JNCC Report 750

Technical assistance programme for effective coastal-marine management in the Turks and Caicos Islands (DPLUS119)

WP3: Marine indicators to monitor changes in coastal-marine natural capital – Phase 1 indicator development

Adam Britton, Adam Smith, David Vaughan,
Laura Pettit and Cristina Vina-Herbon

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For further information on JNCC's report series please contact:
Joint Nature Conservation Committee
Quay House
2 East Station Road
Fletton Quays
Peterborough
PE2 8YY

https://jncc.gov.uk/

Communications@jncc.gov.uk

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Summary

This report outlines the work conducted under Work Package 3 of the technical assistance programme which is a three-year Darwin Plus funded project (DPLUS119) to improve the evidence base in marine and coastal environments to support sustainable coastal marine management in the Turks and Caicos Islands (TCI).

The overall aim of the project is to provide the foundations for strategic, sustainable management of TCI's marine and coastal environment through provision of practical tools and enhanced capabilities to consider biodiversity, conservation, and understand natural capital approaches by decision-makers and local communities.

Work Package 3 will explore potential options for marine indicators to monitor and assess changes in coastal and marine biodiversity. This report outlines a pilot indicator approach to assess seagrass habitat extent.

Data available to calculate seagrass extent in TCI were explored and an approach for calculating seagrass extent, based on The Nature Conservancy (TNC) benthic habitat map (Schill *et al*. 2021), was developed. Additional data are required to improve the method to measure extent as well as to be able to make an assessment of seagrass habitat condition.

Knowledge gaps and additional work required to further develop the indicator approach have been identified. This includes updates to and groundtruthing of the TNC benthic habitat map, exploring the addition of temporal trend data from direct monitoring, and the development of a seagrass condition indicator.

Contents

1 Introduction

This technical assistance programme is a three-year Darwin Plus funded project (DPLUS119) aimed at improving the evidence base in marine and coastal environments to support sustainable coastal marine management in the Turks and Caicos Islands (TCI). An international partnership, consisting of the Joint Nature Conservation Committee (JNCC), the TCI Government Department of Environment and Coastal Resources (DECR) and the South Atlantic Environmental Research Institute (SAERI) will be working together to improve the evidence base.

The overall aim of this project is to provide the foundations for strategic, sustainable management of TCI's marine and coastal environment through provision of practical tools and enhanced capabilities to consider biodiversity, conservation, and understand natural capital approaches by decision-makers and local communities.

Part of the project (Work Package 3) will explore potential options for marine ecological indicators, maximising the use of existing data, to support decision making and the implementation of a new TCI Government Environment Strategy.

This report outlines a proposed indicator approach for assessing environmental change and explores potential applicability of the indicator, for example, how, in the future, the indicator results could inform ecosystem service provision. Linking to natural capital is important to enhance the capabilities of decision-makers and local communities when managing marine resources. The natural capital approach is based on recognising the contribution of nature to human welfare and seeks to integrate nature more effectively into decision making processes (Hooper *et al*. 2021). Changes in marine biodiversity will affect ecosystem service provision and, therefore, have implications for the goods and benefits provided.

1.1 Marine biodiversity indicators

Indicators are tools and methods used to quantify environmental changes, trends and impacts from pressures on biodiversity (McQuatters-Gollop *et al*. 2019; Vina-Herbon *et al*. in prep). They are integral tools available to policy and decision makers to evaluate and understand environmental change. They allow assessments to be undertaken in a more consistent way, without reliance on expert judgement. They allow approaches to be standardised with a clear audit trail of data sources, methods, and production of scientific results. They can also help resources to be used more efficiently because the same indicator could be used for multiple purposes, where methods are adapted or improved, without starting from scratch (Vina-Herbon *et al*., in prep).

Marine biodiversity indicators have two main uses: reporting on the progress and success of environmental policies and assessments of the efficiency of management measures or decision making processes.

1.2 Phase 1 indicator development testing

This report outlines the steps taken to test the development of a first marine biodiversity indicator as part of the DPLUS119 project to assess environmental change in TCI (Phase 1 indicator development) with subsequent potential options for indicator development to be explored in Phase 2.

Following the completion of a literature review (Britton *et al*. 2021) and the preparation of a scoping document (Britton *et al*. 2022), a shortlist of potential indicators which could be applicable to TCI was identified. This shortlist of indicators was discussed with DECR to identify key priorities and the first indicator for development was selected.

An approach for calculating seagrass extent was developed. Seagrass was identified as a priority habitat for monitoring and assessment by TCI and a review of data sources indicated that there was likely to be local and regional data available to test the indicator.

2 Indicator method

2.1 Seagrass extent

The indicator approach proposed below measures the extent of seagrass habitats. Assessing the extent of benthic habitats provides information on the area of habitat and how it is spatially distributed. If repeat assessments are conducted, then any changes in the total area of habitat can be identified, allowing decision makers to evaluate and understand environmental change. This could help to inform where monitoring or management efforts should be focused. Seagrass is an important habitat which provides many benefits, such as providing a food source and habitat for other species, including commercially important species, storing carbon, and stabilising sediment (Valdez *et al*. 2020). A reduction in extent, therefore, could have important ecological and economic implications.

2.1.1 Data sources

Seagrass extent information was taken from The Nature Conservancy (TNC) benthic habitat map (Schill *et al*. 2021). Schill *et al*. (2021) used the PlanetScope (PS) Dove Classic SmallSat constellation, consisting of more than 150 satellites capturing spatially referenced four-band multispectral images over terrestrial and coastal areas, to calculate seagrass extent in the shallow (less than 30 m depth) marine environment of the Caribbean region (Figure 1). The PS provides high resolution (4 m) imagery and nearly daily global coverage. PS images used to create the habitat map were acquired between 1 October 2017 and 15 September 2019. A regional thirteen-class benthic habitat map up to 30 m water depth, covering the Caribbean region was developed from these data using an object-based image analysis (OBIA) approach (Schill *et al*. 2021). The OBIA approach groups small pixels together into vector objects which are then classified using their shape, size, spatial and spectral properties (GISGeography 2021). When compared to global benthic datasets, the method used by Schill *et al*. (2021) captured more detailed, ecologically meaningful, classes at a higher spatial resolution. Data collected through video transects, drone imagery and scuba divers throughout the Caribbean region were used to train the benthic habitat classification algorithm and assess the accuracy of the benthic habitat map. Local experts throughout the region were also consulted to manually adjust and refine the final TNC habitat map (Schill *et al*. 2021).

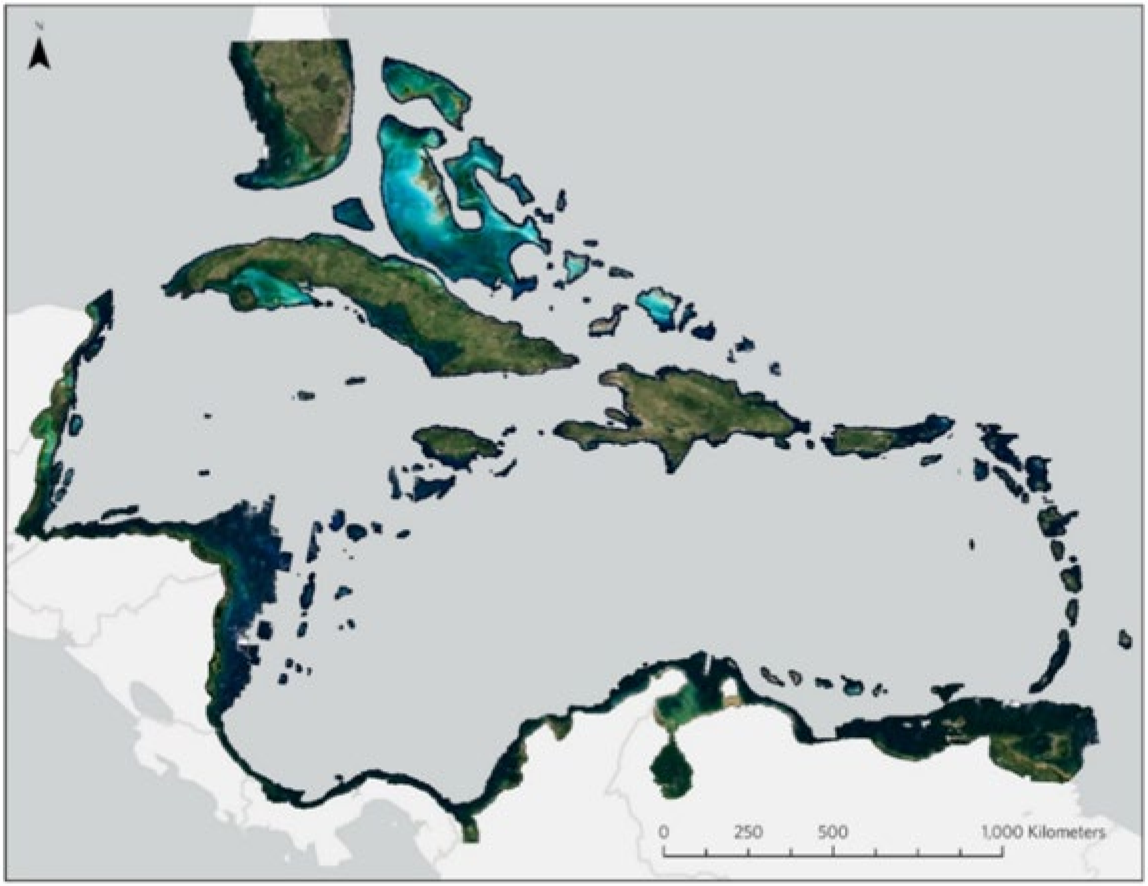

Figure 1. Caribbean region covered by The Nature Conservancy benthic habitat map. Taken from Schill *et al*. 2021.

2.1.2 Methodology

Seagrass extent was calculated using the following method:

1. TNC habitat maps were accessed from the online data portal found at CaribbeanMarineMaps.tnc.org. More information on the TNC benthic habitat map is also available through the TCI data portal. The habitat maps have 13 habitat classes in total, of which two relate to seagrass: Seagrass Dense and Seagrass Sparse (Table 1). The classification of seagrass into dense and sparse within The Nature Conservancy benthic habitat map was derived from the whole of the Caribbean region and was based on an automatic threshold (Schill *et al*. 2021) according to the definitions as outlined in Table 2.
2. Data, which were in raster format, were converted to polygon data using Geographic Information Software (GIS, using the Raster to Polygon tool in ArcGIS version 10.1, or the Polygonize function in QGIS 3.16) and then the dissolve tool (available in both ArcGIS and QGIS) was used with habitat classes as the dissolve field to create one polygon per habitat.
3. Habitat extents were calculated by adding a field to the attribute table of the vector layer and using the calculate geometry function, with units as km^2, ensuring that the projection remained the same as the original raster in The Nature Conservancy's benthic habitat map (TNC custom Lambert equal area projection centred on the Caribbean) (Schill *et al*. 2021).
4. The extent of dense and sparse seagrass was calculated along with total seagrass habitat extent values.

Table 1. The benthic habitat classes used in The Nature Conservancy benthic habitat map (Schill *et al*. 2021).

Habitat	Benthic habitat class
Coral Reefs	Reef Crest
	Fore Reef
	Back Reef
	Coral/Algae
	Spur and Groove Reef
Seagrass	Dense Seagrass
	Sparse Seagrass
Hardbottom	Hardbottom Dense Algae
	Hardbottom Sparse Algae
Other	Sand
	Muddy Bottom
	Boulders and Rocks
	Dredged

Table 2. Definition of dense and sparse seagrass classifications used across the Caribbean region in The Nature Conservancy benthic habitat map. Taken from: https://tnc.app.box.com/s/i9at8fnh19tdtn1lismuvk646ym810s3.

Classification	Definition
Dense seagrass	Found in shallow lagoons or relatively sheltered zones at a depth of 2–10 m, characterized by a low relief, sand substrate with dense living community cover (greater than 50% cover). Living cover is dominated by a mix of seagrass species: *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii* and *Halophila decipiens*; and commonly associated with green algae genera: *Ulva* spp., *Chaetomorpha* spp, *Caulerpa* and *Avrainvillea* or some coral rubble habitat. There may also be some brown algae (e.g. benthic Sargassum spp., Dictyota spp.). These areas represent a darker spectral response when compared with sparse seagrass.
Sparse seagrass	Found in shallow lagoons or relatively sheltered zones at a depth of 2–10 m, characterized by a low relief, sand substrate with sparse-medium living community cover (less than 50% cover). Living cover is dominated by a mix of seagrass species: *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii* and *Halophila decipiens*; and commonly associated with green algae genera: Ulva spp., *Chaetomorpha spp*, *Caulerpa* and *Avrainvillea* or some coral rubble habitat. In the Eastern Caribbean is commonly dominated by invasive *Halophila stipulacea*. There may also be some brown algae (e.g. benthic *Sargassum spp*., *Dictyota spp*.). May be located adjacent to open patches of sand or dense seagrass. Cyanobacteria often form dense mats between macroalgal stalks covering the underlying sandy substrate. There may also be small patches of encrusting hard coral species fast growing and resistant to sand/sediment clouds (e.g. *Siderastrea radians*). These areas represent a lighter spectral response when compared with dense seagrass.

2.1.3 Limitations

There are several limitations associated with the method described above to calculate seagrass habitat extent. The degree of accuracy in the benthic habitat map and precision of the data needs to be considered. The map was made for the Caribbean region and is predominantly based on remote sensing data, so the seagrass habitat extent figures are predicted. Schill *et al*. (2021) conducted an accuracy assessment of The Nature Conservancy benthic habitat map using 2686 field data points collected between 2010 and 2017. The overall accuracy is an estimate of the percent of the total area mapped that was classified correctly according to the comparison of the map with the field data points. Overall accuracy in the habitat map for the whole of the mapped Caribbean region (see Figure 1) (across 8 of the 13 habitat classes, because coral subclasses (reef fore, reef crest, reef back, spur and groove) were combined into one coral/algae class) was 72% (Schill *et al*. 2021).

User's accuracy reflects the reliability of the classification and calculates if objects were assigned the correct class. It was calculated by Schill *et al*. (2021) from the weighted proportion of correctly classified reference locations divided by the area weighted proportion of reference locations determined to be in each class, multiplied by 100. For dense seagrass there was a user's accuracy of 82.3%, for sparse seagrass this was 55.8%. It can be very difficult to distinguish between dense and sparse seagrass when using satellite imagery data, particularly in deeper waters (Schill *et al*. 2021). When dense and sparse seagrass were combined into one benthic habitat type, the user's accuracy was 81.4%. Although field data points were used to assess the accuracy of the maps, these data were collected throughout the Caribbean region, not specifically around TCI, and subsequently there may be some issues with algae mats being wrongly classified as seagrass by the earth observation data (DECR pers comm). The time lag between when field data was collected and compared to the habitat map derived from satellite imagery data could also influence the accuracy of the extent figures.

Although the PlanetScope data delivers high spatial resolution (4 m) imagery, the spatial resolution of the data can still limit the accuracy of the maps and it may not be possible to detect small areas of habitat.

2.1.4 Further development

The method described above provides a value for seagrass extent, although the limitations of the method need to be taken into consideration. Traditional means of monitoring ecosystems typically require intensive field operations that are expensive and require a significant amount of time to achieve. Therefore, new technologies, such as the TNC Benthic Mapping project using Dove satellite constellations, can be an important tool to decrease costs while increasing efficiency when analysing the extent of benthic habitats.

Decisions need to be taken on how this extent figure could be updated and how, with repeat measurements, changes in seagrass extent could be recorded. If the method used to assign habitat classes in the TNC habitat map changes, this would need to be taken into account in any subsequent analysis. For example, if the method for producing the habitat map changes between repeated measurements, any changes in extent might be because the method has changed, rather than a real change in extent of seagrass habitat. A way of mitigating against this would be to retain pre-processed images to re-run the classification with the new algorithms and then compare any changes.

In the future, more direct monitoring data could be used to groundtruth the maps. If some areas are identified as having higher uncertainty in classifying seagrass, then these could be monitored in more detail to help improve the habitat map.

Limited local activity data for TCI means that it is not currently possible to incorporate activity information into the indicator approach to calculate how local activities may impact seagrass extent. Existing activity data such as for artificial structures and fishing is being used to produce a vulnerability assessment under Work Package 2 of the project which could help to fill some of the current data gaps associated with this indicator.

3 Indicator results and outputs

The display of indicator results depends on the intended use of the results and indicator assessment. Seagrass extent figures could be provided, showing the area covered by dense and sparse seagrass (Table 3).

Table 3: Habitat extent figures, including sparse, dense, and total seagrass. Calculated from the TNC habitat map (Schill *et al*. 2021).

Habitat class	Habitat extent (km^2)
Sand	2,746.70
Total Seagrass	1,977.68
Seagrass Sparse	1,204.22 (60.89% of total seagrass extent)
Seagrass Dense	773.46 (39.11% of total seagrass extent)
Coral/Algae	430.27

Maps could be produced showing the extent of dense and sparse seagrass (Figure 2). This would allow those looking at the indicator results to see where dense and sparse seagrass occurs and gives a spatial context to the indicator results.

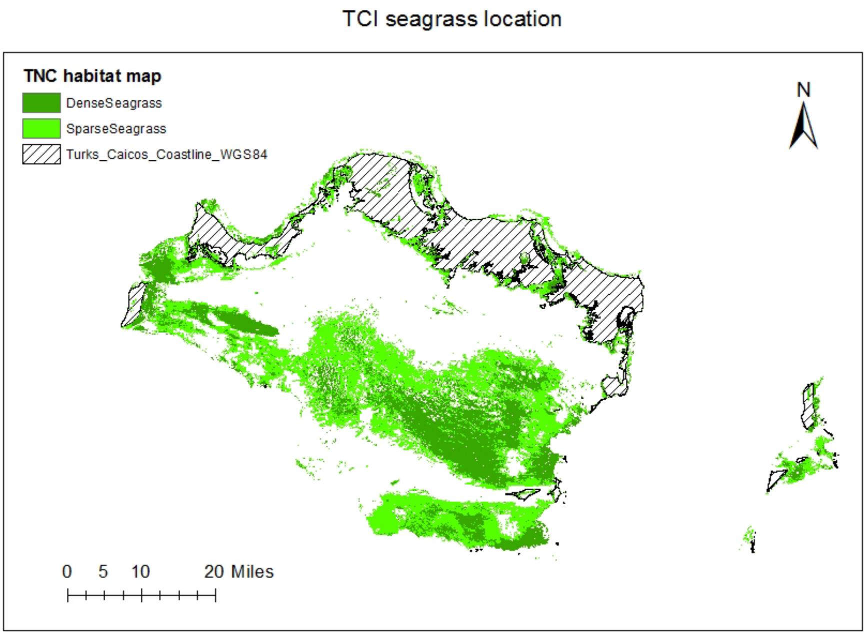

Figure 2. A map showing the location of dense and sparse seagrass across TCI, derived from The Nature Conservancy benthic habitat map (Schill *et al*. 2021).

Given the limitations associated with calculating seagrass extent from The Nature Conservancy benthic habitat map, it would be important to include statements on the confidence or accuracy of the seagrass extent figures alongside any indicator assessment results. This would allow the user to determine if the accuracy of the indicator results are acceptable for the specific purpose for which the indicator results are being used.

If trend data on seagrass extent becomes available, with repeated assessments, change in habitat extent over time could be evaluated. Any changes in the total area of habitat could be identified, allowing decision makers to evaluate and understand environmental change. This could help to inform where monitoring or management efforts should be focused. For example, extent figures could be provided for previous and current assessment time periods (Table 4).

Table 4. An example of how seagrass extent figures could be provided if repeat assessments were to be conducted. Please note that habitat extent figures have not been provided for other time periods because the data are not available, and these assessments have not been conducted.

Habitat class	Habitat extent (km^2) 2017 to 2019	Habitat extent (km^2) 2020 to 2022	Habitat extent (km^2) 2023 to 2025
Total Seagrass	1,977.68	-	-
Seagrass Sparse	1,204.22 (60.89% of total seagrass extent)	-	-
Seagrass Dense	773.46 (39.11% of total seagrass extent)	-	-

4 Monitoring recommendations and information management plan

It has not been possible to develop monitoring recommendations or a data management plan for the indicator, due to the early stages of development and testing. Monitoring is required to collect information and data which can be used in the indicator. Data from monitoring can also help to inform the effectiveness of any management measures. Specific monitoring requirements will depend on the finalised indicator approach. Direct monitoring could help to groundtruth and validate seagrass extent data and will be necessary to assess the condition of seagrass habitats. Aspects to consider when monitoring seagrass could include the following (Walday *et al*. 2018):

1) Which sampling or survey device should be used?
2) How often should the sampling take place?
3) When in the year should the sampling take place?
4) How is the sampling site/survey area selected?
5) How many samples are needed?

In addition to monitoring of the seagras habitats, monitoring of human activities will also provide information which can be used in the indicator. Changes in the intensitiy of certain human activites may affect the extent and condition of seagrass.

A strategy will need to be developed for additional data collection which could feed into the indicator along with an information management plan. For the testing of this indicator approach, data were sourced from The Nature Conservancy benthic habitat map and the TCI data portal. No new data were collected, and therefore, a data management plan was not needed. An information management plan should consider aspects such as data standards, storage, accessibility, metadata requirements and data preservation.

5 Seagrass condition

Assessing the condition of seagrass provides information on the health of the seagrass habitat. Seagrass habitats that are in a good condition are productive and sufficiently extensive to carry out natural functionality. To look at seagrass condition, metrics, such as plant density, fragmentation, morphology, or diversity, have been used (Congdon *et al*. 2018). For example, Gaubert-Boussarie *et al*. (2021) used leaf morphology (length and width), elemental content (% nitrogen and phosphorus) and stable isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$) as key seagrass bioindicators in a tropical lagoon in Panama. In their evaluation of the ecological status of *Posidonia oceanica* meadows of Italian coastal waters, Rende *et al*. (2011) used five metrics: shoot density, shoot leaf surface area, the ratio of epiphytic biomass and leaf biomass, depth, and type of lower limit. Walday *et al*. (2018) suggest a different set of five metrics to assess eelgrass (*Zostera marina*) in Norwegian waters: lower depth limit for growth of eelgrass, shoot density, abundance of filamentous algae on eelgrass, height of the eelgrass and area of the eelgrass bed based on the extent in different directions, including towards the shoreline and to the deepest extent, as well the extent in a line parallel to the shoreline.

To look at seagrass condition, changes in the extent of dense and sparse seagrass, calculated using the above method using The Nature Conservancy habitat map (Schill *et al*. 2021) as the basis, could be taken into account. Other seagrass condition indicators have looked at shoot density, but in the absence of direct monitoring data, the categories of dense and sparse seagrass described in Table 2, and employed within The Nature Conservancy map, could be used as a proxy. A reduction in area of seagrass may indicate poor condition of the remaining seagrass. Factors such as higher shoot density, higher seagrass species richness, higher seagrass species diversity, could suggest better condition of seagrass. These factors are likely to be higher in areas of dense, compared to sparse seagrass. A reduction in the area of dense seagrass could, therefore, indicate a reduction in seagrass condition. Any changes such as these, however, would need to be measured and understood in more detail. Variation in the ratio between dense and sparse seagrass could fluctuate over time due to natural causes, not driven by human activities.

Additional information on seagrass condition could also be obtained from the work conducted under Work Package 2. Work Package 2 aimed to conduct a status assessment for marine/coastal habitats within TCI territorial waters. Sensitivity assessments were undertaken for habitats, including seagrass, for seven priority pressures and a vulnerability assessment was conducted to assess the condition of the seagrass habitat against the activities causing pressures. The vulnerability assessment resulted in the area of seagrass habitat in TCI potentially in unfavourable condition being estimated, due to the possible presence of a pressure, that seagrass is sensitive to, occurring in that area. See Table 5 for example results from the marine activities dataset. However, due to the limitations of the data sets available in this time-limited study, the method should serve as a tool for future marine status assessments, until higher quality activity data becomes available so habitat condition figures can be used with confidence.

Table 5. The area of seagrass habitat in TCI potentially in unfavourable condition being estimated due to the possible presence of a pressure seagrass is sensitive to occurring in that area. Note total habitat extent in TCI (km^2) is 1,977.68 km. Taken from work conducted under WP2 of this project.

Pressure	Area of seagrass habitat likely in unfavourable condition (km^2)
Abrasion/ disturbance of substrate	43.12
Penetration and/or disturbance of substrate	30.3
Physical change	83.54

If more data were to become available, it may be possible to update these area figures to display a trend over time. However, this method also uses the same TNC benthic habitat map so is reliant on the dataset being updated regularly.

Further work is required to explore how metrics, such as plant density, morphology fragmentation or diversity, could be incorporated with current data available to assess the condition elements.

6 Discussion

This pilot has demonstrated that it has been possible to assess and produce figures for seagrass habitat extent for all TCI waters. To measure changes in habitat extent, the TNC habitat map will need to be updated so that trend data can be collected for the indicator. There is no set schedule for TNC updating the benthic habitat map, however, an update is being worked on for 2023 (Schill, pers comm.).

Although extent figures have been produced, there are a number of limitations associated with the use of remote sensing data. A statement of accuracy or confidence should be provided alongside any formal assessment. Despite the limitations associated with using remote sensing data, there are also advantages to this approach. Traditional means of monitoring ecosystems typically require intensive field operations that are expensive and require a significant amount of time to achieve. Therefore, new technologies, such as the TNC Benthic Mapping project using Dove satellite constellations, can be an important tool to decrease costs while increasing efficiency when analysing the extent of benthic habitats.

Seagrass habitats are known to provide a range of ecosystem services (Neto *et al*. 2018, Schill *et al*. 2021). Under Work Package 1 of the project, a literature review was conducted to create an asset-service matrix for habitat assets (Hooper *et al*. 2021). This showed the linkages between habitats and the ecosystem services that they provide. Ecosystem services were divided into three different categories: regulating, supporting and cultural. Regulating ecosystem services are where benefits are obtained from the regulation of ecosystem processes such as flood protection. Supporting services are key functions provided by marine habitats, they are necessary for the production of all other ecosystem services, such as habitat provision for other species. Cultural services are identified as the benefits people gain from their interactions with different environmental spaces, such as tourism.

The asset-service matrix identified the following ecosystem services for seagrass (Hooper *et al*. 2021):

- Regulating services – erosion/flood protection, filtration/storage/sequestration, nursery habitat provision for queen conch, spiny lobster, grouper, shark and turtles.
- Supporting services – carbon storage, habitat provision for queen conch, spiny lobster, grouper, reef fish and turtles.
- Cultural services – snorkelling.

Through this asset-service matrix, sparse and dense seagrass were identified as a dominant habitat asset, accounting for 24.78% and 12.28% of the Turks and Caicos shallow marine-coastal area respectively (Hooper *et al*. 2021).

More work is needed to determine how the outputs of a seagrass extent indicator could be used to inform ecosystem service provision. A reduction in the extent of habitat may result in the loss of the service provision. For example, a loss of seagrass habitat could also mean the loss coastal protection which that seagrass habitat was providing. Links between the condition of seagrass habitat and ecosystem service provision are more complex. A change in condition may not necessarily mean a loss of service provision if the overall function of the habitat remains the same. It will be important to explore which metrics of condition (e.g. shoot density, species diversity) best relate to ecosystem service provision.

The indicator approach could help to inform management through identifying areas where management should be focused. If trend information becomes available, locations with a reduction in seagrass habitat or a change in condition could be used to focus management efforts. The effects of any management measures could also be explored if the indicator were to be run using data from before and after the implementation of management measures. Identification of data or knowledge gaps could also help to identify areas in which to focus further data collection.

More data are required before an indicator to assess seagrass condition can be developed. The Nature Conservancy habitat maps do, however, provide extent figures for dense and sparse seagrass, meaning that these metrics could be used as a proxy for seagrass condition if temporal trend data could be acquired. Using The Nature Conservancy Benthic habitat maps as a proxy for condition has the advantage of being less resource intensive and allows for a wider geographic coverage. It is, however, likely to be less accurate and any repeat assessments would be reliant upon there being an update to the habitat maps. In addition, any changes in the area of dense and sparse seagrass, would need to be measured and understood in more detail. Variation in the ratio between dense and sparse seagrass could fluctuate over time due to natural causes, not driven by human activities.

Alternatively, direct monitoring data would be required to be able to calculate metrics such as plant density, fragmentation, or diversity, and incorporate these into an indicator to assess seagrass condition. Direct monitoring data may provide more detailed and accurate information on condition but would cover a smaller spatial scale and be more resource intensive. It would not be possible to directly monitor all seagrass beds across TCI and therefore certain areas would need to be selected for repeat monitoring and then the results extrapolated across a wider geographic area. Staff resources and equipment would be required to collect and analyse any data obtained through direct monitoring, in addition to time required to design and plan the monitoring. Obtaining data directly from monitoring is likely to provide a better link if looking at the effectiveness of any management measures. For example, if there are plans to put a management measure in place then monitoring could take place before, during and after the implementation of the management measure, allowing the effect of the management measure to be explored. This is unlikely to be possible if habitat maps are being used as a proxy for condition. The spatial resolution of the habitat maps may be too coarse to determine the effect of management measures. There would also be a much longer time lag between management measures being put in place and obtaining habitat extent figures from the habitat map. Even if the data underpinning The Nature Conservancy maps were of higher quality, additional data would be needed to understand the relationship between the changes in extent driven by anthropogenic pressures and distinguish those from natural variation. One solution to obtain direct monitoring data for seagrass in the future, could be to include it in the upcoming Blue Belt Programme TCI Research and Monitoring Plan.

Information on the provision of ecosystem services, developed under Work Package 1, could also help to inform where direct monitoring should take place. For example, monitoring could be focused in areas where many services are provided by the same habitat asset. Any changes in condition in these areas may affect a range of ecosystem services and, therefore, monitoring to enable the early detection of any changes in condition could be very valuable.

6.1 Future indicator development

There are several knowledge gaps that need to be filled before the indicator approach can be further developed.

More information is needed on the next planned update of the TNC benthic habitat map. This will allow us to estimate when trend data could become available. It would also be important to know if the methods for producing the benthic habitat map are expected to stay the same or change. Any changes or updates to the method may mean that any changes in calculated seagrass habitat extent may be due to the change in the method, rather than real change in extent.

Further exploration is needed as to the degree to which the TNC habitat map can be used to detect changes in seagrass extent. It is important to know how much 'real' change in habitat extent on the ground is required for this to be detected and reflected in the habitat map. The degree of accuracy in the benthic habitat map needs to be taken into account and a statement of accuracy or confidence should be provided alongside any formal assessment.

Further discussions are needed with DECR to agree on how the indicator could be developed in the future. It may be possible to obtain other sources of seagrass density data, such as field survey and earth observation data along with incorporation of additional metrics, such as shoot density, taxonomic composition, and species diversity of the seagrass community to further develop the condition aspect of the indicator. DECR need to decide if this is the approach that they want to take, considering factors such as resource availability, costs, and monitoring capacity.

Future monitoring is required to ensure that the indicator approach can be developed beyond this initial, pilot assessment and monitoring and research priorities need to be identified. A strategy will need to be developed for additional data collection which could feed into the indicator along with a data management plan.

Once the approach has been developed, assistance and training on the use of the indicator will be required along with dissemination and communication to stakeholders. More work is required on linking the indicator output to management measures. It would be crucial to understand the relationship between the changes in extent driven by anthropogenic pressures and distinguish those from natural variation.

Phase 2 of Work Package 3 will provide recommendations and options for future indicator development.

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