

# Variation in spawning and recruitment of the blue mussel, *Mytilus edulis*

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## Introduction

The blue mussel, *Mytilus edulis*, 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<sup>1</sup>. The life history of *M. edulis*, is briefly summarised below according to Lutz and Kennish<sup>2</sup>.



Figure 1: Weekly labelled mussel ropes.

Egg fertilization takes place in the water column. The larvae form cilia and a shell before going through several developmental 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  $\mu\text{m}$ . The veliger stage lasts for one to four weeks<sup>3</sup> 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'. 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<sup>4</sup>, until a suitable substrate is found. Once settled and metamorphosed, the mussel is referred to as a plantigrade.

In Scotland, rope grown mussel production (Figure 1) accounts for nearly 92% of Scottish shellfish culture for human consumption with Shetland accounting for 54% of the 4 200 tonnes of mussels produced annually<sup>5</sup>. In Shetland, the rope grown mussel industry is valued at

over £2 million per annum<sup>6</sup>. Understanding factors which affect mussel larvae settlement is highly beneficial to the successful management of mussel production in the rope grown industry<sup>7</sup>. 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 biological and environmental factors. It is widely known that mussel spawning time is highly variable from site to site and that it 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.

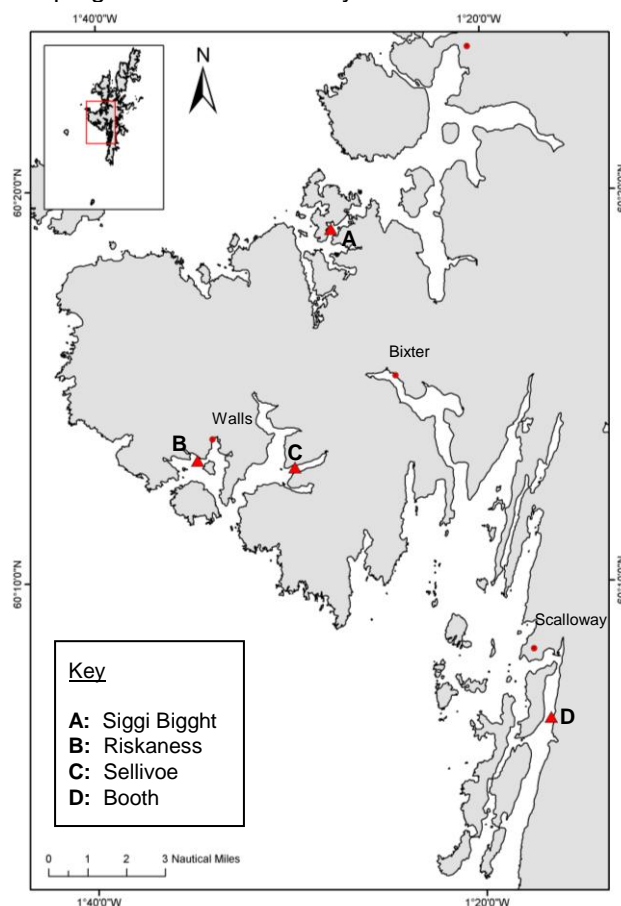


Figure 2: Map of sites (triangles) sampled in Shetland.

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## Methods

The study ran from the 28<sup>th</sup> May to the 26<sup>th</sup> September 2007. Four sampling sites were established at existing mussel farm sites on the west coast of Shetland. Sampling sites included Booth, Riskaness, Sellivoe, and Siggie Bight (Figure 2). Every week water samples were collected using a sampling hose and the mussel farmers at each site agreed to put out a rope dropper per week (Figure 1) to look at variation in recruitment over time. In addition, two small-scale experiments were carried out examining differences in D-larvae counts between a sampling hose and a phytoplankton net, and the effects of D-larvae concentration over a tidal cycle.

Weekly water samples were taken back to the laboratory, stained with Lugols Iodine, and filtered through a 53  $\mu\text{m}$  mesh before being left to settle overnight. The following day a 1 ml sample was carefully pipetted onto a Sedwich Rafter Cell from the bottom of the 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.

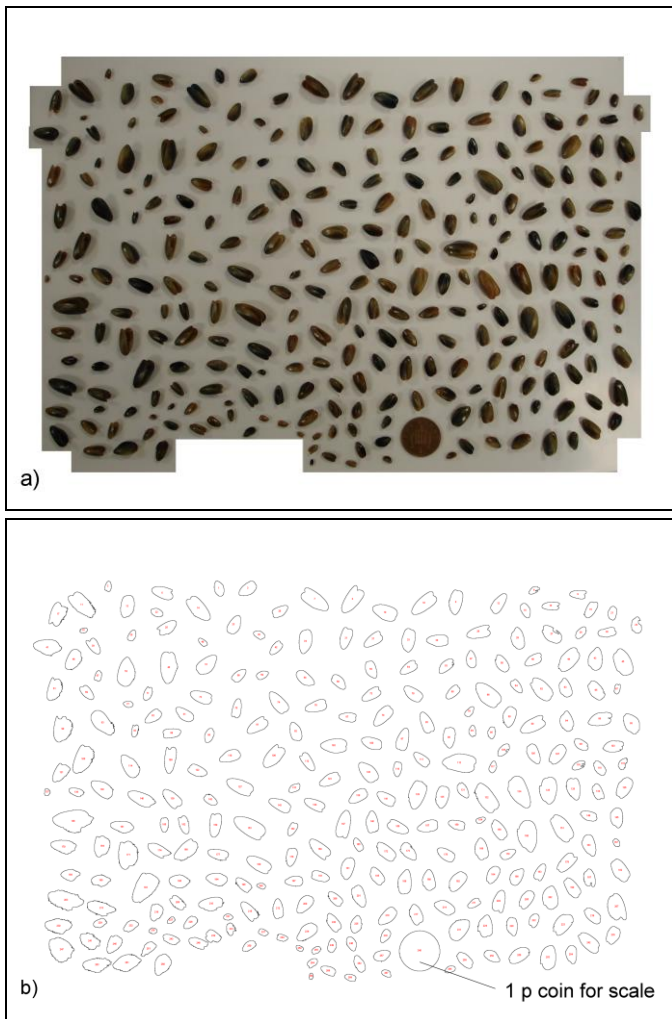


Figure 3: An example of the (a) input and (b) output from Image J showing the outlines of the measured mussels. A coin was also measured for scale.

At the end of the study a 5 cm section from the top and bottom of each rope was 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 mussels were removed, evenly spaced on a white background and digitally photographed for image analysis using "Image J" (National Institutes of Health, USA 2007; Figures 3a and 3b).

## Results

The concentration of D-larvae was found to vary between the four sites (Figure 4). D-larvae were found to be present throughout the study at Booth, which was also found to have the highest D-larvae concentration. Concentration peaks were recorded at Booth on the 5<sup>th</sup> September (100 000  $\text{m}^{-3}$ ), Riskaness on the 13<sup>th</sup> August (8 000  $\text{m}^{-3}$ ), Sellivoe on the 11<sup>th</sup> June (56 000  $\text{m}^{-3}$ ), and Siggie Bight on the 18<sup>th</sup> July (80 000  $\text{m}^{-3}$ ). D-larvae concentrations were found to be significantly different with a significantly higher concentration recorded at Booth than Riskaness, Sellivoe, and Siggie Bight. No significant difference in concentration between the latter three sites was found.

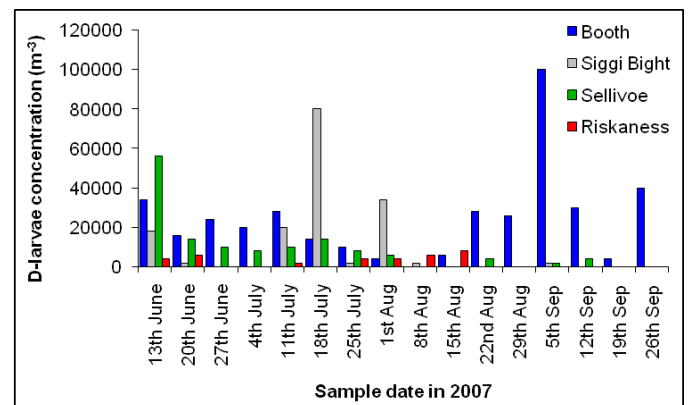
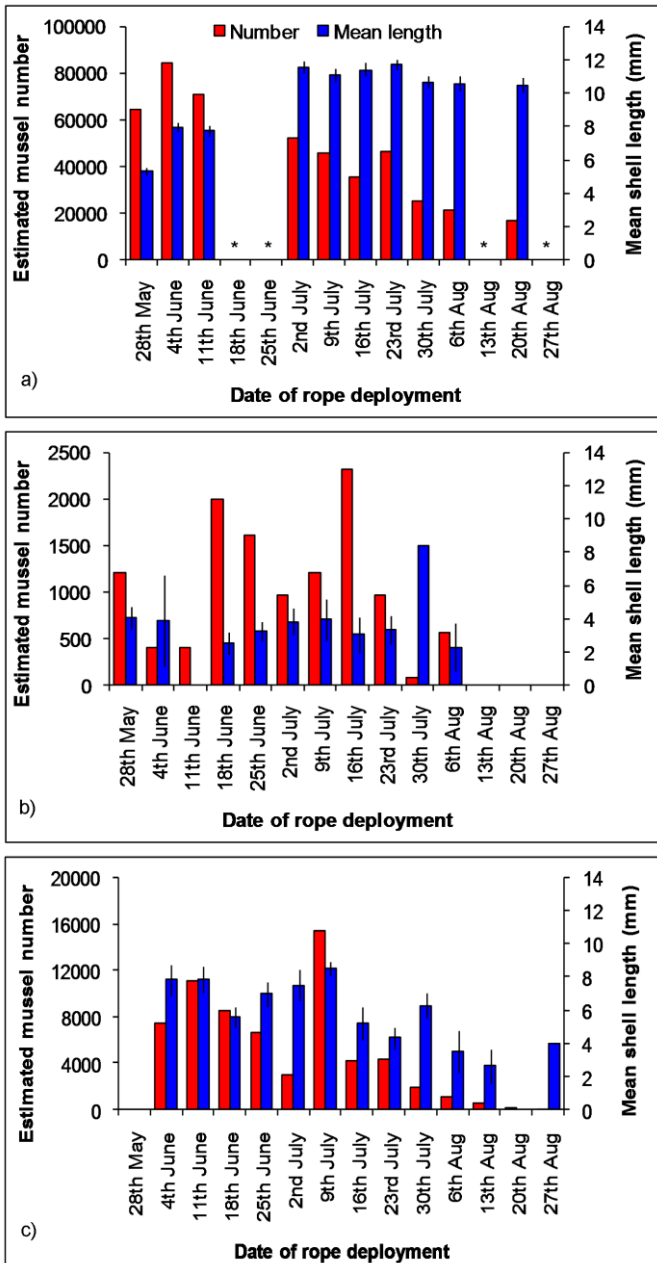


Figure 4: Concentration of D-larvae ( $\text{m}^{-3}$ ) at the four sampling sites from 13<sup>th</sup> June to 26<sup>th</sup> September 2007.

From the initial four sites, data from the ropes were only available for Booth, Riskaness, and Sellivoe. Samples were collected on 2<sup>nd</sup> November, 22<sup>nd</sup> October and 6<sup>th</sup> 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 4<sup>th</sup> June) compared to Riskaness (138 mussels/10 cm from the rope deployed on the 16<sup>th</sup> July) and Sellivoe (804 mussels/10 cm from the rope deployed on the 9<sup>th</sup> July). The number of mussels for an 8 m section of rope was then estimated for each site based on the day of sampling (Figures 5a, 5b, and 5c). Sellivoe had the longest recruitment period lasting up to the 3<sup>rd</sup> September, followed by Booth (20<sup>th</sup> August) and Riskaness (6<sup>th</sup> August).

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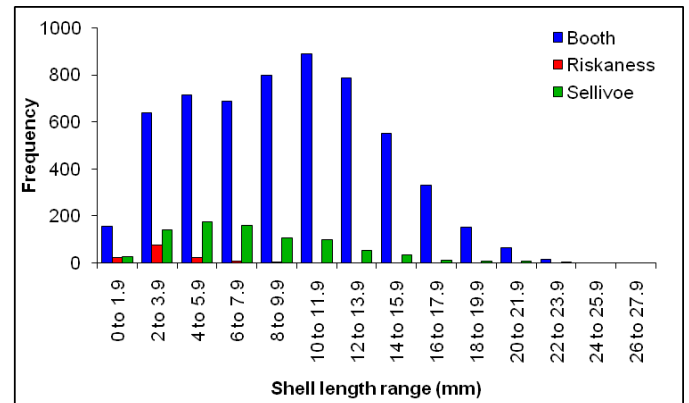


**Figure 5: Mean shell length and estimated mussel number (per 8 m of rope) for each dropper deployed at Booth (a), Riskaness (b), and Sellivoe (c). Note differences in y-axis scales. 95% confidence intervals are shown. \* indicates no data available.**

Change in mean shell length over the study period 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 9<sup>th</sup> July (Figures 5b and 5c). An increased mean shell length was also recorded from earlier ropes at these sites (28<sup>th</sup> May through to 11<sup>th</sup> June). Ropes deployed at Booth were found to have mussels with a significantly greater mean shell length than those at the other two sites (Figures 5a, 5b, and 5c). Mean shell length at Booth was found to remain relatively constant from 2<sup>nd</sup> July onwards with a mean shell length over this time period of 11 mm. 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 5a). Large mean shell lengths were also noted at the start of July at Riskaness (Figure 5b) and Sellivoe (Figure 5c).

The largest mussels were found at Booth (mean = 9.6 mm, range = 0.9 to 26.3 mm) with smaller size ranges recorded at Sellivoe (mean = 7.4 mm, range = 0.4 to 23.7 mm) and Riskaness (mean = 3.5 mm, range = 0.4 to 16.3 mm) (Figure 6). All three sites had a single peak in the 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 6: Mussel length frequencies at each site.**

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  $5\ 540\ m^{-3}$ .

A significantly higher concentration of D-larvae were recorded during the ebb of the tide (Figure 7) compared with the flood tide. Mean sea surface temperature was found to be similar during the flood and ebb of the tide ( $12.7\ ^\circ C$  and  $12.8\ ^\circ C$ , respectively) however, Secchi disc depth (an indication of water clarity) 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.

## Discussion

It was evident from the data that the initial spawning at each of the four sites was not recorded (Figure 4). With the exception of Sellivoe, larval concentrations peaked later 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 5) 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 six weeks after spawning<sup>3, 7</sup>. 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 six weeks prior to the ropes being deployed. High mussel recruitment in early June at Booth suggests a much earlier spawning time at this site. This is backed up with the length-frequency plot (Figure 6) which showed Riskaness and Sellivoe to have

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smaller mussels, indicating more recent spawning and recruitment. Such differences between sites could be due to food availability and environmental variables, such as temperature, which has been shown to have an important affect on mussel growth<sup>8</sup>.

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 5) which showed that deploying mussel ropes as close to the spawning time as possible may not be the most efficient method of obtaining high yields. However, deploying ropes in July showed an increased mean shell length with a decreased number of mussels, as recorded at both Booth and Sellivoe.

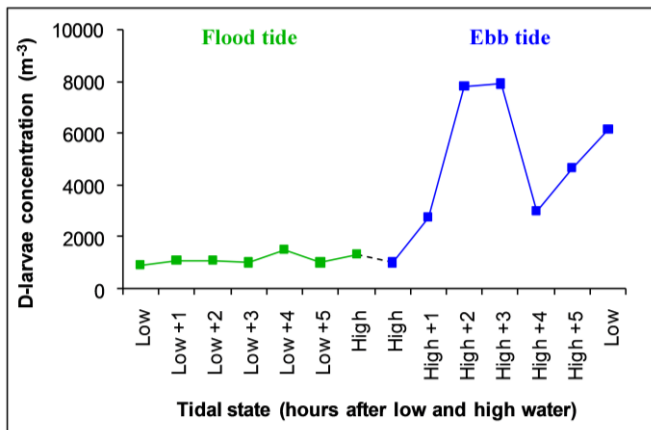


Figure 7: Concentration of D-larvae (m<sup>-3</sup>) over a tidal cycle.

Concentrations of D-larvae obtained using the sampling hose were found to be much greater than previous published results<sup>7-11</sup> which was probably due to variation in equipment rather than higher concentrations. It was therefore not possible to compare results 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 but results seem to vary between studies<sup>9, 10</sup>. Knights *et al.*<sup>10</sup> suggested that larvae may actively avoid transportation during ebb tides. These results conflict with those reported during this study which showed that there was a greater concentration of D-larvae during the ebb of the tide compared to the flood (Figure 7). 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 water clarity. 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 predation from the adult mussel population as mentioned by

Bayne<sup>4</sup>. 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.

The data clearly shows a distinct biological difference between the site at Booth and the remaining sampling sites during 2007. 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. 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 comparative samples are taken at the same point in the tidal cycle.

## Acknowledgements

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