries. In addition, the rural location makes it difficult to attract and retain employees, but potentially less so on the islands.

Some of the mainland producers consulted suggest site availability, an often-cited reason for limited mainland development, was not a constraint in some areas. For example, in the Western Isles only 9% of consented water space is currently being farmed. It may be that the 'right' sites are not available; such as sites with good spat supply or where production expansion would be possible.

Many of the above constraints point to the benefit of public-sector assistance in (a) providing the planning & exploratory groundwork to remove some of the regulatory and biological uncertainties of site development and (b) reducing capital costs/risk through financial instruments and facilitating more collaborative working.

3 FARM VIABILITY

This section describes the farm production model developed under this project and presents the results at a range of scales of production.

The model considers mussel production as a stand-alone venture. The smallest scale presented is a 150t per annum farm, which is more than many Scottish farms currently produce.

Very small-scale operations (<50t p.a.) are often operated within a lifestyle/crofting set-up. While not viable as a separate enterprise, mussel production can contribute to overall income without being labour-intensive. Some production tasks can be serviced using general equipment or producers can seek assistance from larger producers at critical production stages such as harvest.

3.1 MODEL STRUCTURE

The Critical Mass Mussel model has been designed as a tool to determine any potential benefit of operating mussel farms in a collaborative (loch-wide) basis. It explores various options for a cluster of mussel farms located within the same loch that would share some key aspects of operations (including capital items) with the aim of reduced funding/investment requirements for each member of the cluster. The assumption is that through adopting a collaborative approach, small and medium sized mussel farms within a particular cluster would be able to reap the sort of benefits normally only achieved by large scale, well-financed ventures.

The model framework applies a simplified set of parameters to investigate and demonstrate the potential economic performance of mussel farms with differing production outputs starting from 150 tonnes per annum but with the cumulative loch-wide production target of 750 tonnes per annum.

Based upon interlinked spreadsheets, the model is driven by a set of values and assumptions derived from industry data and supported by additional information sourced from third parties or available in the public domain.

Data is handled and presented on an annual time frame with a 10-year horizon for the production plans and financial projections of the businesses. A projected Profit and Loss statement based on production parameters only was prepared for the theoretical companies and the year 7 data was chosen for analysis as this represented a potential stage when the companies would be expected to have reached full production output but before the need to replace key assets.

3.2 ASSUMPTIONS

The main assumptions were selected to incorporate and reflect current industry standards and up-to-date practices and are intended to simulate mussel growing conditions that are likely to be prevalent for operations based in relatively sheltered loch sites that can be found in mainland Scotland.

3.2.1 Systems & equipment

Spat operations

The options available within the model include buying in spat from third parties or collecting own spat with the latter being the default assumption. In both cases this relates to the use of wild mussel seed. It is assumed that the total length of spatting rope per longline is slightly less than that used for grow-out operations (9000 metres of spatting rope per 220 metre longline) although in practice this varies between sites, systems and companies.

Grow-out operations

The model presumes the New Zealand continuous rope culture system is used as the mussel grow-out technology with the assumed default set-up being a 220 meter longline with two headropes. Attached to this there is 10,000 metres of grow-out rope and the system is supported by 300 litre volume surface floats.

3.2.2 Production performance

Spat operations

The key assumption is that the spatting lines are collected, stripped and re-socked onto grow-out ropes within twelve months of having been set in the water. This assumes optimal performance and timing of placing the spat collection ropes into the water to avoid any need to collect, clean and re-set them due to fouling occurring prior to spat settlement.

Grow-out operations

The assumed duration is 2 years based on 1-year old spat being used to start the grow-out operations. Under such a scenario, the final high density of spat on the spatting lines means that there should be sufficient seed from each one metre of spatting lines to stock 2.5 metres of grow-out rope.

3.2.3 Additional inputs

The following data is also used in the model

Category	Parameter	Default value	Notes
Sales	Selling Price	£950 per tonne	Farm gate price in bulk bags, (non-depurated). Price reflects a realistic level of mussel being rejected by the customer due to broken shells or fouling
	Harvest size of mussels	21g (average live weight)	Equates to 40-50 mussel per kg
Production	Mussel mortality during grow-out phase	20%	
	Labour productivity	250T/pp (worker) and 500T/pp (skilled or manager)	These productivity levels assume a certain amount of automation (mussel stripping, grading and socking equipment) and access/use of a suitable boat and shore facilities.
Investment	EU grant funding	50%	Assumes all Capex items required are eligible for and receive 50% grant funding
	Capex requirements	Circa £1000/tonne of mussels produced including 5% contingency	This relates only to the initial purchase of capital items such as specialist production and harvesting equipment, workboat (but does not allow for a large, custom built boat) and shore support installations.
Funding	Type of funding	Share capital only (no debt finance)	In practice, some level of debt finance should be available particularly for an established business that shows it is operating on an economically viable basis.
Financial	Depreciation	Straight line method	Model assumes most assets have a useful life of more than 10 years. The exceptions to this are: spat, grow-out rope & accessories (e.g. snoods, brackets), vehicles and forklift. An allowance has been included in the model to replace these in year 8.

3.2.4 Model limitations

NOTE: the model does not include the time and costs associated with starting up a new business (i.e. site selection, obtaining the various necessary licenses, permits and permissions), the cost of debt finance which is likely to be a key factor in considering the commercial viability of any business and nor does it include the cost of depurating, end product testing, marketing or sales all of which are important financial considerations in business planning.

A number of financial indicators are presented in the report for comparative purposes. Other indicators can be calculated from the model.

The model does not include dynamic changes in environmental parameters that would be expected to have a significant impact upon the mussel farm's performance. Examples include:

- The carrying capacity of a site (or loch)
- Variable factors affecting mussel growth e.g. water temperature, depth and current speeds and food availability (microalgae concentration levels)
- Heavy predation or spoilage levels (due to shell fouling) [Note a fixed mortality allowance is included in the model – but it assumes only moderate losses from such factors]

3.2.5 Model outputs

The model includes the following 10-year financial projections:

- Profit & Loss
- Balance sheet
- Cash Flow schedule

Sensitivity analysis has been applied using changes to key production parameters to show the potential impact on the businesses. The selected criteria are as follows:

Table 3: Sensitivity analysis parameters and their impact on company financials

Parameter	Base case	Impact on financial results
Mussel seed cost	£282/tonne	A decrease in costs has a positive impact
Mortality levels during grow-out	20%	A decrease in mortality has a positive impact
Density of mussels on grow-out rope at harvest (Kg per metre)	4Kg/metre	An increase in mussel density has a positive impact
Labour (increase or decrease in overall labour costs)	Variable[2]	A decrease in costs has a positive impact
Sale Price (£/Kg)	£950/tonne	An increased selling price has a positive impact
Average weight of mussels when harvested (grams)	21g (60mm)	An increase in mussel weight has a positive impact
Repairs and Renewals costs[3]	3% of Capex	A decrease in costs has a positive impact

[2] Labour costs depend on production output and the mix of staff categories (manual or managerial) employed

[3] In this model the 'Repairs and Renewals' cost is a direct reflection of the level of capital expenditure incurred by a company on purchasing assets (with the assumption that 50% EU grant funding is secured on all assets purchased).

The sensitivity analysis function in the model allows change to the above parameters of between +20% to -20% (in 5% increments) and shows any changes that this has on the revenue and earnings in a given year. This is considered as Earnings Before Interest and Tax (EBIT). The EBIT ratio describes these earnings as a proportion of annual income.

Example: The assumed base case level of mortality during the grow out phase is set at 20% in the model. The sensitivity analysis then applies changes (in 5% increments) to the base case such that a positive change of 5% in the mortality level (i.e. applying a +5% sensitivity) to the 20% base case assumes a mortality rate of 21% [20% + (20% x +5%)] NOT a mortality level of 25%. This has a negative impact on a company's financial performance (as it would result in lower revenues but the same costs and hence the EBIT is reduced).

3.3 RESULTS

3.3.1 Production scales

Four farm level production scenarios were selected (Table 4) to explore farm scale viability. These were then used as the basis for developing the comparative loch-wide scenarios described in section 4. Table 4 presents some of the production characteristics that the model uses at the four scales of production and the comparative financial performance of those farms.

Table 4 Farm production scale characteristics and financial performance

Farm scale	Farm 150	Farm 250	Farm 450	Farm 750
Scale				
total annual production (tonnes)	150	250	450	750
total length of grow-out line (m)	37,500	62500	112,500	187,500
no. lines	16.00	27	46.00	76
spat lines	2.00	3	5.00	8
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*Operational expenditure = total expenditure - depreciation of capex (in year 7)

**Earnings Before Interest and Tax (EBIT) as a % of turnover

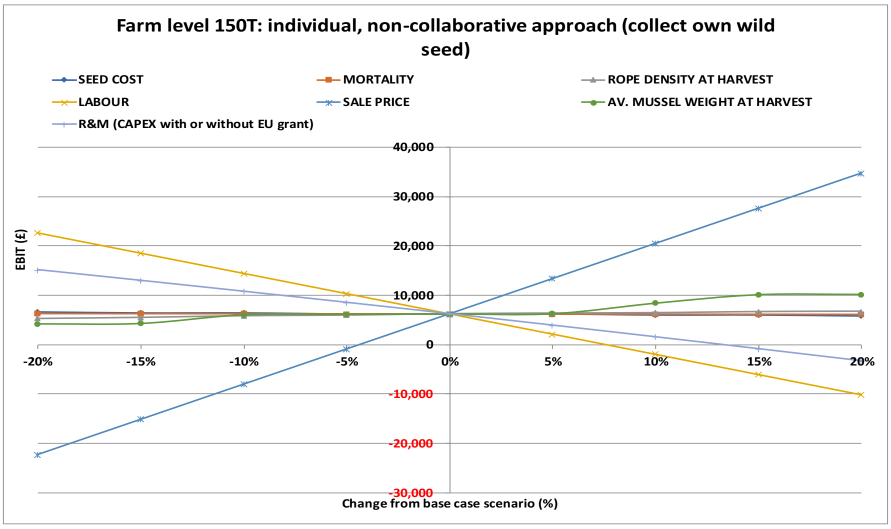
The results indicate that while gross earnings (EBIT) are positive for all scales, the smallest scale presented (150t) results in a negative internal rate of return (IRR) and Net Present Value (NPV) over 10 years. The results also illustrate the production 'plateau' that can be experienced by operators that seek to increase the scale of their business. The 450t farm shows a marginal IRR and negative NPV due to the high cost of a second workboat. In practice, many operators look to reduce the investment required by purchasing second-hand or modified vessels.

3.3.2 Sensitivity analysis

The results of the sensitivity analysis on earnings (EBIT) are shown below for three scales of farm (150t, 250t, 750t per annum). In addition to sales price, which impacts performance most significantly, the next largest impact on financial performance comes from changes to labour costs. Seed costs also noticeably influence performance. Other variables are less significant.

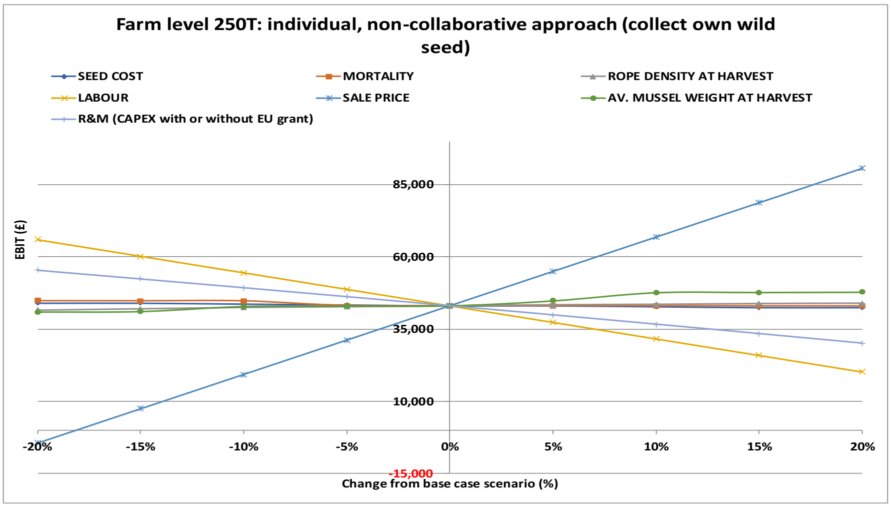
150 tonne per annum farm

Figure 3-1: Sensitivity analysis graph 150 tpa



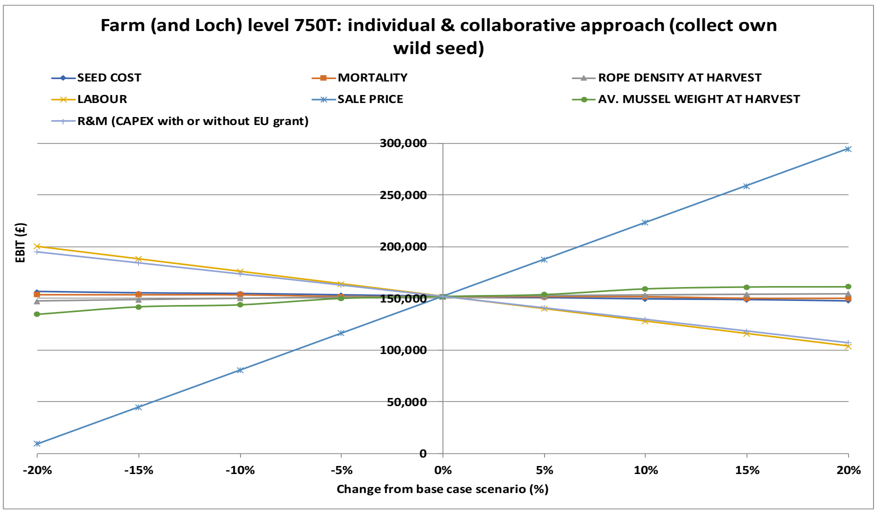
250 tonne per annum farm

Figure 3-2: Sensitivity analysis graph 250 tpa



750 tonne per annum farm

Figure 3-3: Sensitivity analysis graph 750 tpa



3.3.3 Implications of water categorisation

The model assumes that mussels are sold 'as is' immediately after harvesting. However, in practice mussel farms may be located in waters classified as category B, which means production marketed live will require to undergo a process of purification (depuration) prior to human consumption. This process is both expensive, time consuming as well as being a potential stressor to the mussels. Estimations have indicated that capital expenditure on systems and equipment can range from £50,000 to £150,000 whilst the increased operational costs associated with carrying out this labour-intensive process can reportedly be as much as £400 per tonne[4].

If categorisation as B grade waters results in the need to depurate, it will inevitably reduce the viability of the farms.

The potential for a relaxation in the required duration of this process from 42 hours to as little as 6 hours suggests these costs could be reduced in the future, but details have yet to be agreed with the competent food authorities on a local basis. Regardless of the cost and inconvenience issues, a more intransigent factor is that many of the multiple retailers do not want products sold in their stores that originate from category B waters as this creates an 'image' (marketing) problem.

3.3.4 Spat collection versus buying-in spat

The model enables a comparison of the costs of collecting spat (incurring the costs of necessary lines and boat days) against the costs of purchasing spat (based on quoted price per tonne for available spat from Ireland plus delivery cost). The costs presented are based on consultation with the industry. Irish spat is used as the most available source of spat at the time of writing (€230/tonne plus £1,500 transport costs per 20t lorry = £282[5]). It assumes that the operator will target the production capacity of the farm, i.e. a 250t farm will require enough seed to produce 250t rather than accepting reduced production output.

Collecting 100% of the required spat at the farm site is usually cheaper than buying in wild spat. The assumptions made in the model suggest this may not be the case for large farms where a second (dedicated) workboat is needed in order to undertake spat collection operations. While large amounts of seed have been available for sale in recent years, a large-scale farm may find it difficult to source 100% of its spat from spat suppliers on a regular basis and this is still from wild sources with unknown levels of hybridisation.

Industry consultation revealed that the amount of spat being collected is irregular year to year (due to reduced amounts of spat in the water and/or fouling of spat ropes with other organisms preventing spat settlement), requiring bought-in spat to top-up spat collection. There is also a perception in some locations that there is less spat in the water than in previous years. In addition to 100% spat supplied through collection and 100% spat bought in, two scenarios are explored whereby 75% and 50% of spat is collected, which is then topped-up to 100% by bought-in spat. The assumption is that all the costs for 100% collection are still incurred as spat ropes must still be worked irrespective of percentage coverage. The bought-in seed is therefore an additional cost to the producer. At smaller scales of production these additional costs still do not exceed the higher cost of 100% bought-in spat. However, at the larger production scales (450t and 750t) the purchase of seed to top-up any short-fall in spat collection is a larger total cost than buying in 100% of spat. This negatively impacts farm earnings as illustrated in the figure (b) and table 4 below.

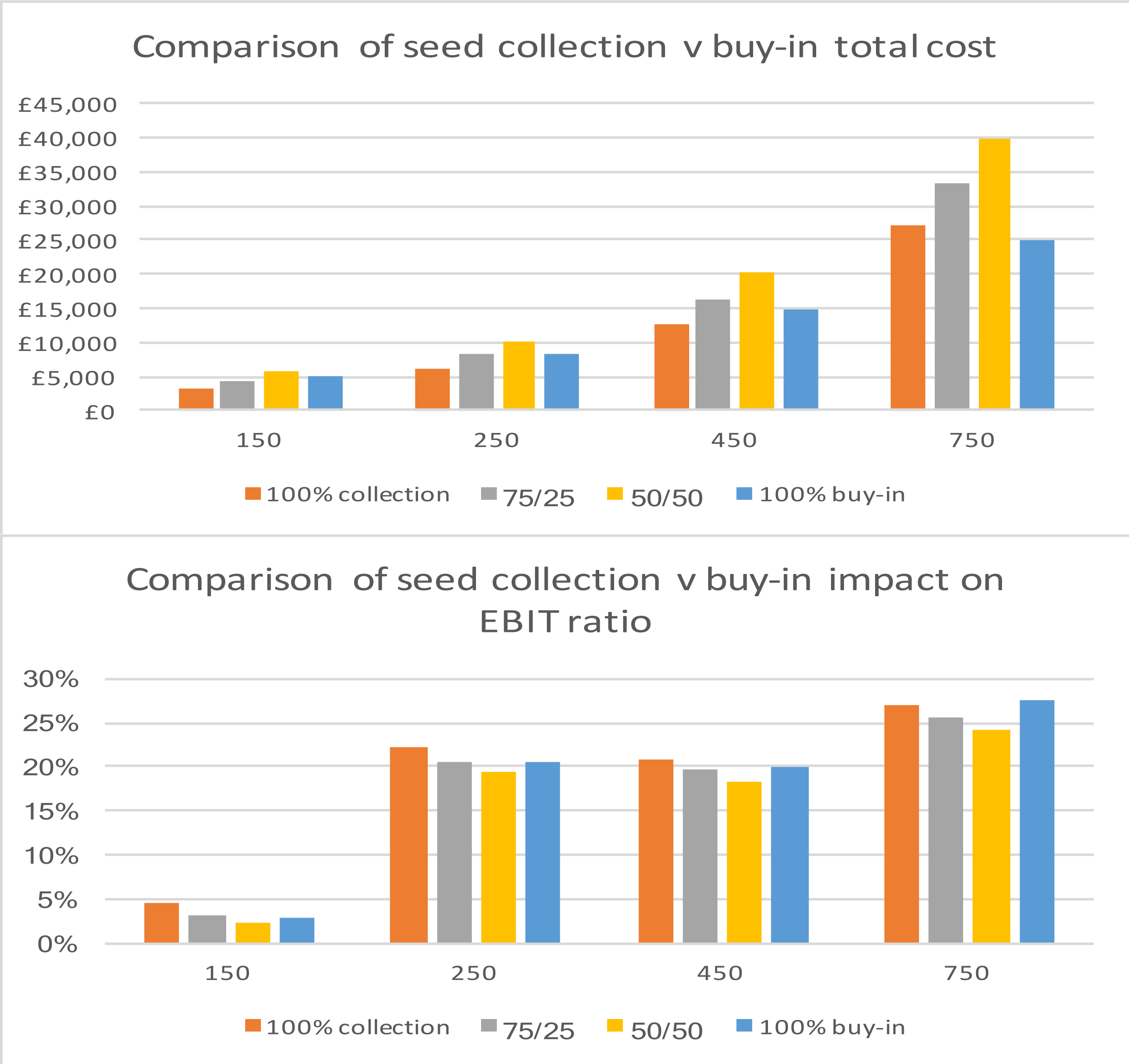
[4] http://www.shellfish.org.uk/files/PDF/68146SAGB%20Farming%20WQ%20Leaflet%20-%20FINAL.pdf

[5] based on exchange rates August 2017

Table 5 Total cost of seed and impact on earnings ratio for a range spat supply scenarios

	total cost of seed				EBIT			
	100%	75/25	50/50	100%	100%	75/25	50/50	100%
Scale of farm	100% collectic	75/25	50/50	100% buy-in	100% collectic	75/25	50/50	100% buy-in
150	£ 3,129	£ 4,374	£ 5,620	£ 4,982	4.60%	3.3%	2.4%	2.90%
250	£ 6,116	£ 8,192	£ 10,268	£ 8,304	22.1%	20.6%	19.4%	20.5%
450	£ 12,658	£ 16,395	£ 20,131	£ 14,946	20.9%	19.7%	18.4%	20.0%
750	£ 27,211	£ 33,439	£ 39,667	£ 24,911	27.1%	25.7%	24.3%	27.6%

Figure 3-4 Spat collection versus bought-in wild spat. (a) total cost and (b) earnings



A comparison of performance shows that at smaller scales (150t and 250t) even if only 75% of spat can be collected, the cost of buying in the remainder is less than buying-in 100% of spat from suppliers of wild spat. This changes for larger scale farms: spat is more expensive for a 450t farm when only 75% of expected spat is collected compared to buying-in 100% in the first place.

Several producers consulted mentioned the problem of thin shells resulting in more breakages at harvesting and therefore a lower yield. It is understood this may result from hybridisation with *M. trossulus* and/or environmental factors. This increase in mortality (beyond the assumed 20% level used as the default in the model) is a reduction in yield and in terms of sensitivity has the same impact as reduced prices, rather than mortality during grow-out. In effect, a 250t farm has all the costs of a 250t farm without all the expected revenue. The sensitivity analysis presented above shows such changes to significantly impact earnings (EBIT).

A final aspect to the decision of whether to buy-in spat is business planning. Without knowing year to year what amount and quality of spat can be collected and the reliance on bought-in spat, it is very difficult for the producer to plan effectively activities and expenditure, which can have major implications for cash flow.

The issues described above suggest that, even though buying in wild spat is more expensive for smaller farms, the benefits of knowing your stocking levels and the ability to plan accordingly makes buying in spat an attractive proposition. This of course assumes that good quality spat is available to purchase from the wild (the level of hybridisation is not known), which points to the potential for hatchery supply (discussed further below).

3.4 DISCUSSION

The results show that all four scales of mussel farm result in positive earning under the assumptions used in the model. However it is clear that the smallest of these (150 tonnes pa output) would be very susceptible to relatively small (negative) changes in operating conditions.

Table 6: Earnings per tonne of production for the three farm output scenarios (yr 7)

Production output (tonnes)	150	250	450	750
EBIT per Tonne produced	£41.78	£172.22	£92.99	£202.83

The sensitivity analysis shows that for a company producing only 150 tpa almost any adverse changes to the sale price or the cost of labour would result in a loss. Such changes could occur for reasons outside the control of the company, for example if a higher proportion of mussels were unsaleable due to higher than expected levels of shell fouling or there is an increased incidence of broken mussel shells through damage occurring during harvesting.

The other variable that is highlighted through the sensitivity analysis as having a potential negative impact on earnings is the cost of repairs and maintenance (R&M). Since this figure is derived in the model directly from the level of capital expenditure incurred through the purchase of assets (Capex), if operating as standalone, independent farms then the smaller mussel farming companies are likely to be more constrained in what equipment and systems they can buy and thus are more likely to need to improvise or work under less efficient operating conditions.

The sensitivity analysis of the 250 tpa farm shows there is only one scenario where changes in the key costs investigated would result in a loss to the company (i.e. if the sale price dropped by 20%) so clearly this level of production provides a more robust business case. Nevertheless, the level of projected earnings (at £43,000) needs to be put into perspective; in terms of cash flow it equates to enough money to cover just over two and a half months of operating costs (assuming annual operational costs were to be averaged out to a stable monthly figure). Alternatively, it equates to just under 20% of the projected capital expenditure (Capex) needed to invest in assets to set up the farm.

The earnings from the largest farm (750 tpa) is considerably better than either of the other farm sizes as it benefits from economies of scale. This result is achieved even though at this level of production it has been assumed that a company would need to purchase two workboats rather than just making do with one. It is assumed that at this higher annual production level, a second workboat would be justified if it is dedicated to mussel seed operations (laying and harvesting spat lines and re-socking onto grow-out ropes). This comparatively higher capex for 750tpa is illustrated in Table 7.

Table 7: Comparison of capital expenditure ratios for the four farm output scenarios

Production output (tonnes)	150	250	450	750
Capex per mussel seed stocked	£0.037	£0.033	£0.036	£0.046
Capex per tonne of mussels produced	£2.21	£1.95	£2.17	£2.74

The expected need for a second workboat at larger scales means that while a farm at 450 tpa shows reasonable earnings, it achieves a lower level of profitability than the 750t farm or indeed the 250t farm. These variations in the level of capex expenditure between farms with different production outputs reflects a wider issue associated with ‘production plateau’s’ wherein farms can find it difficult to progress to the next level of production output due to the disproportion change in the level of investment and resources needed to expand operations. In discussions with industry representatives it was suggested that one such plateau occurs at a production level of around 400 tpa with the purchase of a second workboat.

3.5 SUMMARY

On a farm level basis there are clear financial benefits to having a larger production output based on the production scenarios investigated and modelled for this project. A 150t farm only shows marginal positive earnings even with 50% grant support for capital expenditure provided at start-up. Sensitivity analysis shows that this marginal viability can quickly be lost with very small negative changes to prices or through higher costs or lower than expected yields.

One such addition cost is depuration (or purification). If categorisation as B grade waters results in the need to depurate, it will inevitably reduce the viability of the farms.

There are production plateaus wherein a company that looks to invest in the necessary infrastructure to substantially grow its production becomes less profitable at certain levels of production output. This is generally at the point where a second workboat (and the necessary labour to operate it) is required.

Sensitivity analysis show that companies with a larger output are more robust and therefore should be able to cope better with any adverse changes in operating conditions. If these traits could be mirrored through several smaller companies acting together in a collaborative manner (and coordinated and controlled through an over-arching entity) it could be one way of stimulating the expansion of the Scottish mainland mussel farming sector.

The amount and quality of spat collected from the wild is uncertain. Comparing spat collection to bought-in spat shows that it is still beneficial for smaller scale operators to supplement collection rather than switching to 100% bought spat. However, at larger scales, the cost of having to supplement collection exceeds the cost of buying in 100%.

When the uncertainty of spat collection is considered against a consistent supply of good quality spat harvesting, for all scales of operation the benefits of purchasing spat are expected to outweigh the cost. The consistent provision of good quality spat is a clear benefit of an effective hatchery operation.

4 COLLABORATIVE WORKING

4.1 LOCH SCALE SCENARIOS

The farm production model described in the previous section was used to explore loch-scale scenarios involving varying scales of farm that collaborate to different extents. For comparative purposes these scenarios all aim for a total production of 750 tonnes per annum (tpa), which also enables comparison with a single 750tpa operator.

4.1.1 Loch 1: 5 x 150t farms

While a single loch is producing a significant volume of mussels (750tpa) all five operators are acting independently.

4.1.2 Loch 2: 3 x 250t farms

2a: 3 x 250t farms with no collaboration

This option is to enable comparison with the collaborative approaches explored in 2b and 2c.

2b: 3 x 250t farms with collaboration on Capital expenditure items

This option considers 250tpa production scales, but with some capital expenditure shared between the three producers. It assumes each farm can operate with the same workboat and storage as a 150tpa, with the capital costs of a second workboat and secondary storage for additional capacity (as per a 250tpa farm) are shared evenly between the three with spend spread over ten years.

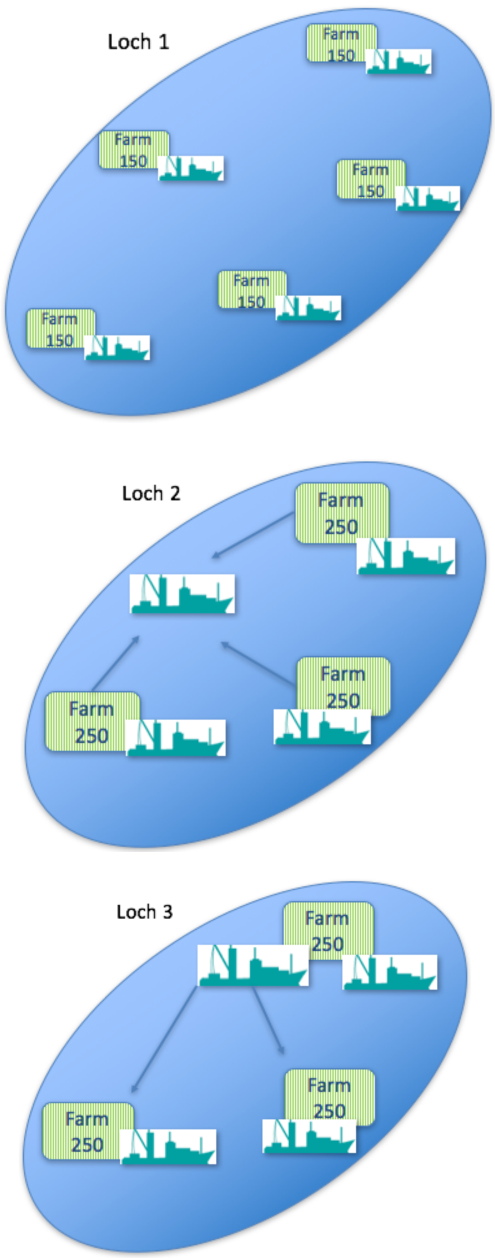
2c: 3 x 250t farms with collaboration on the same capex items plus some shared labour.

This option considers the same capex as 2b, but with a shared labour cost for two workers (as per a 250tpa farm), which may be a more likely arrangement if a second workboat is shared.

4.1.3 Loch 3: 1 x 250t farm providing 2nd vessel services to 2 x 250t farms

This assumes a 2nd 250tpa capacity workboat is purchased by one farm and this, along with 2 boat handlers, is leased at a cost of £325 per day (estimated boat costs plus 15%) to 2 other farms to enable them to achieve 250tpa.

Figure 4-1 Schematic of loch-scale scenarios



4.2 RESULTS

The table below summarises the differences in operation and performance resulting from the various scenarios.

Loch 1 shows that with no farms benefiting from economies through collaboration, the financial result is the same as single 150tpa farms, i.e. marginal EBIT ratio of around 5% (if 100% of spat is collected at the site). Loch 2a shows the better performance of larger 250tpa farms, but each continues to operate independently.

Loch 2b reduces initial total capex on boat and associated equipment down from £510,000 to £430,000 per farm. This is not found to benefit overall performance when annual contributions to the shared cap ex are factored in as additional operating expenditure.

The benefit of shared labour costs is evident in Loch 2c. Sharing just one worker across 3 farms gives a 10% labour cost saving and results in an overall performance for these farms that comes closest to a single 750tpa operation.

Rather than shared operations, Loch 3 explores the provision of services by one of the operators to the other two. Purchasing a second vessel and then leasing the vessel for 200 days per year only results in a less profitable outcome for the farm supplying the services. It is only when the vessel is leased for 240 days that the additional revenue from leasing results in the same earnings achieved as a single 250tpa farm.

At the pricing levels applied, for the two farms operating boats of 150tpa capacity and then leasing vessels services for 120 days a year to achieve 250tpa capacity shows a lower level of earnings compared to 250tpa farms owning the larger capacity vessels.

The rental services are an additional revenue to the supplier farm (resulting in a similar performance to a 250tpa farm that is only producing mussel. For the smaller farms, even though cap ex is lower to achieve the 250t production levels, the cost of renting the equipment from the larger farm results in lower profitability compared to a 250tpa farm using its own equipment. Overall relative profitability across the three businesses combined is lower than if three farms operated at 250tpa independently. The main benefit is from considerably lower capital expenditure to achieve the same level of production.

The relative profitability and therefore desirability of the arrangement in Loch 3 depends on the price at which vessel services are set, the number of days required and the timing of those days. It also points to the need for vessel service providers to supply more than two farms to achieve sufficient usage of the second work boat. However, it may be difficult for just two farms to each lease 120 vessel days without there being clashes and a lack of availability. This indicates the need for significant collaboration/planning between the three producers.

Table 8 Comparison of loch scale scenarios

	Loch 1	Loch 2a	Loch 2b	Loch 2c	Loch 3	750t farm
Variable						
no. farms	5	3	3	3	3	1
total production	750	750	750	750	750	750
no workers	5	6	6	5	7	4
no managers	5	3	3	3	3	2
labour cost	£ 400,000	£ 330,000	£ 330,000	£ 300,000	£ 360,000	£ 220,000
Total Cap Ex	£ 1,655,681	£ 1,532,082	£ 1,290,845	£ 1,290,845	£ 898,044	£ 2,056,571
Shared cap ex	n.a	n.a	£ 757,500	£ 757,500	n.a	n.a
% of p.a capex			2%	2%		
Total Op Ex*	536,581	457,998	472,168	453,248	505,378	412,682
Shared op ex	n.a	n.a.	n.a.	60,000	n.a	n.a
% of p.a. opex				13%		
earnings @ yr 7	£ 31,333	£ 129,167	£ 117,536	£ 147,536	£ 92,369	£ 152,119
EBIT ratio** @ yr 7	4%	18%	16%	21%	12%	21%
EBIT/tonne	£ 41.78	£ 172.22	£ 156.72	£ 196.72	£ 105.66	£ 202.83
Net Present Value	(£579,153.82)	£78,068.48	(£121,220.29)	£117,572.36	(£230,111.64)	£504,394.50
Internal Rate of Return	-6%	5%	2%	5%	0%	12%

*Operational expenditure = total expenditure - depreciation of capex (in year 7)

**Earnings Before Interest and Tax (EBIT) as a % of turnover

4.3 DISCUSSION

This analysis has focused on areas where consultation identified that collaboration or collective action may prove beneficial. The model illustrates that economies of scale can be achieved if resources are collectively pooled in various ways. However, only the closest collaborative arrangement of shared capital investment and labour results in a loch-wide performance that is close to a single large operator.

Consultation with producers identified the practical limitations to collaboration. Differing production systems and cycles mean that requirements for certain equipment may differ, as will the timing and usage of that equipment.

Theoretically pooling resources is more profitable for producers than the rental of vessel services, but this brings with it the practical issues of who will purchase, repair, maintain and own any shared equipment. Trust is a key issue in any such collaborative arrangements and operators are generally not of a scale that enables strategic planning and co-ordination to this degree.

With the economies of scale evident with a single 750tpa operator, ultimately one operator within a loch may buy out other capacity. However, such consolidation has not happened to date in the mainland shellfish sector. This may be because all operators have not achieved the necessary scale to consider taking over other operators in a water body. With closures due to biotoxins there is also an incentive to spread risk across different water bodies rather than consolidate within one (even though this would provide the efficiencies sought).

Instead the current situation for Scottish mainland producers persists where collaboration only occurs to the extent of larger operators assisting small scale producers on an ad-hoc basis as and when their own requirements allow.

Developing the arrangements for use and upkeep of common assets and ownership of those assets is complex. Additional effort is required to co-ordinate with other operators, which is difficult for time-poor small business owners that often have other occupations. A significant level of trust is required to achieve such co-operation, which is difficult to establish between operators that may perceive each other as competitors.

This points to the need for either:

(a) an independent third party that can manage an agreed system for collaborative purchasing and use of equipment in an equitable manner.

(b) A private sector supplier of services to producers

Infrastructure such as piers & jetties and other assets such as despatch facilities and transport and distribution links would facilitate the use of shared assets and further enhance collaborative production activities.

Other areas of potential collaboration include group purchasing and group marketing. There is already extensive collaboration on marketing through the Scottish Shellfish Marketing Group (SSMG) and this area of collaboration will not be explored further here.

France is a good example of group purchasing in the shellfish sector using a cooperative approach. A 'cluster' approach may be more practical for Scotland where several farms in a locality can work together on certain cost items (e.g. purchasing of spat sharing freight costs or shared waste provision). This may require facilitation by a third party to instigate such discussions.

There is also the potential for collective action in start-up. This could be led or facilitated by public bodies to establish Aquaculture Development Areas (ADAs) where all the necessary licensing is in place for production sites in a water body (at viable scales) and operators then lease those sites. This reduces start-up costs, time and the uncertainty of consenting that can hinder financing and planning. Further support, including infrastructure and services could be provided in addition to leasing of sites[6].

There are benefits to decision-making at a water-body or loch-wide scale. This is already evident in planning and management in other sectors (such as salmon farming's Area Management Agreements) and other countries (such as the CLAMS model developed in Ireland[7]). The benefit of more regular engagement with other stakeholders on certain issues is increasingly recognised. Operators in some lochs have moved in this direction, for example the Loch Roag Working Group (see Box 1).

Box 1 Loch Roag Working Group

The group was started in 2014 and incorporates a range of stakeholders including anglers, creel fishermen and environmental groups. The Group discusses common issues including navigation, marine litter/waste management and organizes activities such as beach clean-ups. It functions based on a consortium agreement and a key part of that means no minutes from meetings are circulated, so whatever is said and agreed in the room during the meetings, stays in the room. Some of the producers involved believe more of such groups could be beneficial for mussel farmers as they would provide a confidential means of communication between stakeholders.

This analysis has highlighted the potential benefits of collaboration in seed supply. The ability to spread the risk of operations through better planning seed supply would give greater certainty in production and avoid the significant costs of insufficient seed collection. Pooling resources in this area via a hatchery could also address the major concerns expressed over wild seed quality, hybridisation with *M. Trossulus* and disease management.

[6] As with the Aquaculture Parks seen in Malaysia for lobster and shrimp and the offshore mussel production developed in Portugal. For further details: https://www.researchgate.net/profile/Mohammad_Noor_Amal_Azmai_amal_Mna/publication/317616468_Transforming_the_Aquaculture_Industry_in_Malaysia/links/594394b5a6fdccb93ab51ec6/Transforming-the-Aquaculture-Industry-in-Malaysia.pdf

http://www.aquaspace-h2020.eu/?page_id=12735

[7] Co-ordinated Local Aquaculture Management System (CLAMS) see: http://www.bim.ie/clams/

A more certain supply of seed for stocking will improve the ability to produce a robust business case at start-up and to plan future growth in scales of production.

Involvement of community

The involvement of the local authority and the local community in the development of an area can be beneficial to the developer as the planning approval and consenting process is likely to be shorter and more certain if local interests are generally supportive of a development. That support could be expected to be increase in line with how involved the community is in a development. One example of community involvement in shellfish production is Porlock Bay Oysters (see Box 2).

Box 2 Porlock Bay Community Oyster Production

In 2012 Porlock Parish Council set up ' Porlock Futures' to improve employment in the Porlock area. In 2013 a project to grow and sell shellfish in Porlock Bay within the Bristol Channel began. A Community Interest Company called Porlock Futures C.I.C. was established with all profits used for the benefit of the community of Porlock. The company was set up using loans from over 140 households and businesses (amounting to over £65,000) together with a grant from Power to Change of £75,000. Trading as Porlock Bay Oysters and employing 7 part time staff, the company initially stocked 3 tonnes of oysters in 2016, supplying local restaurants and food outlets. It operates a small boat and a depuration plant to support further growth of the business.

Source: http://www.porlockbayoysters.co.uk

The benefits to the local community from any development could extend beyond direct employment, indirect and induced expenditure in the local economy if community involvement were formalised. With a vested interest in a development, the local community has more influence upon a development to see that it is most appropriate to their interests (e.g. scale, visual impact or location of onshore infrastructure) and of economic benefit.

There are already a lot of consented sites, many of which do not have equipment in the water. This work has demonstrated that to move this consented capacity into production, some aggregation of consented sites is required to achieve a viable scale of production. In many waterbodies, this may not be a net expansion of consented capacity at all, but a re-structuring of consented production.

As described in previous sections, the development of shellfish production may be stymied by several factors, including:

- The identification of good sites suitable for both spat collection and on-growing;
- The uncertainty and associated costs of gaining planning permission from the local authority;
- The scale necessary to be viable is off-putting to commercial start-ups;

These issues point to the potential benefit in collaboration between community interests and an established operator. The local authority could facilitate shellfish development through supporting the investigative studies and considering infrastructure necessary for suitable sites that are identified.

The exact structure of community collaborative arrangements could vary depending on the parties involved, their objectives and the oversight required. A Community Interest Company (CIC)[8] (as with Porlock Oysters described in Box 2) includes a statutory asset lock that should see the site lease and associated infrastructure remain within community ownership, while the management and harvesting of shellfish from the site(s) could be through an arrangement with a private sector operator. A Limited Liability Partnership (LLP) could be formed between a private sector operator and community interests as general and limited partners respectively[9].

It is recommended that local authorities take advice to determine the most appropriate structure for development arrangements that deliver the safeguards and benefits sought by local communities.

[8] Guidance on CICs: https://www.gov.uk/government/publications/community-interest-companies-business-activities/cic-business-activities-forms-and-step-by-step-guidelines#form-a-community-interest-company-cic

[9] Guidance on LLPs: https://www.gov.uk/guidance/set-up-and-run-a-limited-partnership

5 CONCLUSIONS

5.1 CONCLUSIONS

2016 saw modest growth in Scottish mussel production, increasing to 7,732 tonnes. Shetland accounted for 74% of production with 74% of its active sites producing shellfish. Elsewhere in Scotland, far fewer active sites and far smaller tonnage businesses reported production.

Only 27.5% of Scottish mussel sites currently produce more than 200 tonnes. The financial model developed indicates that only marginal gross earnings are achieved from mussel farms producing 150t. Low mainland production may be a consequence of the sites not achieving the scale or level of collaboration required to be viable stand-alone enterprises.

The growth of mussel production throughout Scotland will require increased scales of production. This can be achieved through the re-structuring of existing licenced sites (not necessarily increasing total licenced tonnage within a loch) to establish farm units that can operate viably.

Significant capital investment is needed to increase in scale, which can be a barrier to growth. The sector also encounters production plateaus, which often relates to the scale and number of workboats required for harvesting.

Collaborative purchasing can over-come some investment hurdles, but this does present practical difficulties, particularly with shared equipment. The rental of vessel services (from larger-scale producers) can enable small-scale producers to increase production without the large capital expenditure required. In the long-term, however, farms are likely to be more profitable with their own equipment. Shared labour presents more collaborative benefit, reducing a significant operating cost.

Collaboration outside of production may be more practical and beneficial, namely:

- Collaborative marketing (already evident for SSMG members);
- Start-up assistance (e.g. by establishing ADAs or extending this to the aquaculture parks model where infrastructure and services are provided); and
- Collective decision-making (e.g. the Loch Roag Working Group)

Greater involvement of the local community, particularly through some form of collaboration with an established producer could address some of the problems encountered at start-up of new sites.

Spat collection is a major production uncertainty in terms of quantity and quality of spat. For small scale operations, spat collection is cheaper than buying in all spat. At larger scales this speculative approach is counter-productive. If spat settlement is not as expected, a top-up with bought-in spat is needed and the comparative benefit of spat collection is quickly lost.

The uncertainty over the amount and also the quality of spat at many sites points to the potential need for a mussel hatchery that can deliver known volumes and quality controlled spat to producers.

5.2 RECOMMENDATIONS

Further model development

The farm-level production model was used to identify development constraints and to inform loch-scale scenarios. It could be developed as a business planning tool for producers by creating a more user-friendly interface that enables more flexibility with different production assumptions & scales.

Hatchery feasibility

The constraint of depending on unknown amounts of collected wild spat of variable quality (due to lack of genetic selection) points to the benefit of hatchery supply. The Shetland hatchery project is not configured to supply spat, but to test the feasibility of such a hatchery approach. Further work will be required to determine the viability and optimal location of a mainland hatchery for mussel and the potential to supply a growing industry.

Financial assistance

The model illustrates that, even with 50% grant funding, other forms of financial support may be needed (bank guarantees etc.) to encourage investments in mussel production at smaller scales. Only larger tonnage operations appear to show the potential for expansion through re-investment.

Community involvement

Consultation identified that uncertainties over planning approval and set-up costs represent further barriers to development that could be addressed through collaborative working and community involvement to promote preferred areas of development at a loch scale. The benefits of various enabling approaches (e.g. area of permitted development, aquaculture park, community interest group, etc.) should be explored in more detail to determine appropriate business structures.

Market study

The model uses a constant, current price. It does not take into account price elasticity whereby increased supply of mussel into the current market could reduce prices without an equivalent increased in demand. A market study could explore how increased supply will fit with the demand side of the market. This should result in an industry conceived and producer supported marketing strategy to best ensure increases in production can maintain or improve the prices being achieved.