Stock assessment of the blue mussel (*Mytilus edulis*) beds in the Blyth estuary - 2021

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Summary

Annual NIFCA surveys of the mussel bed in the Blyth estuary were conducted in 2021. The perimeter of the mussel bed was mapped for five separate sectors identified in previous surveys, and percentage cover of mussels was estimated using the MarinX 'Dutch Wand' survey technique. 28 samples of mussels were collected, and shell lengths and weights of 121 individual mussels were measured. The 2021 survey introduced new analysis of samples to better understand the spatial population demographics of the Blyth estuary mussel beds.

Key results:

- Though mussel bed area has varied over time since 2015, there is no overall trend and due to the subjective nature of determining bed perimeter, confidence in these estimates is low.
- This year had high proportions of spat (juvenile mussel) with 25% of individuals <5mm in length.
- The largest measured mussel was 59mm which is the lowest of any surveyed year. This is because the density of mature mussels (>45mm) has decreased significantly (by almost tenfold) over time.
- Overall mussel density has varied but declined over time. It varies significantly across the mussel bed.
- Percentage cover has declined slightly over time with the lowest recorded cover overall (14%) in 2021. This is highly variable both over time and spatially.
- Mussel meat content (10.2%) could indicate poor physiological condition of mussels in the estuary and has decreased since 2019, which could indicate a lack of available nutrients.

2021 survey results confirm the continued decline in mussel density in the Blyth estuary, particularly of the older, mature population. There were a relatively high proportion of juvenile mussels in the 2021 survey compared to other size classes, however still at lower densities than in previous years. The decline in the adult population regardless of sporadic recruitment indicates that recruitment at current levels is not enough to sustain the population in the long-term if pressures impacting the beds are not addressed. Continued work to understand the causes of decline and improve methodology through the use of an unmanned aerial vehicle (drone) is being undertaken through collaboration with Newcastle University, the Environment Agency and Natural England.

Introduction

The Blyth estuary covers an area of 168 hectares, including the River Blyth east of Bebside and a beck on the northern side called Sleekburn and is adjacent to Blyth town and the Port of Blyth. The estuary has an industrial past with major industries in coal, ship building and breaking in the 20th century and is still a major port with current growth in the renewable energy sector. Ongoing redevelopment work includes a project at Bates Terminal to the south and a nearby major development for offshore energy with a new deep-water dock on the northern edge of the estuary.

The Blyth estuary is part of the Northumberland Shore Site of Special Scientific Interest (SSSI)[1] which includes most of the coastline between the Scottish border and the Tyne Estuary. The intertidal mudflats of the estuary provide important low-water feeding grounds and high-water roosting grounds for large numbers of overwintering waders including oystercatcher, ringed plover, lapwing, dunlin, redshank and turnstone. Eider duck, knot, curlew and terns (sandwich and common) also use the estuary during the summer.

Blue mussel (*Mytilus edulis*) beds are on the OSPAR (Annex V) list of threatened and declining species and habitats. The blue mussel is a suspension feeding bivalve mollusc which feeds on algae, detritus and organic material in the water column. Mussels can form dense beds in the intertidal zone, the upper limits of which are controlled by temperature and desiccation while the lower limits are controlled by predation, competition and sand burial. Mussels spawn in spring and late summer, but larval mortality is high resulting in sporadic recruitment. Mussels are an important prey item for some species of estuarine bird such as the oystercatcher, eider and curlew.

In late 2014, Northumberland Inshore Fisheries and Conservation Authority were notified of an increase in bait collection activity in and around the mussel beds on the Blyth estuary. Due to the importance of the site for important birds and concerns from the public, NIFCA began monthly stock assessment surveys of the mussel beds to assess stock health between March 2015 and February 2016 and have conducted annual surveys in March/April since then.

Methods

This survey was conducted on 1st April 2021. For consistency, only surveys from March/April in 2015 and 2016 were analysed for annual comparisons with later surveys.

Study site

The study site is located on the Blyth Estuary in Northumberland. Historically, the mussel bed was divided into six sectors. Sectors 1 to 4 are based on the feeding/roosting sites defined in Holliday

[1] https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S2000134&SiteName=&countyCode=

(2000) and were surveyed in the 2015-16 surveys. An additional two areas of mussel bed were added to the survey as sectors 5 and 6 in 2017. For the 2020 and 2021 surveys, conditions did not allow for sectors 5 and 6 to be surveyed, however mussel density in 2019 was so low in these areas that area could not be estimated. Officers will continue to monitor this area and may revisit these sites in future if mussels return to the area. During the 2020 survey, a new bed area (sector 7) was discovered and surveyed in 2021. Mussel bed sectors surveyed in 2021 are shown in Figure 1.

Figure 1. Blyth estuary mussel bed sectors surveyed in 2021.

Survey methodology

Two Inshore Fisheries & Conservation Officers (IFCOs), one of whom had previously walked the perimeter, walked the perimeter with a handheld GPS. Confidence in the accuracy of the area is low as the area of the mussel bed is difficult to define. There is no WFD definition of what constitutes a mussel bed so it can be subjective to define mussel bed area. Bed areas were calculated in ArcGIS from GPS perimeters.

The percentage cover of mussels on the mussel bed was estimated using the MarinX 'Dutch Wand' survey technique (McGrorty *et al.,* 1990). Surveyors walked in a zigzag across the mussel bed, in a randomly determined direction (Figure 2). The Dutch wand (a 4ft bamboo cane with an 11cm ring attached to the end) was placed out to one side every three steps and the result of either a ‘hit’ (if the ring contained live mussels) or a ‘miss’ (if the ring did not contain live mussels) was recorded. Percentage cover was then calculated using the equation:

$$Percentage\ cover = \frac{Number\ of\ Hits}{Number\ of\ Hits + Number\ of\ Misses} \times 100$$

Figure 2. Officer during the survey of the mussel bed using the Dutch Wand methodology.

A mussel sample was taken from inside the 11cm ring at the site of every third ‘hit’. The total number of ‘hits’/samples taken per transect was recorded and samples were cleaned. Total shell lengths of all the mussels sampled were then measured (to the nearest millimetre) using a vernier calliper and divided into the following size groups: ≤25mm, 26-49mm and ≥50mm. The total weight (g) of mussels in each size category was also recorded for each sample. The density of mussels on the mussel bed was then calculated using the following equation:

$$Mussel\ density\ (number/m^2) = \frac{Number\ of\ mussels\ per\ m^2\ x\ Percentage\ Cover}{100}$$

Using a combination of mussel weight, density, percentage cover and bed area, the approximate total stock of mussels was calculated:

$$Mussel\ biomass\ (g/m^2) = \frac{Total\ mussel\ weight\ per\ m^2\ x\ Percentage\ Cover}{100}$$

$$Mussel\ Stock\ Biomass\ (tonnes) = \frac{Area\ of\ bed\ (m^2) \times\ Mussel\ biomass\ (g/m^2)}{1\ 000\ 000}$$

Since 2019, meat content has been measured as an additional monitoring tool of overall bed health. The sample of all mussels was bulk weighed, then boiled for five minutes so that the valve opened. Soft tissue was collected and bulk weighed to calculate the weight of the meat, which was then used to calculate percentage meat content:

$$Meat\ Content\ (\%) = \frac{Meat\ Weight\ (g)}{Total\ weight\ (g)} \times 100$$

Results

A total of 121 individual mussels from 28 samples were sampled in 2021. Overall the percentage cover of live mussel in the beds was 24%, and the density over the whole bed was 109 mussels/m^2 when taking percentage cover into account. The total area of the surveyed beds was 30 330m^2. The results of individual sectors are summarised in Table 1. Only one sample was taken from sector 7.

Table 1. Results of the Blyth mussel survey 2021 by sector and for the overall surveyed beds.

Sector	Area (m^2)	Number samples	Number of mussels	Total weight (g)	% cover	Density (mussels/m^2)	Biomass (kg/m^2)
Sector 1	14320	8	15	325.5	19%	38.1	0.83
Sector 2	5341	9	37	483.5	38%	162.9	2.13
Sector 3	5165	5	39	298	23%	186.1	1.42
Sector 4	2369	5	25	224	23%	120.9	1.08
Sector 7	3135	1	5	63	17%	87.7	1.10
Overall	**30 330**	**28**	**121**	**1394**	**24%**	**109.0**	**1.26**

Bed Area

Mussel bed area has varied over time, though no overall trend is obvious (Figure 3). Of the four sectors (1-4) consistently surveyed over time, sectors 3 and 4 remained roughly the same. The decline in overall area of these sectors from 2015/16 to 2018 is due to a 60% decrease in sector 2, which then remained at a similar extent.

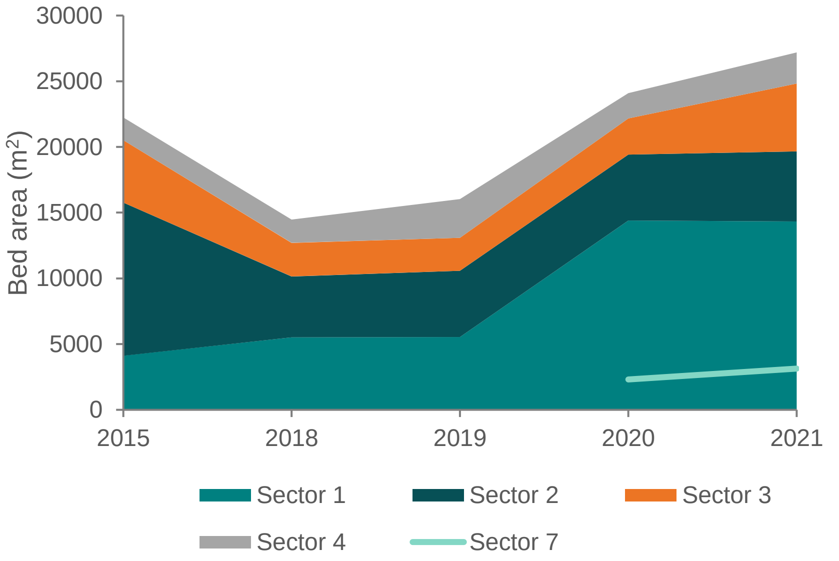


Figure 3. Total mussel bed area (m^2) of consistently-surveyed Sectors 1-4 over time from 2015/16 surveys to present. Area of sector 7 in 2020-21 surveys is displayed but not included in total area. Area for sector 2 was not calculated in 2020 therefore 2019 data were used. Data were unavailable for 2016 and 2017 surveys.

The large increase in area of sectors 1-4 from 2019 to 2020 is due to a 2.5-fold increase in area of in sector 1 downstream, which was also recorded in 2021 (Figure 4). Compared to 2019 and 2020 there are slight increases in the areas of sectors 2 and 3 upstream, while the shape and area of sector 7 has changed from 2020-21 (Figure 4). Overall bed area in 2021 is the highest recorded.

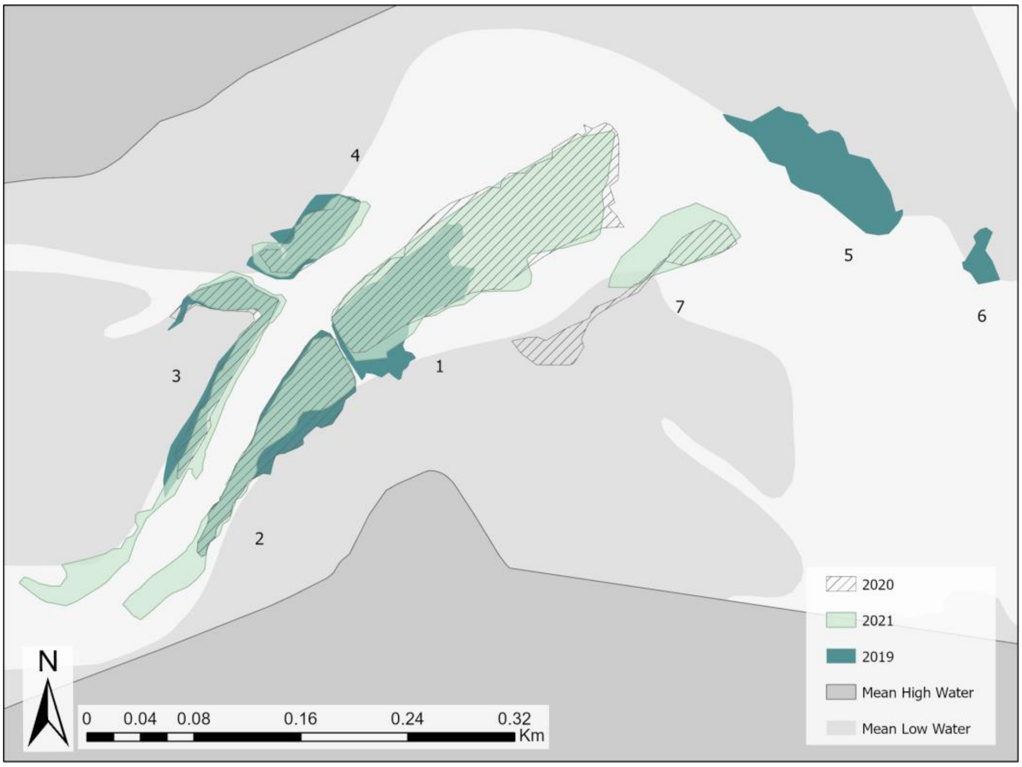


Figure 4. Mussel bed sectors surveyed in 2019, 2020 and 2021.

Length Frequency

Mussel shell length varied from 0.5 – 59mm with a mean length of 30.8mm (Figure 5). There were two peaks in frequency at <5mm and >40mm indicating different age classes. There was a high proportion of young mussel (spat) found including 25% of individuals <5mm in length and 39% under 25mm (Figure 6a). The proportion above 45mm, the Minimum Landing Size available for bait collection, was 39%.

The proportions of size classes varied in different sectors (Figure 5). Sector 3 had the largest proportion of juvenile mussel <5mm making up 56% of the mussels in that sector by number. Sector 4 also had a relatively high proportion (24%) of mussel <5mm compared to other sectors where the majority of individuals were at least 40mm in length. The three highest density samples from the middle sections of sectors 3 and 4 had high proportions of young mussel <25mm indicating the high densities in this section were due to good recruitment. Several samples from sector 2 also had relatively high proportions of young mussel though at lower densities. Sector 1 had higher proportions of larger mussels compared to other sectors with very few mussels under 25mm and five out of eight samples only containing mussels over 50mm in length. The mussels found in sector 7 were all under 50mm in length however only one sample was taken from this smaller bed so this may not be representative.

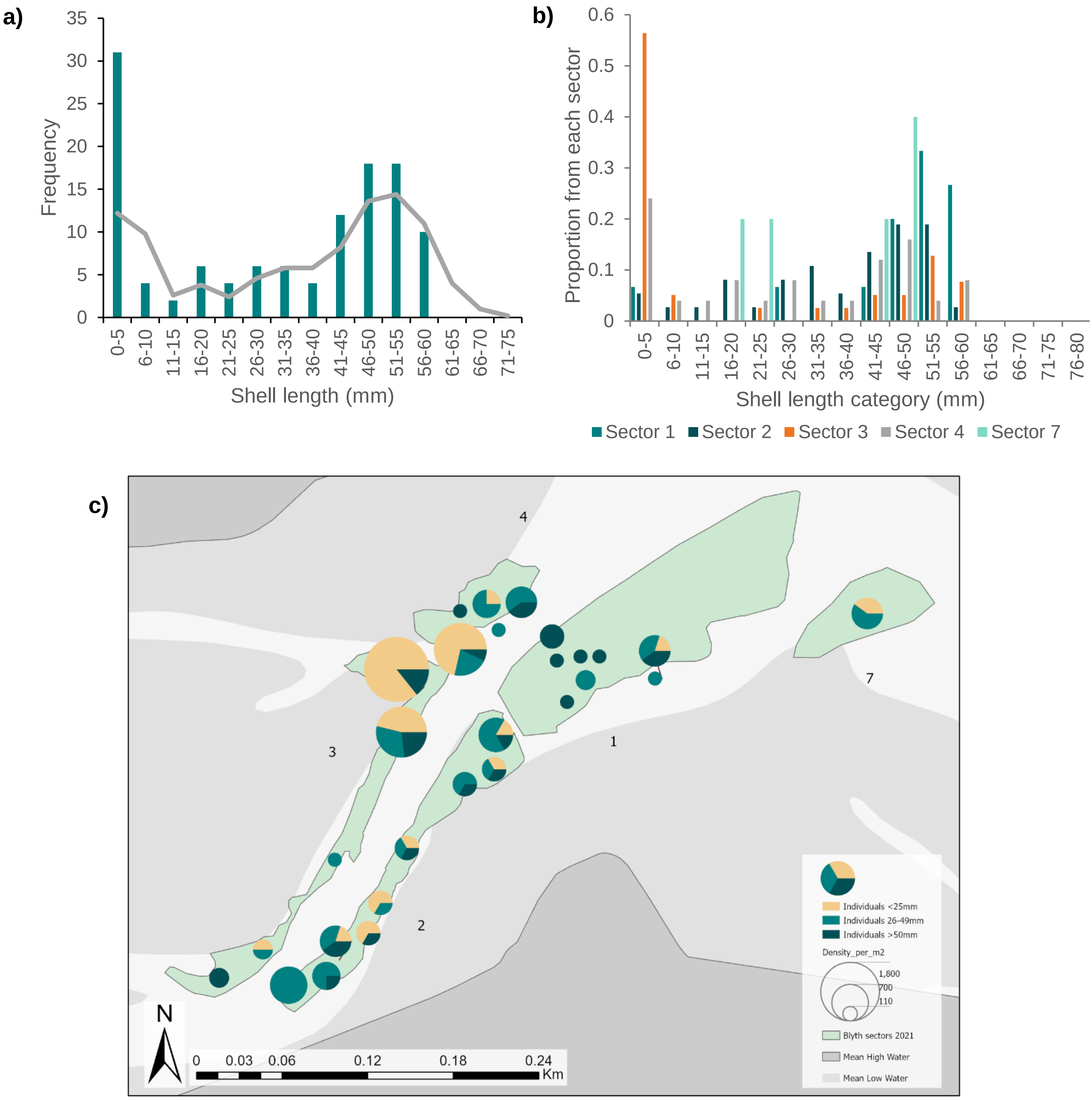


Figure 5. Frequency and distribution of mussel shell lengths in the Blyth estuary, 2021. a) shell length frequencies of individuals in the Blyth estuary overall, with averaged trendline; b) shell lengths as proportions of the total number of mussels per sector, and c) locations of samples showing density (mussels/m^2) as the circle size and proportion of size classes (<25mm, 26-49mm, >50mm) per sample. Locations are not exact to ensure they do not overlap.

Compared to previous years, there was a high proportion of young mussel in 2021 with the highest proportion (25%) of <5mm mussels of any surveyed year. The bi-modal distribution of shell lengths is similar to 2016, 2018 and 2019 (see previous report[2]). The larger size classes (60-80mm) present in all previous years were absent in 2021. Over time, the proportion of mature mussels in the Blyth

[2] Analysis of the Edible Mussel (Mytilus edulis) Bed surveys in the Blyth Estuary, 2015 – 2020. NIFCA Report.

is decreasing compared to smaller (<50mm) size classes (Figure 6a) causing a decline in the mean shell length of mussels within the estuary (Figure 6b). The proportion of those in the smaller size classes has more inter-annual variation however the proportion <25mm appears to be increasing relative to the other size classes.

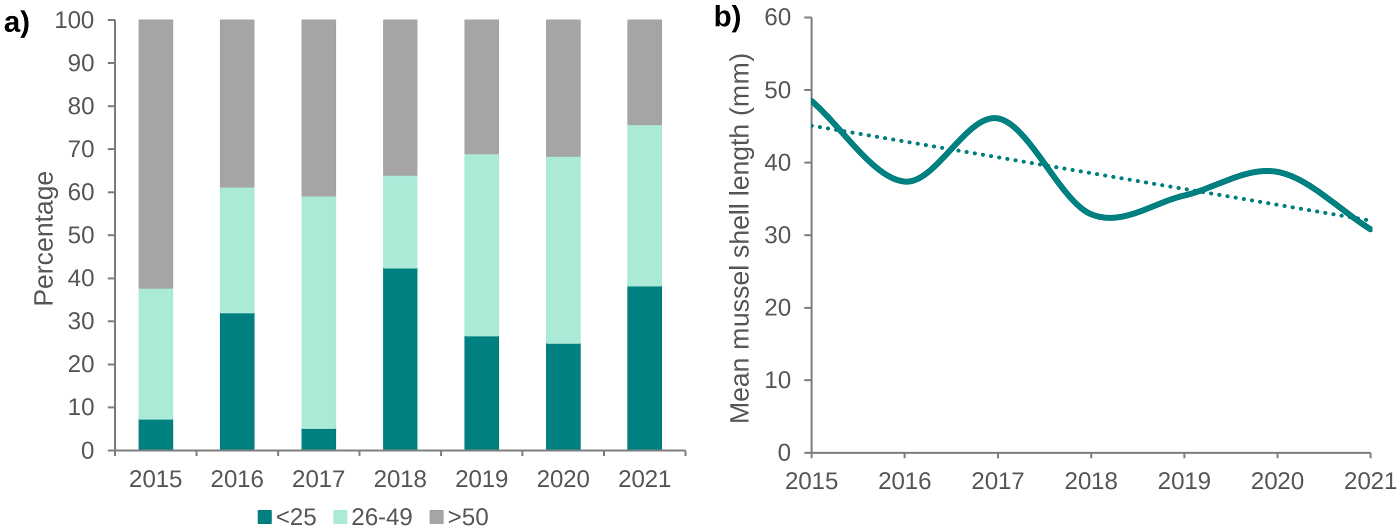


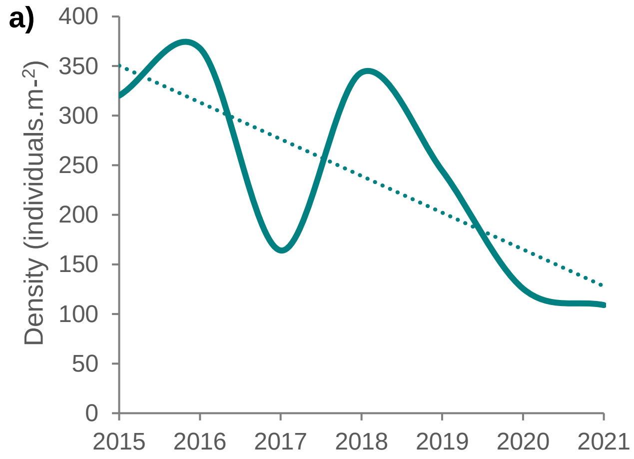
Figure 6. a) Percentage of mussels in size classes (<25mm, 26-49mm and >50mm) and c) mean shell length, from 2015-2021.

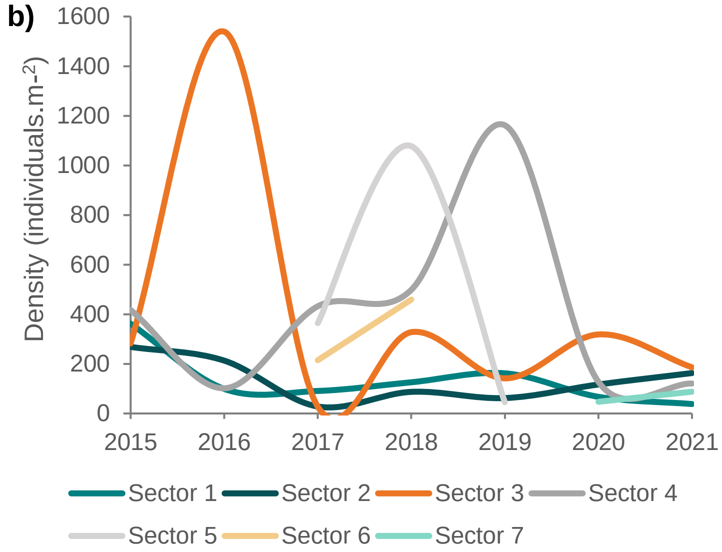
Density

Density was also highly variable across the 28 samples (Figure 5c). Sectors 2 and 3 had the highest densities overall (Table 1) though density was more consistent across sector 2. Sector 3 had a greater range of densities with two of the three highest sample densities (2210 and 1368m^{-2}) in the estuary. Sector 4 had the next highest density overall and the second highest individual sample (1473m^{-2}), towards sector 3. Sector 1 had the lowest overall densities and five out of the eight samples only had one mussel in (corresponding to a density of 110m^{-2}). Only one sample was taken from sector 7.

Density has varied over time both overall and for different sectors (Figure 7). Overall density is highly variable over time but has decreased. See previous report[2] for a full description of results over time. Years with higher density correspond with high densities in individual sectors in that particular year which are not maintained in subsequent years (Figure 7b). Densities in 2020 and 2021 are the lowest as all sectors had relatively low mussel densities compared to previous years.

The densities of the different size classes have also varied over time (Figure 7c). The larger size class (>50mm) has declined almost tenfold density since 2015, while the middle size class (26-49mm) has declined but at a slower rate. The density of the smallest size class (<25mm) has varied significantly between years with peaks in 2016 and 2018, and with a slight increase from 2020-21 but still relatively low compared to some previous years.





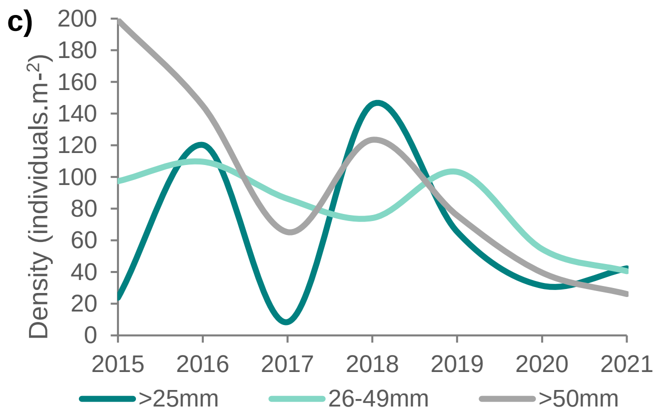


Figure 7. Density of Blyth estuary mussels a) overall with (nonstatistical) linear trendline, b) by sector, and c) density of individual size classes (<25mm, 26-49mm, >50mm) from 2015-2021. No samples were taken from sector 6 in 2019 therefore density could not be calculated however was anecdotally very low.

Percentage cover

Percentage cover varied both between and within sectors across different transects (Figure 8). The highest overall percentage cover was in sector 2 where transects had values between 18-50% cover. Sectors 3 and 4 had 23% cover overall, though sector 3 was more consistent (between 20-32%) compared to sector 4 (6-36%). Sectors 1 and 7 had the lowest percentage covers though the upstream/southern end of sector 1 had higher values (26% and 33%) than the transect near its northern edge (7%). Sector 7 is a small area and only one transect was surveyed.

Overall percentage cover has varied over time though with a slight decline and the lowest recorded cover in 2021 at 24% (Figure 9a). Percentage cover in sectors is highly variable over time (Figure 9b); see previous report[2] for a full description of results from 2015-20. In comparison to 2020, percentage cover in Sectors 1, 2 and 7 has remained similar however cover in sectors 3 and 4 has declined by 52% and 62% respectively.

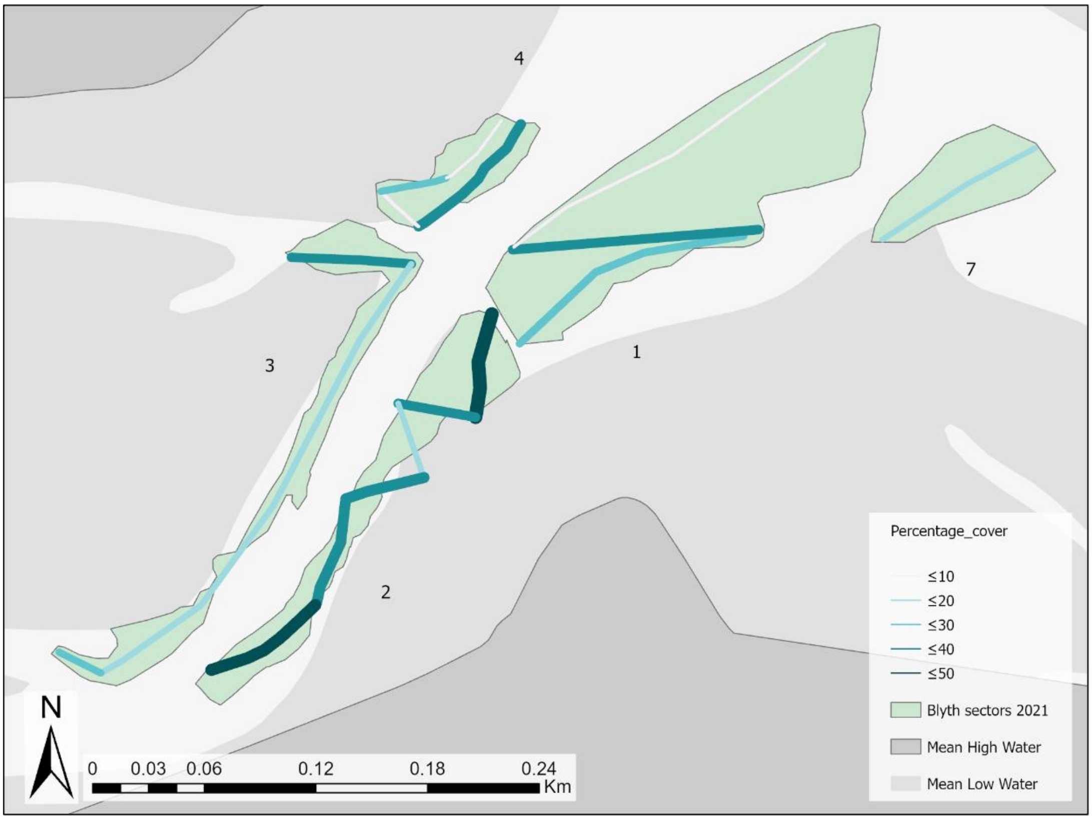


Figure 8. Percentage cover and locations of surveyed transects. Percentage cover increases with transect line darkness/thickness.

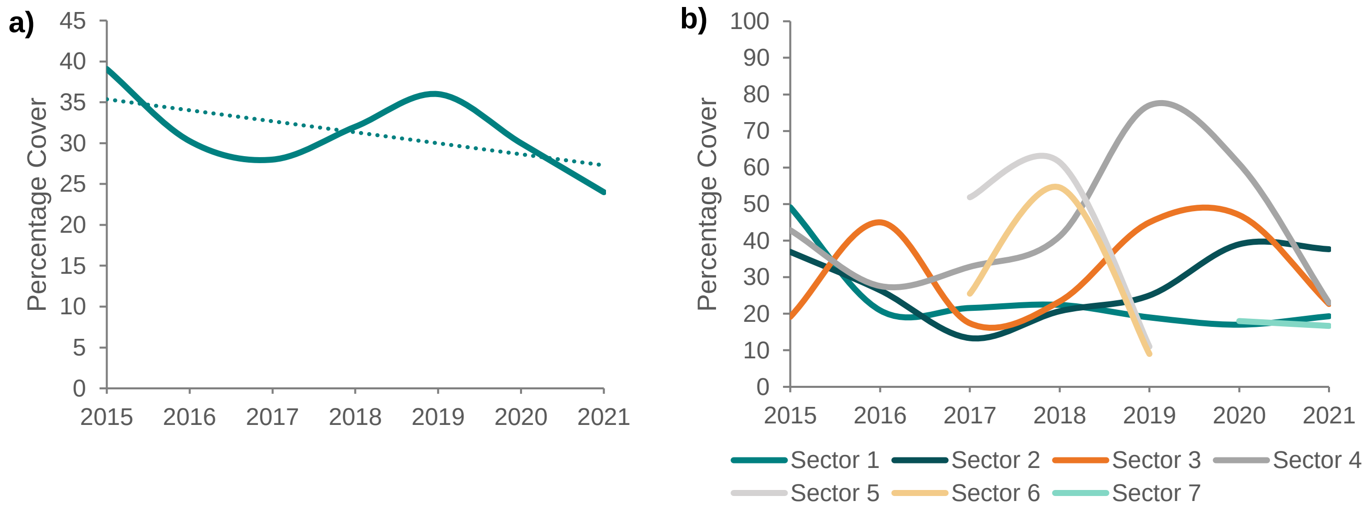


Figure 9. Percentage cover of Blyth estuary mussel beds a) overall with (nonstatistical) linear trendline and b) by sector, from 2015-2021.

Mussel stock biomass

Mussel stock biomass was an estimated 38 tonnes for 2021, similar to 2019 and 2020 surveys (Figure 10). Since 2015 there has been a large decline in estimated stock biomass. The proportion of biomass greater than 50mm has decreased from a high of 84% of total stock in 2015 to 42% in 2021, the lowest value in surveys to date.

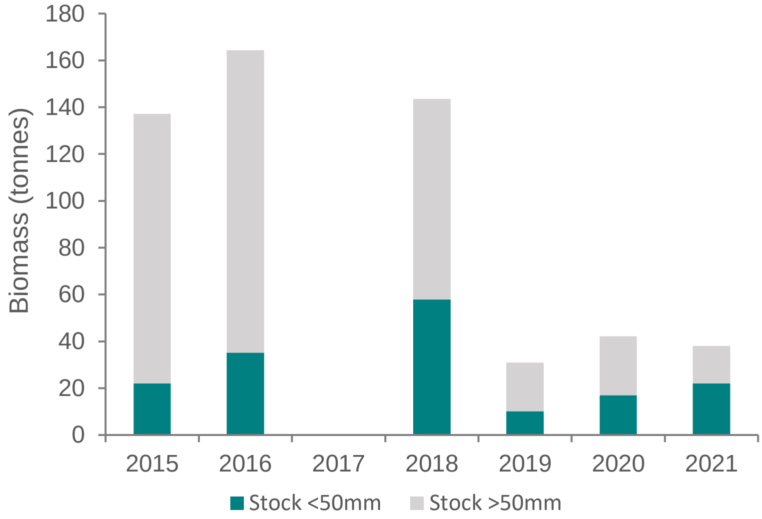


Figure 10. Biomass estimates for the total estimated stock of mussels in the Blyth estuary 2015-21, showing biomass greater and less than 50mm. Bed area values were unavailable for 2017 surveys therefore biomass was not calculated.

Meat content

The combined weight of meat and shell was 1018g while the meat weight was 104g. The meat content was therefore 10.2% of the total weight. This has decreased by 26% since 2019 when measurements began.

Discussion

While surveyed mussel bed area has varied over time, there are no clear trends and due to the difficulties in determining perimeter of beds with low percentage cover of mussel and the subjective nature of the surveys, in addition to changes in NIFCA officers over the years, confidence in these estimates is low. Surveys show that the general mussel bed areas, i.e. areas in the estuary with high enough densities of mussels to be defined by eye, remain similar year-on-year. Mussels do occur in other parts of the estuary though at lower densities and more often individually instead of in clumps. They also occur within the streams which are unable to be surveyed.

The 2021 survey did confirm the continued existence of sector 7 which was added to the surveys in 2020 although the perimeter differed, probably due to the low density of mussels in the sector making defining a perimeter challenging. Previously-surveyed sectors 5 and 6 were unable to be surveyed in 2021 due to access difficulties and have therefore not been surveyed since 2019 when their density was very low. Their status is therefore unknown although anecdotally there are still mussels in those areas of the northern banks. Future surveys could target these areas to better understand mussel distribution and condition across the beds.

Estimated mussel stock biomass has declined over time and remained at low levels from 2019-21 indicating a declining stock, particularly in larger, mature mussels >50mm in shell length. As these estimates rely on accurate bed area estimates, however, confidence is also low although they are a useful indicator of mussel bed health.

In 2021 there was a high proportion of juvenile mussels (spat) especially under 5mm in shell length. The highest densities of spat were found on the northern banks (sectors 3 and 4) towards the centre of the beds, though were found in varying proportions in every sector showing successful larval settlement and growth throughout the estuary. Sectors 3 and 4 have higher densities of mussels and higher proportions of juvenile mussel especially compared to sector 1 which has low densities and an aging population with little recruitment. This could be due to differences in environmental factors such as availability of suitable settlement sites or sedimentation, or a possible consequence of lower levels of exploitation on the northern banks of the estuary which is less accessible.

The decline in mean shell length over time and increasing proportion of young mussel (<25mm) compared to the mature population (>50mm) is due to the large decline in density of larger mussels since 2015 which is a concern. Interestingly the mussel beds at Lindisfarne exhibit an opposite trend of an aging population with an increasing mean shell length although with similar declines in mussel bed density to that observed in the Blyth estuary.

Though the proportion of young mussel in 2021 was high, its density was still much lower than in other years (notably 2016 and 2018). This could be due to reduced spawning of the adult population due to reduced density, a lack of suitable settlement sites on adult substrata which young mussel preferentially settle on, or some other factor influencing larval survival. This survey confirms the trend of overall mussel bed decline, in terms of density, reported from 2015-20.

The proportion of juvenile mussels successfully recruiting into the adult population is unknown. A peak in mussel density <25mm in 2016 may have led to the higher density of large individuals (>50mm) in 2018, while the peak in <25mm mussels in 2018 could have resulted in the increase the following year of the 26-49mm age class. However, growth rates within the estuary are unknown and vary depending on environmental conditions so recruitment is difficult to estimate.

Recruitment in mussel populations is often sporadic, occurring in unpredictable pulses (Seed & Suchanek, 1992), which is the case in the Blyth estuary in surveyed years, with higher recruitment occurring roughly every two years. Persistent mussel beds can be maintained by relatively low levels of sporadic recruitment (McGrorty et al., 1990; Mainwaring et al., 2014), however the decline in mussel density over this time indicates recruitment is not high enough to counter the causes of decline and sustain the population.

Density and percentage cover estimates do not rely on bed area and are therefore more useful than stock biomass estimated in determining trends in mussel bed health over time. Percentage cover overall has decreased slightly over time although has varied between sectors, with most sectors having relatively stable coverage. Sectors 3 and 4 on the northern banks exhibited a decline in percentage cover between 2020-21 which should be monitored in future surveys. This could be due to some physical factor impacting these areas (or ability to detect mussels in surveys), for example sediment deposit on the northern side of the river bend.

The decline in meat content from 2019-21 could indicate declining health of the mussel population. A meat content of around 10-20% in other studies has been recorded in northwest England, with some mussel with measurements as high as 30% (NWIFCA, pers. comms. 2021). Therefore the Blyth estuary mussels are likely to be in poor physiological condition. A low or declining meat content could indicate a lack of food availability (Orban et al, 2002). Mussels may survive losses of up to 78% of their meat biomass because of starvation (Kautsky, 1982), and a 1953 study (Chipperfield, 1953) in the Blyth also found the mussels in the estuary were in poor condition and ‘semi-starved’, though still able to spawn. If a reduction in nutrients is causing the reduced meat content this could impact on spawning and contribute to the decline in mussel density in the estuary.

Meat content is subject to seasonal variation (Okumus and Stirling, 1998): lower food availability in winter and spawning in spring means mussels will have lost meat biomass when surveys are conducted. Since annual surveys are conducted at the same time of year, meat content should be similar however seasonal variation in environmental factors such as temperature could cause inter-annual variation.

Previous surveys did not examine spatial patterns in percentage cover, mussel density or distribution of size classes across the mussel bed sectors, therefore this survey can be used as a baseline to monitor spatial changes within the mussel beds over time. There is variation both between and within mussel bed sectors so this information is useful in determining specific areas where mussels are more successful in settling and surviving within the estuary.

Potential reasons for mussel bed decline

Regionally, the mussel beds in the northeast have declined. NIFCA surveys at Fenham Flats in the Lindisfarne National Nature Reserve show the mussel bed, which is significantly larger than the Blyth mussel bed, has declined in terms of percentage cover, density, biomass and number of mussels from 2006-2019 (Dent/NIFCA, 2019). Within the northeast mussel beds were historically more widespread and there was a sudden and widespread decline in 2009/10 after which they have never fully returned (pers. comms., Jane Delaney, Dove Marine Laboratory). Mussel beds have declined elsewhere in the UK for example in the Wash and in Scotland where they decreased in abundance at 54% of sites between 2002-10 and 2014-15, the greatest decline in any intertidal species surveyed (Burrows, 2014/15).

OSPAR reports widespread declines in the extent and biomass of intertidal mussel beds, particularly in the Greater North Sea, particularly in Germany, Denmark and the Netherlands due to intensive fisheries, as well as in the UK (OSPAR, 2010). *M. edulis* beds are included in the OSPAR (Annex V) list of threatened and declining species and habitats and are listed as a UK biodiversity action Plan (BAP) Priority Habitat (Maddock, 2008). Threats to mussel beds include, but are not limited to, bait collection (Maddock, 2008), gathering for human consumption (Fenton, 1978), pollution (Hilgerloh, 1997), coastal development and anchoring (Maddock, 2008). Within the Blyth estuary factors such as overexploitation, substratum loss, water quality changes and nutrient enrichment, predation and climate change may contribute to the declines (for more information see NIFCA report[3]).

Conclusions

Overall, the 2021 surveys continue the trends identified in 2015-20 surveys. Total mussel bed extent and percentage cover have not shown any overall trends over time, though density has declined since 2015, particularly of the older, mature population. There were a relatively high proportion of juvenile mussels in the 2021 survey compared to other size classes, however still at lower densities than in previous years. The decline in the adult population regardless of sporadic recruitment indicates that recruitment at current levels is not enough to sustain the population in the long-term. Meat content analysis also shows the Blyth mussel population may not be in good physiological condition which could be due to winter, spawning, reduced nutrient availability or other environmental factors.

The 2021 survey introduced new analysis of samples to better understand the spatial population demographics of the Blyth estuary mussel beds which give an indicator of areas which are more likely to sustain themselves, which could help in identifying potential causes of decline. Further work is being conducted to ascertain the reasons for the decline and NIFCA surveys will continue to monitor the status of the beds.

[3] Blue mussel declines in the Blyth Estuary. NIFCA Report 2021.

Further work

The problems in estimating mussel bed area are due to their subjective nature and the difficulty of assessing mussel bed edges on the ground. A current project at Newcastle University aims to use an unmanned aerial vehicle (UAV or drone) to determine whether this method is effective at surveying intertidal habitats such as mussel beds, and early results from the Blyth estuary indicate it could be useful for helping determine mussel bed extent and coverage which could supplement NIFCA survey data and aid in determining bed area over time. Project outcomes include a standard operating procedure for using UAVs for intertidal research within the equipment capabilities of NIFCA.

The exact causes of mussel bed decline are unknown, both in the Blyth estuary, regionally and nationally. There is a current Newcastle University MSc. project partnered with the Environment Agency and Natural England to utilise EA data on water quality and mussel contaminants to better understand the causes of decline, comparing the Blyth estuary and mussel beds at Fenham Flats and Holy Island. Natural England have proposed a larger project to understand more about mussel bed declines which should shed further light on both regional and national declines.

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