Taw-Torridge Estuary
Subtidal Mussel Assessment 2021

Lauren Parkhouse, Lauren Henly and Dr James Stewart
Devon and Severn Inshore Fisheries and Conservation Authority
November 2021

Contents

1. Introduction 3

1.1 The Taw-Torridge Estuary 3

1.2 *Mytilus edulis* 4

1.3 Objectives.. 6

2. Methodology 7

2.1 Side Scan Sonar... 7

2.2 Grabbing... 7

3. Results.. 10

4. Discussion 26

5. Limitations and Recommendations 27

References 28

Annex 1: Images from grabs 30

Version control			
Author/reviewer	**Comments**	**Date**	**Version**
L. Parkhouse and L. Henly	First draft (L. Henly completed LF results section)	24/11/2020	0.1
S. Clark	Minor amendments	01/12/2021	0.2
J. Stewart	Minor amendments	10/12/2021	0.3
L. Parkhouse	Minor amendments	14/12/2021	0.4
Sarah Clark	Final Review	14/01/2022	**1.0**

Cover image: Satellite image of Taw-Torridge Estuary (© Google).

1. Introduction

1.1 The Taw-Torridge Estuary

The Taw-Torridge Estuary, the confluence of the Taw and the Torridge rivers, is located on the North Devon coast, within the North Devon Coast Area of Outstanding Natural Beauty (AONB) and the North Devon UNESCO Biosphere Reserve (Figure 1). The Estuary is an important site for wildlife and has been designated as a Site of Special Scientific Interest (SSSI) (Figure 2) for over-wintering and migratory populations of wading birds, and for the rare plants found on its shores (Natural England, 1988). The Estuary has a large tidal range and extensive areas of sandbanks and, particularly towards the high water mark, mudflats. These areas, along with large beaches and areas of saltmarsh, provide habitat and food sources for diverse animal species, including wading birds (Natural England, 1988). The site supports nationally important numbers of curlew, golden plover and lapwing, and other species of wader are locally abundant, including redshank, dunlin and oystercatcher (Natural England, 1988). The area supports a diverse fish community including mullet, flatfish, pollack and migratory fish species such as salmon, and is a bass nursery area (Kelley, 1986). Blue mussels, *Mytilus edulis*, are present in extensive intertidal and subtidal areas (Natural England, 1988).

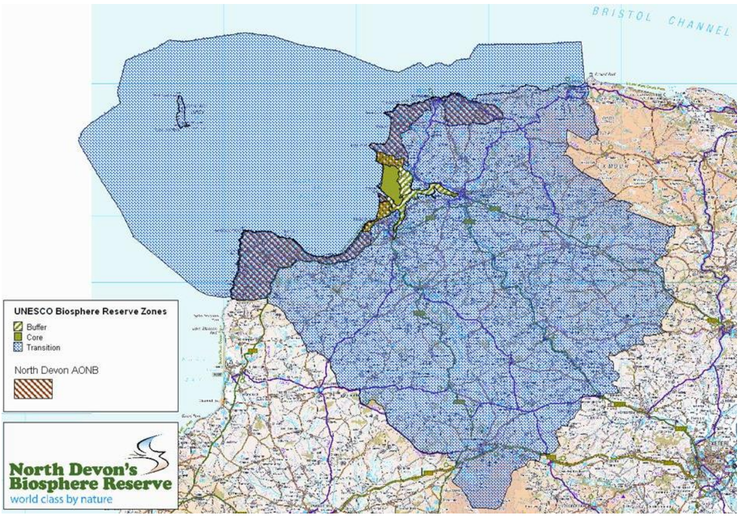

Figure 1 The location of the Taw Torridge Estuary (shown in yellow) within the North Devon Biosphere Reserve and the North Devon Coast AONB. (Taw Torridge Estuary Management Plan, 2010).

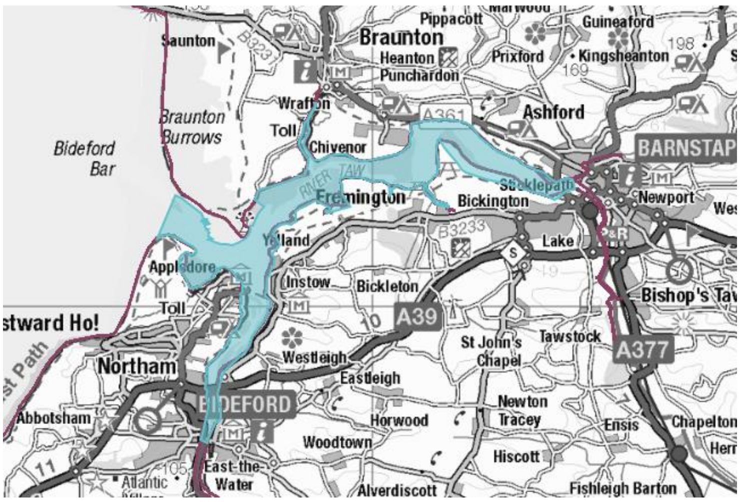

Figure 2 Taw-Torridge Estuary SSSI, shown in blue (Defra, 2016)

1.2 *Mytilus edulis*

Blue mussels, *Mytilus edulis*, are cold-water marine bivalve molluscs which can occur in brackish water (Gardner, 1996). They are found in Europe, on the north Atlantic and north Pacific coast of North America, and in other temperate and polar waters. Blue mussels occur at a range of shore heights from the intertidal to shallow sublittoral (Connor *et al*., 2004), and on a variety of substrates, from rocks to sediments, and in a range of conditions. *M. edulis'* ability 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). Blue mussels are identified as a Habitat of Principle Importance (HPI) under the Natural Environment and Rural Communities (NERC) Act 2006. The board habitat definitions for the HPI include beds of blue mussel *M. edulis* in a range of conditions from open coats to estuaries and marine inlets. Biotopes included are littoral mixed sediments, littoral sand, littoral mud, sublittoral sediment, littoral mixed substrata and infralittoral rock (Mainwaring *et al.,* 2014).

The reproductive strategy of *M. edulis* 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 planktonic larval zygotes undergo six stages of metamorphosis before settlement. Peak settlement (spatfall) occurs in the spring; newly settled post larvae attach themselves to the substrate using byssus threads, which may be intentionally released to allow resettlement if the first settlement location proves to be unfavourable. The shell then begins to grow and, once individuals reach ~20 mm in size, they are termed 'seed mussels'. These seed mussels are often harvested for cultivation elsewhere. The stability of the settlement and growth locations can determine the natural survival rate of seed beds (Dankers *et al.,* 2001).

M. edulis 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 (Maddock, 2008). In the subtidal, starfish, crabs, demersal fish and dog whelks predate on mussels. Predation can influence population size and structure and often prevents extension of subtidal beds (Mainwaring *et al.,* 2014). Little is known about the food web in the Taw-Torridge, but predation is thought to be a key constraint on subtidal mussel populations in comparison to intertidal populations (Seed and Suchanek, 1992); Holt *et al.* (1998) highlight that starfish populations destroy most sublittoral mussel settlements in The Wash each year, and also attack cultivated plots at or below mean low water springs. 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 (Andrews *et al*., 2011; Seed and Suchanek, 1992). Blue mussels are filter feeders, feeding primarily on micro-algae, suspended debris and zooplankton, and play a vital role in estuaries by removing bacteria and toxins.

Current threats to *M. edulis* beds include: commercial fishing, water quality, anchoring, and, particularly for intertidal beds: bait digging, coastal developments and intensive recreational hand gathering (Maddock, 2008). Poor spat settlement combined with a severe winter of storms in 2014 are thought to have contributed to a decline in intertidal mussel stocks in the Taw-Torridge system in 2014. Following this decline, and an increase in interest from numerous commercial harvesters, Natural England, working with D&S IFCA, introduced management measures to ensure that enough mussels would be available to provide an adequate food supply for the birds for which the SSSI is designated. Originally no more than 500kg of mussels could be removed from the SSSI per month, and any business wishing to remove mussels must notify Natural England and D&S IFCA of their intentions to do so by 23rd of the month prior to the month when mussel harvesting is proposed. This allows Natural England and D&S IFCA to determine if the planned removal will, in combination with other planned activities, be likely to result in the 500kg limit being exceeded. If this is the case, planned removal by all individuals will need to be reduced accordingly. Records of the amount of mussels removed (including location) together with copies of movement documents are submitted to Natural England and the IFCA within 14 days of harvesting. This limit has now been increased to 750kg per month due to a review of intertidal survey data and modelling of the mussel resource required by overwintering bird populations.

The changing and variable nature of the hydrological environment can also pose a threat to some mussel populations; for example, in the Taw-Torridge area, there is some local concern that subtidal mussel beds may be prone to scouring and disintegration over winter, particularly during periods in which the strong local tidal movements coincide with high freshwater input and riverine flows. Mussels show preferential settlement and growth in areas of high flow, for example in the mouths of estuaries. However, extreme high flows can depress feeding and growth rates, and cause mussels to become detached from the substrate (Dare, 1976; Jenner *et al.,* 1998; Widdows *et al.,* 2002). The impact of increased flow rates depends on the local context, including the composition of the underlying substrate, the density of the mussel bed, the typical average flow rate, and the magnitude of the increase in flow rate (Mainwaring *et al.,* 2014).

Mussel resilience to increases in flow rate depends in large part on the strength of the byssal attachment to the substrate, which in turn can adapt according to local conditions. The strength and number of byssal thread attachments produced by *M. edulis* and related species is higher in areas that typically experience higher flow rates (Young, 1985; Dolmer and Svane, 1994; Alfaro, 2006). The strength and number of byssal thread attachments also increases in individual mussels over short time periods, allowing further adaptation to gradual increases in flow rate: Young (1985) observed 25% strengthening of attachments within eight hours of increased water agitation associated with a storm commencing. However, sudden increases in water movement do not allow time for such adaptation, and mussels are susceptible to being swept away (Young, 1985).

The composition of the underlying substrate also affects mussel vulnerability to high water flow; individuals attached to rock are typically more resistant to removal than those attached to loose boulders, cobbles or sediment. Increases in flow have the potential to resuspend and remove finer sediments from the Estuary bed (Tyler-Walters, 2008; Mainwaring *et al.,* 2014), and the rate of removal depends in part on the density of the mussel bed. For example, in flume tank studies, Widdows *et al.* (2002) showed that increased water turbulence and scouring around live mussels caused rates of resuspension of sandy sediment that were four and five times higher, respectively, on areas with 25% and 50% mussel cover compared to bare sediment. However, areas with 100% mussel cover remained more stable, with three times lower resuspension rates than bare sediment. On mixed sediment or cohesive mud substrata, increasing mussel density was typically associated with higher stability and lower risk of mussel removal by high water flows (Widdows *et al.*, 2002). However, these flume tank studies used a maximum flow rate of 0.45 m/sec, which is lower than that experienced at peak flow in the Taw-Torridge Estuary; it is therefore unclear how these results translate to the local subtidal mussels at this location (Stewart, 2020).

In 2020 there was interest in the possibility of removing some of the subtidal mussels in the Taw-Torridge Estuary and relaying it onto an intertidal area for it to grow to harvestable size as part of the development of the current fishery. In order to undertake a pilot of removing up to five tonnes, a survey first needed to be undertaken to understand the location of the subtidal mussel beds. In October 2020, working with the local fisher, a broad-scale grab survey of the subtidal areas of the Taw-Torridge Estuary was undertaken, the results of which fed into a SSSI assessment to gain assent from NE to carry out the relaying trial. The 2020 survey report can be read here. Assent was granted and mussel was dredged using a traditional 1m Baird mussel dredge and relocated in the intertidal.

After the trial in 2020, D&S IFCA concluded more detail on the extent of the mussels would help in future management, and a more extensive survey would be needed in 2021 before any more removal was carried out.

1.3 Objectives

The objective of this project was to carry out a side scan sonar (SSS) survey of the Estuary to gain a better understanding of the extent of the subtidal mussel beds. The SSS data was to be ground-truthed using a grab survey, and mussels collected in the grab being measured to assess size classes of mussels in the different subtidal areas.

As this was the first time using the side scan sonar methodology, proof of concept was a secondary objective of the project.

2. Methodology

The surveys were carried out onboard an 8.3 metre multi-use fishing vessel. Two members of crew from the vessel were joined by an Environment Officer from D&S IFCA and the Principal Scientific Officer from Cornwall IFCA (CIFCA). The side scan sonar (SSS) survey was carried out on the 14th October 2021 and the grabbing was carried out on the following day, 15th October 2021. High water on the 14th October was at 13:16 hours at a height of 5.46m, and on the 15th October at 14:43 hours at 5.61m. The weather was fine with light winds from the northwest and calm sea state on both days of the survey.

2.1 Side Scan Sonar

The Side Scan Sonar survey was undertaken using a Tritech SeaKing Towfish. Data were collected at low (300kHz) frequency. The SSS was deployed from the pot hauler on the starboard side of the vessel initially and then tied off to allow for it to be hauled and deployed by hand, once in place. The SSS was towed at a speed of 2-3 knots into the current. The range was set to 30m for all tows, covering a 60m wide swathe For each tow the cable in the water was 4m from the tow point and at 2m depth. A Hemisphere Atlas Link GNSS GPS was attached to the A-frame of the vessel and was in line with the towfish during deployment. As the GPS antenna was in line with the towfish, there was no need to calculate a layback. The layback is used to determine the location of the where the towfish was in relation to the GPS antenna when mapping the side scan output. The towfish can be several metres away from the GPS antenna which, without calculating the layback, would result in errors in mapping.

The survey lines were not pre-planned and were decided throughout the survey based on coverage gained and advice from the skipper of the fishing vessel who has extensive knowledge of the site. This was due to the uncertainty of how the towfish would behave in the conditions of the Estuary.

The SSS signature was watched in real time as well as being recorded for processing using Seanet Pro. The co-ordinates of any areas of interested were noted during the survey.

Processing was carried out using Seanet Pro Dumplog and Coda Octopus straight after the full SSS survey in order to plan the ground truth survey for the next day. The outputs of this processing were GeoTIF files for each survey line, which has geographic positioning information allowing for use in GIS software. The GeoTIF files were then added as layers to a QGIS project (QGIS v.3.4.5), and a brief analysis was undertaken to identify signatures of interest for verification, along with the areas of interest noted during the survey. The coordinates of these areas of interest were then used to plan the grab survey. The SSS signature suspected to be mussels consisted of raised areas with light and dark shadowing which indicates the uneven surface of the mussel bed when compared to flatter sediments.

More detailed analysis of the SSS signatures was undertaken post-survey to determine an approximate extent of the mussels in the survey areas. This was done within QGIS and by watching each line in Seanet Pro.

2.2 Grabbing

From the SSS signature analysis a total of 45 stations were identified to ground truth with the grab (Figure 3). The co-ordinates of the survey stations were input into the vessels MaxSea plotter.

An Offset Day Grab with a sampling area of 0.1m² was used to undertake the survey. The grab was used from the stern of the vessel using the winch to lower and recover it. Once on station, the skipper of the vessel used the winch to raise the grab from the landing table and it was guided out by two crew. Once the grab hit the water another crew member took a waypoint on a handheld GPS and recorded the grab number, waymark number and the latitude and longitude. The waymark number is used as grab number reference throughout this document. Once the grab hit the seafloor it was then recovered using the winch and guided back onto the landing table by the two crew. The top of the grab was opened to check if it had been a successful deployment and a photo (Annex 1: Images from grabswas taken of the contents with the grab number before it was emptied into the bucket underneath. The success of the grab and whether there were mussels or not was recorded on the survey sheet. Any mussels were then transferred to a numbered bag for later measuring. If the grab was not successful it was repeated up to two more times before moving onto the next station.

Once all the grabs were complete a decision was made to deploy a waterproof camera in one area of interest which had a large number of small sized mussels. The camera was attached to the grab and lowered in the same manner as during the grab survey but was lifted slightly once it hit the seabed. The vessel was then allowed to drift for approximately 10 minutes before recovery of the grab and camera. The footage was viewed along with the other post survey analysis.

For each grab containing mussels, the length of all mussels was measured and divided into the following size groups; 1-10mm, 11-20mm, 21-30mm, 31-40mm, 41-50mm, 51-60mm, 61-70mm, 70+mm, and the weight of each size class was recorded to the nearest gram. Length distributions were plotted as histograms and as empirical cumulative distribution functions (ECDFs) and were compared to the length distributions of mussels found in the 2020 grab survey and the intertidal beds surveyed by D&S IFCA in 2021. Figure 4 shows the locations and names of these intertidal beds. These beds were surveyed using the Dutch wand method over transects walked across the beds. In summary, transects were walked in a zig-zag pattern across the intertidal beds. 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 along each transect the cane was flicked out to one side and it was recorded whether it was a "hit" if the ring contained live mussels, or a "miss" if the ring did not contain live mussels. On every fifth hit the contents of the ring were taken as a sample, using an 11cm diameter corer. All mussels from each transect were measured to the nearest mm. Full methods and results of these surveys are available in the Taw-Torridge Intertidal Mussel Stock Assessment 2021. Reports from previous years are available here.

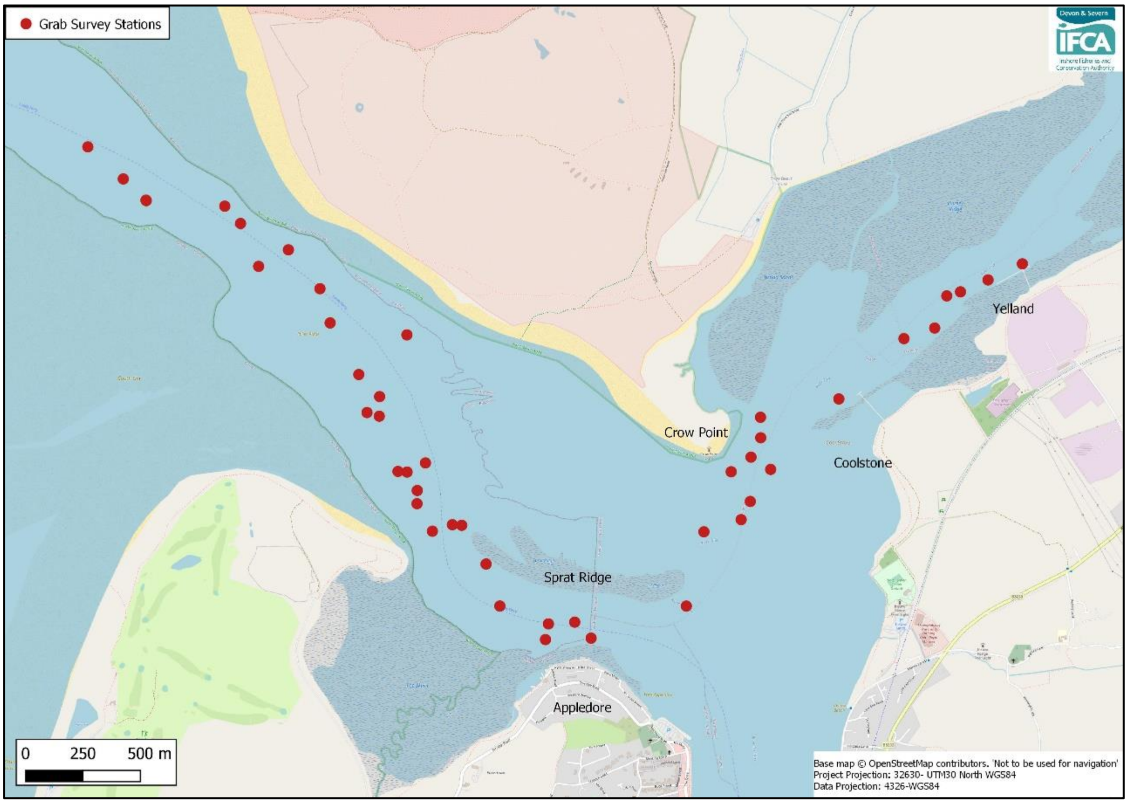

Figure 3 Grab station plan from SSS results

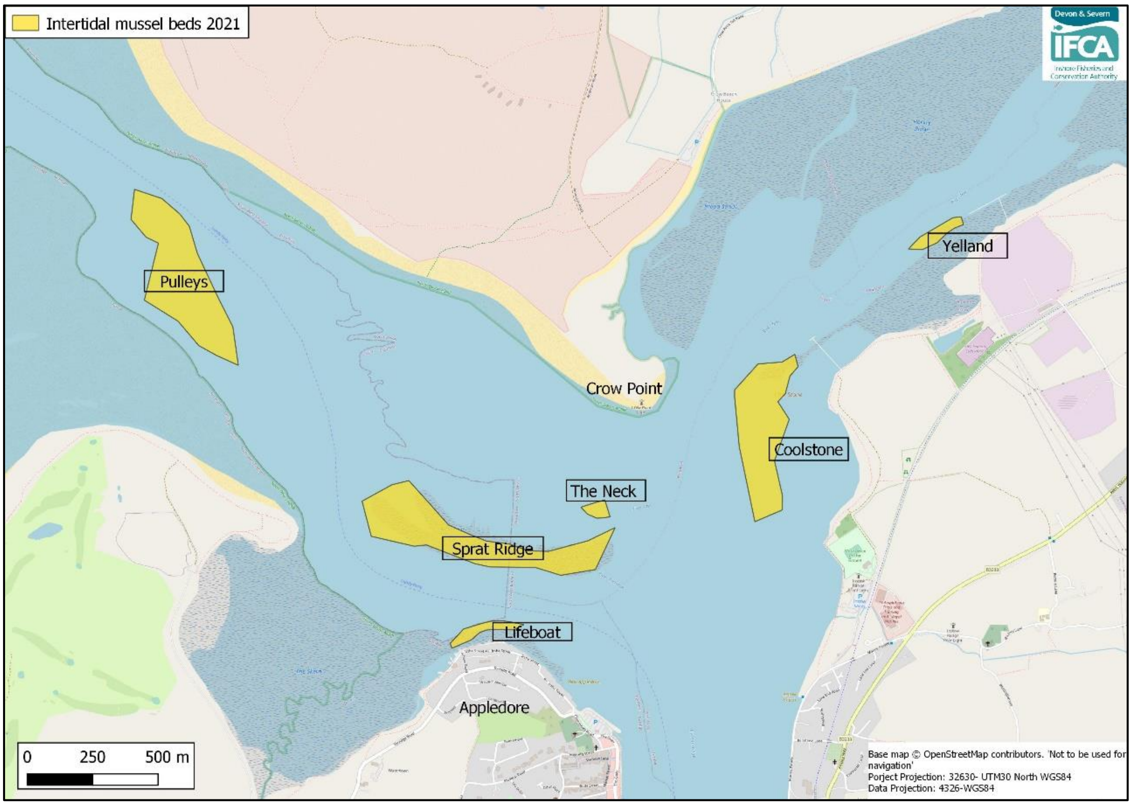

Figure 4 Intertidal beds 2021

3. Results

A total of 13 tows of differing lengths were carried out with the SSS throughout the Estuary. However, due to intermittent issues with the GPS receiver at the beginning of the survey, only 10 tows have complete GPS data for the GeoTIF output. Two were missing part of the tow and one had no data. The missing data were from tows at the mouth of the Estuary and the Pulleys area. With the type of side scan used, the tow lines already undertaken could not be viewed on any software in real time, and the vessels plotter had to be used to monitor coverage. However, this also was not working for the first few tows so some of the Estuary was not covered fully. However, there is still good coverage of areas that could potentially have mussels (Figure 5).

From the SSS signature analysis a total of 45 stations were identified to ground truth with the grab. A total of 89 grabs were carried out altogether, including repeats for failed grabs. Of these, 49 (55%) were considered successful (grab closed). Of the 49 successful grabs, 32 contained mussels (65%). Of the unsuccessful grabs, there were 10 where mussels were present (25%), this was one or two mussels caught in the jaw of the grab which had failed. Most of the failures were due to stones or mussels caught in the jaw of the grab. There were a few occasions when the fisher indicated that the vessel was situated over rock, and one grab contained a piece of sponge in the jaw which suggests the grab took place on harder ground.

Figure 6 shows the recorded locations of each grab sample for the full Estuary. Diamond-shaped markers indicate successful grabs, while unsuccessful grabs are depicted by small circular markers. Green markers of either shape indicate that mussels were present in the grab, while black markers indicate mussel absence. Black circular markers cannot be taken as evidence of mussel absence, due to grab failure. Black diamond markers indicate mussel absence in a successful grab. Grab contents from each sample can be seen in Annex 1: Images from grabs.

The Estuary was split into four areas to undertake length frequency analysis. These areas were based on results from the 2020 grab survey in order to compare length frequency data; one extra area was included in 2021. Figure 7 toFigure *10* shows the success and mussel presence in each of these four areas. The mouth of the Estuary (Figure 7) had the lowest proportion of mussels with 37.5% of successful grabs containing mussels. The area between the Pulleys and Sprat Ridge (Figure 8) had the highest proportion of mussels, with 80% of successful grabs containing mussel. Lifeboat to Coolstone (Figure 9) and Yelland (Figure 10) had similar proportions of mussels to each other with 60% and 67% respectively of successful grabs containing mussels. Grab numbers 70 and 71, highlighted in Figure 11, contained spat and seed mussels with mussel size ranging from 4mm-22mm with one mussel at 54mm. There was a total of 257 mussels in these two grabs, all other grabs, with mussels present, had between 1 and 39 mussels.

Figure 12 shows the mussel count within each successful grab sample (mussels per $0.1m^2$). Highest mussel densities in successful grabs appear to occur in the area between Outer Pulleys and the lifeboat area. This is simlar to the the 2020 survey as can be seen in Figure 13 comparing the two years of surveys. The grab used in 2020 had a sampling area of $0.028m^2$ whereas the 2021 sampling area was $0.1m^2$.

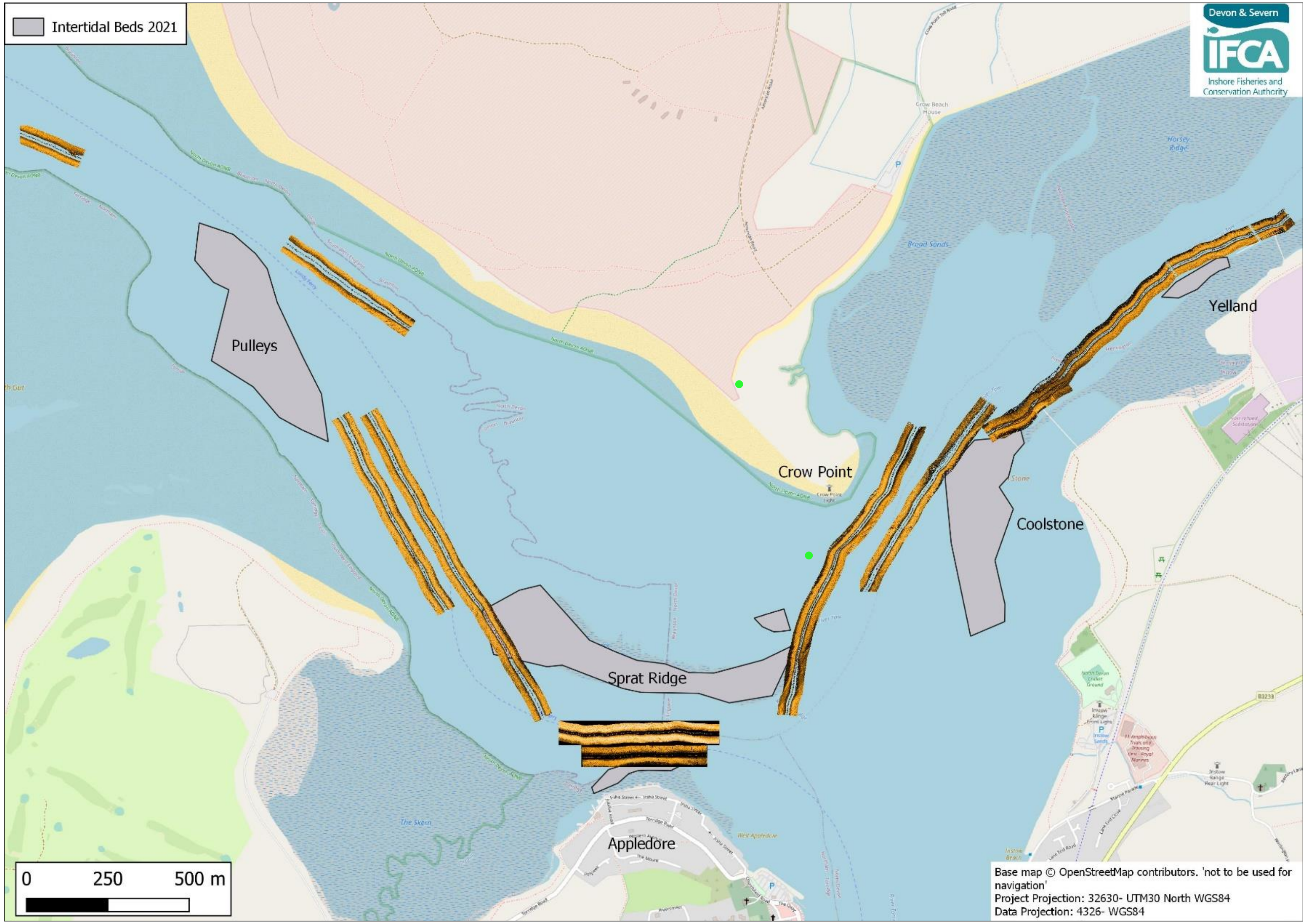

Figure 5 Map of successful SSS data with intertidal beds

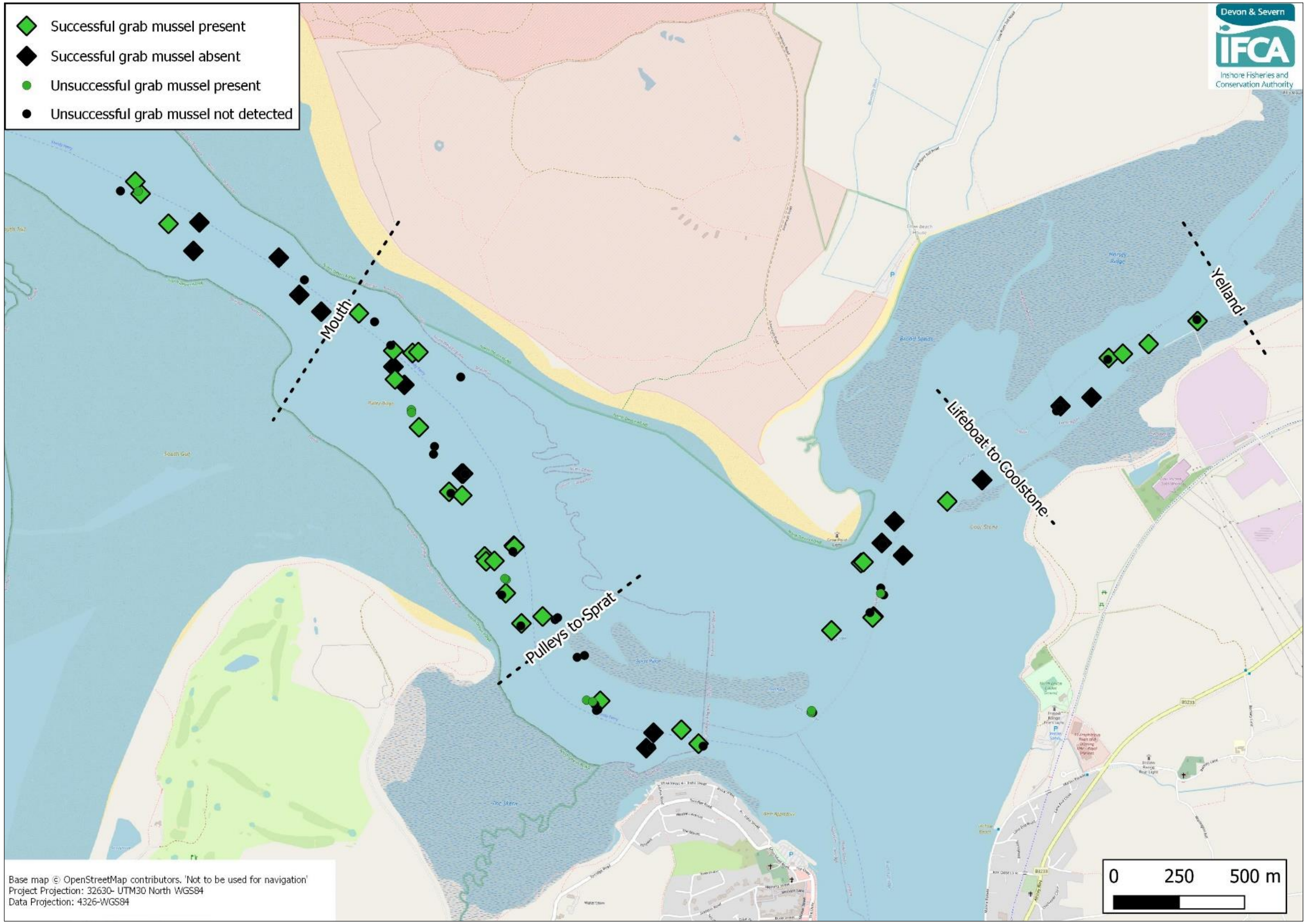

Figure 6 Grab locations for the full Estuary including successful and unsuccessful grabs. Green markers indicate mussel presence, black markers indicate mussel absence, with the caveat that absence of mussels in unsuccessful grabs cannot be taken to indicate mussel absence with any certainty.

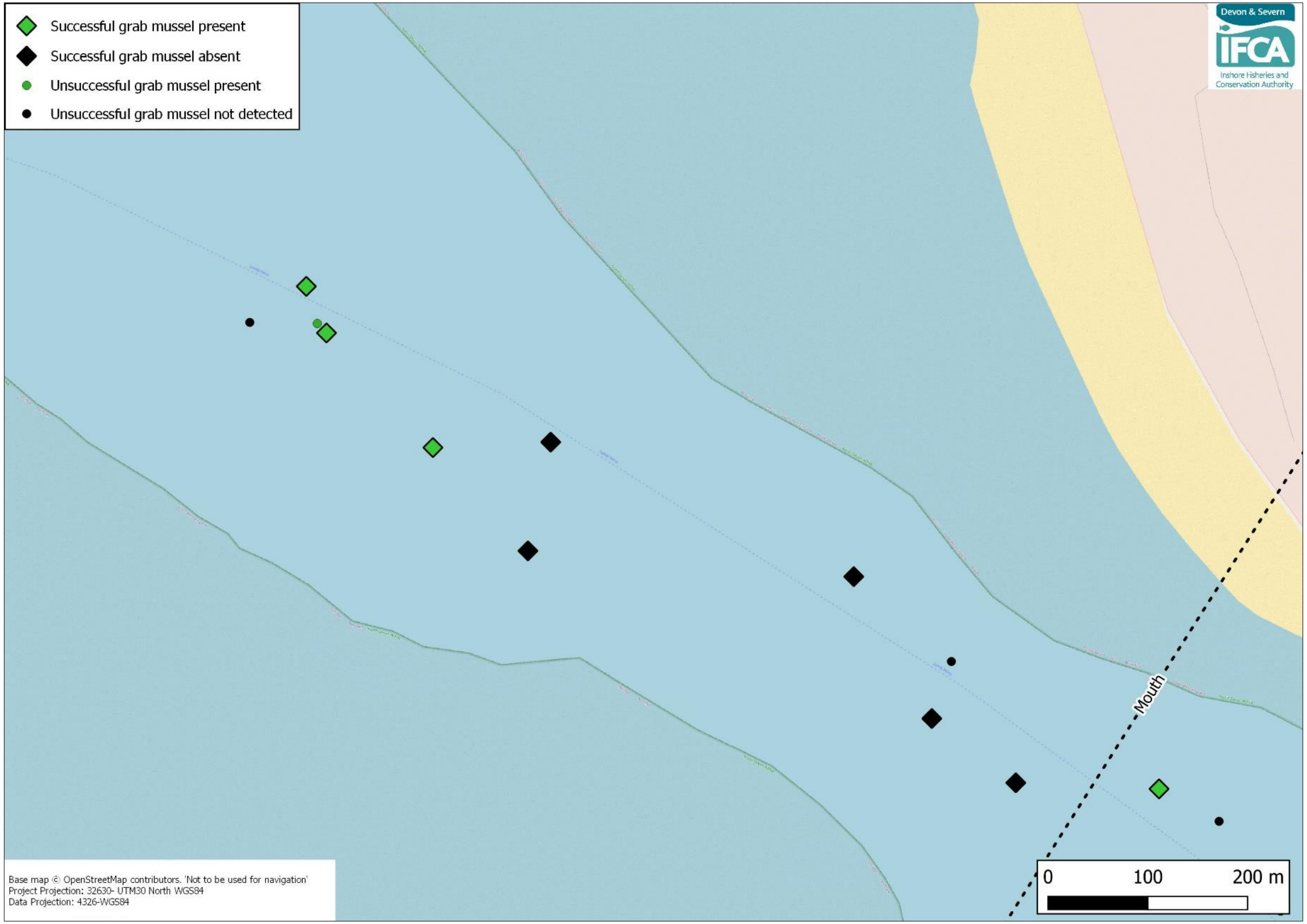

Figure 7 Grabs from area referred to as Outer Pulleys to Mouth in this report. This area is made up of the grabs to the left of the line marked 'Mouth'

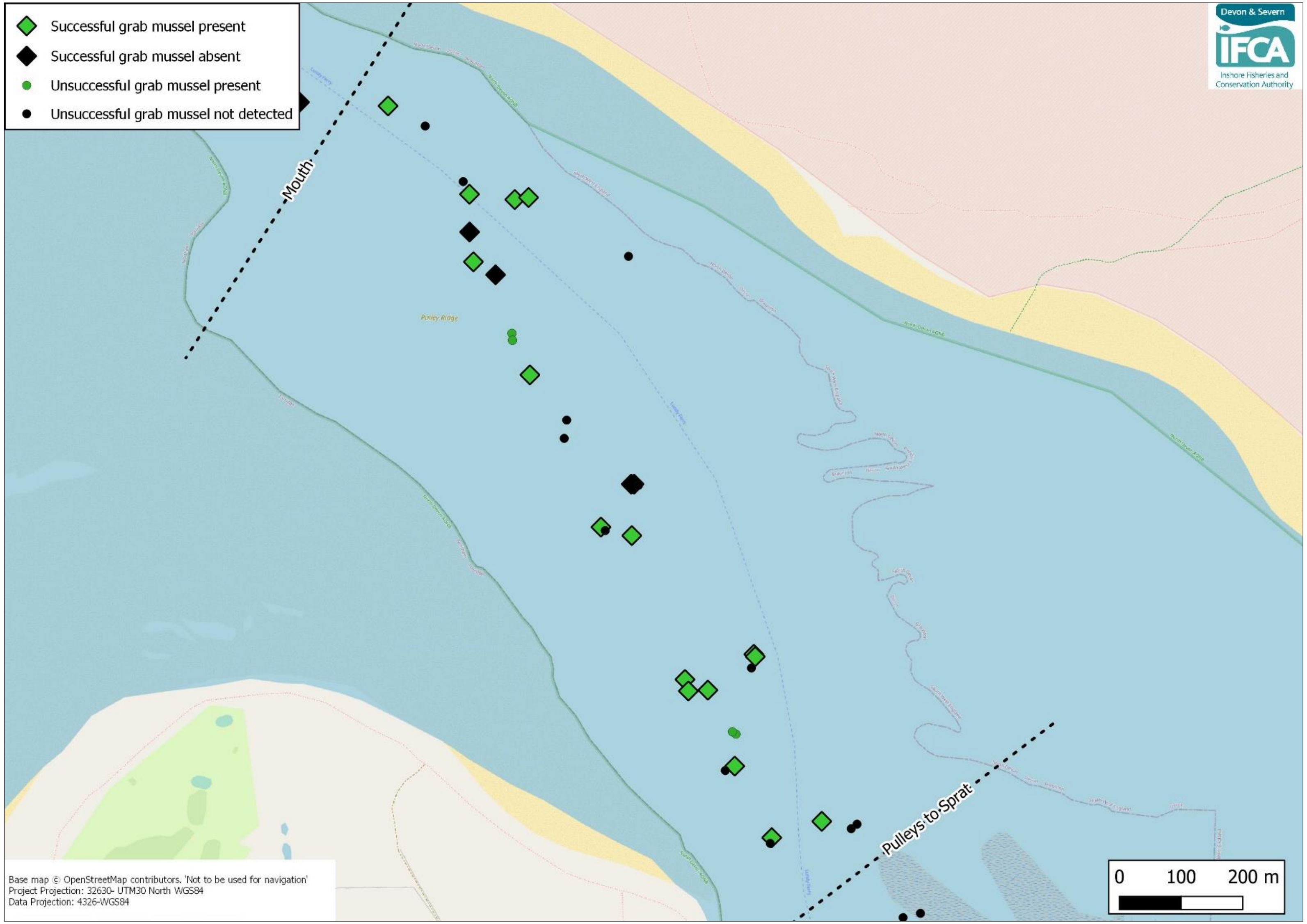

Figure 8 Grabs from area known as Inner Pulleys to Sprat in this report. Between 'Pulleys to Sprat' and 'Mouth' lines.

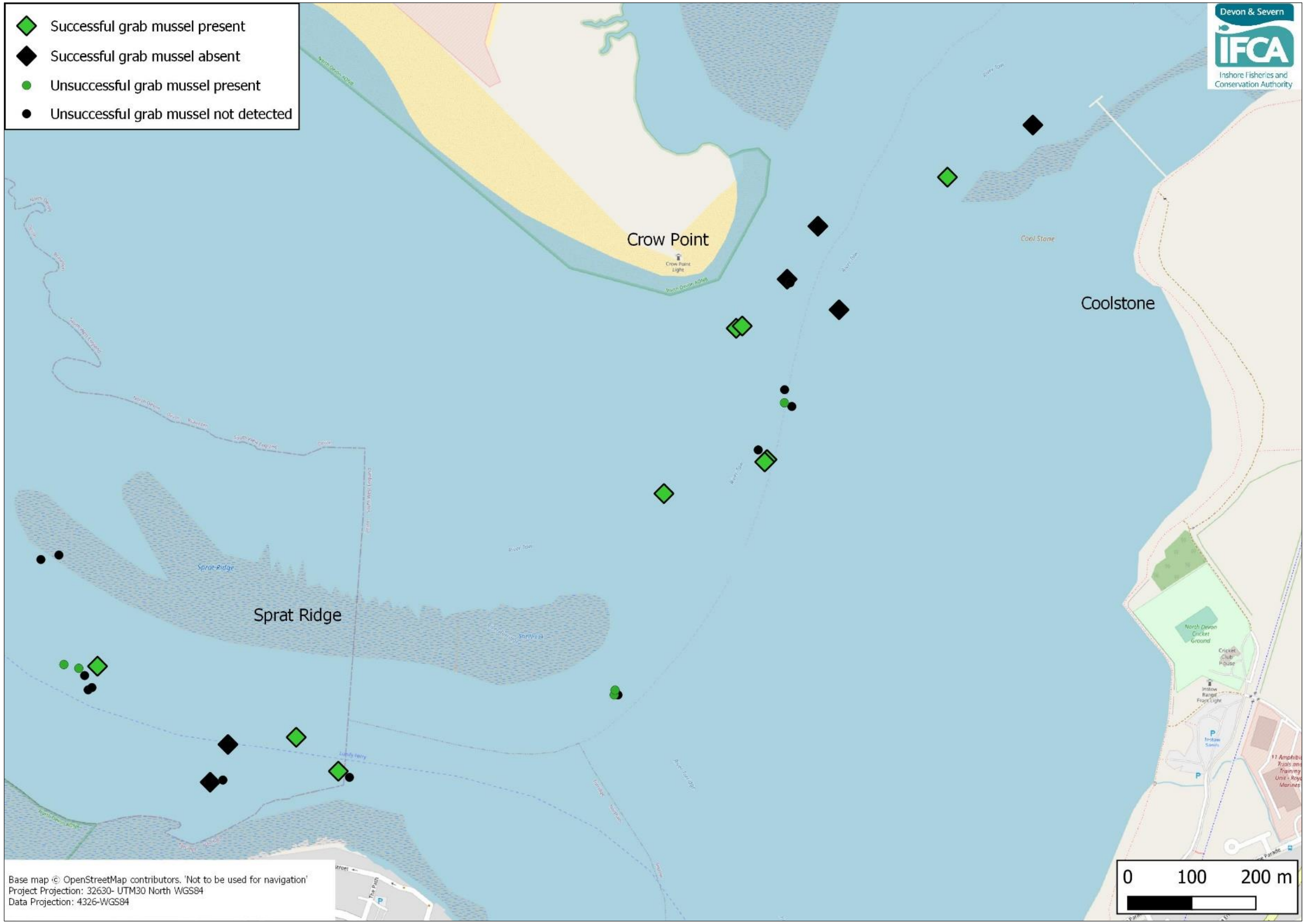

Figure 9 Grabs from the area known as Lifeboat to Coolstone in this report.

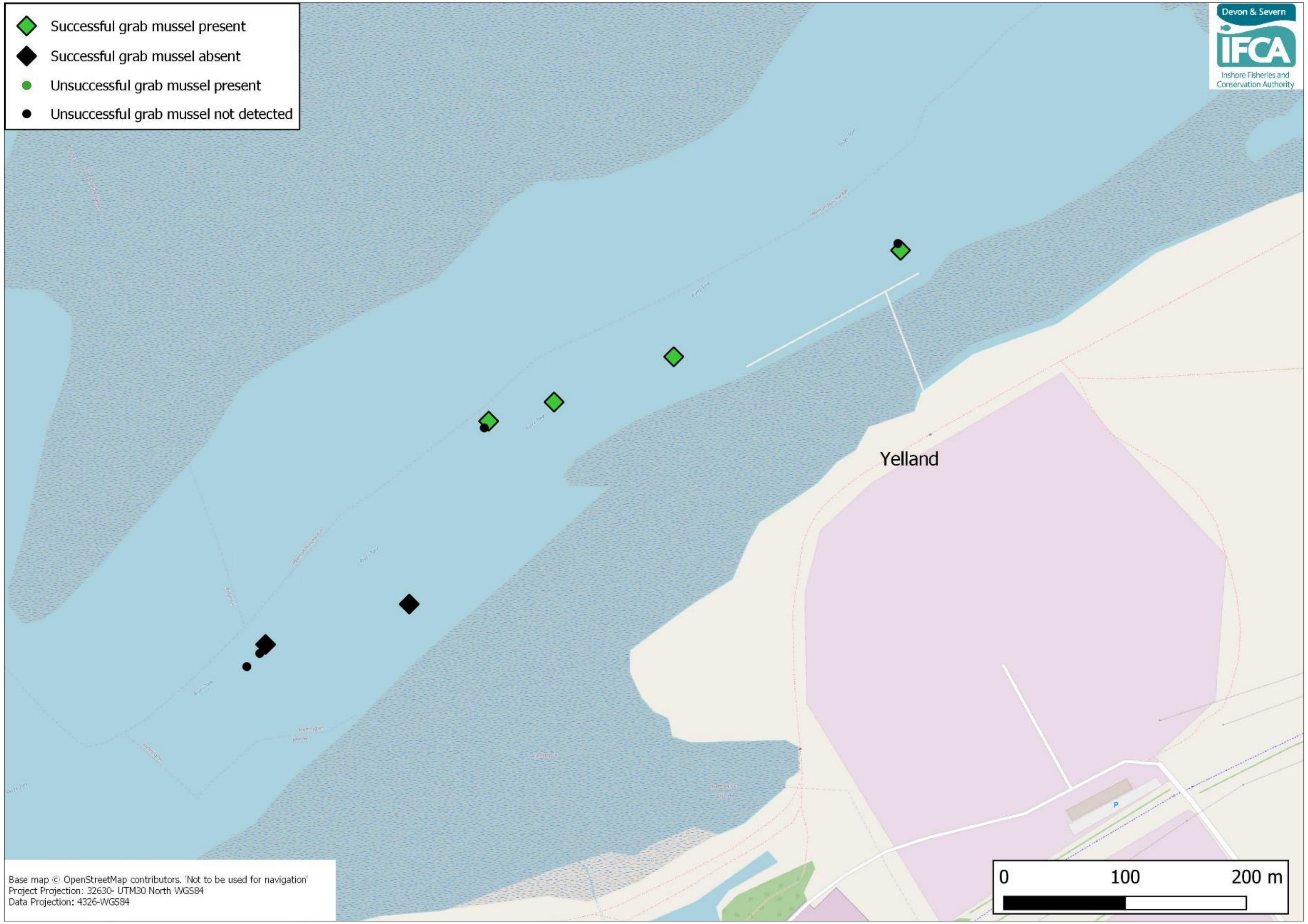

Figure 10 Grabs from the area known as Yelland in this report

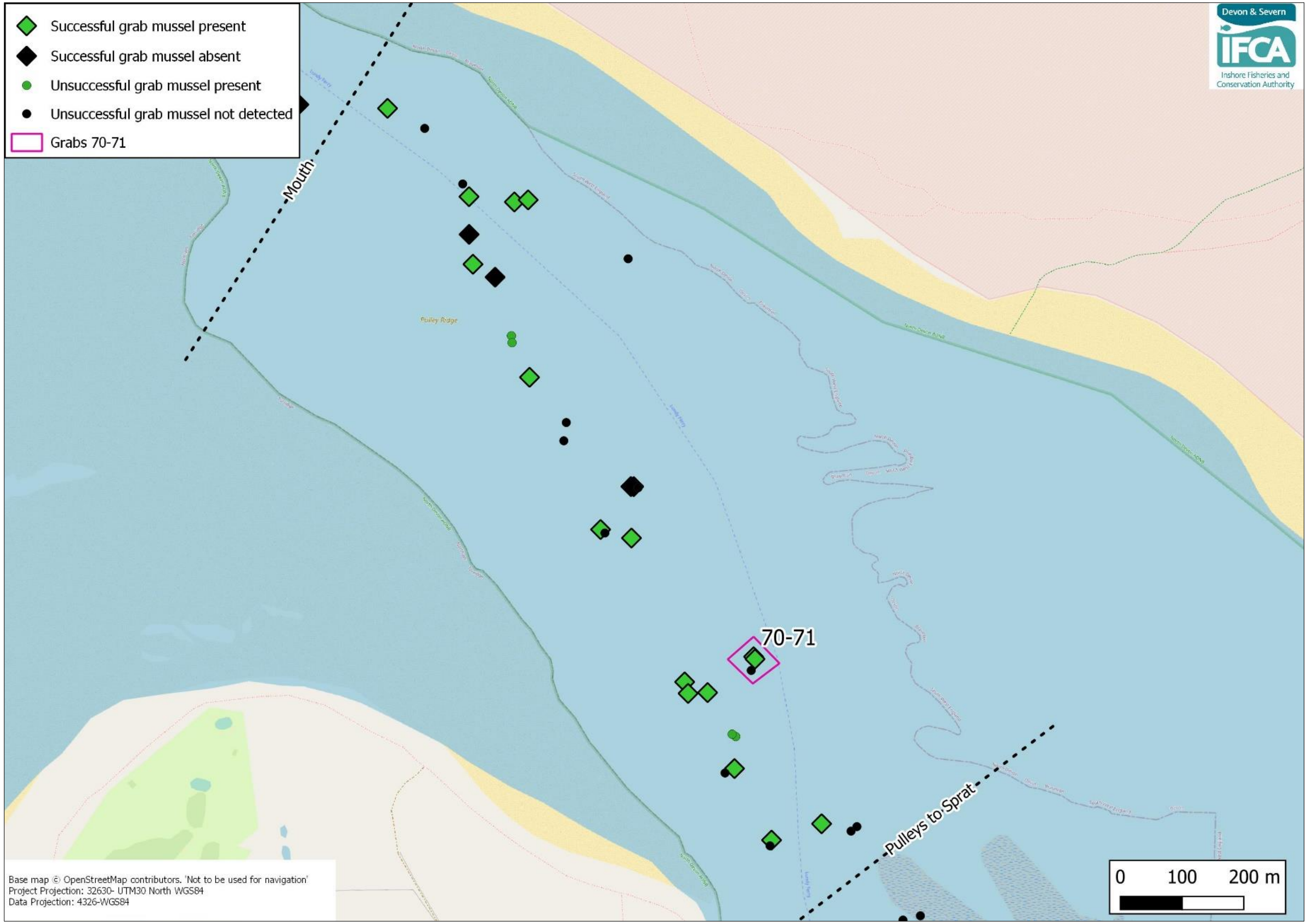

Figure 11 Grabs in the area known as Inner Pulleys to Sprat Ridge. Grabs 70 and 71, highlighted in the pink box, had large numbers of small mussels ranging from 4-22mm

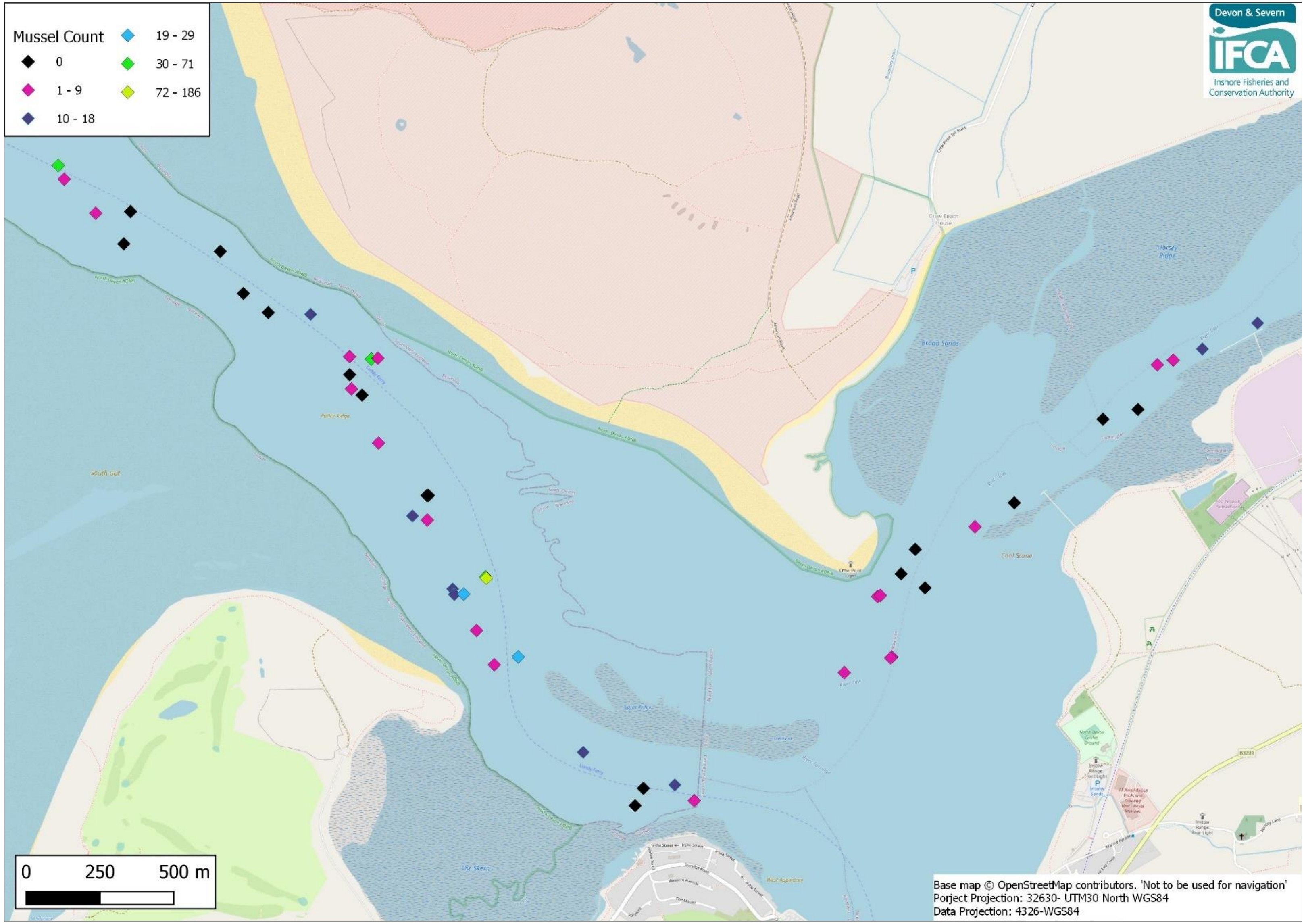

Figure 12 Count of mussels in each successful grab

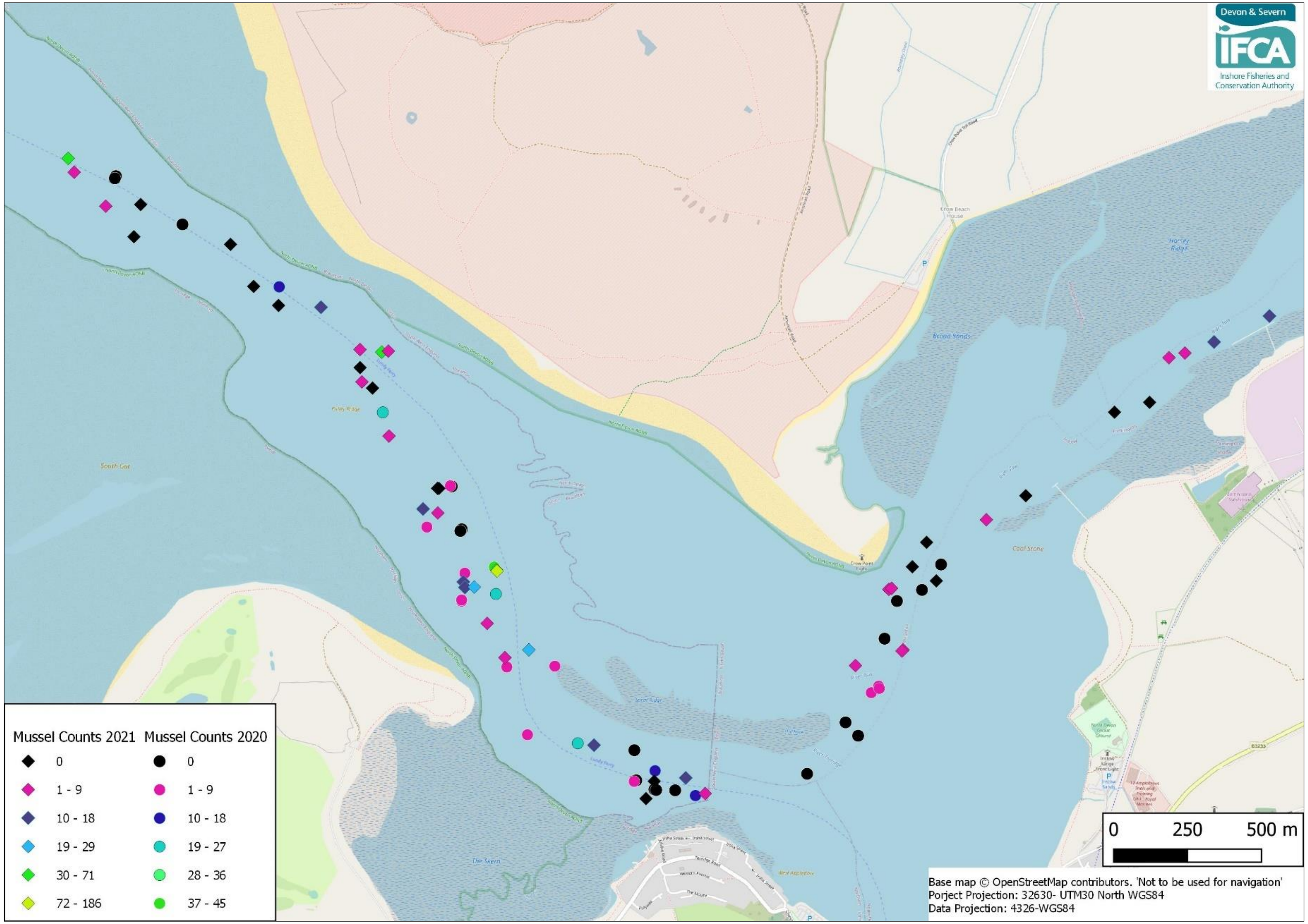

Figure 13 Count of mussels in each successful grab for 2021 and 2020 surveys. The 2021 grab had a 0.1m² sampling area, whereas the 2020 grab had a smaller sampling area of 0.028m². 2021 survey in diamonds and 2020 survey in circles.

The results from the grab survey confirmed the SSS signature for mussels, which was identified by the Officers prior to the grab survey. The signature has raised areas with light and dark shadowing which indicates the uneven surface of the mussel bed when compared to flatter sediments. Local knowledge and the ground truthing allowed for the reviewer to differentiate between the mussels and other hard substrates. The signature confirmation has allowed for the mapping of possible mussel beds throughout the locations of the Estuary which were surveyed with the SSS. The typical signature is shown in Figure 14, with the left side of the track being mussels and the right being sediment.

The camera tow was carried out in the vicinity of grabs 70 and 71 (Figure 15). There are dense undulating mussel beds throughout the video (Figure 16) with sandy patches between mussels, and one patch that is a mixture of mussels and stony areas. This also confirmed the SSS signature and with the peaks and toughs seen within the mussel bed, gave more detail of the undulating bathymetry patterns that were seen in the signature.

The analysis of the SSS data indicated that, in the areas with successful data collection, there is approximately 0.18km² of subtidal mussels. This excludes the area around the Pulleys and the Mouth of the Estuary where the GPS failed. Figure 17 shows the areas established to be mussel bed from the analysis.

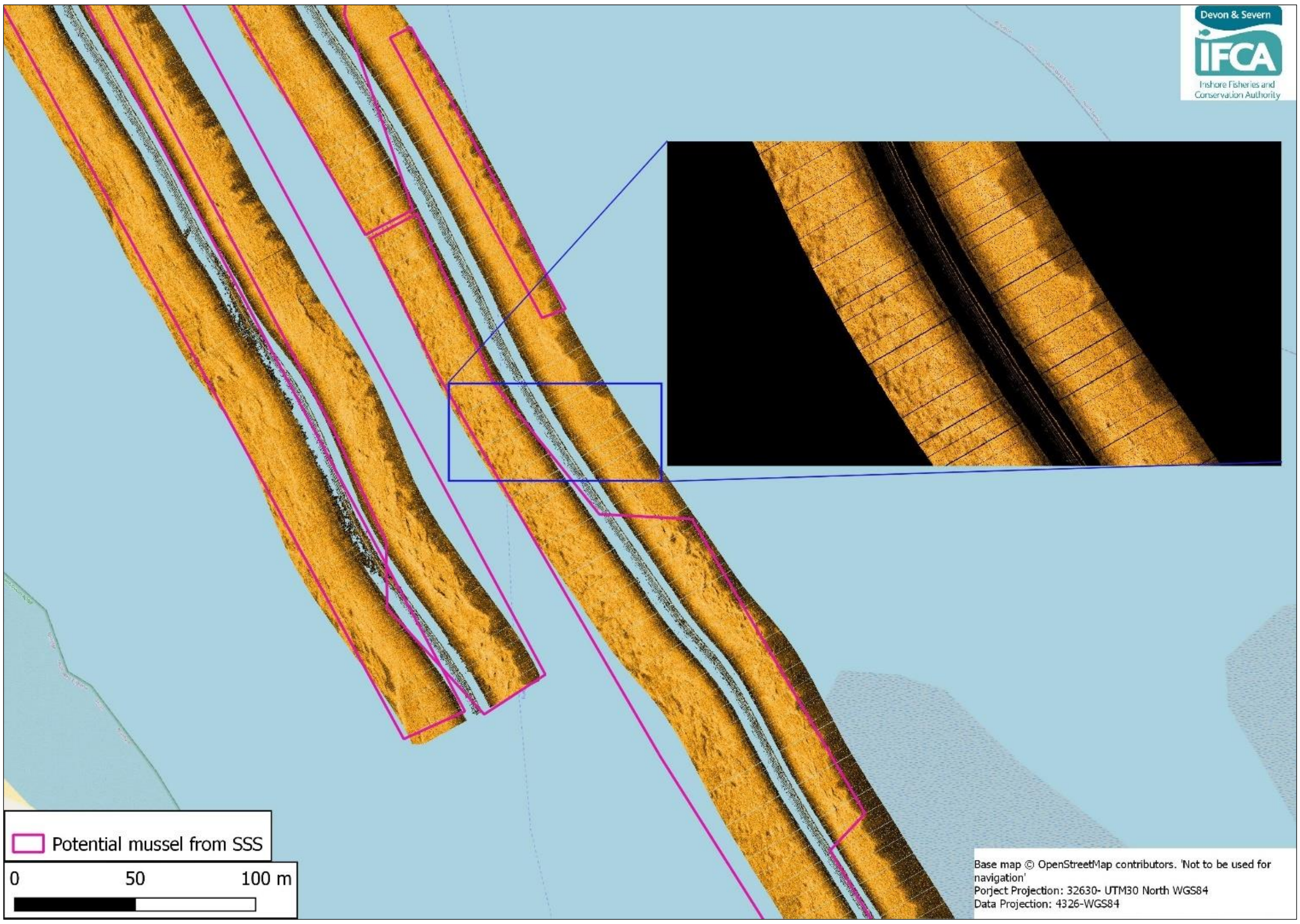

Figure 14 Example of the signature for mussels. Mussels can be seen on the left side of the track as a bumpy texture with shadowing. The right-hand side is smooth and more likely to be sediment

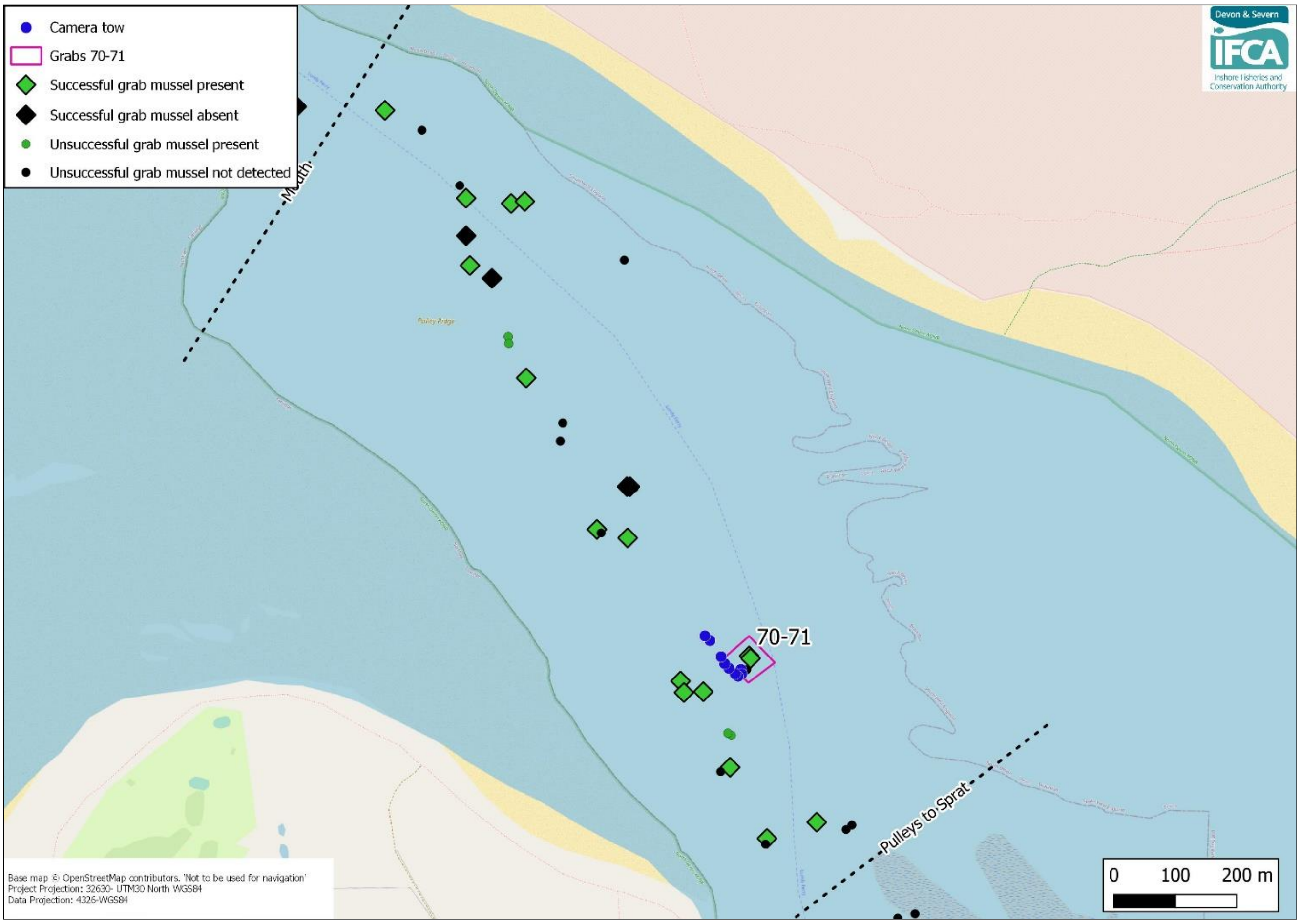

Figure 15 Camera tow in vicinity of grab stations 70 and 71 where dense small mussels were present and there was a strong signature on the SSS data

Figure 16 Example of mussels from camera tow

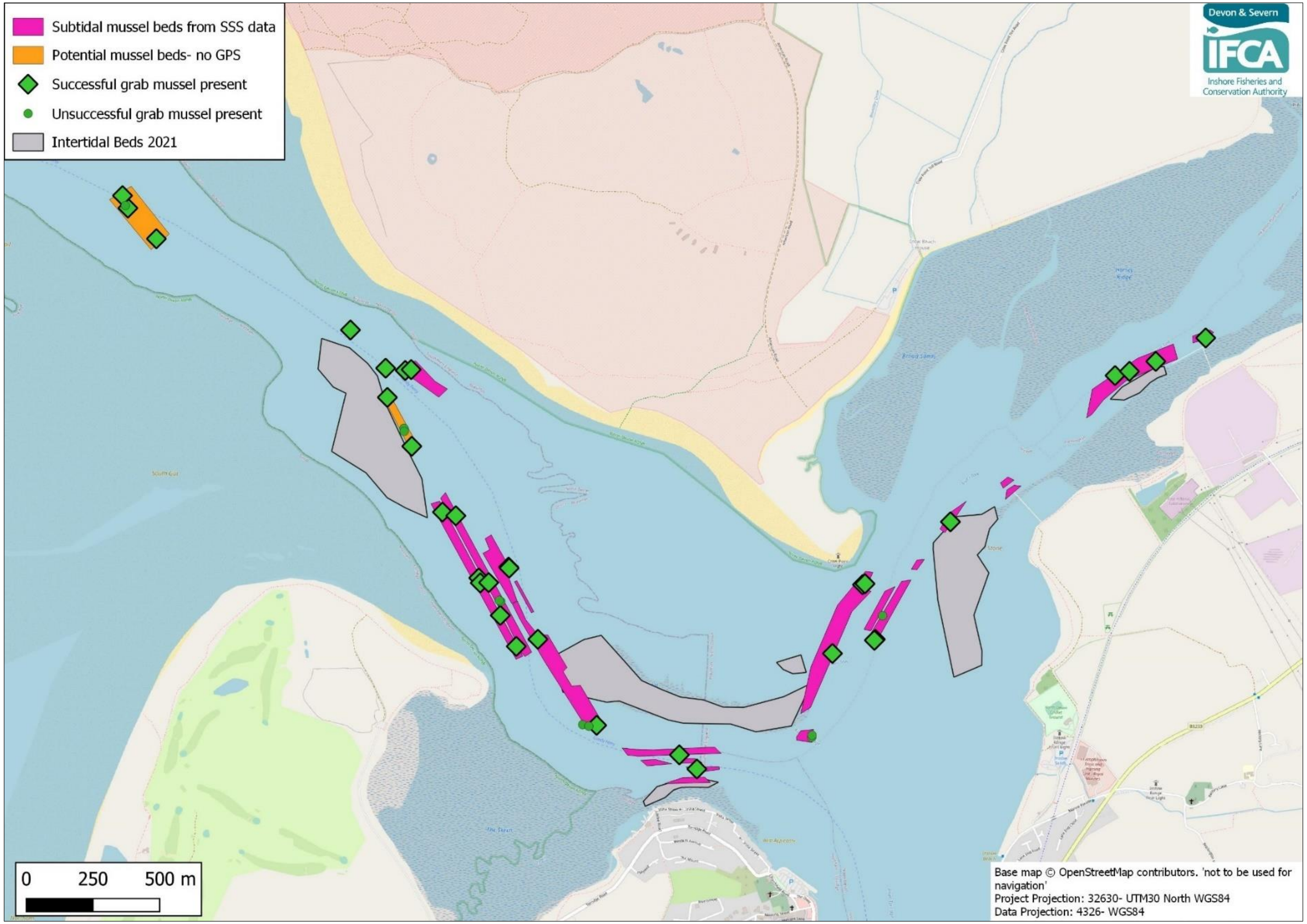

Figure 17 Location of mussel from grabs, SSS and intertidal mussel surveys. Green diamonds represent successful grabs with mussels, green circles are unsuccessful grabs with mussels present, pink polygons represent the mussels identified from the successful SSS tows, whereas the orange represents an estimate of mussels from SSS tows with failed GPS, grey polygons are the intertidal mussel beds from 2021 survey.

The size frequency distribution of mussels observed from all grab samples on 15/10/2021 (Figure 18) is indicative of at least two age classes: there is a clear bimodal (two-peaked) distribution of mussel lengths, with peaks at ~12mm and ~55 mm (Figure 19). A smaller third peak can also be seen at ~38mm. Mussels in the smaller size classes were typically found in the Pulleys to west of Sprat Ridge zone of the Estuary: the smallest 257 mussels (all 22mm or less) were found at stations 70 and 71 (numbered on Figure 11). These 257 mussels make up the entirety of the first age class seen in Figure *18*. The majority of the mussels in this smallest age class were smaller than any of the mussels collected in the 2020 survey. A large majority of the mussels that make up the middle peak (~ 38mm) are those in sample stations seaward of Pulleys, closest to the mouth of the estaury, particularly stations 131 –134. The 16 largest mussels were found in the Yelland area, furthest from the mouth of the Estuary.

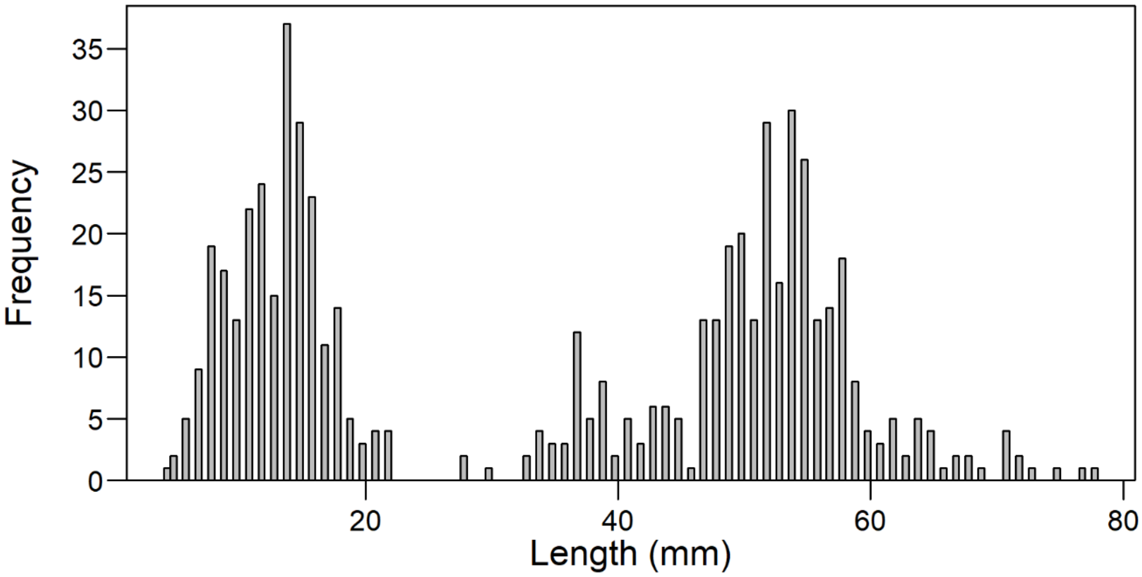

Figure 18 Size distribution of mussels retrieved in grab samples taken from subtidal areas of the Taw Torridge Estuary on 15/10/2021.

The distribution of different mussel lengths among different geographic areas is shown clearly in Figure 19. Figure 19 shows ‘empirical cumulative distribution functions’ (ECDFs), showing the cumulative proportion of mussels of each length found in particular geographic regions. The ECDF curves for the subtidal area between inner Pulleys and Sprat Ridge shows evidence of a bimodal distibution of mussel sizes (i.e. two clear sloping sections in the ECDF curve split by a flat area). Approximately 60% of the mussels sampled in these stations were < 22mm - these small mussels mostly came from stations 70 and 71. There is then a flat portion of the curve between 22mm and 40mm suggesting very few mussels within this size range were found. The rest of the stations in this area yielded mussels between 40 – 60 mm (Figure 19). The stations near the mouth of the Estuary mainly yielded mussels between approximately 24 – 42 mm, whereas in the stations from Lifeboat to Coolstone, and Yelland were generally larger: the majority of the mussels sampled were larger than 42mm (Figure 19).

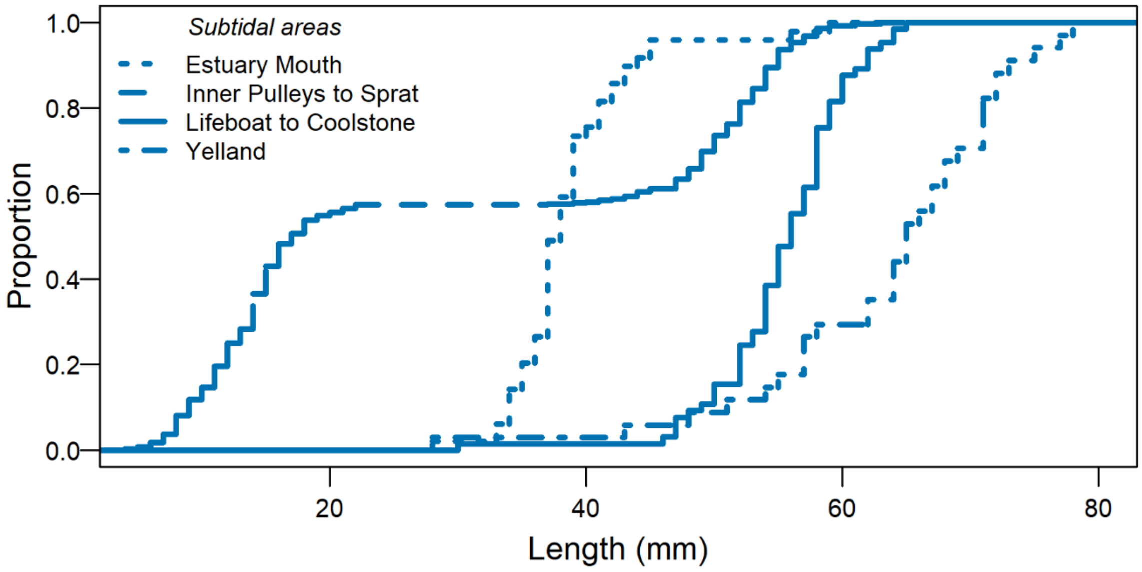

Figure 19 . Empirical cumulative distribution function for subtidal areas of mussels, showing the proportion of mussels in each length category (mm) in each of four subtidal areas: Estuary Mouth (mouth to Outer Pulleys; stations 58-59 & 131-139), Inner Pulleys to west of Sprat Ridge (stations 60-80, 121-130 and 140-144) Lifeboat to Coolstone (stations 56-57 & 81-110) and Yelland (stations 111-120).

Figure 20 overlays Figure 19 with the ECDFs for length of mussels found in intertidal areas surveyed by D&S IFCA during 2021. The median sizes (where proportion on the y axis equal 0.5) of subtidal mussels sampled between the Lifeboat and Coolstone beds and surrounding the Yelland mussel bed were larger than mussels at all intertidal beds. ECDF curves for mussels found at the intertidal Pulleys bed was the only one to show some evidence of a bimodal distibution of mussel sizes. Although these two sloping sections are not as pronounced as those seen in the subtidal area between inner Pulleys and Sprat Ridge, the first ‘bump’ in the ECDF for the intertidal Pulleys bed occurred at a similar size (~ 22mm) than that of the subtidal mussels in the area. Many of the mussels found in the subtidal area in the Estuary mouth were similar to the sizes of mussels found on the intertidal beds, particularly the intertidal Pulleys beds (shown by overlap of dotted blue and solid black lines on Figure 20).

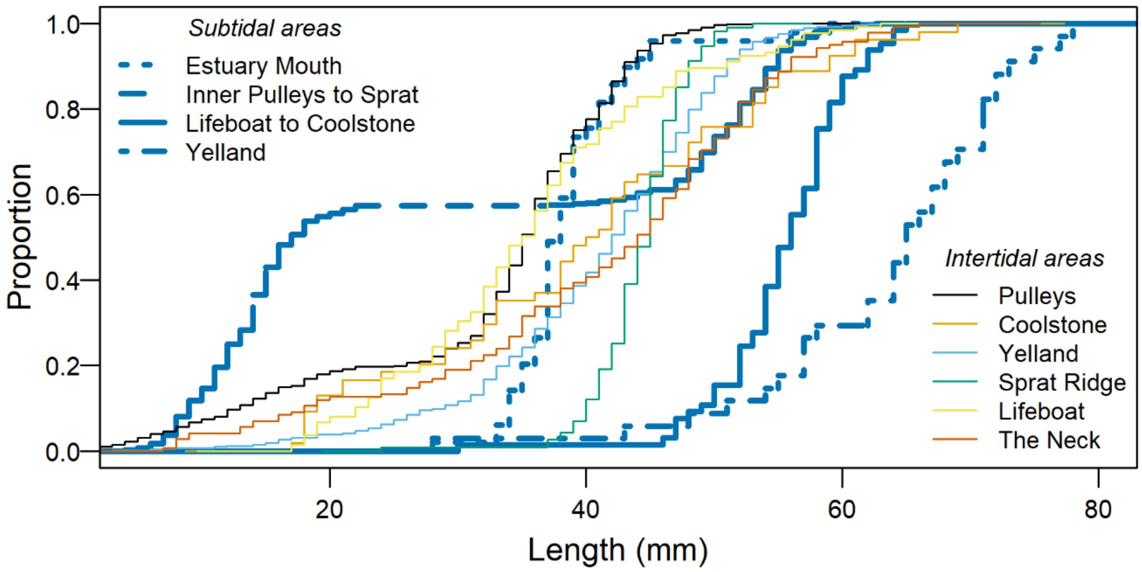

Figure 20 Empirical cumulative distribution function for subtidal and intertidal areas of mussels, showing the proportion of mussels in each length category (mm) in each of three subtidal areas (Estuary Mouth to Outer Pulleys: stations 58-59 & 131-

139; Inner Pulleys to west of Sprat Ridge: stations 60-80, 121-130 & 140-144; Lifeboat to Coolstone: stations 56-57 & 81-110; Yelland: stations 111-120) and six intertidal beds.

When comparing the ECDFs for subtidal areas between 2020 and 2021 (Figure 21), in most cases the shape of the curves between years seems to remain similar but indicates an upward shift in the size of mussels sampled (highlighted by the orange arrows on Figure 21). As mentioned above, the 2021 curve for the inner Pulleys to Sprat Ridge shows a bimodal distribution of mussel sizes with very few mussels between 22 – 40mm. The 2020 ECDF curve does not show the same bimodal distribution, but rather most mussels found were > 38mm. The 2020 survey did not sample subtidal stations surrounding the Yelland mussel bed.

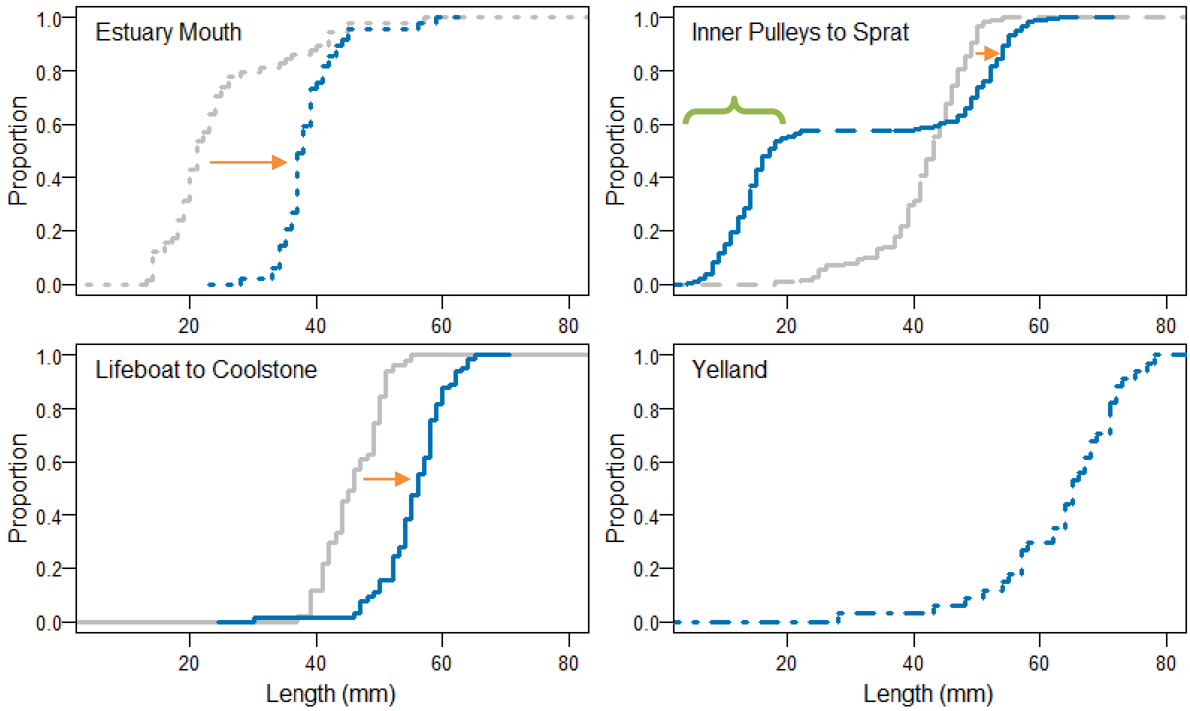

Figure 21 Empirical cumulative distribution function for subtidal areas of mussels in 2020 (grey) and 2021 (blue), showing the proportion of mussels in each length category (mm) in each of four subtidal areas: Estuary Mouth (mouth to Outer Pulleys; (stations 58-59 & 131-139), Inner Pulleys to west of Sprat Ridge (stations 60-80, 121-130 & 140-144) Lifeboat to Coolstone (stations 56-57 & 81-110) and Yelland (stations 111-120). Orange arrows indicate a shift upward in mussel size distribution from 2020 – 2021, suggesting likely annual growth of the mussels in the subtidal beds. The green curly bracket highlights an increase in small (<20 mm) mussels in 2021 in the Inner Pulleys to west of Sprat Ridge zone, which suggests there may have been a spawning event and settlement in this area following the 2020 sampling.

4. Discussion

One of the aims of the project was proof of concept for the side scan sonar methodology to undertake subtidal mussel extent surveys. The use of SSS was successful in identifiying areas of mussels. The signiture the mussels produced was confirmed by the grab survey across the Estuary along with the short camera tow in a small area of what was believed to be dense mussels. The SSS data gave a better undertsanding of mussel bed extent and location than grabbing alone could do. The is a survey that can be repeated with a few changes which will be discussed in the limitations and recommendations of this report.

The area between Sprat Ridge and Pulleys had a high proportion of mussel presence in grabs, this is in line with the fisher's expectations of mussel bed presence in this area and the survey results from 2020. The fisher had some concerns before the survey that much of the mussels from this area may have washed away during some large spring tides with a lot of fresh water run off in the weeks before. The survey revealed that mussels were still present in this area. While some of the mussels may have washed further down stream or out to sea, this could not be confirmed or dismissed on the basis of this survey.

The results indicated that there was a likely spawning event, and subsequent settlement, between the 2020 and 2021 surveys. The small mussels, which were found in the area between Sprat Ridge and the Inner Pulleys, were not seen in the 2020 survey, with small mussels being absent from grabs obtained from subtidal areas upstream from the outer Pulley's area towards Coolstone in 2020 (Stewart, 2020). There is a possibility that this area was missed in 2020, however a successful grab was carried out within 12m of the 2021 grabs and the mussel size ranged from 25-50 mm with the average size being 40. Therefore, it is more likely that a spawning event had occurred. This spawning may have spilled over onto the Pulleys intertidal bed as the intertidal Pulleys bed was the only one to show some evidence of a bimodal distibution of mussel sizes, although not as pronounced as the subtidal area (Figure 20). The ECDF for the Pulleys intertidal bed in the 2020 report (Stewart, 2020), did not show a bimodal distribution, further evidencing that there was a spawining event between the 2020 and 2021 survey. The area around Pulleys could either be the place where the spawning happened or it could be a good place for mussels to settle having spawned elsewhere.

Before the 2020 survey, the fisher indicated an expectation of mussels in the area upstream of Sprat Ridge, towards Coolstone and Crow Point; however there was an absence of mussels in the 2020 survey which may have been attributed to grab failure, although successful grabs in this area also showed a high proportion of mussel absence (Stewart, 2020). However in the 2021 survey, mussels were present in grabs within this region and were picked up on the SSS data, ranging from the eastern end of the intertidal Sprat Ridge bed, up to the end of Crow Point and across the Estuary towards Coolstone in areas that were surveyed with the grab and SSS. The size of the mussels in these grabs ranged from 46 to 65mm, this indicates that these are not new mussels and were, in fact, missed with the grabbing in 2020.

Mytilus edulis growth rates vary by location depending on, for example, water quality, temperature, water flow and food availability, but average growth rates of approximately 10mm per annum may be expected for southern England (Bayne and Worrall, 1980, Handå *et al*., 2011). Figure 21 suggests that the size distribution is the same for the mouth of the Estuary and Lifeboat to Coolstone and the shift upward is caused by annual growth of the mussels on the bed. Although the Pulleys to Sprat Ridge shows a bimodal distribution of mussels which wasn't present in 2020, the second size class shows an annual increase as seen on the other beds.

Figure 19 demonstrates that the size of mussels present increases with distance upstream, with one exception being the first size class at the Pulleys to Sprat ridge area. Similar to the 2020 survey (Stewart, 2020), smaller mussels were lacking from grabs upstream with the average size being 55mm from Lifeboat to Coolstone and 63mm at Yelland. However, unlike the 2020 survey, smaller mussels were not completely absent from the grabs with mussels less than 30mm being present throughout the Estuary.

The short video tow indicated that although the mussels in the area shown in Figure *15* were dense, there were small sandy areas in-between peaks and troughs of mussels. In some cases, this could have resulted in the grab missing mussels in areas of potentially overwise dense mussels. The side scan sonar data allow for a better understanding of the extent of the beds where the grab may have failed or landed between clumps of mussels. Using both methods in tandem gives a clearer understanding of the mussels in the Estuary.

5. Limitations and Recommendations

As this was the first time trialling the use of a side scan sonar in this Estuary to undertake a mussel survey a few problems were encountered that could be improved in future surveys.

Tow lines were not planned pre-survey as it was not clear before the survey which areas of the Estuary would need to be surveyed and how the towfish would work in the tidal conditions present. Tows were carried out from the recommendation of the skipper as the survey was progressing. The software which is used with the SeaKing towfish does not allow for GPS tracks of previous and current tows to be mapped and viewed live; this resulted in the reliance on the vessel plotter to understand where the tows had been carried out. The vessel plotter failed for the first few tows of the day and therefore tow GPS data for these tows were not available for the remaining planning. The vessel plotter also shows the vessel track as a thin line, not allowing the SSS operator to check overlap of towfish tracks during the survey.

As mentioned, there was an issue with the GPS dropping out in the first few tows. This was due to the USB connection on the computer used. The problem was not picked up for the first couple of tows due to the software not showing GPS failure. Once the issue was picked up, the USB was taped into the port which stopped the connection issues.

It would be recommended to use a different side scan sonar for future surveys on this Estuary. The Edgetech 4125 SSS would be recommended as it is lightweight to allow for hand hauling, produces clearer imagery than the SeaKing and the software allows for live viewing of the tracks. This live viewing would allow the surveyor to have a clear picture of the range that has been covered as the survey is in progress and to add additional lines to fill gaps if required.

The SSS survey should be ground-truthed by grabbing to firstly determine the signature acquired by a different frequency and quality of sonar, and to understand any changes in the size distribution which cannot be gained for the sonar data. Overall, the data collected for this report indicate that combining local knowledge with ground-truthed SSS surveys can reliably establish the extent and size distribution of subtidal mussel beds.

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Annex 1: Images from grabs


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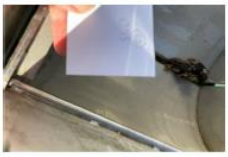
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