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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 – Recommendations for future development of marine indicators

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Summary

This report provides recommendations for the future development and operationalisation of marine biodiversity indicators in the Turks and Caicos Islands (TCI). It follows on from work conducted to test the feasibility of using an indicator approach to measure seagrass extent and considers other options for the further assessment of seagrass habitats. It also explores potential options for assessing the condition of other marine habitats.

The work is part of 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 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.

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.

This report explores potential options for future development and testing of marine biodiversity indicators. The potential options are based on priorities identified by DECR, existing data availability and existing indicator methods and approaches. Indicators are tools and methods used to summarise and communicate aspects of ecosystem state (McQuatters-Gollop *et al*. 2019; Vina-Herbon *et al.* in prep). Measuring ecosystem state is important because it can provide an early warning of changes, provide information on how the ecosystem responds to changes or to management, guide investment in data products and help to support decision making to conserve species and habitats. Ecosystem health has links to biodiversity, natural capital and ecosystem services. A reduction in the extent or condition of habitats could, therefore, have important biological and economic implications.

As part of this project, Britton *et al.* (in prep) piloted an indicator approach to assess seagrass extent. This current report builds on the work of testing an indicator approach to measure seagrass extent and considers other aspects of seagrass habitat that could be measured. It also explores potential options for assessing the condition of other marine habitats.

2 Seagrass habitat

Seagrass is an important habitat in TCI which forms spatially expansive meadows and provides multiple ecosystem services including, stabilising sediment, storing carbon, providing habitat for other species and providing a food source (Nagelkerken *et al.* 2000; Orth *et al.* 2006,;Valdez *et al.* 2020; Hooper *et al.* 2021). Seagrass species occurring across the Caribbean include *Thalassia testudinum*, *Syringodium filiforme* and *Halodule wrightii* (Baker *et al.* 2015; Schill *et al.* 2021).

2.1 Habitat map groundtruthing

Britton *et al.* (in prep) tested an indicator approach for measuring seagrass extent using The Nature Conservancy benthic habitat map (Schill *et al.* 2021). To assist with the further development of a seagrass extent indicator, The Nature Conservancy benthic habitat map would need to be groundtruthed using direct observations. This groundtruthing will help to evaluate how well data collected *in situ* agrees with the habitat classifications in habitat maps obtained from satellite remote sensing. Groundtruthing of remote sensing data can be done using direct observation methods such as diving, grabbing, cameras or videos, or using remote sensing apparatus, such as echosounders or sonar (Komastu *et al.* 2020).

In August 2022, a field validation of The Nature Conservancy benthic habitat map was conducted at dive sites off the southern tip of Grand Turk and near Salt Cay in the Turks and Caicos Islands (Vogel & Minnery 2022). Thirty-eight locations were photographed, observed and recorded to compare with the data provided by the benthic habitat map. Out of the 38 field validation locations of several habitat types, 21 were considered a correct prediction by The Nature Conservancy Habitat map (Vogel & Minnery 2022), and the main discrepancies in the data were mainly around seagrass habitats. Out of the 17 locations which were incorrectly classified by the habitat map, 12 of these were areas of sand or hardground which had been classified as seagrass in the benthic habitat map (Vogel & Minnery 2022). It is possible that seagrass in some of these areas has been removed since the satellite imagery was taken. There were also two instances where the benthic habitat map had classified the habitat as sand, but the habitat present in that location was actually seagrass. This could be because of the growth of new seagrass since the satellite images had been taken or the location could have been covered by sediment when the satellite imagery was obtained (Vogel & Minnery 2022). This evaluation has implications for the further development of any marine biodiversity indicators in seagrass habitats which rely on benthic habitat maps from remote sensing sources, indicating the need to calibrate and improve the predictions as well as to incorporate direct observations to increase the accuracy of the maps.

The data obtained during the study by Vogel and Minnery (2022) could be used to create updated habitat maps, using a composite of The Nature Conservancy benthic habitat map and data obtained from direct observational data. New satellite images could also be retrained using the information provided in the Vogel and Minnery (2022) study.

Additional *in situ* data collection from other sites across TCI would help to further validate The Nature Conservancy benthic habitat map. The sites visited by Vogel and Minnery (2022) could also be revisited to see if any changes have occurred.

The information obtained from groundtruthing the habitat map could be analysed to see if any patterns emerge. For example, it might be that the habitat map is more likely to be incorrect near to the edge of a habitat or at greater depths. This could help to prioritise areas for further sampling and would help to identify areas where there is likely to be lower confidence in the habitat map.

With further groundtruthing of The Nature Conservancy benthic habitat map, the extent of seagrass habitat could be calculated from the habitat map with more confidence.

2.2 Seagrass condition

Britton *et al.* (in prep) proposed using changes in the extent of dense and sparse seagrass from The Nature Conservancy benthic habitat map (Schill *et al.* 2021) which can be used to help measures of seagrass condition. In addition to groundtruthing the habitat map, changes in the areas of dense and sparse seagrass would need to be measured and understood in more detail before an indicator approach could be developed. Changes in the extent of, and ratio between dense and sparse seagrass may fluctuate due to natural causes, rather than be driven by human activities.

Seagrass condition indicators tend to use direct monitoring data and have used metrics such as such as plant diversity, density, morphology, or fragmentation (Congdon *et al.* 2018). In a tropical lagoon in Panama, Gaubert-Boussarie *et al.* (2021), used elemental content (% nitrogen and phosphorus), leaf morphology (length and width), and stable isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$) as key seagrass bioindicators. For condition indicators using metrics such as these to be developed, a monitoring programme would need to be established at a number of sites to help refining the best set of metrics to be used.

Monitoring of human activities could also provide information on the likely condition of seagrass habitats and/or the level of risk to seagrass condition. Changes in the intensitiy of certain human activites may affect the extent and condition of seagrass. If the sensitivity of seagrass to certain activities is known, then the presence those activities in the same location as seagrass could be used to infer the condition that seagrass is likely to be in.

2.3 Carbon storage

One option to increase the understanding of seagrass habitats and act as an initial starting point to eventually begin to link seagrass condition to ecosystem service provision would be to develop an approach for measuring the amount of carbon stored within seagrass habitats.

Seagrass habitats have high carbon burial rates and accumulate large stores of carbon in their sediments (Fourqurean *et al.* 2012; Duarte *et al.* 2013). Seagrass ecosystems are estimated to bury 27–44 teragrams of carbon per year and the organic carbon in the seagrass soils can be preserved for millennia, due to anaerobic conditions (Duarte *et al.* 2005; Fourqurean *et al.* 2012; Bedulli *et al.* 2020). Fourqurean *et al.* (2012) estimated that, globally, seagrass ecosystems could store as much as 19.9 petagrams of organic carbon.

Globally, the loss of seagrass habitats results in a reduction in the amount of carbon sequestered. In addition to the loss of sequestration, it is likely that carbon stored in the seagrass soils will be released if the seagrass habitat is lost. Fourqurean *et al.* (2012) estimated that current rates of seagrass loss could result in the release of up to 299 teragrams of carbon per year. Estimating the magnitude of the organic carbon stores within seagrass ecosystems and how these are affected by degradation of seagrass is required to understand how seagrass condition may affect carbon stores within seagrass ecosystems.

Duarte *et al.* (2013) identified six actions which were required to address current uncertainties in the role that seagrass meadows play as carbon sinks. These six actions included, improved estimates of global seagrass cover, more detailed investigation of carbon stocks and burial rates over different time scales, understanding of the fate of carbon exported from seagrass meadows, knowledge of the factors responsible for variability in seagrass carbon sink capacity, improved models to identify suitable areas for seagrass restoration, assessments of the impacts of the loss of seagrass on the fate of the carbon stored within the habitat.

Measuring organic carbon stocks and accumulation rates within seagrass meadows, by taking soil cores (Bedulli *et al.* 2020; Serrano *et al.* 2021), can provide baseline values for future development of blue carbon strategies, in addition to providing key information for marine planning, based on the blue carbon ecosystem services provided by seagrass (Serrano *et al.* 2021). A manual for measuring, assessing, and analysing coastal blue carbon is available through The Blue Carbon Initiative (Howard *et al.* 2014).

Serrano *et al.* (2021) measured seagrass soil stocks and accumulation rates across the Columbian Caribbean. They estimated that *Thalassia testudinum*, one of the seagrass species also found in TCI (Baker *et al.* 2015), store 241 megagrammes of organic carbon per hectare in the top 1 m of soils, with an accumulation rate of 122 grams of organic carbon per m^2 per year over the last 70 years. *Thalassia testudinum* was estimated to sequester approximately 0.3 teragrams CO_2 per year in the Columbian Caribbean.

Shayka *et al.* (2023) used seagrass distribution data in the Caribbean, obtained from The Nature Conservancy benthic habitat map (Schill *et al.* 2021), to estimate that the 88,170 km^2 of seagrass in the Caribbean stores 1,337.8 teragrams of carbon, with an estimated value of the carbon stored in the seagrass beds of USD$88.3 billion yr^{-1}. For TCI the value of the carbon stored in seagrass beds was estimated to be approximately USD$5.5 billion yr^{-1} (Shayka *et al.* 2023).

Further monitoring and evaluation of carbon storage within seagrass habitats would help to establish baseline data and increase understanding of carbon storage potential within TCI. More work would be required to understand how changes in seagrass extent or condition could affect the amount of carbon storage.

3 Coral habitats

Developing marine biodiversity indicators for coral reef habitats have been identified as a priority for DECR. The extensive tropical shallow- water marine environments of TCI support two major groups of coral habitats: coral dominated accreting reefs and hard bottom habitats that contain corals but are not accreting coral reefs (Logan & Sealey 2013). In The Nature Conservancy benthic habitat map, Schill *et al.* (2021) classify hardbottom reefs into the following types: coral/algae, reef crest, reef back, reef fore and spur and groove.

Coral reef habitats provide multiple ecosystem services including, erosion and flood protection, providing a habitat for other species and cultural services such as tourism and scuba diving (Hooper *et al.* 2021).

Key threats to coral reefs in the Caribbean region include overfishing, eutrophication, coastal development, disease and climate change (Logan & Sealey 2013). These stressors are causing these ecosystems to move away from coral dominated communities to macroalgae dominated states (Alvarez-Filip *et al.* 2013).

3.1 Coral reef monitoring

Measuring the condition of coral reefs ecosystems is important to help prioritise areas for conservation and evaluate the success of intervention efforts (Apprill *et al.* 2023). Monitoring of coral reef habitats typically involves photographic and diver-based documentation such as coral cover, species assemblages, fish abundances and the presence of health-related visual signs (Apprill *et al.* 2023). Condition assessments should consider complexity as well as coral cover (Alvarez-Filip *et al.* 2013: González-Barrios *et al.* 2020).

The Atlantic and Gulf Rapid Reef Assessment (AGRRA) programme was established in 1997 with the aim of conserving coral reefs. AGRRA has established a standardised assessment of key structural and functional indicators to look at spatial and temporal patterns of regional reef condition.

The Global Coral Reef Monitoring Network (GCRMN) aims to provide the best available scientific information of the status and trends of coral reef ecosystems for their conservation and management and provides the foundation for global reporting on coral reefs (Obura *et al.* 2019). It is an operational network of the International Coral Reef Initiative (ICRI). GCRMN metrics include both ecological and pressure metrics that have natural capital applicability.

GCRMN regional network in the Wider Caribbean (GCRMN-Caribbean), is a network of coral reef scientists, managers and government representatives. It aims to strengthen coral reef monitoring across the region to assess the status and trends of Caribbean coral reefs through helping to reinforce existing monitoring programmes and supporting the development of new ones. It has produced guidelines for integrated coral reef monitoring to harmonise efforts across the region. The guidelines include technical coral reef monitoring procedures and help make connections between ecological parameters and pressure sources on Caribbean reefs. GCRMN-Caribbean encourages government environment departments to use new guidelines and request support from the regional network.

GCRMN-Caribbean has agreed on monitoring guidelines that are linked to six metrics (Table 1).

Table 1. GCRMN metrics.

GCRMN METRICS	Description	Data	Type
Abundance and biomass of key reef fish taxa	Core data to collect are density and size structure of snappers, groupers, parrotfish, and surgeonfish. If possible, also estimate density and size of all fish species in survey area such as barracuda, grunts, damselfish and triggerfish, and sensitive species such as sharks and rays, and invasive species (e.g. lionfish). Level 3 method is highly recommended by GCRMN- Caribbean and is based on the AGGRA. Five belt transect of 30 m x 2 m lasting 8–12 minutes each are pooled at each site.	DECR/TCReef/Reef check, AGGRA	State
Relative cover of reef-building organisms and their dominant competitors	Core data to collect is the percentage of reef bottom that is covered by corals (stony corals and gorgonians), sponges, and algae (turf algae, macroalgae and crustose coralline algae). The highly recommended method uses digital photographs of standardised 0.9 m x 0.6 m quadrats taken along the five fish transect lines. 15 images captured per transect line (every other metre) with 75 photographs collected at each site. If volunteers are conducting the surveys, Reef Check methods can be used.	DECR/TCReef/Reef check, AGGRA	State
Assessment of Coral Health	This metric assesses the prevalence of disease in stony corals, not bleaching, following Atlantic and Gulf Rapid Reef Assessment (AGRRA) methods. It measures the relative prevalence rate; the proportion of quadrats that have diseased corals, rather than the proportion of diseased coral colonies. This metric allows survey teams to alert experts if treatment is needed. Uses same data collection methods as coral cover metric above. During analysis photo quadrats of coral colonies which show sign of disease are tagged, and the proportion of images with disease is divided by the total number. Coral disease experts can analyse photo quadrats. Level 2 methods for this indicator includes data collection along a 10 m belt transect using AGRRA methods.	DECR/TCReef/Reef check, AGGRA	Pressure

GCRMN METRICS	Description	Data	Type
Coral Recruitment	Estimates the density of young corals that are likely to contribute to the next generation of adult corals. Coral recruits are hard to identify so are defined as the smallest individuals visible to diver – 0.5–4 cm. Follows AGGRA methodology using 25 cm x 25 cm quadrats. Using first three transects from coral cover indicator above and five quadrats on each will be analysed every other metre. Within quadrats coral recruits are recorded to the finest possible taxonomic level. If expert knowledge is not available, then the number of recruit colonies can be identified. Algae height can also be identified to estimate how competitive the environment is.	DECR/TCReef/Reef check, AGGRA	State
Abundance of key macro-invertebrate species	Estimates the density of ecologically and important species on the reef. Core data include density of long-spined urchin, other urchins, all sea cucumbers, lobsters, and conch. Uses same data collection methods as coral cover metric above, but instead identifies species and abundance of each macroinvertebrate species in each image. Density is calculated by dividing total number of macro invertebrates by the number of images and size of quadrat (0.54 m^2).	DECR/TCReef/Reef check, AGGRA	State
Water quality	Estimates concentration of particulates in water column by collecting data on the depths standardised Secchi discs are visible in the water of the reef. In clear water horizontal measurements can be made instead of vertical. Level 3 monitoring recommends collecting data weekly, and level 2 monthly. Additional information on dissolved oxygen could be collected if equipment is available.		Pressure

The six elements give an overview of reef condition, and overtime will describe status of coral reef health and assess effectiveness of management measures. Along with set protocols, there are species' identification guides, videos and an online portal.

There is previous data available for TCI in the GCRMN Status and Trends of Caribbean Coral Reefs: 1970–2012 report (Jackson *et al.* 2014). It provides previous baseline data for TCI using AGGRA methods for corals and algae (Riegl *et al.* 2003) and fish communities (Hoshino *et al.* 2003).

Britton *et al.* (2021, 2022) identified indicators and metrics which have been developed for coral reef ecosystems and could potentially be used in TCI.

A monitoring programme would need to be established to monitor these metrics. There are ongoing discussions around coral reef monitoring within DECR, looking at global and regional standards.

4 Recommendations and next steps

In addition to seagrass and coral reefs, other habitats that have been identified as a priority for DECR to measure the condition of include mangroves, sandy shores and rocky shores.

One of the main limitations to indicator development has been data availability. Data is critical to establish baselines or reference point for indicator development and in order to further develop some the marine biodiversity indicators, monitoring programmes would need to be established.

Linking the outputs of any marine biodiversity indicators 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. Changes in marine biodiversity will affect ecosystem service provision and, therefore, have implications for the goods and benefits provided. More work needs to be done on establishing the link between condition indicators and ecosystem service provision.

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