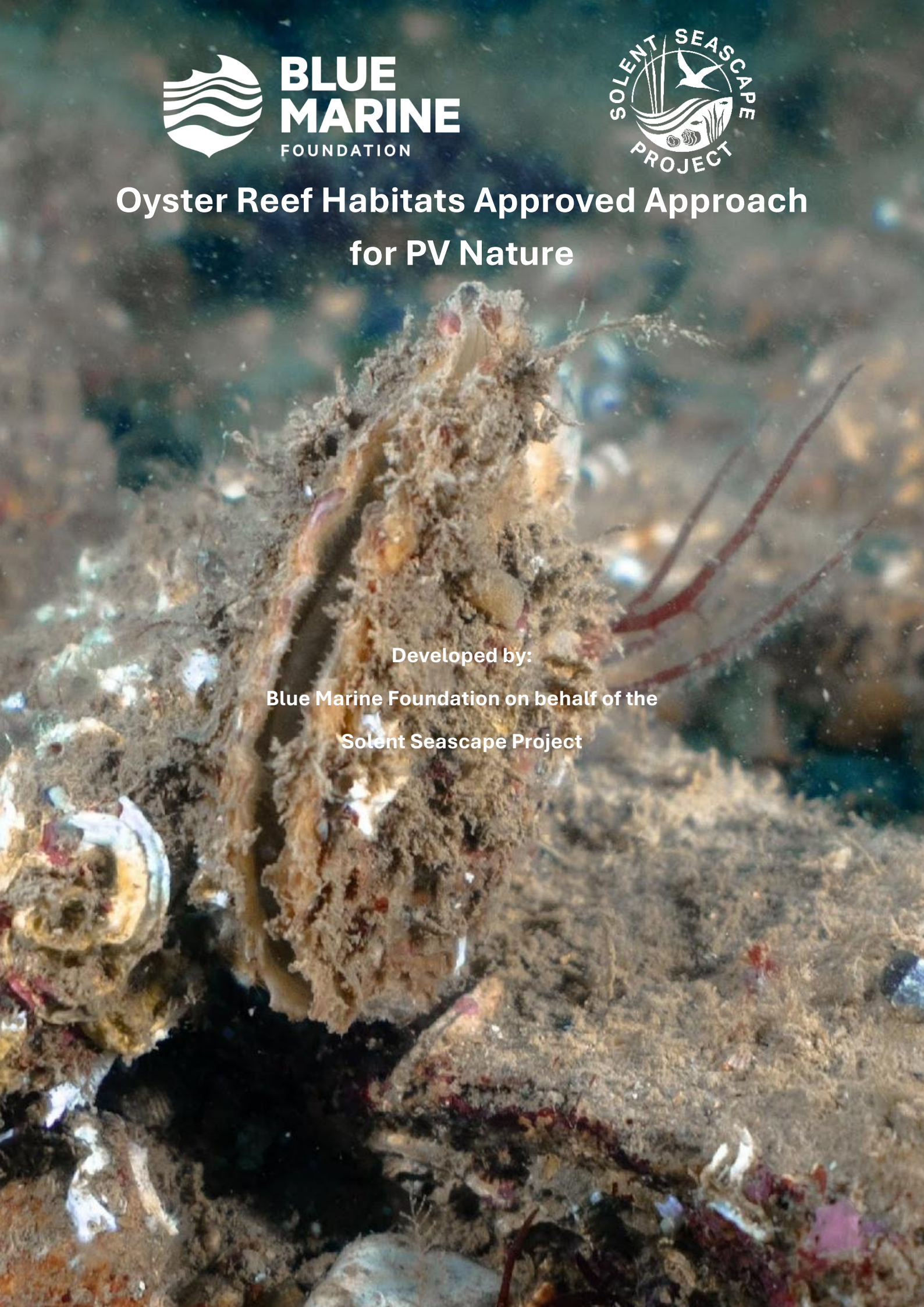


Oyster Reef Habitats Approved Approach for PV Nature

Developed by:

Blue Marine Foundation on behalf of the

Solent Seascape Project

Preface

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 approach was developed by Blue Marine Foundation on behalf of the Solent Seascape Project. Input and technical expertise were provided by University of Portsmouth; the development team would like to extend their thanks for these contributors.

Contents

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). A cohort of 10 pilot projects, two of which 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.

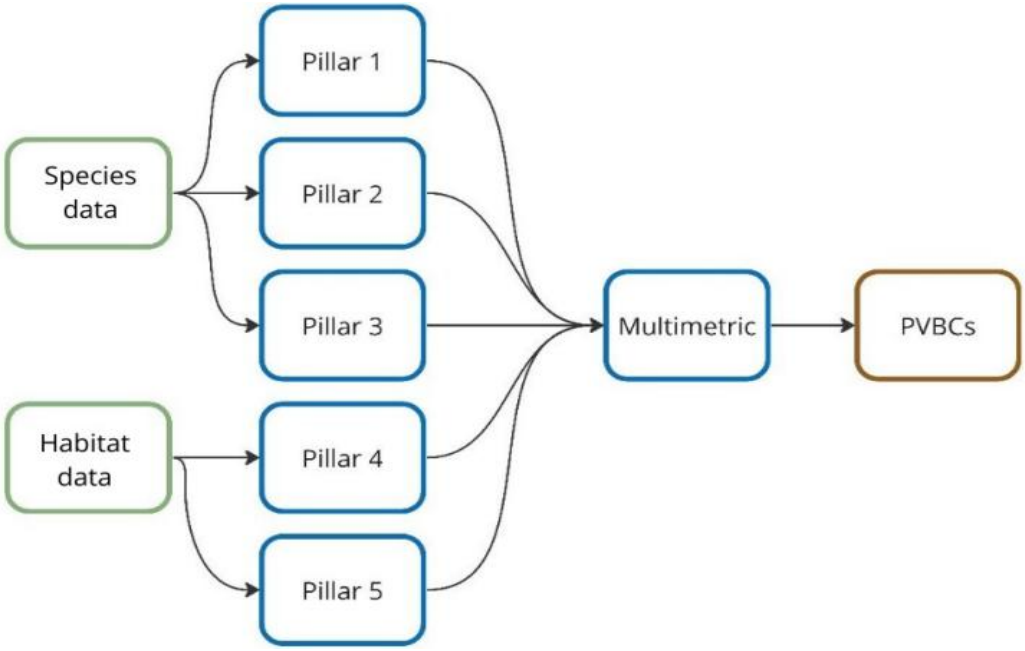


Figure 1: Overview of the analytical steps used to convert biodiversity survey data to Plan Vivo Biodiversity Certificates (PVBCs). For more information, please see the PV Nature Methodology and Data Protocol.

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.

As a result, this document will be 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 and Blue Marine Foundation 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;

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 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.

3. Contextualising this Approved Approach with your project

True oyster species/reefs 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 connectivity across other temperate ecosystems (e.g. seagrass, saltmarsh) and the importance of their associated biodiversity (such as commercial fish species).

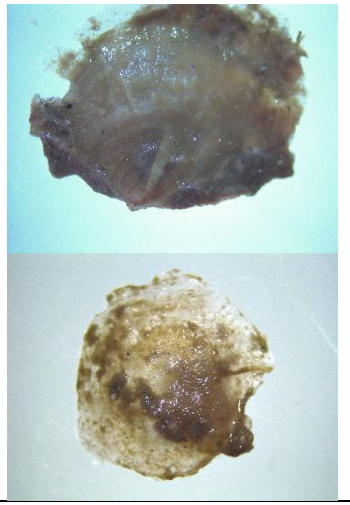
Oyster species and their characteristics vary. This Approved Approach has been developed to work globally and to align with current research in oyster reef restoration, with methods initially developed for *Ostrea edulis*. As such, projects will need to take steps to contextualise this Approved Approach 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.

4. Oyster Reef Habitat Pillar Metrics

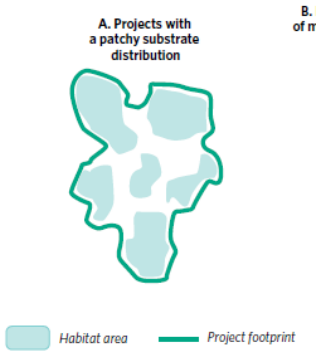
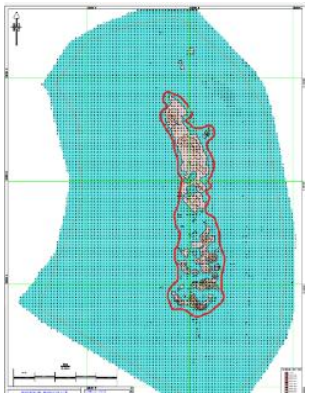
Blue Marine proposed complementary oyster reef habitat metrics aligned with the PV Nature Methodology to provide a clear assessment of the condition and structure of restored oyster reef areas. Oyster recruitment was chosen for Pillar 4 to understand the condition and functioning of the oyster population within the reef area and to track changes in the levels of recruitment over time. 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.

Table 1: Pillar 4 and Pillar 5 overview.

Pillar	Metric(s)	Definition	Reasoning	General sampling approach	Example	Output
Pillar 4 – Habitat condition/ cover	Oyster recruitment	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).	Deploy a minimum of three 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). Remove and assess spat settlement. 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*).	Example of *Ostrea edulis* spat settled on a coupelle.  Examples of removed spat under a microscope. 	Mean number of spat settled.

Oyster Approved Approach

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 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	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 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.	Multibeam bathymetry depth profile of the whole area with residual plots created from 'before-' and 'after-deposition' surveys and subsequent annual surveys.	Example from Restoration Guidelines Handbook.  Real world example from previous work in the River Hamble, Solent. 	Two-dimensional area of project footprint (m^2 or ha etc). Two-dimensional area of habitat area (m^2 or ha etc).

5. Pillar 4

a. Metric and Justification

We propose oyster recruitment for Pillar 4 using larval recruitment as the metric.

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

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.

Methodological Approaches

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.

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) 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 to the naked eye (six months after deployment should be sufficient) and to account for deterioration of 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.

b. 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.

c. Pillar Metric Considerations

Oyster larval recruitment, however, is not without its caveats. For example, identifying the broodstock (adult) source location of the larvae that have settled is not currently feasible and with potential for alternative sources or inputs this could provide a view that is not necessarily fully representative of the restored population. However, this still provides 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 an 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. In terms of anthropogenic 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.

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.

6. 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.).

d. 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.

e. 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.

f. Analysis

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

g. 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 to undertake.

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 in 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.

7. Development Process

h. 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.

i. Development

To develop the Approved Approach, the Blue Marine 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.

8. References

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Appendices

Appendix 1

Example metadata sheet provided by hydrographic surveyors.

SHORELINE SURVEYS LIMITED
Moreford Hall, Moreton, Dorchester, Dorset, DT2 8BA

+44 7950 038317
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

Oyster Approved Approach

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