Shellfish environmental and biological monitoring programme

Shelmerdine, Richard L.; Leslie, Beth

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Shellfish Environmental and Biological Monitoring Programme: Feasibility Study

Richard L. Shelmerdine, Lindsey Clark, and Beth Leslie

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Executive Summary

The blue mussel, *Mytilus edulis* (L., 1758), is common throughout the British Isles and is an important industry in Shetland valued at over £2 million annually which contributes to 54% of the annual rope grown mussels in Scotland. The aim of the study was to address the feasibility of monitoring biological and environmental conditions in order to assist the industry in optimising their production in future years. In order to carry this out, four sites, Booth, Riskaness, Sellivoe, and Siggi Bight, on the west of Shetland were sampled on a weekly basis from May through to September. The study was broken down into four main areas:

1) Concentration of D-larvae in the water column at each sampling site
2) Variation in D-larvae concentrations between two sampling techniques
3) Influence of tidal cycle on D-larvae concentration
4) Estimating mussel recruitment using rope droppers, on a weekly basis, from each site

Main Findings

- D-larvae concentration varied between sites with Booth having the highest concentrations and Riskaness the lowest. D-larvae were recorded throughout the study at Booth with a reduced concentration lasting up to mid August for Riskaness and early September for Sellivoe and Siggi Bight.
- Peaks in D-larvae concentration were recorded at Booth on the 5th September (100 000 m^{-3}), Riskaness on the 13th August (8 000 m^{-3}), Sellivoe on the 11th August (56 000 m^{-3}), and Siggi Bight on the 18th July (80 000 m^{-3}).
- A higher D-larvae concentration was recorded using the sampling hose (44 000 m^{-3}) compared with a phytoplankton net (5 540 m^{-3}).
- Higher D-larvae concentrations were recorded during the ebb tide which also had a greater variation in concentration compared to the flood tide.
- Recruitment was found to be greatest at Booth on the 4th June with 5 800 mussels/10 cm of dropper, lowest at Riskaness (138 mussels/10 cm) on the 16th July, with 804 mussels/10 cm recorded at Sellivoe on the 9th July.

Conclusions

    The data clearly shows a distinct biological difference between the site at Booth and the remaining sampling sites. Similar patterns in recruitment were recorded at both Riskaness and Sellivoe which are geographically close to one another.

    Sampling equipment and time of sampling seem to be highly influential when estimating D-larvae concentration. Although the sampling hose recorded a higher concentration of D-larvae, the present consensus is that phytoplankton nets are a more accurate means of estimating larval concentration as they sample a larger quantity of water. Care should be taken to ensure that samples are taken at the same point in the tidal cycle each week.

    It was clear from this study that further, long term sampling would benefit the industry including starting sampling earlier in the year (e.g. late April/early May), using phytoplankton nets, and incorporate in environmental data such as temperature and salinity using CTD recorders.

1 Introduction

The blue mussel, *Mytilus edulis* (L., 1758), is common throughout the British Isles ranging from the high intertidal down to the sublittoral. Most marine invertebrates, including *M. edulis*, have a planktonic larvae phase which can be easily dispersed in the water column away from their spawning site (Dobretsov & Miron, 2001). Lutz and Kennish (1992) reviewed the literature on the life history of *M. edulis*, which is briefly summarised below.

Egg fertilization takes place in the water column with eggs ranging in diameter from 60 to 90 µm. Cilia start to form after four to five hours and from 24 to 48 hours after fertilisation the ciliated trochophore stage is reached. The larvae then form a shell and go through several stages collectively known as the veliger stage. It is within this stage that the larvae take on a D-shape, ranging in shell length between 100 and 170 µm. The veliger stage lasts for one to four weeks (Page & Ricard, 1990) with the larvae actively feeding in the water column during this period. The final stage of the pelagic larvae is termed the pediveliger stage and is distinguishable by possessing a pedal organ or 'foot'. The foot can be seen in most larvae of a size ranging from 195 to 210 µm in length. It is at this stage that the larvae actively seek out a suitable substrate for settlement and metamorphosis. The pediveliger has the potential to delay metamorphosis, existing in the plankton, for several days (Bayne, 1964), until a suitable substrate is found. Once settled and metamorphosed, the mussel is referred to as a plantigrade.

In their natural habitat, recently settled *Mytilus* species are usually associated with filamentous substrata (primarily large seaweed) or small crevices and depressions, although their settlement behaviour appears to vary considerably among populations (Hunt & Scheibling, 1996; de Vooys, 1999). Colonisation of empty space by *M. edulis* can occur in two different ways; by lateral movement of juvenile or adult mussels (Gilek, *et al.*, 2001) or by recruitment from the water column as primary settlement (Bayne, 1964), which increases if the surface is irregular or fibrous (Seed, 1976; Gilek, *et al.*, 2001). Primary settlement is likely to depend on large scale oceanographic and environmental processes such as oceanic currents, the direction of the prevailing wind, and the intensity of exposure to waves. Recruitment has also been shown to have a large spatial variation, especially between sites of differing exposures (Alfaro & Jeffs, 2003).

Developmental rate of mussel larvae, larval abundance, and the temporal variability of settlement are all influenced by biotic and abiotic factors (Garcia*, et al.*, 2003). The most important of which include wind patterns (Hawkins & Hartnoll, 1982), area hydrography (Gaines & Bertness, 1992), food availability (de Vooys, 1999), and water temperature (for review see Chicharo & Chicharo, 2000) although it would be expected that these factors would have varying degrees of influence at differing geographic locations. This is evident by the study conducted by de Vooys (1999) which noted that water temperature did not influence developmental rates in the Dutch Wadden Sea. Many other studies have shown that time of spawning varies with latitude and, in general, occurs earlier at lower latitudes (Seed, 1969). Bayne (1964) recorded spawning in the Menai Straits, Wales, from April, May, and June, while de Vooys (1999) generalised that spawning occurred in March and April in Great Britain and Ireland and from July to September at higher latitudes of mid-Norway and Iceland (see de Vooys, 1999 for additional authors).

In Scotland, rope grown mussel production accounts for nearly 92% of Scottish shellfish production for human consumption with Shetland accounting for 54% of the 4 200 tonnes of mussels produced annually (Bland & Fraser, 2007). In Shetland the rope grown mussel industry is valued at over £2 million per annum (Anonymous, 2006). Understanding factors which affect mussel larvae settlement is highly beneficial to the successful management of mussel production in the rope grown industry (Frantzen, 2007). There is substantial evidence to suggest that such factors act at a local scale and have the potential to vary in intensity from year to year. The aim of this study was to examine the feasibility of researching variation in *M. edulis* larval concentration and recruitment at mussel sites around Shetland by looking at localised variations in biotic and abiotic factors. It is widely known that mussel spawning time is highly variable from site to site and that spawning does not occur at the same time each year. It is hoped that by monitoring larval concentrations, and relating this to recruitment intensity, a better understanding of the driving factors at each site could be gained, leading to increased productivity and optimising production yields of the rope grown mussel industry in Shetland.

2   Materials and Methods

The study ran for 18 weeks from the 28th May to the 26th September 2007. Four sampling sites were established at existing mussel farm sites on the west coast of Shetland (Figure 2.2). Sampling sites included Booth (60º06′31″N, 001º16′35″W), Riskaness (60º13′08″N, 001º34′46″W), Selivoe (60º12′57″N, 001º29′43″W), and Siggi Bight (60º19′02″N, 001º27′46″W). Every week water samples were collected using a sampling hose (Section 2.1) and the mussel farmers at each site agreed to put out a rope dropper per week to look at variation in recruitment over time (Section 2.2). In addition, two small-scale experiments were carried out examining differences in D-larvae counts between a sampling hose and a phytoplankton net (Section 2.3), and the effects of D-larvae concentration over a tidal cycle (Section 2.4).

2.1   Sampling hose protocol and procedure for estimating D-larvae

At each site the sampling hose (diameter of 25 mm) was rinsed by submerging it in seawater with the valve open. Once rinsed, a sample was taken by slowly lowering the hose down to a depth of 8 m where the valve was then closed off. The contents of the hose were then emptied into a clean bucket at the surface, stirred, and a 500 ml sub-sample taken. Back at the laboratory the sub-sample was stained with Lugols Iodine before being filtered through a 53 μm mesh. The residue was re-suspended and transferred to a clean 20 ml, container containing the filtrate, where it was left to settle overnight. The following day a 1 ml sample was carefully pipetted onto a Sedwich Rafter Cell from the bottom of the 20 ml sample. D-larvae were counted and the process repeated until no D-larvae were present in the sample. The result was a total count of D-larvae for each 500 ml sub-sample which was converted to a value per metre cubed.

2.2 Estimating mussel recruitment

Labelled ropes were deployed at each site every week by the mussel farmer and left *in situ* for the duration of the experiment. At the end of the 17 weeks two 5 cm sections of the rope, 5 cm from the top and 5 cm from the bottom, were sampled with each sample placed in a labelled 500 ml plastic container filled with filtered sea water for later analysis. The length of each rope was visually inspected and any variation in mussel recruitment was noted. At the laboratory each sample was placed in a labelled bag with the remaining water filtered to ensure no mussels dropped off the rope sections during transportation. Macro-organisms from each sample were identified, counted and mussels were removed, evenly spaced on a white background and digitally photographed for later image analysis (see Section 2.2.1).

2.2.1 Image analysis

Mussel lengths were measured using an image analysis program, "Image J" (National Institutes of Health, USA 2007). All photographs were changed to 8-bit with an automatic threshold. The image was edited to separate out any mussels that were found to be touching and before analysis a minimum object size of 40 pixels was set in order to filter out debris. The image analysis program calculated the maximum length of each mussel, and the coin used as a scale, in pixels. These measurements could then be converted to millimetres. Mussel outlines were saved as a separate image file with measurements imported to Excel^{TM} (Figure 2.1).
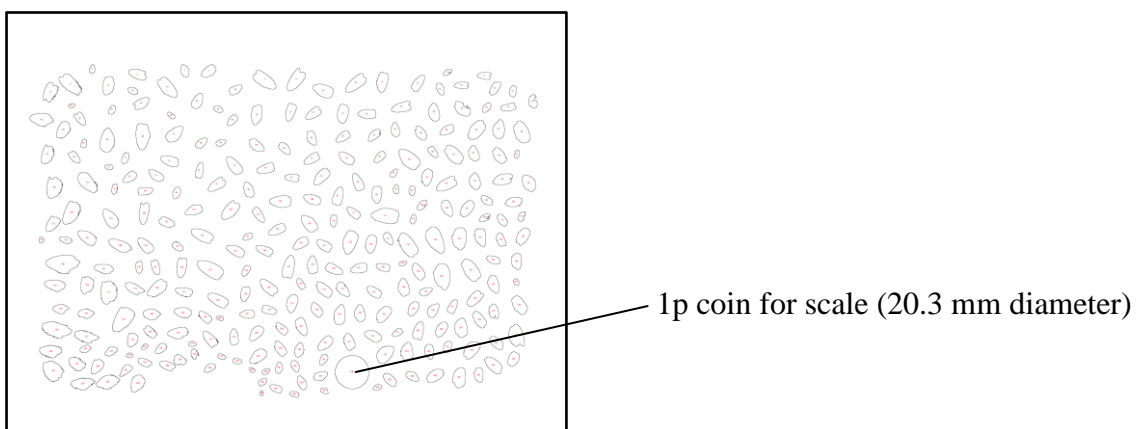

1p coin for scale (20.3 mm diameter)

Figure 2.1 An example of the output from Image J showing the outlines of the measured mussels. A one pence coin was also measured for scale.

2.3 Variation in D-larvae concentrations between sampling techniques

A total of ten water samples were taken, five using a sampling hose (see Section 2.1 for sampling procedure) and five using a phytoplankton net. The phytoplankton net had a hoop diameter of 40 cm and a mesh size of 53 μm with a 250 ml collection bottle at the base of the net. The net was allowed to sink to the desired depth (8 m) where it was then pulled to the surface at a steady, slow speed making sure the hoop remained parallel with the surface. At the surface, the net was washed with seawater from the outside to ensure no D-larvae remained on the inside of the net. The contents of the collection bottle were transferred to a labelled sample bottle with Lugols Iodine. The procedure was repeated five times. Back at the laboratory, each water sample was filtered and re-suspended in a 50 ml container, stirred and three 1 ml samples taken. Each 1 ml sample was transferred to a Sedwich Rafter Cell where the D-larvae were counted under a microscope. The mean of the three samples was taken and converted to the number of D-larvae per metre cubed.

2.4 Influence of tidal cycle on D-larvae concentrations

Hourly samples were taken using a phytoplankton net, following the procedure detailed above (Section 2.3). In addition, water depth, sea surface temperature, and water clarity were measured. Water clarity was estimated measuring the depth at which a Secchi disc disappeared from view. Due to weather conditions and the timing of the tides, the flood tide was sampled on the 7th August 2007 and the ebb tide sampled on the 13th August 2007.
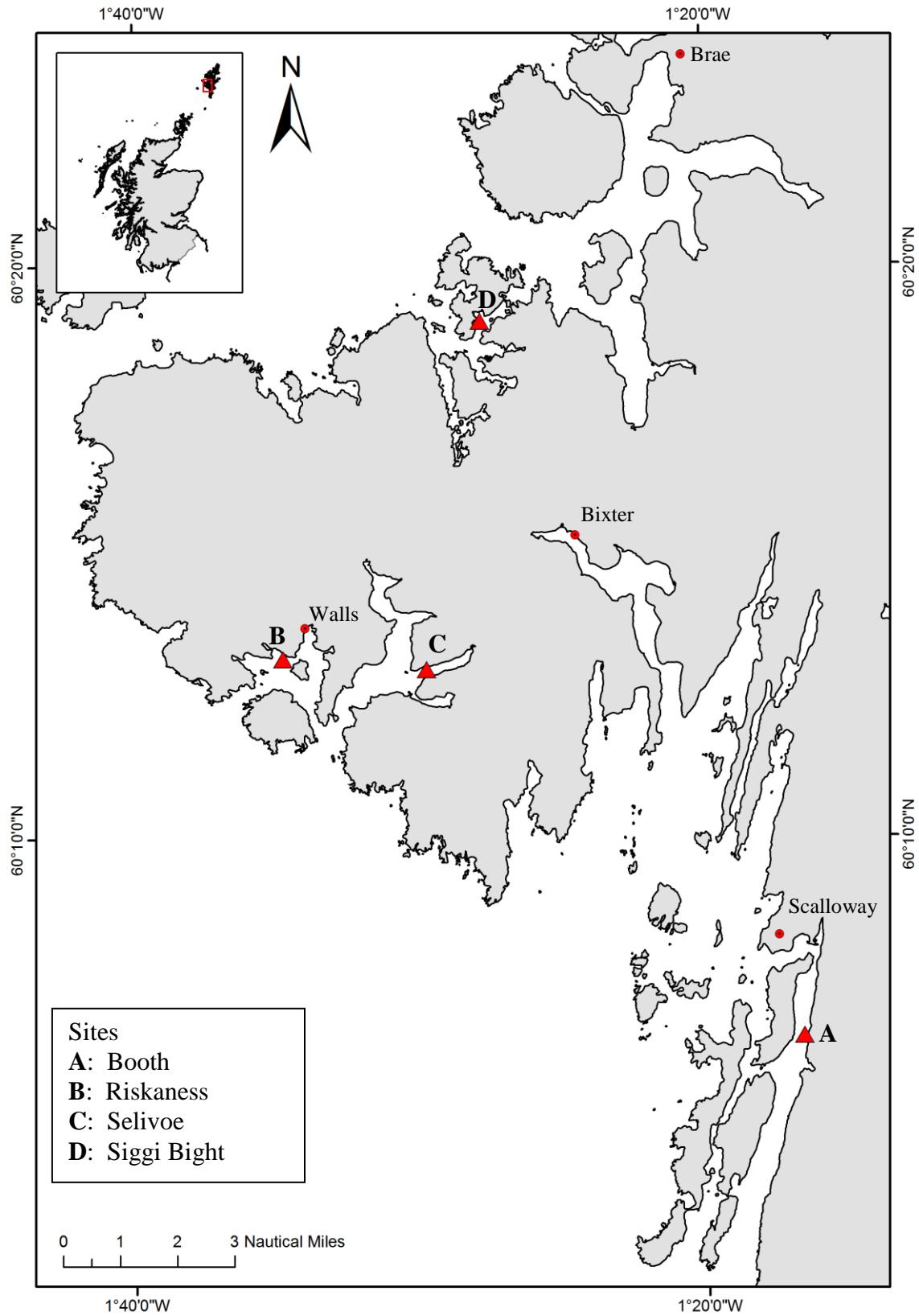
Figure 2.2 Position of sampling sites (triangles) used in the study on the west coast of Shetland. Circles denote positions of nearby villages.

3   Results

3.1   Long-term monitoring and recruitment

The concentration of D-larvae was found to vary between the four sites (Figure 3.1 to Figure 3.4) with D-larvae found to be present throughout the study at Booth which was also found to have the highest D-larvae concentration (Figure 3.1). Concentration peaks were recorded at Booth on the 5th September (100 000 m^{-3} Figure 3.1), Riskaness on the 13th August (8 000 m^{-3} Figure 3.2), Sellivoe on the 11th June (56 000 m^{-3} Figure 3.3), and Siggi Bight on the 18th July (80 000 m^{-3} Figure 3.4). D-larvae concentrations were found to be significantly different (One-way ANOVA, $F_{3,56}$ = 4.89, P = 0.004) with a significantly higher concentration recorded at Booth than Riskaness, Sellivoe, and Siggi Bight (Fisher's LSD test). The post hoc test showed no significant difference in concentration between the latter three sites.

From the initial four sites, data from the ropes were only available for Booth, Riskaness, and Sellivoe. Samples were collected on 2nd November, 22nd October and 6th November, respectively. A total of 6 742 mussels were measured from the 10 cm sections of the ropes sampled. This broke down to 5 800 from Booth, 804 from Sellivoe, and 138 from Riskaness. Mussel recruitment varied between these sites with Booth found to have the highest number of mussels (5 800 mussels/10 cm from the rope deployed on the 4th June) compared to Riskaness (138 mussels/10 cm from the rope deployed on the 16th July) and Sellivoe (804 mussels/10 cm from the rope deployed on the 9th July). The number of mussels for an 8 m section of rope was then estimated for each site based on the day of sampling (Figure 3.5 and Figure 3.6). Sellivoe had the longest recruitment period lasting up to the 3rd September, followed by Booth (20th August) and Riskaness (6th August).
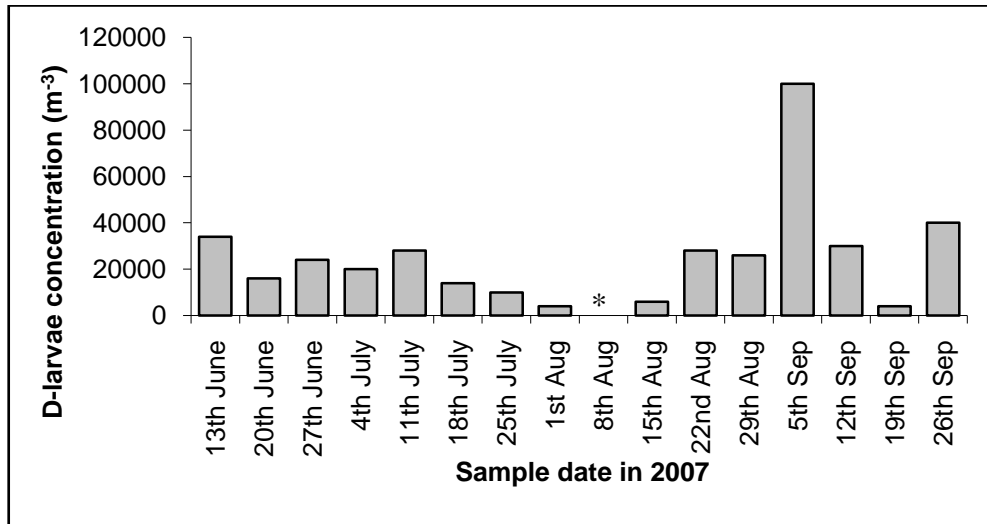
Figure 3.1 Concentration of D-larvae (m^{-3}) at Booth from 13th June to 26th September. * indicates no data available.
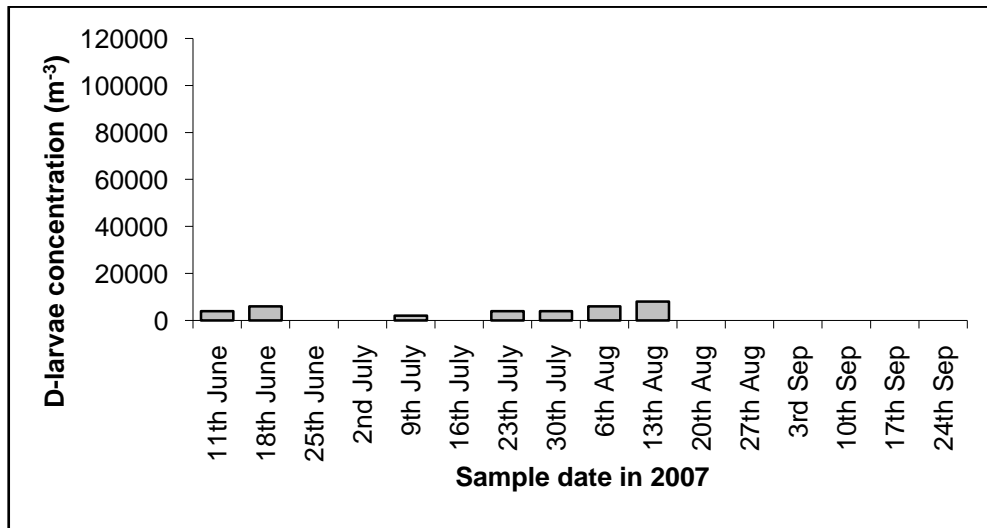
Figure 3.2 Concentration of D-larvae (m^{-3}) at Riskaness from 11th June to 24th September.
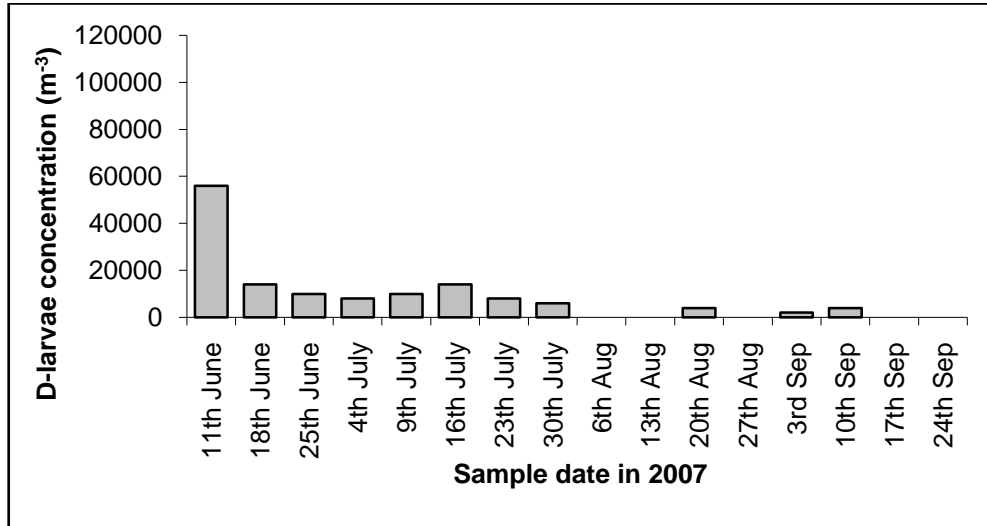
Figure 3.3 Concentration of D-larvae (m^{-3}) at Sellivoe from 11th June to 24th September.
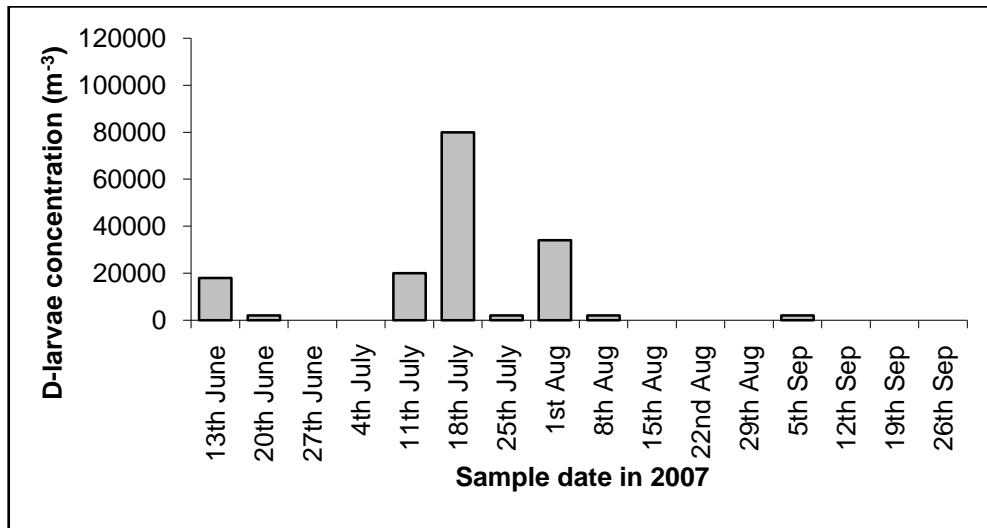

Figure 3.4 Concentration of D-larvae (m^{-3}) at Siggi Bight from 13th June to 26th September.
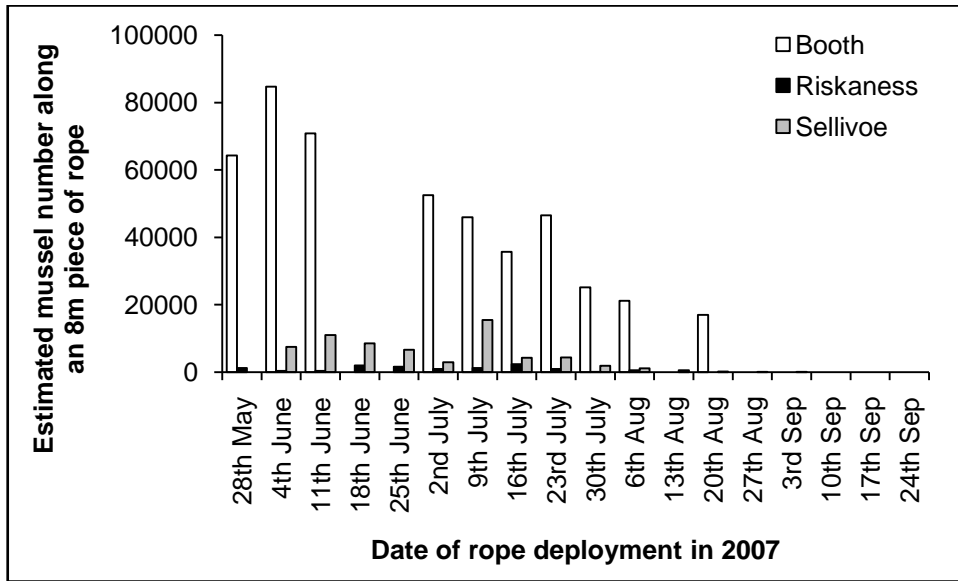
Figure 3.5 Estimated number of mussels per 8 m length of rope, over the study period, at Booth (open bars), Riskaness (black bars), and Sellivoe (grey bars).
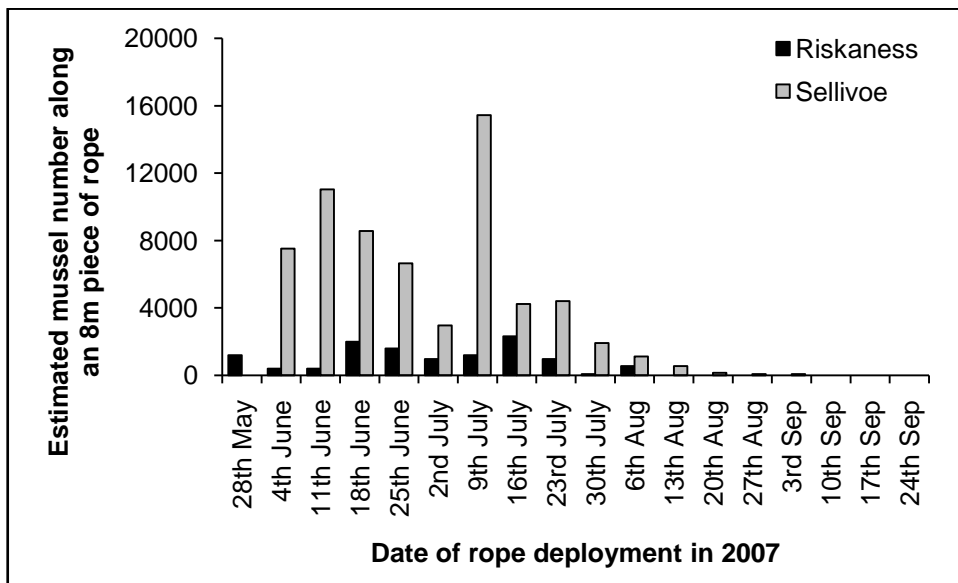

Figure 3.6 Estimated number of mussels per 8 m length of rope, over the study period, at Riskaness (black bars) and Sellivoe (grey bars).

Change in mean shell length was found to be similar at Riskaness and Sellivoe where a slight peak in mean shell length was recorded from the ropes deployed on the 9th July (Figure 3.7). An increased mean shell length was also recorded from earlier ropes at these sites (28th May through to 11th June). Ropes deployed at Booth were found to have mussels with a significantly greater mean shell length than those at the other two sites (Three-way ANOVA, $F_{2,5909} = 122.14$, $P < 0.001$). Mean shell length at Booth was found to remain relatively constant from 2nd July onwards with a mean shell length over this time period of 11 mm (Figure 3.7). When mean shell length was plotted alongside the estimated number of mussels found along an 8 m length of rope, it could be seen that the constant period of mean shell length at Booth was not related to the number of mussels, which were found to decrease over this time period (Figure 3.8a). Large mean shell lengths were also noted at the start of July at Riskaness (Figure 3.8b) and Sellivoe (Figure 3.8c).
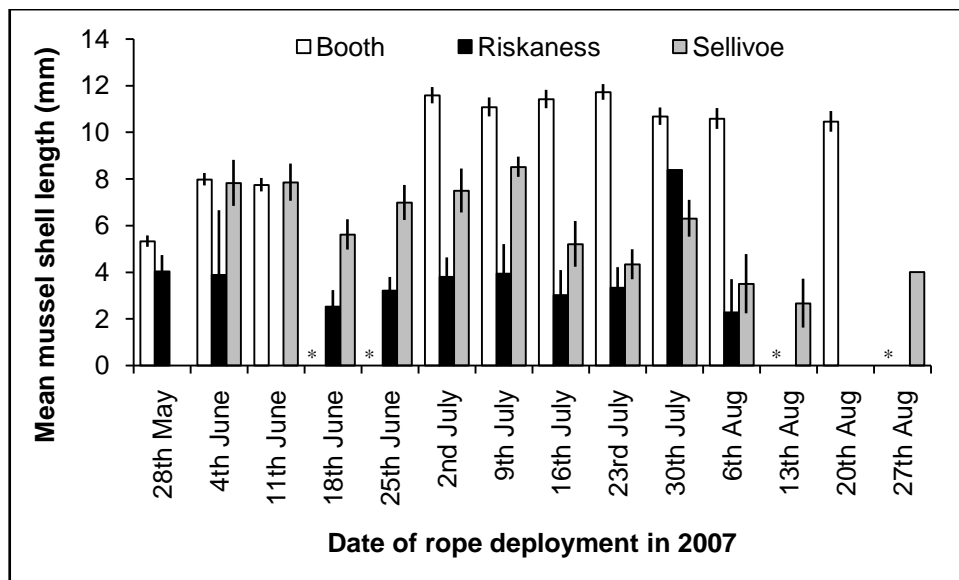
Figure 3.7 Mean shell length (mm) of mussels at Booth, Riskaness, and Sellivoe throughout the study period. 95% confidence intervals are shown. * indicates no data available for Booth.
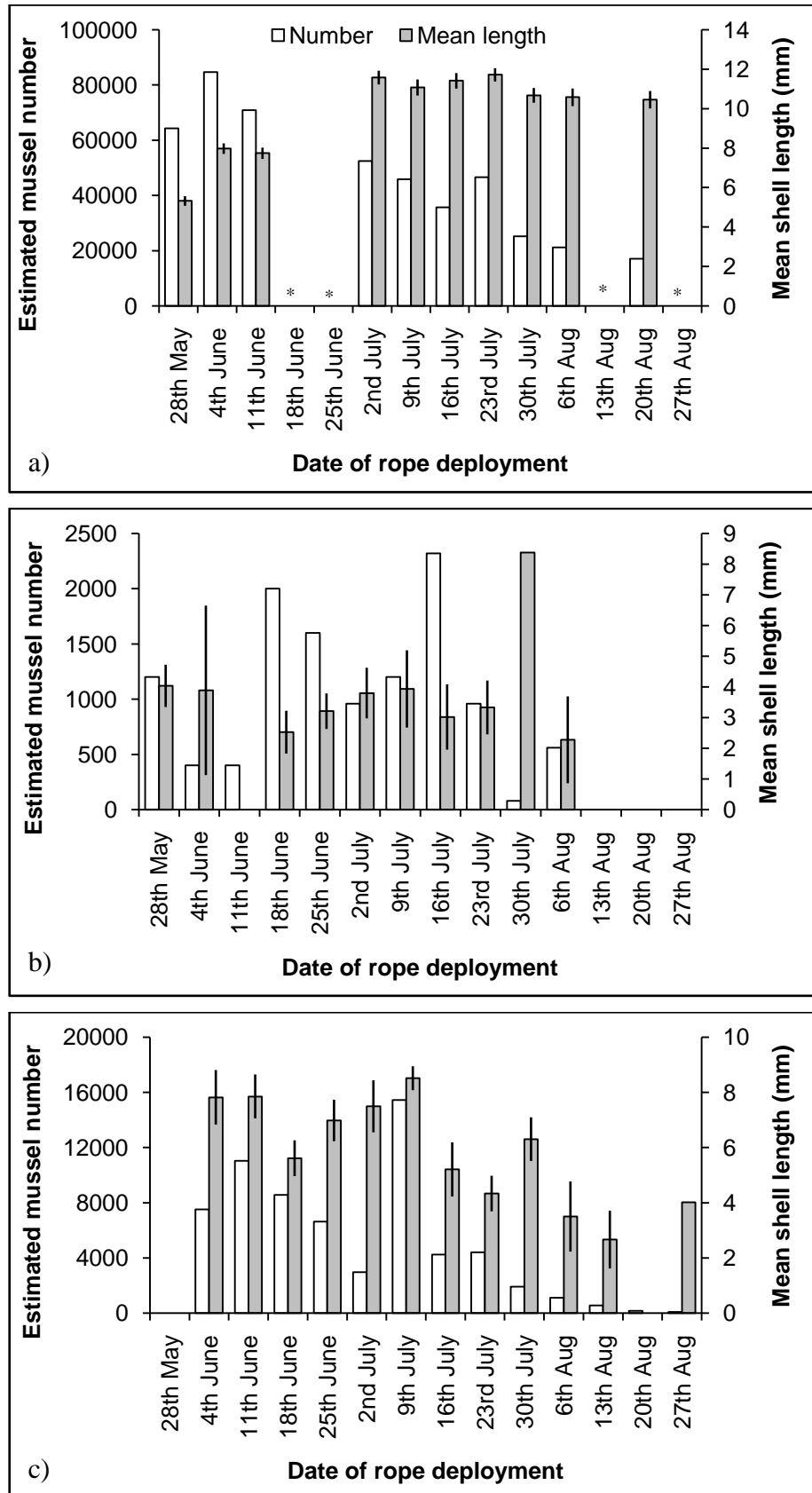
Figure 3.8 Mean shell length and estimated mussel number (per 8 m of rope) for each dropper deployed at Booth (a), Riskaness (b), and Sellivoe (c). Note differences in y-axes scales for each site. 95% confidence intervals are shown. * indicates no data available for Booth.

The largest mussels were found at Booth (mean = 9.6 mm, range = 0.9 to 26.3 mm, Figure 3.9) with smaller size ranges recorded at Sellivoe (mean = 7.4 mm, range = 0.4 to 23.7 mm, Figure 3.10) and Riskaness (mean = 3.5 mm, range = 0.4 to 16.3 mm, Figure 3.10). All three sites had unimodal length frequency distributions which were left-skewed with peaks at 2 to 3.9 mm for Riskaness, 4 to 5.9 mm for Sellivoe, and 10 to 11.9 mm for Booth.
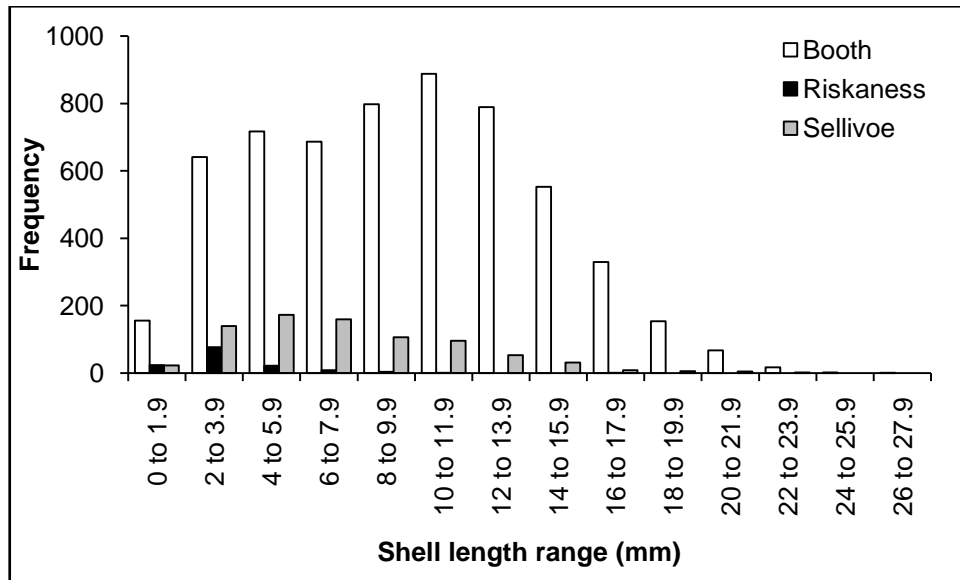

Figure 3.9 Length frequency of mussels collected from Booth, Riskaness, and Sellivoe.
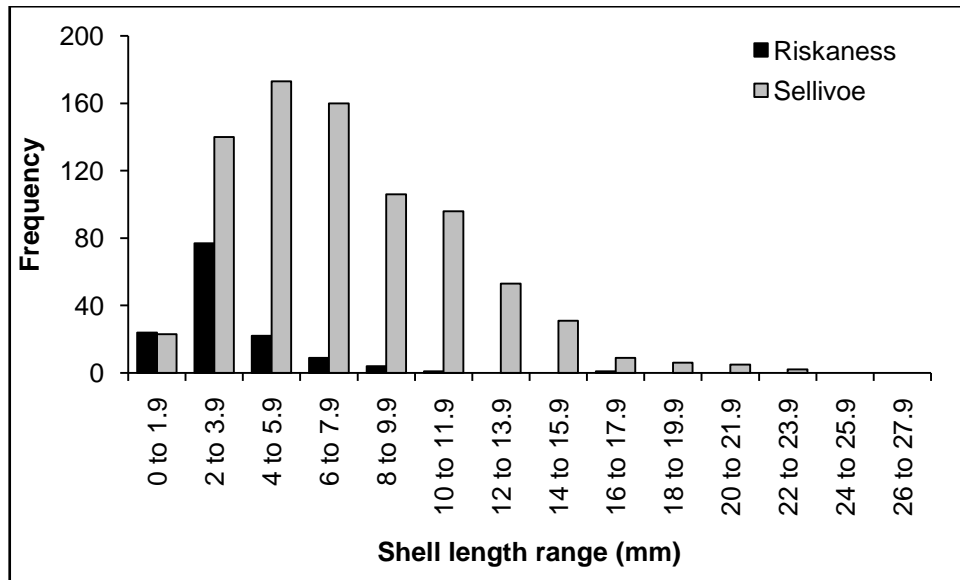

Figure 3.10 Length frequency of mussels collected from Riskaness and Sellivoe.

3.2 Variation in D-larvae concentrations between sampling techniques

The highest mean concentration of D-larvae (44 000 m^{-3}) was sampled using the hose, with the phytoplankton net sampling a significantly lower concentration of 5 540 m^{-3} (One-way ANOVA, $F_{1,18} = 378.55$, $P < 0.001$; Figure 3.11).

Figure 3.11 Mean concentration of D-larvae (m^{-3}) from a sampling hose and phytoplankton net.

3.3 Influence of tidal cycle on D-larvae concentrations

A significantly higher concentration of D-larvae were recorded during the ebb of the tide (Figure 3.12) compared with the flood tide (Wilcoxon's signed ranks test, $P = 0.035$). Mean sea surface temperature was found to be similar during the flood and ebb of the tide (12.67 °C and 12.75 °C, respectively) however, Secchi disc depth was found to be 2 m deeper during the ebb than the flood tide. The deepest Secchi disc reading was recorded during high tide of the ebb where the D-larvae concentration was found to be lower than the corresponding high tide of the flood.
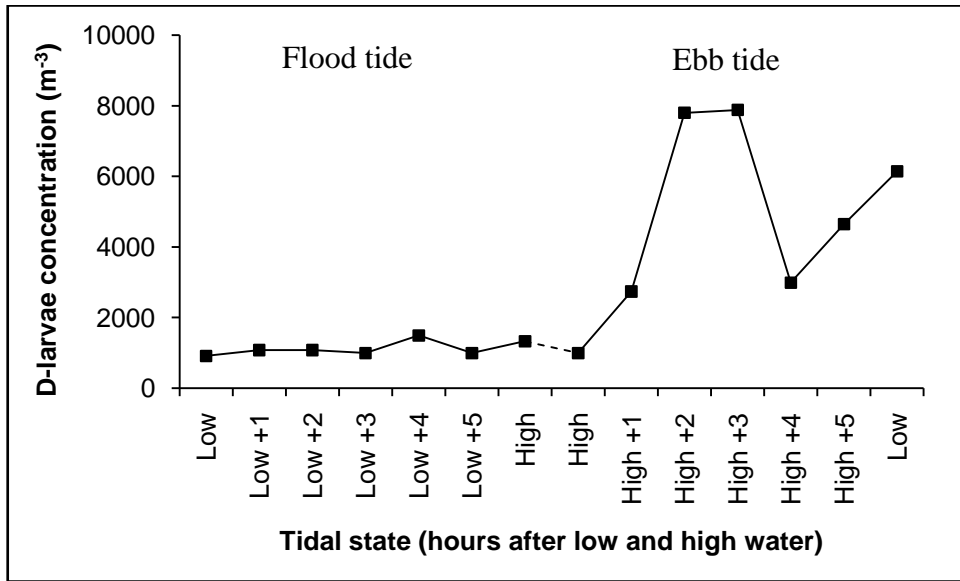
Figure 3.12 Concentration of D-larvae (m^{-3}) over a tidal cycle from the 7th August (flood tide) and the 13th August (ebb tide).

4 Discussion

The data collected during this feasibility study showed distinct and significant differences in mussel larvae abundance and potential yield on a large spatial scale between sites. Due to a delay in obtaining the equipment to monitor environmental data, it was not possible to determine whether these changes were influenced by factors such as temperature or salinity. However, it is proposed to incorporate the CTD recorders in future studies (see Section 4.5). Two additional mini projects were carried out to look at variation in larvae concentration between sampling techniques (Sections 2.3 and 3.2) and the influence of the tidal cycle on larvae abundance (Sections 2.4 and 3.3). These mini projects proved vital in highlighting the need to take samples during the same tidal state and the optimal type of equipment to use in order to monitor larvae abundance (see below for more details).

4.1 Larval concentrations

The commercial fishery in the Dutch Wadden Sea is highly dependent on a good mussel spatfall (de Vooys, 1999) as is the rope grown mussel industry in Shetland. The site at Booth was found to have a significantly higher D-larvae concentration, and more mussel recruitment to the ropes, with mussels found to be larger than those from the other sampled sites. Booth is the furthest south site with both Riskaness and Sellivoe being relatively close to one another in very sheltered areas (Figure 2.2). Connell (1985) proposed three reasons why the density of larval settlement differed between two sites. Reasons included; the immigration of competent planktonic larvae into the area; water characteristics had a positive influence on larval attachment; and the substratum differed between sites. In the case of rope grown mussels the latter reason would have a negligible effect. However, the increased concentration of D-larvae at Booth may be due, in part, to immigration of larvae from surrounding areas. Although all the sites are located in sheltered areas, Riskaness and Sellivoe could be described as being within a semi-enclosed system. This is particularly evident when looking at the location of the Sellivoe site. By nature semi-enclosed systems have reduced flushing times (see Jones, *et al.*, 1984; Edwards, *et al.*, 1986; Grantham & Tett, 1993; Matthews, *et al.*, 1999; Tett, *et al.*, 2003 for further examples) which would lead to reduced rates of larval immigration to these areas. However, on a much smaller scale,

Chícharo and Chícharo (2000) noted a much reduced larval abundance during spring tides when a near total water exchange was observed within a small embayment.

4.2   Spawning and recruitment

It was evident from the data that the initial spawning at each of the four sites was not recorded (Figure 3.1 to Figure 3.4). With the exception of Sellivoe, larval concentrations peaked later (July through to September) in the study. These peaks were most probably from a secondary spawning with the initial spawning occurring during April or May. This was evident when measuring mussel recruitment on ropes at each site (Figure 3.5 and Figure 3.6) with high mussel numbers recorded during the early phase of the study. The high abundance of mussel larvae, near the end of the study, will not be shown as recruitment on the ropes for one to four weeks after spawning, according to Page and Ricard (1990), and six weeks in north Norway (Frantzen, 2007). Likewise, the high numbers of recruited mussels on ropes deployed at the start of the study will relate to a spawning time of one to four weeks prior to the ropes being deployed. High mussel recruitment in early June at Booth suggests a much earlier spawning time at this site compared with Riskaness and Sellivoe. This is backed up with the length-frequency plots (Figure 3.9 and Figure 3.10) which showed Riskaness and Sellivoe to have smaller mussels compared with Booth. Although Booth is the farthest south site in this study, it would not be possible to attribute this difference to latitudinal variation, as mentioned previously (see Section 1), due to this study being carried out at a much smaller geographic scale. It would be more plausible that such differences between the sites would be due to environmental variables and food availability, rather than latitude. Temperature has been shown to be an important environmental variable that affects mussel growth (Hickman, *et al.*, 2005). The authors noted a positive correlation between increased temperature and faster growth rates.

Spawning time is a good indicator of when to deploy mussel ropes in order to maximise the chances of obtaining a large mussel recruitment. However, this study shows that such a technique is not necessarily the most viable option for cultivating mussels to a large shell length. This was clearly obvious when mean mussel length was compared with the number of mussels per rope (Figure 3.8) which showed that deploying mussel ropes as close to the spawning time as possible (April or May during 2007) may not be the most efficient method. However, deploying ropes in July showed an increased mean shell length with a decreased

number of mussels, as recorded at both Booth and Sellivoe. Variations in initial settlement and post-settlement processes such as density dependent, or density independent mortality have been shown to regulate recruitment of sessile organisms (Connell, 1985). It would be expected that predation pressure would have a significant contributory effect to mussel density and shell length, although it was not possible to test for such an effect in this study. However, starfish were not found at Booth from 2nd July onwards or at Sellivoe from 30th July onwards. The absence of starfish at Booth coincides with increased mean shell lengths but this was not the case at Sellivoe where mussels were found to be smaller than previous rope deployments. Unfortunately, it was not possible to determine the impact from predation and how this varied between sites.

4.3 Variation between sampling techniques and influence of tidal cycle

Concentrations of D-larvae obtained using the sampling hose were found to be much greater than previous published results (see de Vooys, 1999; Chicharo & Chicharo, 2000; Hickman, *et al.*, 2005; Knights, *et al.*, 2006; Frantzen, 2007). However, this was probably due to variation in equipment rather than Shetland sites having a higher concentration of mussel larvae compared with other geographic locations. For this reason, it was not possible to compare concentrations with other studies but, as the data was obtained using the same equipment, it was still possible to look at differences between sites. It is well known that tidal state influences mussel larvae concentration (see de Vooys, 1999; Knights, *et al.*, 2006) but results seem to vary between studies. Spawning intensity was assumed to be at a maximum at low tide when water temperatures were high (de Vooys, 1999) and the author found no relationship between spawning time and spring tides. However, Knights *et al.* (2006) recorded a maximum density of larvae during spring tides. Greater larval densities were recorded during flood tides with ebb tides, high water, and low water found to have significantly lower densities (Knights, *et al.*, 2006). The authors found similar results for both spring and neap tides. Knights *et al.* (2006) suggested that larvae may actively avoid transportation during ebb tides. These results conflict with those reported during this study. This study showed that there was a greater concentration of D-larvae during the ebb of the tide compared to the flood (Figure 3.12). The higher D-larvae concentration during the ebb tide was not thought to be due to measured environmental variables, such as sea surface temperature and Secchi disc depth. If the site is located within a semi-enclosed embayment, as seen in this study, an increased concentration of larvae would be expected during the ebb

tide as this is when the water is flowing out of the area. If larval concentration increased during the flood tide, larvae will be prone to intraspecific predation from the adult mussel population as mentioned by Bayne (1964). The non-discriminate filtering of the water by the adult population would lead to unnecessary mortalities for the larval population during the flood tide. Such unnecessary larval mortalities would be disadvantageous to the adult population in terms of loss of energy requirements utilised during reproduction.

4.4 Conclusions

The data clearly shows a distinct biological difference between the site at Booth and the remaining sampling sites. Spawning was estimated to have occurred in April or May with Booth spawning earlier. Similar patterns in recruitment were recorded at both Riskaness and Sellivoe which are geographically close to one another and, although Booth is the furthest site south, environmental factors would probably have a greater influence on recruitment than latitude. It was noted, for 2007, that ropes deployed at the start of July were found to have fewer but larger mussels suggesting there might not be a need to deploy ropes when mussels spawn, although, these ropes would have to be followed through to harvesting in order to make a definitive conclusion.

Sampling equipment and time of sampling seem to be highly influential when estimating D-larvae concentration. Although the sampling hose recorded a higher concentration of D-larvae, the present consensus is that phytoplankton nets are a more accurate means of estimating larval concentration as they sample a larger quantity of water. Care should be taken to ensure that samples are taken at the same tidal time each week.

4.5 Proposed future work

The feasibility study showed that such research could potentially be highly beneficial to the rope grown mussel industry in Shetland. However, many questions remain unanswered. In order to gain a fuller picture of D-larvae concentration and mussel recruitment at sites it is proposed that the following suggestions are followed:

- The study should start earlier in the year and no later than the end of April or the beginning of May.
- CTD (salinity, temperature, and depth) recorders should be used to monitor environmental conditions at each of the sites.
- Phytoplankton nets should be used to estimate D-larvae concentration from weekly water samples.
    - It is proposed that NAFC Marine Centre would supply the participating farmers with phytoplankton nets (there are four available) to take weekly water samples at their site. This could be done alongside the weekly visit from the Sampling Officer who would then take the water sample, taken by the farmer, back to NAFC Marine Centre.
    - NAFC Marine Centre staff would supply the participating farmers with the relevant training in the sampling techniques and care of the equipment.
- Participating farmers would still be required to deploy a weekly rope dropper at their sites which will be sampled at the end of the study (by sampling at least a 10 cm section of each rope).

5   Acknowledgements

6   References

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