Assessment of the blue mussel (*Mytilus edulis*) bed on Holy Island 2022

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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 2022 covered an area of 3.41ha with an average percentage cover of 70%.
- The estimated values obtained for density, biomass and total number of mussels have decreased significantly compared to the 2021 survey.
- Mean length of mussels (42mm) sampled in 2022 increased by 2mm compared to 2021. 56% of mussels sampled were larger than the recommended minimum conservation reference size (MCRS) of 45mm. 36 mussels were collected for sampling this year therefore it was not possible to identify 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 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 Habitat of Principle Importance under the Natural Environment and Rural Communities (NERC) Act 2006.

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 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 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 during a spring tide on the 21st March 2022 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 3.41ha in 2022. 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.

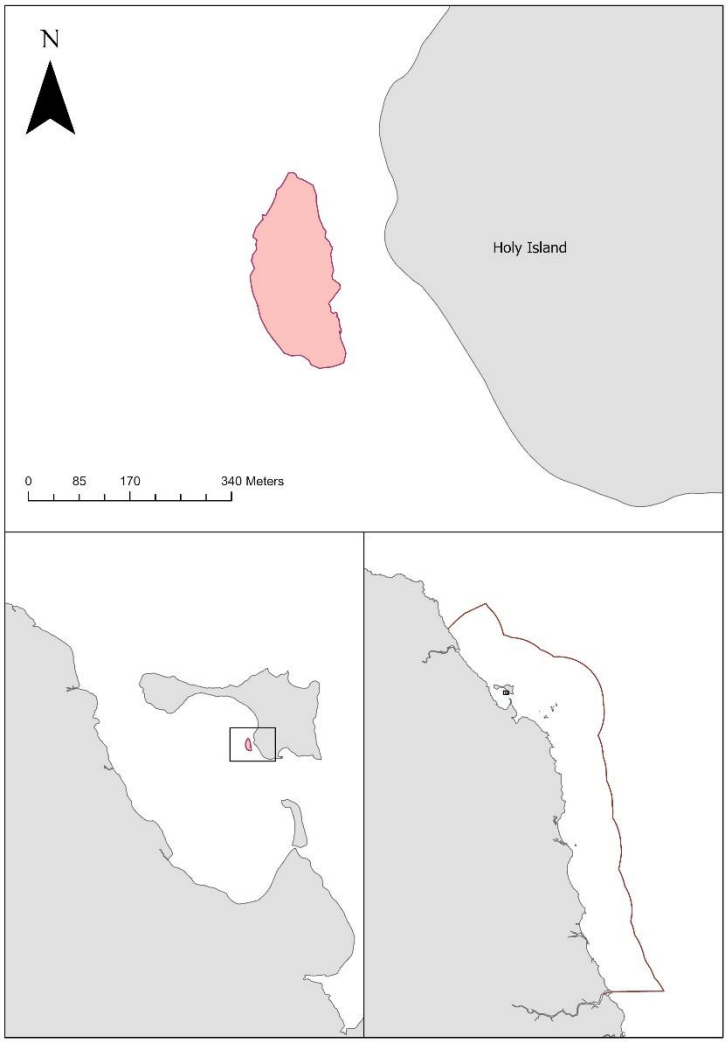

Figure 1. Holy Island Sands blue mussel bed in 2022 and it's position relative to Lindisfarne NNR and the Northumberland IFCA district (from top moving anti-clockwise).

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 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 0.1m² 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:

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

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

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 36 individual mussels were recorded from 10 samples in 2022. A summary of the survey results from 2018 to 2022 can be seen in Table 1.

Table 1: Results for the Holy Island mussel survey between 2018 and 2022.

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
2022	3.41	70%	0.86	42.02	25.2	709	24.2

Bed Area

In 2022 the mussel bed area was calculated as 3.41ha a decrease of 6% compared to 2021 (Table 1 and Figure 3). The bed area has displayed a slow decline since 2019. The smallest mussel bed 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 for the Holy Island in 2021 and 2022

Percentage Cover

2022 percentage cover was highly variable (between 44% and 93%) across the different transects reflecting 2021 results (Figure 4). Areas of highest percentage cover were recorded towards the central and northern area of the mussel bed and lowest percentage cover towards the north-western area (Figure 4). Overall, the average percentage cover for the site was 70%, an increase of 18% compared to last year and returning a similar percentage cover value to 2020 (Figure 5). Since the survey began at Holy Island Sands the overall percentage cover has varied over time, peaking in 2018 at 90%.

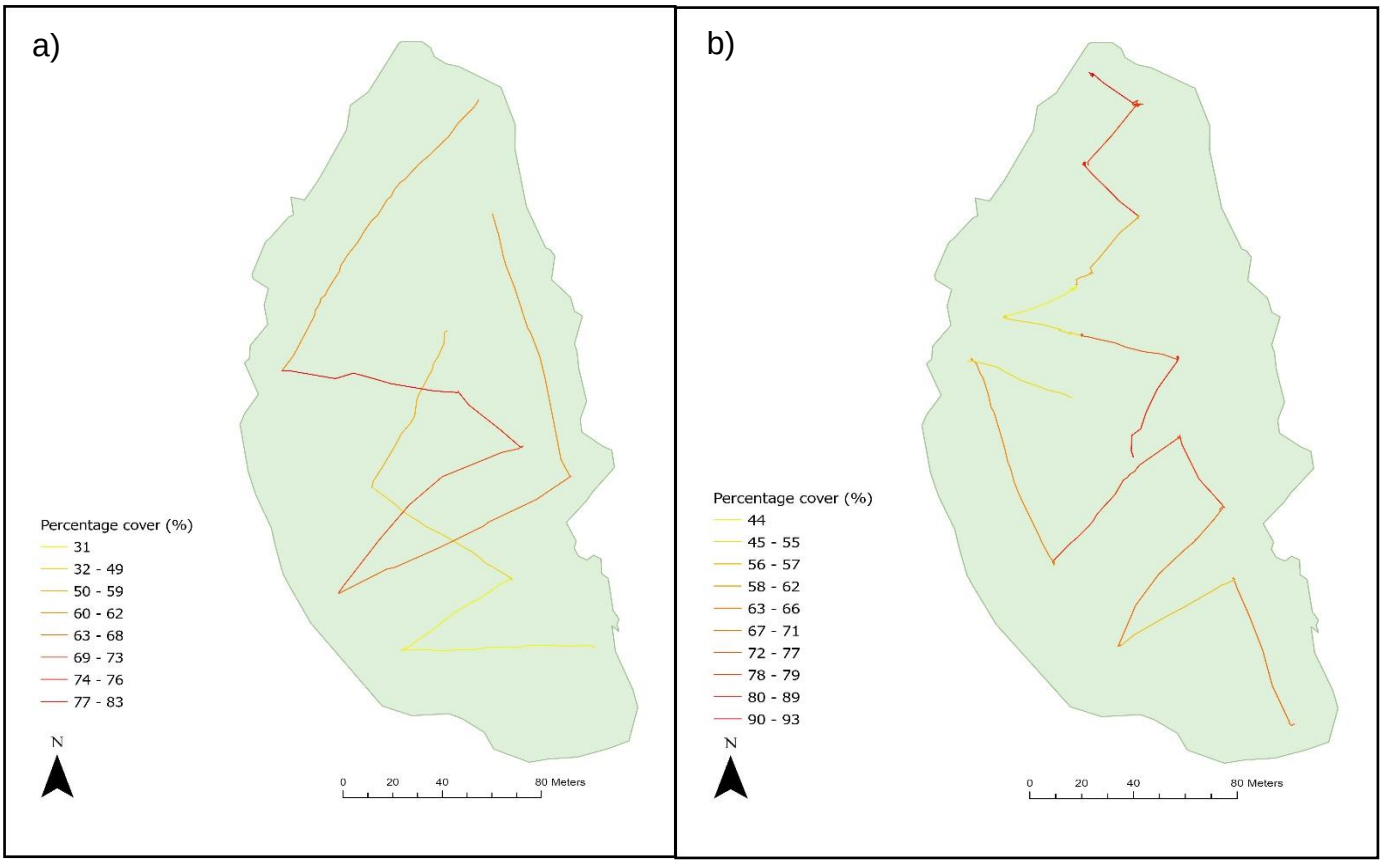

Figure 4. Percentage cover noted over walked transects at Holy Island in a) 2021 and b) 2022.

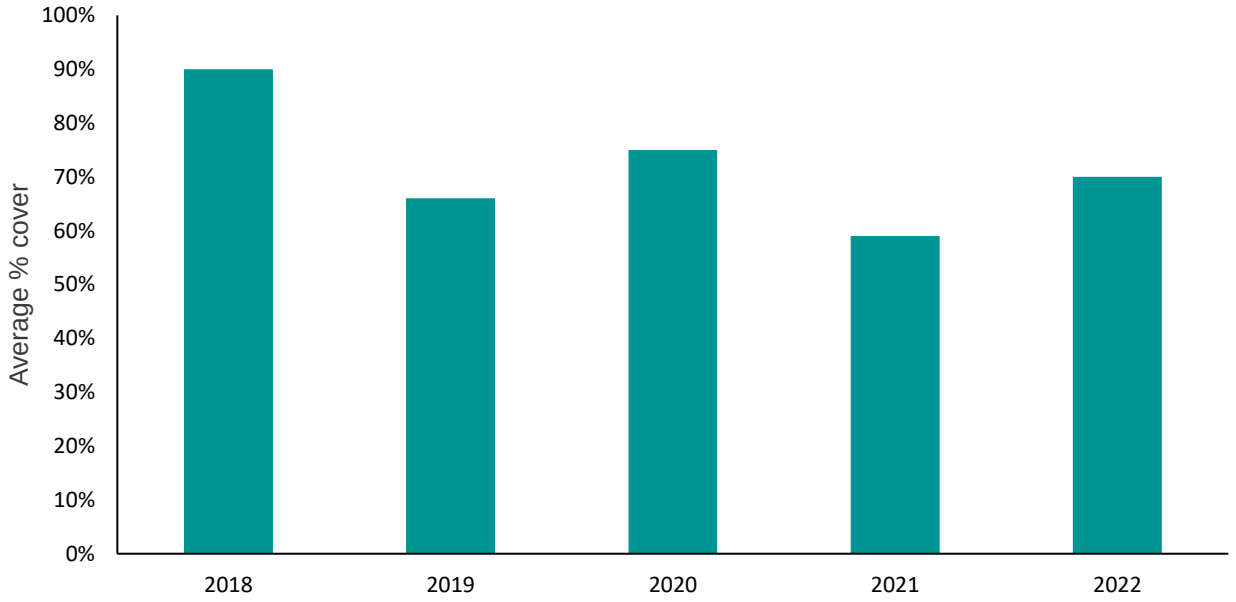

Figure 5. Percentage cover for Holy Island 2018-2022

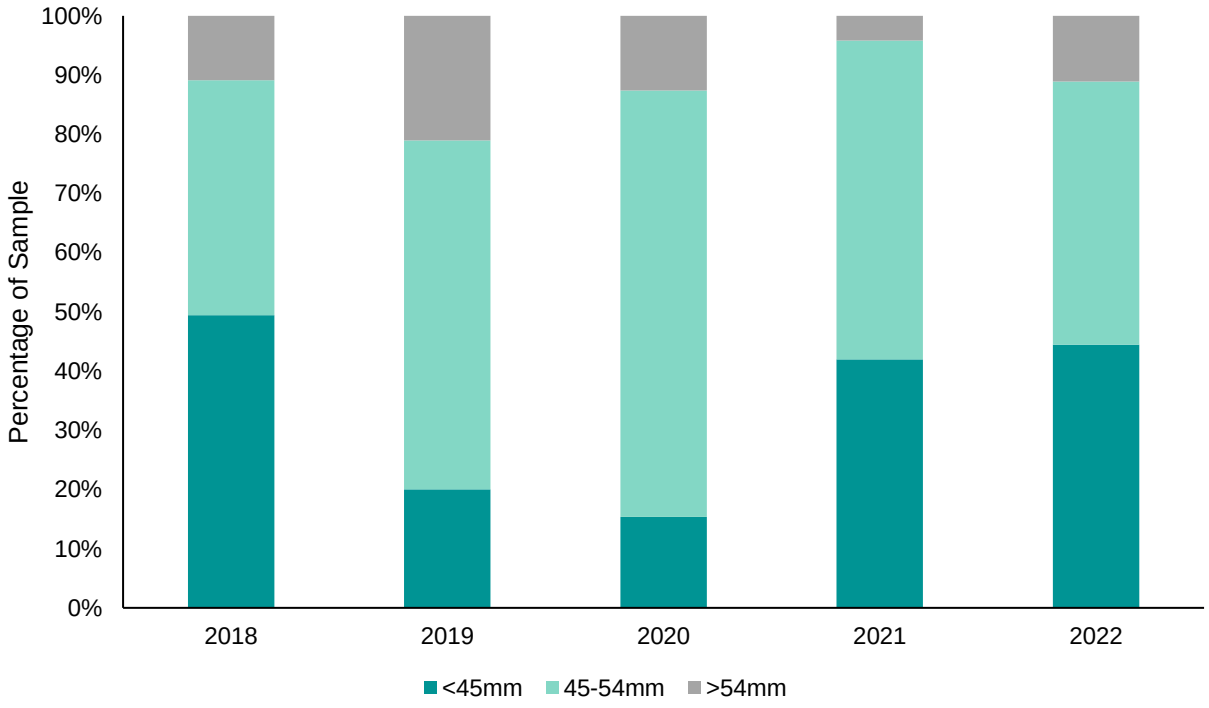

Figure 6. Proportional percentages of sampled mussels size classes between the years 2018 – 2022.

Length Frequency

In 2022, the total number of live mussels sampled from the mussel bed was 36, a significant decline compared to the previous two-years totals of 143. The average mussel size has increased from 40.6mm in 2021 to 42mm length in 2022. Pre-2021, length frequency skewed towards larger

size classes. In 2021, there was a higher proportion of smaller mussel between 7-19mm (Figure 7a). In 2022, 11% of the mussels sampled were >54mm (the largest size group) and the remaining mussels were divided equally (44.5%) between the <45mm (the smallest size group) and 45-54mm. (Figure 6). The grouped class size results reflect last year's survey findings with similar proportions of the sample in both small and middle size groups, and fewer mussel 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 a higher number of smaller sized individuals (<45mm) towards the centre of the surveyed area, medium sized individuals (45-54mm) were found across site but in larger densities towards the centre and north, and a larger number of individuals (>54 mm) towards the south and southeast (Figure 8).

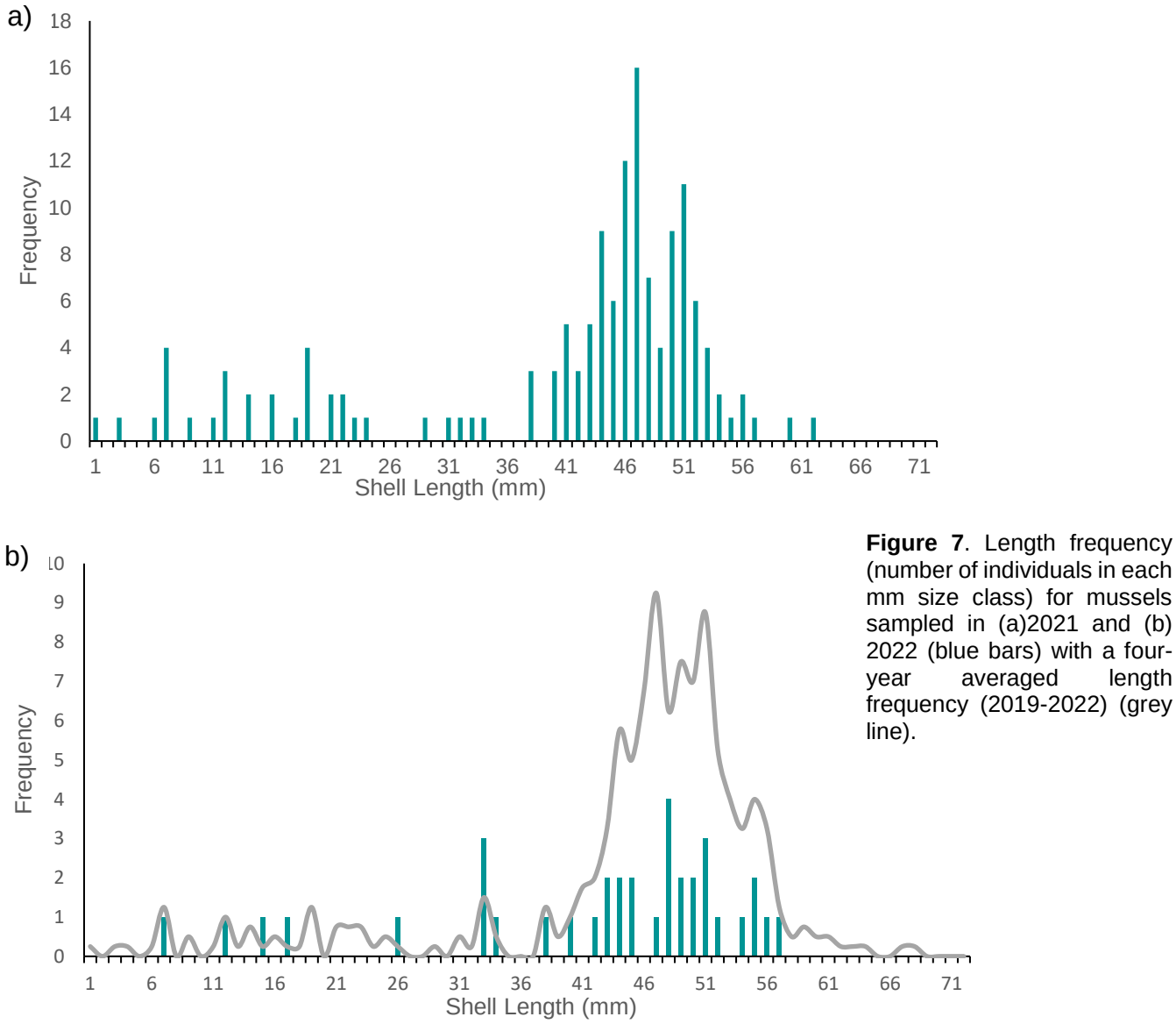

Figure 7. Length frequency (number of individuals in each mm size class) for mussels sampled in (a)2021 and (b) 2022 (blue bars) with a four-year averaged length frequency (2019-2022) (grey line).

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 70 mussels/m^2 in 2021 (a 35% decrease from the 2018 density) (Figure 9).

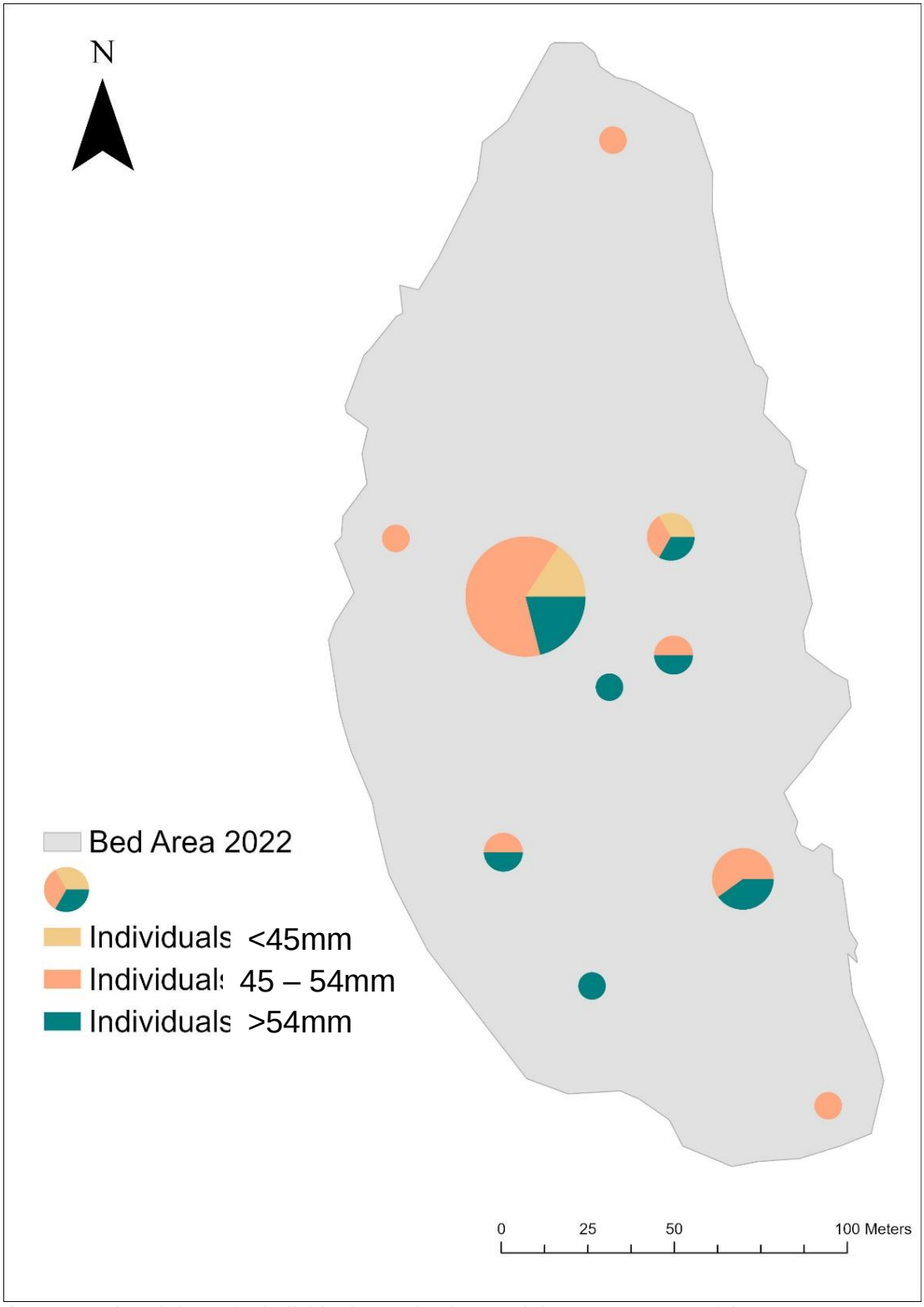

Figure 8. A breakdown for individual sample sites and the percentages of the <45mm, 45-50mm, and >50mm size classes. These points have also been proportionally scaled by the number of individuals recorded at each sample site, with sample sites containing more mussel being displayed larger on the map.

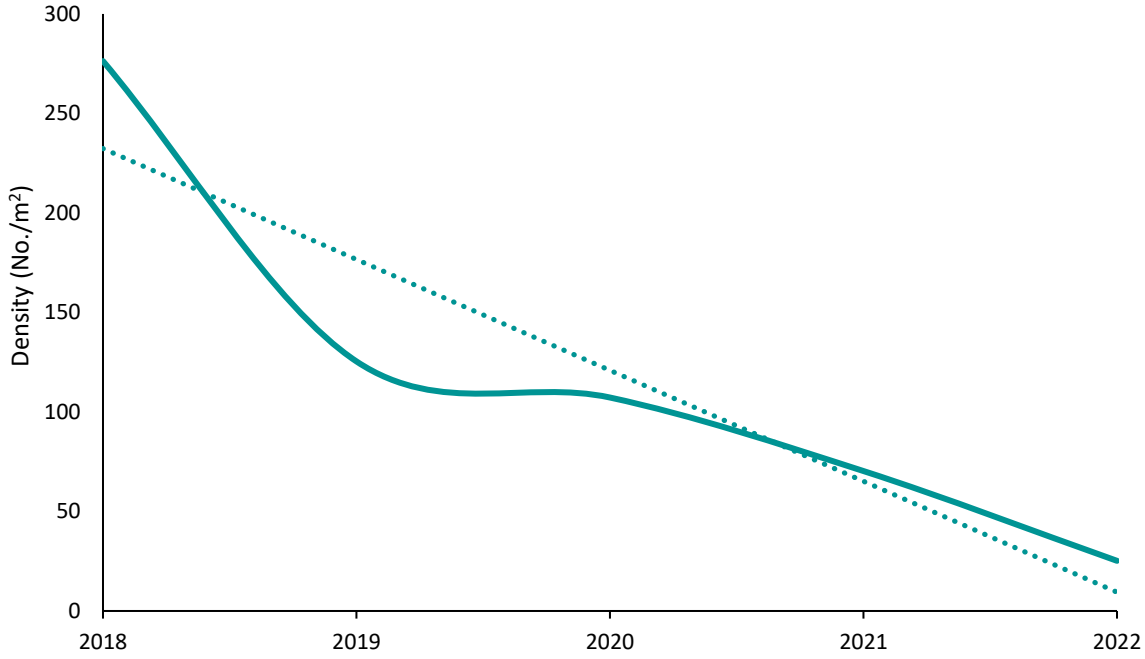

Figure 9 Density of Holy Island Sands mussels (solid line) with (nonstatistical) linear trendline (dashed line).

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 0.86 million in 2022, with total biomass following a similar decline, falling from 111 tonnes in 2020, 72 tonnes in 2021 to 24.2 tonnes in 2022

Discussion

This is the fourth 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.

Bed Area

Over the past four years the mussel bed area has decreased which is indicative of a downward trend. Given there is only four years of data on bed area, this will continue to be monitored to understand whether there is a downward trend. 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 variable, which is to be expected on a mussel bed. Lower percentage cover was recorded on transects towards the northwest of the mussel bed. Overall, the percentage cover increased since last year surveys this could be linked with last year's recruitment.

Length Mean & Frequency

Mean shell length has shown a small increase in 2022 compared to the last year, this will be 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 2022 survey, there is little that can be concluded because of the small number of individuals recorded in the sample. The proportion of size classes reflect some similarities to last year's findings with a smaller proportion of larger sized mussels and equal numbers of small and medium sized mussels. This pattern could 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 higher numbers of these two species during 2019/20 compared to the 2018/19 surveys which could explain the smaller number of mussel in the small and medium size classes recorded that year.. More research would be needed to determine the reliability of this relationship.

Mussel Density and Biomass

The results indicate a sharp decline in mussel stock and biomass which, when compared to the 2020 and 2019 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 the nearby Fenham Flats mussel bed exhibited large fluctuations in mussel density between survey years with an overall decreasing trend, this may be occurring 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. 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 (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 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 mussel stock and biomass values decline, percentage cover has increased however this may be misleading and the increase may be due to the smaller sample size.

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

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 2022 declines were reported for multiple 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 confirm if changes in mussel bed area and total number of mussels is an annual fluctuation or a continuing trend.

Further study is required to determine:

1. Whether the bed area is in decline or whether it is experiencing interannual fluctuations
2. Whether the reduction in the number of mussels sampled (and therefore estimates for density and biomass) is a function of reduced mussel at the site, or inaccuracies in survey sampling.

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 a future study could also look at the 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.

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 project at Newcastle University aimed 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 results from the Blyth estuary indicate it could be useful for helping determine mussel bed extent and coverage that could supplement NIFCA survey data and aid in determining bed area over time using historical satellite and drone imagery. Project outcomes include a standard operating procedure for using UAVs for intertidal research within the equipment capabilities of NIFCA. NIFCA hopes to use its own drone capabilities for future mussel surveys to further validate findings by officers in the field.

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