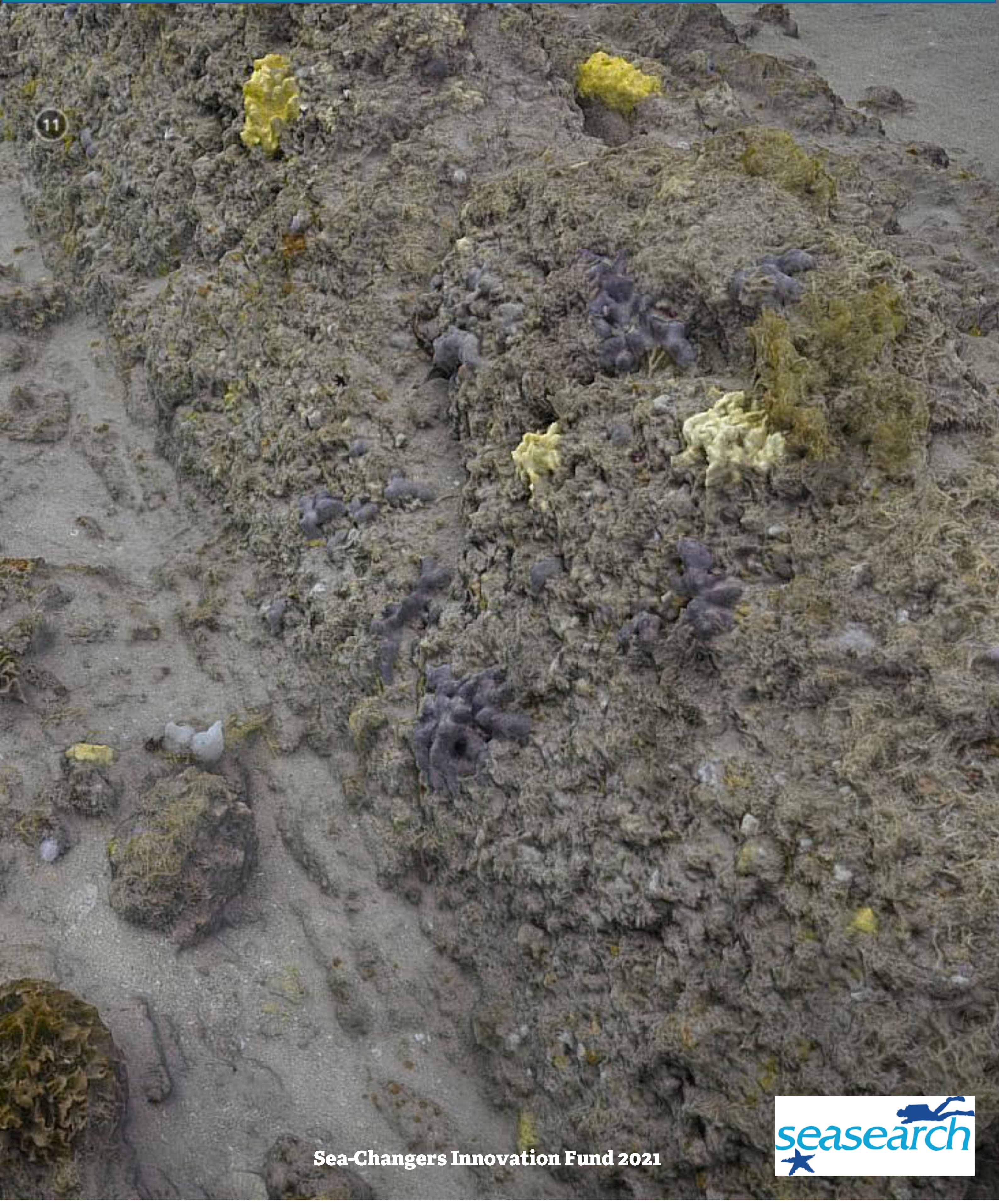
Using photogrammetry to detect change in seabed habitats

Dorset Wildlife Trust



Sea-Changers Innovation Fund 2021

Using photogrammetry to detect change in seabed habitats in a Marine Protected Area

Peter Tinsley &Matt Doggett

A report by Dorset Wildlife Trust
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The use of aerial surveys, from satellites to drones, has proved to be very successful at detecting change in terrestrial and shallow coastal habitats, over a variety of scales. Getting the equivalent information from the seabed is very challenging, even in areas of good underwater visibility, but particularly in the English Channel, where underwater visibility is usually only a few metres. Acoustic remote sensing techniques, such as multibeam echosounder survey (MBES) and sidescan survey are useful for providing detailed physical seabed data at scales up to one metre resolution over large areas and these data can be used, along with data from ground-truthing surveys to create broadscale habitat maps which are useful for informing management decisions. These techniques are generally limited to imaging the physical texture of the seabed – rocks, ledges, sediment banks and ripples - it is rare for such surveys to differentiate areas of biological cover. Some habitats, such as biogenic reefs and possibly seagrass beds, can be detected from acoustic data but generally detecting habitat change involves collecting numerous point or line samples (diver observation, grab sample, drop camera image) and carrying out statistical analyses – all of which is time-consuming and expensive.

Photogrammetry offers an opportunity to visualize the seabed at a scale between the broad scale acoustic survey (1:5000) and the large scale images from individual photographs (1:5 to 1:1) by stitching together hundreds, even thousands of individual overlapping photographs to produce a single, very high resolution scaled image. The technique has been used by underwater archaeologists for some time – this project looked at its usefulness for detecting change on the seabed and whether it can provide useful indicators for assessing the condition of protected reef features.

Three sites were visited in this study. All were examples of protected reef habitat within marine protected areas. The aim was to image an area of at least 5m x 5m – considered the minimum area for determining a biotope. One important factor for site selection was the presence of a landmark feature in or near the site distinctive enough to enable divers to easily re-locate the site on a future visit. For more detailed information on how to collect images for underwater photogrammetry, see Appendix 1.

The resulting images were processed using Agisoft Metashape[1]. This uses a technique known as Structure from Motion (SfM) to create highly detailed, scaled 3D models from large numbers of overlapping photographs. Many conspicuous taxa are easily identifiable in the models and can be counted, measured and assessed for condition. These models provide a previously impossible view of the seabed – a diver rising up from the seabed to get a wider view would lose sight of the seabed before getting a fraction of the view from the model. An example can be seen here - https://tinyurl.com/25z3j8zj and a still image from that model is shown in Figure 1

[1] Other photogrammetry software packages are available – e.g. Pix4Dmapper, Recap, ArcGIS Drone2Map, and 3DF Zephyr. It is also possible to use free, open source software, such as VisualSFM and Meshlab

Figure 1 Example of 3D model showing a section of Long Ledge, Lyme Bay SAC. Credit – Matt Doggett.

It is possible to export a sub-millimetre resolution scaled orthomosaic[2] from the model. This can then be imported into a GIS, such as QGIS, for analysis.   Measurements can be taken from the reference tiles (10cmx10cm) placed on the seabed to ensure that the map scaling is accurate – see Figure 2

(Ventura, et al., 2020) were able to achieve length accuracy of 97% from models of *Sabellaria alveolata* reefs. To achieve that level of accuracy for ross corals, for example, would probably require dedicated modelling of individual colonies. Measurements of the six 10cm ground control points in the June model of the Lulworth Banks site were almost all within 2% of the true value – one diagonal measurement, where the target tile was slightly distorted, had a 6% error.

[2] An ortho-image is a (usually aerial) photo that has been corrected for lens distortion, camera tilt, perspective and topographic relief. This means there is no distortion and the scale is uniform across the image. An orthomosaic is a (very) large ortho-image created from many individual photographs.

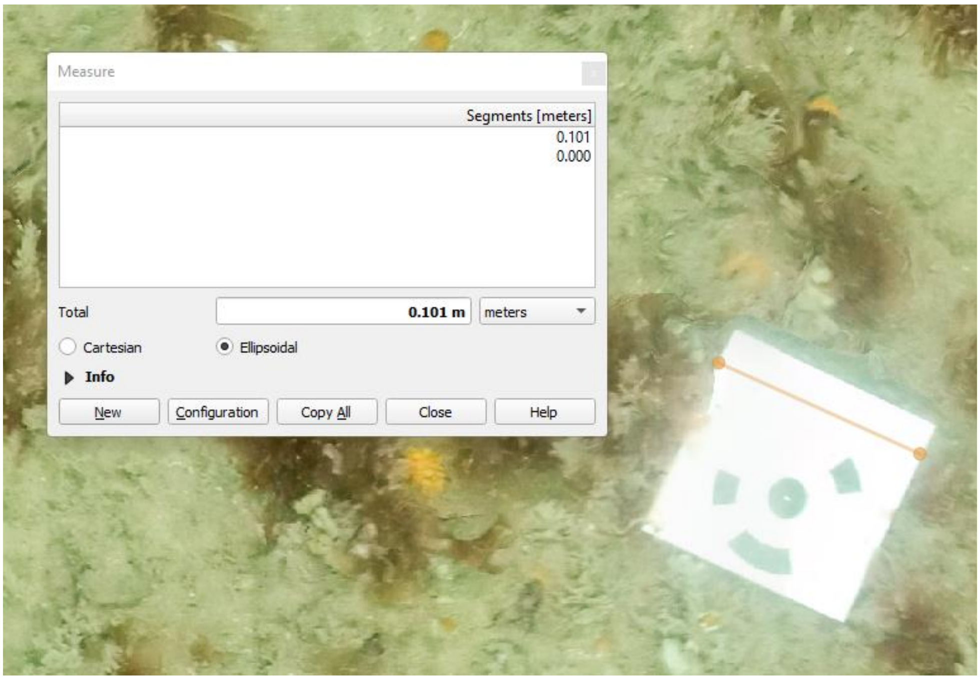


Figure 2 Checking the accuracy of scaling of the final orthomosaic in QGIS

Identifiable and conspicuous taxa, such as ross corals, pink seafans and massive or erect sponges can then be digitized onto a GIS layer by drawing a polygon around the object – each object given a unique identifying number. The *minimum oriented bounding box* tool produces a table with the maximum dimension of each object. It should be noted that measurements taken from an orthomosaic assume the surface is flat.

Subsequent mosaics from future surveys can be georeferenced against the first image, using identifiable landmarks. Any objects in the new layer can be digitised , and individual objects matched against the previous layer, allowing growth rates and survival rates to be calculated. Newly settled individuals can also be identified to indicate recruitment rates, though these are near the limit of detection and are likely to be underestimated.

Site 1: Long Ledges, Lyme Bay

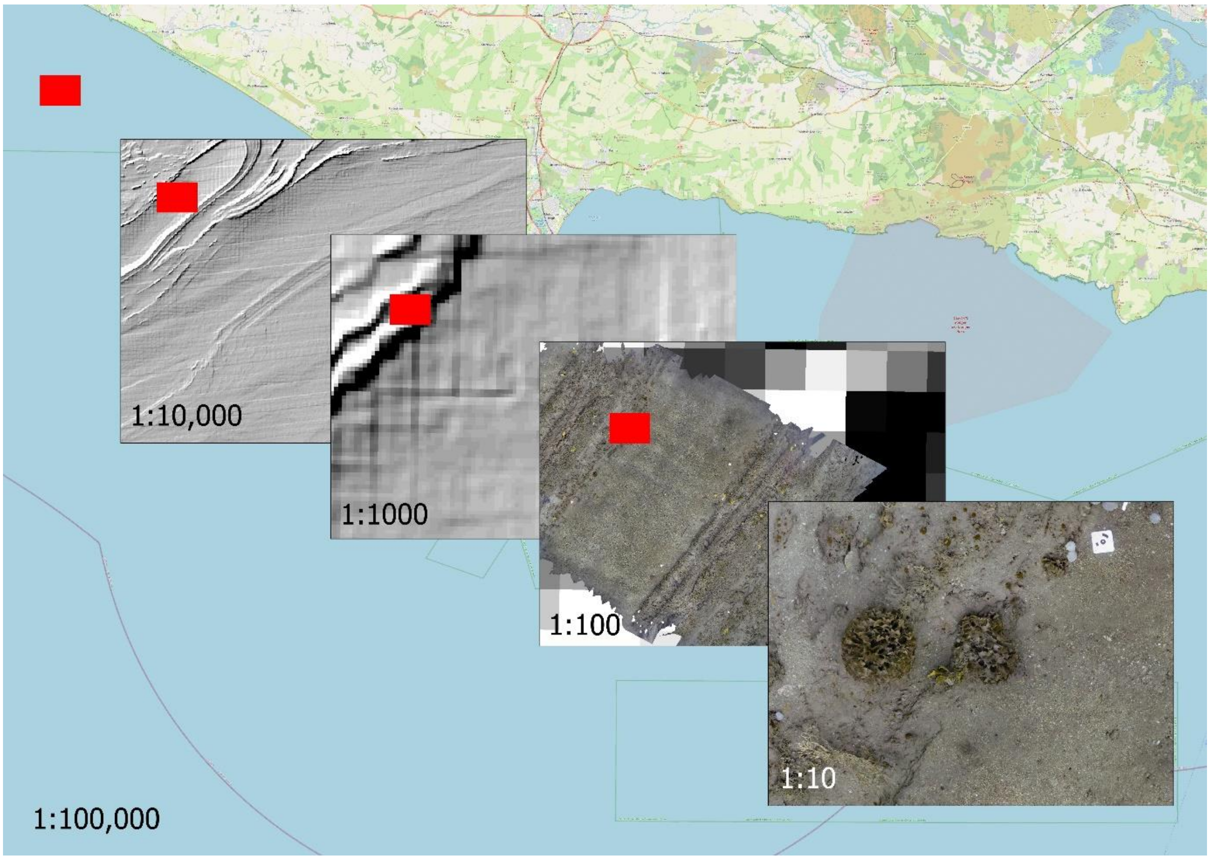


Figure 3 Photomosaic of Long Ledge in the context of different map scales. Note – map scales refer to an A2 printout. Contains map data from openstreetmap.org & contains Ordnance Survey data © Crown copyright

The first trial was at Long Ledges in the Lyme Bay and Torbay Special Area of Conservation, about 4km offshore, between Seatown and Eype. The site is protected from mobile fishing gear by a Southern Inshore Fisheries and Conservation Authority (IFCA) byelaw and by The Lyme Bay Designated Area (Fishing Restrictions) Order 2008. The site was visited on 16/09/2021. The seabed is approx. 23m deep, with the reefs rising about 2m above the intervening sediment. The model (https://tinyurl.com/25z3j8zj) was created from 1844 images taken on a Panasonic Lumix S1H using ambient light and manual white balance. The use of natural light makes the colours look rather muted compared to an artificially lit scene. The mosaic covers an area of approx. 211m^2.

The description from the Seasearch dive is as follows:

> *Parallel rock ledges running SW to NE, separated by mobile sediment in waves with crests perpendicular to the ledges. NW facing scarps with boulders at the base. Some mobile sediment on the dip slope. Mixed sponge/cnidarian/bryozoan turf on all upward facing rock faces; Cellaria dominated turf with some sponge crusts on steep and vertical faces.*

There are three distinct biotopes:

Circalittoral bedrock reef with diverse animal turf

Irregular bedrock slope dipping to the SE, and upward facing surfaces of boulders at the base of the NW facing scarp. Dense and varied mixed animal turf with a thin overlay of mobile sediment in places; many seafans.

Circalittoral bedrock reef with sponge cushions and crusts

NW facing scarp faces, vertical in places with some boulders at the base. Cellaria and sponge crusts on verticals, See habitat 1 for upward facing surfaces.

Circalittoral medium sand

Mobile sediment in waves perpendicular to and between the ledges, probably over some cobble or small boulders. Sponges and seafans with bases part buried in sediment. Some scallops with a preponderance of juveniles 6-7cm. The sediment habitat to the southeast of the ledge looked as though it had been deeply disturbed since last visit. Very little in the way of infauna e.g. no large *Molgulas*, polychaete tubes and burrowing brittle stars. Possibly by surge event at the end of January 2021 with long period waves of 3+ meters.

The full Seasearch species list is found in Appendix 2

The site is known to host an unusually high diversity of sponge species, even compared to nearby ledges (Baldock, 2021). There are two rocky ridges, approx. 10m apart, separated by slightly duned sediment with numerous visible burrows. The ridges run NE/SW with steeply inclined bedding planes producing near-vertical surfaces facing SE and northwest. There are some interesting differences between the two ridges, despite being so close together – most of the ross corals and nearly all of the *Phallusia* sea-squirts are around the NW ridge, for example, while *Aiptaisa* seems to prefer the south-east ridges. As this site contains steep and near vertical rock faces, measurements taken from the orthomosiac on these steep area will not always be fully representative.

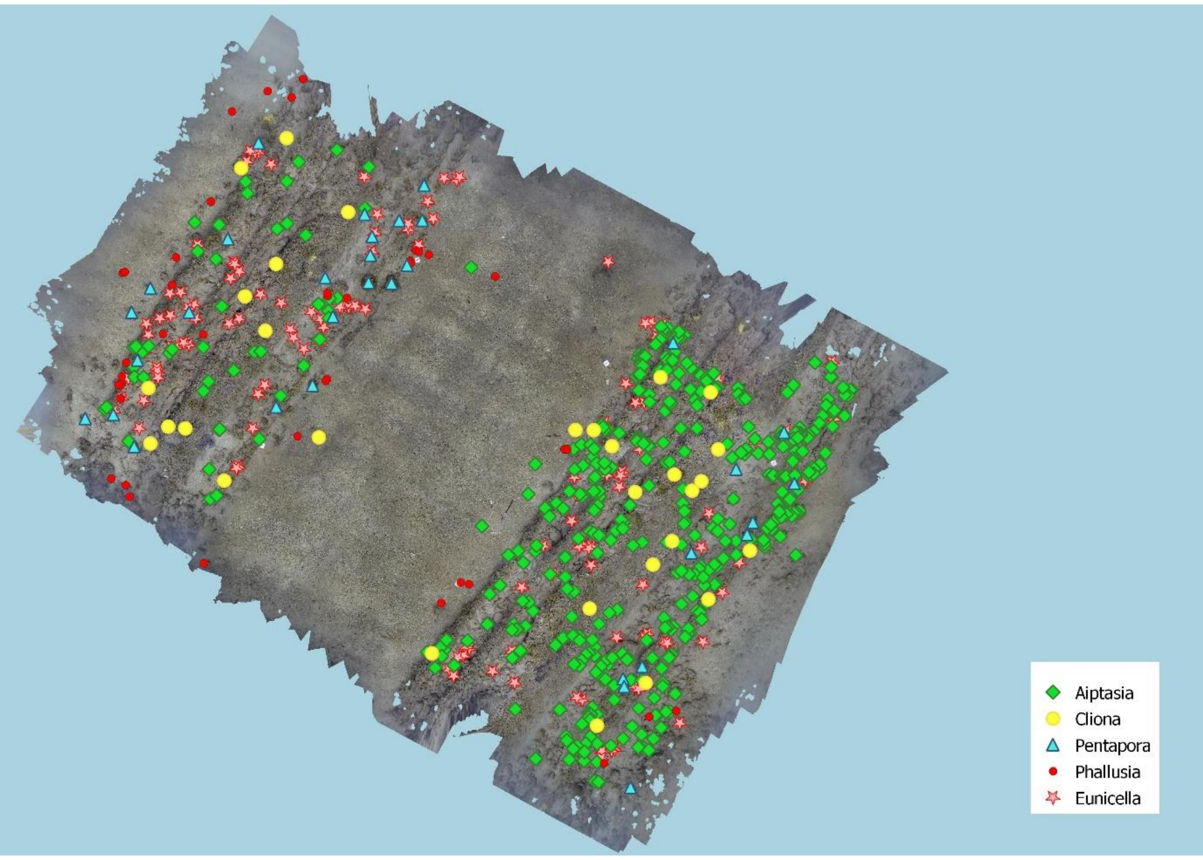


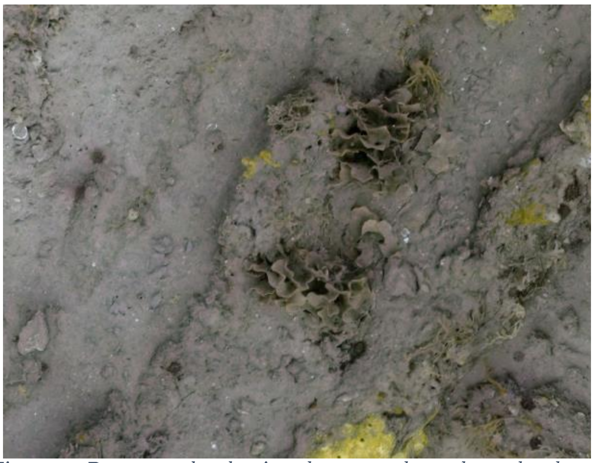
Figure 4 Distribution of conspicuous species at Long Ledge

Ross corals – Pentapora foliacea

Ross corals, *Pentapora foliacea*, are calcified bryozoan colonies. The colonies are slow growing and long-lived, reaching up to 80cm broad and 50cm high. They are distinctive and easy to recognize, forming discrete colonies, and their fragility to both natural disturbance and human impacts makes them an ideal species to study with this technique, tracking the fate of individual colonies over time.

The ross coral colonies proved easy to distinguish in the orthomosaic and 33 individual colonies were detected and digitised. Colonies are mostly located at the bottom of the reefs, with all but 4 found to the east of a ridge, suggesting a preference for shelter.

Colonies range in size from a few centimeters to 39cm across. Colonies 25 and 26 are close together with what look like broken flakes between them. These may have once been a single, larger colony – which would have been 46cm across. Colony 29 may also be broken flakes from a nearby colony.



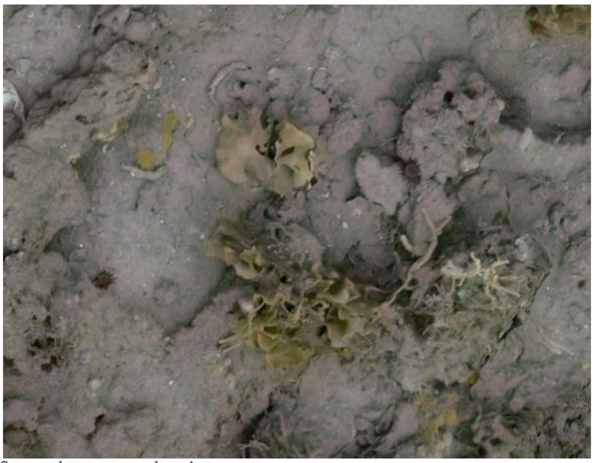


Figure 5 Ross coral colonies that may have been broken from larger colonies.

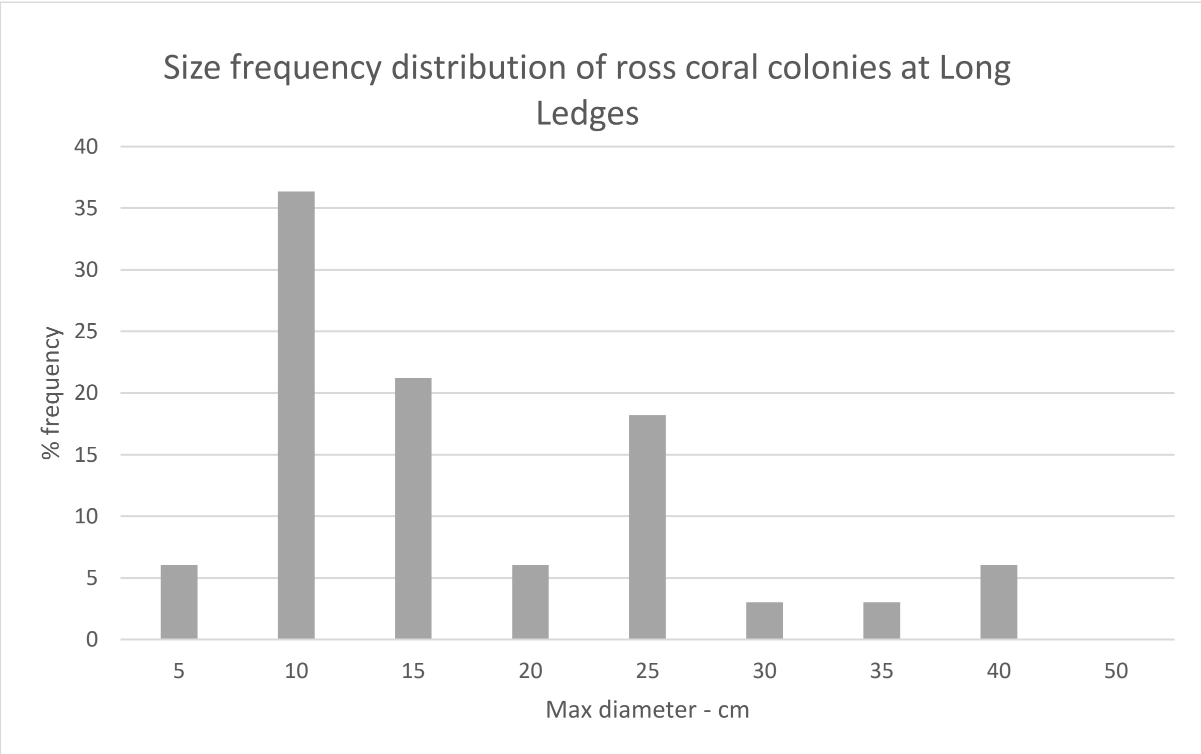


Figure 6 Size frequency distribution of ross coral colonies at Long Ledges, Lyme Bay SAC. n=33

This site has not been revisited, so it is not possible to detect change, but the population structure, along with the signs of visible damage, can provide clues, particularly when compared with other sites. Figure 6 shows the population structure of ross corals at this site – the under 5cm colonies are likely to be under-recorded.

Pink seafans – Eunicella verrucosa

The rock ledges at this site are covered in a tall mixed turf of often spindly sponges, bryozoans and hydroids, with many small seafans. This is challenging for the software to mosaic making it difficult both to identify small seafans and to judge the size of larger fans. The rather muted colours from the available light photography and the number of similar looking branching structures add to the problem of recognizing seafans in the mosaic. An attempt has been made to measure the maximum dimension of each fan but this has to be treated with some caution.

129 seafan colonies were digitized, up to 37cm across. This represents a density of roughly one fan per square metre of rocky habitat.

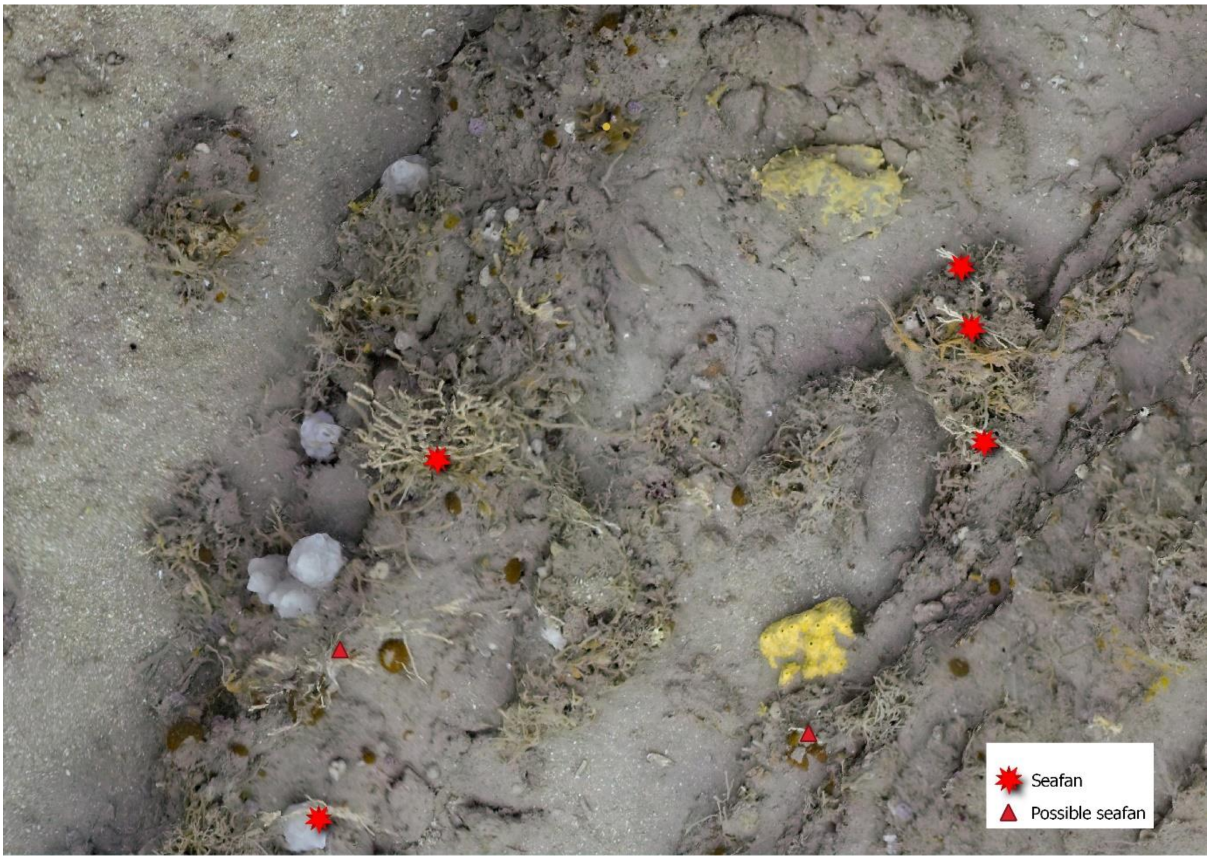


Figure 7 Sample area from Long Ledges orthomosiac illustrating the difficulty in recognising seafans among other turf species.

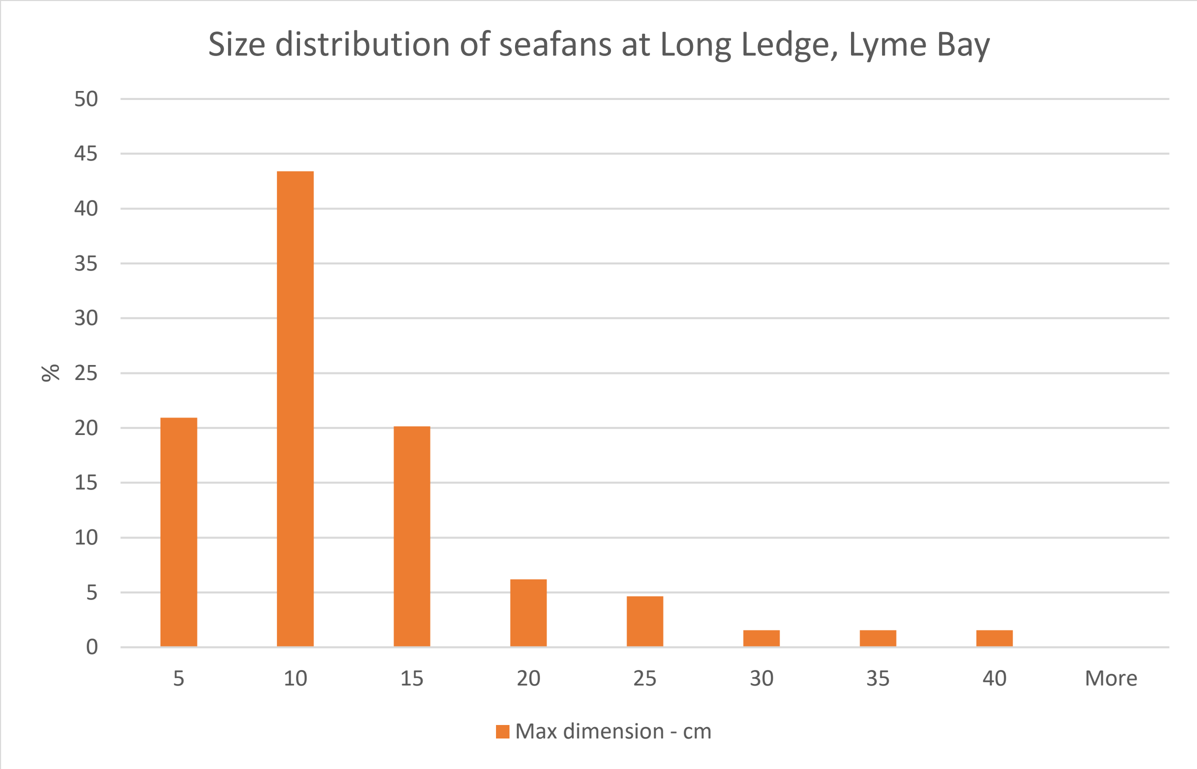


Figure 8 Size frequency distribution of seafans at Long Ledges, Lyme Bay SAC. n = 139

As with the ross corals, the smaller seafans are tricky to spot, but there are a lot of small colonies with only one or two branches. There are few colonies larger than 25cm. There are a couple of instances of detached fans or branches of fans lying on the seabed, suggesting some recent disturbance.

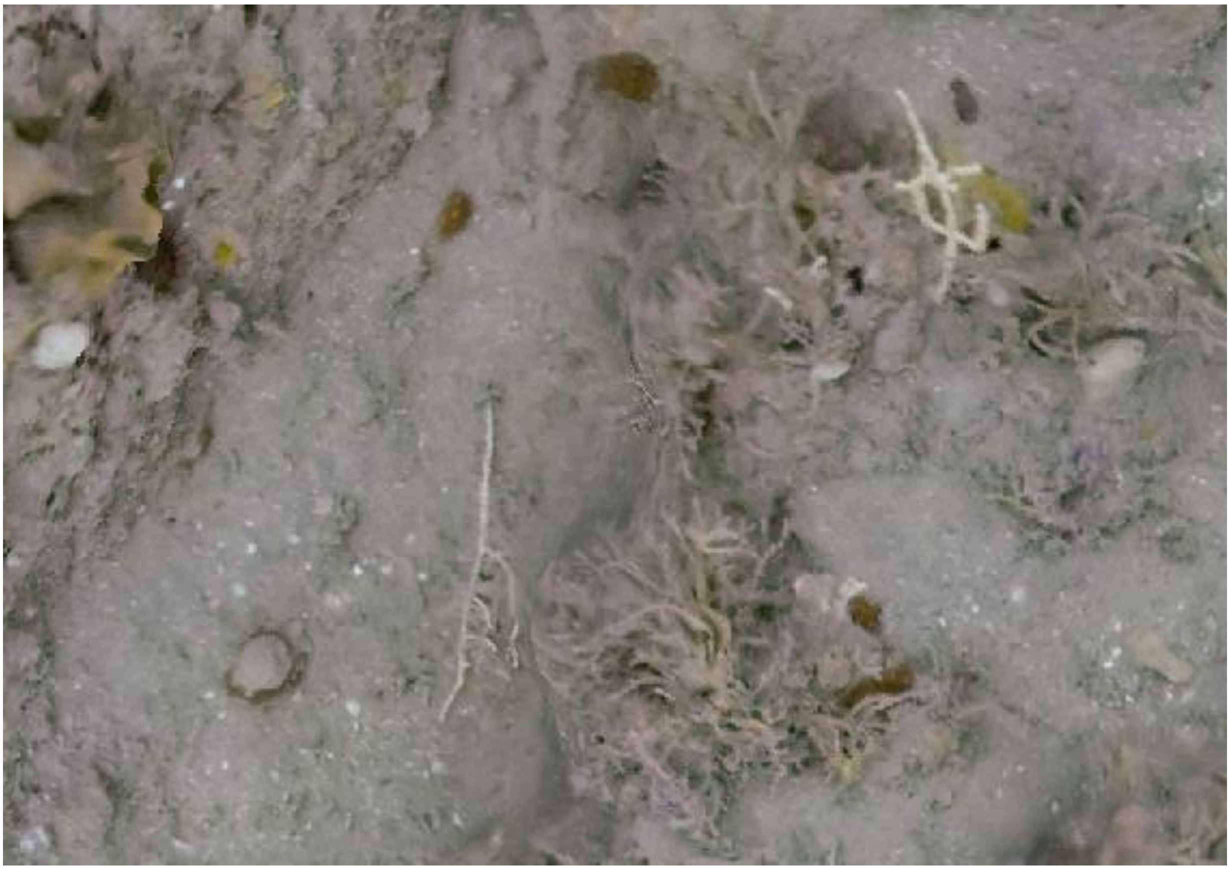


Figure 9 Detached seafan lying on the seabed alongside the ledge.

Site 2: Worbarrow Reefs Seafan site (*Eunicella verrucosa*)

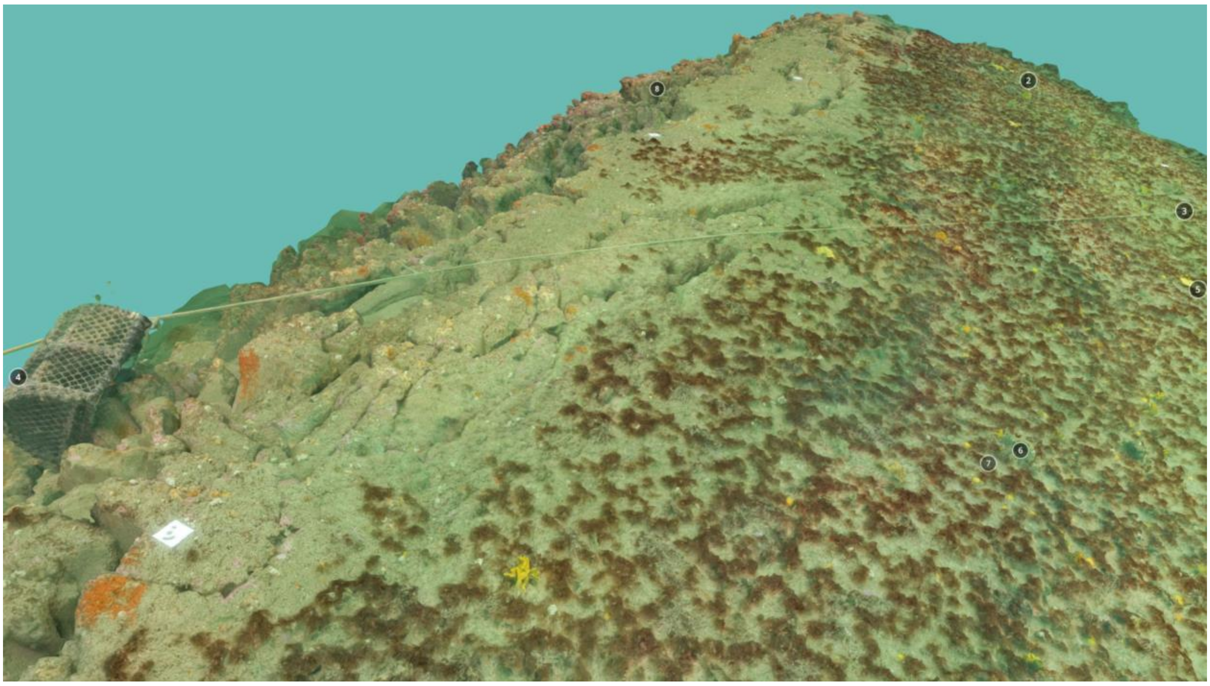


Figure 10 3D model of Worbarrow Reef site – credit Matt Doggett

The second site, south of Worbarrow Tout, is part of a long, narrow ledge with a smooth, gently sloping top about 20m wide, dipping into a gravelly sediment to the north and with an eroding bouldery edge to the south. Depth range is from 19 to 22m. The site is within the Studland to Portland Special Area of Conservation and the Purbeck Coast Marine Conservation Zone and is covered by a Southern IFCA byelaw banning mobile fishing gear. A distinctive fault in the ledge provides a suitable reference point to relocate the site for future surveys. The ledge is known to support a population of pink seafans, *Eunicella verrucosa*, at a density of 2-3 fans per 10 square metres. (Tinsley, 2005).

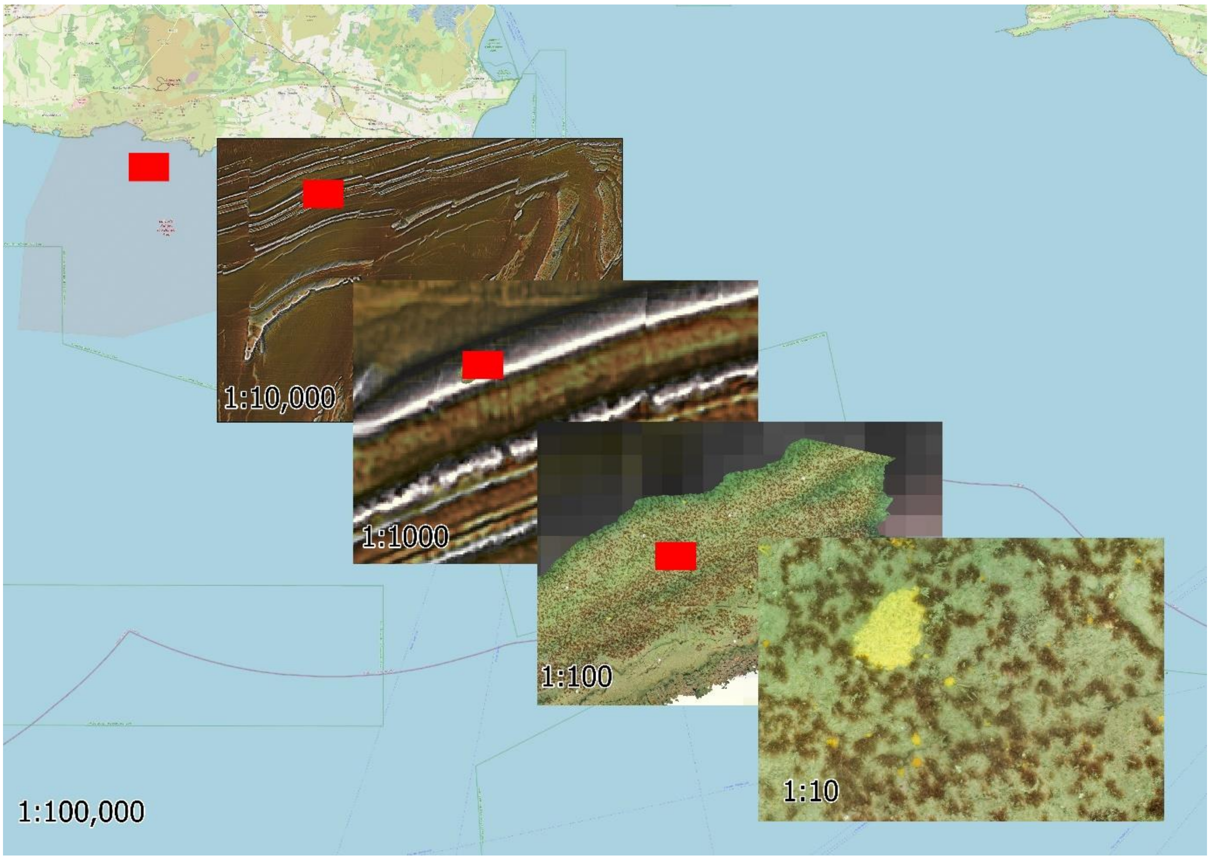


Figure 11 Photomosaic of Worbarrow Seafan reef site in the context of different map scales. Note – map scales refer to an A2 printout. Contains map data from openstreetmap.org & contains Ordnance Survey data © Crown copyright

The site was chosen for its seafans, but other taxa are identifiable in the images. The model can be seen here - https://tinyurl.com/2cehhtaz . Much of the flat reef top is covered in clumps of red algae and scattered among this are sponges – mainly *Polymastia* species, but also branching sponges and a few large *Cliona celata.* There are also some small ross corals, *Pentapora foliacea*, on the reef top. This matches the description of the site in 2004. The seafans here are easier to outline than in the Long Ledges image - the terrain is much flatter and the surrounding turf is low. Measurements taken from the image are thought to be more reliable – as long as any individual colony is wider than it is tall, the maximum size measurement should reasonably dependable. That said, because of the shape and orientation of the colonies, the mosaicing software does not deal with seafans as well as it does ross corals and it can sometimes be a challenge to determine which are whole seafans and which are sections duplicated by the software trying to make sense of all the fine branches. Looking only at the orthomosaic, the seafan shown in Figure 12 could be construed as two, or even three seafans. The 3D model shows that this is most likely a single seafan.

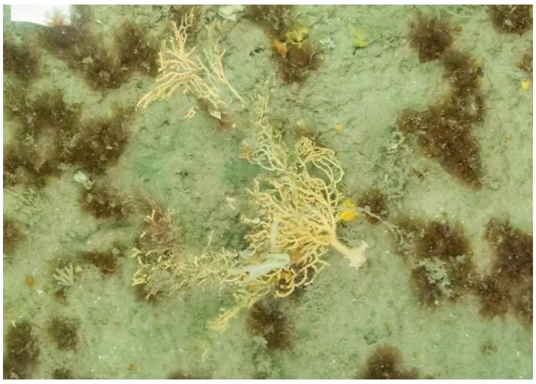
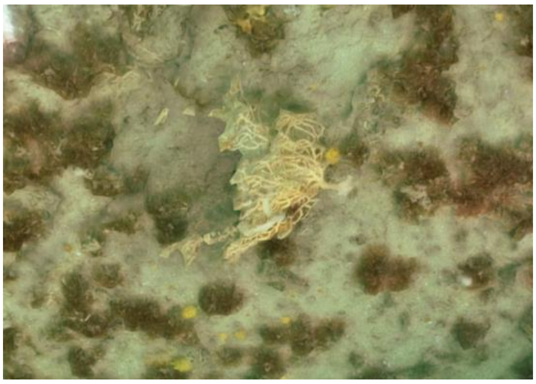
 

Figure 12 The same seafan as rendered in the orthomosaic (left) and the 3D model (right)

The density of seafans is 3.8 per 10 square metres, slightly higher than reported in 2004.

The south-facing edge of the reef is notably different – the surface is very irregular and the biota very different – the are no seafans or ross corals here and the sponges are different – mostly more encrusting species, including *Hemimycale columella* and *Dysidea fragilis*. Mobile species can be seen among the boulders, including starfish, *Henricia*, cuckoo wrasse, *Centrolabrus mixtus*, and large edible crab, *Cancer pagurus*. There are also signs of human impact, including a half-metre long artillery shell – a fairly common sighting in this area, being in the middle of the sea danger area for the Lulworth military firing range, and a lobster pot with the rope stretched across and in continuous contact with the reef top.

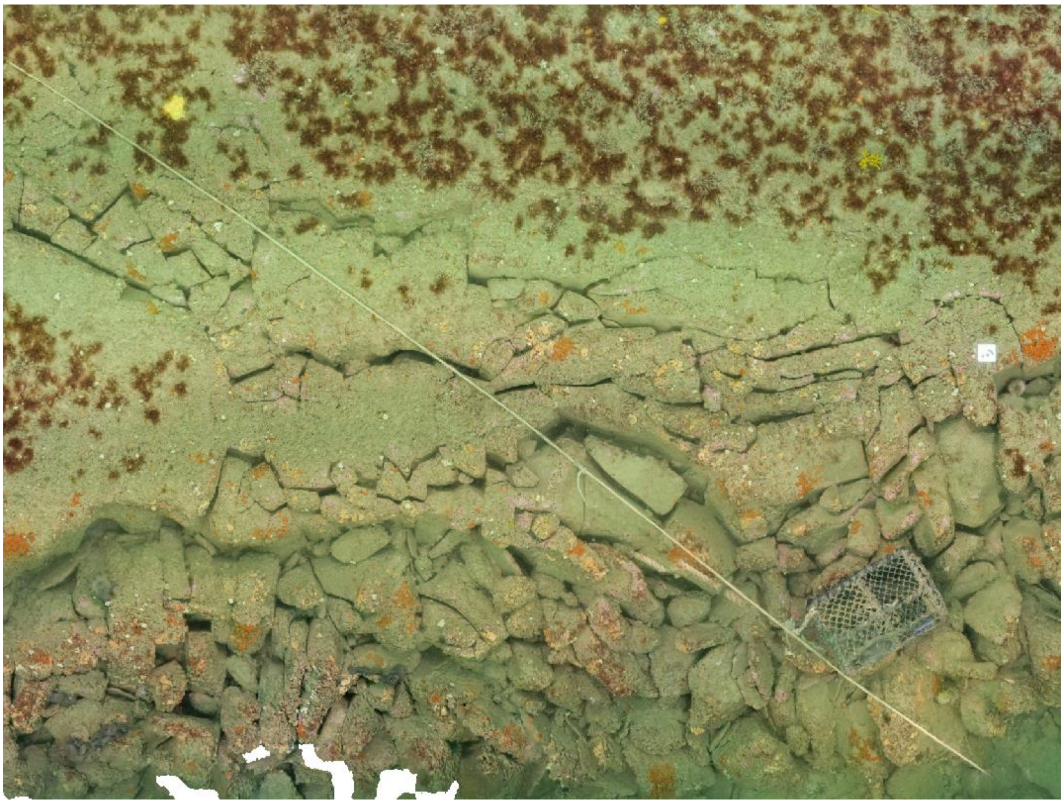


Figure 13Lobster pot with rope stretched across reef top

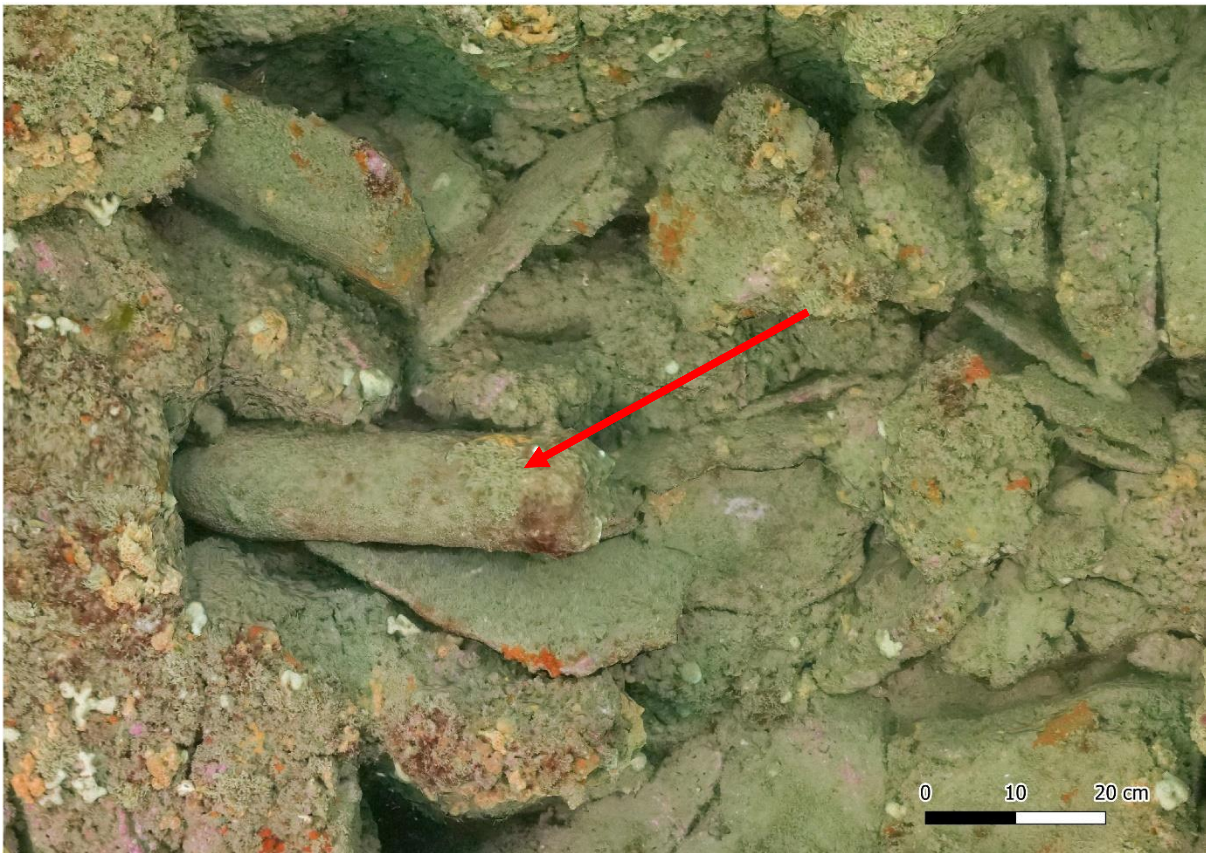


Figure 14 *Artillery shell alongside reef edge*

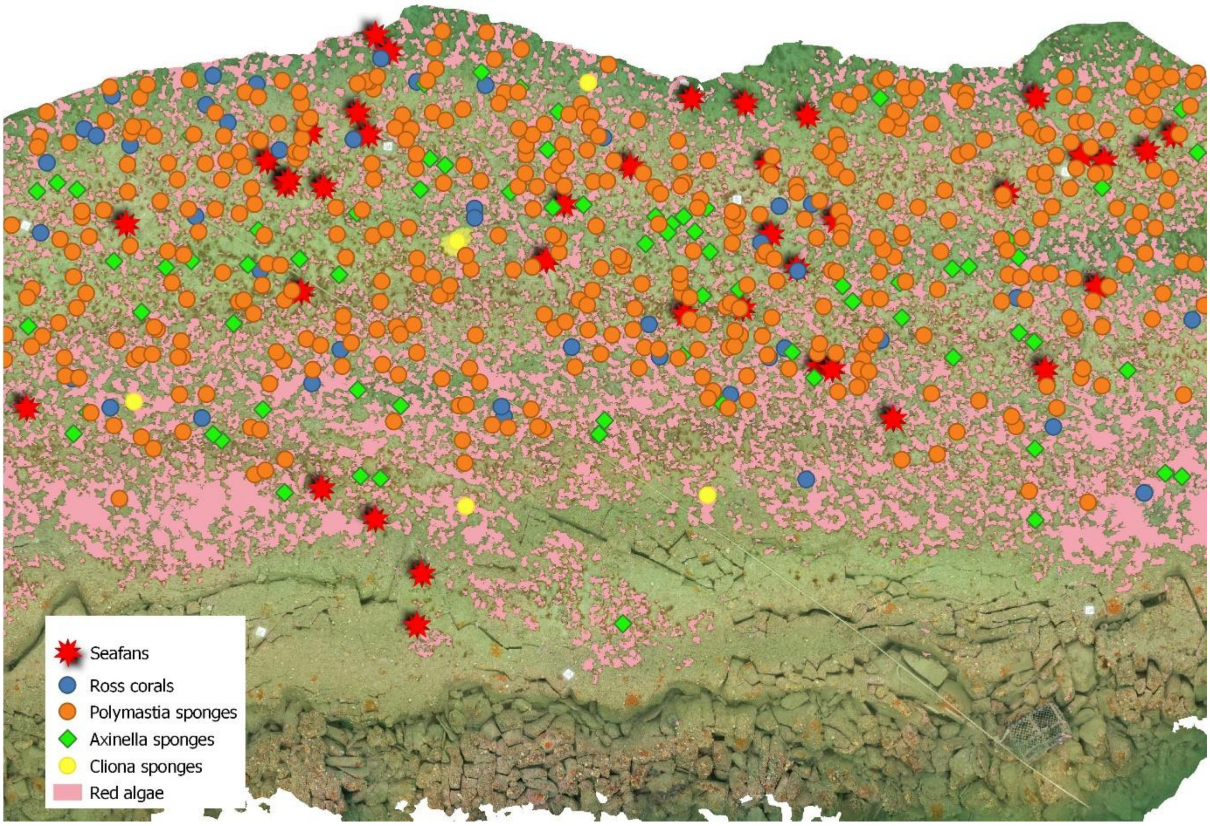


Figure 15 *Distribution of conspicuous species on reef slope*

Seafans – Eunicella verrucosa

Seafans at this site are entirely restricted to the pavement-like reef slope. 45 seafans were recorded, ranging from very small colonies with only one or two small side-branches to one individual over 40cm. There is a greater proportion of large seafans here than at either of the other sites investigated – see Figure 32.

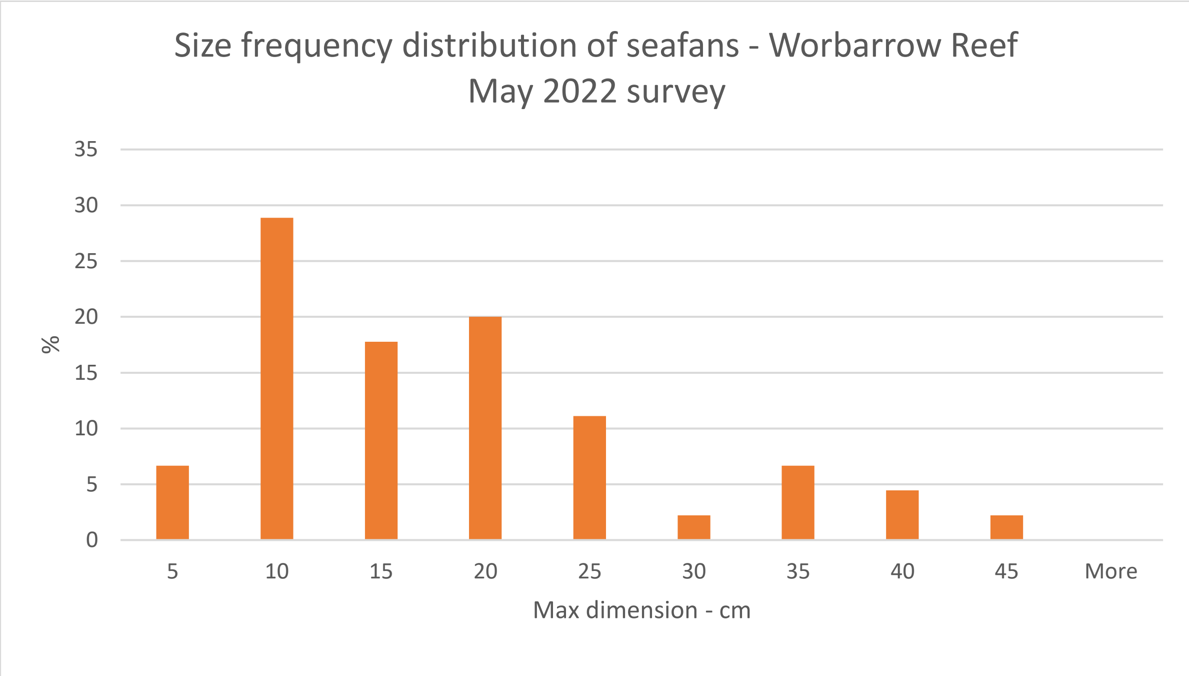


Figure 16 Size frequency distribution of seafans at Worbarrow Reef site. N=45

(Wood, 2002) assessed populations of pink seafans around the southwest using volunteer divers to record the presence, size and condition of fans. The condition was recorded using a subjective 1-5 score, where 5 indicates a fully healthy fan, 1 is almost completely dead or fouled and 2-4 covers varying degrees of fouling or gaps in the fan. Sea fans in Purbeck were given an average score of 4.52, and all populations looked at, with the exception of Lundy, were given an average score of over 4. (Tinsley, 2005) reported that all fans within the Worbarrow Reef study site scored over 4, though one heavily fouled fan was nearby.

We have attempted to apply the same health score to the seafans identified in these surveys – this is not as straightforward as assessing the state of the fans while diving as it is not always possible to get a good viewing angle, but we feel the differences revealed are real (see Figure 17). For more reliable scoring, it may be possible to go back to the original individual photographs – these can be identified from the model. The fans on the Worbarrow Reef site scored an average of 3.9 – many of the larger fans were mis-shapen or covered in fouling organisms. In contrast, the fans on the Lulworth Banks site scored an average of 4.8, with little evidence of fouling. It wasn't possible to score the Long Ledges seafans – these appeared to be more perpendicular to the camera view in the model.

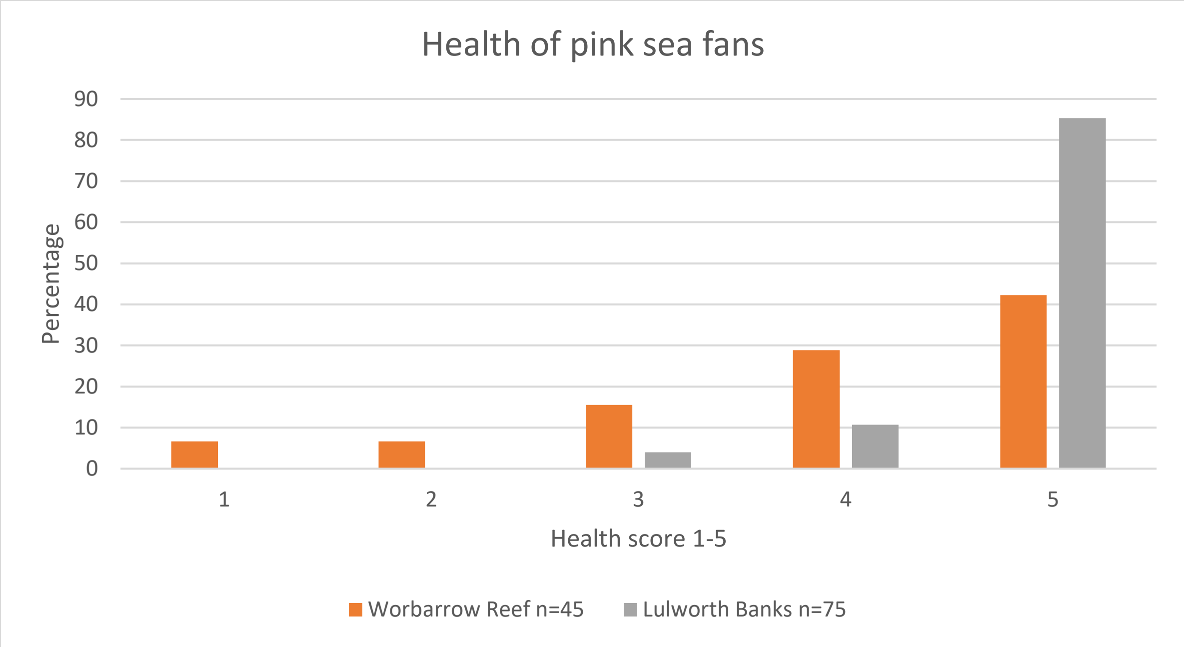


Figure 17

Ross corals – Pentapora foliacea

One clear difference between this site and the two others covered by this study is that there are no large ross corals – none is over 15cm and almost 90% are less than 10cm. The ross corals here grow little larger than the sponge *Polymastia*. The lack of under 4cm ross corals is probably due to the difficulty of discerning them from the background turf, while the brighter sponges stand out. It is possible that the almost pavement-like nature of the reef top is not suitable for ross corals, - that they prefer more rugged surfaces, though there clearly is some settlement and early growth. The presence of the pot-rope across the ledge may be significant – regular abrasion from such ropes would remove larger ross coral colonies – the more robust seafans and low-lying sponges might survive this level of abrasion, though they may experience sub-lethal impacts.

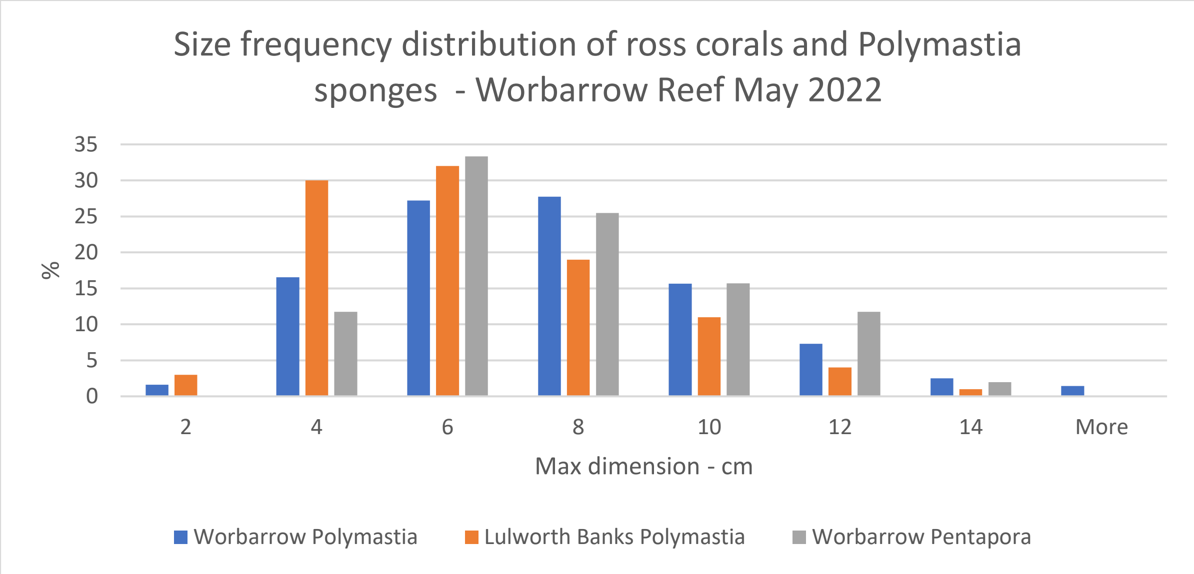


Figure 18

As well as ross corals and seafans, over 100 *Axinella* and over 500 *Polymastia* sponges were digitised from this model, providing a useful baseline dataset for this site. The intention is to revisit this site in the summer of 2023.

Site 3: Lulworth Banks Ross Coral (*Pentapora foliacea*) site

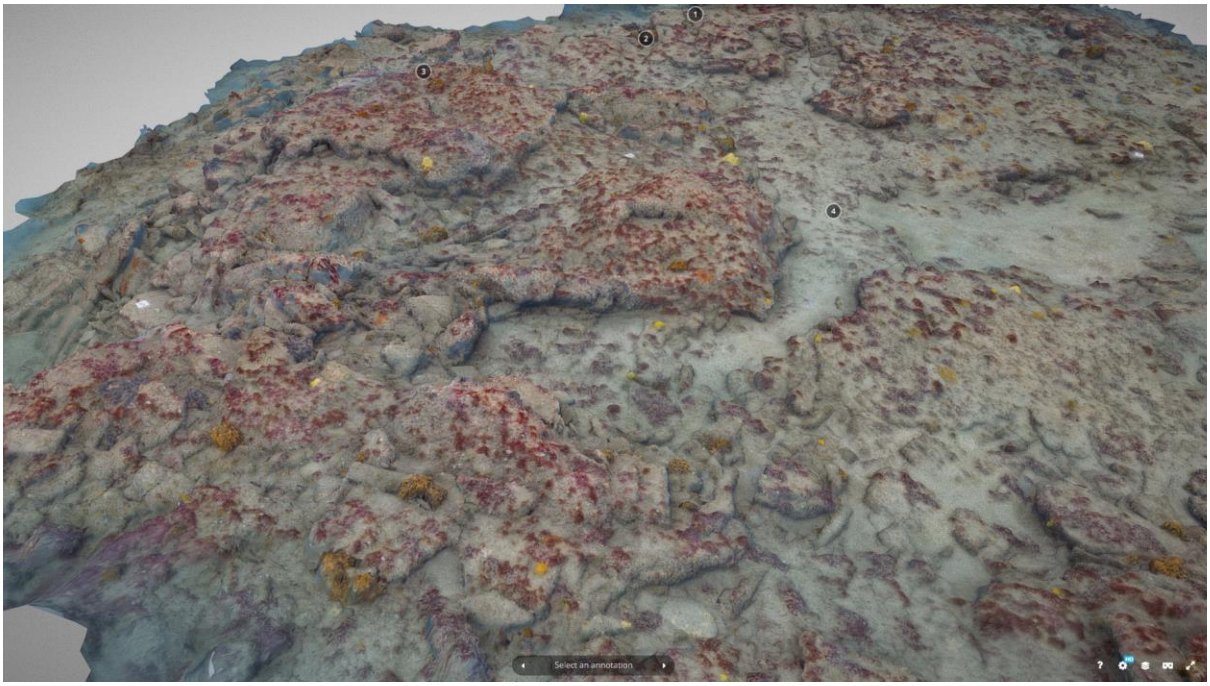


Figure 19 *3D model of Lulworth Banks site. Credit - Matt Doggett*

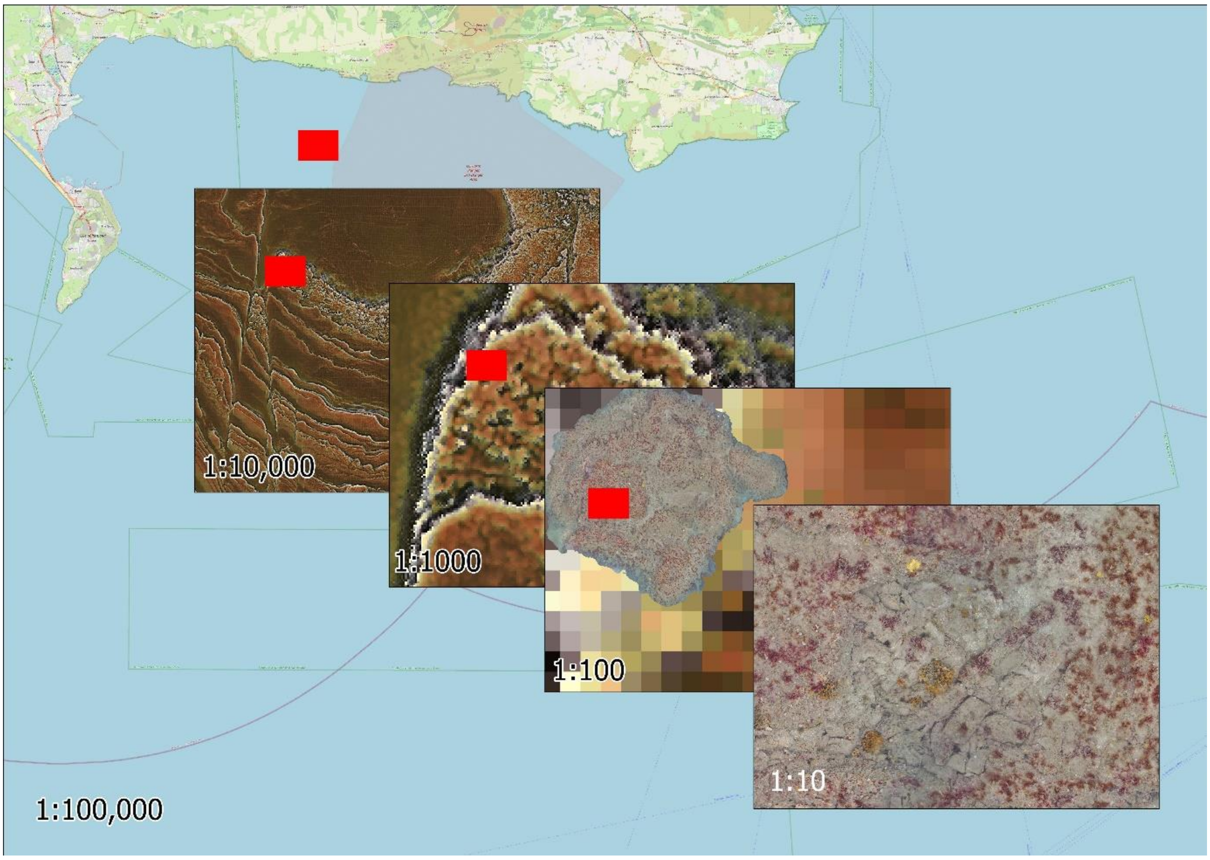


Figure 20 *Photomosaic of Lulworth Banks site in the context of different map scales. Note – map scales refer to an A2 printout. Contains map data from openstreetmap.org Contains Ordnance Survey data © Crown copyright*

The third site visited was chosen for the likely presence of ross corals (*Pentapora foliacea*) and is on the edge of a reef on the western section of Lulworth Banks at about 18m BCD. The site is within the Studland to Portland Special Area of Conservation and the Purbeck Coast Marine Conservation Zone and is covered by a Southern IFCA byelaw banning mobile fishing gear. The reef edge and adjacent gully can be picked up on an echosounder to assist the placement of a diver shotline and there is a distinctive "Z" shaped crack in the rock that provides a useful reference point to start the survey.

The Seasearch description of the site in October 2021 is as follows:

> *Bedrock and jumbled boulders forming W/NW-facing "scarp face" from ca. 18-22m bsl. Large Pentapora colonies, large massive Cliona and Pachymatisma sponges and seafans of all ages from unbranched juveniles to large fans visually dominate the attached fauna. Most of survey along this habitat in NE direction.*

The site was first visited in October 2021 when an area of approx. 118m^2 was surveyed, using a Panasonic Lumix S1H camera with a pair of Keldan video lights. 2700 images were used in compiling the final image. The model can be seen here - https://tinyurl.com/4kxvbrnb. The site was re-surveyed in Jun 2022 and can be seen here- https://tinyurl.com/5smrs64h. Most of the area from the first survey was re-covered, and the survey area extended to cover an additional area of reef almost three times the original survey. The area common to the two surveys covers 93.4m^2. The full Seasearch species list for each of the surveys is given in Appendix 2.

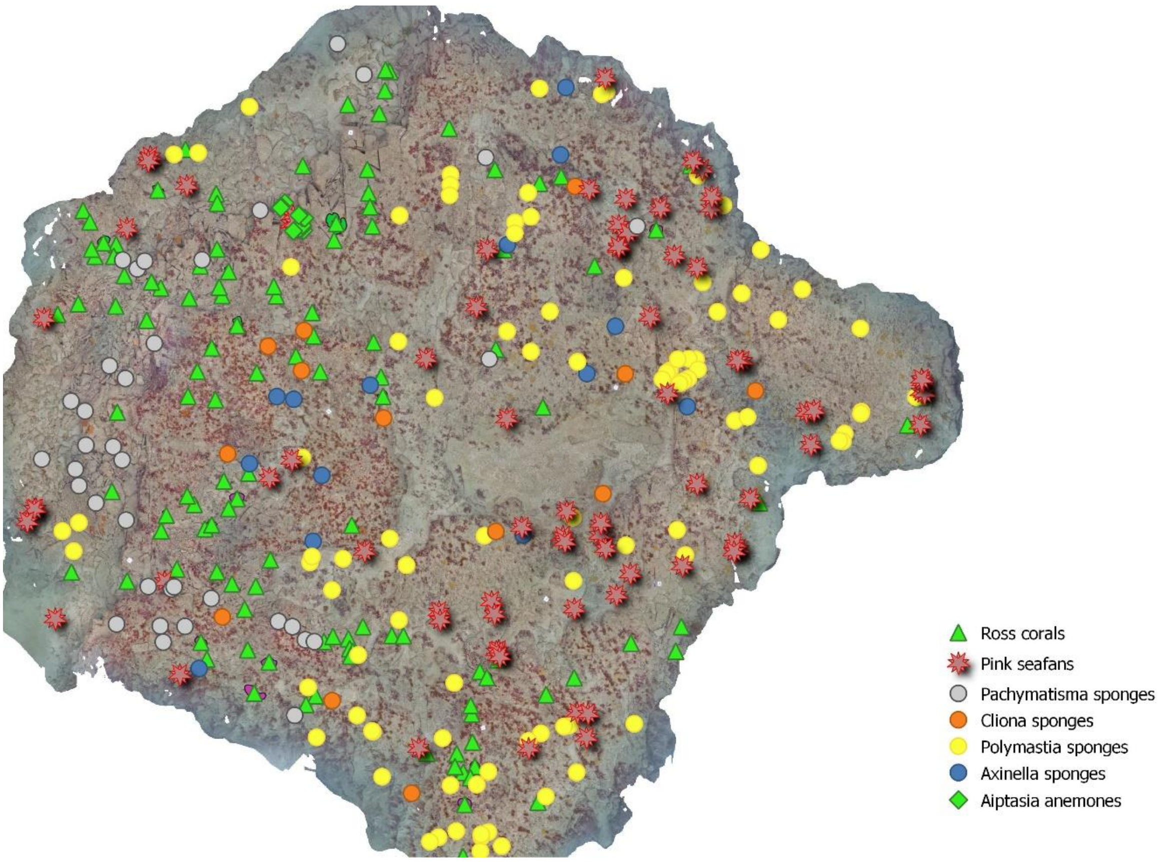


Figure 21 *Distribution of conspicuous species on Lulworth Banks site*

Changes detected between October 2021 and Jun 2022

There were some obvious differences on the seabed between the two surveys. Red algae are more apparent in the June images and there are many patches of *Stolonica* sea-squirts and bryozoan tufts in the summer survey that were not present in the October images. The reef looks siltier overall in the October image but there also seems to be more shelly sediment in the June images, covering some of the smaller crevices visible in the October data. Some of these differences can be seen in the images below (Oct 21 on the left, Jun 22 on the right).

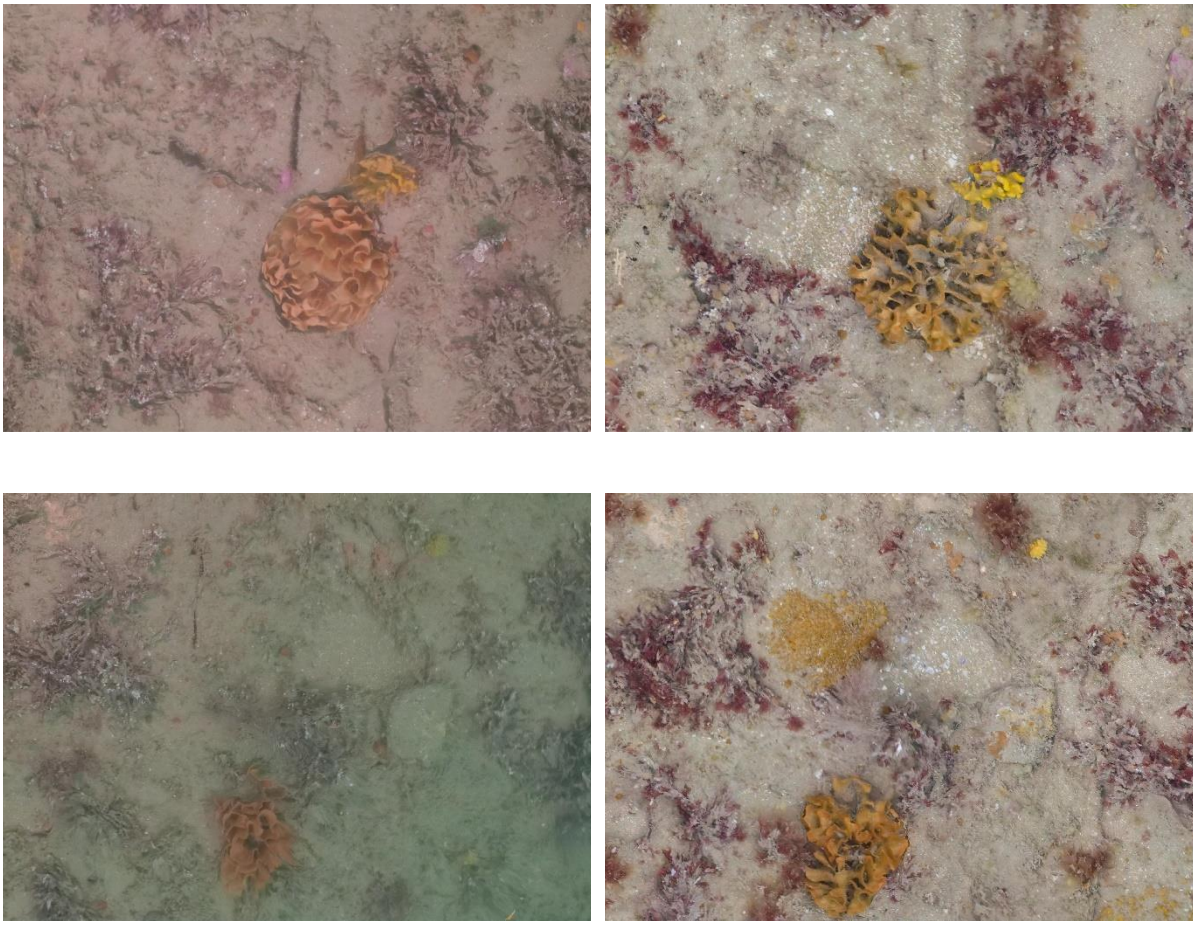


Figure 22 Differences between autumn (left) and summer (right)

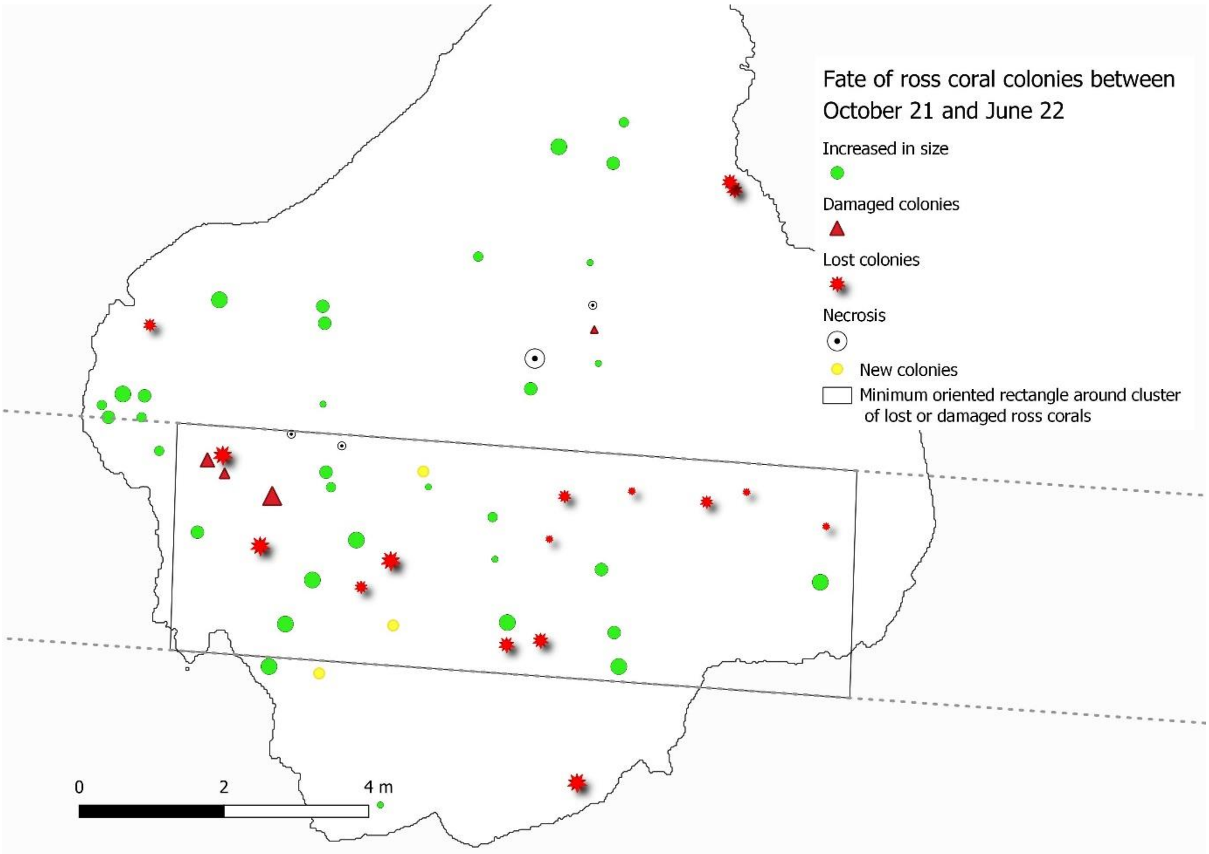


Figure 23 Changes in ross coral colonies detected between October 2021 and Jun 2022. The size of the symbol is proportionate with the size of the colony. The boundary shown marks the area common to both surveys.

Ross corals – Pentapora foliacea

76 ross coral colonies were mapped in the 2021 survey. Of these, 62 were in the area common to both surveys. The second survey in 2022 covered a larger area and recorded 116 ross coral colonies, of which 47 were in the area common to both surveys. 16 colonies noted in 2021 were no longer visible in 2022 and 3 new colonies were identified on the second survey. The number of new colonies is likely to be an underestimate as they are difficult to spot.

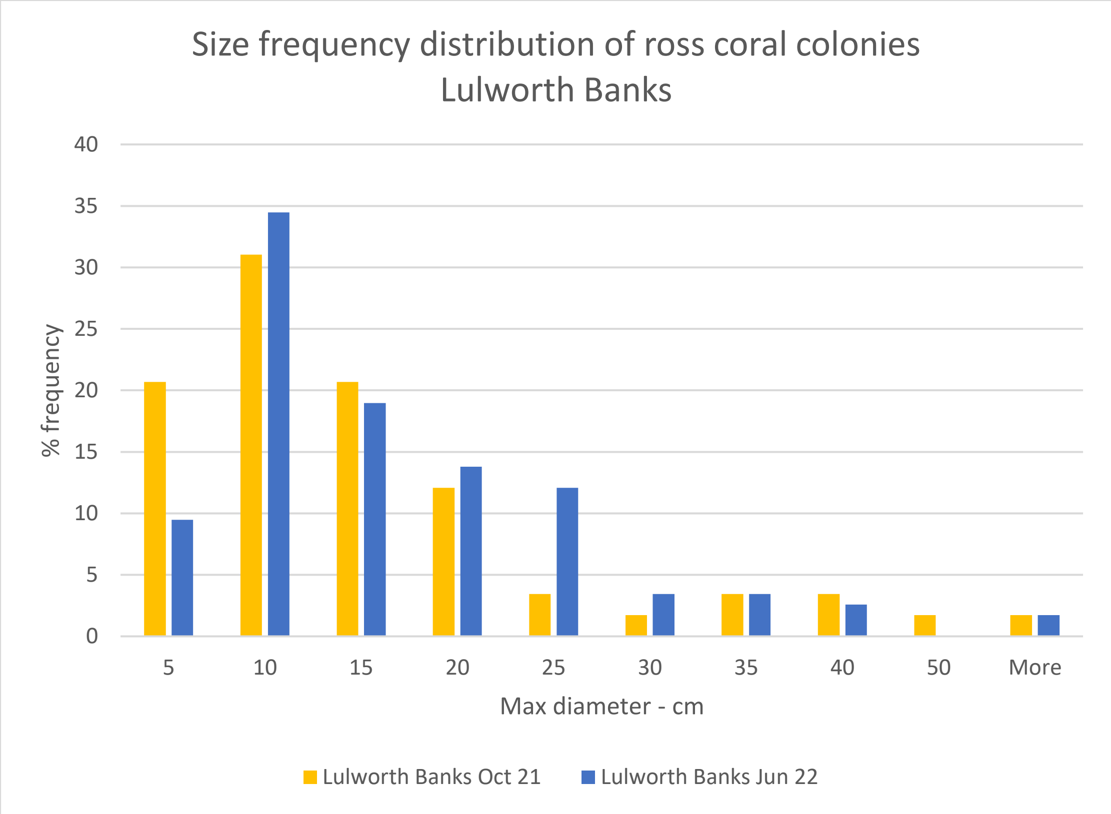


Figure 24

Most of the lost colonies are small – 80% under 15cm, but two large colonies have also completely disappeared (nos. 23 and 35). These two colonies were close together and a third nearby colony (no. 33) also appears to have suffered physical damage, with only about 30% of it left intact. This suggests a single, localised impact. (Figure 26). The majority of lost or damaged colonies fall within an area bounded by the rectangle shown in Figure 23.

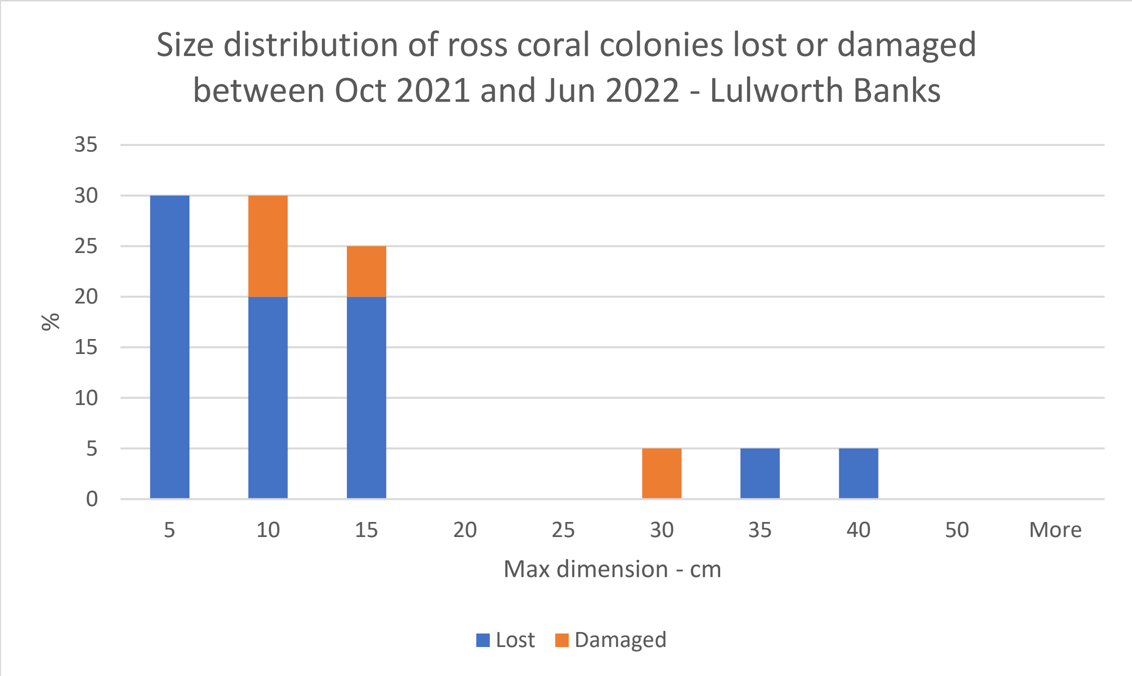


Figure 25

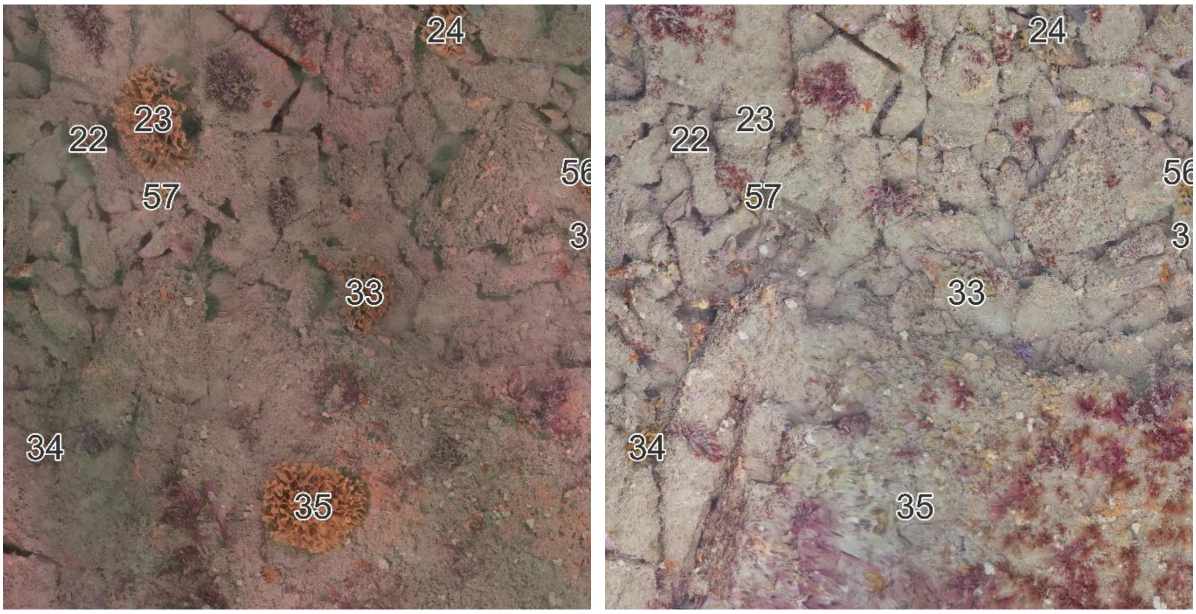


Figure 26 Detail of area where several ross coral colonies disappeared between Oct 2021 (left) and Jun 2022 (right)

Most surviving colonies have increased in size, increasing in radius by approx. 1.25cm on average, over 9 months. If we assume this is a constant growth rate and allow for the missing three months, the largest colony in the area common to both surveys would be 15 years old, with another four colonies more than 10 years old. The largest colony encountered in the whole survey would be 17 years old. The estimated growth rate can be refined following further studies.

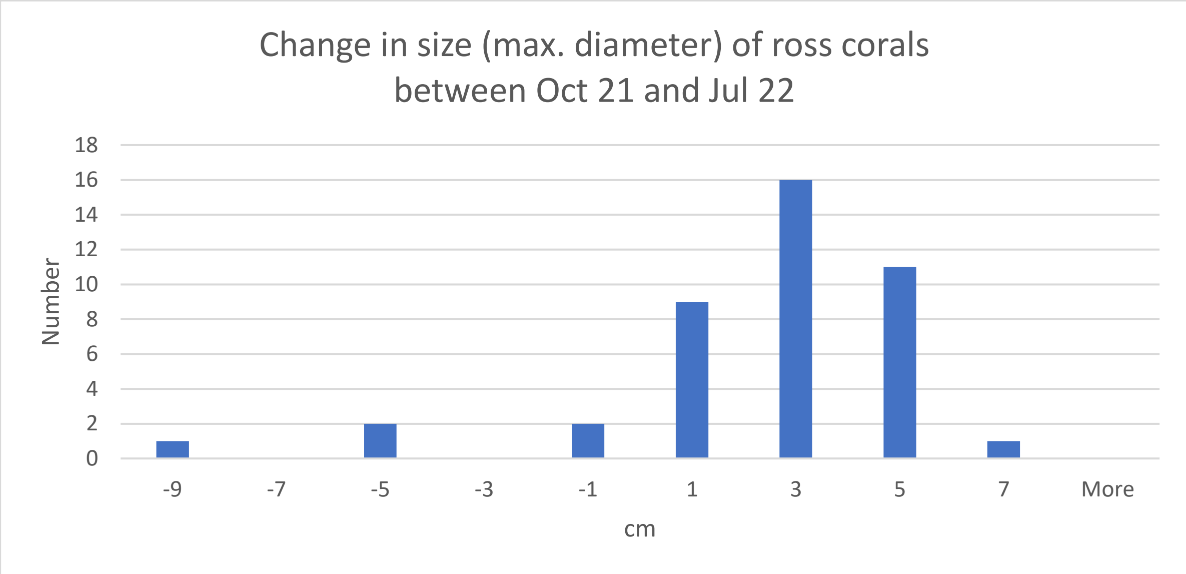


Figure 27 *The change in size of ross coral colonies between Oct 2021 and Jun 2022*

Apart from physical removal or damage, a small number of colonies, including the largest recorded in Oct 2021, shows signs of rapidly spreading necrosis which leads to either crumbling or fouling. (Figure 28). The colony shown in Figure 28 is estimated to be over 15 years old and is not expected to survive.

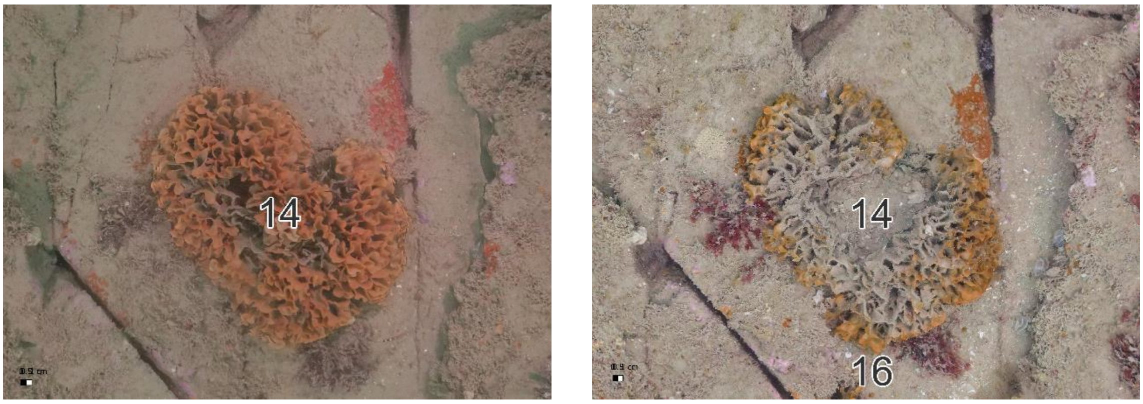


Figure 28 *Necrosis, just visible as a dark scar in 2021 (left) spreads to almost the entire colony 7 months later (right)*

Pink seafans – *Eunicella verrucosa*

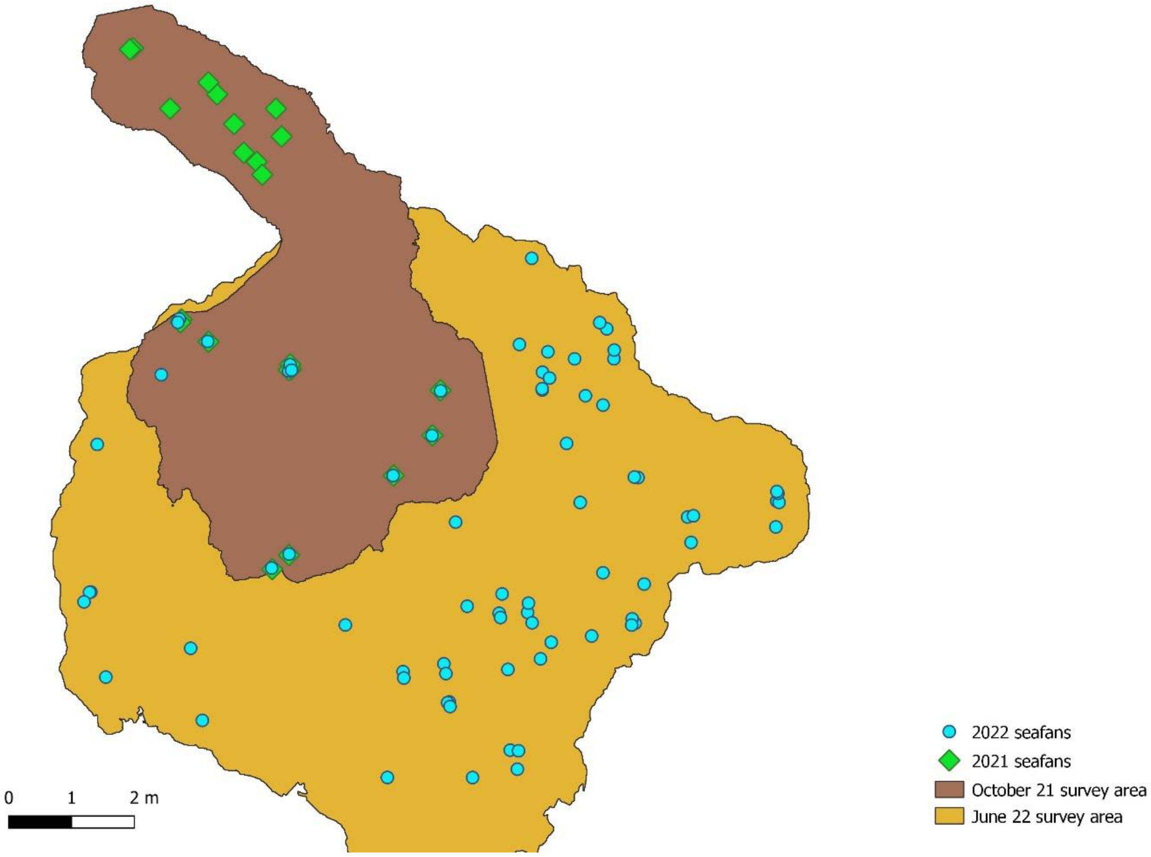


Figure 29 Distribution of seafan colonies across Lulworth Banks survey site

22 seafan colonies were identified in the 2021 survey and 75 in the larger 2022 survey – which equates to 1.7 or 2.2 fans per 10 square metres. Most of these are outside of the area covered by both surveys – only 12 colonies were common to both surveys and could be assessed for changes. One fan appeared to grow by just over 5cm, but this individual was difficult to pick out in the 2021 image and the starting size may have been underestimated. Average growth was just over 2cm in overall dimension, which is consistent with earlier studies. (Tinsley, 2005). Survival rate is 100%, which suggests that seafans are more resilient to physical damage than ross corals, though the sample size is small and there are no large seafans present. One new seafan is visible in the 2022 image.

Lulworth Banks differs from the other two sites in that there are no large seafans here – none greater than 20cm across. (Readman, et al., 2017) suggest a growth rate of approx. 1cm per year increase in branch length, which would make a 20cm wide colony in the region of 10 years old. The lack of any older/larger fans at this site could possibly be linked to the winter storms of 2013/14, but that leaves the question of why this site was more affected than the others.

Other species that can be recognised and measured include some large sponges - *Ciona celata*, *Pachymatisma johnstonia*, *Polymastia* and *Axinella spp.* The sponges seem to be more resilient than the ross corals – with only one *Axinella* and one *Polymastia* lost out of 32 yellow sponges in the area common to the two surveys and all *Pachymatisma* seem to have survived largely unchanged. As well as not being as brittle as ross corals, these sponges do not project as much above the seafloor.

The sponge, *Hemimycale columella*, had a noticeably different appearance in October, with none of the distinctive craters that give it its common name. Figure 30 shows a small rock overgrown with *Hemimycale* and another encrusting sponge – the boundary between the two sponges is remarkably constant.

Figure 30

There is another orange encrusting sponge that is visible in the October 21 images, but not obviously in images from the following summer. Closer inspection shows that the sponge is there in the background but obscured by a mixture of turf species, red algae and sediment. This illustrates how much of a difference time of year can make to the results of a survey and the value of surveying in multiple seasons.

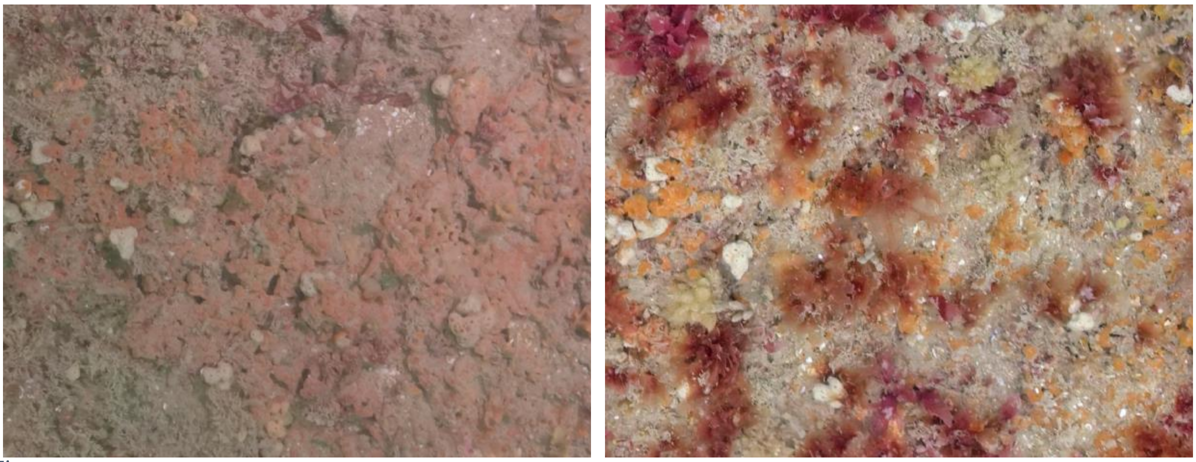


Figure 31

The cup-coral, *Caryophyllia smithii* and the small calcified bryozoan, *Omalosecosa ramulosa*, can also be seen to survive between surveys, though it is not possible to tell if the cup-coral is alive and these species are probably at the limit of being able to detect any change in size due to their small size.

A planned third visit to this site in October 2022 was cancelled due to the weather – a further attempt will be made in spring 2023.

Conclusions

This technique shows a lot of promise for monitoring the condition of some seabed habitats and detecting change over time, whether that be natural or anthropogenic. With relatively simple equipment and in the space of one dive operation, a pair of divers can collect enough images to create a detailed and accurate map of over 300m^2 of seabed. As long as the precise area can be re-located, using distinct underwater landmarks, aided by previous maps and some familiarity with the site, detailed study of change over time can be made.

The ross coral, *Pentapora foliacea,* is especially suitable as an indicator. It is easily recognizable and has well-defined edges and a solid enough structure to be well rendered by the software. It is of a suitable scale to make meaningful measurements and is both long-lived and fragile. Seafans – *Eunicella verrucosa,* are a similar scale and also long-lived, but their structure makes it difficult for the software the render effectively, particularly in a top-down view. Measurements taken from the model are less reliable but it is still possible to trace the fate of individual fans over time.

Other species that may prove useful to monitor over time include the large tunicate, *Phallusia mamillata*, and some of the sponges, such as *Polymastia* and *Axinellla spp.*

To date, only one site has been re-surveyed. This has shown that a small number of large ross coral colonies can be completely removed in the space of less than a year, with the clustering of loss and damage suggesting a fairly localised event. While this would fit with the interaction with potting gear described by Gall (Gall, et al., 2020), there are other possible causes, from a dropped anchor/shotline to a clumsy diver. In the absence of any information on the level of human activities at the site, it is difficult to come to any firm conclusions. The study has also shown that large, apparently healthy colonies can degrade quite quickly.

Survival rate of seafans at Lulworth Banks was 100%, suggesting seafans are perhaps more resilient to physical damage, but the sample was small and only one fan is close to a "lost" ross coral. The lack of any large seafans here also somewhat confounds that suggestion. A further survey here is planned for 2023 and could help to understand the processes at work here.

The results have also revealed significant differences between sites. The Worbarrow Reef site does not support the development of large ross corals, making it noticeably different to the other two sites. The presence of a pot line stretched across the reef-top suggests a possible mechanism to explain this difference but other factors could be at play.

The Lulworth Banks site, in contrast, is lacking in seafans over 20cm across, while the ross coral population, despite evidence of physical removal and damage, is similar to that in the Lyme Bay site. The results from the Worbarrow Reefs site suggest that seafans are more robust than ross corals, so it is difficult to come up with an explanation for the local lack of larger seafans, other than that it might be linked to the 2013/14 storms. The more rugged ground at Lulworth Banks should, if anything, provide more protection from physical damage than the smooth, open reef top of the Worbarrow reef site.

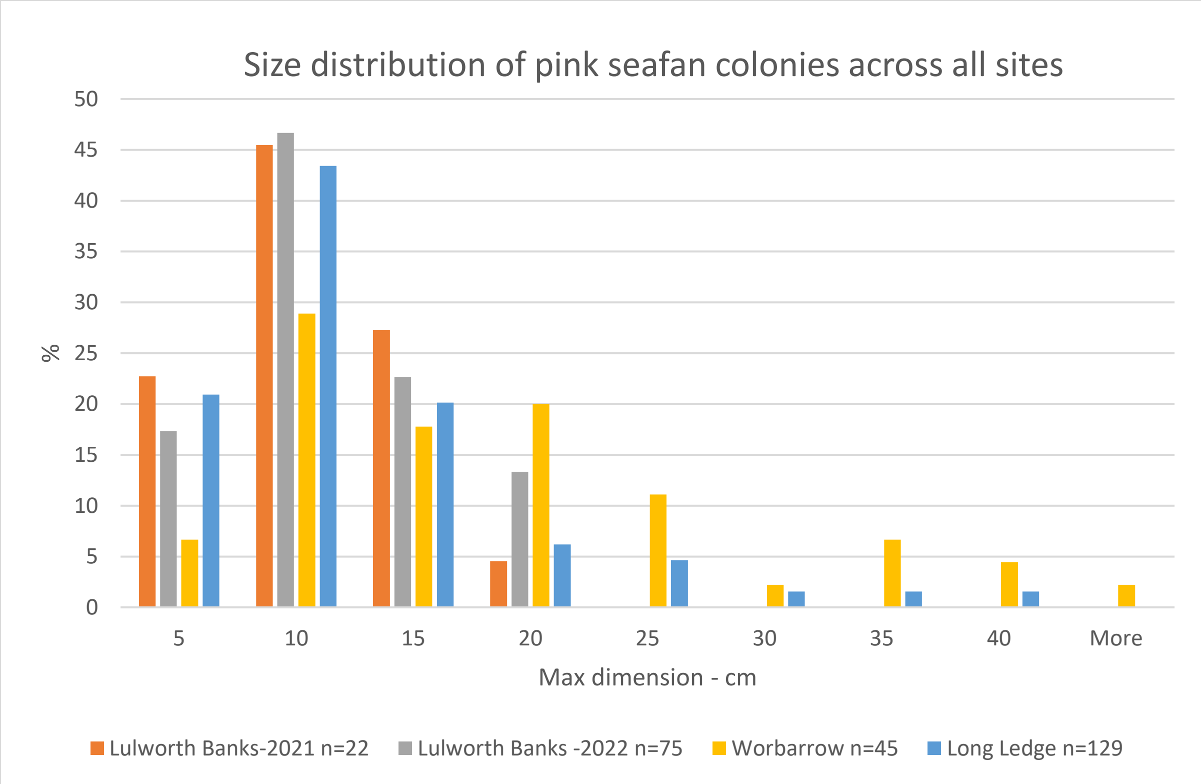
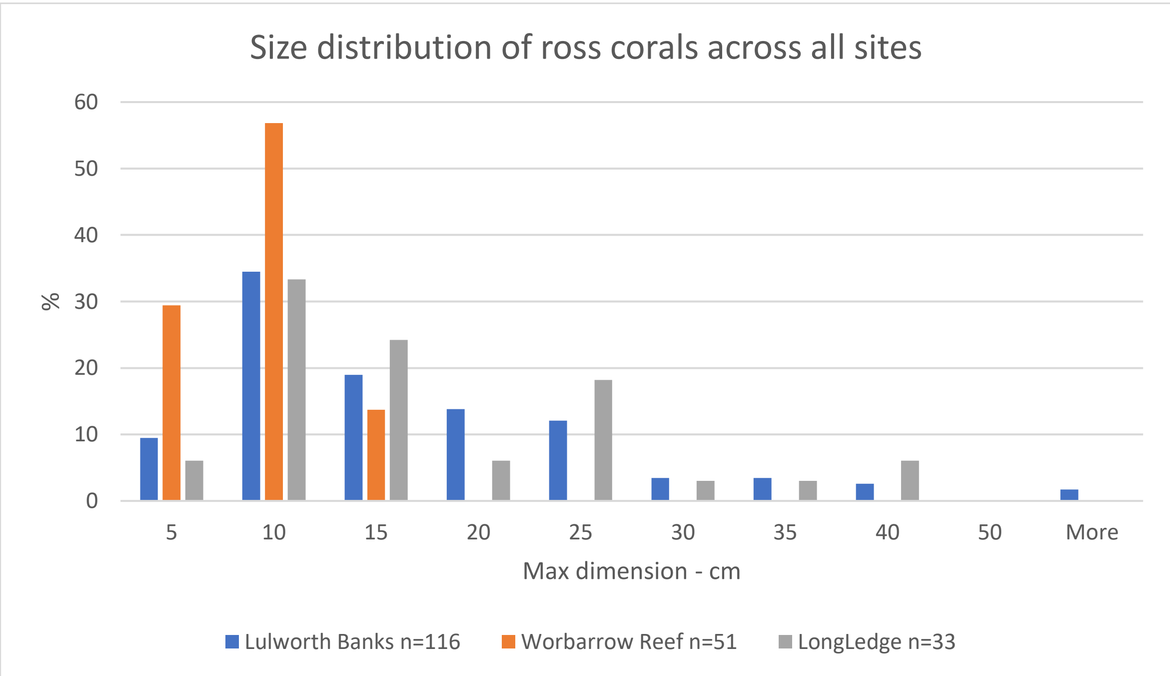


Figure 32



Repeating these surveys at least annually would quickly build up a valuable dataset and running surveys at different times of the year would help to understand seasonal changes. A single survey at a site, while not able to provide evidence of change, can still provide information on the occurrence, health and population structure of fragile indicator species, which could alert site managers to possible pressures.

There is also great potential for public engagement as the 3D models provide an unprecedented opportunity to virtually navigate around an area of seabed. Links to the models are given below.

Acknowledgements

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Appendix 1

Getting started in diving photogrammetry – by Matt Doggett

This introduction to photogrammetry provides a summary of points to consider and methods that can be used to produce 3D models from images or video obtained by divers. Several papers have been published in recent years outlining various methods for capturing images and creating and analysing the subsequent 3D models (Bayley & Mogg, 2020; D'Urban Jackson et al., 2020; Ventura et al., 2020). This guide is intended as a summary to help 'get divers started'.

Why use photogrammetry?

In an increasingly evidence-based world, 3D models, even in their most basic form provide an easily understandable output from the marine environment that most non-divers never see, especially at the larger scales.

From a scientific perspective, 3D models can fill the gap in spatial understanding of the environment, being smaller in size than side scan and multibeam images of broad areas but high in detail and allowing users to see and understand more than a description, line drawing or single photograph. Data collection by survey divers can be complemented and checked against high-resolution ortho-mosaics which themselves offer a new perspective on subtidal monitoring programmes. The repeatability of the method has potential for demonstrating habitat and community dynamics over short or longer-term timescales.

What do you want your model for?

Before commencing your project it is important to consider how you want to use your model(s), what equipment you have available to you and what conditions you are likely to be diving in.

3D underwater models created by divers have many end-uses. Relatively simple illustrative models of habitats or species can be used for public engagement or as examples of biotopes. Highly detailed models can measure changes in species, communities or habitats, provide evidence of the physical structure of a site and produce highly-detailed, 2-dimensional ortho-mosaics (site plans) for accurate quantification of species or geology.

Detail, accuracy and model complexity can all be limited by factors like lighting, underwater visibility, camera resolution and sensor quality, and image overlap.

If your project requires repeat visits to a site, then accurate position-fixing and easily identifiable visual references are key to reproducing site models. Can this be achieved at the site in question and with your available resources?

Models can be as simple or as complicated as you like, ranging from a few tens of images taken *ad hoc* during the dive or several thousand images with permanent visual references, scale bars etc.

Before diving

Before diving, consider what is achievable. How much dive time will you have? What are the known conditions at a site? How might these factors enable or compromise your plans? Slack water and no-deco durations, topographic complexity, visibility and desired model size and detail will all influence how long the image-capture process will take. It will help if you can dive your site and / or subject before attempting to capture the images so you can plan the best methods to use.

How will you light your images?

Models can be made using ambient light or video lights. Strobe flash guns are not recommended, especially for larger projects where the flash recycle-time becomes a major limiting factor in how long it takes to acquire all the photographs. As a guide, use the best video lights you can, to provide a uniform cover over the image frame. Ambient lighting can work very well, even in low vis – just remember to set the white balance manually before starting to take the images.

Do you need a scale bar?

Even for small, illustrative models a scale bar of around 20 cm can be very useful to indicate the size of organisms or the area covered by the model, but it is not essential. For larger models, two or more scale bars of 30-100 cm placed somewhere in the model area are essential for generating scaled, measurable models.

During diving

Camera settings

The exact camera settings needed to produce a good model ultimately depend on your equipment.

High-resolution DSLR or mirrorless cameras with full frame sensors and prime, wide-angle lens will produce the best results. For cameras with full manual control, try to use as wide a lens as possible with a low to mid-range aperture (f5.6 – 7.1) and a shutter speed fast enough to capture sharp images (ideally 1/125 or faster). Blurred images will not be usable. Set ISO to AUTO.

Compact cameras can be problematic for use in photogrammetry, but certain models can be used successfully with some practice. As a rule, try to fix the focus and zoom for the whole dive... and experiment.

Action cameras like GoPro cameras can produce excellent results when the images are well-lit. Set the camera to a wide angle with AUTO ISO. The timelapse function will facilitate image-capture.

You don't need to take images. Models can be derived from video – just make sure autofocus is disabled on cameras with moving lens elements. After your dive, individual frames can be extracted from video footage, converted to jpegs and used to create a model.

Taking the images

Do not adjust focus or zoom once you have begun taking images.

Aim to maintain a constant distance from your subject, typically around 0.5 – 2 m.

Images must overlap by at least 50% to allow the processing software to stitch them together.

Images must be taken as a continuous trail, a bit like a breadcrumb trail. Large gaps between non-overlapping images will confuse the processing software and likely prevent or seriously hinder the production of the final model.

Usually for habitat / biotope models, images should be taken in plan-view or with a slight oblique angle. If shooting in plan-view, take images in a grid format back and forth across the area being modelled or in an expanding spiral (Figure 33). Alternatively images can be taken by swimming around a small-scale, central subject in a circle, gradually increasing both height above the subject and the angle from side-view to plan-view as the process progresses (Figure 33). Figure 34 shows how the swimming pattern might appear in reality. In this example there was not time on the dive for more than one perpendicular line following completion of the first set. Due to the relatively flat nature of the site this did not adversely affect the final model which can be seen in Figure 38.

If using video, be sure to move slowly across the site or around the subject to avoid image blur.

Moving objects like fish and algae will either not show up in the final model or prevent a model from being created. Try to avoid large shoals of fish, other divers, areas of high algal movement, shiny objects and large areas of open water.

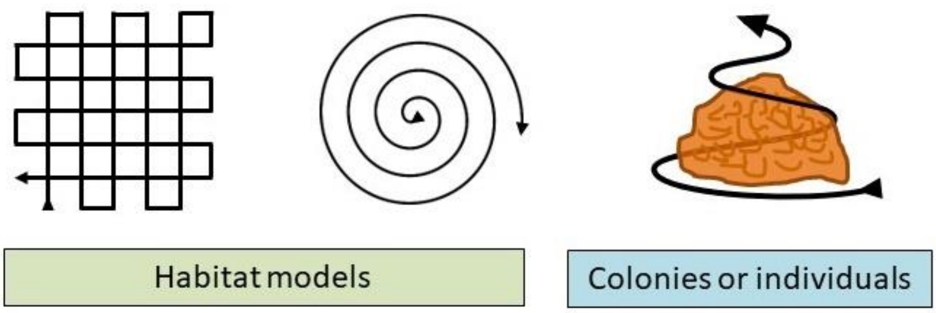

Figure 33: Photography methods for habitats (plan view, left) or colonies / individuals (side view, right) e.g. Pentapora.

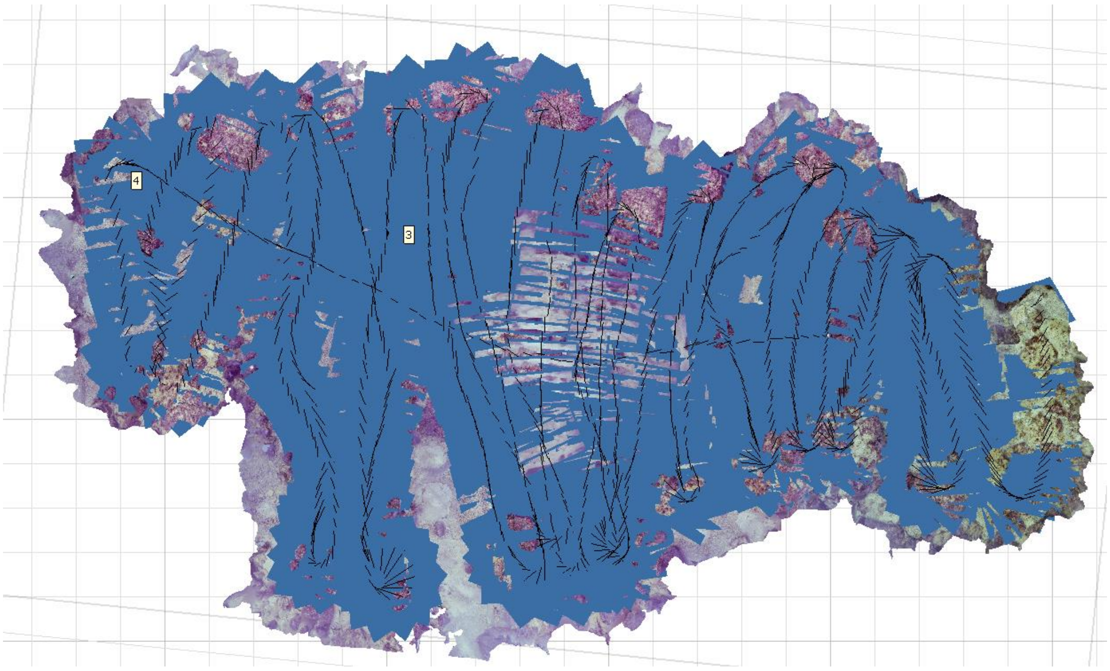

Figure 34: How the swimming pattern can look in reality on a large site with limited visibility.

Smaller models

For modelling small areas to illustrate species, communities or biotopes there is no need for scales, although they can be useful. Small models are easy to photograph or video on any Seasearch dive, only taking a few minutes to capture and not detracting much from other activities. The example below of a reef community in Dorset took just a few minutes to photograph (130 images) with the help of video lights at the end of a dive – it provides a colourful example of the sponges, sea squirts, corals and bryozoans on the reef (Figure 35).

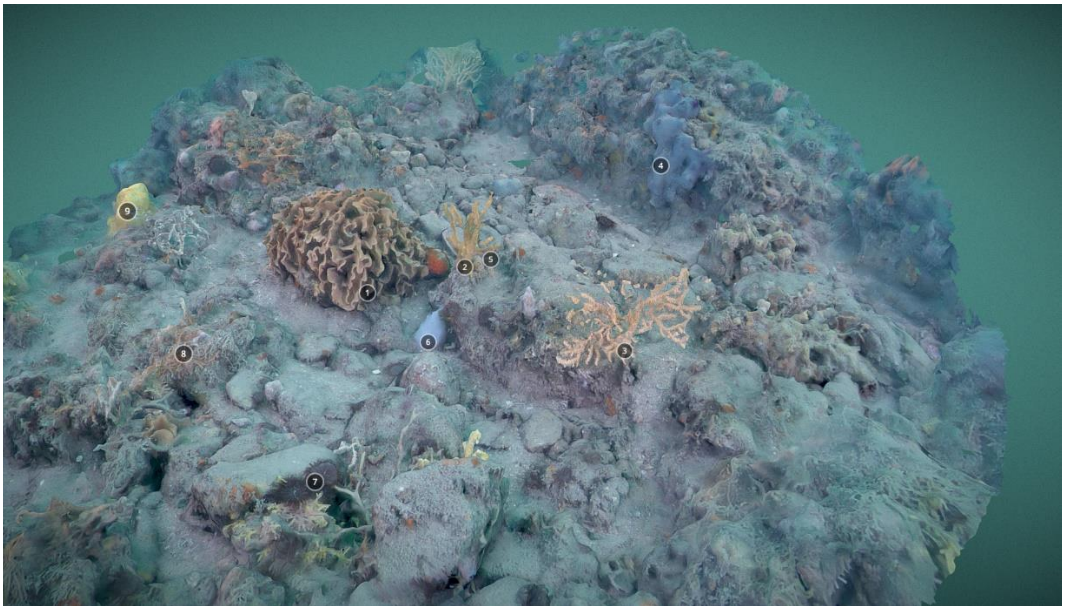

Figure 35: Long Ledges reef community, Lyme Bay, Dorset, https://skfb.ly/o77Vn.

This model of rocky reef ledges in Dorset (~1,280 images) was captured in under 20 minutes and covers an area of around 120 m^2 (Figure 36). It was lit with video lights and taken toward the end of a dive in search of rays and black bream.

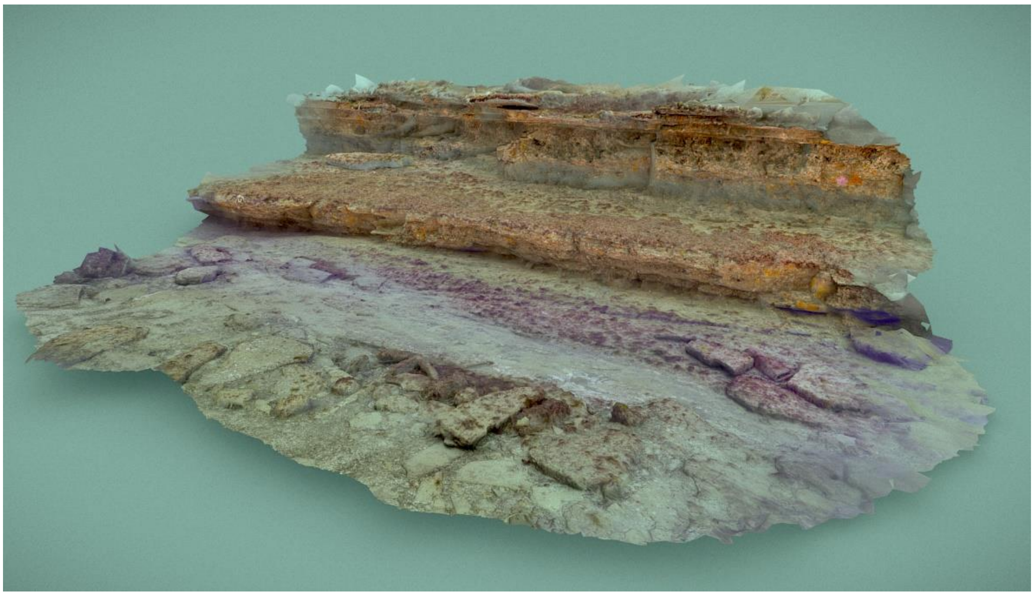

Figure 36: Model of a rocky reef wall with overhangs and a boulder-strewn seabed, Dorset, https://skfb.ly/oBSZV.

Larger models

For modelling large areas, an ideal situation would see one pair of divers set up the site prior to the second pair entering the water to photograph the site. This prevents the diver doing the photographing having to rush to accomplish all tasks.

At sheltered, calm sites you might choose to mark the survey area out using a weighted or pegged tape measure; this isn't always practical but other options are available.

Marking the site boundary and areas within it with printed, weighted targets (ground control points) can help divers navigate a site which is very useful where the site might be 30-40 m across, yet visibility is much lower. Using software-specific printed targets can also help with model processing (Figure 37). In good conditions, these targets can be quickly deployed by a diver immediately prior to image capture.

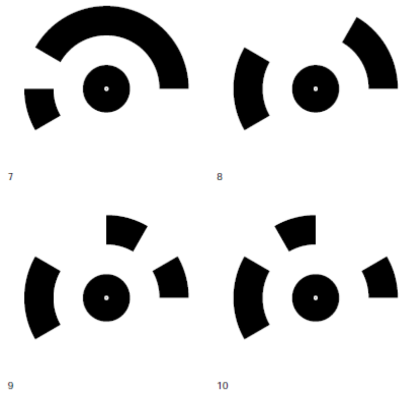

Figure 37: Examples of software-specific targets which can assist in model-processing and aid navigation around a site.

It helps if the depths of at least three of the placed targets are recorded, or depths of scale bars and other markers; these can be used later to orientate the model once it is complete. Spirit levels on tripods may also be used but can add to the logistical tasks of site set-up.

A 'North' marker in the form of a printed tile or carefully placed dive knife aids the final orientation of a site model. It can also help to orientate divers to a site if they are using previous models as a guide for site relocation i.e. we carry a laminated site model when we are relocating a site to repeat a photogrammetry survey.

Depending on currents, visibility, complexity of site set-up, site topography, breathing gas supply / consumption and depth, areas exceeding 400 m^2 can be surveyed in a single dive (Figure 38).

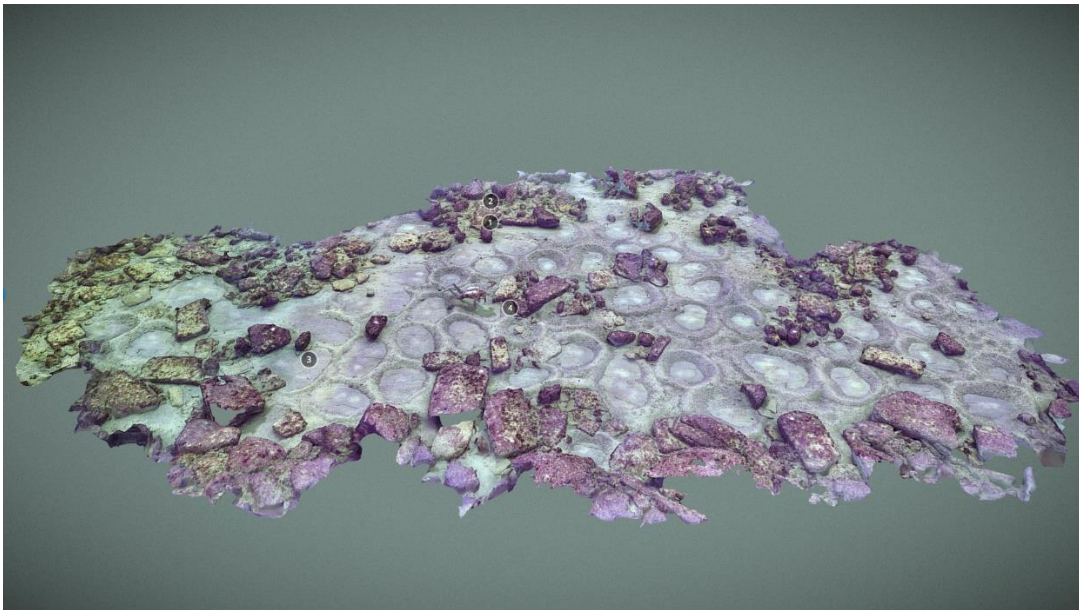

Figure 38: A black bream nest site in Dorset. End-to-end the model is ~43 m long, https://skfb.ly/ou8nC.

Typical photogrammetry dive kit list:

- Camera (essential)
- Compass and dive computer (essential)
- Video lights (optional)
- Site markers / targets / ground control points / tape (optional)
- Scale bars (optional)
- North marker (optional)

Model generation

Highly-detailed models can require several thousand high-resolution images which need to be stored and can add to project costs. Smaller, low-resolution images are often perfectly adequate for producing illustrative models of species and habitats and require less computer processing power.

Generating the 3D models from the images requires specialist software and often powerful computing hardware. Ideally computers will have a minimum of 16-32 GB RAM, a powerful graphics card and a multi-core CPU to reduce processing time and avoid damage to computer hardware from over-heating. Commercial (and excellent) programmes available include Agisoft Metashape and Pix4D whilst free opensource options include VisualSFM, Regard3D or COLMAP.

Processing the images often take the form of following a relatively simple step-by-step process, letting the software do all the hard work. Depending on the number and size of images and model complexity, models can be constructed in anything from a few minutes to many hours.

Each software option comes with its own 'how to' guide that is not repeated here.

Getting started

The best approach is to get diving and start practising with small models, gradually building up to larger and more complex environments. Practice with different camera and lighting set-ups and see what works best for you and your needs.

Useful references

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Appendix 2

Long Ledge species list - Seasearch 16/09/2021

Taxon	SACFORN	Qualifier	Uncertain	Comment
Annelida: Polychaeta				
Protula tubularia	R		☐	
Salmacina		FILOGRANA	☐	
Bispira volutacornis	R		☐	
Arthropoda: Malacostraca				
Cancer pagurus	R		☐	
Bryozoa: Gymnolaemata				
Pentapora foliacea	O		☐	
Bugulina flabellata	R		☐	
Candidae	R		☐	
Cellaria	C		☐	
Cellepora pumicosa	O		☐	
Chartella papyracea	O		☐	
Chordata: Actinopterygii				
Centrolabrus exoletus	R		☐	
Symphodus bailloni		NEST	☐	
Ctenolabrus rupestris	R		☐	
Thorogobius ephippiatus	R		☐	
Labrus mixtus	O		☐	
Parablennius gattorugine	R		☐	
Trisopterus minutus	O		☐	
Trisopterus luscus	R		☐	
Parablennius pilicornis	R		☐	
Chordata: Ascidiacea				
Pyura microcosmus	R		☐	
Stolonica socialis	R		☐	
Phallusia mammillata	O		☐	
Ascidia mentula	R		☐	
Aplidium elegans	R		☐	
Chordata: Elasmobranchii				
Mustelus asterias			☐	
Cnidaria: Anthozoa				
Aiptasia couchii	F		☐	
Alcyonium digitatum	O		☐	

Taxon	SACFORN	Qualifier	Uncertain	Comment
Eunicella verrucosa	R		☐	
Caryophyllia (Caryophyllia) smithii	R		☐	
Epizoanthus couchii	R		☐	
Cnidaria: Hydrozoa				
Abietinaria abietina	R		☐	
Gymnangium montagui	R		☐	
Hydrallmania falcata	R		☐	
Nemertesia antennina	F		☐	
Nemertesia ramosa	O		☐	
Mollusca: Bivalvia				
Rocellaria dubia	O		☐	
Chlamys	R		☐	
Mollusca: Gastropoda				
Calliostoma zizyphinum	R		☐	
Ochrophyta: Phaeophyceae				
Chaetopteris	R		☐	
Phoronida				
Phoronis	R		☐	
Porifera				
Porifera indet crusts	O		☐	
Porifera: Demospongiae				
Stryphnus ponderosus			☐	
Hymedesmia (Hymedesmia) paupertas	R		☐	
Phorbas plumosus			☐	
Polymastia boletiformis	O		☐	
Ciocalypta penicillus	R		☐	
Hymeniacidon kitchingi	O		☐	
Hemimycale columella	O		☐	
Dercitus (Dercitus) bucklandi	R		☐	
Dysidea fragilis	O		☐	
Pachymatisma johnstonia	R		☐	
Adreus fascicularis	O		☐	
Ulosa digitata	O		☐	
Amphilectus fucorum	O		☐	
Iophon nigricans	O		☐	
Haliclona (Halichoclona) fistulosa	O		☐	Checked LB

Taxon	SACFORN	Qualifier	Uncertain	Comment
Aplysilla rosea			☐	
Cliona celata	R		☐	
Stelligera montagui	R		☐	
Halicnemia patera			☐	
Raspailia (Raspailia) ramosa	R		☐	
Raspailia (Clathriodendron) hispida	R		☐	
Axinella dissimilis	O		☐	
Haliclona (Haliclona) simulans	F		☐	

Rhodophyta: Florideophyceae

Taxon	SACFORN	Qualifier	Uncertain	Comment
Rhodymenia ardissonei	R		☐	

Lulworth Banks species list - Seasearch 14/10/2021

Taxon	SACFORN	Qualifier	Uncertain	Comment
Annelida: Polychaeta				
Sabellaria spinulosa	R	CRUST	☐	
Bispira volutacornis	R		☐	
Protula tubularia	R		☐	
Salmacina	R	FILOGRANA	☐	
Serpula vermicularis	O		☐	
Spirobranchus	R		☐	
Terebellidae	R		☐	
Arthropoda: Hexanauplia				
Adna anglica	O		☐	
Acasta spongites			☐	In Dys_fra
Cirripedia	O		☐	
Scalpellum scalpellum	R		☐	
Arthropoda: Malacostraca				
Anilocra	R		☐	On x2 Cte_rup
Cancer pagurus	R		☐	
Galathea strigosa	R		☐	
Maja brachydactyla	R		☐	
Homarus gammarus	R		☐	
Bryozoa				
Bryozoa indet crusts	O		☐	
Bryozoa: Gymnolaemata				
Chartella papyracea	C		☐	
Pentapora foliacea	C		☐	
Flustra foliacea	O		☐	
Chartella papyracea	C		☐	
Electra pilosa	R		☐	
Omalosecosa ramulosa	R		☐	
Cellepora pumicosa	O		☐	
Candidae	R		☐	
Ctenostomatida	C		☐	
Bryozoa: Stenolaemata				
Crisiidae	O		☐	
Chlorophyta: Ulvophyceae				

Taxon	SACFORN	Qualifier	Uncertain	Comment
Flabellia petiolata	R		☐	Filaments
Chordata: Actinopterygii				
Diplecogaster bimaculata	R		☐	
Pomatoschistus pictus	R		☐	
Labrus mixtus	R	FEMALE	☐	
Labrus mixtus	O		☐	
Ctenolabrus rupestris	R		☐	
Thorogobius ephippiatus	R		☐	
Parablennius pilicornis			☐	~8cm long
Parablennius gattorugine	R		☐	
Lepadogaster candolii	R		☐	
Callionymus reticulatus	R		☐	
Chordata: Ascidiacea				
Ciona intestinalis	R		☐	
Styela clava	R		☐	
Stolonica socialis	F		☐	Winterised
Polycarpa	R	MAMILLARIS	☐	
Distomus variolosus	R		☐	
Ascidiacea	F	TURF	☐	
Pyura microcosmus	R		☐	
Ascidia virginea	R		☐	
Ascidia mentula	R		☐	
Aplidium punctum	O		☐	
Diplosoma spongiforme	R		☐	
Didemnum maculosum	O	DENTATA	☐	
Pycnoclavella aurilucens	O		☐	
Botryllus schlosseri	R		☐	
Cnidaria: Anthozoa				
Caryophyllia (Caryophyllia) smithii	O		☐	
Aiptasia couchii	O		☐	
Capnea sanguinea	R		☐	
Actinothoe sphyrodeta	R		☐	
Cylista elegans	R		☐	
Eunicella verrucosa	R	JUV	☐	
Eunicella verrucosa	F		☐	
Caryophyllia (Caryophyllia) inornata	O		☐	

Taxon	SACFORN	Qualifier	Uncertain	Comment
Epizoanthus couchii	O		☐	
Isozoanthus sulcatus	R		☐	
Corynactis viridis			☐	
Cnidaria: Hydrozoa				
Sertularella gayi	R		☐	
Hydrallmania falcata	R		☐	
Sertularella polyzonias	R		☑	
Sertularella	R		☐	
Nemertesia antennina	R		☐	
Halecium	R		☐	
Amphisbetia operculata	R		☐	
Echinodermata: Asteroidea				
Henricia	O		☐	
Anseropoda placenta	R		☐	
Echinodermata: Holothuroidea				
Thyone roscovita	R		☐	
Echinodermata: Ophiuroidea				
Ophiura	R		☐	
Mollusca: Bivalvia				
Pecten maximus	R		☐	
Chlamys	R		☐	
Pholadidae	O		☐	
Rocellaria dubia	R		☐	
Cardiidae			☐	
Mollusca: Gastropoda				
Rissoa parva	F		☐	
Polycera	R		☐	
Thecacera pennigera	R		☐	
Duvaucelia odhneri	R		☐	
Calliostoma zizyphinum	R		☐	
Tricolia pullus	O		☐	
Steromphala cineraria	O		☐	
Bittium			☐	
Ochrophyta: Phaeophyceae				
Chaetopteris	O		☐	
Dictyopteris polypodioides	R		☐	

Taxon	SACFORN	Qualifier	Uncertain	Comment
Phoronida				
Phoronis	R		☐	
Porifera				
Porifera indet crusts	A		☐	
Porifera: Demospongiae				
Phorbas fictitius	R		☐	
Pachymatisma johnstonia	F		☐	
Dercitus (Dercitus) bucklandi	O		☐	
Ciocalypta penicillus	R		☐	
Axinella dissimilis	R		☐	
Polymastia boletiformis	F		☐	
Raspailia (Clathriodendron) hispida	R		☐	
Hymedesmia (Hymedesmia) paupertas	O		☐	
Hemimycale columella	O		☐	
Stelligera montagui	O		☐	
Polymastia penicillus	R		☐	
Raspailia (Raspailia) ramosa	R		☐	
Ulosa digitata	R		☐	
Stelligera stuposa	R		☐	
Cliona celata	F		☐	
Dysidea fragilis	O		☐	
Haliclona (Halichoclona) fistulosa	R		☑	
Iophon	O		☑	
Iophon nigricans	R		☐	
Amphilectus fucorum	R		☐	
Rhodophyta: Florideophyceae				
Hypoglossum hypoglossoides	R		☐	
Corallinaceae	O	CRUST	☐	
Calliblepharis ciliata	R		☐	
Phyllophora crispa	O		☐	
Plocamium	R		☐	
Plocamium cartilagineum	R	SS	☐	
Rhodymenia ardissonei	R		☐	

Lulworth Bansk species list - Seasearch 09/06/2022

Taxon	SACFORN	Qualifier	Uncertain	Comment
Annelida: Polychaeta				
Lanice conchilega	R		☐	
Terebellidae	O		☐	
Serpula vermicularis	R		☐	
Bispira volutacornis	R		☐	
Arthropoda: Hexanauplia				
Adna anglica	R		☐	In C. smithii
Cirripedia	C		☐	
Arthropoda: Malacostraca				
Cancer pagurus	R		☐	
Bryozoa:				
Bryozoa indet crusts	O		☐	
Bryozoa: Gymnolaemata				
Bugula turbinata	C		☐	
Bugula flabellata	O		☐	
Bicellariella ciliata	R		☐	
Alcyonidium diaphanum	R		☐	
Candidae	O		☐	
Vesicularia spinosa	R		☐	
Flustra foliacea	O		☐	
Chartella papyracea	C		☐	
Omalosecosa ramulosa	R		☐	
Cellepora pumicosa	O		☐	
Pentapora foliacea	F		☐	
Bryozoa: Stenolaemata				
Crisiidae	R		☐	
Chordata: Actinopterygii				
Parablennius gattorugine	R		☐	
Gobius niger	F	+nesting	☐	
Spondyliosoma cantharus	R	nest	☐	
Labrus mixtus	O		☐	
Thorogobius ephippiatus	R		☐	
Ctenolabrus rupestris	O		☐	
Chordata: Ascidiacea				

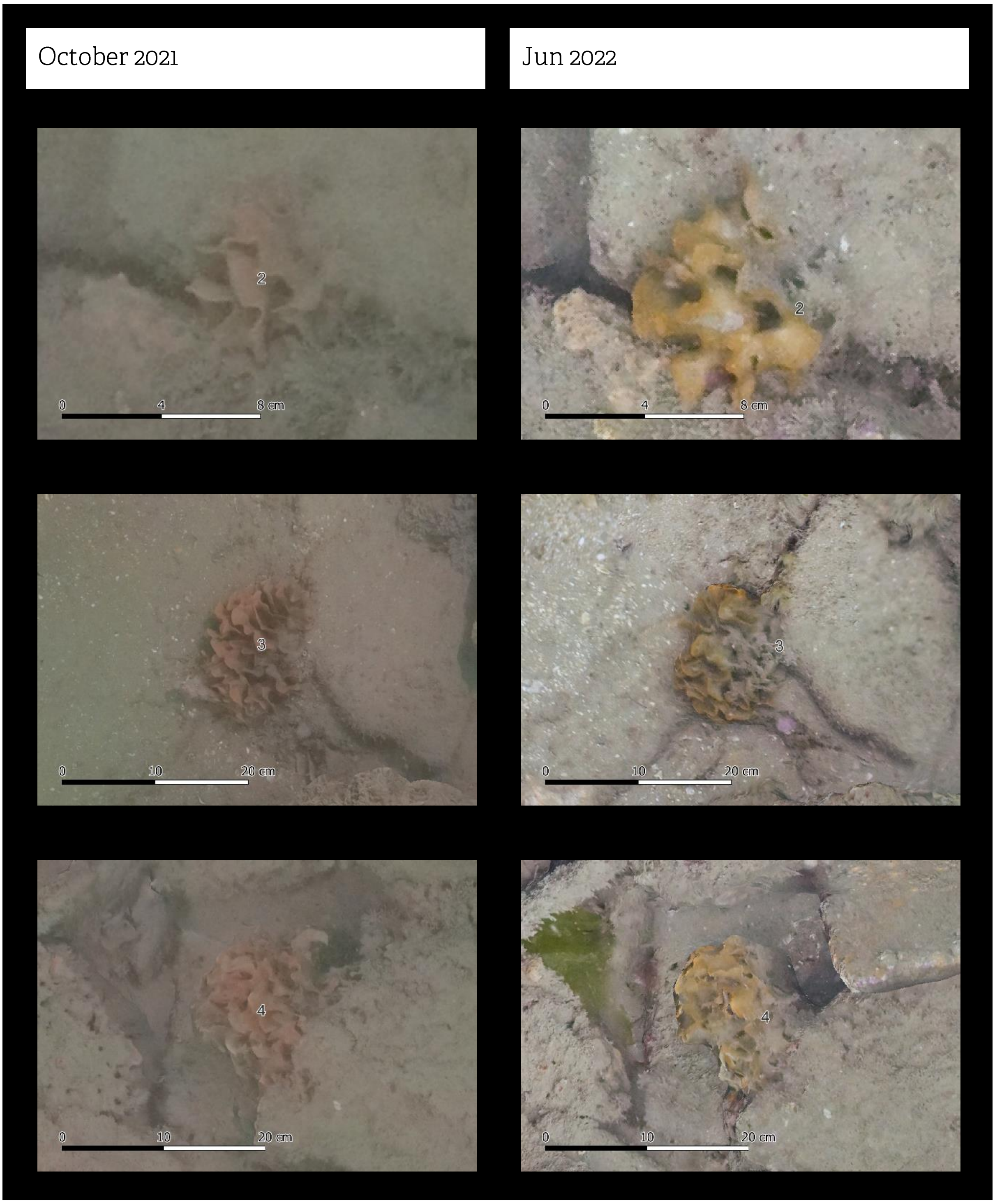
Taxon	SACFORN	Qualifier	Uncertain	Comment
Polyclinidae	R	solid white	☐	
Ascidiella aspersa	R		☐	
Ascidia virginea	R		☐	
Aplidium punctum	O		☐	
Stolonica socialis	F		☐	
Archidistoma aggregatum	C		☑	turf
Pycnoclavella aurilucens	F	white	☐	
Botryllus schlosseri	R		☐	
Styela clava	O		☐	
Chordata: Elasmobranchii				
Scyliorhinus stellaris	R	Eggs	☐	on Eunicella
Raja brachyura	R		☐	
Cnidaria: Anthozoa				
Eunicella verrucosa	O	juv	☐	
Alcyonium digitatum	R		☐	
Caryophyllia (Caryophyllia) smithii	R		☐	
Actinothoe sphyrodeta	R		☐	
Eunicella verrucosa	O	adult	☐	
Cnidaria: Hydrozoa				
Sertularella gayi	O		☐	
Amphisbetia operculata	R		☐	
Hydrallmania falcata	R		☐	
Sertularella	F		☐	
Sertularia argentea	O		☐	
Nemertesia antennina	O		☐	
Demospongiae: Porifera				
Eurypon major	R	red	☑	
Echinodermata: Asteroidea				
Henricia	R		☐	
Asterias rubens	R		☐	
Echinodermata: Holothuroidea				
Neopentadactyla mixta	F		☐	
Pawsonia saxicola	O		☐	
Thyone fusus	R		☐	
Mollusca: Bivalvia				
Bivalvia	C	siphons	☐	

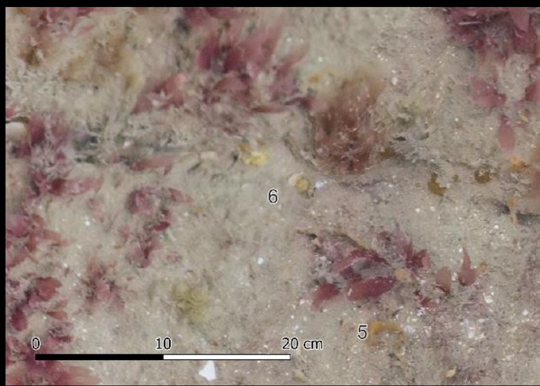
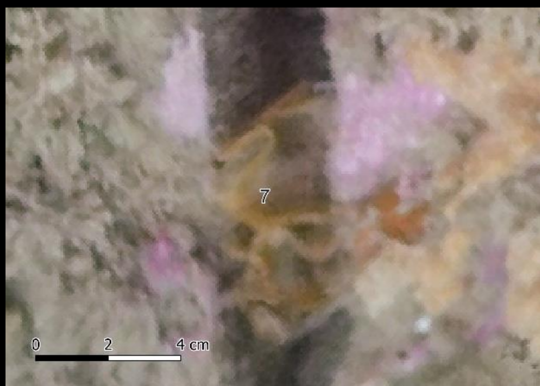
Taxon	SACFORN	Qualifier	Uncertain	Comment
Rocellaria dubia	R		☐	
Hiatella arctica	P		☐	
Pecten maximus	O		☐	
Mollusca: Cephalopoda				
Loliginidae	R	small rounde	☐	
Mollusca: Gastropoda				
Trivia arctica	R		☐	
Tritia reticulata	R		☐	
Calliostoma zizyphinum	R		☐	
Buccinum undatum	R		☐	
Crimora papillata	F	+spawn	☐	
Bittium	P		☐	
Tritia reticulata	R		☐	
Thecacera pennigera	R		☐	
Ocenebra erinaceus	R	eggs	☐	
Tricolia pullus	P		☐	
Ochrophyta: Phaeophyceae				
Dictyopteris polypodioides	R		☐	
Porifera:				
Porifera indet crusts	C		☐	
Porifera: Calcarea				
Sycon ciliatum	R		☐	
Leucosolenia	R		☐	
Porifera: Demospongiae				
Adreus fascicularis	R		☐	
Hymedesmia (Hymedesmia) paupertas	R		☐	
Hemimycale columella	O		☐	
Polymastia agglutinans	R		☑	
Endectyon (Endectyon) delaubenfelsi	R		☐	
Ciocalypta penicillus	O		☐	
Polymastia penicillus	O		☐	
Pachymatisma johnstonia	F		☐	
Polymastia boletiformis	O		☑	
Cliona celata	O		☐	
Axinella dissimilis	R		☐	
Tethya citrina	R		☐	

Taxon	SACFORN	Qualifier	Uncertain	Comment
Raspailiidae	O		☐	
Dysidea fragilis	F		☐	
Haliclona (Halichoclona) fistulosa	R		☐	confirmed LB
Polymastia	R		☐	like agglutinans, bri
Rhodophyta: Florideophyceae				
Phyllophora sicula	F		☐	confirmed LB
Hypoglossum hypoglossoides	R		☐	
Drachiella heterocarpa	O		☐	
Rhodymenia ardissonei	O		☐	
Phyllophora crispa	F		☐	
Calliblepharis ciliata	F		☐	
Asparagopsis	R	Falkenbergia	☐	
Meredithia microphylla	R		☐	confirmed LB
Corallinaceae	R	crusts	☐	
Plocamium	R		☐	

Appendix 3

Ross coral colonies extracted from scaled orthomosaics from Lulworth Banks repeat survey.

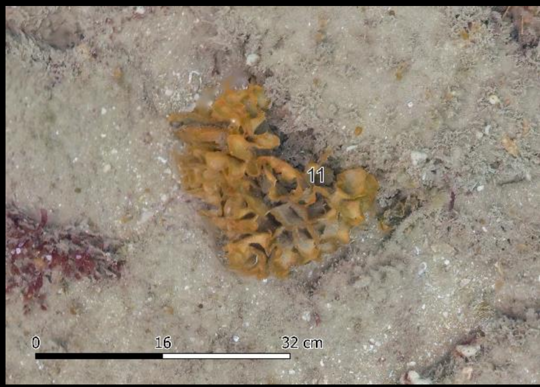


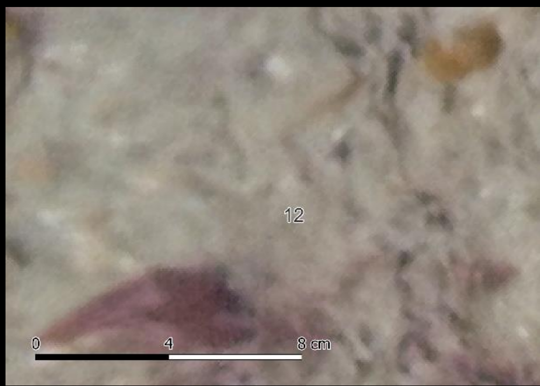
October 2021	Jun 2022
	
	
	

October 2021

Jun 2022

October 2021	Jun 2022





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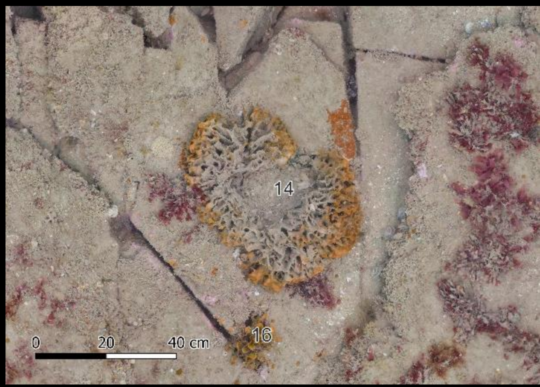
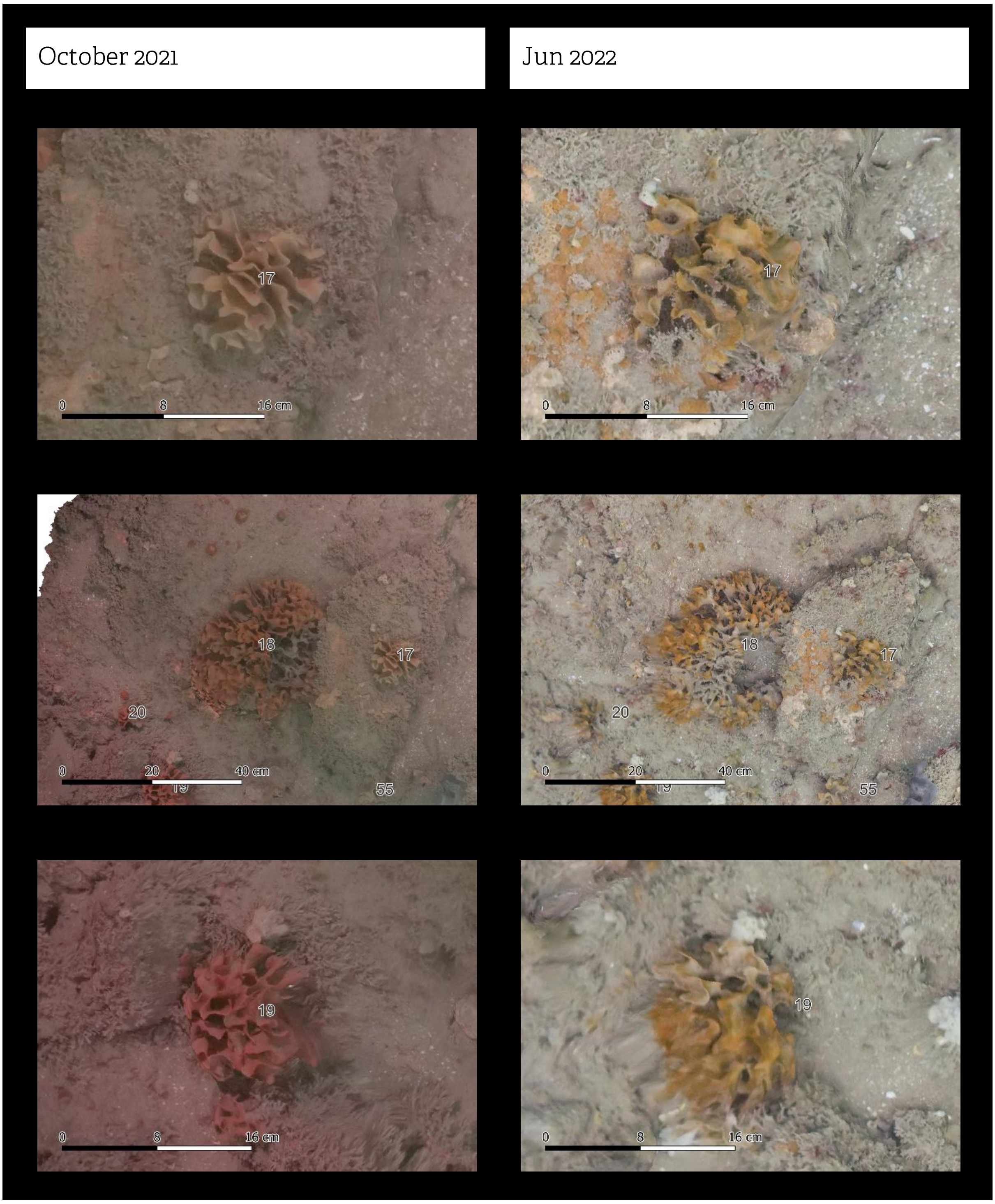
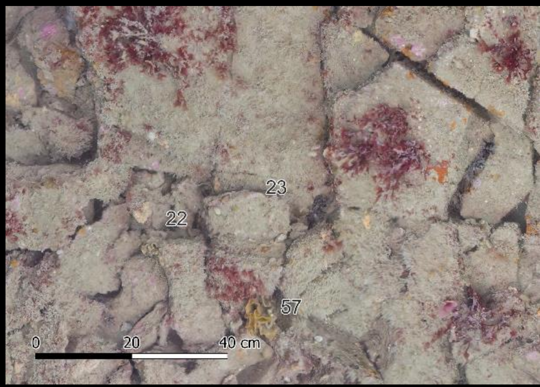


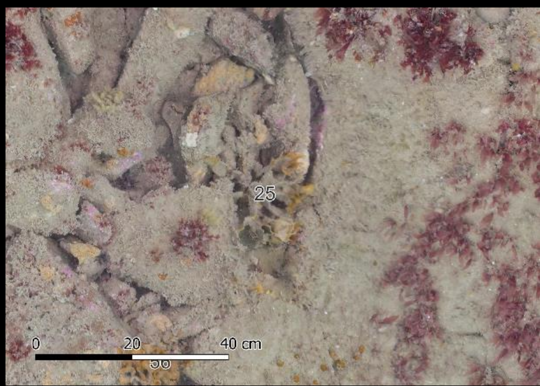

October 2021
Jun 2022
17
0
8
16 cm
17
0
8
16 cm
18
17
20
0
20
40 cm
55
18
17
20
0
20
40 cm
55
19
0
8
16 cm
19
0
8
16 cm

October 2021	Jun 2022

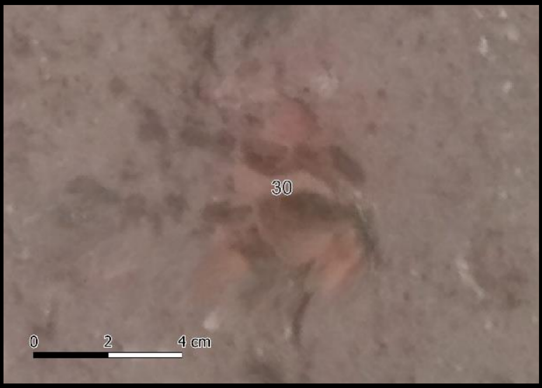
October 2021

Jun 2022

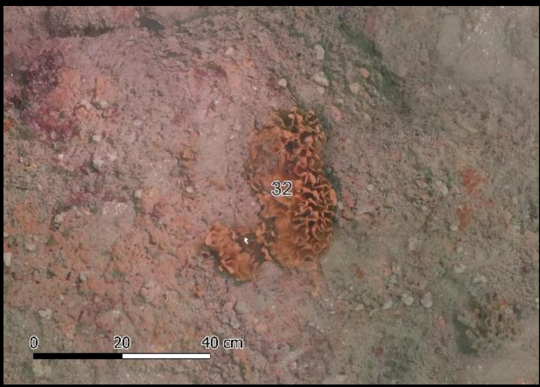


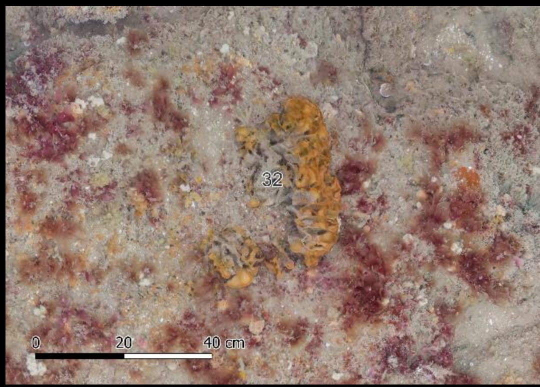


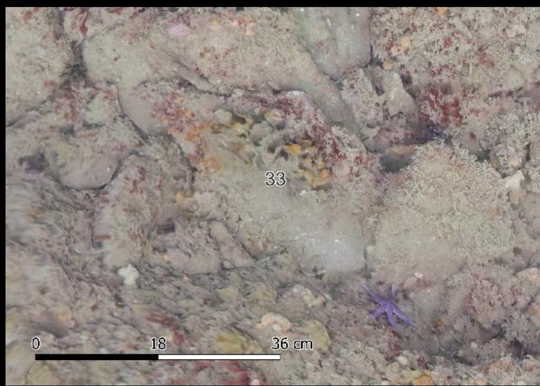

October 2021
Jun 2022
26
0 2 4 cm
26
0 2 4 cm
27
0 2 4 cm
27
0 2 4 cm
28
0 4 8 cm
28
0 4 8 cm

October 2021	Jun 2022
	
	
	

October 2021	Jun 2022

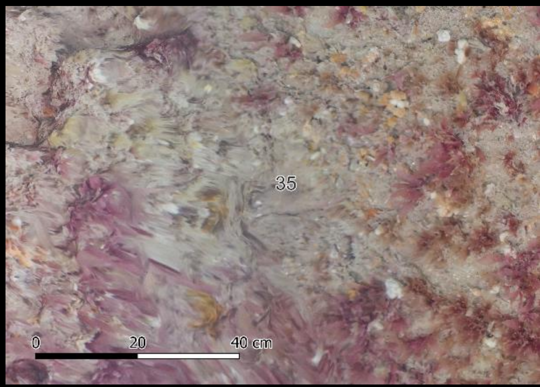


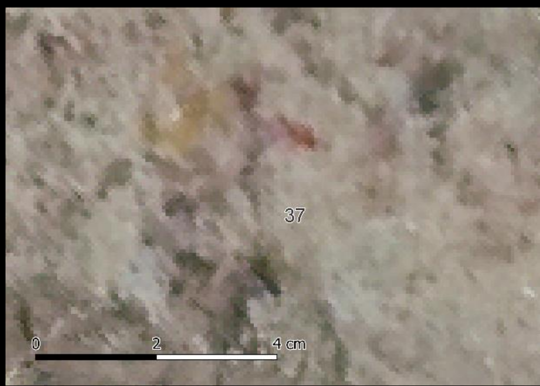


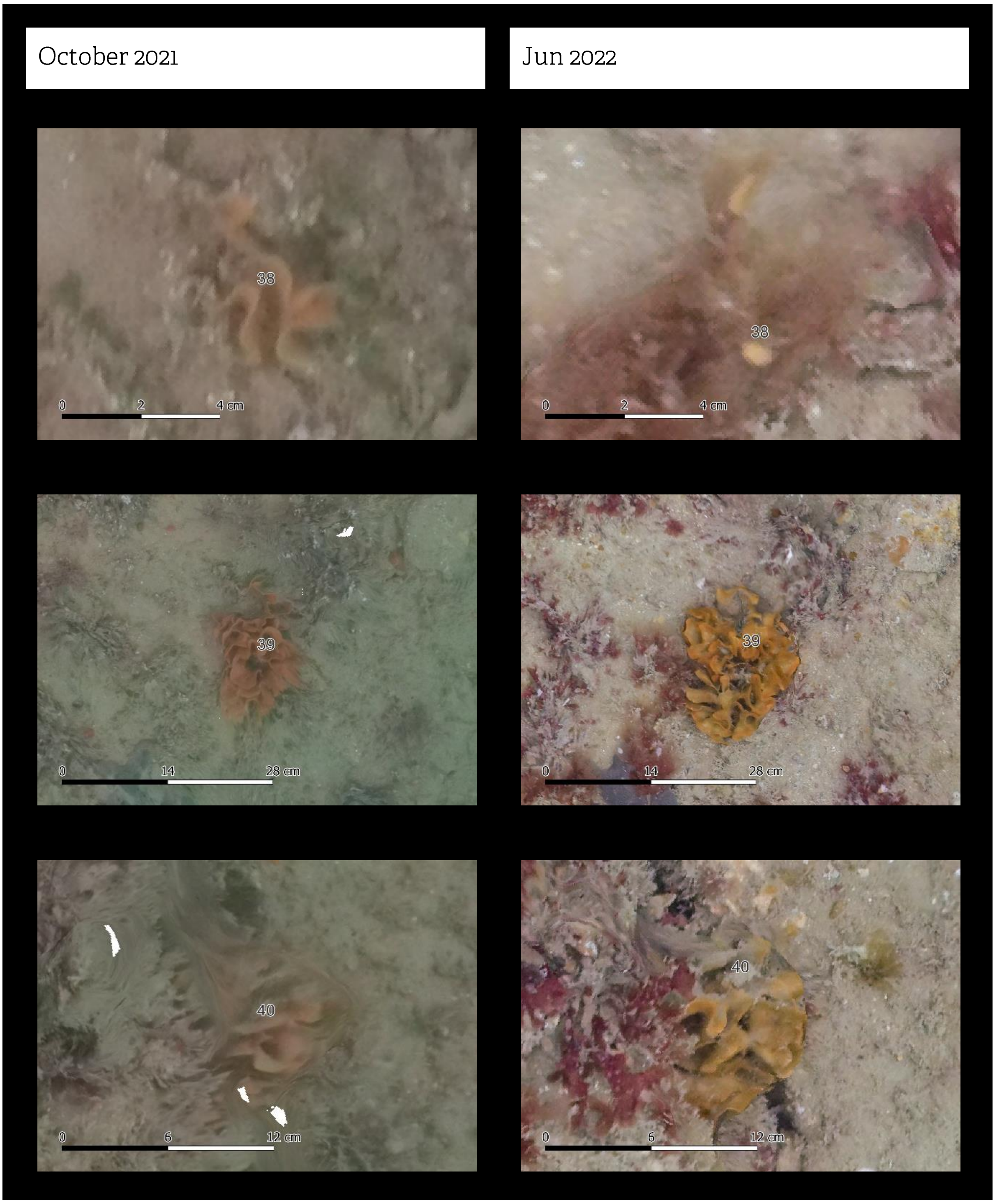


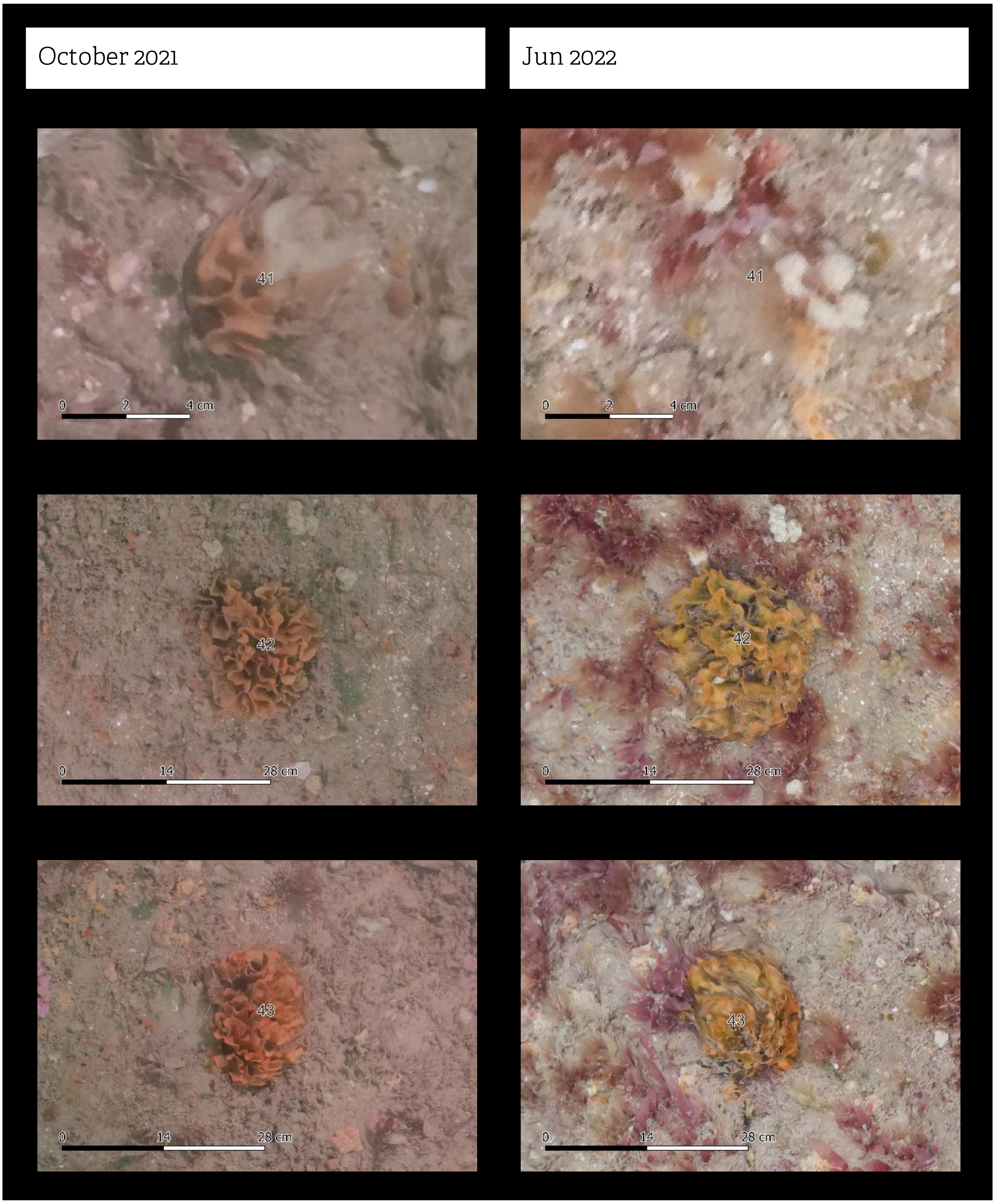
October 2021

Jun 2022

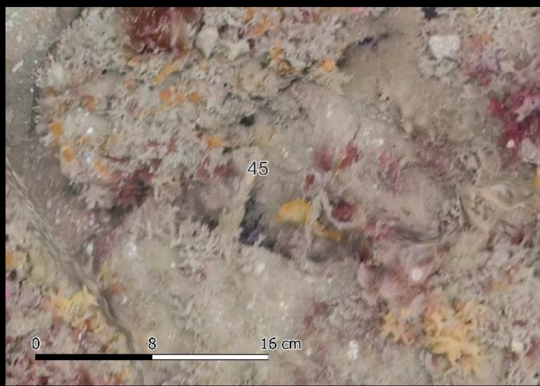


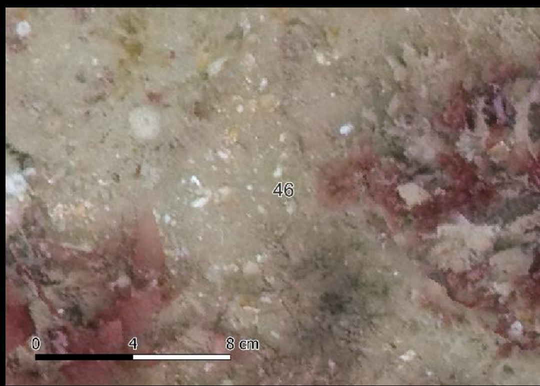


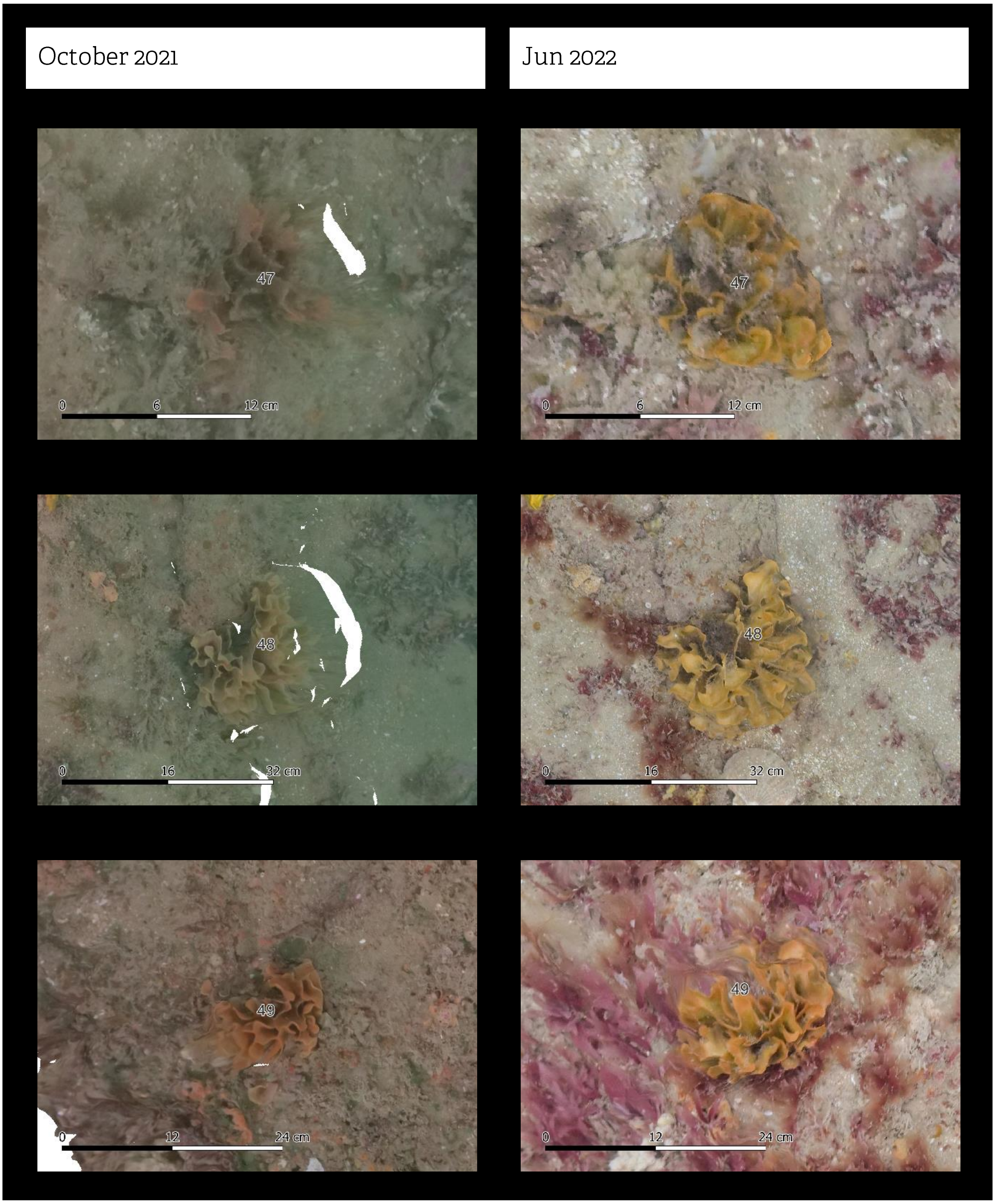

October 2021
Jun 2022
38
0 2 4 cm
38
0 2 4 cm
39
0 14 28 cm
39
0 14 28 cm
40
0 6 12 cm
40
0 6 12 cm


October 2021
Jun 2022
41
0 2 4 cm
41
0 2 4 cm
42
0 14 28 cm
42
0 14 28 cm
43
0 14 28 cm
43
0 14 28 cm

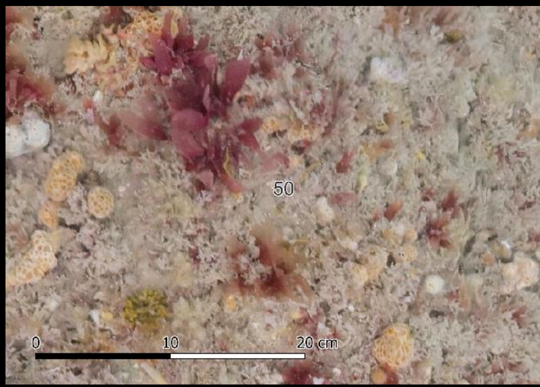
October 2021	Jun 2022

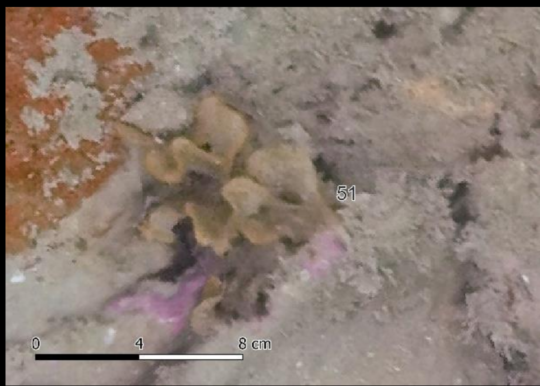




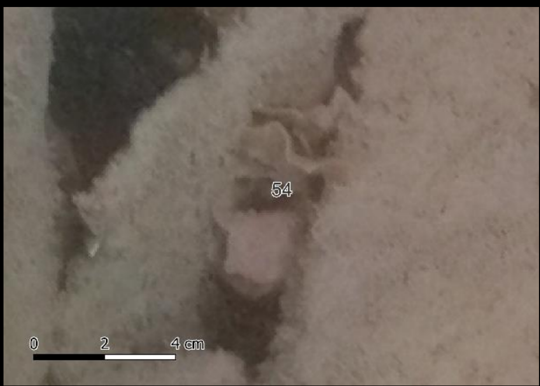

October 2021
Jun 2022
47
0 6 12 cm
47
0 6 12 cm
48
0 16 32 cm
48
0 16 32 cm
49
0 12 24 cm
49
0 12 24 cm

October 2021	Jun 2022





October 2021	Jun 2022



October 2021	Jun 2022