Stock assessment of the blue mussel (*Mytilus edulis*) beds in the Blyth estuary - 2024

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Summary

Annual NIFCA surveys of the mussel bed in the Blyth estuary were conducted in 2024. 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. 15 samples of mussels were collected, and shell lengths and weights of 33 individual mussels were measured.

Key results:

- Overall the mussel bed continues to decline, from 30,661m^2 in 2023 to 27,310m^2. Sector one was the only sector to record an area increase, although confidence in these area estimates low.
- For the 6th year running the overall density coverage continued to decrease but at a lesser rate, from 23 mussels per m^2 in 2023 to 21 mussels per m^2 in 2024
- Compared to 2023 (the lowest year) percentage cover was dramatically lower throughout the mussel bed with an overall decline from 16% to 9% cover.
- The largest mussel measured was 61mm and the average size was 42.5cm, a decrease from 49.7cm in 2023.
- The smallest mussel measured was 3mm and a higher proportion of smaller sized mussels were recorded throughout the survey compared to 2023. Four out the five sectors recorded mussels of the smallest size class, compared to only one sector in 2023.

Introduction

The Blyth estuary covers an area of 168 hectares, which includes the River Blyth east of Bebside and a beck on the northern side called Sleekburn. It is situated next to Blyth town and the Port of Blyth and is a heavily modified at the estuary mouth subsequent to an industrial past in the 20th century with major industries in coal, ship building and breaking. Today it is still a major port with current growth in the renewable energy sector and ongoing development, with five active marine licences involving dredging and construction activities occurring downstream at the time of the survey.

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 duck 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 protected bird species 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 continued to carry out annual surveys in March/April since.

Methods

This survey was conducted on 11th March 2024. For consistency, only surveys from March/April in 2015 and 2016 were analysed for annual comparisons with later surveys.

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

Survey site

The survey 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 (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 the 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 2024 are shown in Figure 1.

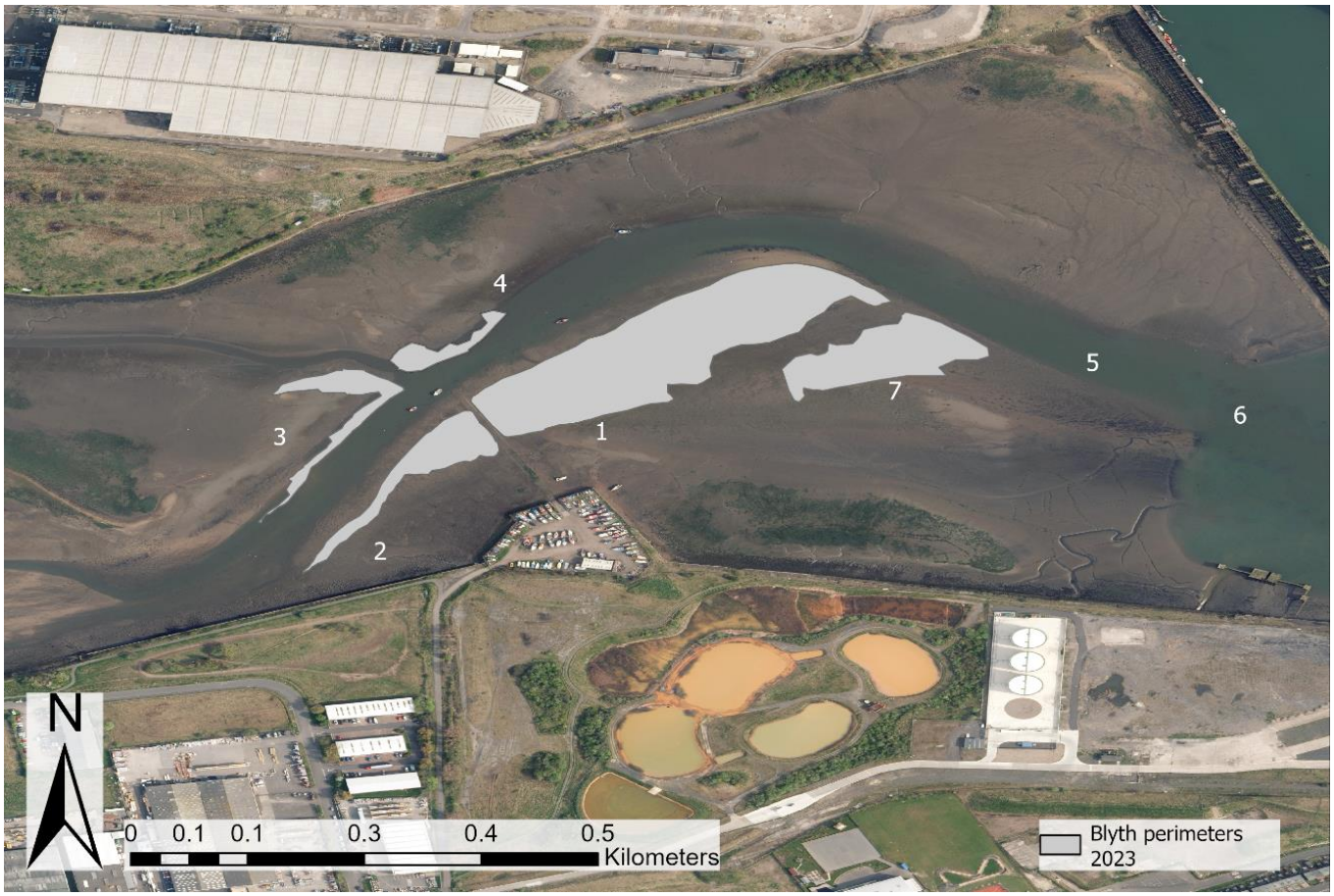


Figure 1 | Blyth estuary mussel bed sectors surveyed in 2024

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 Water Framework Directive 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:

$$\boldsymbol{Percentage\ Cover} = \frac{\boldsymbol{Number\ of\ Hits}}{\boldsymbol{Number\ of\ Hits + Number\ of\ Misses}} \times \mathbf{100}$$

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

$$\boldsymbol{Mussel\ Density}\left(\frac{\boldsymbol{number}}{\boldsymbol{m^2}}\right) = \frac{\boldsymbol{Number\ of\ mussels\ per\ m^2\ x\ Percentage\ cover}}{\mathbf{100}}$$

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

$$\boldsymbol{Mussel\ Biomass}\ (\boldsymbol{g/m^2}) = \frac{\boldsymbol{Total\ mussel\ weight\ per\ m^2\ x\ Percentage\ cover}}{\mathbf{100}}$$

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

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 33 individual mussels from 15 samples were sampled in 2024. Overall, the percentage cover of live mussel in the beds was 9%. The total area of the surveyed beds was 27,310m². The results of individual sectors are summarised in Table 1.

Table 1 | Results of the Blyth mussel survey 2024 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	18,640	2	5	61.2	2%	6.5	0.08
Sector 2	2,890	4	6	71	20%	31.1	0.37
Sector 3	2,020	5	13	241	17%	45.6	0.85
Sector 4	480	3	7	101.2	24%	59.7	0.86
Sector 7	3,290	1	2	56	3%	7.3	0.20
Overall	**27,310**	**15**	**33**	**530**	**9%**	**20.6**	**0.33**

Bed Area

Both the total area and mussel bed areas have varied over time, although no overall trend is obvious (Figure 3; see previous reports for discussion of previous years). Since 2020, sector 1 has been consistently mapped as the largest bed area and with the exception of 2021, recorded a gradual increase in size. This contrasts with sectors 2, 3 and 4 which despite fluctuating over the same time period, have exhibited an overall decrease in size.

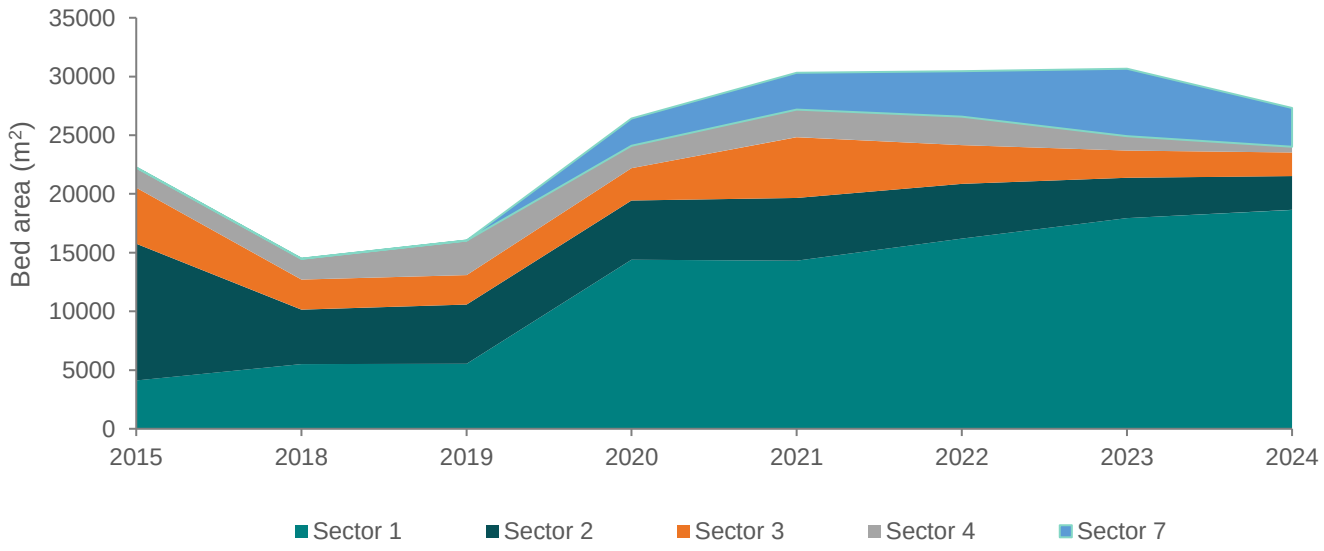


Figure 3 | Total mussel bed area (m2) of regularly surveyed Sectors 1-4 from 2015/16 surveys to present. Area of sector 7 is displayed and included in total area from 2020 onwards. Area for sector 2 was not calculated in 2020 therefore 2019 data were used. Data

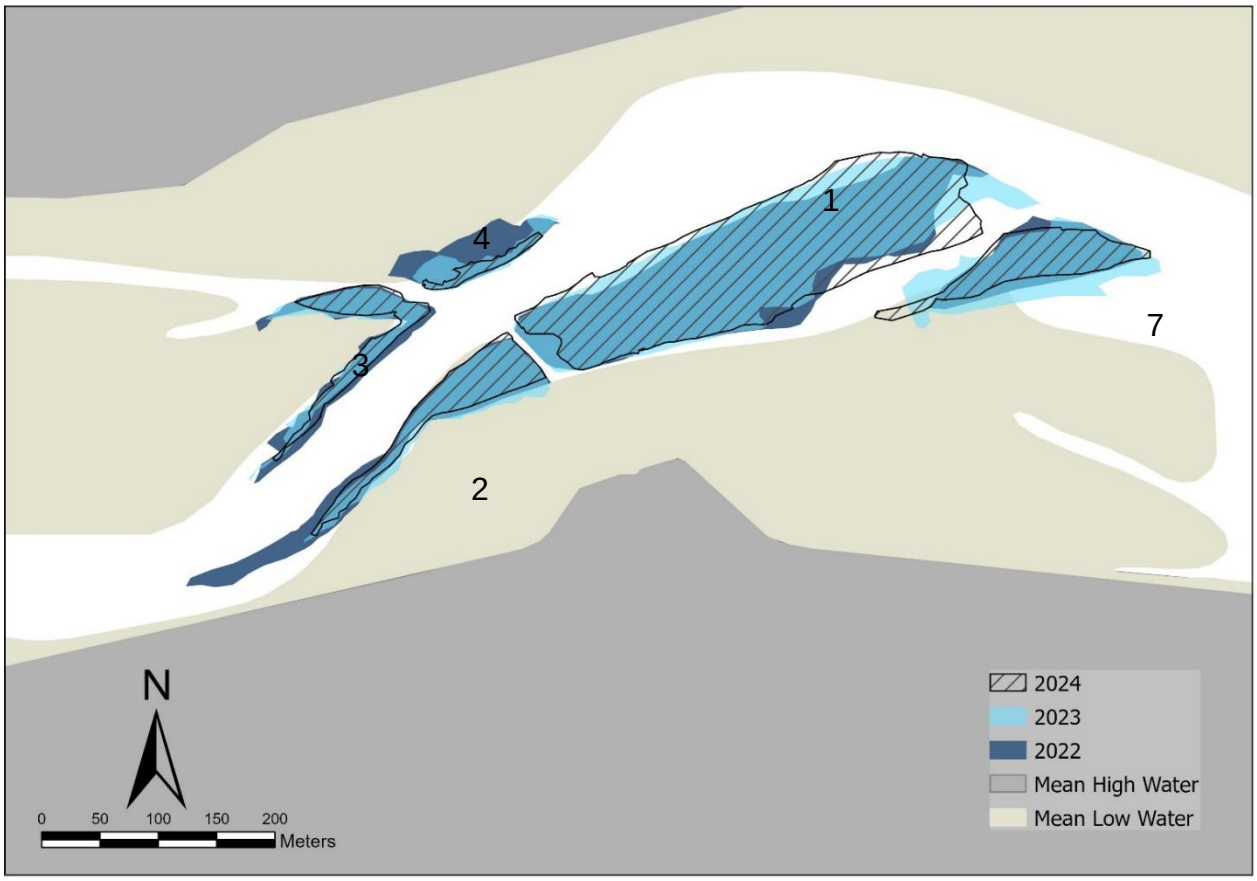
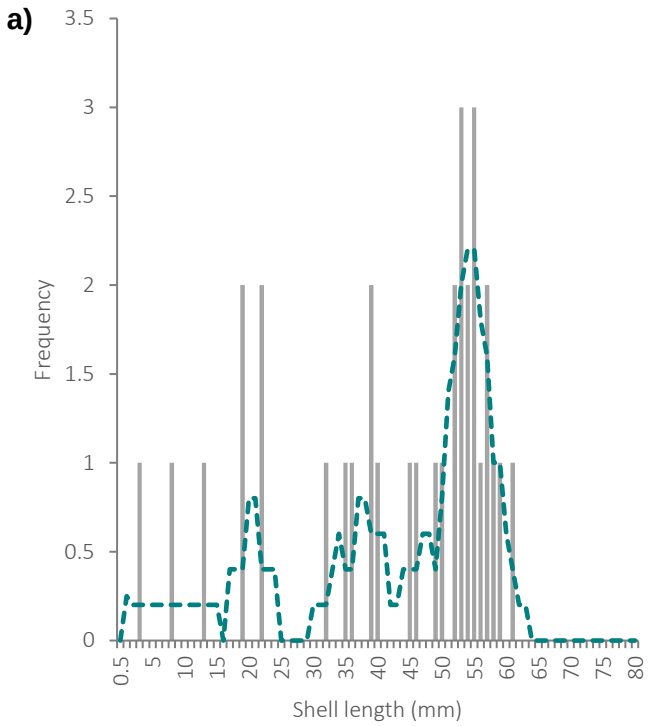


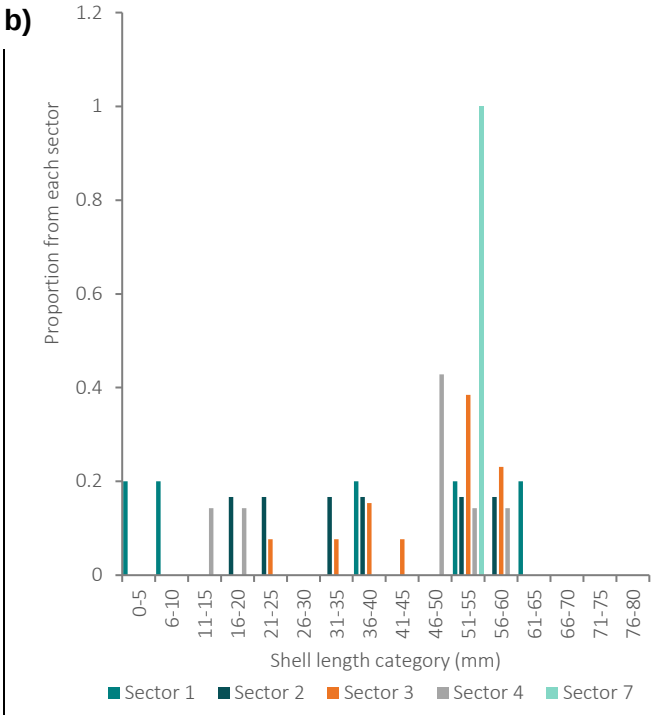
Figure 4 | Mussel bed sectors surveyed in 2022, 2023 and 2024.

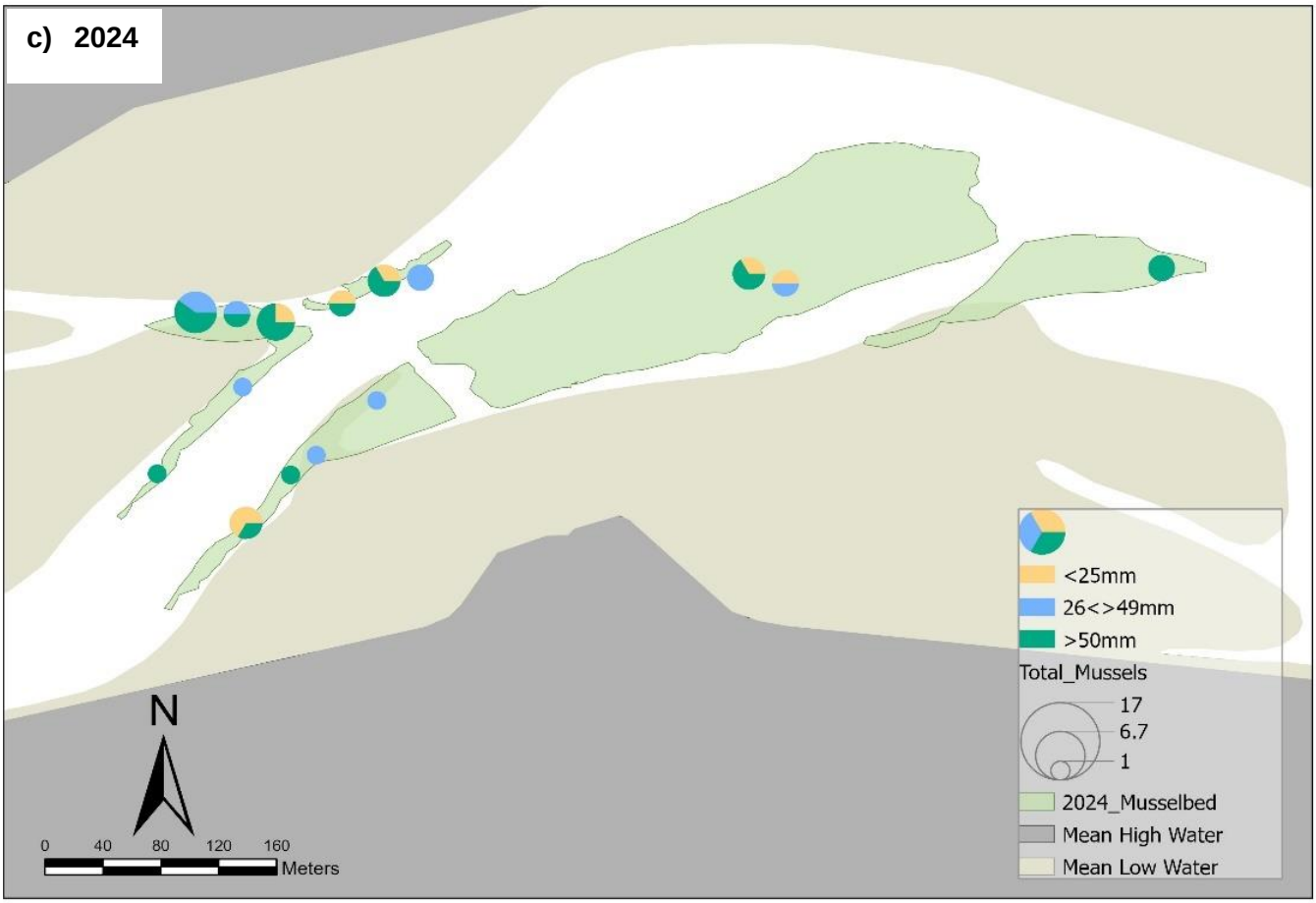
Length Frequency

Mussel shell length varied from 3 – 61mm with a mean length of 42.5mm (Figure 5). There were no distinctive peaks in frequency, but the majority were >46mm indicating an older age class. This older age class is representative of the recommended Minimum Landing Size (>45mm) for bait collection, which has decreased from 77% in 2023 to 57% in 2024. For the smaller size classes, 21% of individuals were recorded <25mm in length, which presents an increase from 4% in 2023 (Figure 6a).

Samples collected from sectors 1 to 4 recorded individuals from all size classes. In sector 7, only one sample was collected, which contained individuals >50mm. The largest (61mm) and the smallest (3mm) individuals were recorded in sector 1, with the majority of >50mm (n=8) noted throughout sector 3 and the majority of <25mm (n=2) found in sectors 1, 2 and 4.


a)
Frequency
Shell length (mm)


b)
Proportion from each sector
Shell length category (mm)
Sector 1
Sector 2
Sector 3
Sector 4
Sector 7


c) 2024
N
0
40
80
120
160
Meters
<25mm
26<>49mm
>50mm
Total_Mussels
17
6.7
1
2024_Musselbed
Mean High Water
Mean Low Water

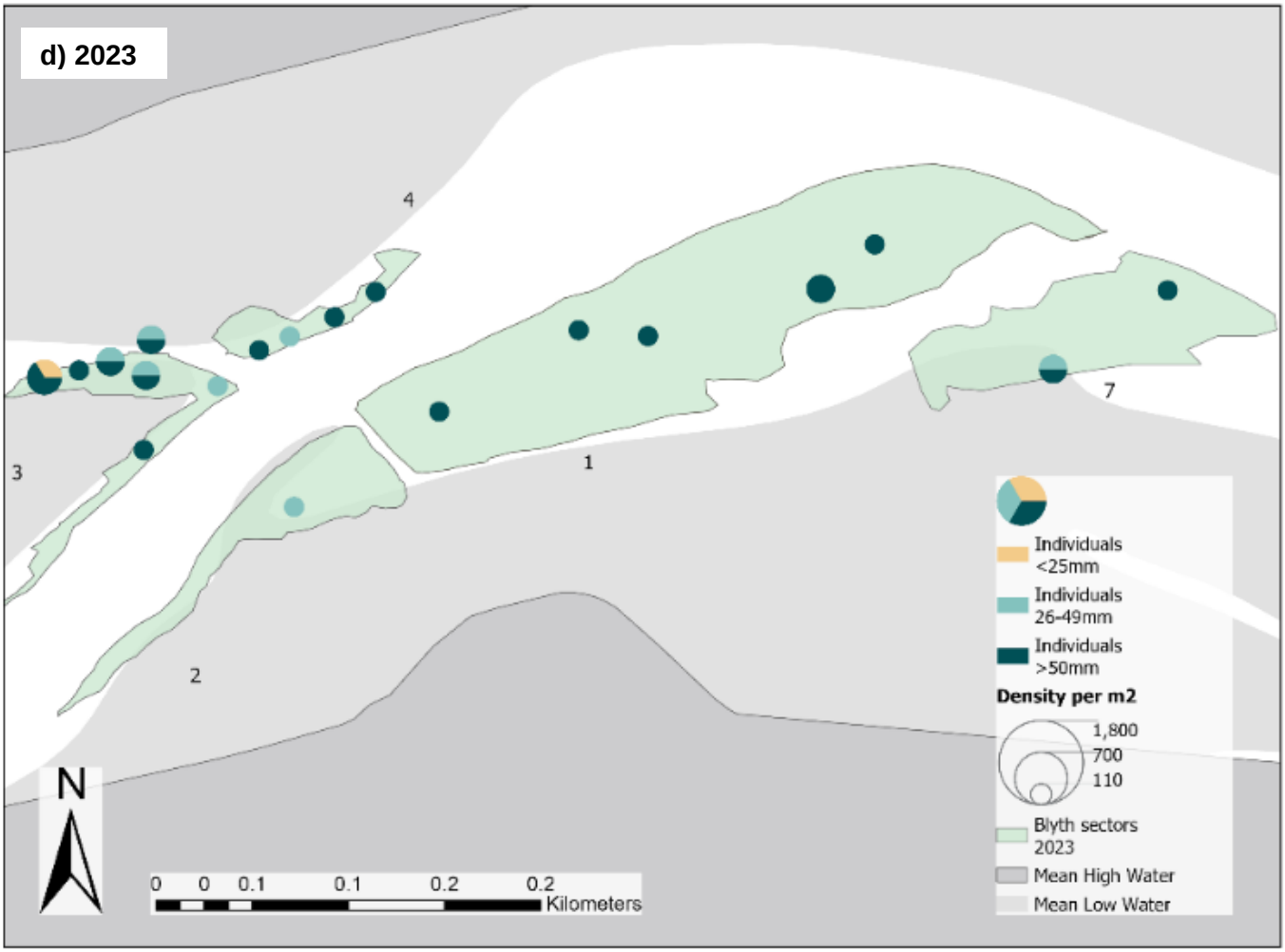


Figure 5 | Frequency and distribution of mussel shell lengths in the Blyth estuary, 2024. a) shell length frequencies of individuals, with averaged trendline; b) shell lengths as proportions of the total number of mussels per sector, c) 2024 and d) 2023, showing number of mussels in the sample as the circle size and proportion of size classes (<25mm, 26-49mm, >50mm) per sample. Locations are not exact to ensure they do not overlap.

In comparison to previous years the proportion of younger mussels recorded in 2024 across the sectors is still low, however, this year's results show an increase of individuals in the <25mm size class in relation to 2023 (Figure 6a). This increase in the proportion of the smallest size class also halts the previous years' trend (2021 to 2023) of an increasing proportion of mature mussels at Blyth and presents a decrease in the overall average of the lengths recorded (Figure 6b).

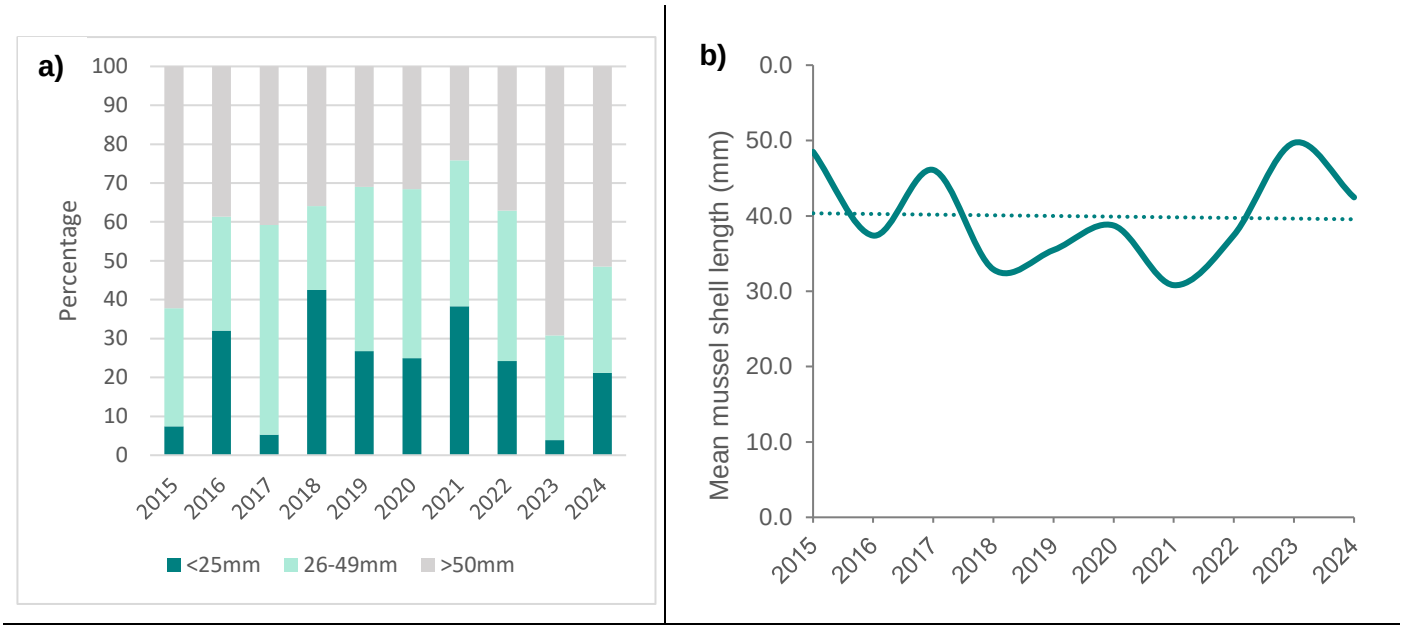


Figure 6 | a) Percentage of mussels in size classes (<25mm, 26-49mm and >50mm) and b) mean shell length, from 2015-2024.

Density

The number of mussels collected across the 15 samples was low (Figure 5c), with highest number of samples and individuals collected in sector 3 (5 samples, 13 individuals) and the lowest in sector 7 (1 sample, 2 individuals). For density (number of mussels and percentage cover combined) this varied between the sites (Table 1). Sector 4 presented the highest density at 59.7 mussels per m^2 due to the higher percentage cover and Sector 1 had the lowest overall density (8.9 mussels per m^2).

The total density has varied over time (Figure 7), presenting an overall continual downward trend. Total density increases have only been recorded in 2016 and 2018, most notably in the latter year during which all sectors exhibited higher densities than the previous year. In most other years, one or two sectors have experienced density increases compared to the previous years, but this has been negated by the density decreases in the other sectors (Figure 7b). 2017 and 2023 are the only years to exhibit density decreases across all sectors. In 2024, sectors 2 and 4 exhibited increases in density compared to 2023, but the total density is the lowest recorded value since surveying began. See previous report[2] for a full description of results over time.

The densities of the different size classes have also varied over time (Figure 7c). The larger size class (>50mm) has declined tenfold since 2015, only experiencing an increase from the previous year in 2018. The middle (26-49mm) and smallest (<25mm) size classes have also declined but at

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

a slower and more varied rate, both experiencing more fluctuations in density over the time frame of the surveys. The lowest density for the smallest and middle size class was reached in 2023 and remained the same in 2024 for the middle size class, with a slight increase for the smallest size class. The 2024 density value for the larger size class represents the lowest density recorded since surveying began.

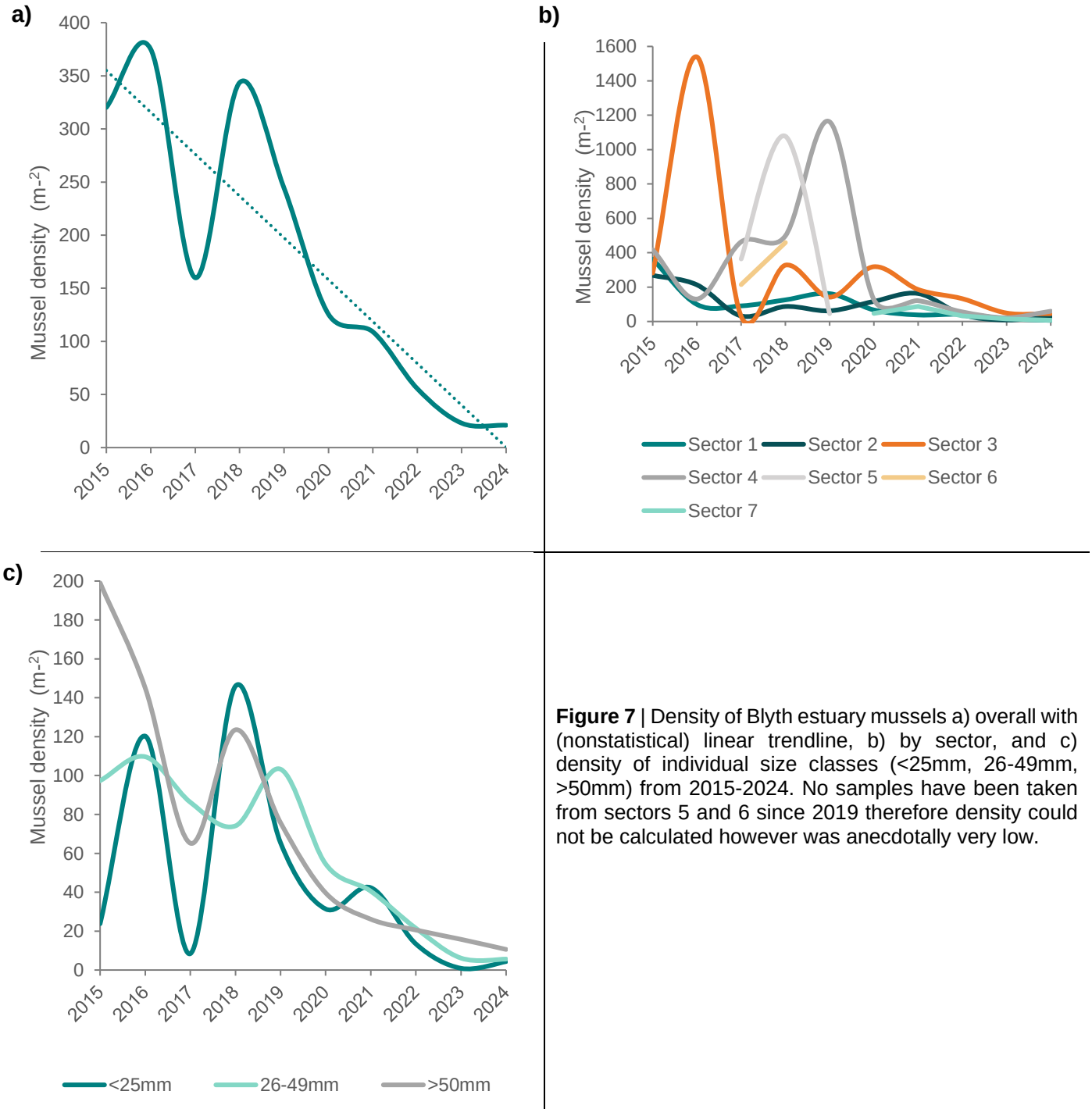
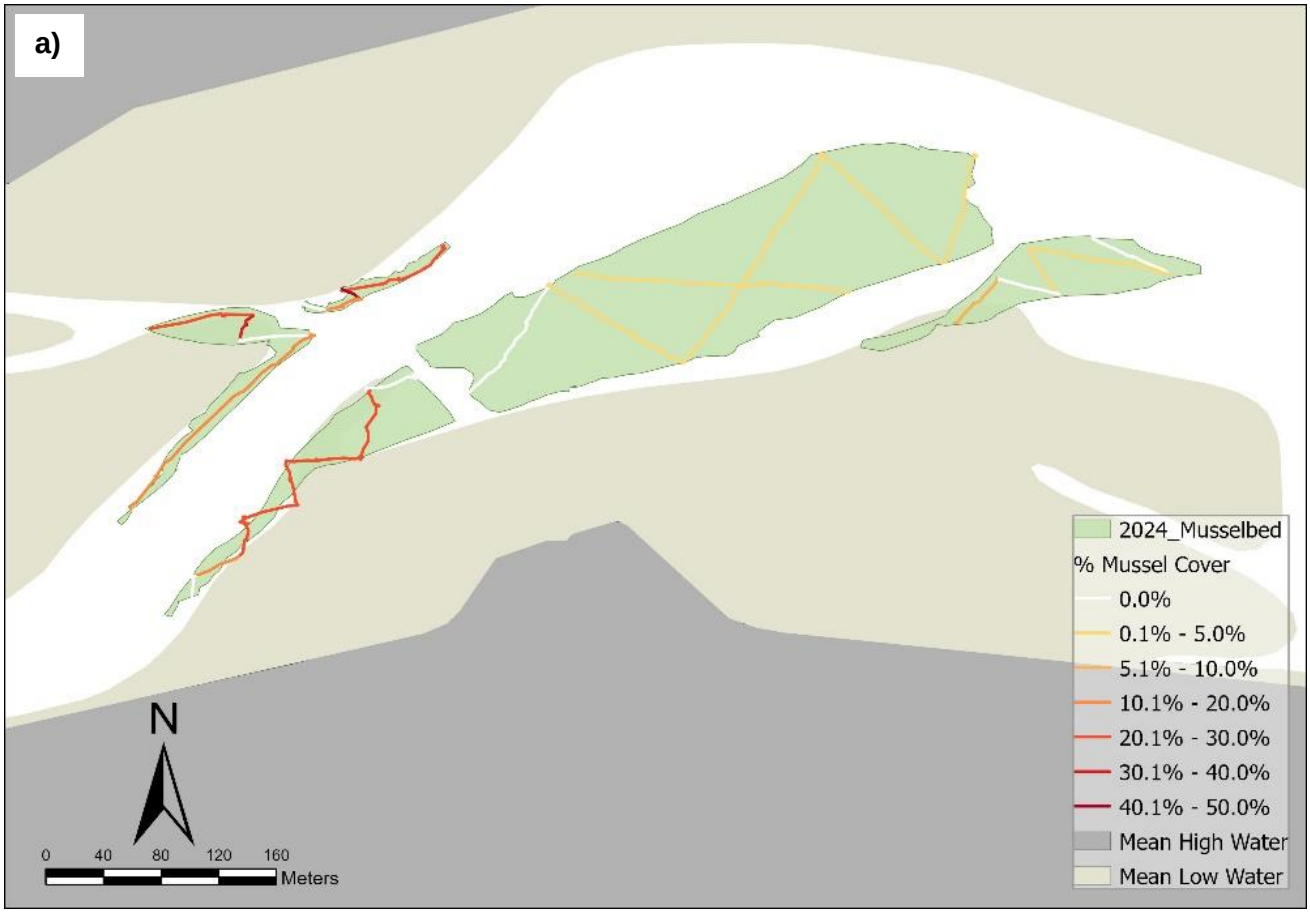


Figure 7 | Density of Blyth estuary mussels a) overall with (nonstatistical) linear trendline, b) by sector, and c) density of individual size classes (<25mm, 26-49mm, >50mm) from 2015-2024. No samples have been taken from sectors 5 and 6 since 2019 therefore density could not be calculated however was anecdotally very low.

Percentage cover

Percentage cover varied both between and within sectors across the different transects (Figure 8). Percentage cover for the transects was generally lower than 30%, with only four transects recording 30% or above coverage (30% and 50% in Sector 4, 37.5% in Sector 3 and 30% in Sector 2). All Sectors contained transects which recorded zero percentage coverage; one transect in Sectors' one, three and four and two transects in two and seven.

Compared to 2023, three Sectors exhibited decreases of 11% (1), 10% (3) and 6% (7) and two Sectors increases of 12% (2) and 3% (4). Overall, the percentage decreases outweighed the increases resulting in the continual decline of coverage recorded in the mussel bed from 16% in 2023 to 9% in 2024; the lowest recorded coverage to date (Figure 9a). Annual comparison of the Sectors shows percentage cover to be highly variable (Figure 9b) with Sectors two, three and four generally exhibiting a higher coverage than Sectors one and seven; see previous report**Error! Bookmark not defined.** for a full description of results from 2015-23.



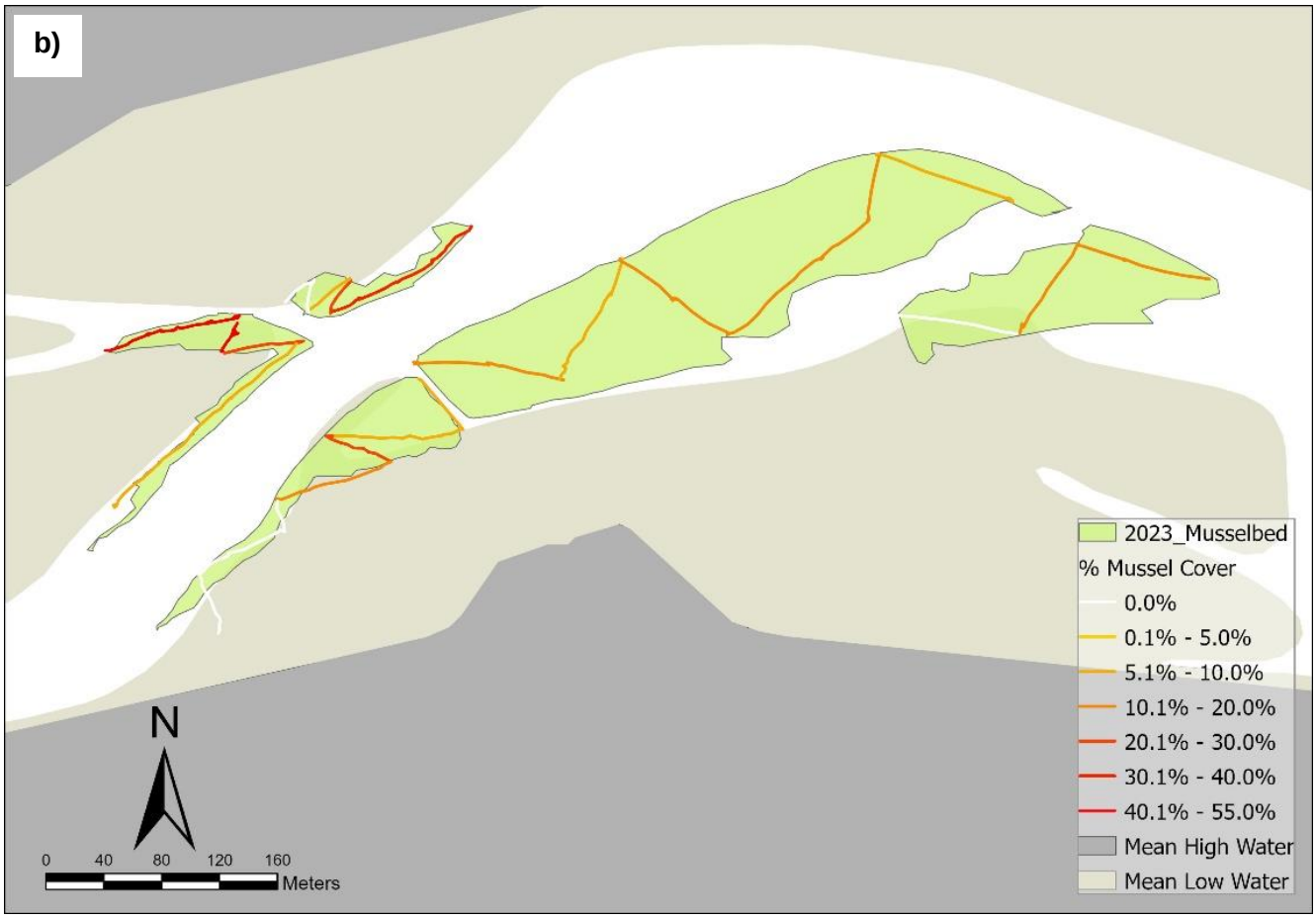


Figure 8 | Percentage cover and locations of surveyed transects in a) 2023 and b) 2024

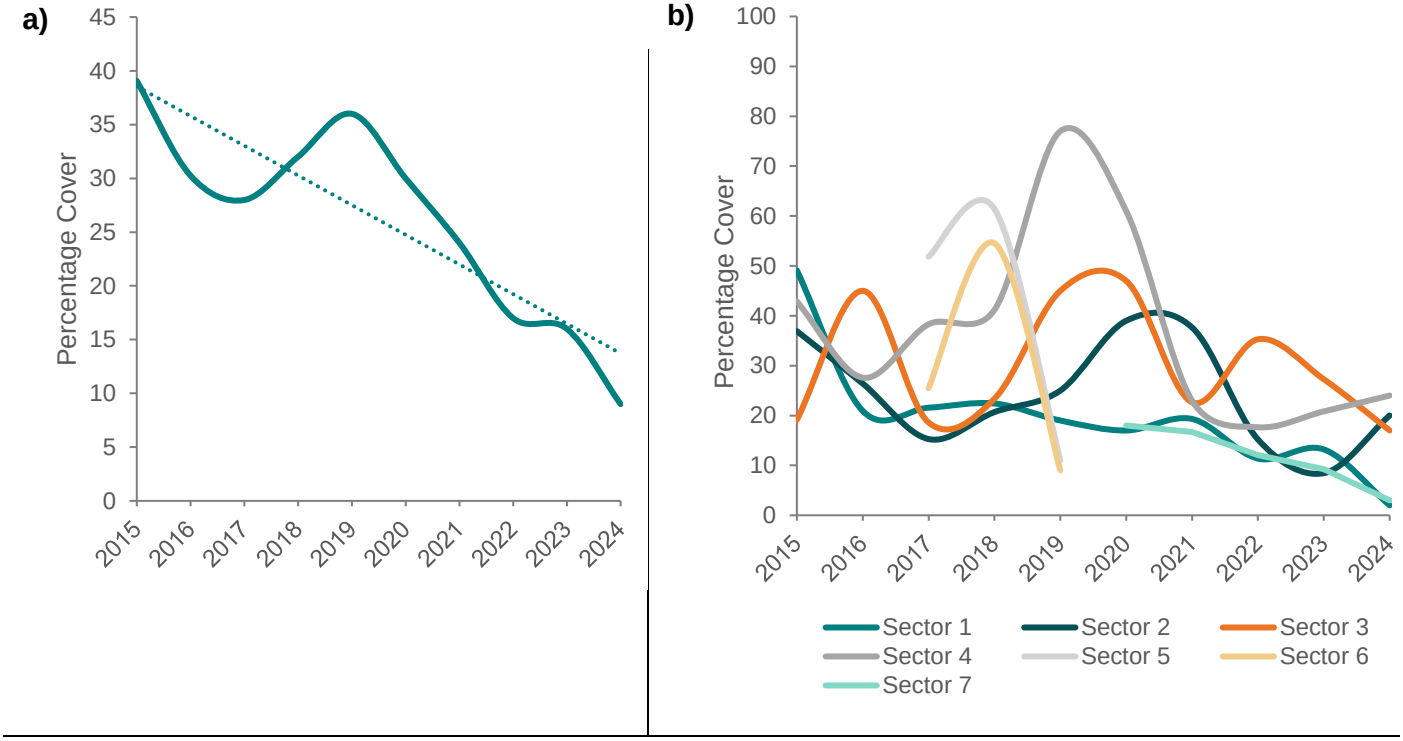


Figure 9 | Percentage cover of Blyth estuary mussel beds a) overall with (nonstatistical) linear trendline and b) by sector, from 2015-2023.

Mussel stock biomass

Mussel stock biomass was an estimated nine tonnes for 2024, the lowest estimated since surveys began (Figure 10). The >50mm stock size class shows a continuous decline from 12 tonnes in 2023 to seven in 2024, more than half the estimated amount in 2022 of 18 tonnes. There was no estimated further decline for the <50mm stock biomass, which was assessed to be the same as 2023, two tonnes. Since 2015 there has been a large decline in estimated stock biomass with consistently low values recorded from 2019 onwards.

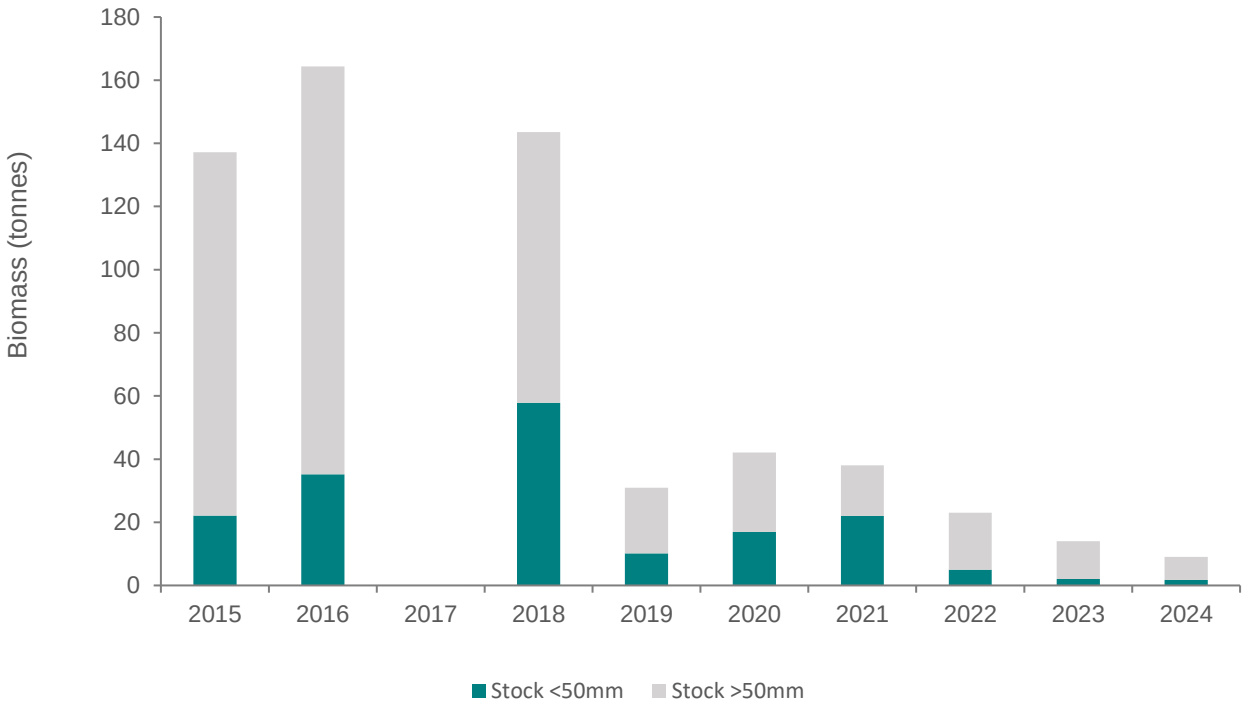


Figure 10 | Biomass estimates for the total estimated stock of mussels in the Blyth estuary 2015-24, showing biomass greater and less than 50mm. Bed area values were unavailable for 2017 surveys therefore biomass was not calculated.

Discussion

Overall the mussel bed area has continued to declined, albeit at a slower rate to previous years, with all sectors except sector one experiencing declines in comparison to 2023. Sector one has continued to exhibit an increase in area since 2019, but caution is needed in interpreting these increases, as during the same timeframe sector one has experienced the highest rate of density decline, 96%. The increasing mussel sparsity in sector one has increased the difficulty for the surveyor to subjectively determine the boundary, and possibly resulting in the reported continual increase.

The 2024 survey sees continued declines in mussel stock biomass from 2019-2023 levels which were already depleted in comparison to earlier years. There was an increase in the proportion of juvenile (spat) and medium sized mussels compared to in 2023. Although this was more notable for the spat, this size class has been highly variable in the past due to differences of the levels of reproduction and recruitment over the years, a normal characteristic of mussel beds. The increase in the smaller sized classes was offset by a decrease in the larger size class, however, the overall percentage cover and mussel density continue to decline, with the values the lowest recorded, despite two sectors (two and four) exhibiting slight increases in both elements.

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 every two to three years. Persistent mussel beds can be maintained by relatively low levels of sporadic recruitment (McGrorty et al., 1990; Mainwaring et al., 2014). 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 or 2023, therefore successful recruitment into the adult population is unlikely to have occurred. For mussel beds located in sheltered estuaries on soft sediments their recruitment success can be positively correlated to adult density (McGorty et al. 1990). Compared with rocky shorelines, coastal soft sediment habitats present lower rugosity, and hence less safe refuge sites for the early development of spat, so at sheltered sites, like Blyth estuary, spat is commonly found in -between the byssal space of the adults, as opposed to other settlement sites (Chipperfield 1953 & McGorty et al. 1990). This could indicate that a combination of low levels of recruitment and declining adult density, reducing recruitment success could be one of the influences hindering the recovery of Blyth Estuary mussel bed.

Low levels of bait collection does occur at Blyth, but sightings of mussel collection are within the streams 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.

Throughout the northeast Atlantic and across the UK, mussel beds have been declining for decades (OSPAR, 2015). No specific factor has been predominantly assigned as to the cause for the declines, but research at various sites have proposed several factors and the in-combination effects of overharvesting, climate change, competition with INNS, predation, disease and pollution as contributors (Baden *et al.* 2021). 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 (Richardson 2021), 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.

Interestingly, observations into the declines of mussel beds have revealed a stark contrast of the mussel beds located on floating structures which appear to be unafflicted to the dramatic declines exhibited on intertidal beds (Christie 2020, Baden 2021 & Meister 2023). In some cases, the location of the floating mussel beds are in close proximity to the declining intertidal mussel bed, helping to eliminate potential factors such as ocean acidification, water quality or parasites at that site (Meister 2023). Further studies have proposed that changes to the local ecosystem population structures have resulted in the increase of demersal predators such as crabs, starfish, small fish and dogwhelks which are unable to reach floating surfaces, are the cause for the decline of intertidal mussel beds (Christie 2020 & Meister 2023). In the NIFCA district, officers have observed established mussel beds attached to the floating pontoons in Royal Quays Marina at North Shields (Figure 11). To date no further investigations have been made at these sites or at other harbours and marinas along the coastline.

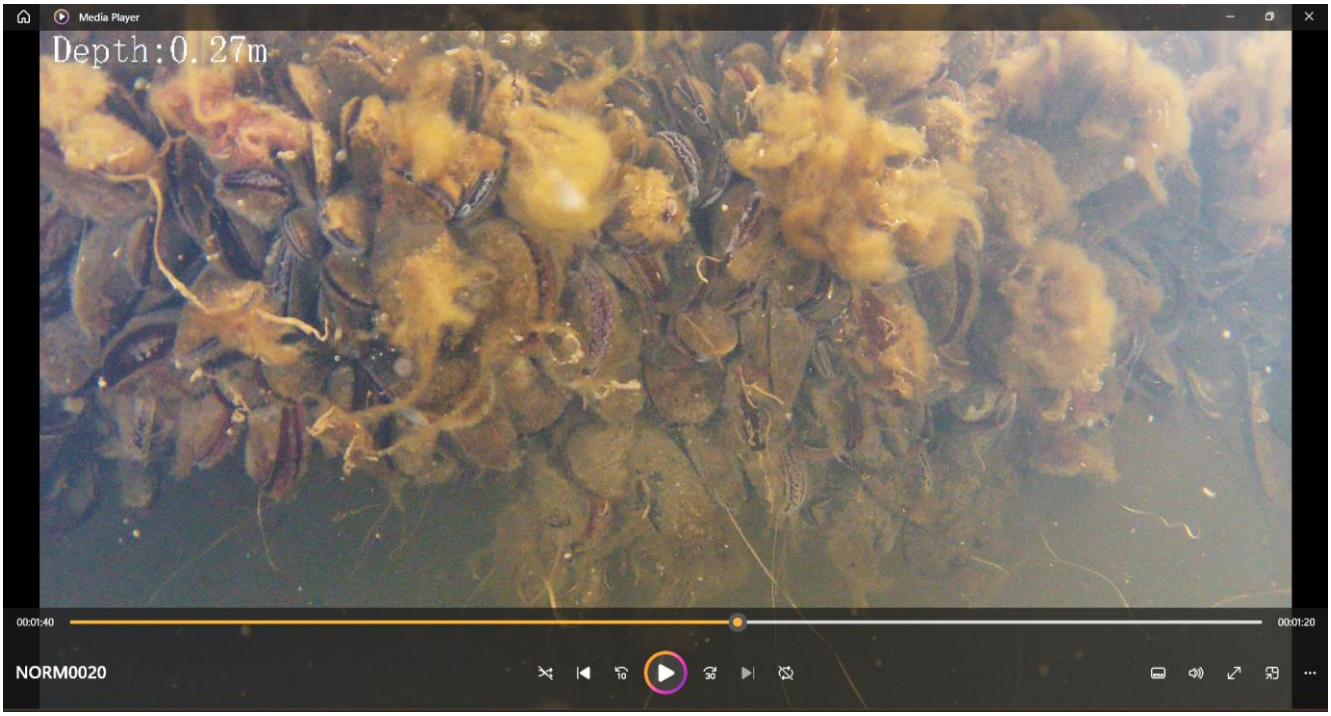


Figure 11 | Mussels on the floating pontoons at Royal Quays marina. ROV footage taken during April 2024.

Conclusions

Similar to other mussel beds, the 2024 Blyth estuary mussel bed survey shows an overall continual decline in its area and density due to unknown causes. Despite a decreasing proportion of medium and larger size classes being recorded, an increase number of spat were found which offers some encouragement. However, future surveys will determine if the recruitment of the spat to the larger size classes is successful.

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.

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 statutory measures.

Considering the successful occurrence of mussel beds on floating structures at Royal Quays, further investigation at this site could be explored to identify potential differences of water quality, environment conditions etc with the intertidal mussel beds in the NIFCA district. Other harbours or marinas could also be investigated for the presence of healthy mussel beds, in particular South Harbour, which is located downstream of Blyth mussel survey area.

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).

Potential causes of mussel decline in the Blyth estuary:

- Overexploitation (bait collection)
- Substratum loss
- Water quality
- Nutrient enrichment
- Hydrological changes
- Climate change
- Predation
- Recruitment and juvenile survival

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