Stock assessment of the blue mussel (*Mytilus edulis*) beds on Holy Island (2021)

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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 2021 covered an area of 3.59ha with a percentage cover of 59%.
- The estimated values obtained for density, biomass and total number of mussels have decreased compared to the 2020 survey.
- Mean length of mussels sampled in 2021 decreased from those sampled in 2020. The length distribution was skewed towards a larger mussel size, with 58% of mussels being larger than the recommended minimum size of 45mm, and an increase in frequency of smaller sized mussels (<45mm) were recorded compared to previous years.
- The mussel meat content percentage and weight increased compared to the previous year.

The aim of this report 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 occurring 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 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). It is currently unknown whether mussel beds are declining because of the threats, due to bird 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 density. The results 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 in include two additional sites (Holy Island Sands and St Cuthbert's) to compare the results from Fenham Flats with that of other mussel beds in the region. However, the beds were only partly surveyed in 2018. Only one of these sites (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 on a spring tide on the 30th March 2021 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 Fenham Flats, covering an area of 3.59ha in 2021. 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.

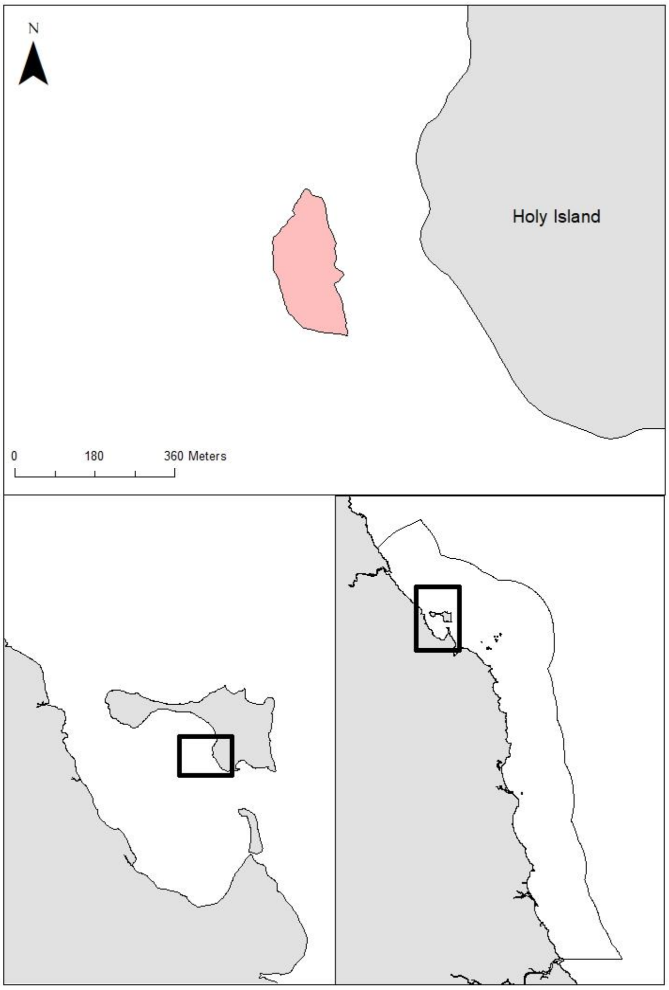

Figure 1 The estimated Holy Island Sands mussel bed area in 2021.

Methods

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 other surveys in the area. 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 $0.1m^2$ 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:

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

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

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

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

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 143 individual mussels were recorded from 12 samples in 2021. A summary of the survey results from 2018 to 2021 can be seen in Table 1.

Table 1: Results for the Holy Island mussel survey between 2018 and 2021.

Year	Bed area (ha)	Average % cover	Total number of mussels (millions)	Mean shell length (mm)	Mussel density (no./m^2)	Biomass per square metre (g/m^2)	Total biomass (tonnes)
2018	3.11	90%	8.59	35.15	276.3	4,165	129.5
2019	4.04	66%	5.07	48.08	125.4	3,506	141.6
2020	4.02	75%	4.31	48.29	107.25	2,763	111.1
2021	3.59	59%	2.52	40.64	70.31	2,014	72.3

Bed Area

In 2021 the mussel bed area decreased by 11% compared to the 2020 value (Table 1 and Figure 3). The bed area remained relatively consistent in the years 2019 and 2020 with an area of 4.04ha and 4.02ha respectively. The smallest area recorded was in 2018, the first year of surveys at Holy Island Sands when the tide was flooding and therefore the bed area was likely to be underestimated.

Figure 3 Mussel bed area estimates in 2020 and 2021.

Percentage Cover

In 2021, percentage cover across the different transects was highly variable, ranging between 31% to 83% (Figure 4). Areas of highest percentage cover were recorded towards the central area of the mussel bed and lowest percentage cover estimates towards the southern area (Figure 4). Overall, the average percentage cover for the site was 59%, decreasing by 19% of the previous year (Figure 5). Since the survey began at Holy Island Sands the percentage cover has been variable over time, peaking in 2018 at 90%. As above, this value must be looked at with caution because the bed was not fully accessible.

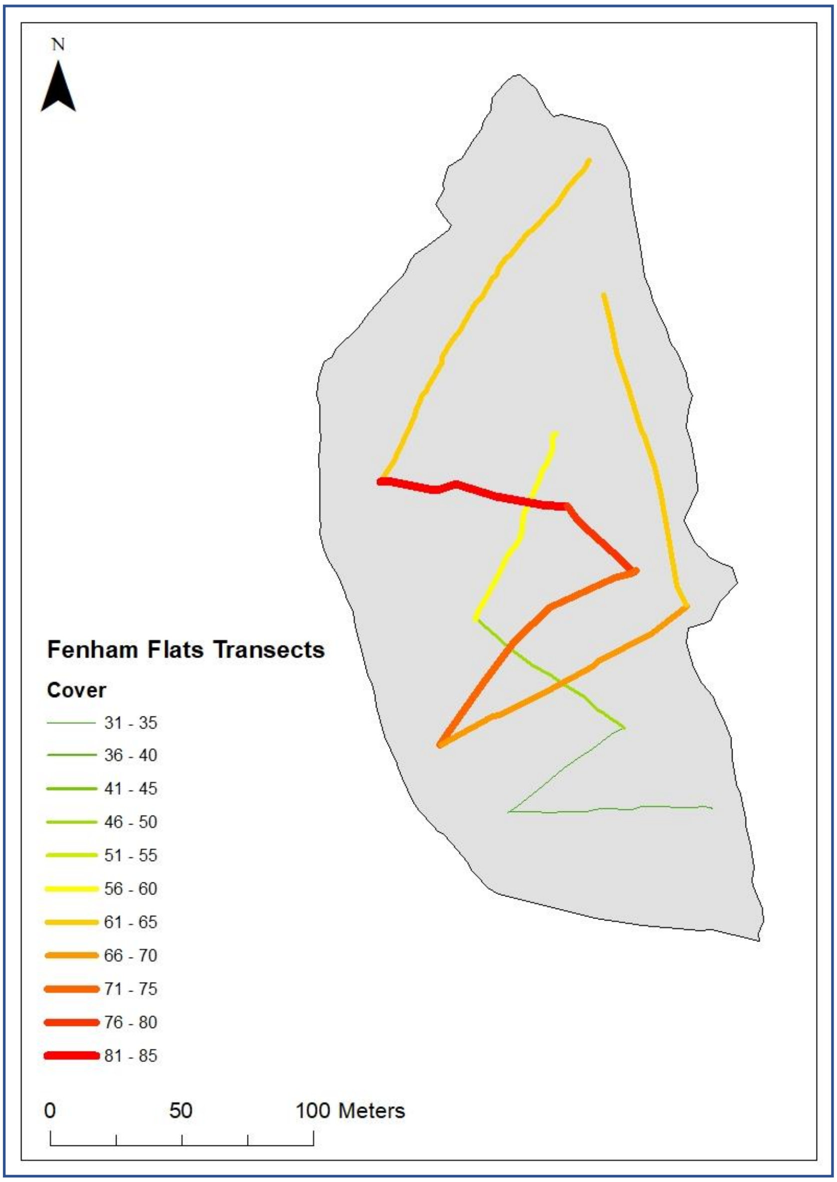

Figure 4. Percentage cover over walked transects at Holy Island Sands in 2021.

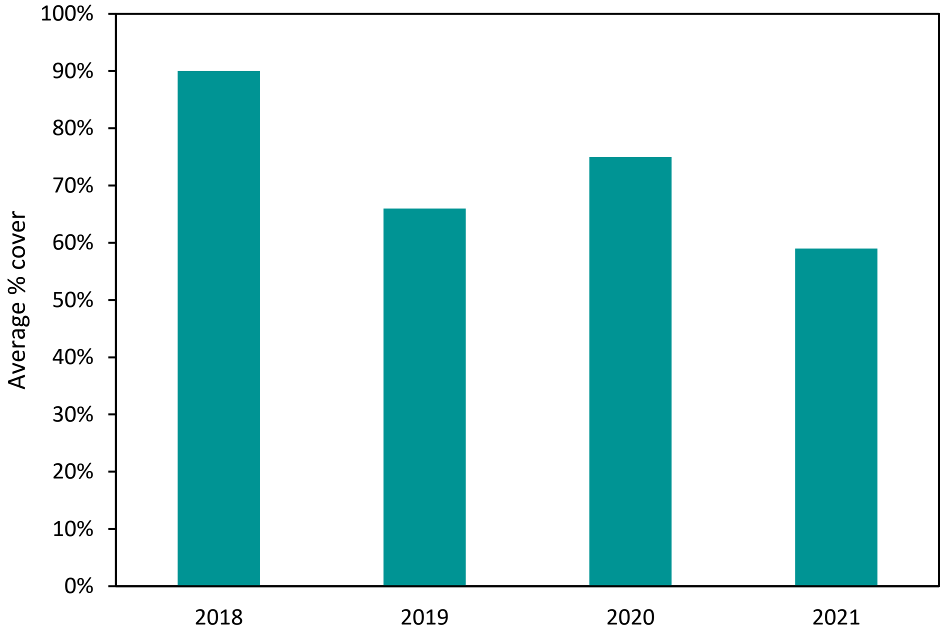

Figure 5 Percentage cover for Holy Island 2018-2021

Length Frequency

In both 2020 and 2021, the total number of live mussels sampled from the mussel bed was 143. In previous years, length frequency skewed towards larger size classes. In 2021, there was a higher proportion of smaller mussel between 7-19mm (Figure 6). The average mussel size has decreased from 48.29mm in 2020 to 40.6mm length in 2021, the lowest value since 2018. In 2021, the smallest mussel size class (<45mm) increased threefold. There were fewest mussel in the largest size class (>54mm) the number of mussel in this size class declined by 67% compared to the previous year (Figure 7). The 2021 values reflect similar trends to the 2018 size classes, but this needs to be compared with caution due to the site only being partially surveyed in 2018. Mussel size distribution varied across the mussel bed, with a higher number of smaller sized individuals towards the centre and north east of the site and a larger number of individuals >54 mm towards the south east (Figure 8).

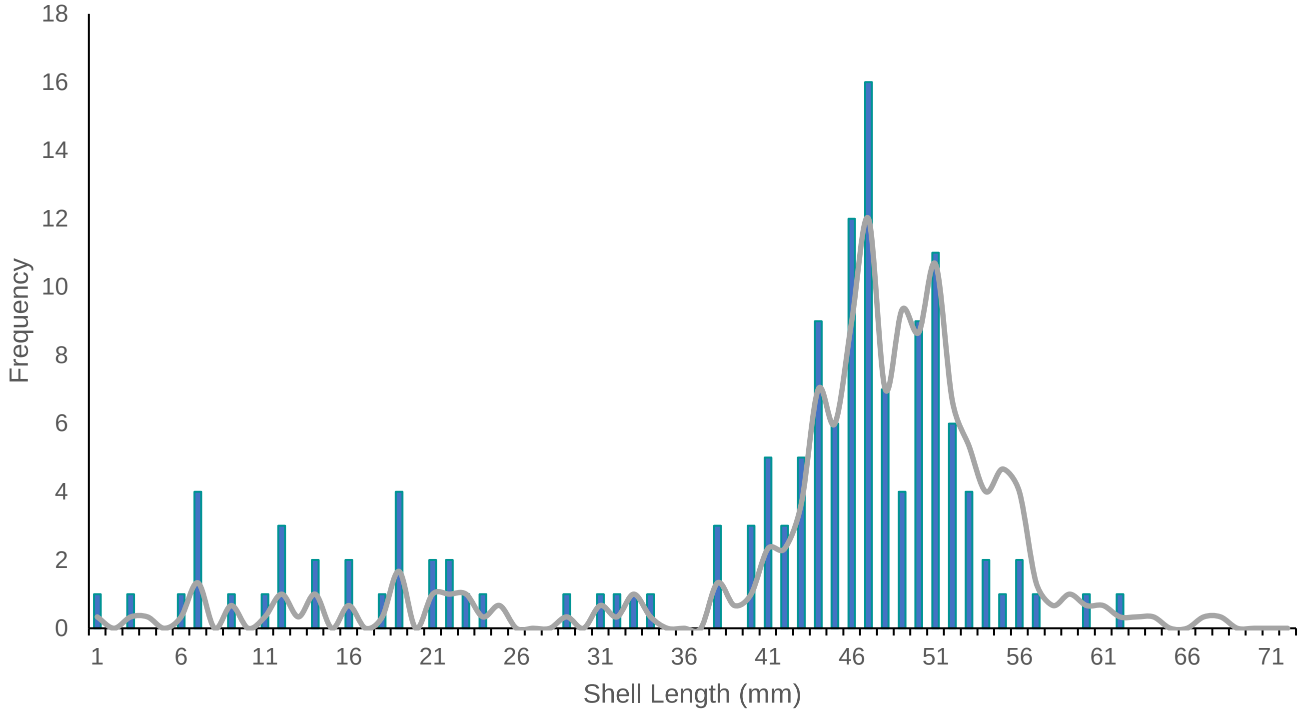

Figure 5 Length frequency (number of individuals in each mm size class) for mussels sampled in the 2021 survey of Holy Island (blue bars). Three-year averaged length frequency (2019-2021) (grey line).

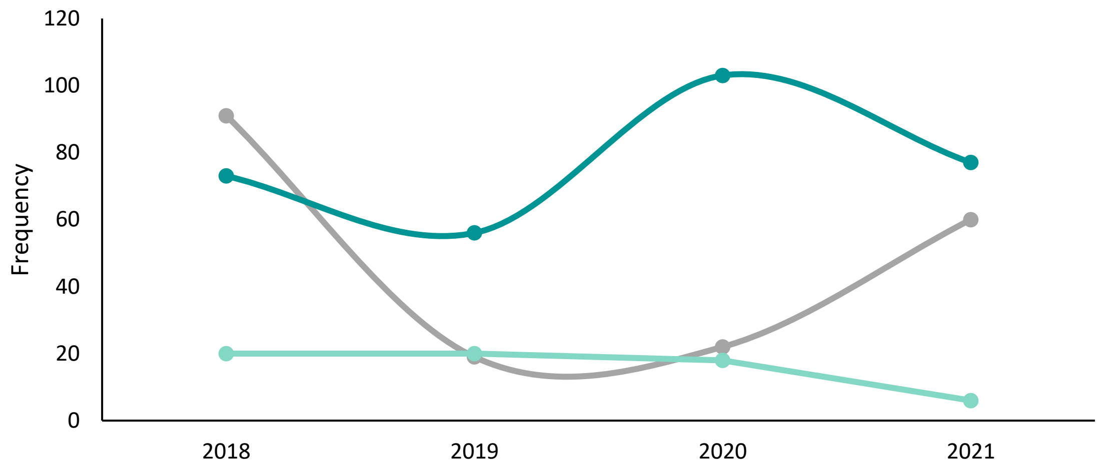

Figure 6 Mussel length frequency at Holy Island in 2021

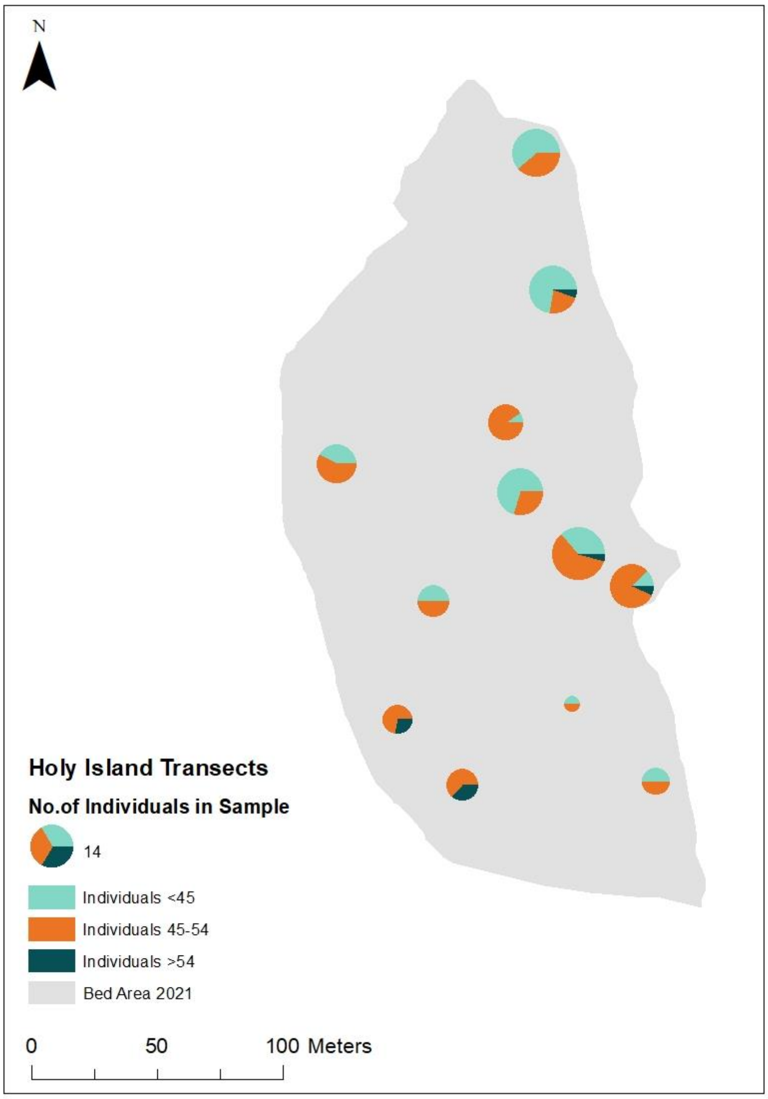

Figure 8 A breakdown for individual sample sites and the proportional percentages of the <45mm, 45-50m, and >50mm size classes. These points have also been proportionally scaled by the number of individuals recorded at each sample site, with sites containing larger sample numbers being displayed larger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

Mussel Stock

Total numbers of mussels at Holy Island Sands fell significantly from 4.31 million in 2021, to 2.52 million in 2021, with total biomass following a similar trend, falling from 111 tonnes in 2020, to 72 tonnes in 2021.

Mussel Density

Overall, mussel density at the site has declined since mussel density peaked in 2018 at 276 mussels/m^2 with a significant 35% decrease to 70 mussels/m^2 in 2021 compared to 107 mussels/m^2 in 2020 (Figure 9).

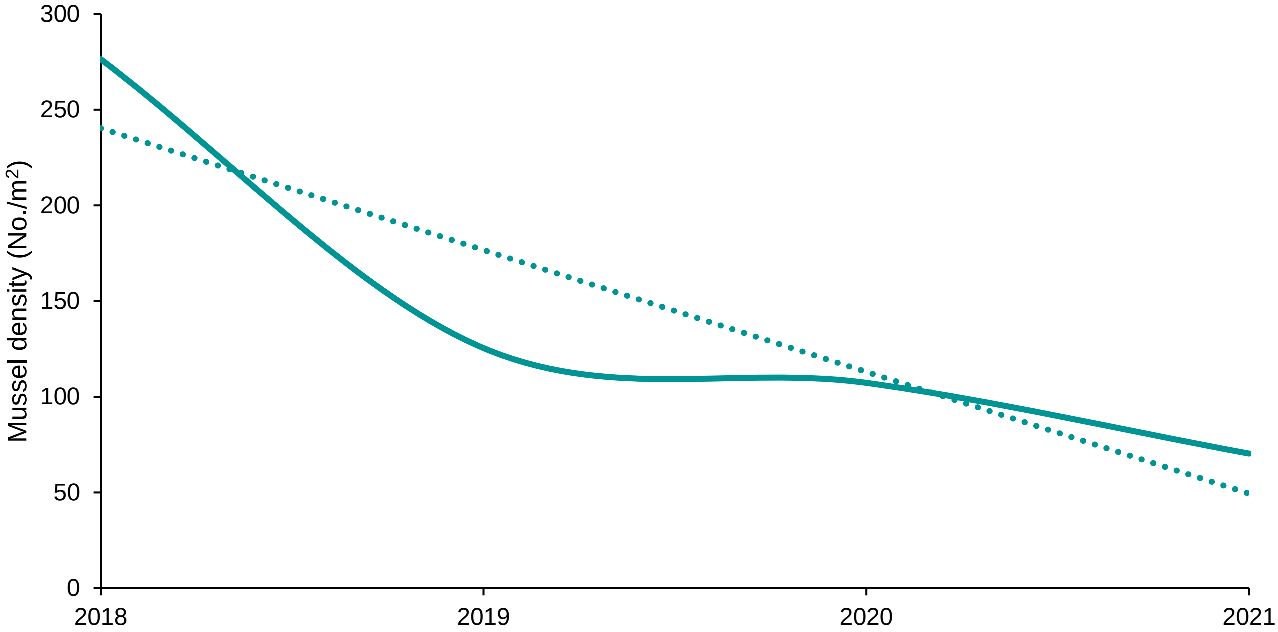

Figure 9 Density of Holy Island Sands estuary mussels a) overall with (nonstatistical) linear trendline.

Meat Content

Meat content in the mussels has increased from the 8.6% in 2020 to 10.9% in 2021, an increase of 27% (Table 2). An increasing trend is displayed from the findings at the site since 2019.

Table 2: Meat content analysis of samples between 2019 and 2021.

Year	Total weight (g)	Meat weight (g)	Meat content (%)
2019	1130	95	8.4
2020	512	44	8.6
2021	1013	110	10.9

Discussion

This is the third year of reliable data analysis (2018 results restricted by tidal flooding). Further monitoring is required to determine the health and long-term trends of this mussel bed.

Bed Area

The mussel bed area decreased this year compared to 2020 therefore annual monitoring of the mussel bed will continue to determine if the decline is due to annual fluctuation or indicative of a downward trend. It should be noted that mapping the mussel bed perimeter is very subjective and it is difficult to calculate accurately. Consistency cannot always be maintained by allocating an IFCO who has previously recorded the perimeter because of staff changes or annual leave. No trends can be identified at this time, given the short duration (3 years) of the surveys at site. As we gain more annual data it may be useful to look at the blue mussel population as metapopulations to detect any spatial trends.

Mussel beds have been found to be highly sensitive to a few human activities including introduction of invasive species, habitat structural changes (including bait colleting) and/or physical loss. 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.

Percentage Cover

Throughout the survey site percentage cover was variable, which is to be expected on a mussel bed. Lower percentage cover was recorded on transects towards the boundary of the mussel bed compared to the centre reflecting similarities to Fenham Flats mussel bed survey data. Overall, the percentage cover was the lowest recorded since surveys began at the site. Further study could include completing a transect northwest of the site to produce a more accurate representation of the average percentage cover on site.

Length Frequency

Mean shell length has decreased in 2021 compared to the two previous years, this will be partly due to higher numbers of smaller mussels being present in the samples and therefore lowering the average value. The increase of smaller sized mussels suggests the survey may have coincided with a period of spat settlement, low predation in the water column and good nutrient levels to enable growth. This could indicate recruitment at this site and continued monitoring will inform on the success of the young mussel settlement detected in this years' survey.

When looking at length frequencies for the 2021 survey, there is a decrease in the frequency of medium sized mussels (19- 38mm). This is also reflected in the three-year average of the frequency of each size. This pattern could be attributed to both nutrient availability and/or predation. Medium sized mussels may be more sensitive to low nutrient levels compared to larger sizes because they would apply a larger proportion of their energetic reserves into reproduction. Size-specific predation may play an important role at the survey site; past studies found eider and oystercatchers' (important species at Holy Island Sands) favour medium sized mussel therefore the larger length mussels will exhibit lower mortality based on predation (Hamilton, Nudds & Neat, 1999, Meire & Erynck, 1968). This would support the trends seen at the site with higher frequencies of smaller and larger sized mussels.

Mussel Density and Biomass

The results indicate a sharp decline in mussel stock and biomass which, when compared to the 2019 and 2020 results shows a decreasing trend overall. Mussel density has continued to decline at the site since 2019. A NIFCA commissioned report (Dent, 2019) highlighted that Fenham Flats mussel bed close by exhibited large fluctuations in mussel density between survey years with an overall decreasing trend, this may be occurring at Holy Island Sands.

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. This is typically indicative of a population that has had poor recruitment in previous years, and as such the population is dying at a greater rate than it is being stocked. The increased recruitment observed in 2021 may indicate that there is hope for this mussel bed. 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. In the UK, there have been anecdotal reports of declines on the east coast from Scotland to the Wash. It is unclear at present what is driving the declines reported, and there are a range of potential factors. Factors include water pollution (Hilgerloh, 1997), coastal development and anchoring (Maddock, 2008), and collection by humans for consumption or use as bait (Fenton 1978; Maddock 2008). As mentioned above, the latter is unlikely to be a pressure facing the bed at Holy Island as there is regulation in place to prohibit this activity (Lindisfarne National Nature Reserve Byelaw, 1999). At this site, there are ongoing issues with water quality that have caused macroalgal blooms, this change in nutrient loading at the site may be a factor here.

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).

While there are many factors that could affect the bed, long term monitoring is required to confirm declines at this bed.

Conclusion

Overall, the 2021 mussel report reflect similar findings to the previous Holy Island mussel surveys (2019 and 2020). Over the last three years, the mussel bed survey findings have shown a decrease in bed area, density, biomass and stock biomass while the meat content has fluctuated.

This year the mean size of mussels decreased due to larger numbers of juvenile mussels (spat) with a decrease in the older, mature population.

The continuation of annual surveys will be able to see if this is an annual fluctuation or continuing trend to monitor the distribution and health of the Holy Island mussel beds.

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. 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.

The exact causes of mussel bed decline are unknown regionally and nationally. This year an MSc. Project by Newcastle University partnered with the Environment Agency and Natural England aims 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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