Taw-Torridge
Mussel Stock Assessment 2024

Lauren Parkhouse
Environment Officer

Devon and Severn Inshore Fisheries and Conservation Authority
March 2025
V 1.0

Contents

1. Introduction 3
1.1 *Mytilus spp.* 3
1.2 Objectives 3
2. Methodology 4
2.1 The Taw-Torridge Estuary 4
2.2 Survey Methodology 6
2.3 Data Analysis 7
2.4 Shellfish Ecological Requirement Model 8
2.5 UAV Survey 8
3. Results 9
3.1 Coolstone 9
3.2 Yelland 10
3.3 Instow 10
3.4. Comparison of Two May Surveys – Coolstone 11
4. Discussion 13
4.1 Analysis of Individual Beds 13
4.2. Comparison of Coolstone Surveys 14
4.3 All Beds 14
4.4 UAV Survey 14
4.5 Ecological Requirements and The Local Fishery 15
4.6 Conclusions 15
4.7 Recommendations 16
References 17
Appendix 1 18

Version control history			
Author	**Date**	**Comment**	**Version**
LP	05/03/2025	Draft report	0.1
	28/03/2025	Finalised following comments from J. Stewart	1.0

1. Introduction

1.1 *Mytilus spp.*

Mytilus spp., mussels such as *M. edulis* and *M. galloprovincialis,* are cold-water mussels which can occur in brackish water (Gardner, 1996). They are found on the north Atlantic and north Pacific coast of North America, Europe and in other temperate and polar waters. *Mytilus spp.* can occur intertidally and subtidally, and on a variety of substrates, from rocks to sediments, and in a range of conditions. “Blue mussel beds on sediment” are listed as a UK Biodiversity Action Plan (BAP) Priority Habitat (JNCC, 2011). This includes a range of sediments, such as sand, cobbles, pebbles, muddy sand and mud. The ability of *Mytilus spp.* to occupy such a range of habitats results from its ability to withstand wide variation in salinity, desiccation, temperature and oxygen concentration (Bayne and Worrall, 1980; Seed and Suchanek, 1992; Andrews *et al.*, 2011).

Mytilus spp. 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, 2011). Mussel beds 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.

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).

Current threats to *Mytilus spp.* beds include commercial fishing, water quality, coastal developments, anchoring, bait digging, and intensive recreational hand gathering (JNCC, 2011).

1.2 Objectives

The objective of this project is to carry out annual surveys of the public mussel beds on the Taw-Torridge Estuary, to undertake a stock assessment on each of the beds to estimate the density of mussels on the beds and the total stock of mussels, including marketable mussels and those required by overwintering birds of the Taw-Torridge Site of Special Scientific Interest. Results of these surveys can be compared inter-annually. This will help inform future management of the mussel beds on the Taw-Torridge Estuary and the development of shellfisheries in this part of the Devon & Severn IFCA’s District.

2. Methodology

2.1 The Taw-Torridge Estuary

The Taw-Torridge estuary is located on the North Devon coast, within the Area of Outstanding Natural Beauty (AONB) and the North Devon UNESCO Biosphere Reserve (Figure 1).

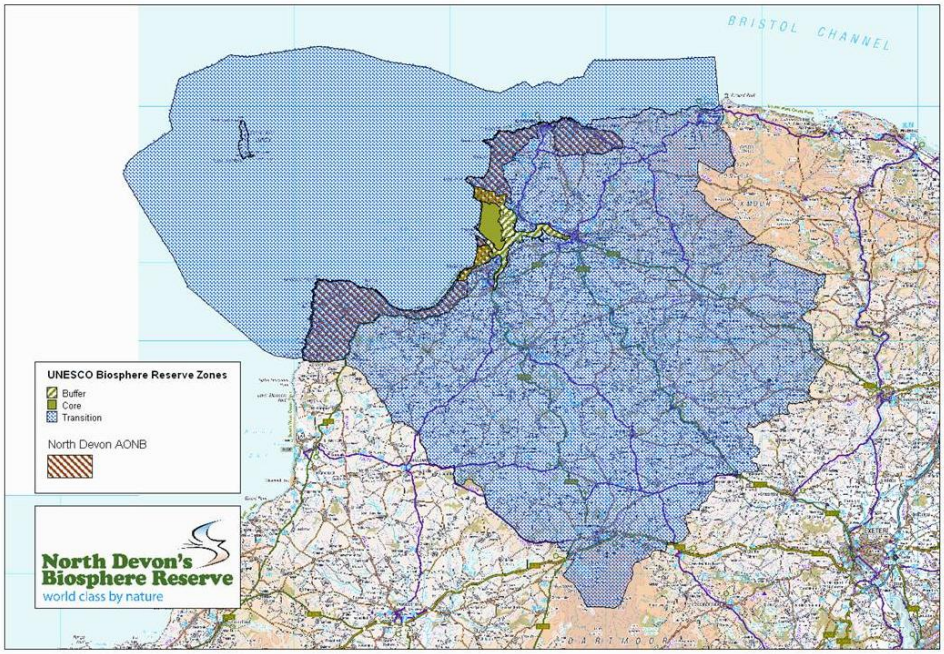

Figure 1 The location of the Taw Torridge Estuary (shown in yellow) within the North Devon Biosphere Reserve and the North Devon Coast AONB. (North Devon AONB and Biosphere Reserve Service, 2010)

The Taw Torridge Estuary is an important site for wildlife and has been designated a Site of Special Scientific Interest (SSSI) (Figure 1) for over-wintering and migratory populations of wading birds, and for the rare plants found on its shores. Upper reaches of the estuary were considered for designation as a Marine Conservation Zone (MCZ) by the Finding Sanctuary Regional Stakeholder Group (RSG) (Figure 3) for six Broad Scale Habitats; subtidal mud, subtidal sand, coastal saltmarshes and saline reed beds, intertidal coarse sediment, intertidal sand and muddy sand, low energy intertidal rock, and one Feature of Conservation Interest (FOCI) species the European eel (*Anguilla anguilla*). However, to date the site has not been designated. Parts of Taw-Torridge Estuary also lie within the Braunton Burrows Special Area of Conservation, also shown in Figure 3.

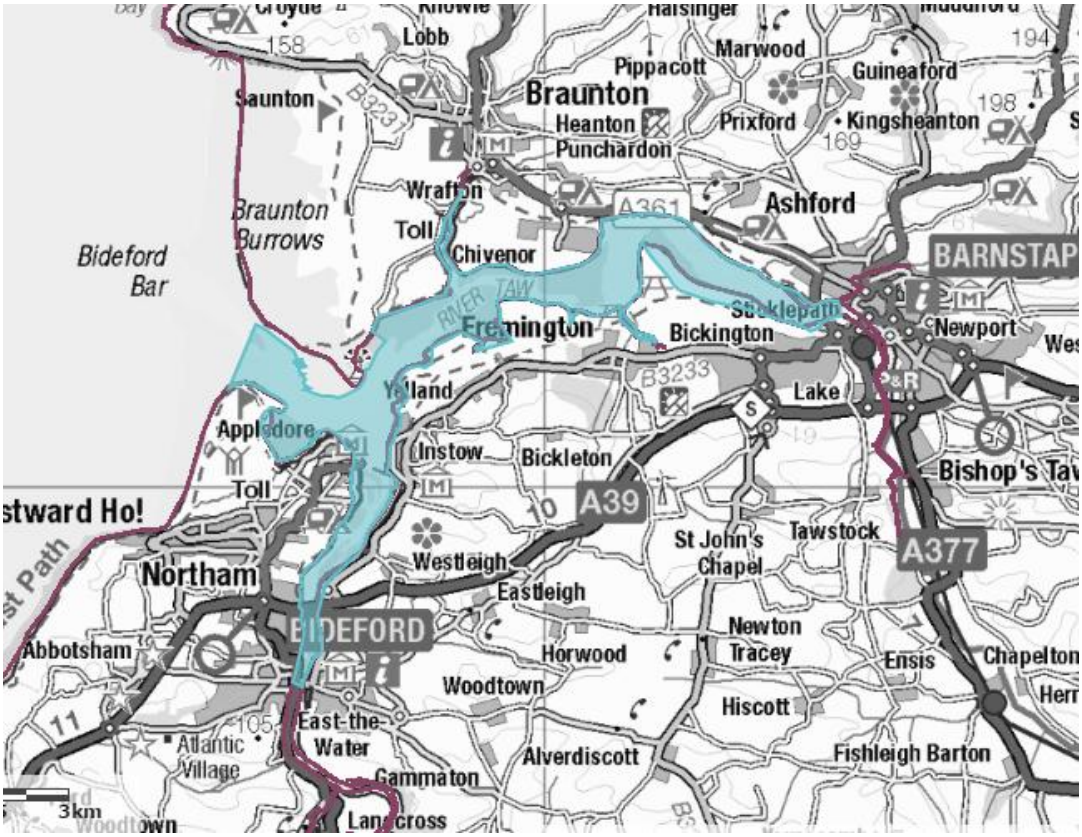

Figure 2 Taw-Torridge Estuary SSSI, shown in blue (Defra, 2020)

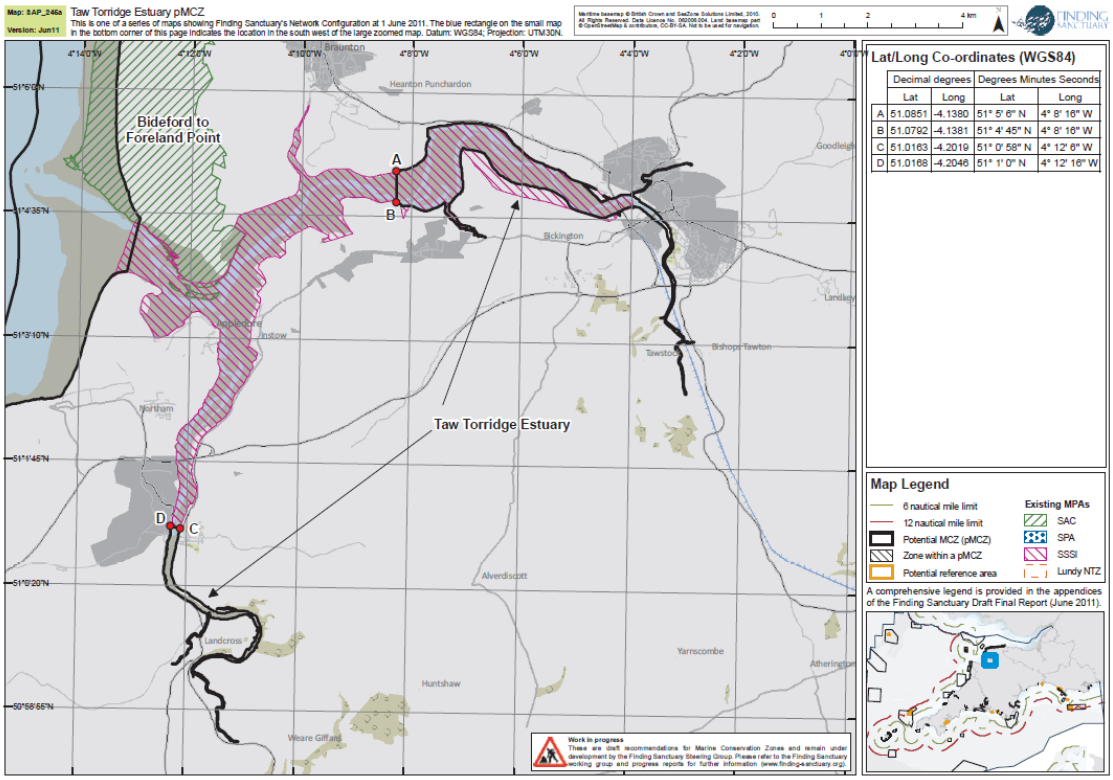

Figure 3 Area of rMCZ, outlined in black. Area of SSSI shown in red hatching, and area of SAC shown by green hatching. (Lieberknecht et al., 2011)

2.2 Survey Methodology

Surveys were conducted annually between 2012–2024 on intertidal beds of the Taw Torridge Estuary. Coolstone, Yelland, Instow and Lifeboat Slip are accessible on foot from land, whereas Pulleys, Sprat Ridge and The Neck are mid-channel and require access by boat.

During the 2024 survey, only Coolstone, Yelland and Instow beds were surveyed. This was due to access issues to the mid-channel beds and very low mussel densities observed at Lifeboat Slip in 2023. Coolstone was surveyed three times in 2024: twice in May and once in August.

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 rather 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 the survey areas within the Taw Torridge Estuary were recorded on the first visit to each bed by walking the extent of the live mussel habitat and marking coordinates with a handheld GPS. Each bed was first visited in 2012, except for the Neck which was first visited in 2020 following consultation with a local fisher, and Instow which was first surveyed in 2023 after officers became aware of the bed during a cockle survey. The perimeters were subsequently mapped in QGIS v3.1. For subsequent visits the perimeter is determined by using the start and end coordinates of each of the transects (Figure 4).

To determine coverage and patch density, transects were walked in a zig-zag pattern across the survey area (Figure 4), up to the extent of the mussel bed (e.g. to the low water mark 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 consisting of 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'.

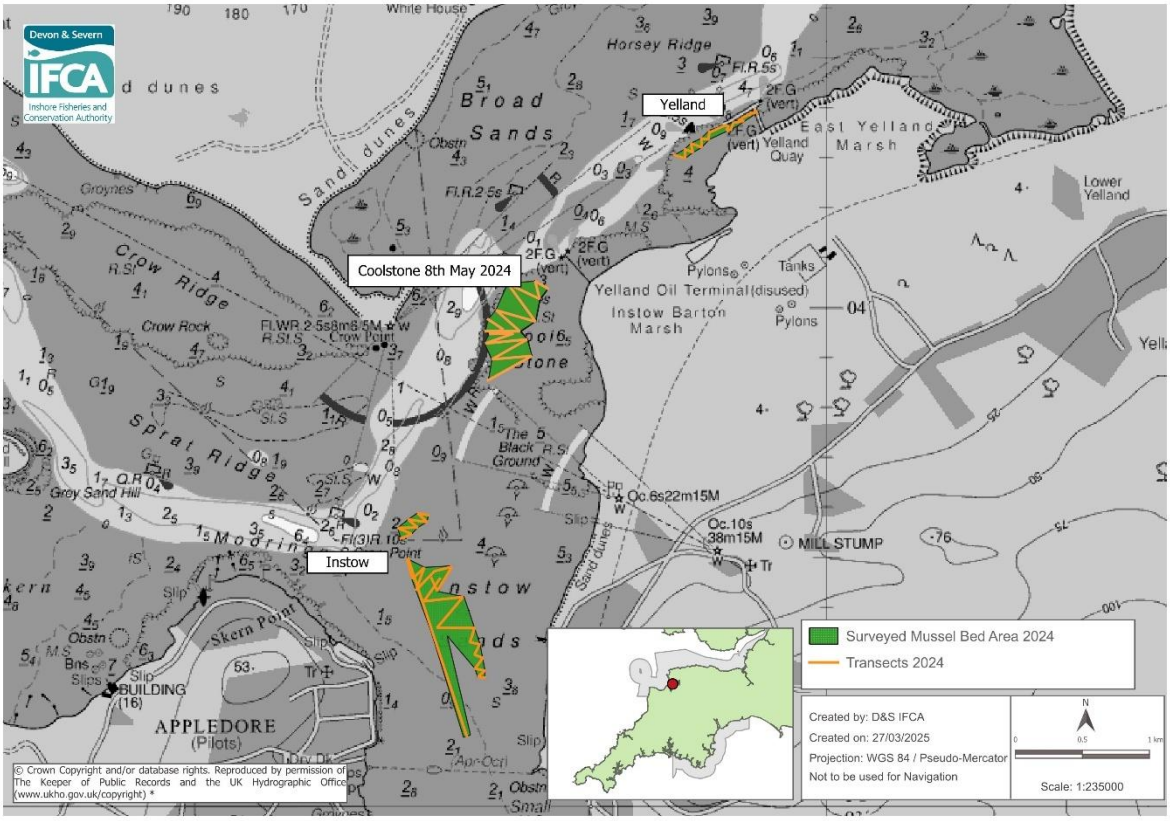

Figure 4 Area of each mussel bed (green) and paths of transects walked in May 2024 (orange).

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

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 on each site (Equation 3).

Total tonnage and survey area across all sites were calculated based on the weight of mussel in the samples taken and scaled up by the density and the area surveyed across all sites combined was calculated. As the Coolstone bed was surveyed twice in May and once in August, the average of the two May surveys were used in the analysis. A comparison between the summary statistics from these occasions was also made for Coolstone. The August survey data will be used in later assessments of inter-survey reliability.
As there is a minimum conservation reference size for mussels on the in the Taw-Torridge fishery of 2 inches (~51 mm), the tonnage of mussels available to be removed from the fishery (≥51mm) was also calculated for each bed. A weighted average bed density and percentage cover across all mussel beds was calculated by weighting the values based on the relative total area of the respective beds. Size distribution data were obtained from the length measurements of mussels in the retained samples.

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

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

Equation 3: Calculation of mussel tonnage

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

2.4 Shellfish Ecological Requirement Model

Natural England (NE) has provided a mathematical model that allows an estimate to be made of the ecological requirements of wading birds (specifically oystercatchers, *Haematopus ostralegus*) feeding on mussel in the areas surveyed by D&S IFCA. Using this model, it has previously been possible to calculate the tonnage of prey-sized mussel required to sustain the bird population, to compare this to the overall tonnage of prey-sized mussel on the surveyed beds and thereby estimate the total mussel available to the fishery.

A new model has been developed Richard Stillman of Bournemouth University, in collaboration with D&S IFCA under the Marine Natural Capital and Ecosystem Assessment programme, and is reported on using up to date Taw-Torridge data from 2019 – 2024 in Stillman et al. (2025).

2.5 UAV Survey

Due to the access issues to the mid-estuary beds, the use of an Uncrewed Aerial Vehicle (UAV), also known as a drone, was trialled for the second time in 2024. This was undertaken with the use of Southern IFCA's (SIFCA) UAV and trained officers. This followed an initial trial undertaken in 2023, as reported in Appendix 1 to this report.

On the 6th August 2024 three SIFCA officers and two DSIFCA officers undertook a survey of the Coolstone mussel bed with a UAV. The UAV used was a DJI Matrice 300 RTK with a Zenmuse H20T camera system.

The survey was carried out within two hours either side of low water on a spring tide. SIFCA Safe Operating Procedures for UAV survey was followed at all times. With an area provided by DSIFCA, the SIFCA UAV operator programmed a predetermined flight path into the UAV. The UAV then flew this predetermined flight path at altitudes of 20m and 12.5m, recording a GPS track, and taking photos every few seconds (approximately one photo every 8 metres, with sufficient overlap to enable later stitching of geotagged photographs if required). The flight was monitored by two operators who could manually override both the UAV and the onboard camera to compensate for obstacles and wind drift.

DSIFCA officers were sent the raw imagery to undertake analysis to try and identify mussel and potentially determine the extent of the mussel bed.

3. Results

3.1 Coolstone

Coolstone was surveyed on 8th and 10th of May and 20th August 2024. For this analysis the averages of the two May surveys were used. An average of 22 samples were collected from 20 transects. Since 2022 the total stock tonnage has decreased by 37%. Bed area has shown an overall decrease since 2022, while density of live mussel decreased in 2023 but increased again in 2024 (Figure 5a, b), but all values still remain a fraction of values observed in the earlier survey years (e.g. 2012–2014). It is important to note that data are averaged for 2012-14 when the Coolstone beds were separate prior to merging into one continuous bed in 2015. Percentage cover of mussels on the Coolstone bed decreased by 46% in 2023 from the 2022 levels however increased again in 2024 back to the same level as in 2022 (Figure 5b). The stock of mussels available to be removed from the fishery (≥51mm) in 2024 was estimated to be 11.61 tonnes out a total 65.65 tonnes on the bed, i.e. 17.7% (Figure **5**5c).

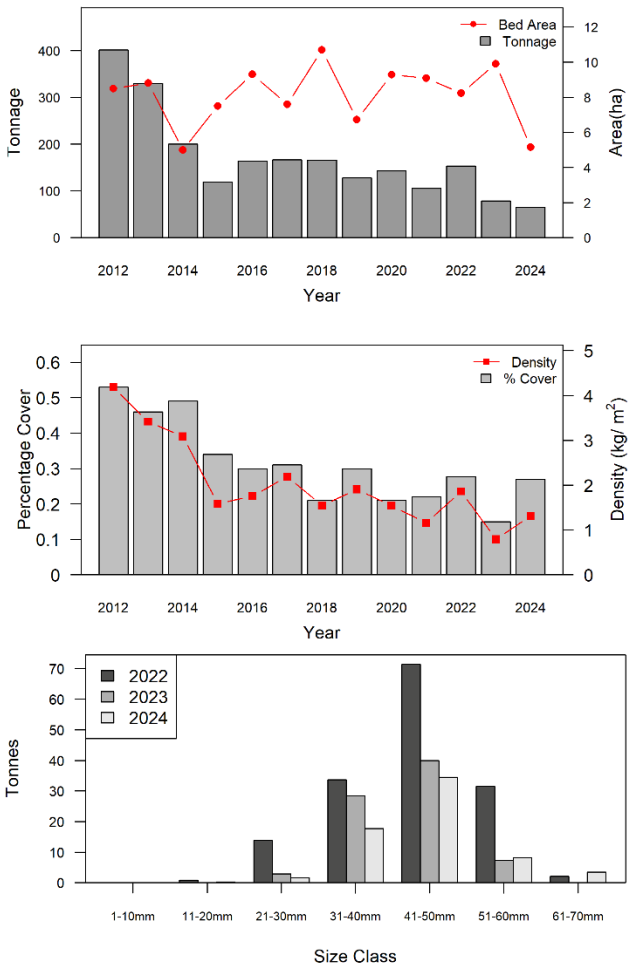

Figure 5 (a) Total area surveyed and tonnage of total stock and (b) average percentage cover and density of mussel between 2012–2024 on the Coolstone mussel bed. (c) Total stock of 10mm size classes for 2022-2024 on the Coolstone bed.

3.2 Yelland

Yelland was surveyed on 10th May 2024; 3 samples were collected from 25 transects. Since 2022 the total stock tonnage has decreased by 28% however there was an increase of 104% from 2023 to 2024 (Figure 6a). Density within the survey area decreased by 48% from 2022 to 2024, this was comprised of an initial decrease of 77% from 2022-2023 and then an 126% increase from 2023-2024. Such large interannual variations suggest a potential sampling effect/ Percentage cover of mussel decreased by 40% from 2022-2023 and was stable from 2023-2024 (Figure 6b). The stock of mussels available to be removed from the fishery (≥51mm) in 2024 was estimated to be 13.67 tonnes out of a total 35.53 tonnes on the bed, i.e. 38.5% of the total stock (Figure 6c).

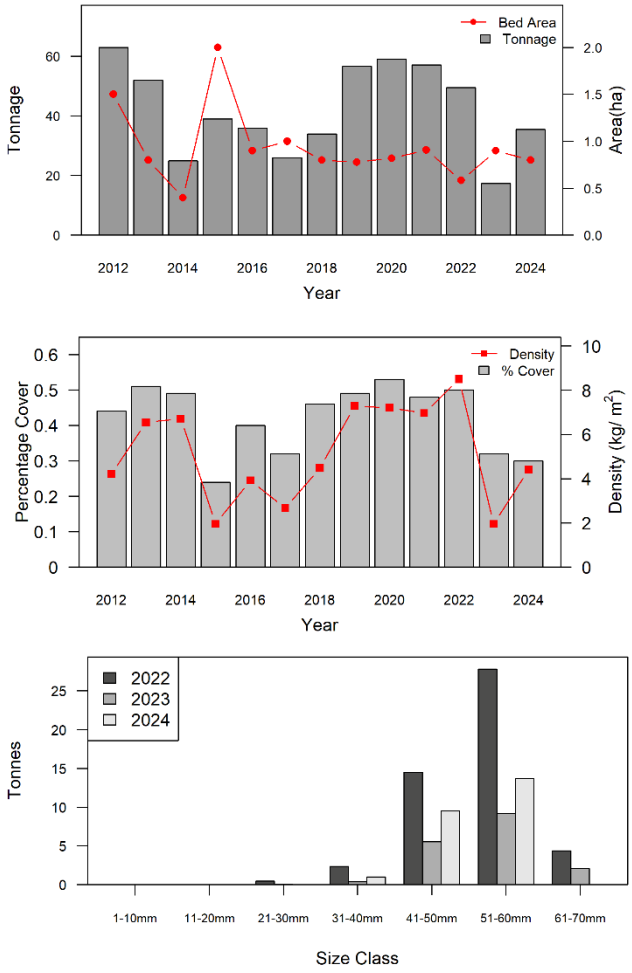

Figure 6 (a) Total area surveyed and tonnage of total stock and (b) average percentage cover and density of mussel between 2012–2024 on the Yelland mussel bed. (c) Total stock of 10mm size classes for 2022-2024 on the Yelland bed.

3.3 Instow

Instow was surveyed on 9th May 2024; 35 samples were collected from 27 transects. This was the second time the Instow bed has been surveyed with the first being in 2023. Between 2023 and 2024 the total stock tonnage has increased by 67.5% and the bed area has increased by 75% (Figure 7a). Density within the survey area decreased by 4%. Percentage cover of

mussel decreased by 8% (Figure 7b). The stock of mussels available to be removed from the fishery (≥51mm) was estimated to be zero in both 2023 and 2024 out of a total of 120 tonnes and 201 tonnes. respectively (Figure 7c). There were 0 tonnes in the 41-50mm size class in 2023 and this increased to an estimated 76 tonnes in 2024.

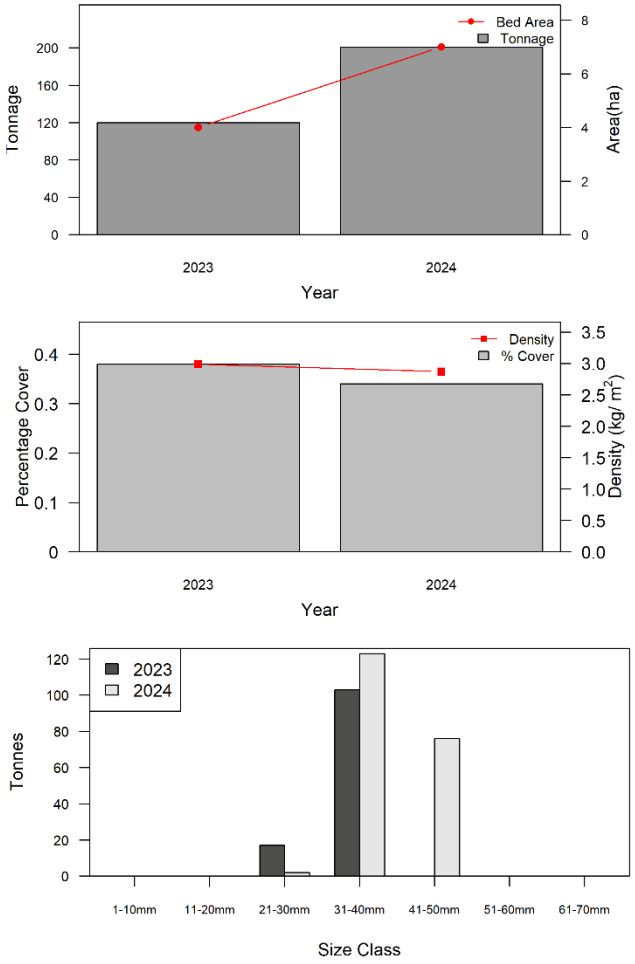

Figure 7 (a) Total area surveyed and tonnage of total stock and (b) average percentage cover and density of mussel between 2023–2024 on the Instow mussel bed. (c) Total stock of 10mm size classes for 2023-2024 on the Instow bed.

3.4. Comparison of Two May Surveys – Coolstone

On the Coolstone bed, a total of 15 transects were surveyed on 8th May generating an area estimate of 4.8 ha, compared to 26 transects on 10th May, which generated an area estimate of 5.5 ha (Figure 8). Although there was an increase in area on the 10th compared to the 8th, the observed total mussel density and total stock estimates within the site on 10th May were both lower than on 8th May (by 53% and 45%, respectively). The observed percentage cover also declined by 6 percentage points (from 30% to 24% cover).

As the bed shape (Figure 8) was different between the two surveys a further analysis was carried out on the just the southern area of both beds where the transects most overlapped. There were still large differences in density and tonnage when comparing the results from

this southern area. There was a 48% decrease in density from 8th-10th of May and a 57% decrease in the tonnage. While there was a six percentage point decrease in percentage cover when looking at the full area surveyed, there was a smaller decrease of three percentage points when comparing the southern end of the bed (from 35% to 32%).

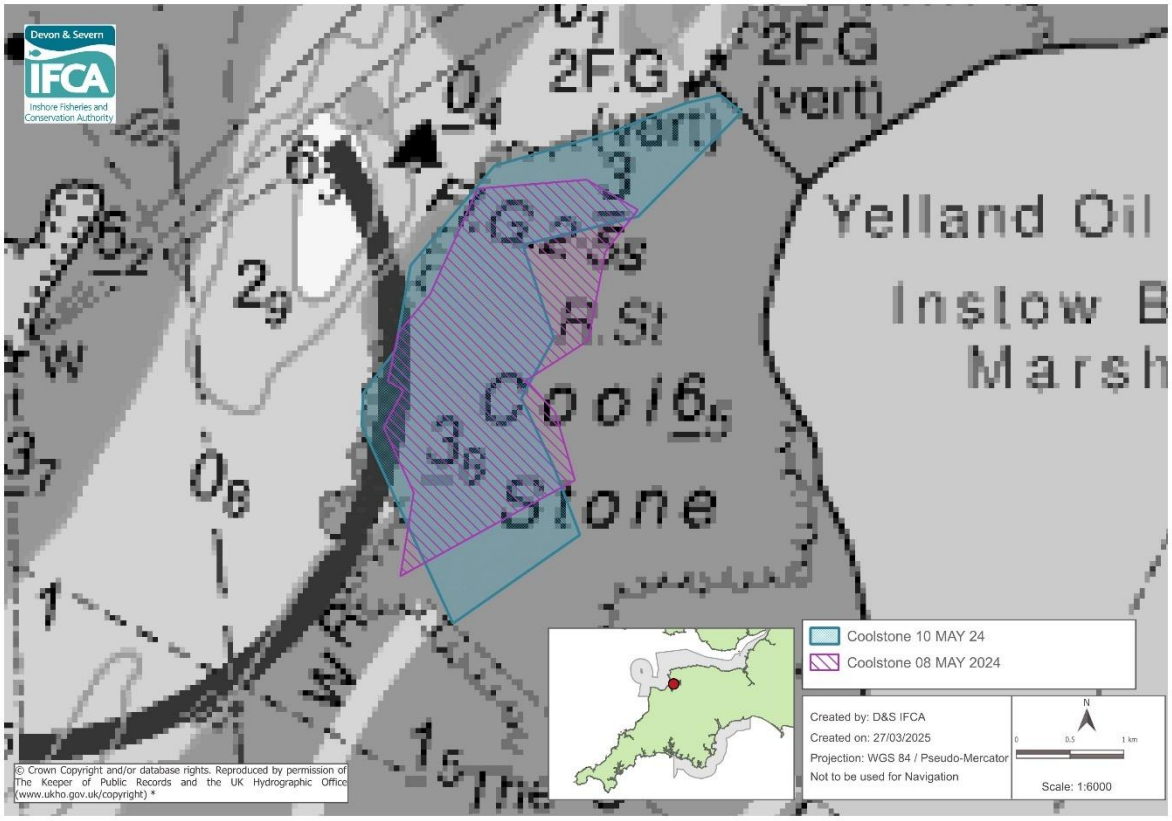

Figure 8 Survey area of mussel beds at Coolstone on 8th May (pink) and 10th May (blue) 2024

4. Discussion

4.1 Analysis of Individual Beds

4.1.1. Coolstone

Between 2016–2018, the tonnage of mussels on the Coolstone bed remained relatively stable, but from 2019 to 2022 there was an apparent decline of between 13–37 % in tonnage across the bed compared to the 2018 levels. During that time, the surveyed bed area fluctuated between around 6 and 11 hectares. Since 2022 this decline in tonnage has continued with an apparent 57% decrease in tonnage from 2022 to 2024. The bed area decreased to 5.15 ha in 2024. The density and percentage cover of mussel across the bed have shown an overall trend of decline since surveys began in 2012, and although there was an increase in 2022 of both metrics there was a decline in 2023 and then an increase in 2024 (although this is not dissimilar to fluctuations observed in previous years). The density of the Coolstone bed had been fluctuating between around 1.5 and 1.9 kg/m^2 since 2015 (Figure 9), which is when the previously separate beds were first considered to be one merged bed. However, this decreased to 0.8 kg/m^2 in 2023, and 2024 saw an increase to 1.3 kg/m^2. Coolstone is a patchy bed due the substrate that mussel is settled on; the areas of gravel where mussel grows best on this bed are broken up by outcrops of rock running through them. The patchy nature of this bed may explain the fluctuations in the measures seen year-on-year, as the values obtained will depend on whether the transects happen to cross over the denser patches of mussel. Further analysis of existing data and future surveys will help Officers to understand the amount of apparent inter-annual variation that is actually due to this kind of sampling bias, and therefore whether the surveys as conducted are capable of providing the statistical power to detect changes of a given magnitude in mussel density, percentage cover and tonnage.

4.1.2. Yelland

Over the 2019–2022 period, the area, tonnage, density, and percentage cover of mussels on the Yelland mussel bed remained relatively stable compared to earlier survey years, although the bed area and tonnage recorded in 2022 appeared to show small declines and the percentage cover may have increased. However, in 2023 the tonnage, density and percentage cover all appeared to decrease with a relative 65%, 77% and 36% decline respectively. Away from the decrease seen in most metrics, the bed area increased by 54% from 2022 to 2023. It may be that in 2023 the surveyed area was larger but included areas of non-mussel bed, leading to apparent declines in density and percentage cover. There was an increase in the tonnage, density and percentage cover in 2024 but not back to the same levels as in 2022 and earlier. The Yelland bed seems to have a healthy stock of larger mussel that continues to remain stable or show increases (e.g. 51-60 mm) year on year with the exception of 2023.

4.1.3. Instow

Unlike the other established beds, the Instow bed surveys only began in 2023. The density and percentage cover on the bed has stayed stable across the two years however there may have been changes in the area and tonnage. The area of the bed appears to have increased by 75% and the tonnage appears to have increased by 67.5%. In 2023 there was only mussel in the 21-30mm and 31-40mm size classes whereas in 2024 there was mussel in those size classes and the 41-50mm size class. In 2024 there was a decrease in the amount of mussel in the 21-30mm size class and an increase in the amount in the 31-40mm class.

The survey needs to be repeated annually to determine if the bed will continue to grow in area and tonnage, and if the mussel size will grow on to a larger stock size.

4.2. Comparison of Coolstone Surveys

There was an opportunity during the 2024 surveys to compare the same bed across two different survey dates to review the methodology used. The Coolstone bed was surveyed on the 8th May and then two days later on the 10th May.

There were large differences in the results of the two surveys. There was a decrease of all metrics of the bed apart from the bed area which had an increase of 14.6%. The largest decreases were seen in the density and tonnage of the bed with a 53% and 51% decrease. There were also large decreases in all stock sizes, ranging from a 32% to 100% decrease.

As the bed shape (Figure 8) was different between the two surveys a further analysis was carried out on the just the southern area of both beds where the transects most overlapped. There were still large differences in density and tonnage when comparing the results from this southern area. There was a 48% decrease in density from 8th-10th of May and a 57% decrease in the tonnage. While there was a 20% decrease in percentage cover when looking at the full area surveyed, there was a smaller decrease of 8.6% when comparing the southern end of the bed.

As the survey dates were two days apart, the difference in results in unlikely to be due to environmental differences and more likely to be down to a difference in surveyor technique. This will be explored further as the differences are large even when just comparing the southern end of the bed where transects did overlap. Further analysis of existing data and future surveys will help Officers to understand the amount of apparent inter-survey variation that is actually due to this kind of sampling bias, and therefore whether the surveys as conducted are capable of providing the statistical power to detect changes of a given magnitude in mussel density, percentage cover and tonnage.

4.3 All Beds

Due to access issues to the mid-estuary beds including Pulleys, Sprat Ridge and The Neck, comparisons across all beds have not been able to be undertaken since the 2022 survey. The Lifeboat Slip bed wasn't surveyed in 2024; however, this bed is the smallest bed with the most sporadic mussel coverage. Without results from these four beds no conclusions can be drawn on potential changes across the estuary as a whole. Officers continue to explore options for access to mid-channel beds to enable appropriate surveys to take place.

4.4 UAV Survey

A trial of using a UAV was undertaken in 2024 after an initial trial in 2023. A different UAV was used, and an attempt was made to fly this at a lower altitude than in 2023.

As with the 2023 UAV survey, the resulting imagery was not sufficient to identify individual mussel or bed extent (see Appendix 1). When zooming into the images the substrate becomes blurred, and mussels cannot be reliably distinguished from small pebbles and rocks, and it is not possible to distinguish live mussel from areas of shell (Appendix 1). Mapping could not be carried out using the data gathered.

Although trials using an UAV were unsuccessful on the Taw Torridge Estuary, the method has had success elsewhere. Schnurawa *et al* (2024) successfully undertook UAV surveys of mussel beds on the tidal flats of the Wadden Sea. The UAV system used was a fixed-wing

drone with both a Red, Blue, Green (RGB) camera and multispectral system being utilised. The RGB camera allowed for the manual determination of the bed extent and the images from the multispectral camera had machine learning approaches applied to determine the coverage of the mussel within the bed (Schnurawa *et al*, 2024).

The areas around the mussel beds surveyed in the Wadden Sea study were characterized by sandy soft-bottom, muddy zones (Schnurawa *et al,* 2024) where the extent of the mussel beds is clear. By comparison, the Coolstone mussel bed on the Taw Torridge does not have a clear boundary and the substrate itself is difficult to discriminate from areas of mussel with the available sensors. It may be possible to increase the resolution (and discriminatory use) of the imagery by using alternative sensors, lower flight altitude and much lower flight speed. However, this presents significant resourcing challenges (e.g. staff time and cost) which are compounded by the limited survey time available over the suitable low tide windows, making this approach practically prohibitive.

4.5 Ecological Requirements and The Local Fishery

D&S IFCA has recently collaborated with Bournemouth University, Association of IFCAs, Natural England and EAD Ecology on a project funded under the Marine Natural Capital and Ecosystem Assessment programme. The purpose of this project was to assess the shellfish food requirements of oystercatcher (*Haematopus ostralegus*) overwintering in the Taw Torridge Estuary to inform the management of the site and its mussel fishery. The assessment is made using a model, MORPH, which has previously been applied to understand the effect of shellfishing and other factors on survival of waders and wildfowl throughout the UK and internationally. As oystercatchers consume cockles and mussels within similar size ranges to those harvested by fishing, the stock assessments of these shellfish made in the Taw Torridge Estuary provided an assessment of the food available to oystercatchers. The model makes predictions for the winters of 2019/20, 2020/21, 2021/22, 2022/23, 2023/24 and 2024/25, and provides outputs applicable to future years, meaning that mussel tonnage estimates derived from D&S IFCA's mussel stock assessments can be compared to the ecological requirements of the bird population in each year, to assess the quantity of mussel potentially available to a fishery. This work is reported in Stillman *et al*. (2025).

4.6 Conclusions

For a second year in a row the Pulleys and Sprat Ridge beds were not surveyed due to continuing access issues to the mid-channel beds and therefore conclusions cannot be drawn on the current state of the mussel stock across the full intertidal area of the Taw Torridge Estuary. Officers continue to explore options for access to mid-channel beds to enable appropriate surveys to take place.

There was a continuation of interannual variation on the mussel beds that were surveyed. Yelland and Instow both had an increase in tonnage whereas Coolstone appeared to continue to decrease. Further analysis of existing data and future surveys will help Officers to understand the amount of apparent inter-survey variation that is actually due to sampling bias versus actual change in the mussel stock, and therefore whether the surveys as conducted are capable of providing the statistical power to detect changes of a given magnitude in mussel density, percentage cover and tonnage.

After two attempts at surveying with an UAV using visible light sensors in 2023 and 2024 it can be concluded that this method cannot be used to survey the mussel beds on the Taw Torridge.

4.7 Recommendations

It is recommended that the Taw Torridge Estuary mussel stock assessments continue to be carried out on an annual basis, to monitor any future changes to the stock of the beds. This will help to inform any future management D&S IFCA may bring in for the collection of mussels, as part of its review of existing byelaws and development of a possible Hand Working Byelaw, as well as working with Natural England to ensure the mussel harvesting limit remains suitable to balance the environmental and economic interests in the mussel stocks.

Due to the inconsistencies between the two May 2024 surveys on the Coolstone bed, it is recommended that a review of the methodology is carried out to ensure that the right method is used for the type of patchy beds present at this location.

As the mid-channel beds have not been surveyed since 2022, it is recommended that a solution is found to the access issues to undertake a full stock assessment within the Taw Torridge Estuary. This full stock assessment will ensure that the bird food availability model produces the most accurate results.

References

Albrecht, A. S. 1998. Soft bottom versus hard rock:: Community ecology of macroalgae on intertidal mussel beds in the Wadden Sea. Journal of Experimental Marine Biology and Ecology, 229: 85–109.

Andrews, J. W., Brand, A. R., and Maar, M. 2011. Assessments Isefjord and East Jutland Danish blue shell mussel - MSC Fisheries. https://fisheries.msc.org/en/fisheries/isefjord-and-east-jutland-danish-blue-shell-mussel/@@assessments (Accessed 22 March 2021).

Bayne, B., and Worrall, C. 1980. Growth and Production of Mussels Mytilus edulis from Two Populations. Marine Ecology Progress Series, 3: 317–328.

Defra. 2020. Magic Map Application. https://magic.defra.gov.uk/MagicMap.aspx (Accessed 22 March 2021).

Handå, A., Alver, M., Edvardsen, C. V., Halstensen, S., Olsen, A. J., Øie, G., Reitan, K. I., *et al.* 2011. Growth of farmed blue mussels (Mytilus edulis L.) in a Norwegian coastal area; comparison of food proxies by DEB modeling. Journal of Sea Research, 66: 297–307.

JNCC. 2011. UKBAP-PriorityHabitatDescriptions-Rev-2011.pdf. JNCC. https://data.jncc.gov.uk/data/2728792c-c8c6-4b8c-9ccd-a908cb0f1432/UKBAP-PriorityHabitatDescriptions-Rev-2011.pdf (Accessed 22 March 2021).

Lieberknecht, L., Hooper, T., Mullier, T., Murphy, A., Neilly, M., Carr, H., Haines, R., *et al.* 2011. Finding Sanctuary final report and recommendations. A report submitted by the Finding Sanctuary stakeholder project to Defra, the Joint Nature Conservation Committee, and Natural England. Finding Sanctuary. www.finding-sanctuary.org.

North Devon AONB and Biosphere Reserve Service. 2010. Taw - Torridge Estuary Management Plan Report 3: Action Plan 2010 - 2015. North Devon AONB and Biosphere Reserve Service. https://www.northdevonbiosphere.org.uk/uploads/1/5/4/4/15448192/_4-estuary_management_plan-action-plan.pdf (Accessed 22 March 2021).

Schnurawa, M., Mueller, J., Schade, H., Nehls, G. 2024. Drone-based monitoring of intertidal blue mussel beds in the Wadden Sea- comparison of a threshold and two machine learning approaches. Front Mar. Sci. 11:1381036. doi: 10.3389/fmars.2024.1381036

Seed, R., and Suchanek, T. 1992. Population and communtiy ecology of Mytilus. *In* pp. 87–169.

Stillman, R. A., and Wood, K. A. 2013. Towards a simplified approach for assessing bird food requirements on shellfisheries. A report to the Welsh Government. Monograph. Bournmouth University. 41 pp. https://eprints.bournemouth.ac.uk/21905/ (Accessed 15 February 2023).

Stillman, R.A., Goss-Custard, J.D. and Morris, S.E. (2025). Assessing the shellfish food requirements of oystercatchers in the Taw Torridge Estuary. Marine Natural Capital and Ecosystem Assessment (mNCEA) report, draft version 0.2, March 2025.

Appendix 1: Summary of Uncrewed Aerial Vehicle Surveys in the Taw-Torridge

In 2023 and 2024, D&S IFCA worked with two drone operators to test whether Uncrewed Aerial Vehicles (UAVs) with visible light camera payloads could capture imagery of sufficient resolution to identify mussel on the Taw-Torridge mussel beds, and to use this information to define the bed extent and percentage cover of mussels.

Trials in 2023

Due to tidal constraints and boat logistical difficulties, access to two of the main Taw Torridge Estuary mussel beds, Sprat Ridge and Pulleys, was not accomplished during the mussel surveys in 2023. In order to overcome this problem, Officers worked with a commercial drone operator to take aerial imagery of the beds on 30th September 2023 and 1st October 2023. The operator aimed to carry out flights at 8m, 10m and 20m altitude over the Coolstone bed, and at 18m altitude over the Pulleys and Sprat Ridge beds, using a Mavic DJI M3E UAV and sensor, aiming for a ground sampling distance (cm per pixel) of approximately 0.1 – 0.25. Due to in-built collision avoidance mechanisms it proved difficult to fly the drone below 10m in practice. During the drone flights over the Coolstone beds, Officers also placed individually identifiable quadrats in random locations over the mussel bed, and took photographs from approximately 1m above the surface for each quadrat, so that in-field estimates of mussel coverage could be compared to those obtained from the drone imagery. Analysis of the drone imagery identified that it was not possible to reliably differentiate live mussel from dead mussel on the ground, and in many cases not possible to differentiate mussel from the underlying substrate. Therefore, this imagery could not be used to inform the assessment of stocks on these beds. Example images are shown below (Figure A1).

Trials in 2024

Due to tidal constraints and ongoing boat logistical difficulties, access to two of the main Taw Torridge Estuary mussel beds, Sprat Ridge and Pulleys, was still not possible for the mussel surveys in 2024. In order to overcome this problem, Officers worked with drone operators from Southern IFCA (SIFCA) to take aerial imagery of the beds, building on lessons learned from trials in 2023. The drone operators aimed to carry out low altitude flights (at around 12.5 and 20m) to achieve high resolution imagery of the Coolstone bed. Time constraints limited trials in 2024 to the Coolstone bed. The UAV used was a DJI Matrice 300 RTK with a Zenmuse H20T camera system.

Analysis of the drone imagery identified that it was not possible to reliably differentiate live mussel from dead mussel on the ground, and in many cases not possible to differentiate mussel from the underlying substrate. Therefore, this imagery could not be used to inform the assessment of stocks on these beds. Example images are shown below (Figure A2).

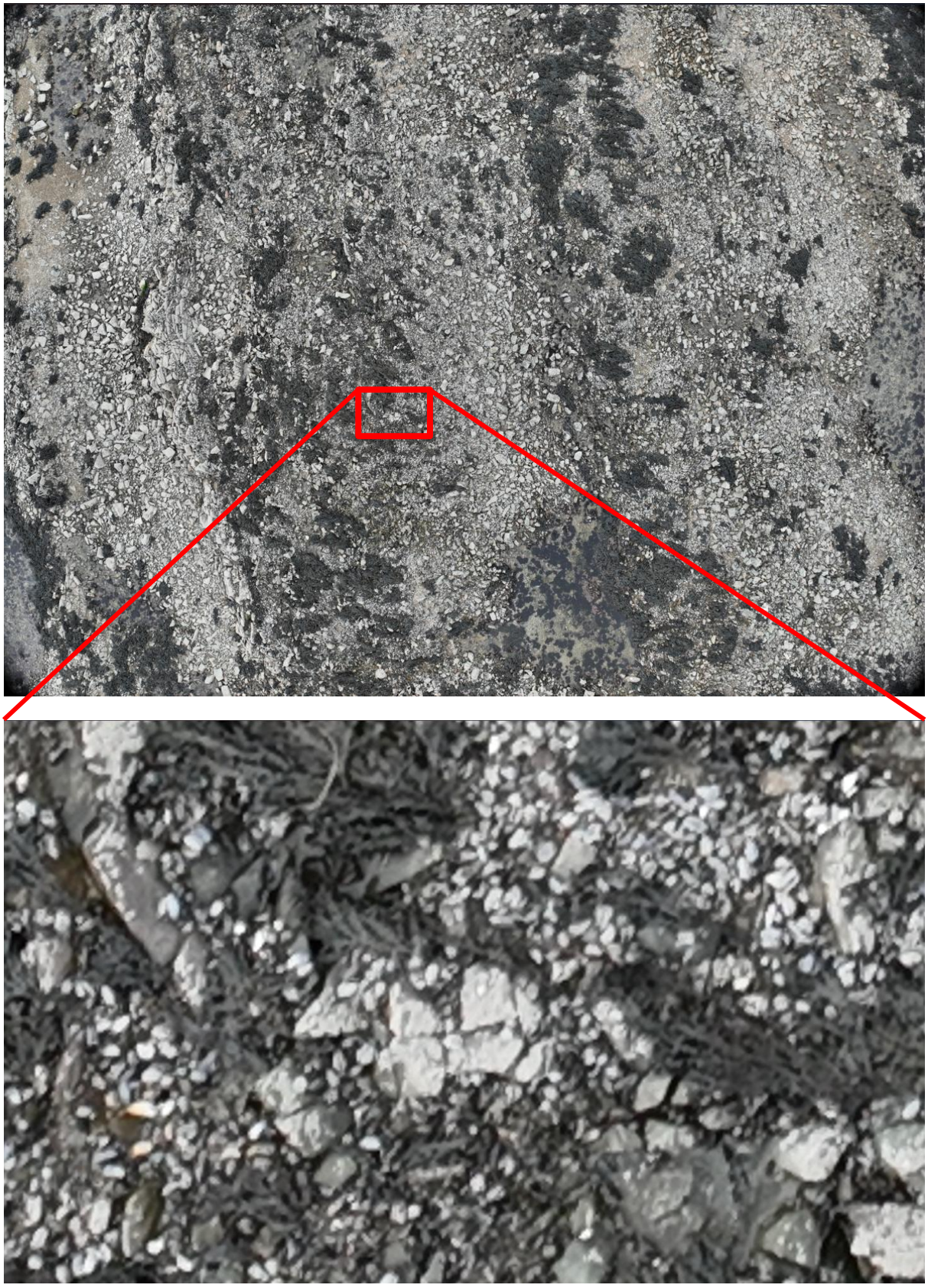

Figure A1. Example image of Coolstone bed taken from approx. 10m altitude (not original resolution, top) in 2023, showing example of a ‘zoomed-in’ area (bottom).

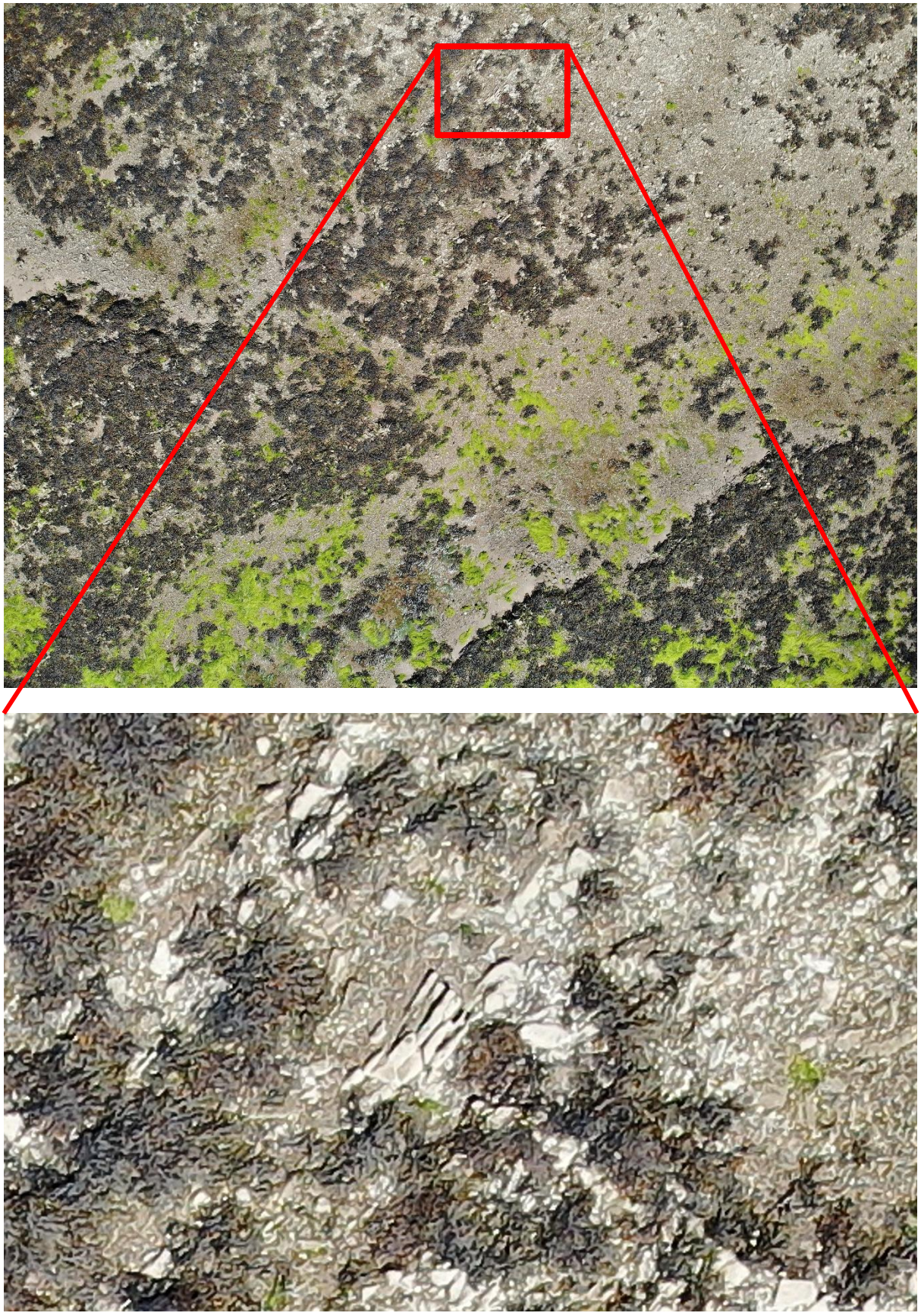

Figure A2. Example image of Coolstone bed taken from approx. 12m altitude (not original resolution, top) in 2024, showing example of a ‘zoomed-in’ area (bottom).