Exe Estuary
Mussel Stock Assessment 2024

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1. Introduction

1.1 *Mytilus* spp

Populations of the common mussel, *Mytilus* spp. are keystone species of intertidal and subtidal hard bottom communities throughout the temperate to subarctic coasts of the Northern Hemisphere (Väinölä and Strelkov, 2011).

Mussel beds play an important role in the healthy functioning of marine ecosystems; having a role in coastal sediment dynamics, acting as a food source to wading birds, and providing an enhanced area of biodiversity in an otherwise sediment-dominated environment (JNCC, 2016). They support their own diverse communities as the mussel matrix, composed of interconnected mussels and accumulated sediments and debris, provides numerous microhabitats and an organically enriched environment (Seed and Suchanek, 1992; Andrews *et al.*, 2011). *Mytilus* spp. are filter feeders, feeding primarily on micro-algae, suspended debris and zooplankton, and play a vital role in estuaries by removing bacteria and toxins.

Mytilus edulis, commonly known as the Blue Mussel are cold-water mussels which can occur in brackish water (Gardner, 1996). Its native region has been difficult to identify because of the presence of similar species and subspecies (*Mytilus galloprovincialis* and *Mytilus trossulus*). However, its native distribution is thought to span across the North Atlantic and North Pacific coast of North America, Europe and in other temperate and polar waters.

Mytilus edulis and *Mytilus galloprovincialis* often occur in the same location in the northern range of *Mytilus galloprovincialis.* They are often difficult to distinguish due to their variation in shell shape as a result of environmental conditions. In addition, they may hybridize.

The reproductive strategy of *Mytilus* spp. is to deploy a large number of gametes, approximately three million eggs, into the surrounding water where fertilisation takes place (Andrews *et al.*, 2011). Following fertilisation, the zygotes, as planktonic larvae, undergo six stages of metamorphosis before settlement. Mussels can adapt their reproductive strategy depending on environmental conditions. For example, the release of gametes can be timed to complement favourable environmental conditions, and the planktonic phase can last between two and four weeks depending on temperature, food supply and availability of a suitable substrate to settle on (Andrews *et al.*, 2011). Depending on temperature and nutrient levels, spawning may occur just once or several times per year (Bayne and Worrall, 1980; Seed and Suchanek, 1992; Handå *et al.*, 2011).

Threats to *Mytilus* spp. beds include commercial fishing, water quality, coastal developments, anchoring, bait digging, and intensive recreational hand gathering (JNCC, 2016).

1.2 Objectives

The objective of this project is to carry out and report on biennial surveys of the mussel beds on the Exe Estuary, to define where the mussel beds are and accurately map, using GIS, the overall extent of each of the mussel beds. The surveys provide data for a stock assessment of the beds to estimate the density of mussels on the beds and the total stock of marketable-sized mussels, which can be compared to previous years. This will help inform future management of the mussel beds on the Exe and the development of shellfisheries in this part of the D&S IFCA's District. The data can also help inform the food availability for the overwintering birds for which the Estuary is designated, should Natural England request the data for this purpose. D&S IFCA Officers have not tried to identify *Mytilus edulis* from *Mytilus galloprovincialis* during this survey.

2. Methodology

2.1 Study Site: Exe Estuary

The Exe Estuary is the one of the most highly designated nature conservation sites in Devon; it is a Ramsar Site, a Special Protection Area (SPA), and a Site of Special Scientific Interest (SSSI). It encompasses over 3,000 hectares of diverse aquatic and terrestrial habitats (EEMP, 2020). The Exe Estuary SPA includes both marine areas (i.e. land covered continuously or intermittently by tidal waters) and land which is not subject to tidal influence (Figure 1). Sub-features have been identified which describe the key habitats within the European Marine Site necessary to support the birds that qualify within the SPA. Bird usage of the site varies seasonally, with different areas being favoured over others at certain times of the year. The mussel beds are important in supporting the wintering wader and wildfowl assemblages to enable them to acquire sufficient energy reserves to ensure population survival (Natural England, 2020). Oystercatchers are the main bird species to use the mussel beds, along with redshank, curlew, turnstone and greenshank. Several thousand oystercatchers overwinter on the Exe Estuary and predominantly feed on the mussels, a few will also feed on cockles, winkles and ragworms (Goss-Custard and Verboven, 1993).

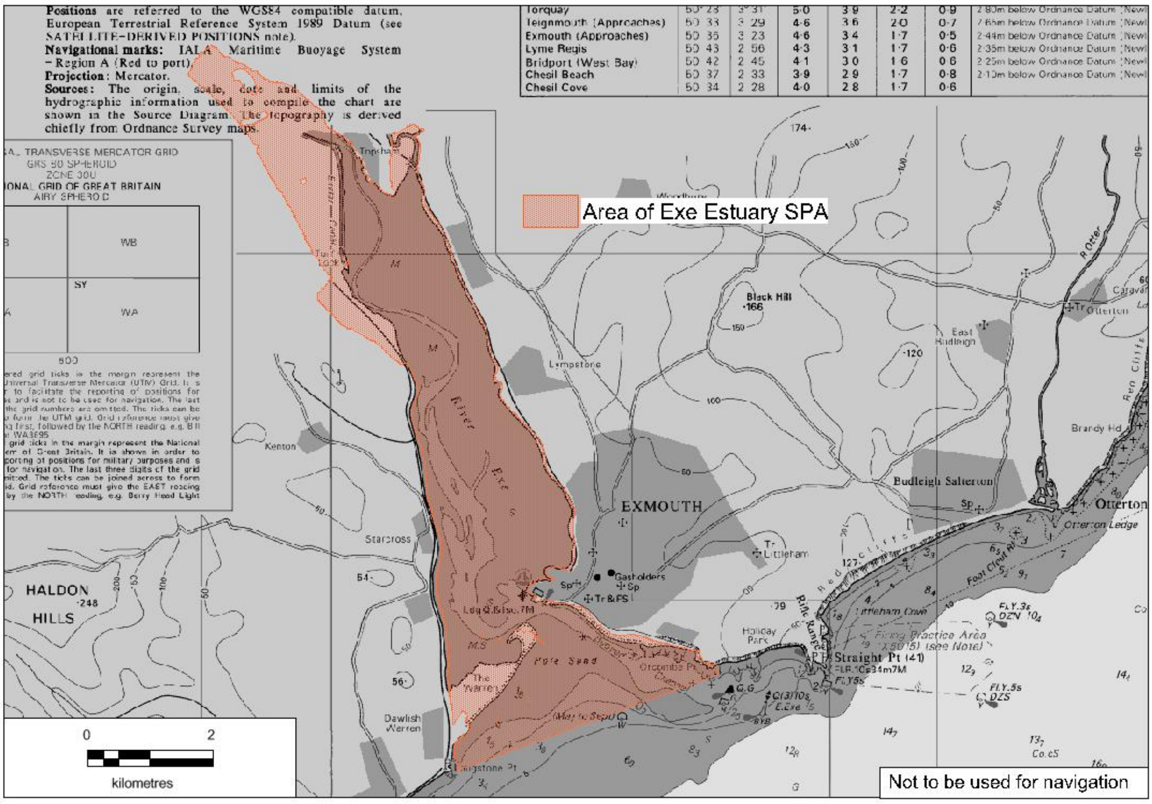

Figure 1 Area of the Exe Estuary SPA

Commercial mussel harvesting can only take place on classified beds (Figure 2) and is predominantly occurring sub-tidally. D&S IFCA introduced a temporary closure, from 1st May 2019, on the public shellfish beds in the Exe Estuary due to the stocks in these areas being severely depleted

Devon & Severn Inshore Fisheries and Conservation Authority's (D&S IFCA) stock assessments focus on the public fishery beds of Bull Hill and, when access is possible, at Lympstone. The beds at Starcross, which fall within the private fishery boundary, have previously been surveyed but, as mussels have not been harvested or re-laid to this area for several years, the surveying of this bed was discontinued in 2022.

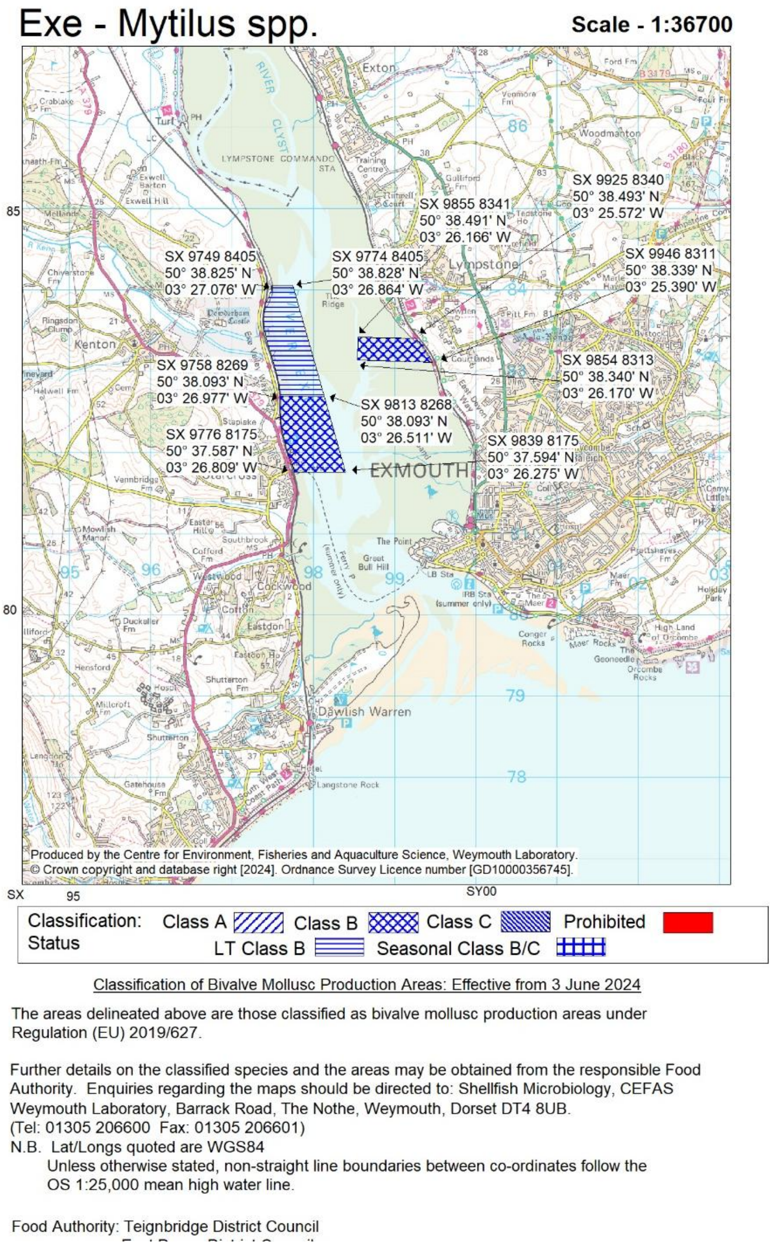

Figure 2 Classified mussel harvesting areas on the Exe Estuary (Cefas, 2024)

2.2 Survey methodology

This document reports on surveys conducted between 2013–2024. Due to mussels being largely absent from the 2019 surveys and access issues, surveys were not subsequently undertaken at Lympstone. See the 2019 report (Thomas, 2019) for details of additional beds that were not surveyed during 2022 and 2024. Surveys conducted on 8th April 2024 focused on the Bull Hill bed only (see Figure 3 and 4). The survey site of Bull Hill is mid-channel and, due to changes in the channel, required access by boat from Exmouth Docks in 2024. Bull

Hill was surveyed on a spring tide to ensure the full extent of the mussel bed was accessible; the survey area was determined based on previous survey locations and local stakeholder input as to the presence of mussel.

Due to the varying levels of patchiness and density the area surveyed cannot always be indicative of the size of a true mussel 'bed' and is a representation of the area in which live mussels were located. This means that the survey area will not always be purely on mussel bed, but also on areas where mussels occur in small, dispersed patches. The perimeter of this survey area was recorded on the first visit to the bed by walking the extent of the live mussel habitat and marking coordinates with a handheld GPS. The bed at Bull Hill was first visited in 2013. The perimeter was subsequently mapped in QGIS v3 (Figure 3 and 4).

At the Bull Hill site (Figure 3 and 4), to determine coverage and patch density, transects were walked in a zig-zag pattern across the survey area, up to the extent of the mussel bed (e.g. to the water's edge or the point at which substrate changed or mussels disappeared). The start and end coordinates of each transect were recorded using a handheld GPS. A 4 ft bamboo cane with an 11cm ring attached to the end, arranged so that the ring sits flat on the ground when held out to one side, was used to determine the mussel coverage for each transect: Every three paces (one pace equals a single step) along each transect the cane was placed out to one side and the presence or absence of live mussels within the ring were recorded. On every fifth hit (presence) the contents of the ring were taken as a sample, using an 11cm diameter corer. All mussel samples from the same transect were collected together in one bag and kept separate from those of other transects. This methodology is known as the Dutch Wand Method.

Once all transects are complete mussel samples are sieved and cleaned. For each transect the number of samples taken is recorded, all mussels are then measured and divided into the following size groups; 1-10mm, 11-20mm, 21-30mm, 31-40mm, 41-50mm, 51-60mm, 61-70mm, 70+mm.

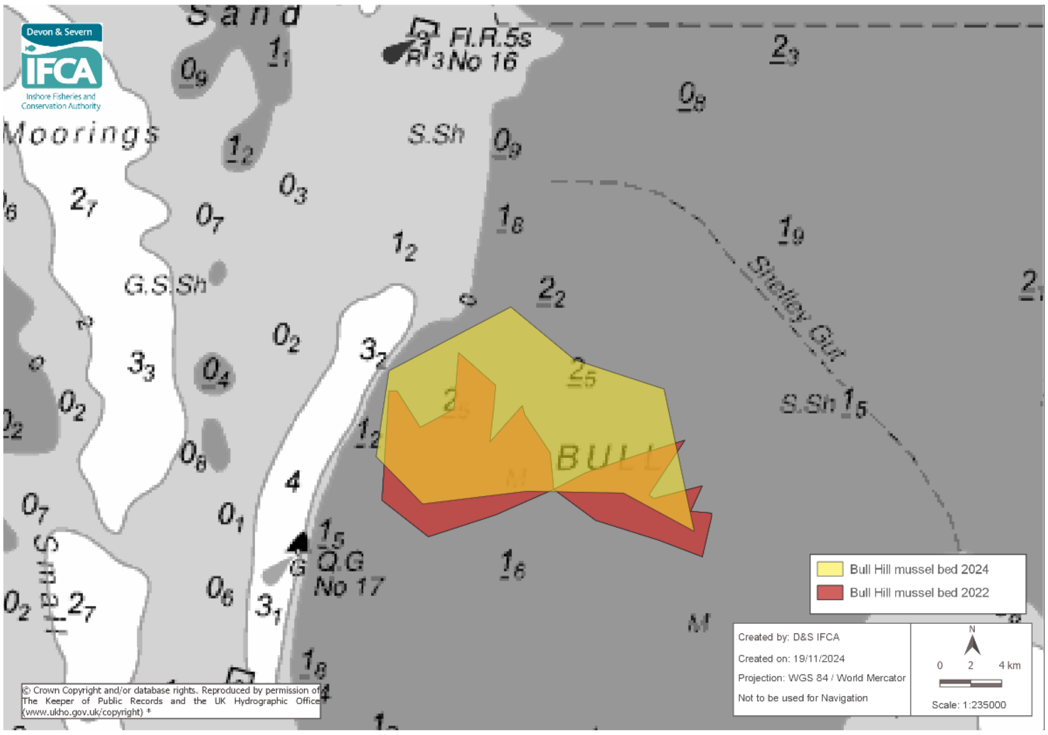

Figure 3 Area of mussel bed at Bull Hill surveyed in 2022 (red) and 2024 (yellow). Mapped by generating a minimum convex polygon around the transect lines. The survey area in 2024 does not fully overlap the areas surveyed in 2022. * www.ukho.gov.uk/copyright

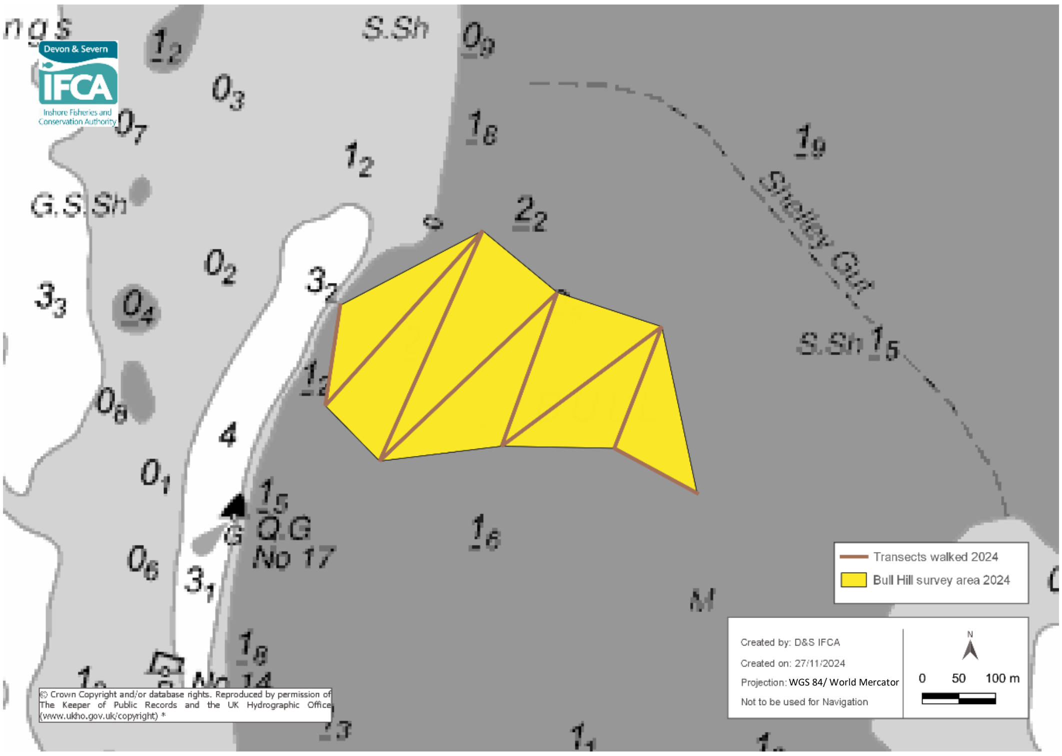

Figure 4 Area of mussel bed at Bull Hill surveyed in 2024 (yellow). Transect lines walked in 2024 are shown in brown. Bed area mapped by generating a minimum convex polygon around the transect lines.* www.ukho.gov.uk/copyright

2.3 Data analysis

The data collected from both the transects and samples were used to calculate the percentage cover (Equation 1), density (Equation 2) and area of the survey area (by generating a minimum convex polygon around the transect lines), which were then used to estimate the mussel tonnage (Equation 3). Total tonnage across Bull Hill was calculated based on the weight of mussel in the samples taken and the metrics described above.

Equation 1: Calculation of the percentage cover of mussel

$$\% \, \boldsymbol{cover} = \frac{no.hits}{no.hits + no.misses}$$

Equation 2: Calculation of the density of mussel cover

$$\boldsymbol{Density} \, (\boldsymbol{kg/m^2}) = \frac{total\ mussel\ weight\ sampled}{surface\ area\ sampled} \times \% \, cover$$

Equation 3: Calculation of mussel tonnage

$$\boldsymbol{Tonnage\ of\ mussel} = \frac{Density \ \times 10{,}000 \ \times Area(ha)}{1000}$$

3. Results

A total of 16 samples were collected from 8 transects on Bull Hill. Only sparse mussel has been detected here since 2014, with the exception of a small, dense area of spat found in 2019 covering an area of 0.25ha which was deemed too small to survey. In 2024 the surveyed area covered 6.9 hectares and contained a calculated 227 tonnes of mussel, compared to 395 tonnes in 2022 (Figure 5), a decrease of 43%. This area of mussel bed has decreased in density and percentage cover of mussel since 2022 (Figure 6). Of the total 227 tonnes stock observed in 2024, 89% of this was >41mm in length, and 0.8% was spat (<30mm) (Figure 7). Although the percentage of larger (>41mm) mussel has increased since 2022, the total tonnage of mussel in this size class has decreased by 45 tonnes since 2022 (Figure 7), reflecting the overall decline in total tonnage across most size classes.

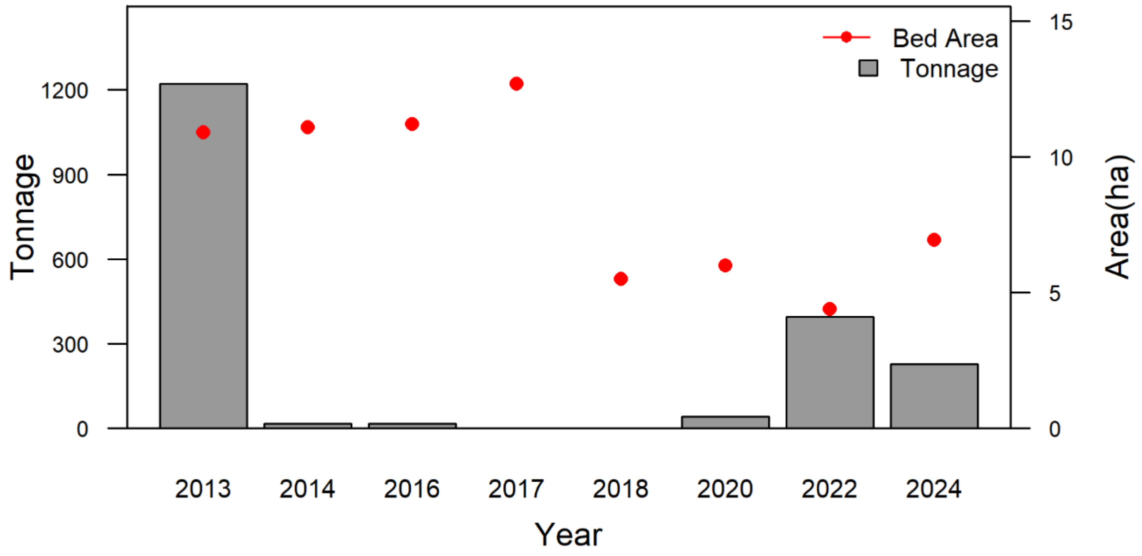

Figure 5 Total area surveyed plotted over tonnage of total stock within the Bull Hill mussel bed between 2013–2024.

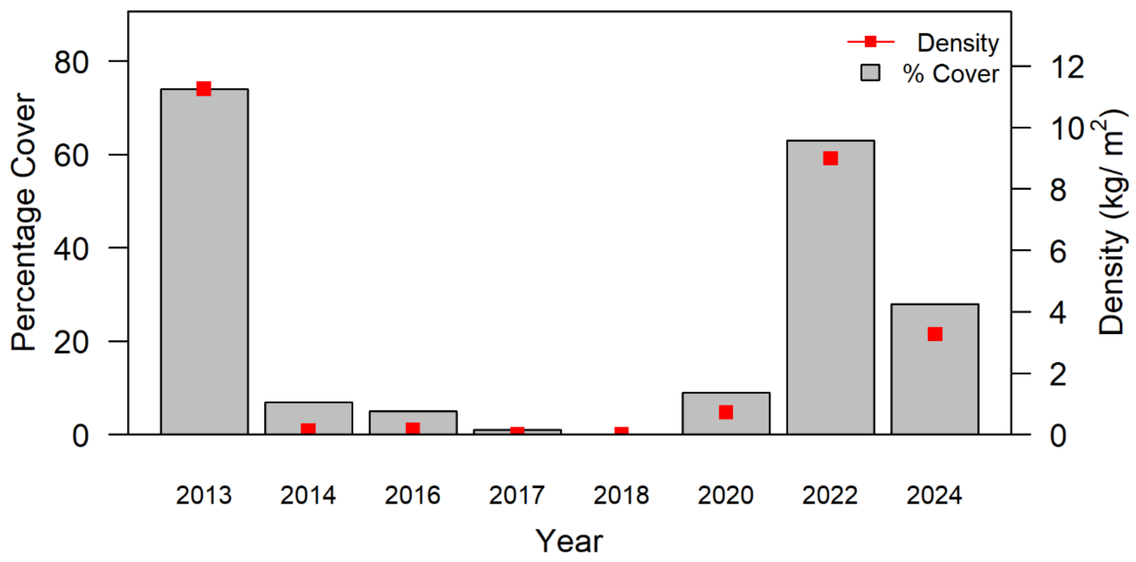

Figure 6 Percentage cover and density of mussels on the Bull Hill bed 2013–2024.

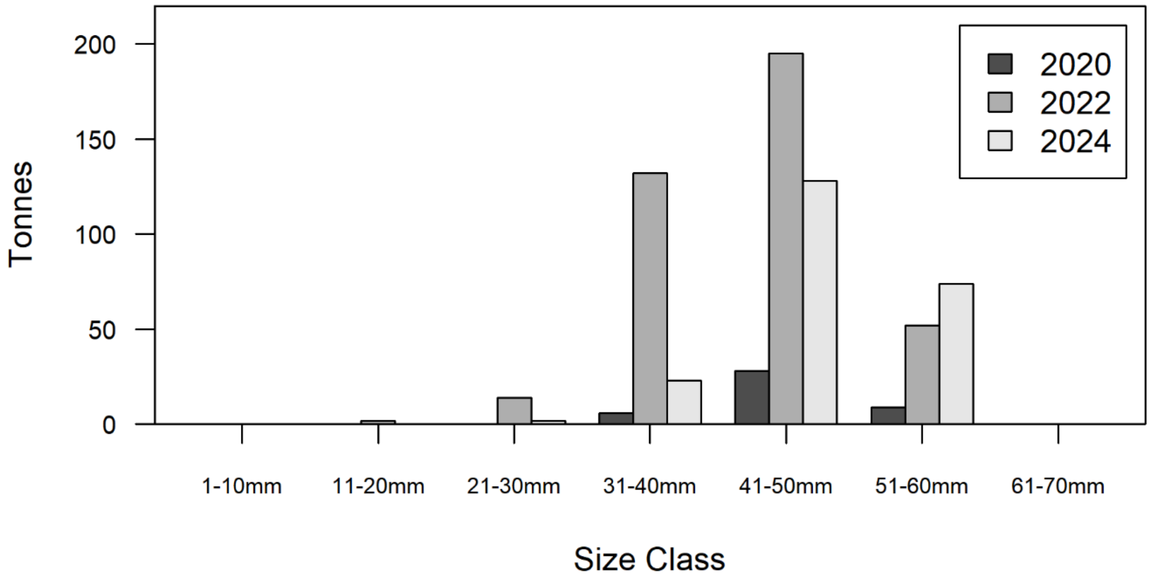

Figure 7 Tonnage of each 10mm size class for the Bull Hill stock from 2020-2024

4. Discussion

In 2014 large storms scoured away previously-stable mussel beds, which reshaped the local hydrology. This was later followed by several Harmful Algal Bloom (HAB) incidents which reduced mussel populations further. Since these events, mussel populations have been unable to recover to anywhere near the previous population estimates and have been absent in anything that could be described as a dense, homogeneous, and stable population within the estuary.

Local stakeholders have also expressed concern that increased sedimentation in the estuary has smothered a proportion of the mussel and are of the opinion that this sedimentation has been caused or exacerbated by human activities (primarily the Dawlish Warren Management Scheme). The Exe Estuary Management Partnership has recently published a sedimentation report for the Exe Estuary which identifies the estuary has undergone significant changes in both accretion and erosion since 2005 (Ward and Johnson, 2024). A review of Light Detection and Ranging (“LiDAR”) data from 2007-2023 identified the Estuary experienced a net sediment gain of 202,566m^3 (0.97%) between 2014-2018. This period coincides with the flood defence work undertaken at Dawlish Warren in 2016/2017 and therefore the increase in sediment could be as a result of this. However, this increase only relates to the net sediment change at that time. The long term data shows that between 2007-2018 the estuary actually experienced a net sediment loss of approximately 1.5 million cubic meters (6.58% decrease in sediment) (Ward and Johnson, 2024). This highlights the complexity of sediment transport within the Exe Estuary and suggests changes are as a result of both natural cycles and human interventions over time, therefore requiring a comprehensive understanding of their combined effects (Ward and Johnson, 2024).

One of the sources of mussel recruitment in the estuary is the relaying of mussel seed into the estuary, to be grown on for harvesting, by Exmouth Mussels Ltd. As part of their relaying activity, a portion of this seed is relayed intertidally to increase food availability for the over-wintering bird species, for which the estuary is designated as a SPA. Prior to 2017 Exmouth Mussels Ltd re-laid some seed mussel in the Starcross area although most was re-laid sub-tidally. In 2014 there was an unusual seed mussel settlement on Bull Hill Bank. D&S IFCA worked with Exmouth Mussels Ltd and Natural England and an agreed portion of this settlement was removed and some was re-laid on to the Starcross intertidal area to provide food for the birds. The remaining seed was re-laid sub-tidally. Since 2017 very few mussels have remained on the Starcross bed and no further relaying of seed mussel has taken place in this area. No recovery of the mussel beds has been observed in this area of the Exe Estuary.In addition, large numbers of Pacific oyster, *Crassostrea (Magallana) gigas,* have established on the intertidal area of Starcross since 2018 and in 2022 the survey site appeared to be forming a Pacific oyster bed. Though there is limited evidence in the literature of competitive displacement of mussels by oysters, it appears likely that the mussel populations previously found within the survey site of Starcross will see little to no recovery at all over the coming years. This is based on the near total absence of any established populations across the site, the current hydrological dynamics of the estuary and no relaying of mussel in the area. As a result, this site was not surveyed in 2024, and surveys are unlikely to continue in the future.

The area of bed surveyed at Bull Hill Bank in 2024 is larger than that surveyed in 2022. Changes in the navigational channel due to erosion in the east/ southeast of the bank (Ward and Johnson, 2024) coupled with tide conditions resulted in transects being walked further north compared to 2022 (Figure 3). Due to a lack of staff, only two officers were able to conduct the surveys in 2024 and therefore survey effort across the bed in 2024 has decreased compared to 2022. This is reflected in the amount and width of the transects walked over the bed (Figure 4). Wider transects being conducted over larger areas may miss smaller spatial scales of dense mussel patches within the bed and therefore result in fewer 'hits' being acquired to obtain a sample. This may partially explain the apparent changes in percentage cover and density of mussels between 2022 and 2024. Survey effort should therefore be considered when interpreting the results. Data from the Taw Torridge mussel surveys in 2024 are being analysed to determine any sampling bias that may occur as a result of the methodology in order to understand the implications for data analyses.

The decrease in density and percentage cover observed may also be the result of sediment changes within the Estuary. LiDAR data from surveys conducted in 2023, coupled with historic survey data, showed that between 2018-2022, Bull Hill Bank has experienced a mix of low-level erosion on the south-eastern half of the bank and accretion to the west (Ward and Johnson, 2024). Physical sediment disturbance is a common feature of coastal environments and arises from natural causes such as storms, floods and extreme tides (Hinchey *et al.*, 2006; Hutchison *et al.*, 2016). In addition, anthropogenic activity such as beach restoration, costal defence and dredging can result in substantial sediment suspension and deposition, causing a smothering event which can be detrimental to mussels. (Hendrick *et al.*, 2016; Hutchison *et al.*, 2016). For example, Hutchinson *et al* (2016) reported increased mortalities of *M. edulis* with increasing burial depth, duration and burial by finer sediment fractions. Mortality also increased with an increase in water temperature, from 20% at 8°C to over 60% at 14.5 and 20°C. Despite these mortalities *M. edulis* were capable of emerging from shallow burials (<2cm) and coarse sediment due to increased byssus production. However, the availability of hard vertical surfaces were important for emergence from burial. Mussel beds with a high density of individuals provide more of a hard vertical surface to aid survival. The lack of a dense homogenous mussel bed on Bull Hill could result in higher mortalities if a smothering event occurs.

In 2022 a small mussel population had established on Bull Hill (Figure 3). It was hoped that this area would grow in spatial distribution and density, however between 2022 and 2024 there was a decline in density (Figure 6) and all stock sizes apart from 51-60mm size group (Figure 7). This suggests that there is no new recruitment or settlement of mussel spat on the Exe and the small population observed in 2022 has not established. The reduction in mussel coverage may have been a contributing factor to the erosion observed on Bull Hill (Ward and Johnson, 2024). Results from erosion studies indicate that a reduction in mussel coverage from 100 to 50% or less will enhance erosion at current velocities >0.25 m s^{-1}, resuspend biodeposits and make the mussel bed more vulnerable to erosion during spring tides and storm events (Widdows *et al.*, 2002). Once beds have been severally eroded they are difficult to re-establish and recovery from a bed of the current size to Bull Hill's previous population levels, even without disturbance, could take decades (Robins *et al.*, 2016, Widdows and Brinsley, 2002).

The hydrology and fast-flowing nature of the Exe Estuary make it difficult for mussel spat to settle. McGrorty et al. (1990) found that on the Exe there was a strong positive correlation between densities of spat settlement and adult densities on the mussel beds, with spat rarely occurring at other sites on the estuary than in the byssal threads of adults. Spat seem only able to protect themselves by settling deep within the byssal threads of already established adults. The transport of sediment within the estuary as reported in the sedimentation report by the Exe Estuary Management Partnership, has resulted in changes to the hydrography of the estuary. These factors may have influenced the extent and density of the mussel beds in these survey sites. Ongoing monitoring on a biennial basis should provide data relating to the rate and scale of any further decline or recovery.

5. Recommendations

It is recommended that the stock assessment continue to be carried out on at least a biennial basis, to monitor any future changes and to detect any signs of further decline or recovery, especially whilst D&S IFCA's closure of harvesting mussel from the public shellfish beds remains in place. All future surveys will focus on the public beds on Bull Hill. However, the feasibility of future monitoring will be largely determined by safety of access to Bull Hill Bank for the required survey periods.

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