PLAN VIVO

PV Nature

Approved Approach for Seagrass Habitats

To be used in line with the PV Nature Methodology

Version 1.0

Developed by:

Association for Coastal Ecosystem Services

Vanga Seagrass Project

Kenya Marine and Fisheries Research Institute

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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[1]. It is not permitted to use this Approved Approach independently or as a standalone methodology.

This Approved Approach provides a roadmap for monitoring seagrass habitats in line with the Plan Vivo Biodiversity Standard, PV Nature, and has been reviewed and refined as per the Approved Approach Review Process.

This Approved Approach has been co-developed by the Association for Coastal Ecosystem Services (ACES), Vanga Seagrass Project (VSP) and Kenya Marine and Fisheries Research Institute (KMFRI).

We would like to extend our thanks to Edinburgh Napier University (ENU), Blue Marine Foundation, Okala and Plan Vivo, for their significant input and technical expertise. We would also like to extend our thanks to the PV Marine Working Group, Technical Review Panel reviewers and public consultation process for their review and comments.

1 Introduction

Seagrass meadows are a vital yet underappreciated coastal ecosystem. One of the core 'blue carbon' ecosystems – alongside mangroves and saltmarsh – seagrass meadows not only trap and store carbon, but boost biodiversity and fisheries, protect coasts, filter water, and provide a suite of other regulating, provisioning and cultural services and benefits.

Seagrass ecosystems have struggled to fit within Payment for Ecosystem Services frameworks such as carbon credits, limiting funding opportunities for conservation of these vital habitats (Shilland et al., 2021). 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 were marine focused, led 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.

[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

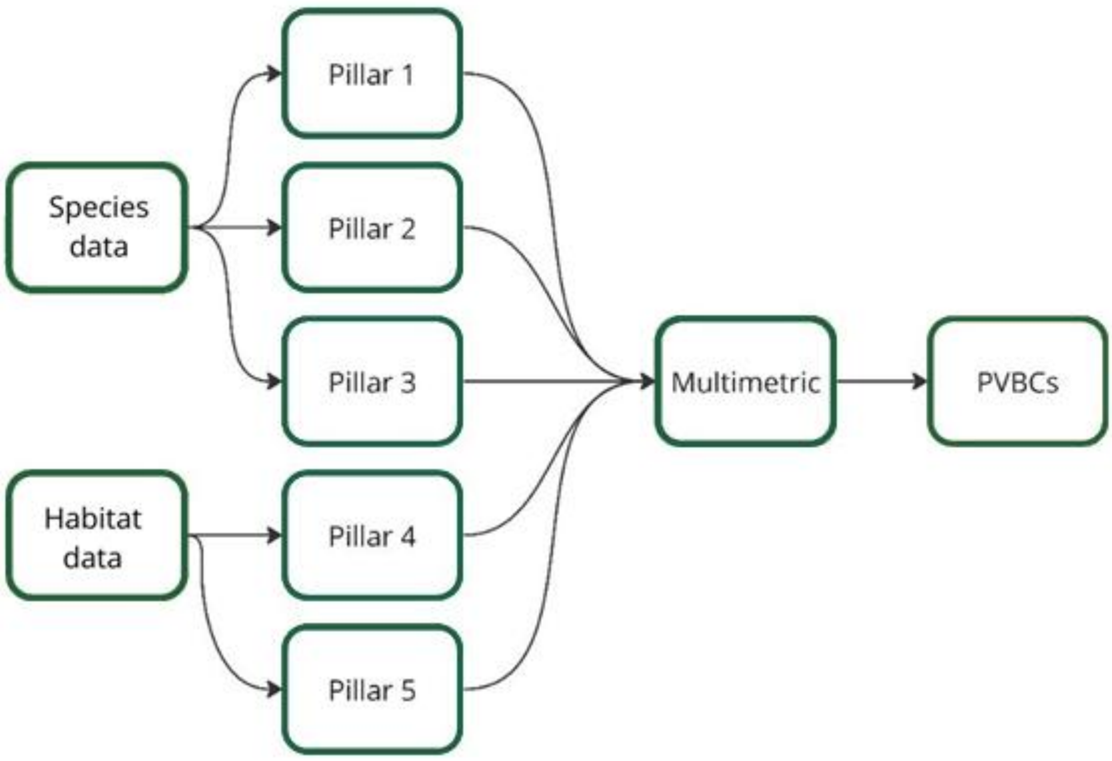


Figure 1: *Overview of the analytical steps used to convert biodiversity survey data to Plan Vivo Biodiversity Certificates (PVBCs). For more information, please see the PV Nature Methodology and Data Protocol.*

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 first Approved Approach under PV Nature and will outline a methodological approach to monitoring seagrass 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 seagrass meadows 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. This may work for solid structures such as coral reefs but is not an appropriate measure of habitat complexity or health for soft-substrate and highly flexible foundational species such as seagrass.

As a result, developing a PV Nature Approved Approach for the seagrass habitat metrics was agreed between Plan Vivo, the Association for Coastal Ecosystem Services (ACES) and Vanga Seagrass Project teams. The Approved Approach aims to outline metrics, methodologies and justifications for seagrass habitat monitoring that are compliant with PV Nature and the PV Nature Methodology principles and are globally applicable to any PV Nature seagrass project.

The aims of the seagrass Approved Approach were decided collaboratively by the Association for Coastal Ecosystem Services (ACES) and Plan Vivo. Consensus was drawn on three key aims for Approved Approach development which included:

1. a desire to develop a globally applicable seagrass approach;

2. an assurance that monitoring approaches would be accessible for community involvement 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.

2.1 Contextualising this Approved Approach with your project

Seagrass meadows are present around the world providing important ecosystem services ranging from carbon sequestration and coastal protection. They have become of increased interest for restoration due to their connectivity across other ecosystems (corals and mangroves) and the importance of their associated biodiversity (such as fish which have greatly suffered from anthropogenic pressures and impacts from climate change).

Seagrass species and their characteristics vary greatly, from the tall wide fronds of *Enhalus* to the thinner, simpler leaves of *Zostera*. This approved approach has been developed to work globally and to align with current research in seagrass meadows. However, 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 as the application of the methodology and metrics will vary across the different seagrass ecosystems. The Monitoring Plan - which will be developed in conjunction with each individual project, Plan Vivo and the chosen Data Analytics Provider - must take place in consistent seasonal and tidal windows relevant to the baseline data collection for consistent comparability.

Seagrass species transition zone. © Anthony Ochieng Onyango

3 Seagrass Habitat Pillar Metrics

ACES propose complementary seagrass habitat metrics aligned with the PV Nature Methodology to provide a clear assessment of the condition and structure of the seagrass meadows. Percentage cover was chosen for Pillar 4 to understand the condition of the seagrass within the meadows and to track changes in the condition of the seagrass itself. Percentage cover can track fluctuations in seagrass cover which may not be picked up when mapping the meadows as a whole (e.g. if the extent of the meadow stays the same, but the seagrass cover within the meadow increases from 40% cover to 60% cover). Seagrass areal extent was selected for Pillar 5 to gain an understanding of habitat spatial structure within the project areas and extent can also glean insights into overall habitat connectivity within project areas.

Pillar 4 differentiates from Pillar 5 by tracking changes in vegetation condition (cover) but does not track changes in the spatial distribution of habitat types – i.e., it does not track habitat connectivity, which is a different, important, structural aspect of ecosystem condition. Where sampling efforts are required to determine percentage cover and indeed the "resolution within the extent" (Pillar 4), a broader understanding of seagrass distribution and variation is necessary (Fonseca et al., 2002; McKenzie et al., 2022). As a result, seagrass areal extent was selected for the Pillar 5 metric. A comparison of the Pillar 4 and 5 metrics can be seen below (Table 1) and further detail on these metrics are provided in later sections of this Approved Approach. Both metrics are listed by the Global Ocean Observing System (GOOS) within their seagrass Essential Ocean Variable (EOV) (GOOS Biology and Ecosystems Expert Panel, 2025). EOVs are a minimum set of key variables identified by the GOOS expert panel that are critical to understanding ocean change.

Both seagrass cover and extent are good indicators of biodiversity outcomes related to project interventions and protections as these metrics are often impacted by common anthropogenic stressors that interventions are likely to be addressing. For example, areas with high fishing activity, especially areas that are subject to damaging gears such as seine netting that actively uproots seagrass have lower cover and extent on average. A field experiment showed that a single instance of seine netting caused a significant loss of seagrass cover of 8.3% within the area fished (Mwikamba et al., 2024). Improvements in water quality from nutrient reduction has also been shown to directly improve seagrass coverage (van Katwijk et al., 2024). To ensure changes in these metrics are due to biodiversity outcomes, we encourage projects based in areas with seasonal fluctuations in seagrass cover to monitor more frequently in-line with these changes and all monitoring should take place in consistent annual windows for comparability.

Table 1: Pillar 4 and Pillar 5 overview.

Pillar	Metric	Definition	Reasoning	General sampling approach	Example	Output
Pillar 4 – Habitat condition	Seagrass percent cover	The percent of substrate covered by seagrass plants in a defined sample area	Provides the "resolution within the extent" and will show changes within the seagrass meadows	In situ imagery within a defined quadrat. Measure cover of seagrass as a percentage of the quadrat.	 © Amy Mumo	0-100% cover of seagrass plants within the meadows
Pillar 5 – Habitat structure	Seagrass areal extent	The horizontal spatial extent of the overall seagrass meadows within the project areas	Provides insight into meadow extent and therefore, structure within the project areas. Provides a big-picture overview.	Map seagrass meadow extent either using imagery or in-person sampling approaches	 © Harcourt at al., (2019)	Map of seagrass meadow extent in appropriate measurement for the project area (m^2, hectares, km^2).

Percentage cover data collected using 50m transects and 0.5x0.5m quadrats. Photo-quadrat images captured using a GoPro Hero 11 and a dive slate used to record sampling effort, field data and notes. © Killian Chembe at Lifetime254

3.1 Pillar 4

3.1.1 Metric and justification

We propose a habitat condition/cover approach for Pillar 4 using seagrass percentage cover as the metric.

Table 2: *Proposed Pillar 4 metric for seagrass ecosystems*

Seagrass Pillar 4	Metric	Output
Habitat Condition/Cover	**Percent cover of seagrass**	**0-100% cover**

The literature describes percentage cover as one of the best-established and most used metrics in seagrass ecology (Duffy et al., 2019), this metric also has a long history in terrestrial plant ecology. It is also an efficient and cost-effective measure for understanding seagrass condition and it is responsive to spatial and temporal changes in seagrass ecosystems (Fourqurean et al., 2001, Neckles et al., 2012, Congdon et al., 2023). Seagrass percentage cover is also a key metric identified by the Global Ocean Observing System (GOOS) that identifies 'essential ocean variables' which are metrics that are classed as critical to understanding ocean change (GOOS Biology and Ecosystems Expert Panel, 2025). Seagrass cover and composition is recognized as an Essential Ocean Variable (EOV) because it provides vital insights into ocean health, biodiversity, and climate resilience. Critically, alongside its prominent use within the seagrass scientific community, percentage cover also meets the three key criteria defined as part of the approved approach: it has scientific backing, can be collected digitally and there are already-established methods for seagrass percentage cover citizen-science data collection. Percentage cover captures the density of seagrass, as the foundational species, in areas identified as seagrass habitat.

3.1.2 Methodological approaches

There are a number of methodologies that projects could use to collect data for seagrass percentage cover within their project areas. Detail on a ground-based approach is included below; however, a new methodological approach can be proposed to meet the requirements of the Pillar 4 metric outlined in this document without requiring a full new Approved Approach. New data collection methods can be outlined in the Monitoring Plan as part of the PDD and will be discussed and agreed upon by Plan Vivo.

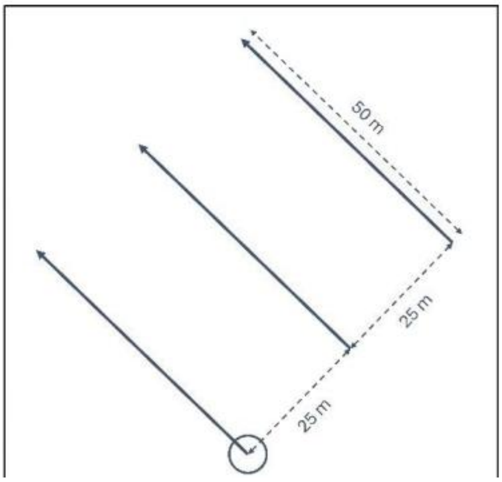
Quadrats and transects

Percentage cover calculated using quadrats and transects is the most inclusive approach to monitoring as relatively cheap and simple protocols have been developed by the seagrass community with citizen scientists in mind. We recommend using established methods for laying out transects and quadrats such as those developed by Seagrass-Watch[2]. Seagrass-Watch Protocols are included in Appendix 1. Low tide is the best time to conduct percentage cover data collection activities, both for ease of access to the sampling sites and to improve image quality. This method can be carried out on foot in intertidal seagrass meadows or via snorkel or scuba for subtidal seagrass meadows. To ensure a standardised approach is taken to seagrass monitoring across PV Nature projects, minimum sampling requirements for quadrat and transect monitoring must be followed, these are listed below.

Table 3: *Minimum sampling requirements for transects and photo-quadrats*

Quadrat size	Quadrats must be 50cmx50cm with a clear middle (no dividing strings).
Transect requirements	Transect length will be decided by the project's Data Analytics Provider to ensure they are reflective of the project area, however, 50m transects are recommended. Transects must run perpendicular to the shoreline to ensure sampling takes place along the depth gradient. Quadrat sampling should be taken ever 5m along the transect starting at point 0m (11 quadrats per transect if 50m).
Effort per sampling point	Each sampling point should consist of a 50mx50m sampling unit with 3 transects completed at each sampling point at points 0m, 25m and 50m. Starting points are parallel to the shore but as above, sampling transects must run perpendicular.

[2] https://www.seagrasswatch.org/wp-content/uploads/Methods/manuals/PDF/SeagrassWatch_Mapping.pdf

	 Visual of sampling points effort where the arrows represent a transect and point out to sea along the depth gradient and the dashed bottom line is parallel to the shoreline.

Due to the requirement for 3rd party digital data analysis as part of the PV Nature Methodology, a standardised approach to photo angle and height should be taken for capturing photo quadrat imagery. Specifications should be agreed with a project's data analytics provider to ensure effective image processing and analysis.

3.1.3 Project -level considerations

This Approved Approach outlines the Pillar 4 metric and proposed methodologies for seagrass ecosystems however, decisions at project-level will still need to be made and included in the PDD as part of the monitoring plan. This will ensure that collected data protocols are site-specific and consider the seagrass dynamics and site conditions local to the project areas. Some key considerations are included below:

Sampling frequency and timeline – As part of the PV Nature Methodology, monitoring events for Pillar 4 must happen at least annually. The time of year to monitor should consider biodiversity fluctuations, data quality (e.g. impacts of water clarity/turbidity) and ensure that sites are accessible and safe. Data collection must take place in the same season each year with conditions in that season (e.g. tidal window) maintained to ensure accurate year-on-year comparability.

Projects with natural seasonal variability in seagrass habitats may want to collect both cover and extent data twice a year aiming for a data collection event at the meadow's estimated maxima and minima seasonal windows as more frequent sampling is allowed within the PV Nature Methodology (for example, to enable assessment of seasonal patterns at the site). This is likely to be the case for most temperate seagrass projects as in temperate zones, seasonal changes in seagrass properties are distinct (Mohr et al., 2025). If multiple data collection efforts are not possible, consistent annual habitat monitoring should be conducted when the annual maxima is most likely (Metz et al., 2020). Data collection must take place at repeatable intervals to ensure stability in changes in cover and therefore, metrics feeding into credit generation are attributable to project-related changes.

Sampling points – This Approved Approach recommends using a ratio of both permanent sampling points repeated annually and random sampling points generated annually. Permanent points will be able to track change in seagrass habitats such as potential effects of disturbance whilst random sampling points ensure that there is a representative approach to monitoring the project area as a whole. However, the ratio of permanent:random sampling points should be decided at project-level as some sub-tidal seagrass projects that have strong ocean conditions or tidal patterns may struggle to return to the same permanent sites annually. A project-level approach to sampling ratios allows local considerations and safety to be taken into account when making monitoring decisions. A sampling plan will be developed by the project's data analytics provider – with input from the project and Plan Vivo – to ensure an objective and representative approach to sampling plan design which achieves the right balance between costs, safety and statistical power.

Combining data collection efforts – For projects that may also wish to capture seagrass species data under the species pillars (species richness, species diversity and taxonomic dissimilarity), data collection efforts can be combined to allow photo quadrats to be analysed in multiple ways. Projects should liaise with their data analytics provider and integrate this approach into a representative sampling plan design.

3.1.4 Analysis

Analysis will be undertaken by the project's data analytics provider in agreement with both the project and Plan Vivo.

3.1.5 Pillar Metric Considerations

Percentage cover, however, is not without its caveats. For example, in project areas with high diversity in seagrass species, such as seen in Vanga Bay, Kenya where nine species of seagrasses are found in the project region, there is potential that percentage cover could increase but this could not necessarily be beneficial for the ecosystem. An example of this could be where more mature, slow growing and diverse seagrass species could decline due to disturbance and the area could be colonised by fast-growing successional seagrass species. On its own, the percentage cover metric would not detect this change. Furthermore, increased percentage cover does not always equate to a more functional ecosystem as other considerations such as habitat connectivity and proximity to ecosystems such as coral reefs are also important indicators for understanding ecosystem functionality, habitat provisioning and therefore, faunal distribution within seagrass meadows (Ho et al., 2018). However, Plan Vivo's approach of using 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.

3.2 Pillar 5

Originally, Habitat Spatial Structure 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.)

3.2.1 Metric and justification

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

Table 4: *Proposed Pillar 5 metric for seagrass ecosystems*

Seagrass Pillar 5	**Metric**	**Output**
Habitat Spatial Structure	Seagrass Extent	GIS shapefile of extent Area (numerical value)

Seagrass extent is also listed as an Essential Ocean Variable (EOV) and is classed as a key measurement to understand seagrass cover and composition by the Global Ocean Observing System (GOOS) (GOOS Biology and Ecosystems Expert Panel, 2025).

Historical data on seagrass presence, distribution and trends are limited and large knowledge gaps remain, particularly outside of Europe, in turbid waters and in areas most likely to experience seagrass decline (Harcourt et al., 2018; Davies et al., 2024; Floyd et al., 2024; Lugendo et al., 2024). Seagrass meadows, like all other ecosystems, are, and will continue to be, impacted by climate change, pollution and other anthropogenic pressures creating additional variations and potentially ineffective predictions (Davies et al., 2024; Lugendo et al., 2024). For PV Nature certified projects aiming to conserve or restore biodiversity associated with seagrass meadows, there is a need for a metric to estimate habitat structure via digital data collection, we propose seagrass extent as this metric.

Seagrass extent is classed as a key measurement to understand seagrass cover and composition, an EOV defined by GOOS (GOOS Biology and Ecosystems Expert Panel, 2025). EOVs are critical for understanding ocean change, and seagrass extent is one of the metrics used to assess seagrass meadow health and has been shown to be useful in ecosystem management (Fonseca et al., 2002; Davies et al., 2024; Lugendo et al., 2024). Similarly to terrestrial systems, seagrass extent has typically been measured through remote sensing (satellite imagery) (Kuster et al., 2020; Floyd et al., 2024). However, additional considerations are needed when monitoring in the marine environment. Multiple studies have shown underestimation of seagrass meadows; therefore, projects will need to use a relevant combination of monitoring methods to achieve a meaningful understanding of the habitat they are working with (Roelfsema et al., 2013; Poursanidis et al., 2023; Lugendo et al., 2024; Mwikamba et al., 2024).

3.2.2 Methodological approaches

There are several methodologies that projects could use to collect data for seagrass extent within their project areas. Details on common approaches are included below, however, a new methodological approach can be proposed to meet the requirements of the Pillar 5 metric outlined in this document without requiring a full Approved Approach. New data collection methods can be outlined in the Monitoring Plan as part of the PDD and will be discussed and agreed upon by Plan Vivo.

This Approved Approach recognises that the choice of techniques will vary across different projects based on the accessibility to the site, water depth and quality, the overall size of the project area and other factors. We recommend combining techniques to collect the most accurate data e.g. using satellite imagery alongside ground truthing. Some key considerations for certain monitoring methods include:

Remote sensing (satellite imagery via Google Earth Engine, Landsat, Sentinel-2, etc.)

Satellite imagery has typically been used for land cover classification and has been shown to be an effective approach for large-scale mapping of seagrass (Floyd et al., 2024). Sampling approaches include acquiring imagery and applying image classification techniques (GOOS Biology and Ecosystems Expert Panel, 2025). Where adequate satellite imagery cannot be attained (e.g. due to cloud cover, resolution or water depth), combining imagery with in-situ spot checks/ground truthing with local knowledge will provide a more accurate picture of seagrass extent. The use of openly available data is possible in some seagrass ecosystems (including national data in-situ spot checks/ground truthing), analytics programs (McKenzie et al., 2022; Traganos et al., 2022; Lugendo et al., 2024). Potentially Artificial Intelligence tools can be used to interpret the imagery and can increase accuracy but this will be dependent on the project's selected data analytics provider and the trained models they have available.

Minimum sampling requirements for remote sensing include a resolution of at least 10m and projects should aim to select images that are cloud-free and at low-tide (Davies et al., 2024). This resolution is available from open-source platforms (e.g. Sentinel-2) which offer good baseline capability. Sentinel-2 data are available through public access hubs and cloud-processing environments such as Google Earth Engine — enabling large-area coverage, rapid processing, and time-series analysis. Studies using Earth Engine have successfully mapped thousands of km^2 of seagrass meadows in the Mediterranean Sea (Traganos et al., 2018; 2022). If projects are utililsing open-source platform with 10m resolution, then ground truthing must also take place to ensure image accuracy. It is recommended that an 80% ground truthing accuracy as recommended by McKenzie et al. (2001) needs to be obtained where ground truthing is needed to confirm accuracy of satellite data (e.g. in patchy areas with high uncertainty) "i.e. the percentage of correct estimates against incorrect ones". Ground-truthing should be prioritised around habitat edges and transition zones between seagrass and non-seagrass, as well as in smaller meadows and isolated patches as these are more difficult to interpret from 10m resolution imagery. Sampling effort to obtain this will be decided by the projects Data Analytics Provider to ensure it is appropriate for the project area and available sampling imagery.

If projects wish to utilise higher-resolution imagery then this is encouraged, especially in areas where higher spatial resolution is needed — for example, to map narrow meadows, transitions, or small patches in complex shallow coastal zones — paid high-resolution satellite imagery may be more appropriate. Commercial providers such as Planet Labs (with ~3 m PlanetScope imagery and more detailed SkySat/taskable acquisitions) or Maxar Technologies (with <1 m WorldView/very-high-resolution archive and tasking options) can provide the detail necessary to resolve fine-scale patch boundaries, fragmentation, or small transition zones that may be indistinguishable at 10m resolution. These higher-resolution products can complement free data (e.g. Sentinel-2) however, ground-truthing may be more cost-effective for projects and paid imagery vs ground truthing will need to be decided on a project-basis.

In-situ monitoring and ground truthing

If an in-situ monitoring approach or ground truthing is needed due to a lack of airborne or satellite imagery quality in your project area (e.g. subtidal seagrasses), projects should develop an appropriate sampling plan in conjunction with their data analytics providers that is applicable to their specific seagrass ecosystem and project resources.

High earth monitoring (Drone or being airborne e.g. by helicopter)

With technological advancements and improvements in recent years, UAVs (or more commonly referred to as drones) are increasingly popular in determining habitat extent and "effectively bridging the gap between satellite and on the ground data collection" (McKenzie et al., 2022). Their effectiveness (in cost and use) can be enhanced using machine learning models (McKenzie et al., 2022).

Other airborne methods, such as helicopters have been used in areas of limited accessibility (e.g. Great Barrier Reef) however, studies have highlighted that the use of airborne methods (e.g. helicopters) alone can lead an overestimation of the area (and can be remedied by combining this with in-situ spot checks/ground truthing with local knowledge (see McKenzie et al., 2022). Meadowscape details are often lacking (which can be remedied by the inclusion of Pillar 4 detailed above).

3.2.3 Project-level considerations

As with all elements of developing a PV Nature project, there must be project-level considerations before any implementation can take place. Resolution is an important consideration as too coarse a scale will miss changes in seagrass extent. As mentioned above, minimum resolution requirements for satellite imagery is 10m however, this will need to be supplemented with either ground-truthing or finer scale satellite imagery to ensure accuracy. Where conditions limit the accuracy of satellite imagery (e.g. adverse weather conditions, water depth, turbidity, cloud cover etc.) Ground truthing must take place. Data Analytics Providers and the project are responsible for outlining the limitations of satellite imagery in the project area and implement well-justified mitigation methods (e.g. ground truthing, drop cameras, UAVs) within the Monitoring Plan. The scale decided on at the point of baselining needs to either be maintained throughout the project or changes logged with Plan Vivo as a change in scale (e.g. if higher-resolution satellites become available) could impact the projects ability for year-on-year comparison.

Projects need to determine the most suitable method(s) to develop a meaningful understanding of the seagrass extent in their project area; This may include ground-truthing where satellite imagery quality is unreliable or difficult to obtain. McKenzie et al. (2001) recommend an 80% ground truthing accuracy "i.e. the percentage of correct estimates against incorrect ones". These considerations should be determined in collaboration with the project's chosen data analytics provider.

Pillar 5 will be measured at least every 5 years in line with verification events; these efforts of determining seagrass extent can be complementary to the project's habitat mapping activities. More frequent monitoring of seagrass extent is encouraged and to reduce the impact of seasonal variability on extent metrics, satellite imagery and ground truthing must take place within the same seasonal window each year. Further detail to consider including in these efforts and maps could be an understanding of species distribution, historical presence and areas of potential recovery.

3.2.4 Analysis

Analysis will be undertaken by the project's data analytics provider in agreement with both the project and Plan Vivo. Data Analytics Providers should apply depth-invariant processing (e.g., DII/Lyzenga) and water column corrections to multispectral or hyperspectral imagery (Sentinel-2, PlanetScope, or airborne hyperspectral) to reduce water-column influence and produce depth-neutral benthic reflectance layers that improve discrimination of seagrass from other substrates. Data Analytics Providers can also develop specific indices — including a novel "Submerged Seagrasses Identification Index" (SSII) — to distinguish seagrass from sand and bare substrate (Li et al., 2023). This should then be combined with ground-truthing as an accuracy assessment to ensure data reliably tracks changes in extent on seasonal to annual timescales, documents potential limitations (e.g. insufficient water clarity may impact satellite imagery and as a result, increase ground-truthing efforts), and supports repeatable monitoring under Plan Vivo criteria.

3.2.5 Pillar Metric Considerations

In recent decades, the recognition of the importance of seagrass has improved alongside technological advances. Efforts to map seagrass extent in regions of limited data have often used satellite imagery (Traganos et al., 2022; Lugendo et al., 2024; Mwikamba et al., 2024). The review by Kutser et al. (2020) highlight these technological advances – albeit mainly in coral reefs – and the limitations of technological methods for shallow water (<3 metres) remote sensing. Difficulty in separating different seagrass species and seagrass from algae remain, and water turbidity/low water quality can restrict capture of spatial imagery resolution.

Studies also conclude that remote sensing should be combined with additional methods, such as local ecological knowledge and ground-truthing for a comprehensive understanding of seagrass extent (Kutser et al., 2020; Traganos et al., 2022; Davies et al., 2024; Mwikamba et al., 2024).

4 Development Process

4.1 Aims

The aims of the seagrass Approved Approach were decided collaboratively by the Association for Coastal Ecosystem Services (ACES) and the PV Nature Marine Working Group. Consensus was achieved on three key aims for Approved Approach development which included:

1. a desire to develop a globally applicable seagrass approach;

2. an assurance that monitoring approaches would be accessible for community involvement 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 seagrass 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 seagrass ecosystems including both temperate and tropical seagrass species and both inter and subtidal habitats. This provides a consistent approach across PV Nature seagrass projects and improves monitoring efficiency for projects that may have a mixture of intertidal and subtidal seagrass meadows within their project areas.

Another key aim was to ensure that recommended monitoring methodologies include approaches that are accessible to communities. Plan Vivo as a Standard largely focuses on community-centred projects with high levels of local ownership and leadership. As a result, methods and metrics needed to be cost-effective and have relatively simple and repeatable data collection methods that are achievable for Indigenous Peoples, local communities and/or citizen scientists to carry out with technical support and training from the project and its partners where required.

Finally, the Approved Approach must align with PV Nature Methodological Framework. This includes developing metrics that work within the multimetric 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 ACES, VSP and KMFRI teams worked with a number of key actors to increase the global applicability of the Approved Approach and to ensure relevant experts, technical advice and professional opinion was included in the development process.

A steering group was formed to review, critique and decide on metrics and specifics related to this Approved Approach. The group was led by ACES and included a range of scientific, technical and project experts who refined, reviewed and agreed upon the metrics and approaches outlined in this document.

Following development, the review process was followed as per PV Nature's Approved Approach Review Process document. This includes review from the Plan Vivo Marine Working Group, PV Nature's Technical Review Panel and a public consultation.

Mangroves in the seagrass © Anthony Ochieng Onyango

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Appendices

Appendix 1

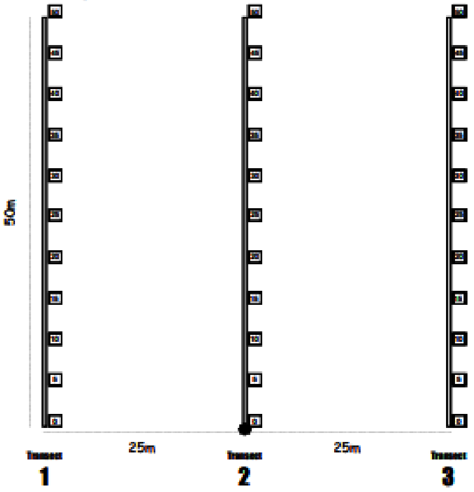
Seagrass-Watch (est. 1998) is a not-for-profit organisation highly recognised for its scientific rigour. It is one of the largest long-term seagrass observing networks globally (Global Seagrass Observing Network). The network has conducted over 5914 assessments, and more than 25 countries participate in the Global Seagrass Observing Network (GSON), monitoring & researching the status and trends in seagrass condition. The Seagrass-Watch Protocols were developed by the team and can be viewed on the field resources page of the Seagrass-Watch website. Details of the protocols on how to set-up transects and quadrats ready for photographing are included below. We encourage projects to submit data to SeagrassWatch alongside PV Nature monitoring efforts. Full credit is given to Seagrass-Watch for the protocols and materials.

Further data such as GPS coordinates or environmental condition data may need to be collected during data collection events to aid analysis. Projects should speak directly to their chosen data analysis provider to understand analysis requirements and how this can be incorporated into fieldwork protocols.

Seagrass-Watch Protocols

Source: www.seagrasswatch.org/manuals

Site layout



Quadrat code = site + transect+quadrat

e.g., AP1225 = Archer Pt. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

Create a timetable of times of departure and arrival back, and what the objective of the day is and what is to be achieved on the day. Give a copy of this to all participants involved in advance so they can make their arrangements to get to the site on time. List on this timetable what the participants need to bring.

Have a Contact Person

Arrange to have a reliable contact person to raise the alert if you and the team are not back at a specified or reasonable time.

Safety

- Assess the risks before monitoring - check weather, tides, time of day, etc.
- Use your instincts - if you do not feel safe then abandon sampling.
- Do not put yourself or others at risk.
- Wear appropriate clothing and footwear.
- Be sun-smart.
- Be aware of dangerous marine animals.
- Have a first aid kit on site or nearby
- Take a mobile phone or marine radio

Necessary equipment and materials

- ❑ *3x 50metre fibreglass measuring tapes*
- ❑ *6x 50cm plastic tent pegs*
- ❑ *compass*
- ❑ *1x standard (50cm x 50cm) quadrat*
- ❑ *3x Monitoring datasheets*
- ❑ *clipboard, pencils & 30 cm ruler*
- ❑ *camera*
- ❑ *quadrat photo labeller*
- ❑ *percent cover standard sheets*
- ❑ *seagrass identification sheets*

Each sampling event

Within the 50m by 50m site, lay out the three 50 transects parallel to each other, 25m apart and perpendicular to shore (see site layout). Within each of the quadrats placed every 5m along each transect for sampling, complete the following steps:

Step 1. Take a photograph of the quadrat

- Photographs are taken of **every quadrat** (or at 5m, 25m and 45m if film is limited) along each transect. Use a quadrat free of strings and place the quadrat photo labeller beside the quadrat and tape measure with the correct code on it.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat label and tape measure. Fill the field of view as best as possible and avoid any shadows or patches of reflection off any water. Check the photo taken box on datasheet for quadrat.

Appendix 2

Public Consultation Feedback

Summary of Feedback	Response
It was raised that delivery of projects needs to provide baseline design and repeatability, governance continuity, behavioural additionality, monitoring activities and governance or operational interventions. The commenter also provided information on how they deploy non-baited, fixed-location video for species monitoring.	The goal of the Approved Approach is to outline seagrass habitat metrics related to Pillars 4 and 5 in the PV Nature Methodology. We would like to assure the reviewer that this is not a stand-alone document and is part of the wider Plan Vivo Biodiversity Standard (PV Nature). Plan Vivo is a leading certification system for community-led projects in climate and nature markets and PV Nature is designed to help locally driven projects show that their work is making a real, measurable difference for ecosystems, while also opening the door to fair and equitable funding. Through PV Nature certification, projects gain a recognised way to show that their work meets high standards for both nature and people. There are extensive project and methodology requirements that need to be met outside of this Approved Approach and Plan Vivo has a strong focus on FPIC, good governance and equitable benefits sharing. Alongside utilising this Approved Approach, PV Nature seagrass projects must prove their eligibility, present a Project Idea Note (PIN), a Project Design Document (PDD), an Environmental and Social Screening, a Monitoring Plan, conduct baselining and sampling in-line with the PV Nature methodology and go through a Validation and Verification process. For wider questions around PV Nature we recommend reviewing the Plan Vivo website[3].

[3] https://www.planvivo.org/projects/certify-a-project/pvnature/pv-nature-documents

	Thank you for the information on your approach to video-based monitoring however, this monitoring method is more targeted towards species rather than habitat data collection and is not a method included in this Approved Approach. We recommend reviewing the PV Nature Methodology for more information on species-related data collection.