Stock assessment of the blue mussel (*Mytilus edulis*) beds in the Blyth estuary - 2022

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Summary

Annual NIFCA surveys of the mussel bed in the Blyth estuary were conducted in 2022. 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. 20 samples of mussels were collected, and shell lengths and weights of 62 individual mussels were measured.

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 lower proportions of spat (<5mm mussels) than in 2021, though 24% of mussels were still juveniles under 25mm in length.
- The largest measured mussel was 64mm and the average size was 37.4mm, an increase from 30.8mm in 2021. However, this is not due to an increase in frequency of the larger sizes compared to last year, but the fewer juvenile mussels found.
- While density varies across the mussel bed, it is consistently low in all sectors. Overall density was the lowest in 2022 since surveys began, following two years of low density in 2020 and 2021. Overall density has decreased over fourfold since 2015 which is a cause for concern.
- Compared to 2021 (the previous lowest year) percentage cover was much lower throughout the mussel bed with an overall decline from 24% to 17% cover.

2022 survey results confirm the continued decline in mussel density in the Blyth estuary, particularly of the older, mature population. The lowest percentage cover and densities recorded consistently across sectors point to low health of the mussel beds overall. 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. A collaborative Masters' research project with Newcastle University, the Environment Agency and Natural England examined mussel contaminants in two mussel beds at Holy Island and Fenham Flats, finding negative correlations of percentage cover with the contaminants PBDE154 (a flame retardant), dieldrin and endrin (pesticides) which have all been banned since 2007, 1989 and 1984 respectively. Storm frequency was also negatively related to percentage cover at Fenham Flats (but not Holy Island). Biocontaminants in the Blyth estuary have also been measured by the EA but were not within the scope of this project, though the estuary's heavily industrialised past and current use as a port mean that the potential for biocontamination impacting on mussel beds is significantly higher than at Lindisfarne beds.

Though the causes of decline are unknown, and unlikely to be elucidated, it is clear that the intertidal mussel beds in the Blyth estuary are declining in terms of percentage cover and density, and that this is driven largely by the decline in larger sizes of mussel, which are also the sizes targeted by collectors.

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 19th April 2022. 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. Sectors 5 and 6 have not been surveyed since 2019 due to logistics, 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 subsequent years. Mussel bed sectors surveyed in 2022 are shown in Figure 1.

Figure 1. Blyth estuary mussel bed sectors surveyed in 2022.

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:

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

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:

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

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

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

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

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

In surveys from 2019-2021, meat content was measured as an additional monitoring tool of overall bed health (see previous survey reports). However, the decision was taken not to measure this moving forward since the method was not accurate enough.

Results

A total of 62 individual mussels from 20 samples were sampled in 2022. Overall the percentage cover of live mussel in the beds was 17%, and the density over the whole bed was 156 mussels/m^2 when taking percentage cover into account. The total area of the surveyed beds was 30,444m^2. The results of individual sectors are summarised in Table 1.

Table 1. Results of the Blyth mussel survey 2022 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	16 188	4	14	168	11%	41.9	0.50
Sector 2	4675	6	15	300	15%	40.0	0.80
Sector 3	3297	7	25	274	35%	132.7	1.45
Sector 4	2410	1	3	42	18%	55.7	0.78
Sector 7	3874	2	5	70.5	12%	31.8	0.45
Overall	**30 444**	**20**	**62**	**855**	**17%**	**55.5**	**0.76**

Bed Area

Mussel bed area has varied over time, though no overall trend is obvious (Figure 3; see previous reports for discussion of previous years). Since 2020 no major changes in area have been recorded (Figure 4). The only change in extent was in 2021 in sector 3, where an extra area of mussel bed was recorded, however this was not surveyed in 2022 therefore mussel density is assumed to be too low to accurately detect mussel bed area.

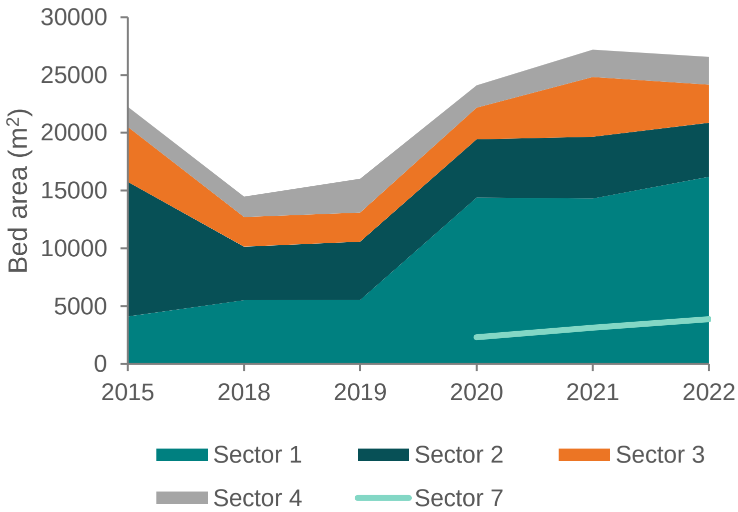


Figure 3. Total mussel bed area (m^2) of consistently-surveyed Sectors 1-4 over time from 2015/16 surveys to present. Area of sector 7 in 2020-22 surveys is displayed but not included in total area. Area for sector 2 was not calculated in 2020 therefore 2019 data were used. Data were unavailable for 2016 and 2017 surveys.

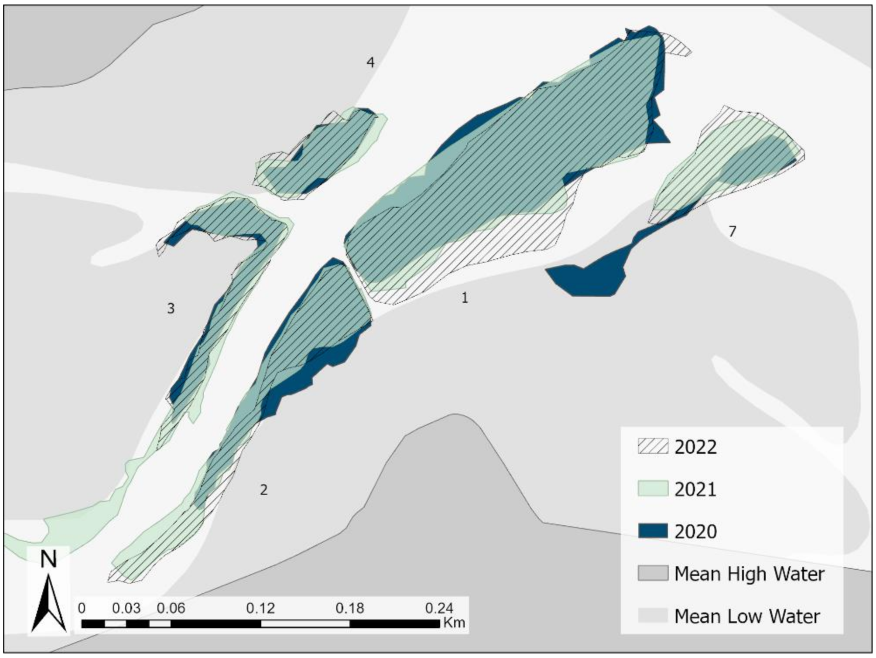


Figure 4. Mussel bed sectors surveyed in 2020, 2021 and 2022.

Length Frequency

Mussel shell length varied from 1 – 64mm with a mean length of 37.4mm (Figure 5). There were two peaks in frequency at <10mm and >35mm indicating different age classes. 15% of individuals were <5mm in length and 24% under 25mm (Figure 6a), less than in 2021. The proportion above 45mm, the Minimum Landing Size for bait collection, was 47% compared to 39% in 2021.

The proportions of size classes varied in different sectors (Figure 5). Sectors 1 and 7 had the largest proportion of juvenile mussel <5mm making up 29% and 20% respectively of the mussels in each sector by number. The majority of mussels were >35mm in all sectors. The proportion of young (<25mm) and mature mussels varied across the bed, with around half the samples containing young mussel (Figure 5c).

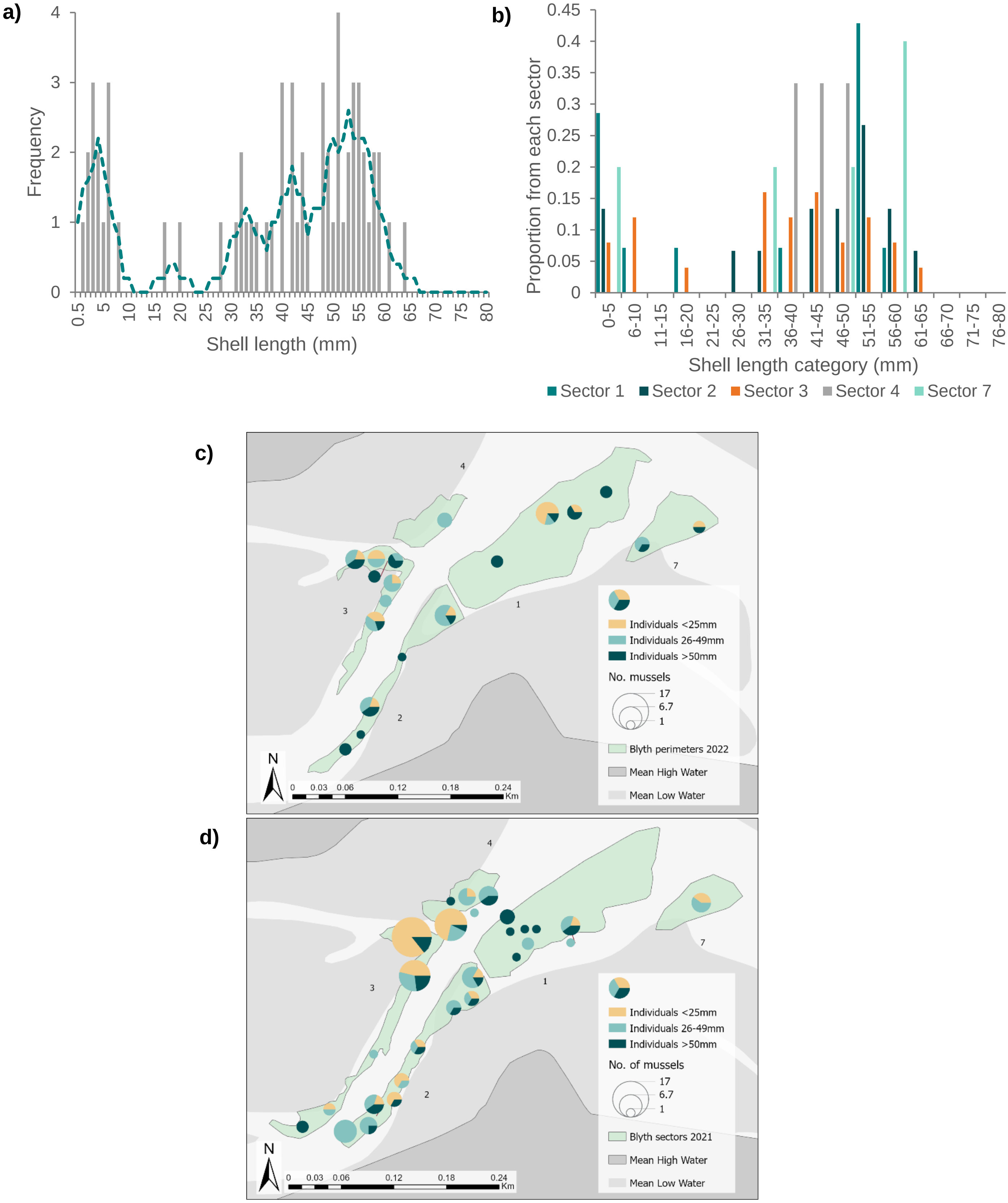


Figure 5. Frequency and distribution of mussel shell lengths in the Blyth estuary, 2022. a) shell length frequencies of individuals in the Blyth estuary overall, with averaged trendline; b) shell lengths as proportions of the total number of mussels per sector, and locations of samples in c) 2022 and d) 2021 showing number of mussels in the sample 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, proportions of size classes were similar to 2019 and 2020, while there were reduced numbers of young mussel (<25mm) compared to 2021 and 2018 (Figure 6a). The bi-modal distribution of shell lengths is similar to 2016, 2018, 2019 and 2021 (see previous report[2]). There were two individuals larger than 60mm which is more than 2021 where no mussels in the larger size classes (60-80mm) were found, however this is still lower than in previous years. Over time, the proportion of mature mussels in the Blyth is decreasing compared to smaller size classes (Figure 6a) causing a decline in the mean shell length of mussels within the estuary (Figure 6b). The proportion of smaller size classes has more inter-annual variation but has been more consistent in recent years compared to 2015 and 2017 when there were very low numbers of young mussel.

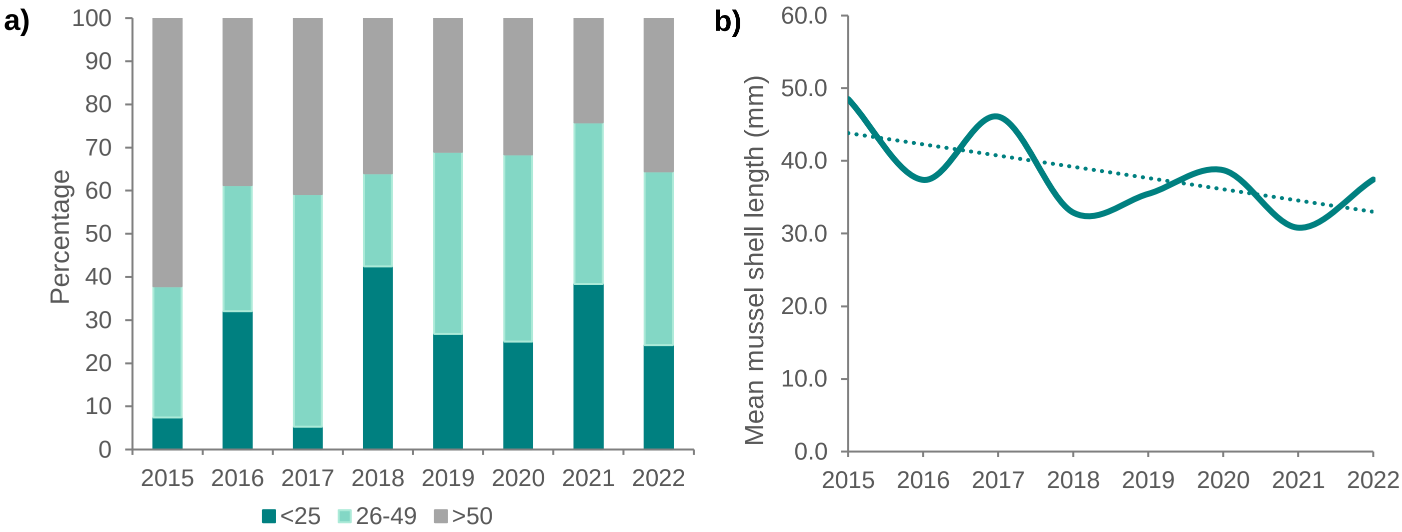


Figure 6. a) Percentage of mussels in size classes (<25mm, 26-49mm and >50mm) and c) mean shell length, from 2015-2022.

Density

Number of mussels per sample was highly variable across the 28 samples (Figure 5c). Compared to 2021, there were less samples taken and the number of mussels (particularly <25mm) per sample was smaller in 2022 (Figure 5d).

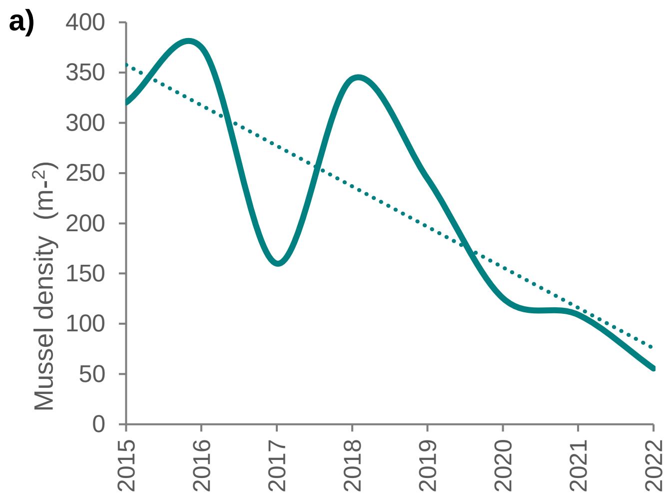
Density (number of mussels and percentage cover combined) varied between the sectors (Table 1). Sector 3 had the highest density overall at 132.7 mussels per m^2 due to the higher percentage cover . Sector 7 had the lowest overall density (31.8 mussels per m^2).

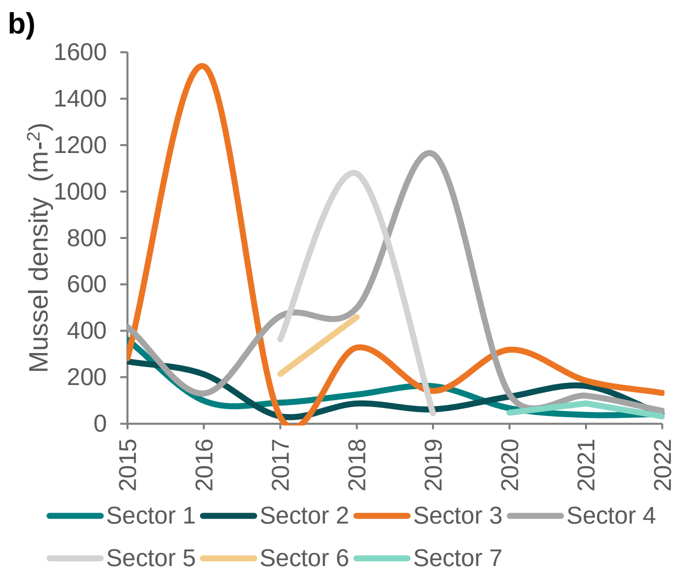
Density has varied over time both overall and for different sectors (Figure 7). Overall density is highly variable over time but has decreased, reaching the lowest value in 2022 after two years of low

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

density in 2020 and 2021. See previous report[2] for a full description of results over time. Since 2019, no Sector has exhibited very high densities which explains the low densities overall in the estuary.

The densities of the different size classes have also varied over time (Figure 7c). The larger size class (>50mm) has declined tenfold 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 low densities since 2020 reaching the lowest in 2022.





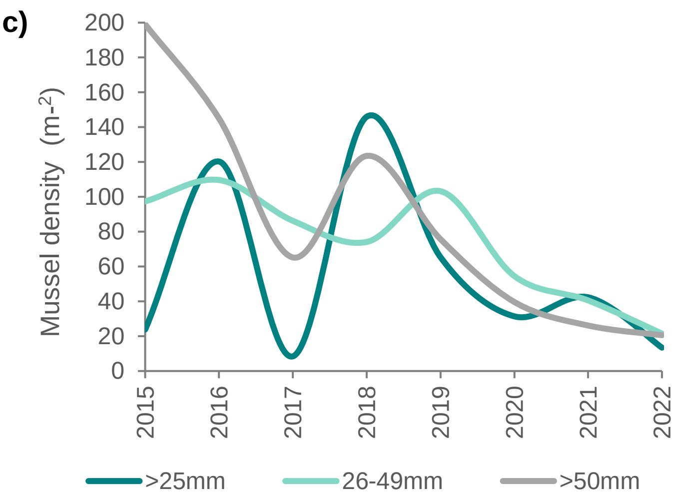


Figure 7. Density of Blyth estuary mussels a) overall with (nonstatistical) linear trendline, b) by sector, and c) density of individual size classes (<25mm, 26-49mm, >50mm) from 2015-2022. No samples were taken from sector 6 in 2019 therefore density could not be calculated however was anecdotally very low.

Percentage cover

Percentage cover varied both between and within sectors across different transects (Figure 8). Percentage cover was generally below 30% with only two transects higher than this (31% in Sector 2 and 68% in Sector 3). Two transects in Sector 2 had zero percentage cover.

Compared to 2021 percentage cover was much lower throughout the mussel bed with an overall decline from 24% to 17% which was mainly caused by the decline in Sector 2 from 38% in 2021 to 15% in 2022.

Overall percentage cover has varied over time though with a slight decline and the lowest recorded cover in 2022 at 17%, again lower than 2021 which was the previous lowest figure 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 2021, Sectors 4 and 7 have remained similar overall while percentage cover in Sectors 1 and 2 decreased and Sector 3 increased. Figure 8 compares transects in 2021 and 2022 and overall the decline in percentage cover is noticeable.

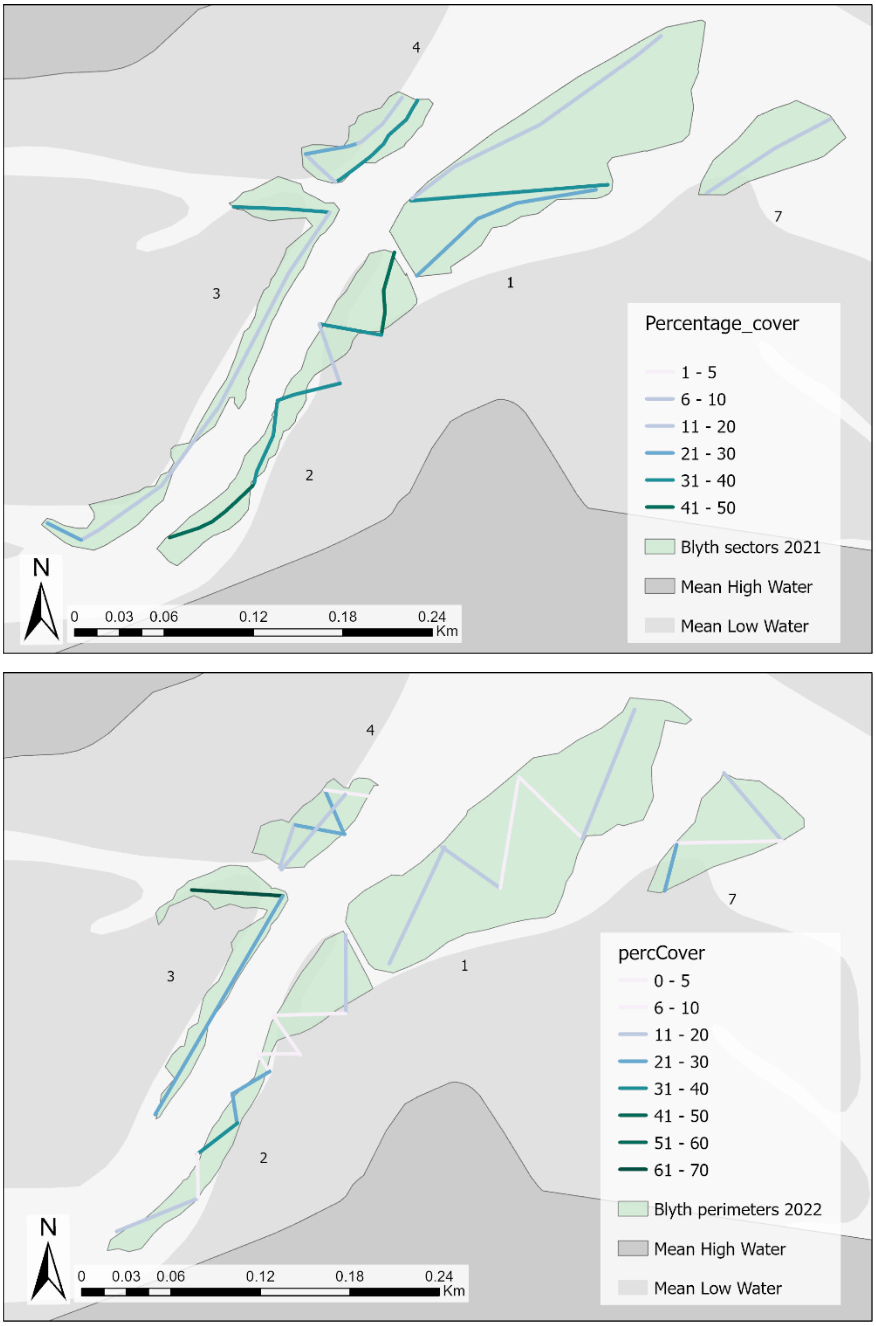


Figure 8. Percentage cover and locations of surveyed transects in a) 2021 and b) 2022.

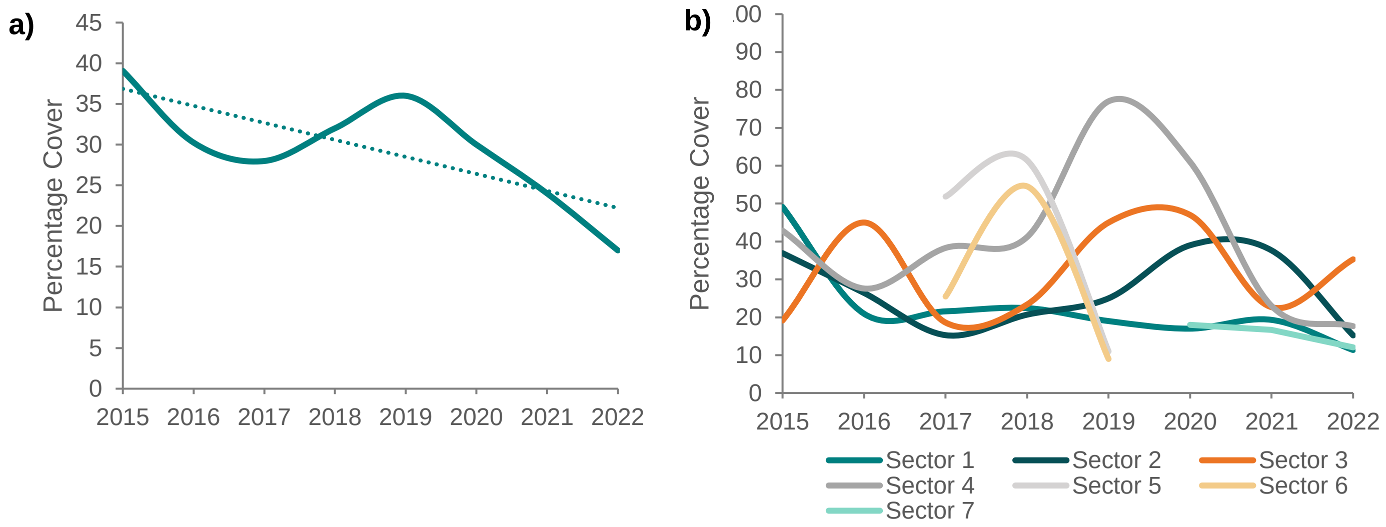


Figure 9. Percentage cover of Blyth estuary mussel beds a) overall with (nonstatistical) linear trendline and b) by sector, from 2015-2022.

Mussel stock biomass

Mussel stock biomass was an estimated 23 tonnes for 2022, the lowest estimated since surveys began (Figure 10). While stock >50mm has increased since 2021 from 16 to 18 tonnes, stock below 50mm has decreased significantly from 22 to 5 tonnes, half of the previous lowest estimate in 2019 which was 10 tonnes. Since 2015 there has been a large decline in estimated stock biomass with consistently low values from 2019 onwards.

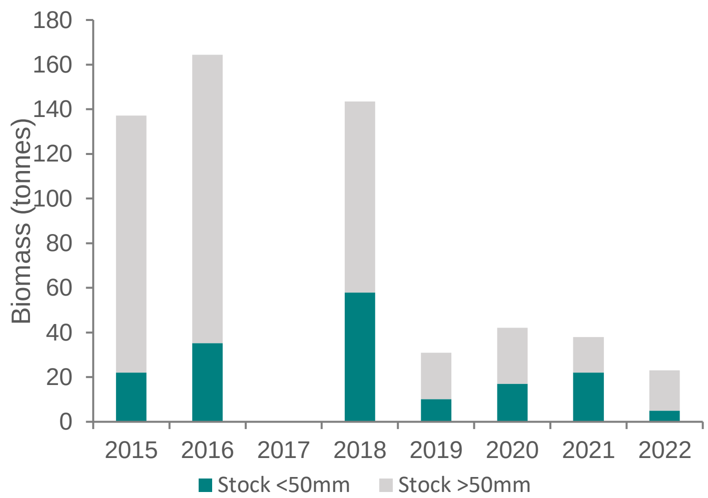


Figure 10. Biomass estimates for the total estimated stock of mussels in the Blyth estuary 2015-21, showing biomass greater and less than 50mm. Bed area values were unavailable for 2017 surveys therefore biomass was not calculated.

Discussion

Mussel bed area remained similar to previous years (see previous report[3]). The 2022 survey sees continued declines in mussel stock biomass from 2019-2021 levels which were already depleted in comparison to earlier years. There was a reduction in the proportion of juvenile mussels (spat) compared to in 2021 although this has been highly variable in the past and is due to different levels of reproduction and recruitment in different years, a normal characteristic of mussel beds. However, percentage cover of live mussel and mussel density were the lowest values this year indicating a continued decline in the health of the mussel bed. The declines in density were for all size classes and continue the trends observed in previous years of a steep decline in mature (>50mm) mussels and a shallower decline in medium sized (26-49mm) mussels.

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.

The bigger decline in larger mature mussels above MCRS could indicate bait collection as a potential cause, although most sightings of mussel collection are within the steams and also further upstream than the surveyed sectors (see Appendix Figure 1). According to anecdotal evidence the sediment characteristics in the estuary mudflats have changed recently, becoming harder and possibly less suited to mussel settlement. Work is ongoing to dredge the ash dock and improve port facilities on the northern bank which may change sediment characteristics within the estuary, though there is no proven link.

Other potential causes of decline include overexploitation (bait collection), substratum loss, water quality, nutrient enrichment, hydrological changes, climate change, predation, recruitment and juvenile survival. These are discussed in previous reports[3,4] and contextualise the declines in the Blyth estuary against widespread blue mussel declines in the UK and northeast Atlantic, the exact causes of which are currently unknown.

[3] Blyth Estuary Blue Mussel Stock Assessment 2021. NIFCA Report
[4] Blue mussel declines in the Blyth Estuary. NIFCA Report 2021.

Conclusions

Overall, the 2022 surveys continue the trends identified in 2015-21 surveys, and show declines in percentage cover, density and therefore total stock since 2021, continuing the trend in overall decline which is a concern. The higher proportion of juveniles found in the 2021 survey did not lead to a higher density of medium or larger size mussels in 2022 therefore successful recruitment into the adult population may not have occurred. 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.

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. In 2021 a project in collaboration with Newcastle University used an unmanned aerial vehicle (UAV) to determine mussel bed extent and percentage cover in the Blyth estuary when compared to traditional ground-based surveys (Dutch wand) conducted by NIFCA. It was successful in determining mussel bed extent based on live and dead shell cover, however could not differentiate between live and dead mussels unlike ground-based surveys. There is potential to use these methods to determine mussel bed extent in the Blyth estuary as well as at Fenham Flats and Holy Island to more accurately determine changes in mussel bed area over time. Though a standard operating procedure for using UAVs to determine mussel bed extent was a successful project outcome, it required the use of a more specialised (multispectral) UAV than NIFCA owns therefore the use of this method in future surveys will be evaluated.

The exact causes of mussel bed decline are unknown, both in the Blyth estuary, regionally and nationally. A Newcastle University project in 2021 used Environment Agency data on water quality and mussel contaminants to better understand the causes of decline, and found significant relationships with the biocontaminants PBDE154, Dieldrin and Endrin at Lindisfarne mussel beds, though the Blyth was not analysed. Given the remote location of Lindisfarne compared to the industrial Blyth estuary, it is likely there will be far more contamination of the mussels in the Blyth which could be having an impact. 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.

It is unlikely whether the exact causes of mussel bed decline in the Blyth estuary will be discovered as it is likely a combination of multiple factors including bait collection, changes in river hydrology and sedimentation, nutrient runoff and contaminants from the industrial past and current port expansion. In 2021 a new voluntary Bait Collection Code of Conduct for the estuary was developed in conjunction with stakeholders, and the efficacy of this needs to be evaluated before considering if there is anything more NIFCA can do to protect the valuable blue mussel beds in the estuary.

Appendix

Figure 1. NIFCA surveyed mussel bed areas in 2019 and 2020 (dashed blue) and NIFCA sightings of mussel collectors 2014-20 (dark blue points) where mussels are also present. From previous report 'Blue mussel declines in the Blyth Estuary' (2021).

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