Exe Estuary
Mussel Stock Assessment 2026

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June 2026

Contents

Version control history			
Officer	**Date**	**Comment**	**Version**
S. Curtin	20 May 2026	Draft report	0.1
J. Stewart	08 June 2026	QA	0.2
S. Curtin	15 June 2026	Amendments following QA	0.3
J. Stewart	29 June 2026	Finalised for publication	1.0
S. Clark	29 June 2026	Final Review	1.0
S. Curtin	3 August 2026	Amendments made regarding biomass figure and report re-published	1.1

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, Brand, and Maar 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.

M. 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 (*M. galloprovincialis* and *M. 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.

M. edulis and *M. galloprovincialis* often occur in the same location in the northern range of *M. 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, Brand, and Maar 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, Brand, and Maar 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 Devon and Severn Inshore Fisheries and Conservation Authority (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 *M. edulis* from *M. galloprovincialis* in 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).

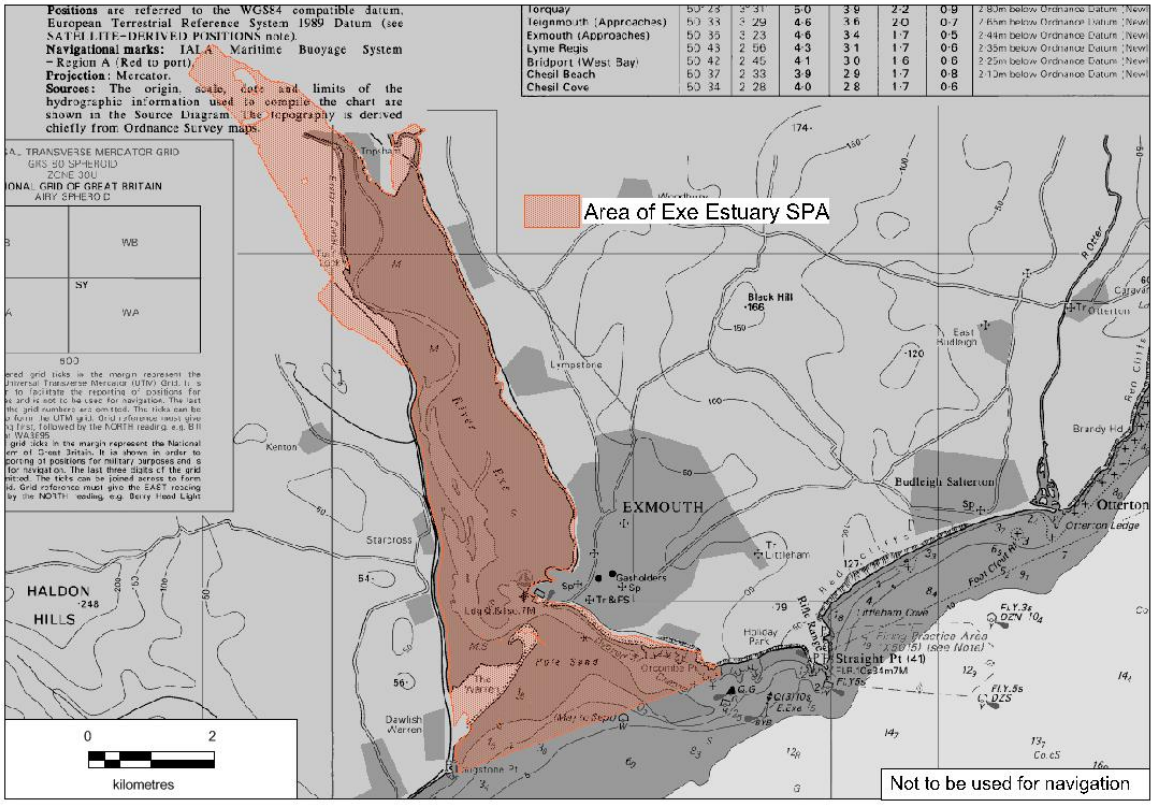

Figure 1 Area of the Exe Estuary SPA

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. Due to the absence of mussels at Lympstone since 2019, surveying of this bed has been discontinued.. 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.

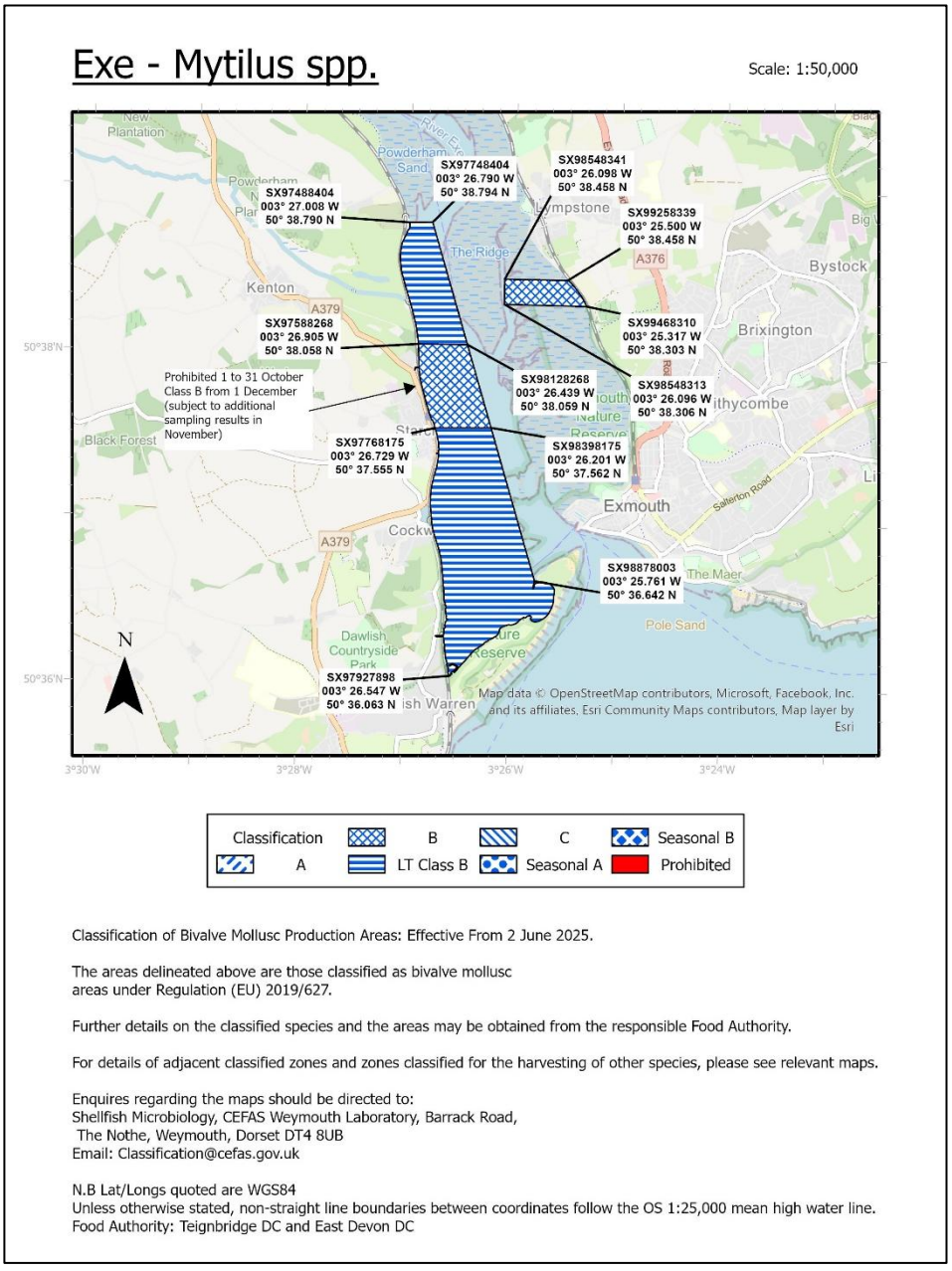

Figure 2 Classified mussel harvesting areas on the Exe Estuary (Cefas, 2025)

2.2 Survey methodology

This document reports on surveys conducted between 2013–2026 on Bull Hill only. See the 2019 report (Thomas 2019) for details of additional beds (Lympstone and Starcross) that have not been surveyed since 2019.. Surveys conducted on 19th April 2026 and 1st May 2026 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 Lympstone in 2026. 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 is subsequently mapped in QGIS v3.22 around the extent of the transects walked. (Figure 3 and 4). Prior to the survey, officers conducted a preliminary walkover of the Bull Hill site (Figure 3 & 4) to identify the extent of the mussel bed. The start of the mussel bed was defined by the presence of live mussels occurring in a continuous, homogenous patch. To assess coverage and patch density, transects were walked in a zig-zag pattern across the survey area, following the extent of the mussel bed. Transects continued while mussels remained present and were terminated when mussels were no longer observed, or when a physical boundary, such as the water's edge or a change in substrate type, was encountered. 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 two 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 third 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. The method used in 2026 differs from the surveys conducted pre-2026, which recorded a 'hit' or 'miss' every three paces and took a sample on every fifth hit. This change was implemented to increase the sampling frequency to obtain higher resolution data, with a view to increasing the accuracy of subsequent biomass estimates from the survey data.

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.

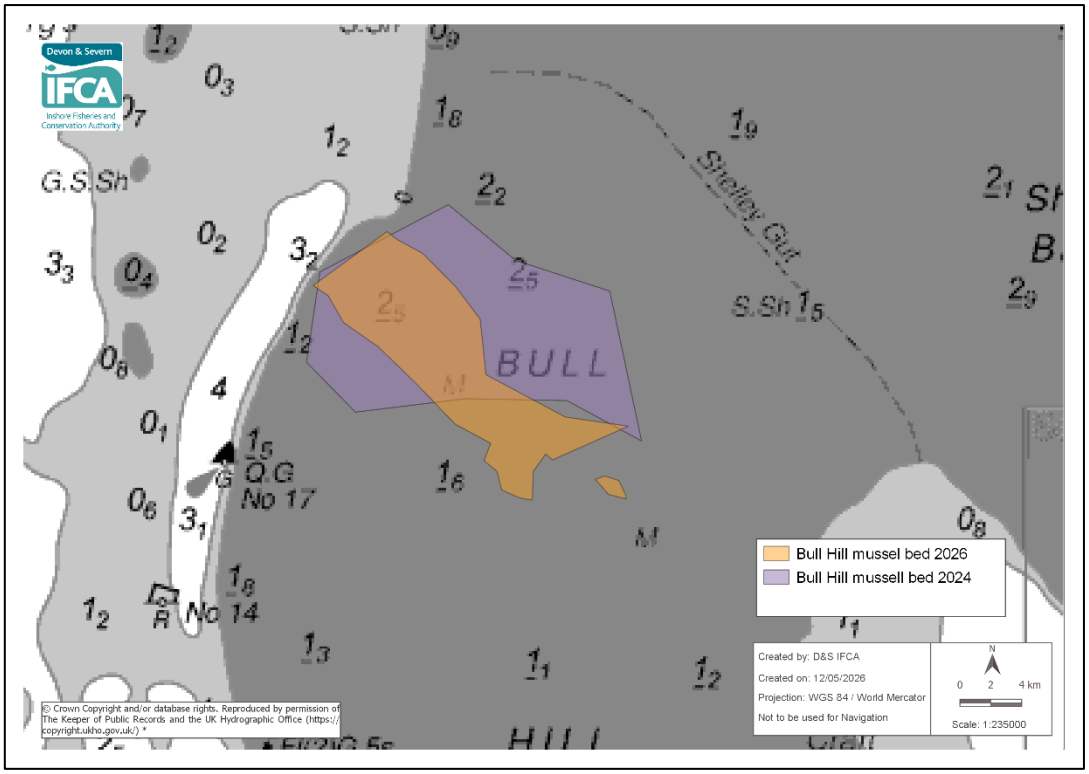

Figure 3 Area of mussel bed at Bull Hill surveyed in 2024 (purple) and 2026 (orange). Mapped by generating a minimum convex polygon around the transect lines. The survey area in 2026 does not fully overlap the areas surveyed in 2024. * www.ukho.gov.uk/copyright

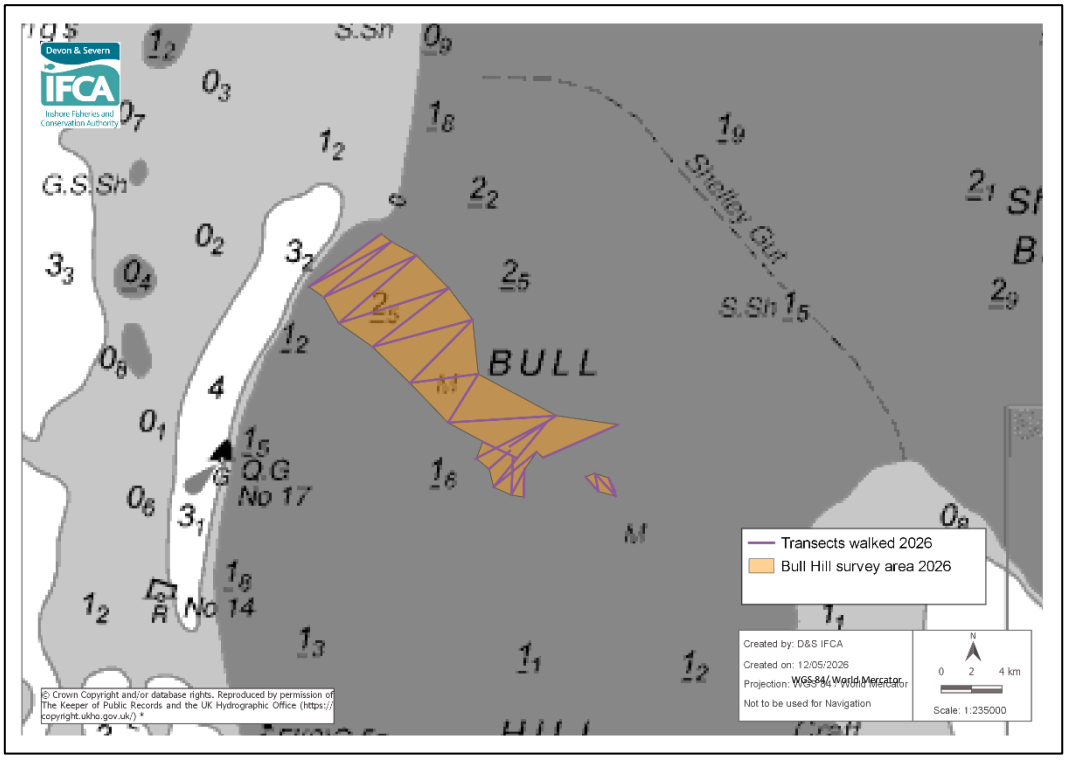

Figure 4 Area of mussel bed at Bull Hill surveyed in 2026(orange). Transect lines walked in 2026 are shown in purple. Bed area mapped by generating a minimum convex polygon around the transect lines.* www.ukho.gov.uk/copyright

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 55 samples were collected from 28 transects across Bull Hill. Sampling was conducted in two areas: the main Bull Hill bed, which accounted for 50 samples, and a smaller area located slightly southeast of the main bed, referred to hereafter as Bull Hill SE (5 samples; figure 4). Only sparse mussel has been detected on Bull Hill since 2014, with the exception of a small, dense spat settlement identified in 2019 covering approximately 0.25ha, which was considered too small to survey. In 2026, the total surveyed area covered 3.72ha (comprising 3.67 at the main Bull Hill bed and 0.05ha at Bull Hill SE), and contained an estimated 84 tonnes of mussel, compared to 227 tonnes in 2024 (Figure 5), a decrease of 63%. This area of mussel bed has decreased in density and percentage cover of mussel since 2024 (Figure 6). Of the total 84 tonnes stock estimated in 2026, 87% of this was >41mm in length, and 2.3% was spat (<30mm) (Figure 7). The percentage of larger (>41mm) mussel and total tonnage of mussel in this size class has decreased by 2% and 127 tonnes, respectively, since 2024 (Figure 7), reflecting the overall decline in total tonnage across all size classes.

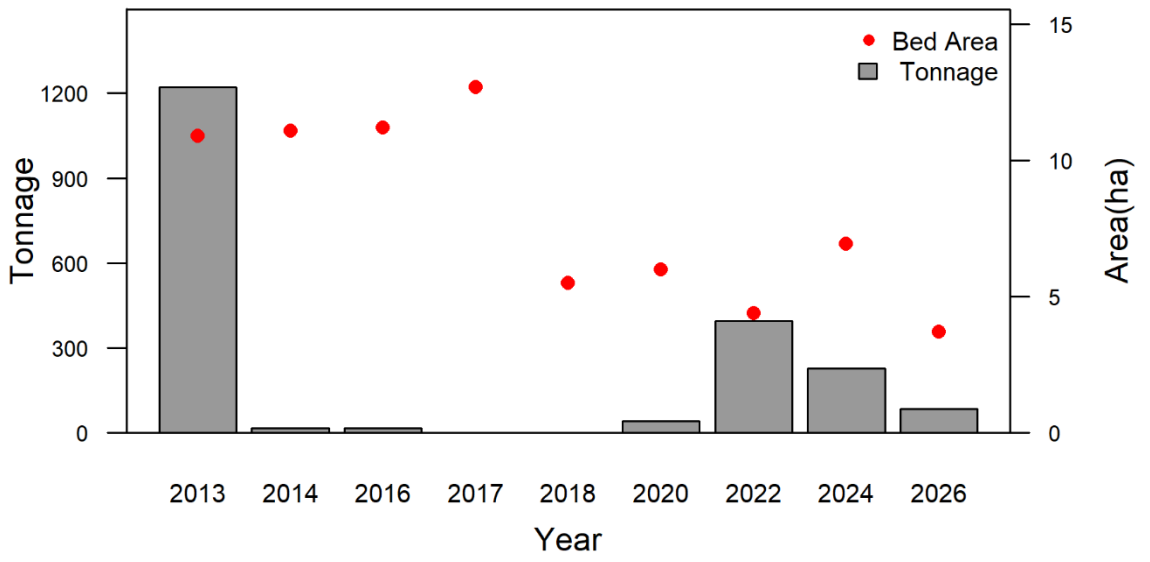

Figure 5 Total area surveyed plotted over tonnage of total stock within the Bull Hill mussel bed between 2013–2026

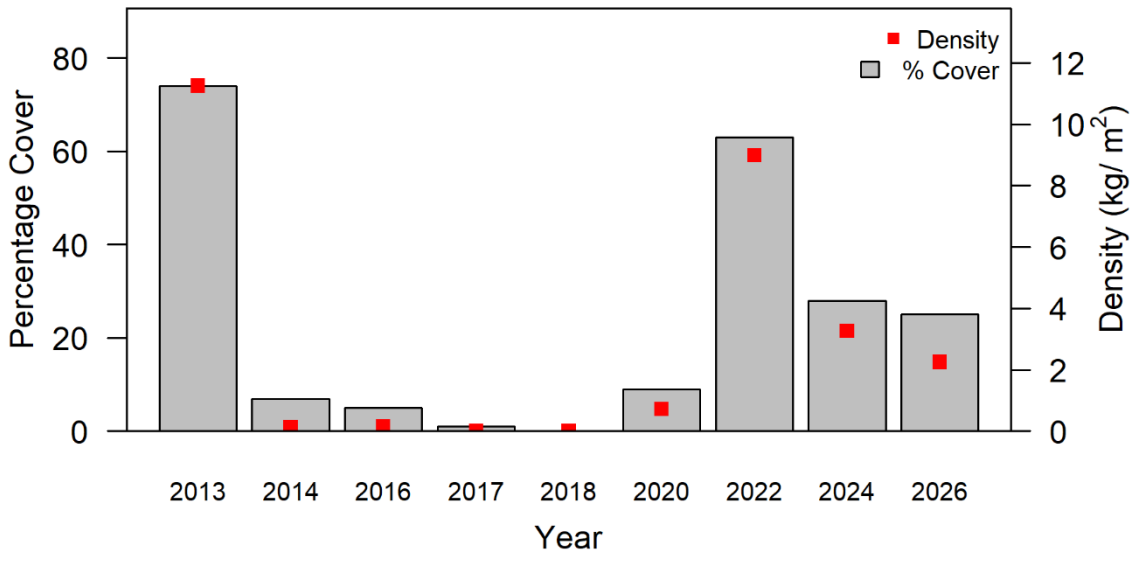

Figure 6 Percentage cover and density of mussels on the Bull Hill bed 2013–2026.

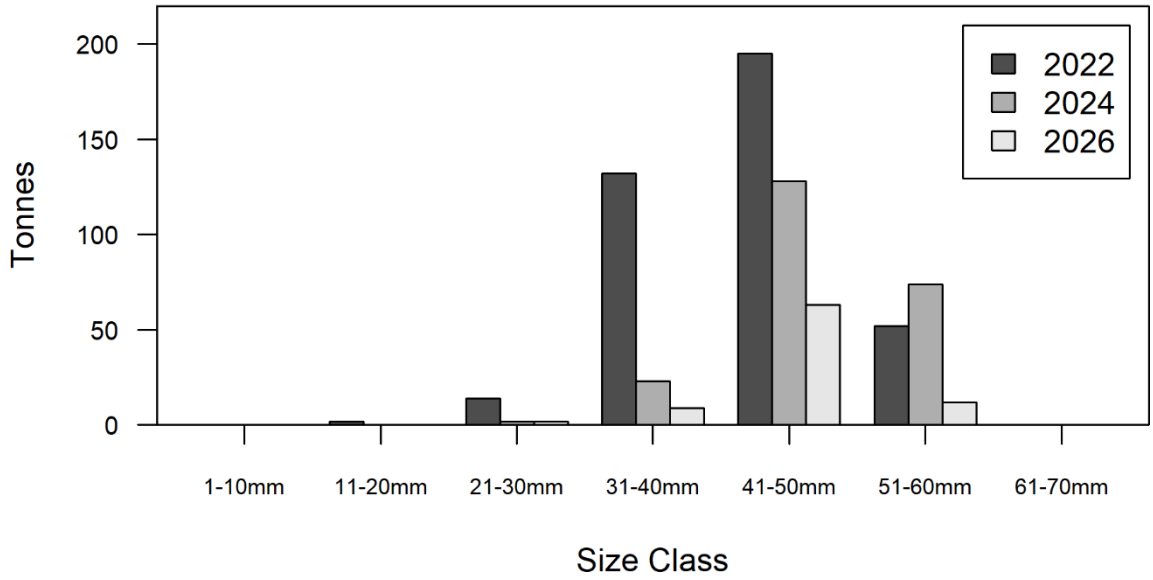

Figure 7 Tonnage of each 10mm size class for the Bull Hill stock from 2022- 2026

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 incidents which reduced mussel populations further. Since these events, mussel populations have been unable to recover to anywhere near the previous population size 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 sediment deposition within the estuary has resulted in the partial smothering of mussel beds. It has been suggested that the sedimentation may have been caused or exacerbated by human activities (primarily the Dawlish Warren Management Scheme). Recent analysis published by the Exe Estuary Management Partnership identified substantial spatial and temporal variations in both accretion and erosion across the Exe Estuary since 2005 (Ward and Johnson, 2024), emphasising the complex and dynamic nature of sediment transport processes within the system. The report concluded that observed geomorphological changes are likely driven by an interaction between natural coastal processes and long-term human interventions, highlighting the need for a comprehensive understanding of their combined influence on estuarine sediment dynamics and associated ecological impacts.

The decrease in density observed between 2022 and 2026 may 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, Hutchison, and Last 2016, Hutchison *et al.* 2016).

One of the sources of mussel recruitment in the estuary has been 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. Although 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 2026, and surveys are unlikely to continue in the future.

The area of mussel bed surveyed at Bull Hill Bank in 2026 was smaller than that surveyed in 2024 (Figures 3 and 4). Changes in bed morphology and mussel distribution resulted in a reduction in the area of visible mussels, leading to shorter and narrower transects being surveyed and an additional smaller area being surveyed towards the southeast of the bank relative to the 2024 survey extent. These observations suggest a contraction in the spatial extent of the mussel bed between survey years. Despite the reduced bed extent, survey effort increased in 2026 relative to 2024, with more transects being walked over a denser area of the bed (Figure 4). Modifications to the survey methodology, including sampling on every third live mussel encounter rather than every fifth encounter, resulted in a greater number of recorded hits and a corresponding increase in sample collection. Increased sampling intensity would be expected to improve the precision of density estimates. Consequently, survey effort should be taken into account when interpreting changes between years. However, given the scale of observed change, it appears unlikely that the increased sampling intensity alone would fully explain the reductions observed in stock metrics.

A revised survey methodology, involving evenly spaced pre-defined transects orientated parallel to the shoreline, has recently been trialled during the Taw–Torridge mussel survey. This approach has demonstrated improved consistency in spatial coverage and reduced the likelihood of mussel patches being overlooked. Consequently, this methodology will be adopted for future mussel surveys within the Exe Estuary.

Tonnage estimates are derived from mean mussel density and total bed area, and the decline in biomass estimated between 2024 and 2026 (Figure 5) was driven by reductions in both parameters. Mean density decreased from approximately 3.5 kg m^{-2} to 2.5 kg m^{-2}, while mussel bed area contracted from approximately 6.5 ha to 3 ha (Figure 5 & 6). The reduction in occupied bed area was the dominant contributor to the decline in stock biomass, which fell by approximately 65% over the survey period. This reduction is considered more

likely to reflect a genuine decline in stock extent and abundance than a sampling artefact. Furthermore, the results suggest that the partial “recovery” observed in 2022 (Figure 6) was not sustained, with the mussel stock becoming increasingly restricted in distribution and concentrated within fewer occupied areas. In parallel with the contraction in bed area, estimated stock biomass declined from approximately 227 tonnes in 2024 to less than 100 tonnes in 2026 (Figure 5). Density and percentage cover also remained substantially lower than those recorded during the apparent “recovery” observed in 2022, indicating a continued deterioration in stock condition.

Declines were also observed across all mussel size classes between 2024 and 2026 (Figure 7). Reductions in the larger size classes are particularly significant, as these individuals contribute disproportionately to total biomass and tonnage (Seed and Suchanek, 1992). Their decline is therefore likely to have contributed substantially to the observed reduction in stock biomass. The widespread decline across all size classes, combined with the limited presence of smaller mussels, suggests that recent recruitment has been insufficient to offset losses from mortality and other sources of stock decline.

D&S IFCA had been informed of a mussel spat settlement event on Bull Hill Bank several weeks prior to the surveys; however, little to no spat was recorded during the survey period, indicating that the settlement event did not successfully recruit into the surveyed population. The remaining mussel bed on Bull Hill Bank was composed predominantly of adult mussels within the 31–50 mm size classes. Although limited in extent, these remaining adult mussels may provide a foundation for future recovery by increasing local density and providing suitable substrate and favourable microhabitat conditions for spat settlement and survival. Existing mussel beds can enhance larval settlement through the provision of stable attachment surfaces, increased habitat complexity, and localised reductions in hydrodynamic stress (Commito et al., 2014).

The hydrology and fast-flowing nature of the Exe Estuary are known to present challenges for successful mussel settlement. McGrorty et al. (1990) reported a strong positive relationship between spat settlement and adult mussel density within the Exe, with spat occurring primarily within the byssal threads of established adult mussels rather than on surrounding substrates. Successful recruitment may therefore depend on the persistence of sufficiently dense adult mussel beds capable of retaining and protecting newly settled spat. In addition, changes in sediment transport processes within the estuary, as identified in the Exe Estuary Management Partnership sedimentation report, may have altered local hydrographic conditions and influenced both the distribution and persistence of mussel beds within the survey area.

Overall, the period between 2024 and 2026 indicates a decline in stock condition following the partial “recovery” recorded in 2022. Although mussels remain present within parts of the estuary, reductions in bed area, density, biomass, percentage cover, and stock size structure suggest that both the extent and condition of the population have deteriorated. The contraction of the mussel bed appears to be a key driver of the decline in biomass**.** Continued biennial monitoring will be important for determining whether the remaining population is capable of recovery or whether further declines occur in response to ongoing environmental pressures. However, it should be noted that the increased sampling frequency may be expected to improve accuracy, therefore care should be taken when comparing 2026 results to potentially less-accurate evidence from previous surveys.

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 employ the new methodology of walking pre-determined transects in order to obtain more accurate data and 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.

References

Andrews JW, Brand AR, Maar M. Assessments Isefjord and East Jutland Danish blue shell mussel - MSC Fisheries. 2011. https://fisheries.msc.org/en/fisheries/isefjord-and-east-jutland-danish-blue-shell-mussel/@@assessments (22 Mar. 2021, date last accessed).

Bayne B, Worrall C. Growth and Production of Mussels Mytilus edulis from Two Populations. *Mar Ecol Prog Ser* 1980;**3**:317–28. https://doi.org/10.3354/meps003317.

Cefas. Classification zone maps - Cefas (Centre for Environment, Fisheries and Aquaculture Science). 2021. https://www.cefas.co.uk/data-and-publications/shellfish-classification-and-microbiological-monitoring/england-and-wales/classification-zone-maps/ (May 2026, date last accessed).

Commito JA, Commito AE, Platt RV *et al.* Recruitment facilitation and spatial pattern formation in soft-bottom mussel beds. *Ecosphere* 2014;**5**(12):art160. https://doi.org/10.1890/ES14-00200.1.

EEMP. Exe Estuary Management Partnership - Wildlife designations. *Exe Estuary Management Partnership* 2020. https://www.exe-estuary.org/visitor-information/wildlife/wildlife-designations/ (10 Mar. 2021, date last accessed).

Gardner JPA. The Mytilus edulis species complex in southwest England: effects of hybridization and introgression upon interlocus associations and morphometric variation. *Marine Biology* 1996;**125**(2):385–99. https://doi.org/10.1007/BF00346319.

Goss-Custard JD, Verboven N. Disturbance and feeding shorebirds on the Exe estuary. *Wader Study Group Bulletin* 1993;**68**:8.

Handå A, Alver M, Edvardsen CV *et al.* Growth of farmed blue mussels (Mytilus edulis L.) in a Norwegian coastal area; comparison of food proxies by DEB modeling. *Journal of Sea Research* The AquaDEB project (phase II): what we've learned from applying the Dynamic Energy Budget theory on aquatic organisms, 2011;**66**(4):297–307. https://doi.org/10.1016/j.seares.2011.05.005.

Hendrick VJ, Hutchison ZL, Last KS. Sediment Burial Intolerance of Marine Macroinvertebrates. *PLOS ONE* 2016;**11**(2):e0149114. https://doi.org/10.1371/journal.pone.0149114.

Hinchey EK, Schaffner LC, Hoar CC *et al.* Responses of Estuarine Benthic Invertebrates to Sediment Burial: The Importance of Mobility and Adaptation. *Hydrobiologia* 2006;**556**(1):85–98. https://doi.org/10.1007/s10750-005-1029-0.

Hutchison ZL, Hendrick VJ, Burrows MT *et al.* Buried Alive: The Behavioural Response of the Mussels, Modiolus modiolus and Mytilus edulis to Sudden Burial by Sediment. *PLOS ONE* 2016;**11**(3):e0151471. https://doi.org/10.1371/journal.pone.0151471.

JNCC. *UK Biodiversity Action Plan Priority Habitat Descriptions. Blue Mussel Beds on Sediment*. JNCC: JNCC, 2016. https://data.jncc.gov.uk/data/c9721550-e422-4181-805d-2a0b58afa9d7/UKBAP-BAPHabitats-04-BlueMusselBeds.pdf (22 Mar. 2021, date last accessed).

McGrorty S, Clarke R, Reading C *et al.* Population dynamics of the mussel Mytilus edulis: density changes and regulation of the population in the Exe estuary, Devon. *Mar Ecol Prog Ser* 1990;**67**:157–69. https://doi.org/10.3354/meps067157.

Natural England. European Site Conservation Objectives for Exe Estuary SPA - UK9010081. Natural England - Access to Evidence. 2020. http://publications.naturalengland.org.uk/publication/6369979498758144 (10 Mar. 2021, date last accessed).

Seed R, Suchanek T. *Population and Communtiy Ecology of Mytilus*. 1992, 87–169.

Thomas O. *Exe Estuary Mussel Stock Assessment 2019*. 2019. D&S IFCA.

Väinölä R, Strelkov P. Mytilus trossulus in Northern Europe. *Mar Biol* 2011;**158**(4):817–33. https://doi.org/10.1007/s00227-010-1609-z.

Ward E, Johnson R. *Assessing Sedimentation and Siltation Dynamics in the Exe Estuary*. Exe Estuary Management Partnership: Exe Estuary Management Partnership, 2024.