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WP3: Marine indicators to monitor changes in marine-coastal natural capital

Review of indicators from the literature

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Executive Summary

As part of the Darwin Plus '*Technical assistance programme for effective coastal-marine management in the Turks and Caicos Islands*' project we conducted a review of the literature to provide an overview of marine ecological indicators and types of data required. We summarised potential local, regional and global data which could be used, or adapted, to be applicable to local features and resources to support ecological indicators in TCI. This has helped to identify which indicators could be prioritised for development as part of the project.

Measuring change in ecosystems and evaluating progress towards environmental goals requires suitable indicators (Teixeira *et al*. 2016). Marine ecological indicators are scientific tools intended to examine and determine the trends in status of complex environmental systems, such as the extent and condition of habitats and species, and the pressures impacting them. Marine indicators can also be response based, including those relating to Marine Protected Areas, such as coverage and management effectiveness.

One of the key gaps identified through the literature review was data availability, particularly the limited amount of monitoring data. This will restrict the type of indicator which can be developed. It is important to identify cost-effective ways of assessing ecological status that can, ideally, be used for multiple purposes. This is particularly important where there are limited resources. Next steps include further discussions on key priorities, selection of indicator frameworks or approaches for development and determine a plan for development of the indicators.

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1 Introduction

1.1 Project background

This technical assistance programme is a three-year Darwin Plus funded project to improve 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 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 aim of this project is to provide 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 provide in-depth support and capacity building in developing and using marine ecological indicators, maximising the use of existing data, to support decision making and the implementation of a new TCI Government Environment Strategy. The aim is to develop marine indicators to monitor and assess changes in coastal and marine natural capital, enabling progressive adoption of a monitoring programme developed through a capacity building process with Turks and Caicos Islands Government (TCIG) staff. There are three main objectives:

- identify metrics to underpin indicator sets required to monitor changes to coastal/marine natural capital enabling progressive adoption of a monitoring programme as project proceeds;
- develop set of indicators for monitoring environmental change based on the 25 Year Environment Plan framework;
- build additional information management capacity for the storage, analysis and dissemination of indicator related information to allow DECR to monitor and report environmental change.

This report consists of a literature review, providing an overview of marine ecological indicators and types of data required. It summarises information from the literature to look at different types of ecological indicator methods and types of data used in indicator calculation. We then summarise potential data available to support ecological indicators in TCI and provide suggestions on the indicators which could be developed.

2 Overview of indicators and types of data required

Measuring change in ecosystems and evaluating progress towards environmental goals requires suitable indicators (Teixeira *et al*. 2016). Marine ecological indicators are scientific tools intended to examine and determine the trends in status of complex environmental systems, such as the extent and condition of habitats and species, and the pressures impacting them. Marine indicators can also be response based, including those relating to Marine Protected Areas, such as coverage and management effectiveness. As there are an array of different indicators, robust selection, transparent use of evidence and appropriate communication aids successful environmental management.

2.1 Types of indicator methods

The approaches of ecological indicators vary considerably in detail, but indicators used in the assessment of ecosystem state fall broadly into three main types:

1. simple or multimetric indicators based on data collection from regular monitoring and surveys,
2. model-based indicators, based on a combination of monitoring, pressure data and modelling approaches or,
3. expert judgement-based indicators, based on local knowledge, progress of implementation of plans or other socio-economic elements.

Factors that should be considered when assessing an indicator method include resources and technical requirements, complexity, and data availability.

2.1.1 Simple or multimetric indicators

Simple or multimetric indicators are often based on ecological monitoring, which consists of the collection and analysis of biological and environmental data. Monitoring programmes regularly target specific biological and/or environmental parameters but can also be adapted to multiple species and habitats, for example marine mammals, seabirds, fish, and benthic habitats. Data collection methods could include population and species counts and subsequent calculations of species diversity, as well as biomass calculations and biological trait identification. Biological data can be analysed across different environmental and human activity parameters, such as pressure gradients, to inform conservation management. The ability of simple indicators to measure changes at a range of spatial scales will depend on the type of monitoring programme and the resultant data available. The regularity of monitoring programmes can also determine temporal scale; if regular sampling is conducted, trends could be calculated.

2.1.2 Model based indicators

Model based indicators use ecological, environmental, and socioeconomic data collected from monitoring programmes and baseline assessments. However, they differ from simple or multimetric indicators by using the data to infer results over a larger spatial and temporal scale. Confidence in the model-based indicator outputs can depend on the quality and quantity of monitoring data used, and the levels of assumptions made.

Examples of the types of model-based indicators can include:

- high-level, risk-based assessments which provide an evaluation of current activities. This type of indicator can use more available socio-economic data in its assessment, however, it may underplay the complexity in the correlation of biological condition to

current activities. Analysing the geographical growth of fishing ports, or port activity from Earth Observation data is an example of this indicator type;
- disturbance analysis which combines habitat distribution and sensitivity, with the distribution and intensity of pressures. This type of indicator provides a cost-effective analysis over a wide geographic area, if the underlying data (pressure information, and benthic habitat maps) are available. However, barriers may arise with the availability of data and understanding of the sensitivity of biological features to pressures. The OSPAR extent of physical damage indicator is an example of this type of indicator, which uses physical abrasion information from fishing and the sensitivity of the underlying habitats to determine likely disturbance caused to the seafloor;
- sensitivity and pressure index combinations which map anthropogenic pressures against certain biological variables. The availability of these global variables, consisting of the presence or absence of pressures in a particular area are advantageous to this model, but relies on assumptions surrounding the complex interactions between pressures and environmental features. An example of this is the Ocean Health Index (Halpern 2012);
- analysis of multispectral imagery usually from earth observation (EO) data to analyse the condition of certain habitats. Products obtained from earth observation EO data providers often require detailed knowledge regarding the type of processing and data required; however, EO data is generally accessible and covers a large geographic area. An example of this may include measuring the change in seagrass extent (Hedley 2012).

2.1.3 Expert judgement-based indicators

Expert judgement can be used where there is a lack of ecological data available to inform biodiversity indicators. Using expert judgement can bring biases to the indicator development process so the selection of those involved in the judgement should include a variety of expertise (Barnard & Boyes 2013). To reduce the risk of inconsistent advice being given, expert opinions can be weighted, in addition to a structured and transparent process to elicit the expert judgement (Barnard & Boyes 2013).

2.2 Types of data used in indicator calculation

The types of data used in marine environmental indicators varies depending on the indicator and the data available. The data required to run an indicator can include some or all the following:

1. biological aspects such as abundance, biomass, species diversity, biological traits, or an estimation of cover for a benthic habitat;
2. associated environmental data, such as sea surface temperature, light, sediment type or water quality; and
3. data on human activities and associated pressures which have potential impacts on ecological systems such as industry, tourism, or fishing.

Indicators typically require at least one of these three types of data, and commonly use two or three types. In the absence of biological data, environmental and human activity/pressure data can in some cases be used as a proxy for ecological condition. Environmental data is also important to assess potential effects or impacts from climatic drivers.

2.2.1 Ecological data

Ecological data collected directly from monitoring programmes includes the biological and environmental data collected at the local level. Direct data can be analysed in a variety of

ways, including just considering the raw data or modelling it. There is often a paucity of direct ecological data, particularly for marine habitats.

Ecological data may consist of biological information such as abundance, percentage cover, biomass, presence/absence, fish length, habitat types or environmental information such as water depth and sea temperature. Biological information may be collected using direct observation in the case of some species. To collect biological information for benthic habitats, grab sampling, beam and otter trawls, and photographic or video methodologies are some of the approaches which could be used. Ecological data may derive from locally collected surveys and monitoring programmes (such as the Conch Visual Survey 2013, containing presence and abundance information of Spiny Lobster and Queen Conch within shallow waters of TCI, present within the TCI Marine Spatial Planning (MSP) Tool), which are often costly to implement and maintain. As a result, data sharing standardised methodologies and protocols for the collection of ecological data are often compiled into extensive global databases such as the Ocean Biodiversity Information System (OBIS) and analysed globally such as the Global Coral Reef Monitoring Network Global Report on the Status of Coral Reefs, which sets data standards for its regional hubs.

Ecological data may also be derived from remote sensing methods. Remote sensing is a technique of acquiring indirect ecological data through a variety of earth observation (EO) methods. Monitoring using EO can include: acoustic remote sensing using sonar to identify marine species and habitats that are not visible from the surface, airborne and drone based digital images, and EO satellite that use a range of sensors to gather information in near surface waters. The advantages of remote sensing are that fewer resources are needed for data collection, and repeatable time series data can be collected if satellites are used. However, there are costs associated with data collection, data often require processing to be of sufficient quality, and the data needs to be validated with ground truth data (JNCC 2019).

The use of EO in deeper waters (below 20m) is difficult, but satellite EO data has been used at shallower depths to detect change in marine habitats. For example, changes in seagrass bed extents (León-Pérez *et al.* 2019), monitoring changes to global mangrove extent (Thomas *et al.* 2017), identifying sargassum bloom conditions in the Caribbean (SAWS 2020) and identifying coral health in the Southwest Pacific (Allen Coral Atlas 2018). Although, coral EO data can be difficult to interpret because the presence of macroalgae can make it hard to discriminate between the two habitats.

2.2.2 Pressure data

Direct sources of human pressure data can include fishing activity such as those from vessel monitoring systems, or locations of dredging activities or anchorage sites. Licencing information, locations of industrial sites (e.g., presence of oil and gas infrastructure), footprint developments (e.g., area of marina or port developments), and direct monitoring data (e.g., scarring on seafloor from fishing trawling activities, underwater noise for marine mammals) can also provide invaluable information on the distribution scale, and intensity of human pressures.

Data within the TCI MSP tool may provide location, scale and extent information on anthropogenic activities that will put pressure on marine ecosystems. Examples of pressure data include marine activities identified by stakeholders and man-made structures found on the coastline. Additionally, datasets such as swimming zones in Providenciales and Grand Turk and dive sites in Turks and Caicos, whilst a pressure in themselves, may also be used as a proxy to indicate the presence of other pressures, for example seasonal tourism was identified to increase marine litter by up to 4.7% on known tourist beaches on islands in the Mediterranean (Grelaud & Ziveri 2020).

Indirect measures of pressure data correlated with human activity, could be calculated using environmental data such as sea surface temperature (SST). Changes in SST over time is widely used as a proxy for the impacts of climate change in coral reef ecosystems, but increasing SST is also associated with pressures on a host of other species and habitats, such as seagrasses (Repolho *et al.* 2017). SST can be identified using methods such as remote sensing (NOAA coral reef watch) and modelling monitoring data. Human impacts on water quality can be indirectly measured by monitoring plankton blooms caused by eutrophication from excessive nutrient input into coastal habitats. Plankton blooms can be monitored with EO sensors, e.g., the European Space Agency's (ESA) Sentinel 3 satellite. Furthermore, the ESA Sentinel 2 satellite has been used to investigate pressures in the form of litter, using the Floating Debris Index (Biermann *et al.* 2020). Indirect data from pressures such as tourism and fishing can be inferred from socio-economic information. Often expert judgement is used to evaluate these pressures, such as the presence of destructive fishing, and the impact of tourism on marine litter (Halpern *et al.* 2012). Additionally, human pressures can be modelled with proxy information, such as pollution data in the reefs at risk report (Burke *et al.* 2004).

2.2.3 Selection of appropriate methods

The selection of the most appropriate methods to be used for metrics to underpin indicator sets required to monitor changes to coastal/marine natural capital depend on the element being assessed and the type of data required. However, method selection will often depend on data availability, given the resource restraints of comprehensive monitoring programmes. Local data is generally of higher precision but is more resource intensive to collect. Whereas regional and global data may be more readily available but may have lower accuracy and have costs associated with acquiring and processing. However, with the onset of some time series global datasets becoming freely available, there is value in exploring global data.

3 Developing indicators for TCI

3.1 Sources of data for TCI

Indicators are typically selected and developed according to the required purpose and use of the indicator (e.g., policy drivers, reporting requirements), but it is also important to consider data availability. Some of the marine ecosystems of TCI have received a relatively low level of scientific research and monitoring (Thomas *et al.* 2017; O'Leary *et al.* 2019; Hogg 2019), therefore, there will be some data limitations that will impact the indicator development phase of the project. To identify local, regional, and global scale data sources to aid monitoring changes in TCI marine-coastal natural capital, online searches of publicly available information in grey and scientific literature were conducted. The data sources are presented in Tables 3.1, 3.2, 3.3 and 3.4, however, it should be noted that these are not an exhaustive summary of marine biodiversity research and monitoring occurring within TCI.

3.1.1. Local data

Local data included a range of smaller scale projects, though a comprehensive national monitoring programme was not identified. There may, however, be additional local data sources available that were not publicly available through online searches, for example from NGOs such as The School for Field Studies Centre for Marine Resource Studies.

Table 3.1: Examples of local data available for the development of indicators.

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
The Nature Conservancy benthic habitat map for the Caribbean	Benthic habitat map	Data for TCI available	Satellite imagery	Marine benthic habitats	https://dataportal.gov.tc/en_AU/dataset/benthic-habitat-map-tci
TCI Marine Spatial Plan data portal	Details in Table 3.4 below	Freely accessible	Biological, environmental and socio-economic data	TCI	https://dataportal.gov.tc/
TC Reef Fund	BEST 2.0 Programme: Understanding East Caicos KBA's Corals and Coasts: A Key to Safeguarding TCI's Future 2016 - 2019	Data will be shared with DECR	Baseline surveys and two-yearly monitoring	Coral reef	https://www.tcreef.org/east-caicos-reef-project
Tourism data	TCI Tourist Board Statistics Report	Freely accessible	Visitors, accommodation, originating country, cruise statistics	Tourism	https://www.gov.tc/stats/statistics/economic/41-tourism
Fishing data	TCI licence data	On request from TCI	Licencing information	Fish stocks Benthic habitats	Limited to wide area
TCI 2006 coral reef assessment	Global Coral Reef Alliance and DECR	Data available on request	Ecological and environmental	Coral reefs	Goreau *et al.* 2008
BEST 2.0 Programme RESCQ Restoration of Ecosystem Services and Coral Reef Quality	IMARES, Wageningen UR, TC Reef Fund	Data available on request	Coral restoration	Coral reef	https://www.wur.nl/en/project/RESCQ-Restoration-Ecosystem-Services-and-Coral-Reef-Quality.htm

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
Mapping for evidence-based policy, recovery and environmental resilience and Coral Reef Quality	Environment Systems	Data available on request	Satellite data to map and model the marine and terrestrial environment in the TCI	All	https://www.envsys.co.uk/sustainable-landscapes/mapping-for-evidence-based-policy-recovery-and-environmental-resilience/
Assessment of the coral reefs of the Turks and Caicos Islands	Atlantic and Gulf Rapid Reef Assessment - AGRRA	Data available on request	Stony corals, algae and fish communities	Coral reef	Hoshino *et al* 2008; Riegl *et al.* 2003

3.1.2. Regional data

Listed below are Caribbean specific data sources, including both one off assessments and time series monitoring, with some freely available to access.

Table 3.2: Examples of regional data available for the development of indicators.

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
Global Coral Reef Monitoring Network-Caribbean	Coral species, coral disease, coral bleaching, coral damage, reef fish and invertebrate data	Data available on request	Direct biological	Coral reefs	https://gcrmn.net/resource/caribbean-guidelines-integrated-coral-reef-monitoring/ https://www.icriforum.org/wp-content/uploads/2020/05/GCRMN-Caribbean_Guidelines.UNEP(DEPI)CAR_WG38.INF17-en.pdf

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
Atlantic and Gulf Rapid Reef Assessment (AGRRA)	Coral reef monitoring – coral and fish	Freely accessible – but not currently available	Ecological data	Coral reefs	https://www.agrra.org/data-explorer/explore-summary-products/
Caribbean Sargassum watch	Earth Observation products on chlorophyll a concentration, floating algal index, colour index, sea surface temperature.	Freely accessible	Indirect pressure	Sargassum blooms	https://optics.marine.usf.edu/cgi-bin/optics_data?roi=ECARIB&current=1
CARICOMP	Abundance of hard and soft corals, algae, sponges, urchins, and abiotic material such as substrate type.	Freely accessible	Ecological abundance data Substrate type	Coral reefs	https://catalog.data.gov/en_CA/dataset/caribbean-coral-reef-seagrass-and-mangrove-sites-caricomp-nodc-accession-0000501
Cartagena Convention -Specially Protected Areas and Wildlife	Caribbean Marine Protected Area database	Data available on request	Geospatial	Marine	https://sites.google.com/cep.unep.org/campamgeospatialdatabase/home

3.1.3. Global data

There is a wide variety of global data that could potentially be used to monitor changes in TCI marine-coastal natural capital. Including ecological, environmental, and anthropogenic pressures and impacts data. Ecological data includes habitat data for coral reef, mangrove and seagrass ecosystems, and species data on benthic invertebrate organisms, reef fish and hard and soft corals. Pressures data primarily focuses on human impacts on coral reef ecosystems, such as coral disease and bleaching.

Table 3.3: Examples of global data available for the development of indicators.

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
NOAA coral reef watch	The tool identifies coral reefs that are at risk of bleaching by analysing near real time and historical satellite SST measurements to calculate the temperature thresholds of coral reefs across the globe	Freely available	Daily global 5km satellite coral bleaching heat stress data, as well as time series data available since the 1990s. Indirect pressure	Coral reefs	https://coralreefwatch.noaa.gov/
Global mangrove watch	Mangrove habitat extent in km^2 using optical and radar remote sensing. Mangrove net change in km^2 between two points in time. Mangrove blue carbon – sum of above ground carbon and soil organic carbon values, measured in Mt CO_2e). Mangrove height – Mean canopy height in m of mangrove habitat from Lidar and SRTM.	Freely available	Earth Observation and modelled habitat data	Mangroves	https://www.globalmangrovewatch.org/

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
Global Coral Reef Monitoring Network	Coral species, coral disease, coral bleaching, coral damage, reef fish and invertebrate data	Data available on request	Direct biological	Coral reefs	Reef check http://data.reefcheck.us/ https://gcrmn.net/about-gcrmn/2020-global-report-status-coral-reefs/
UNEP-WCMC	Habitat data	Freely accessible through the TCI portal	Remote sensing and survey data	Coral reef, seagrass, mangrove and saltmarsh	https://data.unep-wcmc.org/
World Resources Institute	Coral reef pressure data. See TCI MSP table for details	Freely available	A 500m resolution map of global and local anthropogenic threats to coral reefs	Coral reefs	https://www.wri.org/publication/reefs-risk-caribbean
Allen Coral Atlas	Coral/Algae, Seagrass, Microalgal mats, Rock, Rubble and Sand Benthic Class and Geomorphology extent	Will be made downloadable at a future date	3.7m resolution global habitat maps from daily satellite imagery.	Benthic habitats	https://allencoralatlas.org/atlas/
UKHO	The UK Hydrological Office (UKHO) holds marine geospatial data for six UKOTs, including, bathymetry, tidal and a range of seabed features collected in 11 surveys	Lidar data has been collected but unsure on availability	The marine spatial data allows habitat maps to be created at greater depths than EO data but the amount of data available is limited.	Benthic habitats	https://www.admiralty.co.uk/digital-services/data-solutions/admiralty-marine-data-portal?gclid=EAIaIQobChMImMf9qsa87gIVqIFQBh2s7AiuEAAYASAAEgJS9_D_BwE
IUCN	Red List	Freely available	Overall extinction risk for species	All species	https://www.iucnredlist.org/
OBIS	Ocean Biogeographic Information System	Freely available	Species Abundance Data. Can filter by EEZ and IUCN red list	All species	https://obis.org/
CABI	Invasive species compendium	Freely available	Distribution – presence/absence	All	https://www.cabi.org/ISC

Data source	Relevant data	Accessibility	Type of data	Target habitat/system	Source
EU Space Agency Copernicus programme	Sentinel 1 satellite	Freely available	Active satellite that collects 10m resolution data which could potentially be used to provide a snapshot of large vessels present in a territory	All	https://www.copernicus.eu/en
EU Space Agency Copernicus programme	Sentinel 2 satellite	Freely available	Multispectral data passively at 10m resolution every two days and can identify global patterns of coral bleaching (Hedley *et al.* 2018), and could map marine ecosystems such as seagrass beds, kelp forests, mangroves and intertidal zones	All	https://www.copernicus.eu/en
EU Space Agency Copernicus programme	Sentinel 3 satellite	Freely available	Multispectral data at 300m resolution and could potentially map sea surface temperature, turbidity and chlorophyll a concentration	All	https://www.copernicus.eu/en
Worldview	NASA's Earth Observing System Data and Information System (EOSDIS)	Costs associated with some of the data	High-resolution real-time imagery layers and underlying data	Physical/ Environmental parameters	https://worldview.earthdata.nasa.gov/
Reef Life Survey	Global reef fish dataset	Freely available	Bony fishes and elasmobranch point data	Coral reefs	https://www.gbif.org/dataset/38f06820-08c5-42b2-94f6-47cc3e83a54a
Coral Watch	Coral Health Chart	Data available on request	Coral health surveys	Coral reefs	https://coralwatch.org/

3.1.4. TCI Marine Spatial Planning (MSP) GIS tool and Data Portal

Some of the local, regional, and global data listed above is available through the DPLUS094 TCI MSP GIS tool and data portal developed by SAERI for and with DECR. The MSP GIS tool is available at: https://webgis.gov.tc/. The data portal is available at: https://dataportal.gov.tc/.

Table 3.4: Data contained in the Marine Spatial Planning (MSP) GIS Tool and Data Portal.

Area	Layers	Potential use for biodiversity indicators	Scale of data (if applicable)	Spatial resolution	Source
Conservation	Protected areas	Useful to know species and habitats within protected areas.	NA	NA	DECR
	Important Bird and Biodiversity Areas (IBA) in the Turks and Caicos Islands	Provides information as to the location and extent of IBAs.	NA	Varies	BirdLife International
Economy	Conch visual survey	Provides species presence and/or abundance information for two commercially important species.	Presence, Abundance	18km x 18km	DECR
	Lobster morphometrics database	Provides fisheries information (number of fishermen, fishing area, etc.) as well as morphometric details on lobsters.	NA	NA	DECR
	Modelled total dollar value of reef tourism	Could provide information on human activities and direct and indirect pressures on coral reefs.	Reef-Adjacent Value, On-Reef Value	500m	The Nature Conservancy (TNC)
	Likelihood and range data for conch and lobster	Could provide information on fishing pressure for conch and lobster.	NA	NA	DECR
Structure	Artificial structure in the coast (l)	Could provide indication of potential human activities.	NA	At least 1m	DECR
	Artificial structure in the coast (p)	Could provide indication of potential human activities.	NA	At least 1m	DECR
Biota	Species presence grid for the Turks and Caicos Islands	Could provide information as to the presence of marine species, and areas requiring further surveying.	Presence, No information available	1km	DECR

Area	Layers	Potential use for biodiversity indicators	Scale of data (if applicable)	Spatial resolution	Source
	The Turks and Caicos Islands shorebird counts from 2016 to 2020	Could provide abundance, location data on the presence of 58 shorebird species, and areas requiring further surveying.	NA	50m	US Fish and Wildlife Service
	Occurrence records from the GBIF database	Provides occurrence data on selected taxa for TCI.	NA	NA	Global Biodiversity Information Facility (GBIF)
	REEF Tropical Western Atlantic database	Could provide environmental and biological information on species abundance, density, etc.	Presence/ Absence, Abundance, Density, Sighting Frequency	NA	REEF
Vulnerable areas	Threat to reefs: Integrated	Could identify high risk areas where indicators will need to be applied/monitoring could be focused. Could provide indication of potential human activities.	Very high, High, Medium, Low	500m	WRI
	Threat to reefs: Coastal development	Could identify high risk areas where indicators will need to be applied/monitoring could be focused. Could provide indication of potential human activities.	High, Medium, Low	500m	WRI
	Threat to reefs: Marine Pollution	Could identify high risk areas where indicators will need to be applied/monitoring could be focused. Could provide indication of potential human activities.	High, Medium, Low	500m	WRI
	Threat to reefs: Overfishing	Could identify high risk areas where indicators will need to be applied/monitoring could be focused. Could provide indication of potential human activities.	High, Medium, Low	500m	WRI
	Threat to reefs: Watershed Pollution	Could identify high risk areas where indicators will need to be applied/monitoring could be focused. Could provide indication of potential human activities.	High, Medium, Low	500m	WRI
Workshops	Marine activities	Could be used to identify human activities.	NA	Point data	DECR
	Main species	Could be used to identify presence of a species.	NA	NA	DECR

Area	Layers	Potential use for biodiversity indicators	Scale of data (if applicable)	Spatial resolution	Source
	Favourite places	Could add to mapping of potential human activities.	NA	NA	DECR
	Vulnerable places	Could identify high risk areas.	NA	NA	DECR
Human Activities	Dive locations	Probably of less use but could add to mapping of potential human activities.	<12 feet, 12-24 feet, 24 - 36 feet, >36 feet	Various	Turks and Caicos Reef Fund
	Swimming zones	Probably of less use but could add to mapping of potential human activities.	NA	Between 2 and 5m	DECR
	Mooring sites	Probably of less use but could add to mapping of potential human activities.	NA	High	Turks and Caicos Reef Fund
	Kitesurfing locations	Probably of less use but could add to mapping of potential human activities.	NA	Approximate	Various internet sources and local knowledge
	Snorkelling locations	Probably of less use but could add to mapping of potential human activities.	NA	Approximate	Various internet sources and local knowledge
	Hobie Cat rentals	Probably of less use but could add to mapping of potential human activities.	NA	High	Field survey
	Parasailing in Providenciales	Probably of less use but could add to mapping of potential human activities.	NA	Approximate	Field surveys, various internet sources and local knowledge
	Cultural use of coastal ecosystems	Could be used to provide cultural links with ecosystem services, and also human activity information.	NA	High	Online and telephone surveys conducted by DECR and EFTEC

Area	Layers	Potential use for biodiversity indicators	Scale of data (if applicable)	Spatial resolution	Source
Habitats	The Turks and Caicos benthic habitat map	Could be useful for reference for extent of habitats and for mapping change.	Habitat	4m	TNC
	Coral Reef distribution	Could be useful for mapping any change in the extent of habitats.	NA	30m	UNEP-WCMC
	Seagrass distribution	Could be useful for mapping any change in the extent of habitats.	NA	30m	UNEP-WCMC
	Mangroves distribution	Could be useful for mapping any change in the extent of habitats.	NA	30m	UNEP-WCMC
	Coastal Habitats	Could be useful for mapping any change in the extent of habitats.	Beach, salt marsh, mangrove, sand, rock/sand, rock	Between 2 and 10 meters	UNEP-WCMC
Geographic	Grid 1km x 1km	Could be useful background data for mapping purposes.	NA	NA	TCI
	Maritime borders	Could be useful background data for mapping purposes.	12-mile limit, 200 mile fishing limit, etc.	Between 2 and 10 meters	TCI
	Turks and Caicos Reef Bank	Could be useful background data for mapping purposes.	NA	10m	DECR
	Bathymetry contours	Could be useful background data for mapping purposes.	NA	NA	General Bathymetric Chart of the Oceans
	Inland waters	Could be useful background data for mapping purposes.	NA	1-2m	DECR
	The Turks and Caicos Islands digital elevation model	Could be useful background data for mapping purposes.	NA	10m	DECR
	Seabed morphology worldwide	Could be useful background data for mapping purposes.	29 categories of geomorphic features	10km	Blue Habitats (SRTM)

Area	Layers	Potential use for biodiversity indicators	Scale of data (if applicable)	Spatial resolution	Source
	Satellite-derived bathymetry (SDB) for the Turks and Caicos shallow water areas	Could be useful background data for mapping purposes.	NA	10m	DECR
Climate	Monthly average daytime sea surface temperatures (SST)	Could be useful for mapping impact of SST on corals.	Divided into months and temperature categories.	100m	MODIS-Aqua, DECR
	Monthly average night-time SST	Could be useful for mapping impact of SST on corals.	Divided into months and temperature categories.	100m	MODIS-Aqua, DECR

3.2. Shortlisting indicators for development

When deciding on an appropriate indicator that's fit-for-purpose, selection can take several approaches. Typically, a goal or area of interest is identified, after which a suitable indicator is found that is feasible and appropriate for the intended purpose. In cases of severe data limitation, it may be wiser to select an indicator based on available data. Additionally, in the absence of a comprehensive local monitoring programme, the use of global data can be explored.

Through correspondence with DECR, priorities for future monitoring have been identified, which include habitat loss, tourism, fisheries, and corals (particularly coral health). Therefore, an indicator shortlist including a variety of metrics will allow DECR to identify which options best fulfil their needs, after which a pilot study can be conducted to ensure the appropriate data is available or can be realistically collected in the future.

TCI is not a signatory to some of the Multilateral Environmental Agreements such as the Convention on Biological Diversity or the Cartagena Convention SPAW protocol, so these conventions are not direct policy drivers for monitoring changes in TCI's marine-coastal natural capital. However, this review is looking at the use of existing or proposed methods, so the approaches of these conventions may be useful for DECR to consider, it is not making the assumption that TCI might be part of RSC or CBD in the future.

Listed below are a broad range of metrics that could potentially be used to monitor changes in TCI's marine-coastal natural capital. The shortlist is wide-ranging because a single 'out of the box' indicator has not been identified due to a lack of available data from a comprehensive national monitoring programme. Although it should be noted that several baseline assessments of marine biodiversity in TCI have been conducted by TC Reef and AGRRA (Hoshino *et al.* 2008; Riegl *et al.* 2003). The shortlist includes biological metrics such as coral reef health, socio-economic parameters such as fishing infrastructure, and global indicators such as trends in mangrove extent. These metrics are based on those used for the Convention on Biological Diversity (CBD), and by one of the partnerships formed at the first CBD conference of parties the International Coral Reef Initiative (ICRI). To support ICRI's work to preserve coral reef ecosystems around the world the Global Coral Reef Monitoring Network (GCRMN) was established, with regional hubs to gather scientific information on the status and trends of coral reef ecosystems.

Metrics used by the ICRI through GCRMN may contribute to Convention on Biological Diversity (CBD) indicators, so the ability for DECR to align indicator work with CBD would be extremely beneficial, as would alignment with ICRI's GCRMN-Caribbean hub's integrated coral reef metrics. GCRMN metrics include both ecological and pressure metrics that have natural capital applicability. However, some would require data collection and therefore would require resourcing. GCRMN regional network in the Wider Caribbean 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 pressures sources on Caribbean reefs.

3.2.1. Global Coral Reef Monitoring Network - Caribbean metrics

Five relevant socio-economic parameters have been identified (Table 3.5) that relate to tourism and fishing pressure. Data for drivers of pressure on TCI reefs could be collected from existing information held by government departments or primary data collection maybe required. For full indicator details see: https://gcrmn.net/wp-content/uploads/2019/08/GCRMN-caribbean-guidelines-for-integrated-coral-reef-monitoring.pdf

Table 3.5: GCRMN-Caribbean socio-economic parameters.

Parameter	Type	Description
Tourism Arrivals	Pressure	This parameter can be used as a proxy of reef pressure, including data on national tourism statistics, annual hotel occupancy and cruise ship arrival statistics.
Tourism Recreation	Pressure	This parameter provides information on reef related pressures, including data on the number of operators and when and where their activity occurs.
Tourism Infrastructure	Pressure	This parameter can also be used as a proxy for reef pressure. Data includes the collection of statistics on number, size, and location of tourism establishments such as hotels.
Fishing Infrastructure	Pressure	This parameter links to fishing activities and pressures on the reef. Data includes national fishing statistics such as vessel data, and field sampling at landing sites and markets.
Fishing Pressure	Pressure	This parameter links to the level of fishing activity at specific landing sites. Data includes fisheries statistics and information on exports. Can be correlated with ecological data (below) to confirm presence/absence of indicator species.

Data for the Tourism Arrivals, Recreation, and Infrastructure parameters could be available as national tourist statistics from the TCIs tourist board and port authorities, but the availability will need to be investigated. As will the availability of fishing data for the Fishing Infrastructure and Fishing Pressure parameters. The GCRMN-Caribbean integrated coral reef monitoring guidelines also includes agriculture, pollution and land use pressure-based parameters that may also be relevant to TCIG.

In terms of global pressure data that could be used for indicator development, fishing and tourism data is available through global coral reef threat data from the World Resources Institute and the Marine Trophic Index from Sea Around Us, also global SST data is available from NOAA Coral Reef Watch, but these sources are not feeding into GCRMN-Caribbean indicators at present.

GCRMN-Caribbean also has guidelines on monitoring coral reefs using biological metrics. These metrics involve direct data collection, however some data may be available through efforts of local NGOs such as TC Reef Fund through the BEST 2.0 Programme to survey East Caicos, and the School for Field Studies, if following Reef Check methods.

UNEP Caribbean Environment Programme works with GCRMN through the Specially Protected Areas and Wildlife Protocols to monitor coral reef habitats. GCRMN-Caribbean partners have agreed that there is great value in coordinating and standardizing future monitoring efforts. Additionally, the work feeds into CBD reporting with indicators such as Live Coral Cover.

For monitoring to partner with GCRMN-Caribbean, locations with between 5-100km of coastline need to be defined. A GCRMN-Caribbean technical committee is available to assist with site selection. The unit of replication within the location is called a site and this is the monitoring station, e.g., a dive site. Twenty random sites per location are recommended with monitoring at depths of 8-18m in the zone of most reef development once every two years.

Descriptions of the GCRMN-Caribbean biological metrics are included in Table 3.6, with more detail available at https://www.icriforum.org/wp-content/uploads/2020/05/GCRMN-Caribbean_Guidelines.UNEP(DEPI)CAR_WG38.INF17-en.pdf

Table 3.6: GCRMN-Caribbean biological metrics.

Metric	Type	Description
Relative cover of reef-building organisms and their dominant competitors	State	The Live Coral Cover component is a Biodiversity Indicators Partnership (BIP) indicator with data available from the GCRMN 2020 report. Global baselines are also available for the fleshy algae cover part of this metric and will be updated from 2020 onwards. 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 0.9m x 0.6m 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.
Coral Health	Pressure	Priority metric as Stony Coral Tissue Loss Disease has been observed in TCI. Efforts have been made by DECR, JNCC and experts to mitigate against this to promote disaster resilience. This metric assesses the of 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 10m belt transect using AGRRA methods.
Coral Recruitment	State	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 – 4cm. Follows AGGRA methodology using 25cm x 25cm 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.

Metric	Type	Description
Cover of key macro-invertebrate species	State	Global baselines are available for the cover of key benthic groups part of this metric and will be updated from 2020 onwards. 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 (0.54m^2).
Abundance and biomass of key reef fish taxa	State	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 transects of 30m x 2m lasting 8 – 12 minutes each are pooled at each site.

Working towards the GCRMN-Caribbean metrics described would be beneficial on several levels. Including, potentially contributing to international reporting such as CBD and GCRMN global assessments and increasing TCI engagement with GCRMN-Caribbean. Furthermore, the GCRMN-Caribbean hub is coordinated by the UN Caribbean Environmental Programme, which forms the programmatic framework for the Cartagena Convention, through its Specially Protected Areas and Wildlife (SPAW) Protocol. The SPAW Sub-Programme has published a “Regional Strategy and Action Plan for the Valuation, Protection and/or Restoration of Key Marine Habitats in the Wider Caribbean 2021-2030” to support conservation and sustainable use of coastal and marine ecosystems in the wider Caribbean (UNEP-CEP 2020). The Regional Strategy and Action Plan includes a framework for implementation of four goals and ten objectives, each with indicators and targets (Table 3.7). The goals and objectives are relevant to a range of Multilateral Environmental Agreement targets, including the CBD Aichi Targets, and may be further refined as part of a monitoring and evaluation framework to address the CBD Post-2020 Global Biodiversity Framework. Potentially useful response-based indicators relating to coral reef, mangrove and seagrass habitats and MPAs include:

- coverage by zoning schemes or other formal conservation/protection mechanisms for important coral reef, mangrove, and seagrass sites;
- restoration activities undertaken at priority sites for coral reefs, mangroves, and seagrasses;
- area of seagrass, mangrove and coral reef with enhanced ecological integrity and function;
- area of coral reefs, mangroves and seagrasses benefitting from threat reduction initiatives;
- Regional Strategy and Action Plan baseline data and end line assessment conducted on extent and location of coral reefs, mangroves and seagrasses;
- uptake of disease monitoring and management protocols by MPAs;
- number of new sites with habitats of outstanding ecological value listed under the SPAW Protocol, Article 7;

- number of SPAW-listed sites approved prior to 2019 with completed management effectiveness evaluations.

Table 3.7: UN Caribbean Environment Programme Regional Strategy and Action Plan Goals and Objectives.

Goal	Objective
1. Improve ecosystem health, biodiversity and resilience	Enhance ecological integrity and function of coral reefs, mangroves, and seagrass beds
	Decrease and reverse habitat loss
	Support species diversity and species populations within the three habitats
2. Sustainably use coastal and nearshore marine resources for national and regional development	Mainstream coral reefs, mangroves, seagrasses, and associated sub-ecosystems and essential species in sectoral, national and regional policies and plans as well as national budgets, accounting and reporting systems
	Reduce threats to the habitats from coastal/marine-based sectors and development activities that impact coral reefs, mangroves and seagrasses
3. Strengthen regional governance systems and partnerships for the management of the marine/coastal resources of the wider Caribbean	Enhance coordination and reduce conflicts and gaps to improve programme synergies
	Improve governance of marine and coastal resources at national, sub-regional and regional levels
4. Strengthen legal and institutional frameworks to effectively manage the marine/coastal resources of the wider Caribbean	Improve science-based decision-making and use of local/traditional knowledge in policy, planning, and management of coastal ecosystems
	Improve the effectiveness of resource and protected area management institutions and the impact of management interventions
	Enhance the sustainability of financing mechanisms for protected areas and other site-based conservation efforts

3.2.2. Convention on Biological Diversity indicators

Given the need for data to be collected for some of the GCRMN-Caribbean metrics listed above, those with an existing data set may be more appropriate to TCI at this time. Global indicators that are potentially suitable for TCI would look to address DECRs priorities of habitat loss, fishing, tourism, and coral reef health. Table 3.8 lists indicators that are operational or under development and have either been proposed for previous Aichi Target reporting or may contribute to the CBD post 2020 Global Biodiversity Framework. Some of these indicators benefit from being part of a framework where they relate to goals and targets, and often have time series data available. Many of the indicators global data sets can also be used at the national level so would be suitable for inclusion in the TCI Environment Strategy, particularly because they would be very appropriate for natural capital assessments. Additionally, several are linked to the Biodiversity Indicator Partnership so have prescriptive methodologies and have been peer reviewed, such as Live Coral Cover. Please note that the list of indicators in Table 3.8 may change following CBD discussions.

Table 3.8: Indicators that potentially contribute to the Convention on Biological Diversity.

Indicator	Type	Organisation	Description
Live Coral Cover*	State	GCRMN	The primary indicator recommended for assessing reef health by the Biodiversity Indicators Partnership (BIP): https://www.bipindicators.net/indicators/live-coral-cover Data available on request from the 1970s for the Caribbean region, with updated data available from the GCRMN 2020 report.
Coral Reef Extent	State	Allen Coral Atlas	Remote sensing-based indicator that can detect coral reef extent. Being developed in conjunction with GCRMN and ICRI.
Global Coral Reef Extent*	State	UNEP-WCMC, WorldFish Centre, WRI, TNC and partners	The UNEP-WCMC data is available through the TCI MSP portal: https://data.unep-wcmc.org/datasets/1 A freely available single year global coral reef dataset, however, ICRI state this is likely to be superseded by the Allen Coral Atlas Coral Reef Extent Indicator.
Global Seagrass Extent*	State	UNEP-WCMC	The UNEP-WCMC data is available through the TCI MSP portal: https://data.unep-wcmc.org/datasets/7 National data is aggregated for global use.
Global Saltmarsh Extent	State	UNEP-WCMC	The UNEP-WCMC data is available through the TCI MSP portal: https://data.unep-wcmc.org/datasets/43 National data is aggregated for global use.
Trends in mangrove extent*	State	Global Mangrove Watch	Data available on TCI MSP data portal from Global Mangrove Watch: https://data.unep-wcmc.org/datasets/45 Global data can be disaggregated for national use. Contributes to Sustainable Development Goal Indicator 6.6.1 Change in the extent of water related ecosystems over time.
Continuous Global Mangrove Forest Cover*	State	Salisbury University	Global canopy cover data that can be disaggregated for national use. Trend from 2000-2014 available. BIP indicator with data freely available at: https://www.bipindicators.net/indicators/cgmfc-21-continuous-global-mangrove-forest-cover-for-the-21st-century
Protected Area Coverage*	Response	World Database of Protected Areas – UNEP-WCMC, IUCN, WCPA	BIP indicator with national data freely available: https://www.bipindicators.net/indicators/coverage-of-protected-areas-terrestrial-and-marine National data available for TCI: https://www.protectedplanet.net/country/TCA

Indicator	Type	Organisation	Description
Protected Area management effectiveness*	Response	World Database of Protected Areas – UNEP-WCMC	Addresses CBD Goal A component – protection of critical ecosystems National data on number of PAME evaluations conducted are available for TCI: https://www.protectedplanet.net/country/TCA
Coverage of other area based effective conservation measures*	Response	World Database of Protected Areas – UNEP-WCMC	Addresses CBD Goal A component – protection of critical ecosystems National data available for TCI: https://www.protectedplanet.net/country/TCA
Protected Area Coverage of Key Biodiversity Areas*	Response	BirdLife International, UNEP-WCMC & IUCN	BIP indicator: https://www.bipindicators.net/indicators/protected-area-coverage-of-key-biodiversity-areas Data for TCI available from: http://www.keybiodiversityareas.org/kba-data
Percentage of coral reefs included in effectively managed MPAs and OECMs	Response	CBD, ICRI and GRMN indicator	Under development for 2021. Could calculate from UNEP-WCMC data on TCI portal, also for seagrass, mangroves and saltmarsh.
Red List Index (reef-building corals and coral species)	Pressure	IUCN	BIP indicator, but would need development for reef building corals: https://www.bipindicators.net/indicators/red-list-index/red-list-index-reef-building-corals
Ocean Health Index	PSR	Conservation International	Annually updated data is available for TCI on a range of natural capital related themes: http://www.oceanhealthindex.org/region-scores
Marine Trophic Index	Pressure	Sea Around Us	BIP indicator: https://www.bipindicators.net/indicators/marine-trophic-index National data for TCI is available
Reef Fish Thermal Index	State	Reef Life Survey	BIP indicator: https://www.bipindicators.net/indicators/reef-fish-thermal-index Would require data collection
Large Reef Fish Index	State	Reef Life Survey	Data available from the Global Biodiversity Information Facility: https://www.gbif.org/dataset/38f06820-08c5-42b2-94f6-47cc3e83a54a
Index of Costal Eutrophication	Pressure	UNEP	Based on SDG indicator 14.1.1. measuring loads and ratios of nitrogen, phosphorous and silica delivered by rivers to coastal waters. Recommended by ICRI for CBD.

Indicator	Type	Organisation	Description
Structural Complexity – coral		WCS	Under development
Carbonate budgets – coral		University of Exeter	Under development
Condition of intertidal seagrass communities in coastal waters	State	EA	UK Marine Strategy Indicator: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/benthic-habitats/intertidal-seagrass/
Potential Physical Loss of Predicted Seafloor habitats	State	JNCC	UK Marine Strategy Indicator: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/benthic-habitats/physical-loss/
Extent of Physical Damage Indicator to Predominant Seafloor Habitats	State	JNCC	UK Marine Strategy Indicator: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/benthic-habitats/physical-damage/
Index of Coastal Eutrophication	Pressure	ICRI	International Coral Reef Initiative recommended indicator: https://www.icriforum.org/faqs/
Red list Index of ecosystems	Pressure	IUCN	International Coral Reef Initiative recommended indicator: https://www.icriforum.org/faqs/

* Indicators starred include those that have data available for TCI at this time.

3.2.3. Regional Sea Conventions core indicator set

In addition to the Cartagena Convention indicators in Table 3.7. The UN Regional Sea Conventions (RSCs) have a core indicator set (Table 3.9). These indicators are also relevant because the RSCs are the main legal frameworks for protecting marine and coastal environment at the regional level.

Table 3.9: Regional Seas Conventions core indicator set. (https://www.unenvironment.org/resources/report/regional-seas-core-indicators-set)

Number	Category	Indicator	Type
1	Total inputs of nitrogen and phosphorus from agriculture, sewage and atmospheric nitrogen	Chlorophyll a concentration as an indicator of phytoplankton biomass	State
2	Inputs of marine chemical pollution Trends for selected priority chemicals	Trends for selected priority chemicals including POPs and heavy metals	Pressure

Number	Category	Indicator	Type
3	Overall levels of marine litter and quantification of beach litter items	Quantification and classification of beach litter items	Pressure
4	Ocean warming	Annual mean sea surface temperature (25m below the surface)* Data potentially available on TCI MSP tool and NOAA Reef Coral Watch	Pressure
5	Fish landings	Fish catches within EEZs (tonnes) – total capture production	Pressure
6	Aquaculture	Application of risk assessment to account for pollution and biodiversity impacts	Response
7	Aquaculture	Destruction of habitat due to aquaculture	Pressure
8	Population pressure / urbanization	Length of coastal modification and area of coastal reclamation (km^2)	Pressure
9	Eutrophication status	Location and frequency of algal blooms reported	Pressure
10	Pollution hot spots	(1) Concentration of Status of selected pollutant contamination in biota and sediments and temporal trends; (2) Number of hotspots	Pressure
11	Ocean acidification	(1) Aragonite saturation; (2) pH; (3) Alkalinity	Pressure
12	Level of exploitation of commercial fisheries	(1) FAO stock status; (2) % stock overfished compared to MSY	Pressure
13	Species replacement as a consequence of capture fisheries	Marine Trophic Index*	Pressure
14	Endangered species	Distribution of Red List Index Species* Data available on OBIS	Pressure
15	Loss of critical habitat	Trends in critical habitat extent and condition	State
16	National Action Plans to reduce input from Land Based Sources	National Action Plans to reduce input from LBS: Percentage (%) of national action plans ratified or operational	Response
17	Wastewater treatment facilities	(1) Percentage (%) of coastal urban population connected to sewage facilities; (2) percentage (%) of wastewater facilities complying with adequate standards; (3) percentage (%) of untreated wastewater	Pressure

Number	Category	Indicator	Type
18	Incentive to reduce marine litter at source	(1) Percentage (%) of available port waste reception facilities; (2) incentives to reduce land-based sources in monetary terms; (3) Percentage (%) of recycled waste on land	Pressure
19	Climate change adaptation	(1) Percentage (%) of national adaptation plans in place; (2) Sector based national adaptation plans; (3) Number of existing national and local coastal and marine plans incorporating climate change adaptation	Response
20	Fish harvested within safe ecological limits	Fisheries measures (by-catch limits, area-based closures, recovery plans, capacity reduction measures) and multilateral / bilateral arrangements for fisheries management are in place	Pressure
21	Critical marine habitat under protection	% Marine protected areas designated* Data available from Protected Planet	Response
22	National ICZM in place	National ICZM guidelines and enabling legislation are adopted	Response

***** Indicators starred include those that have data available for TCI at this time.

The last indicator to consider is the Defra 25 Year Environment Plan K4 indicator - extent and condition of terrestrial and marine protected areas in the UK Overseas Territories. However, this indicator is currently under development, so will only be useful if completed before the end of this project.

4 Conclusions and next steps

4.1 Indicator development

There are many different indicator types, each of which have different data requirements. As well as exploring existing local data resources, we have looked at regional and global data sources which could be of use, or adapted, to be applicable to local features and resources.

We have identified some potential indicators to monitor changes in TCI's marine-coastal natural capital. In developing any indicator, several considerations need to be taken into account, including, data availability, the applicability of the indicator for its intended use, adaptability of the indicator to other purposes, time requirements taken to run the indicator, and complexity of any indicator method (Teixeira *et al*. 2016).

One area which requires further exploration is the intended end use of the indicators and how any indicator will fit with the TCI Government Environment Strategy. This will set out the requirements and prioritisation for condition indicators, in terms of biological scope and purpose.

One of the key gaps that we have identified through the literature review is data availability, particularly the limited amount of monitoring data. This will restrict the type of indicator which can be developed. The MSP toolkit and datasets provides useful information which could feed into an indicator. Although they all have various levels of accessibility, local, regional, and global data could also be used.

One important aspect would be to identify cost-effective ways of assessing ecological status that can, ideally, be used for multiple purposes. This is particularly important where there are limited resources. It is for this reason that we have outlined CBD indicators and GCRMN metrics which could be of use to TCI.

Certain adaptations to the indicators could be made to increase their applicability for other uses. For example, if social indicators are of interest then there are certain steps that can be taken to increase their applicability to determining ecological condition. For example, rather than a straightforward measure of the number of tourists, spatial information on tourism activities would be helpful, as this could help to determine if certain sensitive habitats might be impacted.

A fully operational indicator may take some time to develop. Next steps include further correspondence with DECR to discuss key priorities, select indicator frameworks or approaches for development and determine a plan for development of the indicators.

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