PLAN VIVO

PV Nature

Approved Approach for Oyster Reef Habitats

To be used in line with the PV Nature Methodology

Developed by:

Blue Marine Foundation

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Solent Seascape Project

Version 1.0 Approved by:

Plan Vivo Technical Review Panel

PV Nature Secretariat

Contents

Preface....3

1 Introduction....3

2 Justification....5

2.1 Contextualising this Approved Approach with your project....6

3 Oyster Reef Habitat Pillar Metrics....6

3.1 Pillar 4....16

3.1.1 Metric and justification....16

3.1.2 Methodological approaches....18

3.1.3 Analysis....20

3.1.4 Pillar metric considerations....21

3.1.5 Community involvement....23

3.2 Pillar 5....23

3.1.6 Metric and justification....23

3.1.7 Methodological approaches....24

3.1.8 Analysis....25

3.1.9 Pillar metric considerations....25

3.1.10 Community involvement....26

4 Development process....26

4.1 Aims....26

4.2 Development....27

5 References....28

Appendices....29

Appendix I....29

Appendix II....33

Preface

This Approved Approach must be applied in conjunction with, and in full adherence to, the requirements set out in the PV Nature Methodology and Data Protocol. It is not permitted to use this Approved Approach independently or as a standalone methodology.

This Approved Approach was developed to provide a roadmap for monitoring oyster reef habitats in line with the Plan Vivo Biodiversity Standard, PV Nature.

This Approved Approach was co-developed by Blue Marine Foundation and the University of Portsmouth on behalf of the Solent Seascape Project

1 Introduction

Oyster reef habitat is a vital yet underappreciated coastal ecosystem. Important for water filtration, boosting biodiversity and fisheries, coastal protection and cultural services, oysters are well understood for their ecological and economic importance.

Oyster reef habitats have struggled to fit within Payment for Ecosystem Services (PES) frameworks such as carbon or nutrient credits, due to the ongoing and often contradictory debate around source vs sink (of reefs and oyster farming), limiting funding opportunities for conservation of these vital habitats (Fodrie et a., 2017; Lee et al., 2020; 2024; Chen et al., 2025; Pernet et al., 2025). However, the growth in nature markets in recent years has offered a route to channel funding to projects that may not fit in traditional PES frameworks. The release of Plan Vivo's Biodiversity Standard (PV Nature) in 2023 provided an avenue for directing ethical investment to local communities whilst also catalysing the conservation and restoration of biodiversity and nature.

PV Nature is aimed at projects generating high-integrity biodiversity certificates that deliver robust and credible outcomes for nature alongside social and climate benefits. PV Nature is aligned with high-level principles including those outlined by the Biodiversity Credit Alliance, International Advisory Panel on Biodiversity Credits and World Economic Forum (High-level Principles to Guide the Biodiversity Credit Market)[1]. A cohort of 10 pilot projects, two of which

[1] https://www.biodiversitycreditalliance.org/wp-content/uploads/2025/05/377455_High_Level_Principles_to_Guide_the_Biodiversity_Credit_Market_En_v7_May-2025.pdf

were marine-focused, pioneered the application of PV Nature and contributed to the refinement of its methodology.

In summary, the PV Nature Methodology and Data Protocol consists of five Pillar Metrics. Pillar Metrics 1-3 are species-based metrics and are measured through in-situ monitoring across a minimum of three Target Groups (for marine projects) (e.g. fish, vegetation, invertebrates (Figure 1)). Pillars 4 and 5 are habitat-based metrics measuring habitat health and structure. Additionally, the PV Nature Methodology is founded on a digital approach to monitoring through third-party analysis to increase independence of calculation, removal of project level biases, and increased auditability. Unlike carbon, which is stored within biomass and soil, biodiversity is more mobile; digital data collection enables a historical record of a project's measured biodiversity.

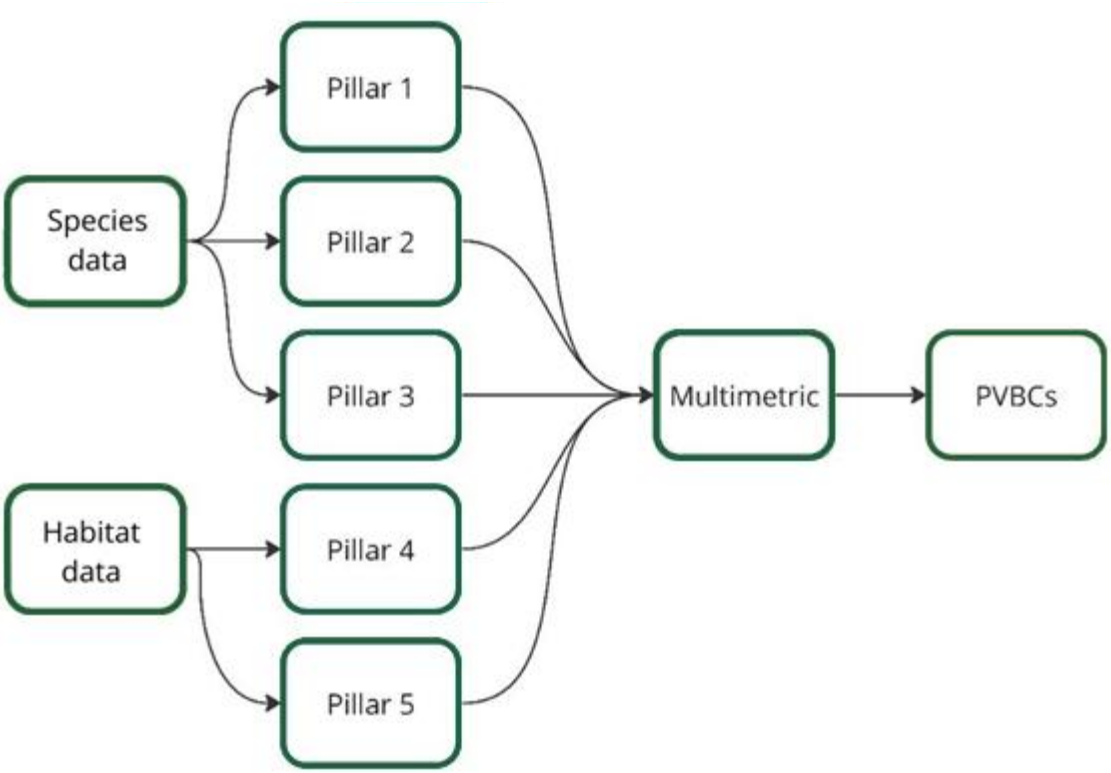


Figure 1: Overview of the analytical steps used to convert biodiversity survey data to Plan Vivo Biodiversity Certificates (PVBCs). For more information, please see the PV Nature Methodology and Data Protocol.

The PV Nature Methodology, and its application, needed significant research and testing in marine ecosystems. There are unique challenges in marine monitoring due to dynamic ecosystems and impacts from environmental factors such as tides, sedimentation and the need for underwater monitoring. It became clear that an ecosystem-based approach would be needed to develop monitoring approaches specific to the habitat pillars (Pillars 4 and 5) for marine ecosystems.

Approved Approaches have been used by Plan Vivo projects for some time across version 4 of the Plan Vivo Carbon Standard (PV Climate) when specific techniques are needed to meet accreditation requirements that are not within the scope of current Plan Vivo methodologies. Plan Vivo define an Approved Approach as a methodology or tool that is used for quantification, risk, additionality or for monitoring data for a certified or prospective Plan Vivo project.

This document will provide the second Approved Approach under PV Nature. The first Approved Approach focused on seagrass habitats. This Approved Approach will outline a methodological approach to monitoring oyster reefs in line with the PV Nature Methodological framework and specifically habitat Pillars 4 and 5.

2 Justification

Whilst the species pillars (Pillars 1-3) of the PV Nature Methodology are transferrable across projects and ecosystems, including in marine systems, the existing and suggested habitat Pillar Metrics (Pillars 4 and 5) were not readily applicable for marine ecosystems, including oyster reefs and this inapplicability was recognised by Plan Vivo.

Pillar 4 aims to track habitat health and/or quality, with an ecosystem-specific approach suggested for marine projects. Pillar 5 focuses on structural complexity, with a suggestion of rugosity as the marine metric. While this may work for solid structures such as coral reefs in tropical regions or potentially temperate oyster reefs, it is not always an appropriate measure of habitat complexity or health for temperate regions that experience high turbidity and poor visibility much of the year, and it can be expensive to obtain data in a high enough resolution.

As a result, developing a PV Nature Approved Approach for the oyster reef habitat metrics was agreed between Plan Vivo, Blue Marine Foundation and University of Portsmouth teams. The Approved Approach aims to outline metrics, methodologies and justifications for oyster reef habitat monitoring that are compliant with PV Nature and the PV Nature Methodology principles and are globally applicable to any PV Nature oyster reef project.

The aims of the Oyster Reef Approved Approach were decided collaboratively by Blue Marine Foundation and Plan Vivo. Consensus was drawn on three key aims for Approved Approach development which included:

1. a desire to develop a globally applicable oyster reef approach (with some flexibility depending on local contexts);

2. an assurance that elements of reef monitoring and oyster deployment could be accessible for community involvement where feasible and;
3. that approaches align with the PV Nature Methodological Framework, especially its requirement for digital data collection. Further details on the aims are included in the Development Process section towards the end of this document.

2.1 Contextualising this Approved Approach with your project

True oyster (Ostreidae) species and the biogenic reefs they create are present around many of the world's coastlines, providing important ecosystem services, from water filtration to coastal protection. They have become of increased interest for restoration due to their severe global decline, raised awareness of the importance of their connectivity with other temperate ecosystems (e.g. seagrass, saltmarsh) and high levels of associated biodiversity (such as commercial fish species).

Oyster species and their characteristics vary. This Approved Approach has been developed to work globally and to align with current research in oyster reef restoration, with methods initially developed for *Ostrea edulis*. As such, projects will need to take steps to contextualise this Approved Approach in their own project areas and environments. By this it is meant that the context within which this Approved Approach is applied should be explained in the project documents, namely the Project Design Document (PDD) and associated Monitoring Plan within the Technical Specification, as the application of the methodology and metrics will vary across the different oyster reef ecosystems.

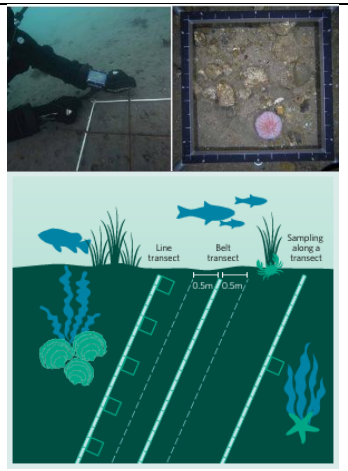
3 Oyster Reef Habitat Pillar Metrics

The proposed complementary oyster reef habitat metrics aligned with the PV Nature Methodology to provide a clear assessment of the condition and structure of restored oyster reef areas. Oyster density and size class frequency, and oyster recruitment, were chosen for Pillar 4 to understand the condition and structure of the oyster population within the reef area and to track changes in recruitment over time. While oyster density and size class are the preferred metrics, recruitment has been included where the previous metrics are not possible to monitor. Project footprint and habitat extent were selected for Pillar 5 to gain an understanding of habitat spatial structure within the project areas. Project footprint can also provide insights into overall habitat connectivity within project areas.

Pillar 4 differentiates from Pillar 5 by tracking changes in population viability but does not track changes in the spatial distribution of habitat types. These sampling methods were selected as they are commonly used in reef studies and provide insights into population function and therefore habitat health, particularly valuable for sites where oyster reefs have become functionally extinct (zu Ermgassen et al., 2021). To represent spatial distributions and to be balanced with feasible cost and sampling effort, project footprint and habitat extent were selected for the Pillar 5 metric. A comparison of the Pillar 4 and 5 metrics can be seen below (Table 1) and further details on these metrics are provided in later sections of this Approved Approach. Both metrics are listed in the European Native Oyster Habitat Restoration Monitoring Handbook.

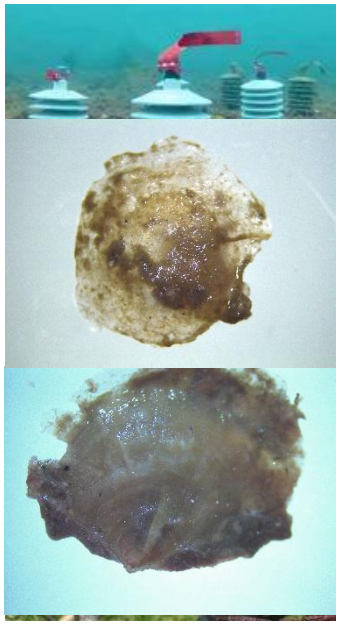
Please also note the following guidance from the Handbook: *Native oyster restoration projects vary in extent, restoration materials, morphology, form and tidal depth. As such, the number of samples (e.g. quadrat samples, core samples, etc.) to be taken per site for each metric will be different for each restoration project.*

Table 1: Pillar 4 and Pillar 5 overview.

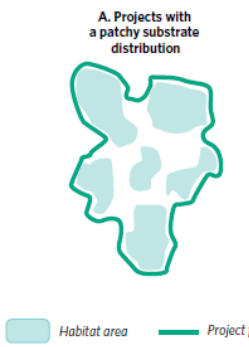
Pillar	Metric(s)	Definition	Reasoning	General sampling approach	Example	Output
Pillar 4 – Habitat condition /cover	Minimum metrics required (both): Oyster density Size-frequency	The number of live oysters within the defined sampling area. Per cent or number of oysters measured within size classes within the defined sampling area.	The density of oysters on the restored habitat provides evidence of the suitability of conditions for oyster survival. It demonstrates retention of any placed onto the restored area and any changes over time, ideally with increases in population size becoming apparent. The size-frequency of oysters on the reef provides insight into the suitability for natural recruitment and multiple year classes to establish over time. By grouping	For subtidal environments SCUBA surveys will be required. Please note that poor visibility and colonisation by other species can make it challenging to have confidence in data obtained through Remote Underwater Video methods. However, it is appreciated that these issues with regards to video quality and visibility may not limit all project locations so this may be a feasible method for other project. Similarly, diver survey feasibility and requirements will also differ with project locations. For example, dive surveys in locations like the UK mean that qualifications for diving for work are rigorous and challenging to obtain, alongside the species ID requirements, and at considerable costs.		Number of oysters per square meter (individuals/cm^2± SE). Per cent of individuals within each size class within quadrats.

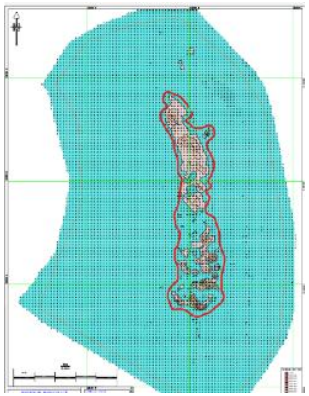
			into size classes, different cohorts can be observed over time. This metric is universally applicable with a variety of modifications that can be applied to suit the conditions of most sites.	For intertidal areas, surveys on foot can be carried out. Intertidal areas are often zonal. This should be taken into account when developing a sampling design. Stratified random sampling with quadrats, or sampling along a transect is therefore the most appropriate option. Transects are laid out to a pre-defined length. Alternatively a shot line is dropped, and divers place a quadrat at the base of the shot then conduct shorter transects on compass bearings (N, E, S and W) with at least 3 quadrats placed at 3m intervals along the four transects. The shot GPS locations and/or transect start and finish points should be allocated to cover the area of restored habitat. Quadrats are placed on the seabed along the transects at predefined intervals and excavated to the depth necessary to capture all living oysters.		

				Size frequency: In high-density populations a sub-sample should be measured, 3 to 5 oysters per quadrat should be achievable if conducting 9-12 quadrats per dive, for example. Ideally, a minimum of 50 oysters will be measured across the total replicate transects (see the Handbook for more info). Sampling frequency requirements are every five years as a minimum but should ideally be undertaken annually for the first three to five years to gain an insight into the project at its inception and then can be undertaken every five years. Sampling should maintain consistency with the chosen sampling design and appropriate dive times and other conditions that are site specific.		

Pillar 4 – Habitat condition / cover	Oyster recruitment *(optional additional metric to be used where size class frequency and oyster density are not possible to obtain)*	The number of juvenile oysters (or 'spat') settled over the spawning season on deployed settlement structures.	This indicates that the habitat is of suitable condition to allow for reproduction, larval distribution and settlement and will hopefully show an increase over time as the population increases (or potentially decreases). This metric is universally applicable with a variety of modifications that can be applied to suit the conditions of most sites and localised requirements. See pages 28 -31 of the European Native Oyster Habitat Restoration Monitoring Handbook for information on this.	Deploy a minimum of three collectors ('coupelles' or alternative 'spat collector' devices) to the seabed or suspended appropriately for the duration of the spawning season of the species (accounting for regional variation). All units used should maintain the same geometry, material, depth band, processing method etc. The collector style and deployment should mimic the restoration approach and shell substrate being used as best possible. For example, benthic reefs should use benthic collectors at the same or similar depth, with collectors mimicking oyster shell surface and texture – using hydrated lime is a good example of this. Another example would be for any restoration of species on mangrove roots or other vertical structures should use collectors in a similar	Example of benthic collectors and *Ostrea edulis* spat settled on a collector after six months.  Examples of removed spat under a microscope.	Mean number of spat settled per unit area (individuals/cm^2± SE). Note: This will need to be standardised for the project depending on the settlement material and area used. This should remain consistent throughout the project.

				vertical, slightly suspended, manner with a woody root like material. Distance between deployed collectors should also be appropriate for the site so that pseudo replication is avoided as best possible. For larger, dispersed seabed reef deployments 50m should be considered the minimum distance between units. Removal and assessment of spat settlement should take place in clean and controlled conditions. Where needed, molecular analysis can be used to determine and confirm species where more than one species of interest is present (with spat of similar appearance at early life stage) – including invasive and/or non-native species (e.g. *Ostrea edulis* and *Crassostrea gigas* in Europe). Sampling should be undertaken during the spawning season of the relevant species. Sampling frequency		

				requirements are every five years as a minimum but should ideally be undertaken annually for the first three to five years to gain an insight into the project at its inception and then can be undertaken every five years. Sampling should maintain consistency with the chosen sampling design and appropriate dive times and other conditions that are site specific		
Pillar 5 – Habitat spatial structure	Project footprint Habitat extent	The **project footprint** is the maximum areal extent over which active restoration activity is planned or permitted. This measurement does not account for the inherent patchiness in	An accurate measurement of the area of seabed impacted by the project activities is critical. Two separate measurements will be reported: **project footprint** and **oyster reef habitat area**. The restored habitat area provides the total (summed) areal extent over which the restoration	<u>For subtidal environments:</u> Multibeam bathymetry depth profile of the whole area with residual plots created from 'before-' and 'after-deposition' surveys and subsequent annual surveys. Ground-truthing is required, as outlined in the Handbook: *Given the low relief, low density nature of many native oyster habitats, the resulting data should be ground-truthed by video and/or grab sampling to ensure that areas identified as native oyster habitat actually contain living oysters and/or cultch.*	 Example from Restoration Guidelines Handbook.	Two-dimensional area of project footprint (m^2 or ha etc). Two-dimensional area of habitat area (m^2 or ha etc).

		oyster reef habitat coverage. The restored **habitat area** provides the total (summed) areal extent over which the restoration activities have resulted in an increase in cultch cover and living oysters	activities have resulted in an increase in cultch cover and living oysters. It will include any area over which oyster density and size distribution is assessed, such that multiplying the reported densities by the area provides an estimate of the oyster population size of the restored habitat. Combined with oyster density and size frequency data from Pilar 4 this will provide a realistic overview of the habitat extent.	Diver surveys may also be appropriate over smaller areas and/or in area with good visibility. See guidance from the Handbook: *SCUBA diving can be used to determine the project footprint and oyster habitat area. Divers, followed by a boat, assess the edge of the project footprint visually and deploy small buoys at regular intervals along the edge of the reef. The boat crew plots the positions of the buoys using a handheld GPS. Alternatively, if hydrodynamic conditions (currents) allow, the divers can tow a surface buoy with a mounted portable GPS. GPS positions can then be entered into mapping software. Shell cover and oyster density should be considered when assessing the oyster habitat area.*	Real world example from previous work in the River Hamble, Solent, UK. 	

				<u>For intertidal habitats:</u> Drone surveys or walk-around surveys with handheld GPS devices can be used. Sampling frequency requirements are every five years as a minimum but should ideally be undertaken annually for the first three to five years to gain an insight into the project at its inception and then can be undertaken every five years. Sampling should maintain consistency with the chosen sampling design and appropriate dive times and other conditions that are site specific.		

3.1 Pillar 4

3.1.1 Metric and justification

We propose using oyster density (oysters/m^2) and size class frequency (per cent of individuals in size classes) as the preferred metrics. Where this is not possible, oyster larval recruitment could be used as an alternative for Pillar 4.

Table 2: Proposed Pillar 4 metric for oyster reef habitats

Oyster Pillar 4	**Metric**	**Output**
Habitat condition/cover	Oyster recruitment	Mean number of spat settled per unit area
Habitat condition/cover (preferred metrics)	Oyster density Size frequency – mean oyster shell height (mm)	Mean density - Individuals (including recruits >35mm)) / m^2 ±SE Per cent or number of oysters measured within size classes

Oyster recruitment is highly indicative of a functioning population that is healthy and reproducing to a point where spat (larval) settlement can be observed through the deployment of settlement structures. It also indicates that the environmental conditions are suitable for larval settlement and survival (zu Ermgassen et al., 2021).

These structures themselves can vary depending on the environmental and physical characteristics of the site where they are being deployed – maintaining a consistent design across a project. They are relatively cost-effective way of understanding oyster reef condition. Critically, recruitment meets the three key criteria defined as part of the Approved Approach: it has scientific backing, can be monitored in a way that can have digital data collection incorporated into the sampling plan and there are established methods that can be adapted for local requirements. Community involvement is also a key part of this monitoring approach, as the large number of coupelle discs to process means that community participants need to be trained and involved over several days in order to identify and count the spat.

Oyster density and size frequency

Monitoring oyster density within the restored area is crucial to understanding the development of the habitat and has implications for disease transmission and reproductive success. Assessment of oyster density should take place over the oyster habitat area, such that multiplying the reported densities by the area provides the practitioners and funders with an estimate of the oyster population size of the restored habitat. Oyster density is defined as the number of live oysters per unit area (individuals/m2) and includes oysters > 35mm in shell height. Oysters smaller than 35mm are unlikely to be reliably and consistently sampled across sampling methods or sites and should therefore not be included in reported oyster densities but may be included in size frequency assessments. As native oysters commonly have a patchy distribution, measurements must be distributed across the site to ensure reliable reporting of year-on-year trends. Practitioners should consider the range of densities they are likely to encounter during monitoring. Where densities are extremely low, transect methods will yield better results than quadrat or grab methods, which sample small areas intensely. An increasing density of oysters outside the restoration site and the appearance of cohorts in the size class frequency data would indicate repeated recruitment events over time.

The oyster size frequency distribution shows how the population is composed in terms of the age, number and size of oysters. This metric provides information on recruitment success, survival and growth rates and may assist in the identification of key cohorts that may be sustaining a population. Oysters are frequently patchily distributed. A large number of samples may therefore be necessary to capture a sample that is representative of the population. Sampling methods may also result in biases in the sizes represented and this should be considered both when selecting a sampling method and when interpreting the results. The same methods that are used for assessing oyster density can be used to collect oysters to assess of size frequency. All oysters in the sample, including the smallest oysters, should be counted and measured for this metric.

Oyster size distributions should be obtained from living oysters, preferably using callipers, although, a ruler may also be used. Shell height should be measured as the distance from the umbo to the distal margin of the shell (Figure 2).

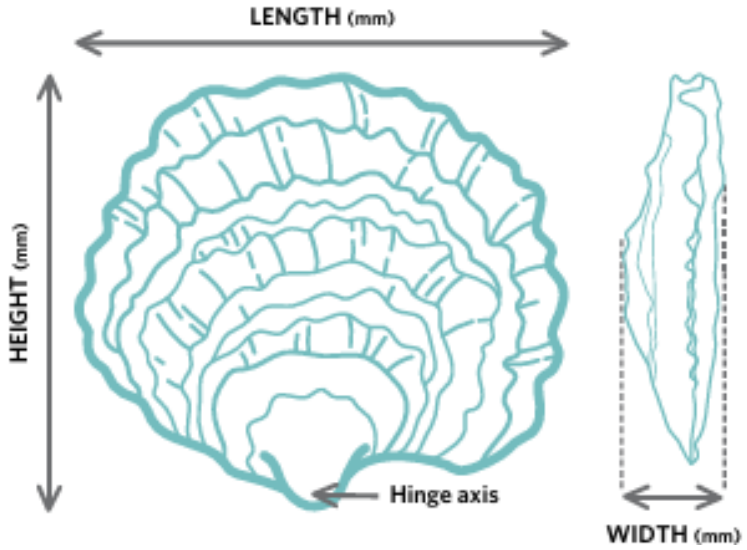


Figure 2: Example of shell height, length, width and hinge axis using *Ostrea edulis*. Source: European Native Oyster Habitat Restoration Monitoring Handbook.

3.1.2 Methodological approaches

Oyster recruitment

There are several structure and settlement devices that projects could use to collect oyster recruitment data within their project areas under this Approved Approach.

Detail on a ground-based approach is included below; however, a new data collection method can be proposed to meet the requirements of the Pillar 4 metric outlined in this document without requiring a new Approved Approach to be developed. New data collection methods can be outlined in the Monitoring Plan as part of the Technical Specification in the PDD and will be discussed and agreed upon by Plan Vivo during the review process.

Depending on the deployment location and methodology, various elements of the approach can be community-led. Creation of settlement structures, deployment/retrieval and analysis can all be incorporated into community schemes (where health and safety and other considerations allow). Ensuring that project devices are standardised should remain a priority, in terms of design, material, deployment depth and other factors.

Structures can be deployed onto the seabed or suspended in the water column depending on context specific factors and logistical limitations but should reflect the restoration actions taken in order to gain the best possible insight.

Collectors - Coupelles or 'spat collectors'

It is essential that a minimum of three settlement devices be deployed across the monitoring area ideally at least 50 m apart in any direction, if appropriate for the project scale, with exact location accounting for navigational limitations or restrictions imposed, especially if marker buoys are required for retrieval.

It is essential that the deployment of the devices occurs at a time that reflects the local spawning season of the oyster species concerned and that this timing is maintained as best possible annually (potentially incorporating degree days - the technique of using the sum of the (average) water temperature per day above the threshold temperature to assess when spawning will occur – see Box 3.3 Temperature Sum, page 27 of the European Native Oyster Habitat Restoration Monitoring Handbook) to allow for direct comparison and optimal settlement opportunity. Retrieval should be conducted at a time where there has been a sufficient period to allow for settlement and growth of spat to a size where they are visible for the method of assessment being used, if microscopy then two weeks is appropriate (but does not account for the whole spawning season) and to the naked eye six months after deployment should be sufficient. This should account for deterioration in weather conditions in appropriate geographic regions to allow for safe and controlled retrieval to avoid damage and loss of samples/structures.

Digital photographs either with high resolution camera and/or microscope will be collated. Due to the requirement for third-party digital data analysis as part of the PV Nature Methodology, a standardised approach to photo imagery should be determined. Specifications should be agreed with a project's chosen Data Analytics Provider (DAP) to ensure effective image processing and analysis.

Oyster density and size frequency

Primary Method for subtidal habitats: Quadrat sampling or transects by SCUBA diving. Random transect positions can be planned in lower-density habitat areas or systematic sampling can be planned for larger higher density areas. For lower density areas or where oysters are clearly visible, divers descend a shot-line and swim side-by-side while unreeling a transect tape (often 25m) with a distance pole at a tangent to count all the oysters in the area they pass over. In higher-density areas or where associated community assemblages make visual assessment more challenging,

quadrats can be deployed randomly along the transect line and may be a more manageable survey method. Average density per unit area calculated in either case.

For intertidal habitats: The same approach applied but with quadrats deployed on foot at low water.

Alternative Method: Drop-down video (DDV) quadrats or video twos. DDV sample locations should be randomly pre-assigned and sampled as follows. Underwater video is operated either as drop-down video (DDV) or as video tows with steel sledges. Current boat position (GPS coordinates) and water depth (per boat lead) should be recorded for georeferencing. Alternatively, video systems and ROVs can be equipped with acoustic systems and GPS to plot the position. If no advanced equipment is available, a handheld GPS or smartphone can be used to mark the position. Laser pointers should be mounted and calibrated to determine the field of view. If capturing images of quadrats, the camera must be pre-positioned to include the entire quadrat within its field of view. Where water clarity allows, lighting should be used to increase the quality of the recording. When operating a DDV, gently lower the system until it contacts the seabed. Upon contact, the rope will go slack. Wait for two to three minutes so that any sediment disturbed by the quadrat has settled before capturing the image. The DDV and quadrat should be recovered before moving to the next sampling location. When towing ROVs or operating underwater video on a sled, the boat should drift (maximum speed of one knot) over the study site. The area covered (m^2) can be calculated from the distance travelled (course plot/average speed) and the field of view.

Note that, given the cryptic nature of native oysters, oyster densities determined from images are likely to be lower than those determined by excavated quadrats. Where possible, sampling efficiency should be ground-truthed by divers (see Primary Method). The cryptic nature of the species means that towed video transects may not be appropriate for determining densities.

3.1.3 Analysis

Where possible, analysis will be undertaken by the project's DAP in agreement with both the Project and Plan Vivo.

Molecular analysis may be required to confirm species identification at early settlement stages where multiple species occur. For this, the individual spat will be collected and removed from the coupelle and placed into an individual vial containing ethanol (Eppendorf tube for example, if appropriate), DNA extraction of the sample will be conducted following the manufactures protocol (Qiagen DNeasy Blood & Tissue kit, for example) with subsequent PCR that will incorporate relevant primer sets for the species in question (in this case for *Ostrea edulis* the Oe fw_1/Oe rev_4 (Gercken

& Schmidt., 2014) and for *Crassostrea gigas* LCO1490/HCO2198 (Folmer et al., 1994)). Positive amplifications will be shown in gel electrophoresis, if required, samples can be sent for sequencing to double verify species.

3.1.4 Pillar metric considerations

Oyster recruitment

Measuring oyster larval recruitment is not without its caveats and may not be suitable for all projects.

Coupelles require time and resource to assemble and deploy. Further, settlement on them is not necessarily representative of settlement on the reef/seabed. While they do have value in providing insight into the functioning of reefs in the area, and the suitability of the site for further restoration action, it is challenging to assign spat settlement on coupelles to a particular restoration site or action due to movement and migration of larvae in the water from their source broodstock. For example, in some areas of France, it would be expected there to be many larvae in the water column, so picking out the signal from a restoration effort would not be possible.

However, in some circumstances they can still provide an indication that the environmental conditions are favourable for settlement and that the restored reef/habitat is likely to provide optimal conditions for recruitment to occur.

There are several environmental and anthropogenic factors that could damage or cause the loss of monitoring equipment and result in no data being obtained for individual or multiple structural units. For example, if a unit sinks into excessively muddy substrate, this can partially occlude settlement surfaces available to spat, even though coupelle units are designed to mitigate against this through the use of a concrete slab at the base. Storm events and other environmental factors can cause loss of units, marker buoys and other equipment.

With regards to anthropogenic risk factors, recreational boat users mooring to marker buoys tethered to monitoring equipment can cause the loss of the marker buoy and hence the unit it is attached to, as these are not designed to be moored to. Impact from propellers would cause the detachment of the marker buoy and make retrieval extremely difficult. Inquisitive individuals may also cause issues with movement or displacement of equipment.

Oyster recruitment alone does not always equate to a more functional ecosystem, however, Plan Vivo's approach of using an aggregation of metrics to provide a multimetric allows the Pillar 4

metric to feed into wider species and habitat metrics to provide a more well-rounded understanding of the ecosystem within project areas.

Standardisation of spat collector units themselves and standardisation across years should be factored in sampling plans and designs. The standardisation should include collector material, design, size, construction, geometry, depth of deployment and processing method, for example.

Additional considerations around sampling design and deployment structures etc would be needed where any restoration efforts included species in or on mangroves or other irregular vertical structures.

In locations with indigenous stewardship the local knowledge and permissions should be incorporated into project planning and sampling design from the outset.

Oyster density and size frequency

SCUBA diving poses inherent risks and the processes in place regarding health and safety should be set to the highest standards.

In the UK there are several requirements for individuals to be able to "dive for work" or undertake Scientific diving and these requirements should be checked and followed at the time of undertaking the sampling. This process should be undertaken for the geographic region where any work is planned.

Individuals undertaking the sampling should not only be competent and qualified for SCUBA, but also in scientific monitoring and species identification.

Visibility in turbid environment (experienced with video surveys) still poses challenges for divers when undertaking monitoring work. Limitations around bottom time, surface intervals, tidal currents (slack water duration included) and number of transects conducted within these timeframes should be planned into any dive plan. When surveying larger areas multiple days and dive teams should be incorporated into plans

Video surveys (either drop-down or tows) are likely to only be an effective tool when the visibility of the water in the environment is extremely good and that the benthic community does not impede visual assessment of the oyster population. As populations establish and climax communities are reached this is unlikely to prove a useful method in determining oyster density and size frequency. In highly turbid environments the time and effort put into video surveys is likely to yield few results and should be carefully considered.

Additional considerations around sampling design and deployment structures etc would be needed where any restoration efforts included species in or on mangroves or other irregular vertical structures.

In locations with indigenous stewardship the local knowledge and permissions should be incorporated into project planning and sampling design from the outset.

3.1.5 Community involvement

For each methodology and metric, the level of involvement will be very project and context dependent. For coupelles, depending on the nature of the settlement devices, community participation could be incorporated into the creation and assembly and deployment of devices. This should follow the Health & Safety requirements of the country/region they are being deployed in. Visual analysis of the spat collectors after they are retrieved could also incorporate community participation and will require basic training in identification skills. Low-cost alternatives could be created in regions where natural materials are used as settlement substrate in lower energy environments - providing that the devices are created in a way that is replicable/identical and that the data obtained is replicable.

If using oyster density and size-frequency, the level of community involvement will be very much dependent on the survey method employed and local qualification requirements. In intertidal systems this is easily achieved through walking transects and quadrats, whereas subtidal reefs require qualified scientific divers. The training required would be to meet local restrictions on diving for work, as well as species identification and underwater surveying qualifications.

3.2 Pillar 5

Originally, Pillar 5 aims to assess the spatial structure, namely extent and structural complexity of a habitat. Plan Vivo acknowledged that, given the variability between different marine habitats in terms of the rate at which their structural complexity changes (Wedding et al., 2011), it may be more appropriate to use different metrics for different marine habitat types (e.g. metrics of structural complexity that are specific to the changes seen in recovering coral reefs, kelp forests, hard bottom habitats, seagrass meadows, etc.).

3.1.6 Metric and justification

We propose a habitat spatial structure approach for Pillar 5 using project footprint and habitat extent as the metric.

Table 3: Proposed Pillar 5 metric for oyster reef habitats

Oyster Pillar 5	**Metric(s)**	**Output**
Habitat Spatial Structure	Project footprint Habitat extent	Survey drawings, residual plots, metadata and XYZ files. Two-dimensional area of project footprint (m^2 or ha etc). Two-dimensional area of habitat area (m^2 or ha etc).

The restored habitat area provides the total (summed) areal extent over which the restoration activities have resulted in an increase in cultch cover and living oysters. It should include any area over which oyster density and size distribution are assessed, such that multiplying the reported densities by the area provides an estimate of the oyster population size of the restored habitat (zu Ermgassen et al., 2021).

Multibeam bathymetry depth profile of the whole area with residual plots created from 'before-' and 'after-deposition' surveys and subsequent annual surveys is an effective way of understanding oyster reef extent. Critically, the habitat spatial structure approach meets the three key criteria defined as part of the Approved Approach: It has scientific backing, can be monitored in a way that can have digital data collection incorporated into the sampling plan and there are established methods that can be adapted for local requirements.

3.1.7 Methodological approaches

Multibeam and multibeam side scan sonar bathymetric surveys will be undertaken by third party contractors. See Appendix 1 for example metadata and equipment used to obtain data. Data can be ground-truthed by benthic grabs to confirm that the reef section is what is reflected in the survey. Please see the European Native Oyster Habitat Restoration Monitoring Handbook for further information on other methodologies to assess project footprint and habitat extent, including SCUBA dive surveys and underwater video approaches. These methods may be more appropriate for other locations where visibility is sufficient and/or multibeam is too expensive, but please see the considerations section below for further thoughts. These alternatives are also more amenable to becoming a community-led approach, following species identification training, health and safety requirements and locally relevant guidance such as the Oyster Restoration Monitoring Handbook linked above. Please note that these methods are for subtidal oyster reefs.

For intertidal oyster reefs, it is possible to follow a similar approach using perimeter walking and edge tracking with GPS devices at low tide.

3.1.8 Analysis

Analysis will be undertaken by an approved DAP in agreement with both the project and Plan Vivo.

3.1.9 Pillar metric considerations

The proposed methodology for this metric is based on guidance from the European Native Oyster Habitat Restoration Monitoring Handbook (zu Ermgassen et al., 2021), developed by leading oyster restoration experts in Europe and with global input from Handbooks created for other regions. It is important to note that multibeam bathymetric or side-scan sonar surveys can be logistically complex and expensive to undertake, which may not be suitable for all projects, particularly those at smaller scales. As outlined in zu Ermgassen et al. (2021), habitat extent data can also be collected by diver surveys (if conditions allow, but this can also be costly).

If dive surveys are feasible at a project site and scale, this would remove the need for benthic grab ground truthing (as visual / recorded assessments would provide confirmation of reef presence through identification of live oysters, dead shell, biogenic structure etc.). However, once an oyster reef community becomes established it may be difficult to distinguish the boundary of the project area and habitat extent using this visual methodology. Dive surveys are also not without their limitations and can be expensive and complicated to undertake (see Pillar 4 considerations).

Studies in Florida have shown that LIDAR data collected via drone may be sufficient for mapping the footprint (and structural complexity, outlined below) of intertidal oyster reefs when exposed at low tide (Espriella et al., 2023), so this could be a more affordable option within projects with intertidal oyster reef habitat. At a smaller scale, intertidal project area and habitat extent can be mapped on foot with a handheld GPS, where conditions are safe to do so.

Structural complexity (rugosity) could also be a valuable metric to consider for oyster reef habitats, as mentioned above and referenced in Wedding et al. (2011). However, the resolution of remotely sensed data, such as bathymetric surveys, required is significantly higher than what is required for habitat extent. This will likely increase the cost of survey methods further when considering subtidal oyster reefs in particular.

Elements of the project that can community led are likely to only be when intertidal restoration is taken out or where specialist equipment is not required. Reef area monitoring on foot with handheld GPS devices is an example where community involvement can be incorporated.

Additional considerations around sampling design and deployment structures etc would be needed where any restoration efforts included species in or on mangroves or other irregular vertical structures. These methods may require an alternative design approach.

In locations with indigenous stewardship, local knowledge and permissions should be respected and considered alongside other evidence in project planning and sampling design from the outset.

3.1.10 Community involvement

For subtidal reefs, underwater video, snorkel or SCUBA surveys may become a community-led approach, following species identification training, health and safety requirements and locally relevant guidance such as the Oyster Restoration Monitoring Handbook linked in previous sections. For intertidal oyster reefs, the perimeter walking and edge tracking with GPS devices at low tide methodology will also be more amenable to community-led approaches, following relevant training in the protocols and species identification.

4 Development process

4.1 Aims

The aims of the Oyster Reef Habitat Approved Approach were decided collaboratively by Blue Marine Foundation and Plan Vivo. Consensus was achieved on three key aims for Approved Approach development, which included:

1. a desire to develop a globally applicable oyster reef approach;
2. an assurance that elements of reef monitoring and oyster deployment could be accessible for community involvement where feasible and;
3. that approaches aligned with PV Nature, especially its requirement for digital data collection. Further details on the aims are included below:

To reduce the need for multiple Approved Approaches in oyster reef habitat ecosystems, it was agreed that the document would be developed with global applicability in mind. As a result, although metrics and methodologies aim to be applied to all projects, the Approved Approach will highlight key areas and decisions where detail will need to be provided at project-level to ensure that this can be adapted to a wide range of oyster reef habitats, including both temperate and tropical oyster species and both intertidal and subtidal habitats. This provides a consistent approach across PV Nature oyster projects and improves monitoring efficiency for projects that may have a mixture on intertidal and subtidal oyster reefs within their project areas.

Finally, the Approved Approach must align with PV Nature Project Requirements. This includes developing metrics that work within the Pillar Metric multi-metric approach to generating credits and ensuring that, where possible, data is collected digitally to allow for 3rd party analysis and auditing.

4.2 Development

To develop the Approved Approach, the Blue Marine and University of Portsmouth team utilised prior experience through the development of monitoring protocols and an existing suite of restoration guideline handbooks. These handbooks were created by experts from across Europe and around the world, several of whom have been involved in projects across a range of scales.

To try increase the global applicability of the Approved Approach the methodologies suggested are relatively standard for the field, involve elements that can be adapted to local settings, with regards to physical, environmental and species-specific requirements, as well as subtidal and intertidal considerations.

5 References

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Appendices

Appendix I

Example metadata sheet provided by hydrographic surveyors.

SHORELINE SURVEYS LIMITED
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surveys@shorelinesurveys.com - www.shorelinesurveys.com

Over 25 years, over 2500 projects

Company number: 04464556 - Vat Registered

SURVEY METADATA

PROJECT	Our reference:	J2511-3		
	PO:	Email Order		
	Location:	Swanwick Bend, River Hamble		
	Description:	Monitoring surveys for Hamble Oyster Reef Restoration project		
	Survey area(s):	Per clients KMZ		
	Survey type(s):	Multibeam & Multibeam side scan sonar		
	Survey date(s):	16 April 2025 Days: 1		
	Despatch date:	16 April 2025		
	Project Manager:			
	Surveyor:		Boatman:	
	Processor:		Checked:	

CLIENT	Contact:	
	Position:	
	Company:	
	Address:	
	Post code:	
	Telephone:	
	Email:	

SURVEY VESSEL	Name:	*Gemini*	
	Type:	Survey vessel	
	Certification:	MCA Category 3	
	Call sign:	MP0H2	
	Size:	6.2 x 2.4 metres	
	Draft:	0.3 metre	
	Speed:	23 knots	
	Engine (main):	60 HP	
	Engine (aux):	60 HP	

SOFTWARE	Acquisition:	HYPACK Survey 2025
	Processing:	HYPACK Survey 2025

POSITIONING	Type:	Multibeam: Applanix POSMV WaveMaster 2
	Correction service:	Trimble VRS NOW
	Accuracy:	0.05 metre horizontal & vertical
	Calibration:	Checked against digital background data
	Frequency:	Static momentary position
	Position:	Observed to be within survey tolerance
	Comment:	Observed to be within survey tolerance

TIDES

(Water levels)

Method:	RTK GNSS using Trimble VRS NOW virtual tide gauge
Datum:	Chart Datum
CD/ODN:	-2.74 m
Charts/ XYZ:	To Chart Datum using the above separation value
Calibration:	Checked against predicted values

MULTIBEAM

Type:	Norbit iWBMS	
Frequency:	400 kHz	
Beam width:	0.9° x 0.9°	
Swathe width:	Typically 130° (steered where necessary)	
Resolution:	0.01 m	
Accuracy:	~0.10 m	
On-line smoothing:	None	
Velocity of sound		
Water column:	Instrument:	Valeport Swift
	Sample rate:	Pre, post and hourly intervals
Beam forming:	Instrument:	Valeport Mini SVS
	Sampling rate:	1 Hz and applied in real time
Motion reference	Instrument:	Applanix POSMV WaveMaster 2
	Location:	Factory installed within the sonar head
Heading reference	Instrument:	Applanix POSMV WaveMaster 2 Dual antenna heading reference
Calibration	Verified patch test and GAMS test	
Processing	GNSS and heave data post-processed using POSPAC MMS	
System:	HYPACK Hysweep 2025	
Smoothing:	None	
Filter:	Minimum beam quality:	3
Output density:	0.2 x 0.2m	Shoal & Average Bias
Output definition:	One point per cell located on actual XY (where possible)	
Presentation rounding:	IHO Rounding Rules	
Post processing:	POSPac	
Comment	Data has been collected to determine bed levels only	
Survey Duration:	1 day	

PROJECT GEODESY

Data collection:	WGS84
Geoid model:	OSGM15
Transformation:	OSTN15
Data presentation:	OSGB36
CD/ODN:	-2.74 metres

DELIVERABLES

Digital	1 x survey drawing(s) (.pdf) & (.dwg)
	1 x residual drawing(s) (.pdf) & (.dwg)
	1 x metadata (.pdf)
	2 X XYZ files (shoal & average) (.xyz)

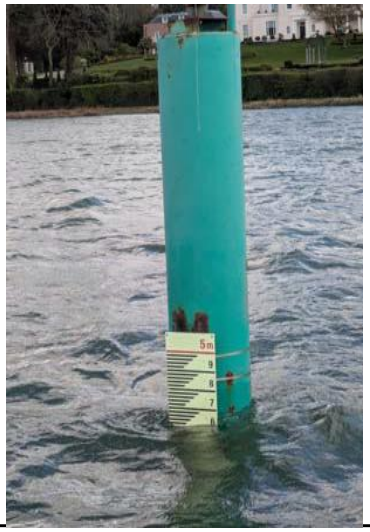
CONDITIONS

Maximum wave height: 0.2 m

Maximum swell height: 0.0 m

Conditions were suitable for the duration of the surveys

14:57 observed RTK tide was 4.50m. The difference between the tide board and the observed was 0.12m



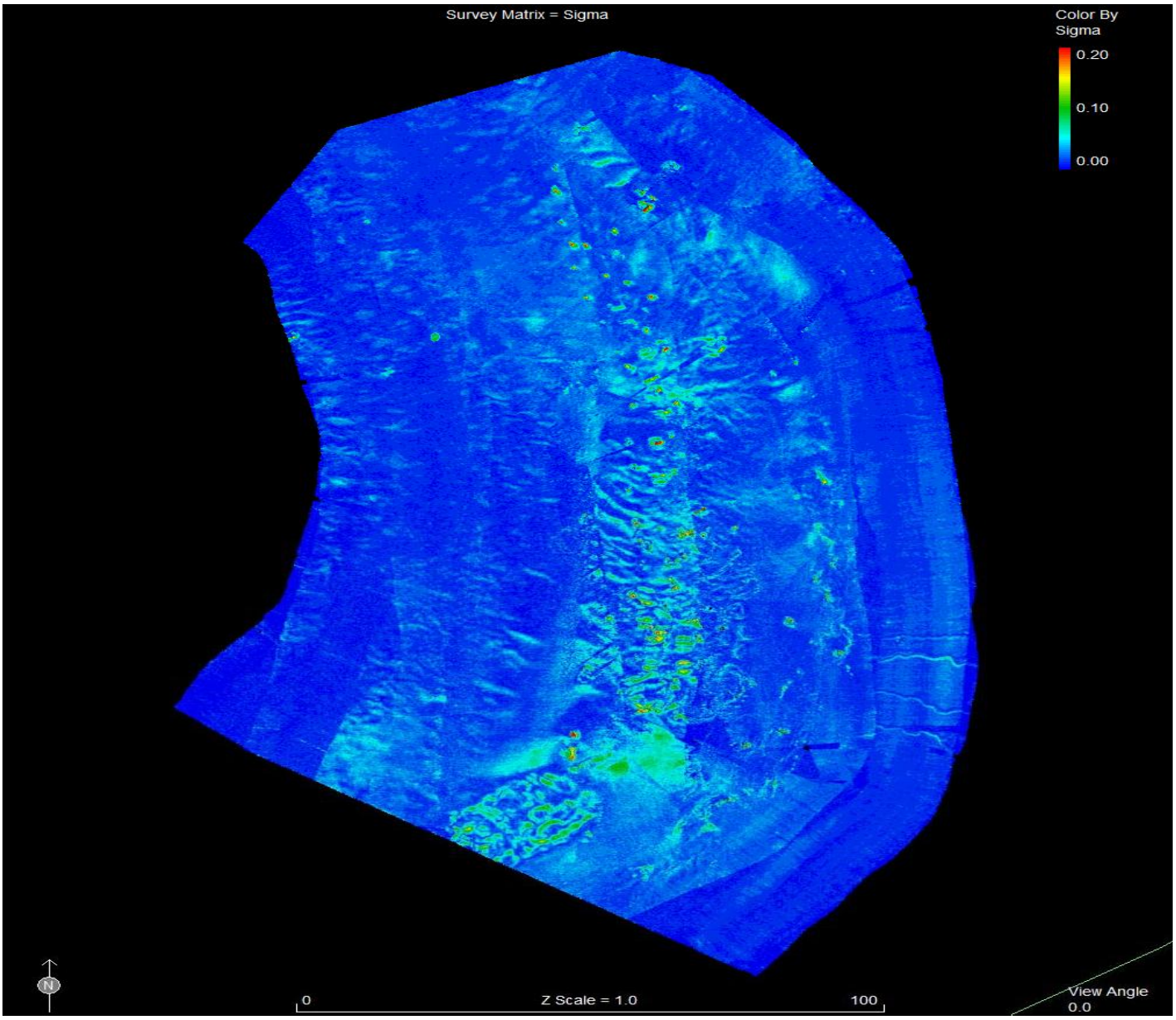
DATA ACCURACY

Data has been collected, edited and presented with the goal of determining accurate information of general bed levels within the survey area. Interpretation has not been focused on the detection of bed mounted features such as wrecks/ debris or other obstructions which will cause harm, incident or impede the safe passage of any craft. If it is imperative that such features are detected and charted we recommend the execution of a high resolution side scan sonar survey.
It is possible that certain features on the seabed will have remained undetected. This will include but not be limited to rebar, scaffolding, wire debris and other targets which are virtually acoustically invisible.
Shoreline Surveys Limited cannot be held responsible for any loss, consequential or otherwise, as a result of the use of this data.
This project has been undertaken on the understanding that the client accepts the above.

QUALITY CONTROL

Shoreline Surveys Limited strives to collect as good quality data as possible. The performance characteristics and operating constraints of the equipment are fully understood and on that basis survey work was undertaken only when the conditions permit. It is our objective to become fully accredited with the ISO Quality Standard and the groundwork for such accreditation has been implemented from the onset of our operations.

SIGMA SCREENGRAB (showing residual differences between overlapping multibeam dataset



PLAN VIVO

Appendix II

Public Consultation Feedback

Summary of Feedback	Response
Pillar 4: querying the reliance on coupelles as a metric of condition. Suggested size frequency on the reef footprint as a better metric of recruitment and the condition of the habitat, as it is a direct measure of the habitat. Pillar 5: requested that oyster density be included within reef area assessments, as area alone does not inform of the condition of the habitat within it.	Oyster density and size class frequency (via SCUBA survey or alternative appropriate method) have now been proposed as a requirement to assess the population on the restoration area. This should address this concern.