Stock assessment of the blue mussel (*Mytilus edulis*) bed on Holy Island - 2023

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Summary

The purpose of this report is to assess and continue to monitor the condition of the mussel bed on Holy Island Sands. The perimeter of the mussel bed was mapped, and percentage cover of mussels was estimated using the 'Walker and Nicholson' technique. Biomass, density, and total number of mussels at the site were also calculated. Samples of mussels were collected, and total shell length and weight were measured.

Key results:

- The mussel bed on Holy Island Sands in 2023 covered an area of 3.01ha with an average percentage cover of 11%.
- The estimated values obtained for density, biomass and total number of mussels have decreased significantly compared to the 2022 survey.
- Mean length of mussels sampled in 2023 (46mm) increased by 4mm compared to 2022. 89% of mussels sampled were above the recommended minimum conservation reference size (MCRS) of 45mm. 18 mussels were collected for sampling this year therefore it was not possible to identify specific trends in mussel size distribution.

The aim of this report as in previous years is to provide information of the health and distribution of the *M. edulis* bed on Holy Island Sands which can be used to inform future management.

Introduction

The blue mussel (*Mytilus edulis*) is a filter-feeding bivalve mollusc consuming phytoplankton, and other particulate organic matter. It can be found on a variety of substrata in the intertidal zone of boreal and temperate waters, in both the southern and northern hemispheres (OSPAR, 2010). The blue mussel often accumulates to form beds and can tolerate a wide variety of environmental conditions including fluctuations in salinity, oxygen, temperature, and desiccation (Andrews et al., 2011). The dense beds which occur in both fully saline and estuarine waters form natural reefs or biogenic reefs which enhance biodiversity (Gardner, 1996). Mussel beds are included in the OSPAR (Annex V) list of threatened and declining species and habitats and are also listed as a Habitat of Principle Importance under the Natural Environment and Rural Communities Act 2006.

Threats to mussel beds include, but are not limited to, overexploitation by bait collection and human consumption (Maddock, 2008; Fenton, 1978), nutrient enrichment and water quality (Hilgerloh, 1997; Richardson, 2022), coastal development and anchoring (Maddock, 2008). It is currently unknown whether mussel beds are declining because of the aforementioned threats or due to predation or a combination of factors (Hilgerloh, 1997).

Northumberland Inshore Fisheries and Conservation Authority (NIFCA) have conducted surveys of the mussel beds at Fenham Flats, Lindisfarne (approx. 2km south-west of Holy Island) on an annual basis since 2006. NIFCA has a long-term record of the population dynamics of the mussel bed at Fenham Flats and the results from recent years have shown a decrease in mussel bed density. The results over time also show an increase in mean mussel size with the largest value recorded to date observed in 2015. Further study was deemed essential to determine if the trends discussed are because of recruitment failure, natural temporal variation, or local factors specific to the Fenham Flats site. NIFCA therefore decided to expand the 2018 mussel surveys to include two additional sites, Holy Island Sands and St Cuthbert's, to compare the results from Fenham Flats with other nearby mussel beds. The mussel beds were partly surveyed in 2018 because of tides. Only Holy Island Sands was deemed comparable (similar underlying substrate and functionally displaying 'bed' characteristics i.e., aggregated mussels) to Fenham Flats mussel bed, therefore this site has been surveyed annually since 2018.

Method

A series of surveys have been conducted on the mussel bed at Holy Island Sands annually since March 2018. The survey was conducted at low water during a spring tide on the 22nd March 2023 by NIFCA officers.

Survey site

Holy Island is situated on the North Northumberland coast, approximately 10 miles south of Berwick-upon-Tweed and accessed via a tidal causeway. The island is a popular tourist attraction and supports a small fishing fleet. Between the western side of the island and mainland there are mudflats in a shallow, semi-enclosed embayment. These mudflats named Holy Island Sands support important intertidal mussel beds (Figure 1). This study site is relatively small compared to the neighbouring mussel bed area at Fenham Flats. This site appears to be an important feeding area for a number of nationally important bird species, similar to Fenham Flats, that feed on the mussel beds.

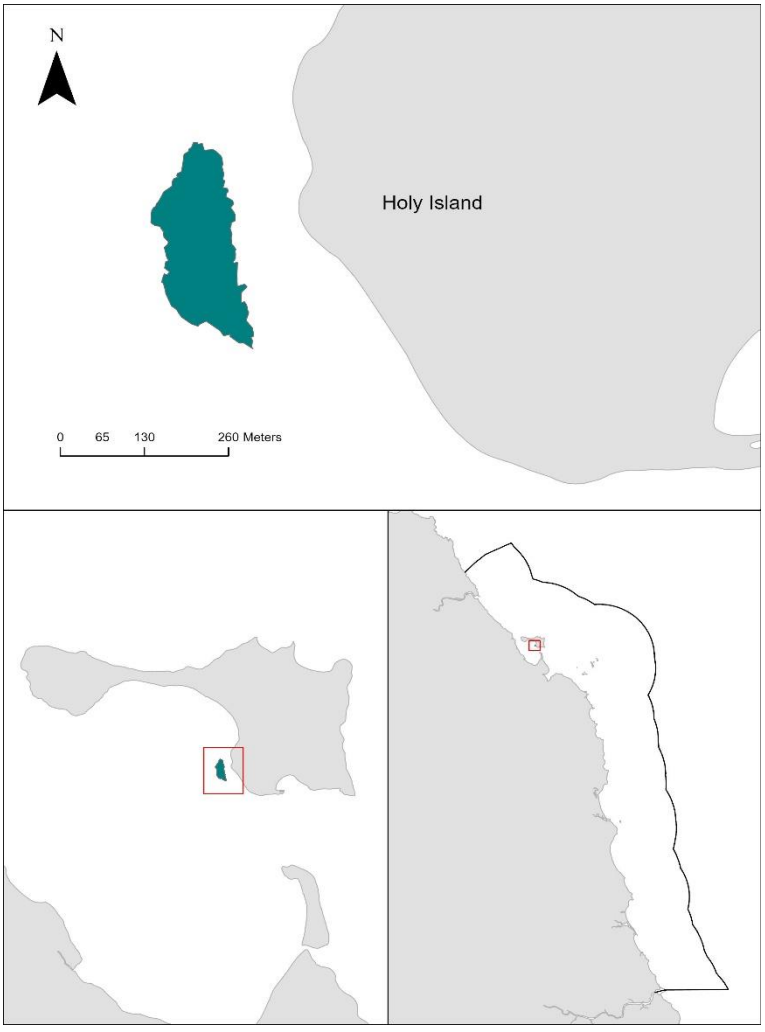

Figure 1. Holy Island Sands blue mussel bed in 2023 and it's position relative to Lindisfarne NNR and the Northumberland IFCA district (from top moving anti-clockwise).

Survey methodology

Two Inshore Fisheries & Conservation Officers (IFCOs), one of whom has previously walked the perimeter, walk 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. The information was exported as a GPX file from the GPS using the Garmin GPS software Basecamp and then imported into ArcGIS to map and calculate the area of the mussel bed.

The percentage cover of mussels on the mussel beds was estimated using the 'Walker and Nicholson' survey technique (Walker and Nicholson, 1986) to allow comparison with the Fenham Flats mussel surveys. Surveyors walked in a zigzag configuration across the mussel beds, in randomly determined directions, recording the proportion of footsteps landing on live mussels. The total number of steps was selected at random at the start of each transect and ranged from 55 to 200. Percentage cover was then calculated using the following equation:

$$Percentage\ Cover\ = \frac{Number\ of\ footsteps\ landing\ on\ live\ mussels}{Total\ number\ of\ footsteps} \times 100$$

A mussel sample was taken at the start and end of each transect from within a 0.1m² sampling quadrat. Each sample was sieved and cleaned in intertidal pools to remove excess sediment. The number of mussels per 1m^2 was later calculated so that further calculations could be compared between sites.

Figure 2. Surveyors using the Walker and Nicholson survey technique.

The samples were processed removing dead shells and debris from the living mussels. Total shell lengths of all the mussels sampled were measured to the nearest millimetre using vernier callipers and divided into the following size classes: <45mm, 45-54mm and >54mm. The total weight

(grams) 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:

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

The total biomass of mussels on the mussel bed was then calculated:

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

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

The estimated total no. of mussels was also calculated using the following equation:

$$Number\ of\ mussels\ = Mussel\ density\ (number/m^2)\ \times Area\ of\ bed\ (m^2)$$

Results

A total of 18 individual mussels were recorded from 11 samples in 2023. A summary of the survey results from 2018 to 2023 can be seen in Table 1.

Table 1: Results for the Holy Island mussel survey between 2018 and 2023.

Year	Bed area (ha)	Average % cover	Total number of mussels (millions)	Mean shell length (mm)	Mussel density (no./m²)	Biomass (g/m²)	Total biomass (tonnes)
2018	3.11	90%	8.58	35.15	276.0	3,749	117
2019	4.04	66%	5.07	48.08	125.4	2,314	93
2020	4.02	75%	4.31	48.29	107.25	2,072	83
2021	3.59	59%	2.52	40.64	70.31	1,188	43
2022	3.41	70%	0.86	42.02	25.2	496	17
2023	3.01	11%	0.06	46.00	1.88	40	1

Bed Area

In 2023 the mussel bed area was calculated as 3.01ha a decrease of 12% compared to 2022 (Table 1 and Figure 3). The bed area has decreased since 2019 with the smallest area recorded this year. Spring tides may have contributed to the decrease in bed area this year, with slightly lower pressure weather system causing some areas to be inaccessible compared to previous years.

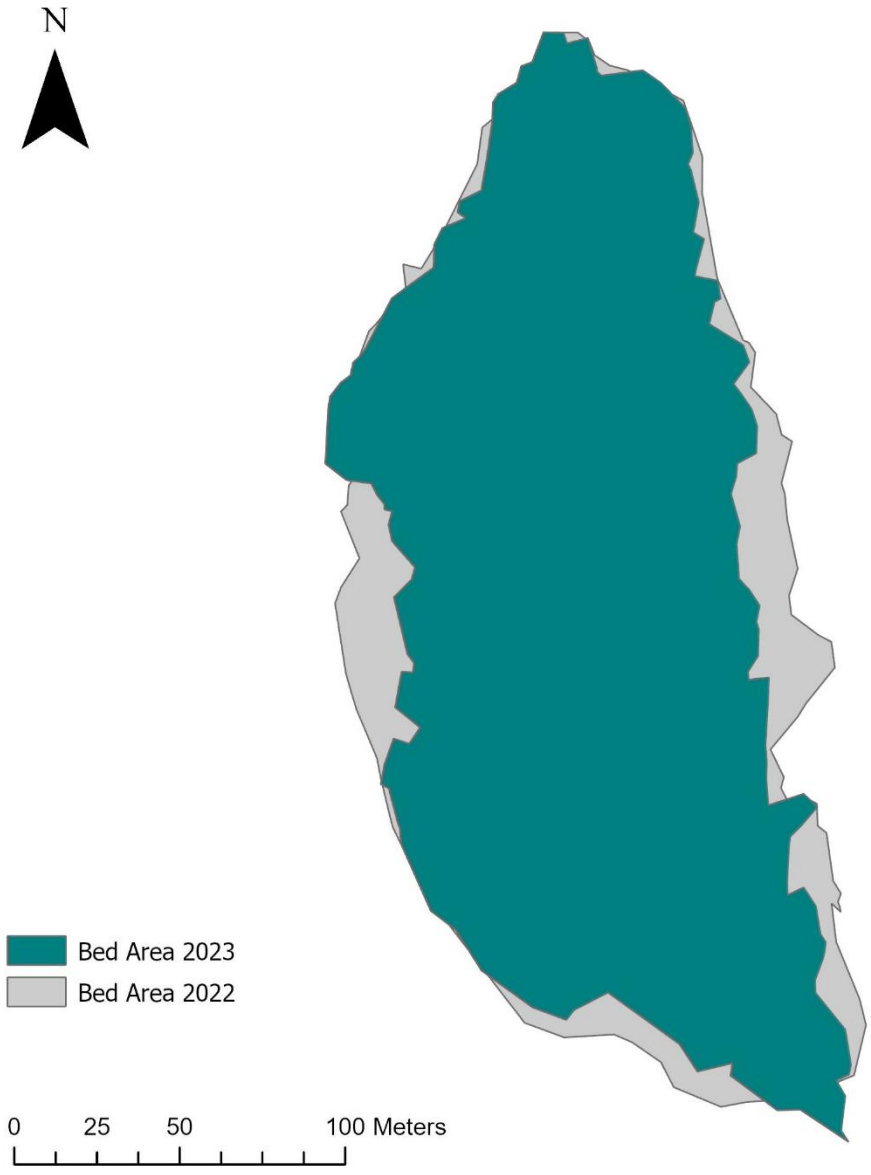

Figure 3. Mussel bed area estimates for Holy Island Sands in 2022 and 2023

Percentage Cover

In 2023, percentage cover was less variable and of lower values (between 2% to 36%) across the different transects compared to 2022 results (Figure 4). Areas of highest percentage cover were recorded towards the central area of the mussel bed and lowest percentage cover towards the most northern point and central-southern half (Figure 4). Overall, the average percentage cover for the site was 11%, a significant decrease of 84% compared to last year and any previous survey years (Figure 5). Since the survey began at Holy Island Sands the overall percentage cover has varied over time, with a peak at 90% in 2018.

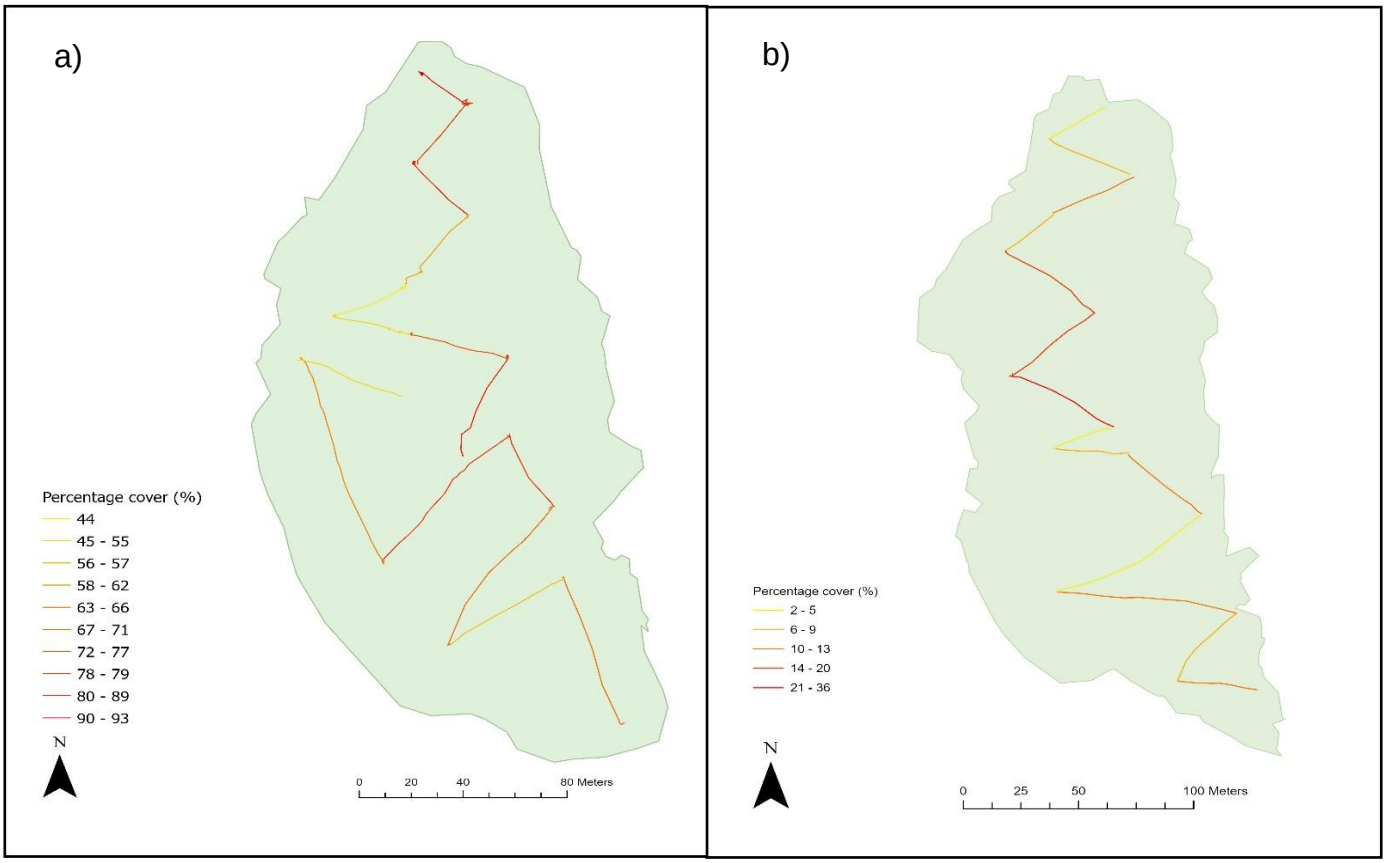

Figure 4. Percentage cover noted over walked transects at Holy Island Sands in a) 2022 and b) 2023.

Length Frequency

In 2023, the total number of live mussels sampled from the mussel bed was 18, half the previous year's total of 36, and a significant decrease compared to the 143 sampled in 2021 and 2020. The average mussel size has increased from 42mm in 2022 to 46mm in 2023. In 2023, 50% of the mussels sampled were >54mm (the largest size group) another 39% of mussels were between 45-54mm and 11% the <45mm (the smallest size group) (Figure 6). Pre-2021, length frequency skewed towards larger size classes. In 2022, there was a higher proportion of smaller mussel between 6-26mm (Figure 7a). The abundance in each size class has changed with a smaller

proportion of the sample in the small size group, and a larger sample proportion of mussels in the larger size group. With low numbers of mussels sampled this year no clear distribution trend can be identified by the mussel length results (Figure 7b).

Mussel size distribution varied across the mussel bed, with smaller sized individuals (<45mm) towards the southeast of the surveyed area, medium sized individuals (45-54mm) were found across site but in higher numbers towards the north, and a larger number of individuals (>54 mm) towards the central and east side of the bed area (Figure 8).

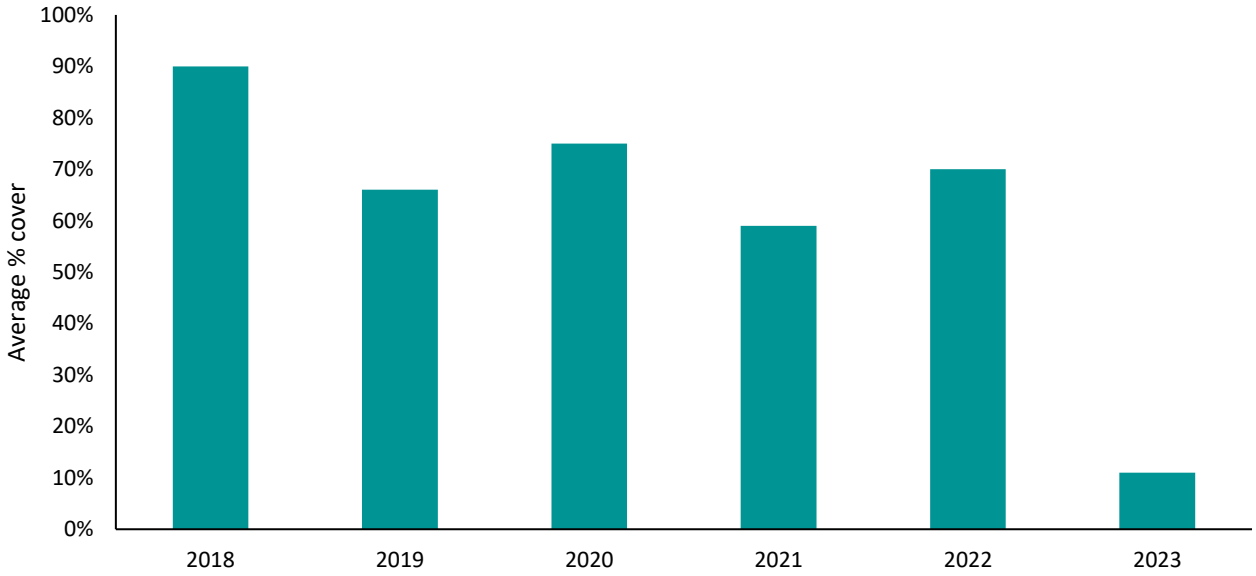

Figure 5. Percentage cover for Holy Island Sands 2018-2023

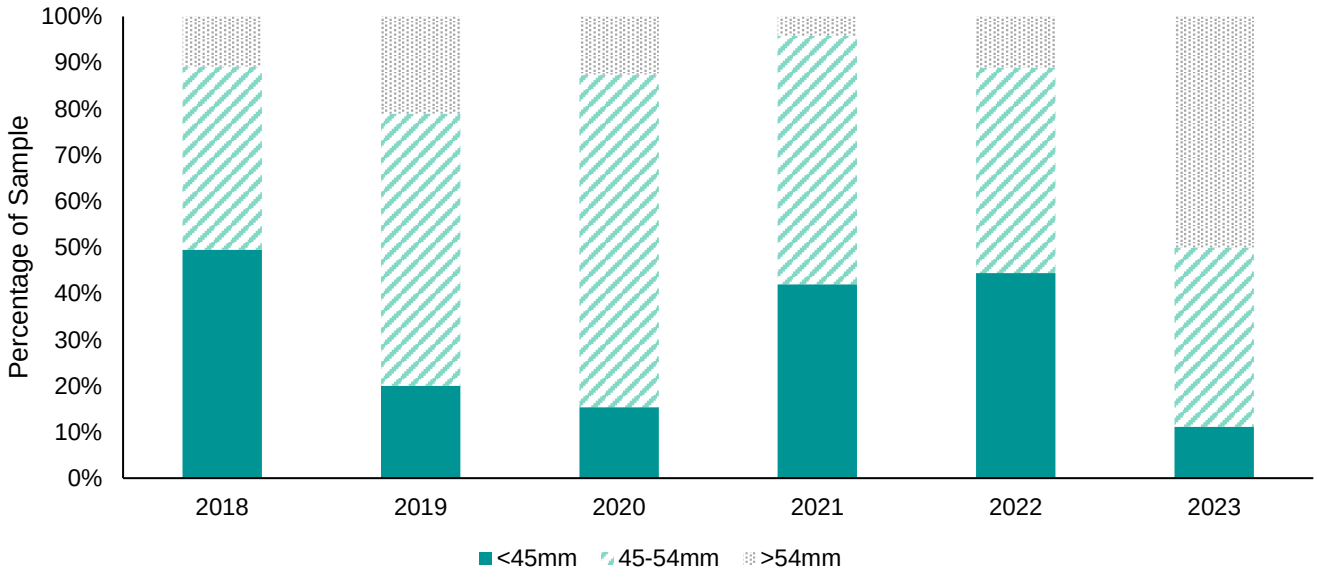

Figure 6. Proportional percentages of sampled mussels size classes between the years 2018 – 2023

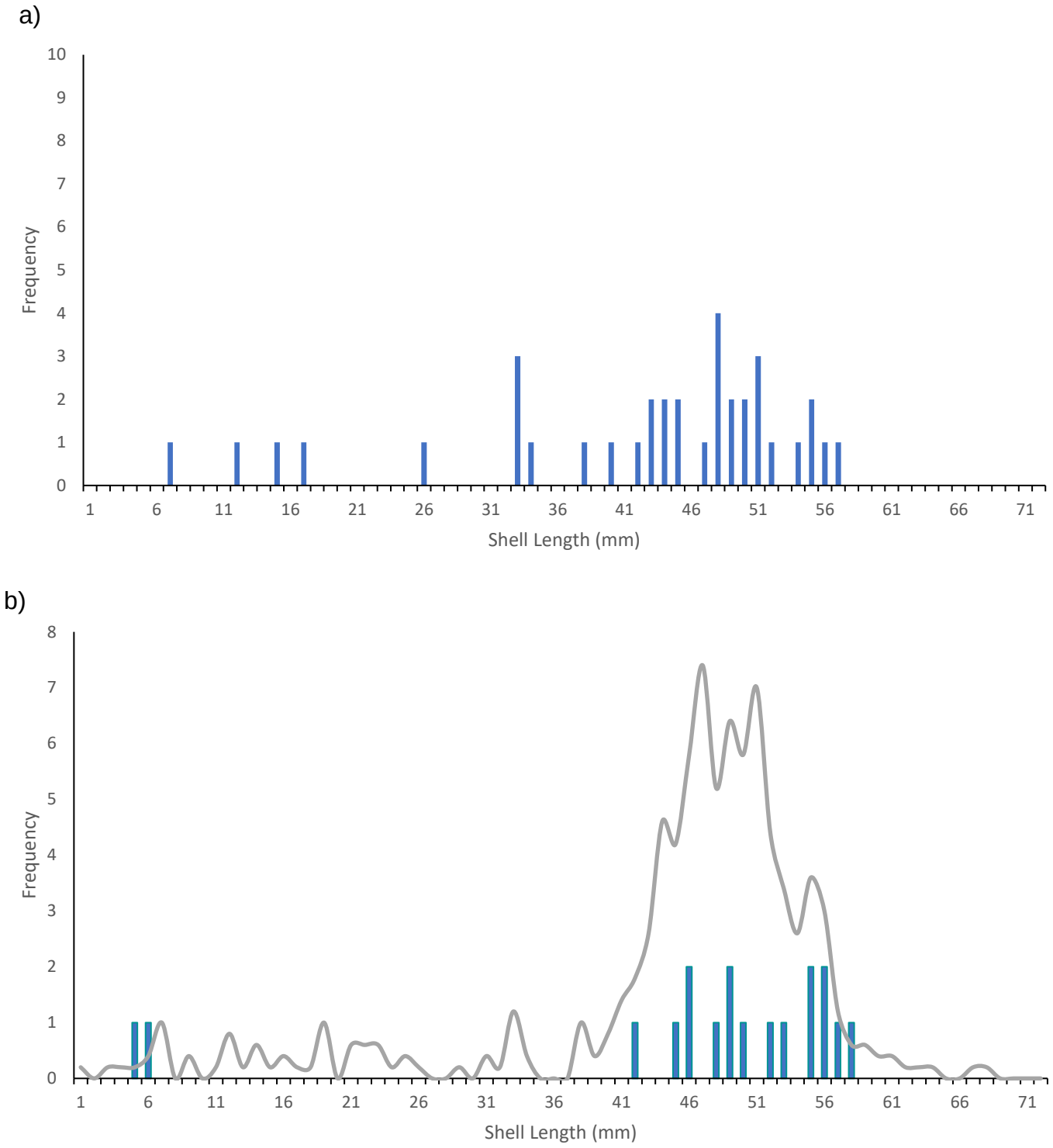

Figure 7. Length frequency (number of individuals in each mm size class) for mussels sampled in (a) 2022 and (b) 2023 (blue bars) with a five-year averaged length frequency (2019-2023) (grey line).

Mussel Density

Overall, mussel density at the site has declined since 2018 from 276 mussels/m^2, to 107 mussels/m^2 in 2020, to 1.88 mussels/m^2 in 2023 (Figure 9).

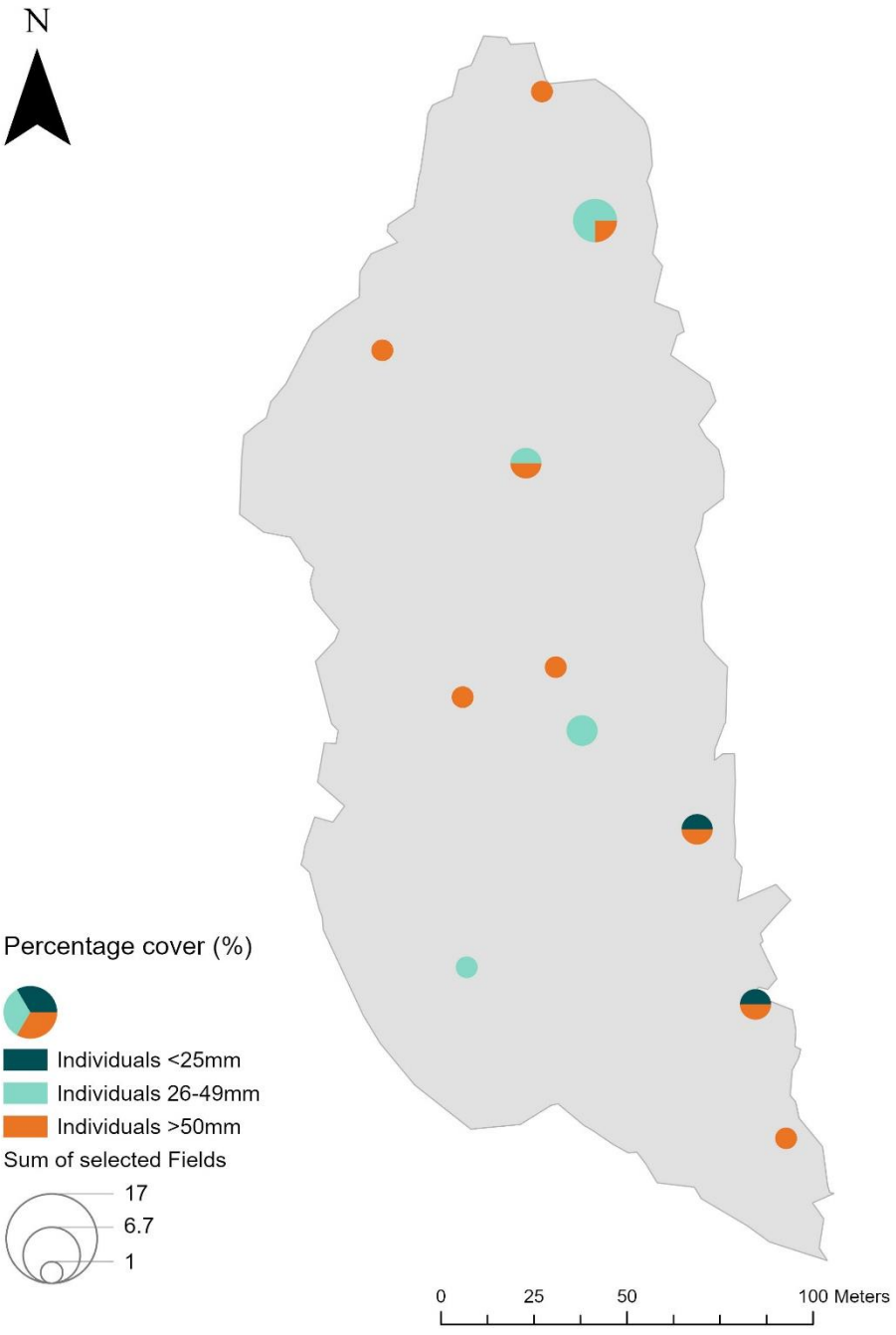

Figure 8. A breakdown for individual sample sites and the percentages of the <45mm, 45-50mm, and >50mm size classes. These points have also been proportionally scaled by the number of individuals recorded at each sample site, with sample sites containing more mussel being displayed larger on the map.

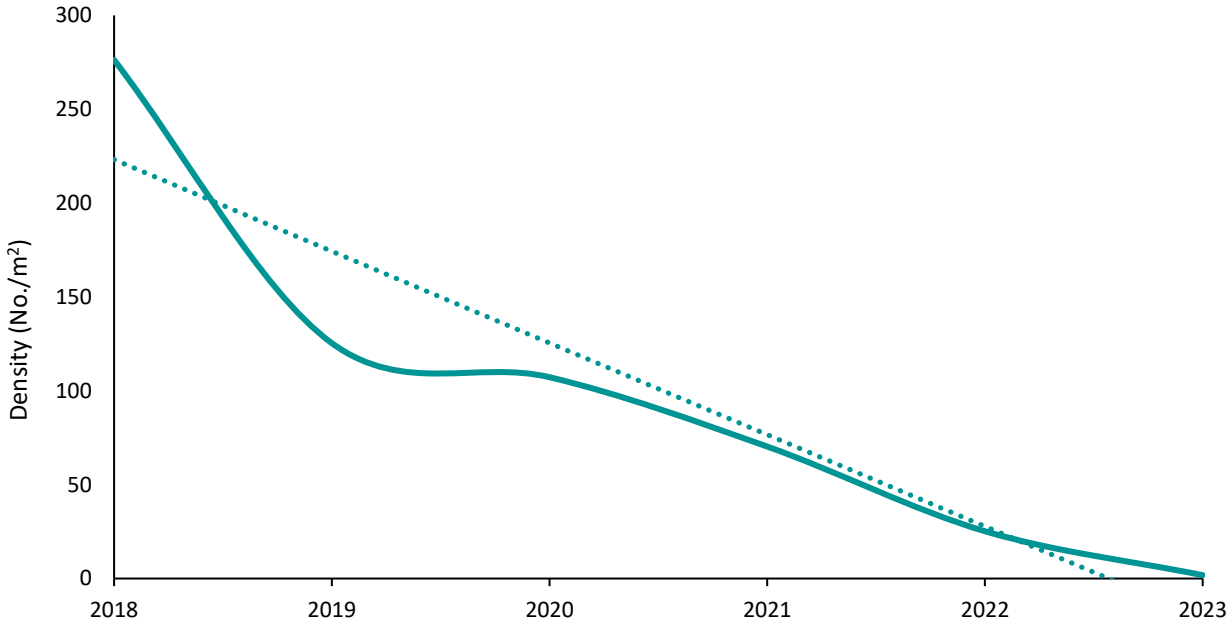

Figure 9 Density of Holy Island Sands mussels (solid line) with (nonstatistical) linear trendline (dashed line).

Mussel Stock

Total numbers of mussels at Holy Island Sands continued to fall significantly from 4.31 million in 2020, 2.52 million in 2021 to 0.06 million in 2023, with total biomass following a similar decline, falling from 43 tonnes in 2021, 17 tonnes in 2022 to 1 tonnes in 2023.

Discussion

This is the fifth year of reliable data analysis (2018 results restricted by tidal flooding). Further monitoring will continue to determine the health and long-term trends of this mussel bed, but it is now evident from the years of surveys that there is a serious concern of potentially losing the mussel bed altogether from Holy Island Sands.

Bed Area

Over the past five years the mussel bed area has decreased. While bed area alone does not determine the mussel bed health, the bed could be shifting or densities of mussel could be congregating in specific locations. If combined with the other parameters monitored and described below, results are consistent with a mussel bed which has declined significantly since surveys began.

It should be noted that mapping the mussel bed perimeter is very subjective and it is difficult to calculate accurately. To ensure consistency between years, IFCOs that have previously walked the bed are tasked with this aspect of the survey. Consequently, at least one of the two IFCOs

walking the perimeter has experience of previously doing so. However, consistency cannot always be guaranteed by allocating an IFCO who has previously recorded the perimeter because of staff changes or annual leave.

Percentage Cover

Throughout the survey site percentage cover was fairly variable, which is to be expected on a mussel bed. Low percentage cover (below 36%) was recorded on all transects with the highest percentages recorded in the northern central area of the mussel bed. Percentage cover was consistently over 50% from 2018 to 2022 but declined to 11% in 2023. This is a significant decline between 2022 and 2023. Declines in percentage cover could be due to a number of factors as outlined above. In 2021, a project investigated the drivers of mussel bed decline at Fenham Flats and Holy Island (Sarah Richardson, 2021). The study findings suggested a correlation between mussel decline and historical farming pesticides, dieldrin and endrin as well as a group of brominated flame retardants (all now banned) however the source of contamination is unknown (Sarah Richardson, 2021). The Environment Agency as part of the Water Framework Directive monitors Holy Island water quality but there were some classification item changes and after 2019 the above biocontaminants (PDBEs) cannot be analysed temporally. Further investigation of this potential relationship would be beneficial considering the rapid decline of the mussel bed.

Length Mean & Frequency

Mean shell length has shown an increase in 2023 compared to last year, this is due to a higher number of larger (>54 mm) individual mussels this year and the impact of a smaller total number of mussels recorded and therefore increasing the average value.

When looking at length frequencies for the 2023 survey, there is little that can be concluded because of the small number of individuals recorded in the sample. The proportion of size classes could indicate some concerns with recruitment failure, juvenile survival and suitable habitat availability with higher proportions of larger sized mussels dominating the bed. This pattern could also be attributed to both nutrient availability and/or predation. Size-specific predation may play an important role at the survey site; past studies found eider and oystercatchers (both important species at Holy Island Sands) favour smaller sized (10mm – 45mm) mussels therefore the larger length mussels will exhibit lower mortality based on predation (Hamilton, Nudds & Neat, 1999, Meire & Erynck, 1968). The Wetland Bird Survey data for Lindisfarne recorded the lowest number of eiders (201 individuals) during 2021/22 compared to previous surveys conducted since 1968/69 and oystercatchers numbers reduced to 701 from 1,052 in 2020/21. More research would be needed to determine the reliability of this relationship.

Mussel Density and Biomass

The results show a sharp decline in mussel stock and biomass which, when compared to the previous year's results shows a concerning decreasing trend overall. Mussel density has continued to decline at the site since 2019. A NIFCA commissioned report (Dent, 2019) highlighted that the nearby Fenham Flats mussel bed exhibited large fluctuations in mussel density between survey years with an overall decreasing trend, this seems to be now mirrored at Holy Island Sands. A decline is typically indicative of a population that has had poor recruitment in previous years which is surprising following last year's number of juveniles, and as such the population is dying at a greater rate than it is being stocked. Declines in extent and biomass of mussel beds have also been recorded in other areas of the Greater North Sea including in Germany, Denmark and the Netherlands (OSPAR, 2010). In the UK, there have been anecdotal reports of declines on the east coast from Scotland to the Wash.

Mussel beds have been found to be highly sensitive to a human induced pressures in a marine environment including introduction or spread of invasive species (including Pacific oysters), habitat structural changes (including bait colleting) (Fenton 1978; Maddock 2008) and/or physical loss (JNCC, 2014). Bait collection and hand gathering is unlikely to be a factor affecting this mussel bed because the activities are prohibited by a Lindisfarne National Nature Reserve Byelaw, 1999. A Pacific oyster (*Crassostrea Gigas*) farm has been in operation adjacent to Fenham Flats since 2007. This introduced species has been evidenced as being able to outcompete and replace mussel beds (JNCC, 2014). The potential impact of the Pacific oysters being present could be looked at in more detail if both Fenham Flats and Holy Island mussel bed area continue to decrease. Other pressures may include water pollution from historically used pesticides (Richardson, 2021; Hilgerloh, 1997), coastal development and anchoring (Maddock, 2008). At this site, there are ongoing issues with water quality that have caused macroalgal blooms, this change in nutrient loading at the site was not seen as a significant to the mussel bed but only 4 years of data was used so by collecting more information a better picture can be created for why there is a significant decline in area.

Other species may be affected by changes in mussel stock levels e.g., in 1990 mussel stock fell to unprecedented levels in the Dutch Wadden Sea and resulted in eider deaths. Eider ducks are one of the nationally important bird species and a qualifying feature for Lindisfarne Special Protection Area (Holt et al., 1998) and are the main feature for Berwick to St Mary's MCZ.

As previously mentioned in this report, overall mussel abundance biomass estimates at the site are significantly lower than in previous years and have displayed an increasing rate of decline.

While there are many factors that could affect the bed, long term monitoring now shows a confirmed population in decline.

Declines are being recorded on both beds suggesting similar impacts are experienced at both sites. The Holy Island Sands survey began as a comparative survey due to concerns in the declines at Fenham Flats, if mussels at Holy Island Sands were found to be healthy while Fenham Flats continued to decline, causes of decline at Fenham Flats could be narrowed down to very localised issues. However, the declines recorded at Holy Island Sands, plus the declines reported elsewhere in the UK suggest the cause(s) of decline are more far reaching and widespread.

Conclusion

This study has mapped the perimeter of the mussel bed, estimated percentage cover, density and biomass, and produced a length frequency distribution of the mussels on Holy Island Sands

Overall, in 2023 declines were reported for all parameters on the Holy Island Sands mussel bed including density, biomass and bed area.

This year the mean size of mussels increased slightly but fewer individuals were sampled therefore confidence in the results for this year is lower than in previous years.

The continuation of annual surveys to monitor the distribution and health of the Holy Island mussel bed will need to be considered following this year's survey results.

Given there is now five years of data on bed area, this may be the time to discuss potential options for work to identify causes of the decline and potential interventions to maintain a mussel bed at Holy Island and Fenham Flats into the future as well as support the marine species and bird populations in the SPA and Water Framework Directive objectives.

Future work

NIFCA plan to continue annual surveys of the mussel beds at Holy Island Sands to better understand the trends and health of the site.

The problems in estimating mussel bed area are due to their subjective nature and the difficulty of assessing mussel bed edges on the ground. It may be possible to replicate the work completed by Newcastle University which used an unmanned aerial vehicle (UAV or drone) to determine the

mussel bed size and percentage coverage which could supplement NIFCA survey data and aid in increasing the accuracy of ground surveys.

Other future survey options include investigating feeding habits of birds at the site to determine 1) how important mussels are to their diet and 2) what size classes are consumed by which species.

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