

Aggregate Biophysical Indicators of Environmental State

Provides guidance on deriving aggregate biophysical indicators of environmental state from ocean accounts.

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Last updated September 2026 **Responsible officer** Dr Jordan Gacutan

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ABOUT THIS GUIDANCE

RECOMMENDED CITATION

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Sections 3.4 and 3.6 are normative for the publication. Every condition indicator in the Technical Guidance, including those in Section 1 decision circulars and Section 6 thematic circulars, is derived using the transformation in Section 3.4.1 – with its inverse-polarity variant and, for pH and other logarithmic-scale variables, the categorical step deduction set out there – and aggregated using the methods and defaults in Section 3.6. Section 3.6.2 additionally specifies how a condition trajectory is projected under a management scenario, which planning and appraisal circulars rely on for scenario comparison. The guidance enables compilers to produce policy-relevant summary statistics from detailed ocean accounts whilst maintaining the transparency and traceability essential for scientific credibility.

Aggregate biophysical indicators support a range of decision use cases for governments managing ocean resources:

MPA effectiveness monitoring: Indicators derived from extent and condition accounts enable tracking of whether marine protected areas are achieving their conservation objectives – see [TG-1.3 OA and Marine Spatial Management](#).

SDG 14 reporting: Extent indicators align directly with SDG indicator 14.5.1 (marine protected area coverage), whilst condition indicators support assessment of SDG target 14.2 on sustainable management and protection of marine and coastal ecosystems.

Ocean health report cards: Composite condition indices aggregated across multiple ecosystem types produce summary scores suitable for public communication through ocean health scorecards and state-of-environment reports.

Fisheries management thresholds: Condition indicators for fish nursery habitats (coral reefs, seagrass meadows, mangroves) inform spatial management decisions in fisheries – see [TG-1.5 OA and Fisheries Management](#).

1. Outcome

¶1 This Circular provides guidance on deriving aggregate biophysical indicators of environmental state from ocean accounts. Aggregate indicators synthesise complex, multi-dimensional information about marine and coastal ecosystem condition into accessible summary measures that support policy communication, tracking of conservation targets, and comparison across spatial units and time periods. Building on the ecosystem condition accounting framework established in **TG-3.1 Asset Accounts**, this Circular explains the conceptual and methodological foundations for constructing extent-based indicators, condition-based indicators, and composite indices for marine ecosystems. Readers will understand the indicator hierarchy from raw condition variables through normalised indicators to aggregate condition indices, the role of reference conditions in indicator derivation, and the specific applications and limitations of aggregate indicators for ocean accounting.

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¶7 **Fisheries management thresholds:** Condition indicators for fish nursery habitats (coral reefs, seagrass meadows, mangroves) inform spatial management decisions in fisheries – see **TG-1.5 OA and Fisheries Management**.

2. Requirements

¶1 This Circular requires familiarity with:

- ¶2 **TG-0.1 General Introduction to Ocean Accounts** – for the conceptual framework and key components of Ocean Accounts
- ¶3 **TG-0.2 Overview of Relevant Statistical Standards** – for the methodological foundations provided by SNA 2025, SEEA CF, and SEEA EA
- ¶4 **TG-3.1 Asset Accounts** – for the structure of ecosystem extent and condition accounts from which indicators are derived. The underlying methodology follows SEEA Ecosystem Accounting (2021), Chapter 5

- ¶5 **TG-0.7 Quality Assurance** – for quality management principles that apply to indicator construction, including uncertainty documentation and fitness-for-purpose assessment

3. Guidance Material

¶1 Within the ocean accounting system, information products are organised in a hierarchical structure sometimes described as an information pyramid¹. At the base of this pyramid sit data and statistics: the raw observations from monitoring networks, surveys, and remote sensing platforms. Accounts occupy an intermediate level, organising data according to internationally agreed classifications and accounting rules. From these accounts, indicators are derived as summary measures that distil complex accounting information into policy-relevant signals. Key indicators at the apex aggregate further to support strategic analysis.

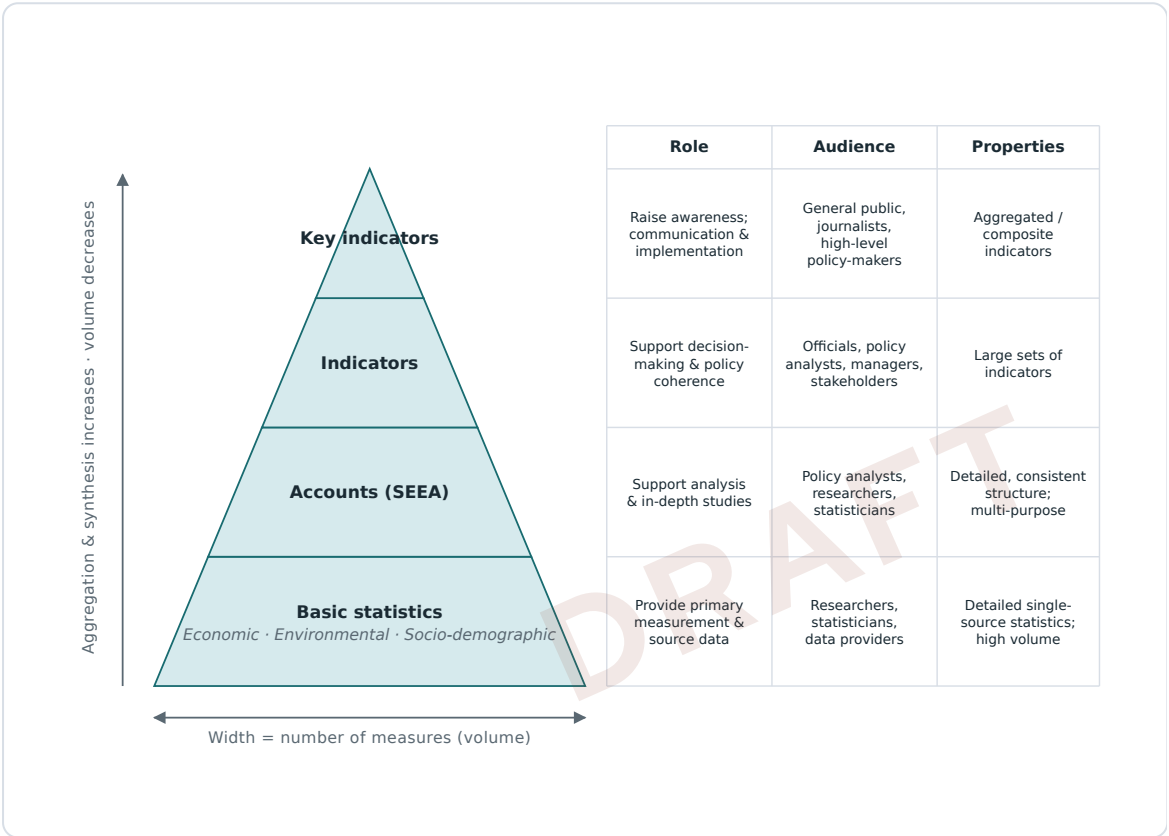


Figure 2.1.1 The information pyramid condenses basic statistics through SEEA accounts into fewer, higher-value indicators for progressively higher-level audiences. Height encodes aggregation; width encodes volume of statistics versus composite key indicators.

Source: SEEA EA 2024, Figure 14.1.

Adapted from: SEEA EA 2024, Figure 14.1 (information pyramid); redrawn in the GOAP figure palette with role / audience / properties tiers.

¶2 Indicators compiled from accounts are more comparable across space and time than indicators taken directly from raw data, as the accounting process applies standardised classifications, reference conditions, and valuation rules that harmonise otherwise disparate data streams. TG-2.1 addresses the derivation of aggregate biophysical indicators (the upper layers of the information pyramid), whilst the construction of the accounts is addressed in the TG-3.x series (particularly **TG-3.1 Asset Accounts**), and data production methods in the TG-4.x series.

¶3 Ecosystem condition accounts compile detailed information on the biophysical characteristics of ecosystems that serve as the ‘data foundation’ for aggregate indicators². See **TG-3.2 Flows from Environment to Economy** for full account structure and compilation procedure³. SEEA

Ecosystem Accounting establishes a three-stage hierarchical approach to ecosystem condition measurement⁴. The first stage records ecosystem condition variables: the raw observations of ecosystem characteristics in their original measurement units. The second stage derives ecosystem condition indicators by normalising variables against reference levels, creating comparable measures on a common scale. The third stage involves optional aggregation into ecosystem condition indices, which combine multiple indicators into summary measures for communication purposes. This Circular focuses primarily on the second and third stages, and provides guidance on deriving indicators and indices for marine and coastal ecosystems within the ocean accounting framework. This Circular supports the indicator derivation and presentation guidance in **TG-1.3 OA and Marine Spatial Management** and **TG-1.5 OA and Fisheries Management**.

3.1 Indicator Framework

¶1 The indicator framework for ocean accounting connects raw biophysical data to policy-relevant summary statistics through a systematic process of classification, normalisation, and aggregation.

3.1.1 Types of biophysical indicators

¶1 Biophysical indicators in ocean accounting fall into three broad categories based on what they measure:

¶2 **Extent indicators** measure the spatial coverage of marine ecosystem types, expressed in units of area (hectares, square kilometres) or, for certain ecosystems, length (kilometres of coastline) or volume (cubic kilometres of water column)⁵. Extent indicators include total area of ecosystem types, changes in extent over time, and proportional coverage within accounting areas. Key examples for marine ecosystems include coral reef area, seagrass meadow extent, mangrove forest coverage, and kelp forest distribution.

¶3 **Condition indicators** measure the health and integrity of ecosystems relative to a reference state, typically expressed as dimensionless indices on a standardised scale (commonly 0–1 or 0–100)⁶. Condition indicators are derived from raw condition variables through normalisation against reference levels. The SEEA Ecosystem Condition Typology (ECT) organises condition characteristics into six classes⁷. Table 1 below summarises these classes with marine-specific examples and typical data sources:

ECT Class	Description	Marine Examples	Data Sources
A1 Physical state	Abiotic physical characteristics	Sea temperature, pH, depth	Remote sensing, buoys
A2 Chemical state	Abiotic chemical characteristics	Dissolved O ₂ , nutrients, salinity	Water sampling
B1 Compositional state	Biotic diversity and composition	Species richness, community structure	Surveys, eDNA
B2 Structural state	Biotic physical architecture	Coral cover, canopy height, biomass	Remote sensing, transects
B3 Functional state	Ecosystem processes	Primary productivity, recruitment	Modelling, sampling
C Landscape context	Spatial configuration	Fragmentation, connectivity	GIS analysis

¶4 **Combined extent-condition indicators** integrate information on both the area and quality of ecosystems to give measures of effective ecosystem capacity. These include weighted indices where condition scores modify extent values, and functional capacity measures that combine area with condition-dependent service delivery potential⁸. For example, an “effective coral reef area” indicator might weight reef extent by a condition index. The resulting single measure captures both spatial coverage and ecological quality.

¶5 Combined extent-condition indicators represent an active area of methodological development for ocean accounting. Whilst SEEA EA does not prescribe a single approach, the combination of extent and condition information addresses a policy need: distinguishing between situations where a large area of ecosystem exists in degraded condition versus a smaller area in good condition. Compilers should present combined indicators alongside their disaggregated components, so that users can identify whether changes in the combined measure are driven by extent loss, condition decline, or both.

3.1.2 Relationship to accounts

¶1 Biophysical indicators derive from and remain linked to the underlying accounting tables. That link ensures that aggregate indicators can be traced back to their component data, which supports verification and allows users to investigate the drivers of observed changes.

¶2 Figure 2.1.2 shows the general ecosystem accounting framework (adapted from 2025 SNA Figure 35.2)⁹.

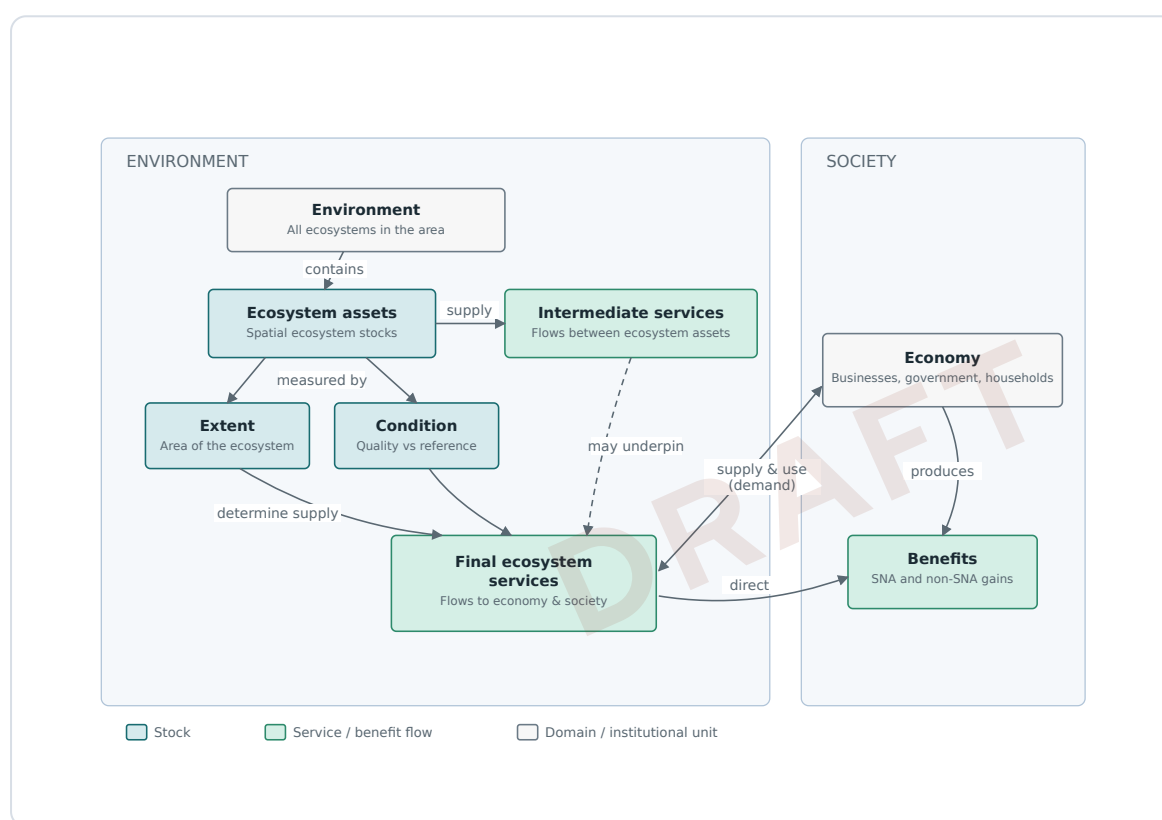


Figure 2.1.2 Ecosystem assets measured by extent and condition supply final ecosystem services to the economy and society. Intermediate services stay within the Environment. Nodes coloured by stock, flow, or institutional domain; economy nested within society.

¶3 The ecosystem condition variable account records raw observations of condition characteristics for each ecosystem type within the accounting area¹⁰. For example, a condition variable account for coral reef ecosystems might record coral cover percentage, fish biomass density, water temperature, and species richness. These values are recorded in their native measurement units (percentages, kg/hectare, degrees Celsius, species counts).

¶4 The ecosystem condition indicator account derives normalised indicators from variables by applying reference levels¹¹. The normalisation process transforms diverse measurement units into a common scale that enables comparison across characteristics and aggregation. A coral cover of 35% might become a condition indicator of 0.70 if the reference condition is 50% cover.

¶5 The ecosystem condition index aggregates individual indicators into composite measures for each ecosystem type, and potentially across ecosystem types for the entire accounting area¹². Compilers should document the aggregation method (arithmetic mean, geometric mean, weighted average, or another approach) together with its implications for the resulting index.

¶6 The methods for remote sensing and spatial data that underpin extent and condition measurement are addressed in **TG-4.1 Remote Sensing Data**, whilst **TG-4.2 Survey Methods** covers field survey approaches for condition variable collection.

3.1.3 Principles of indicator design

¶1 Effective biophysical indicators for ocean accounting should satisfy several design principles established in international statistical and scientific guidance¹³. Table 3.1.3 below summarises these principles.

Principle	Description
Relevance	Indicators should measure characteristics that are meaningful for ecosystem integrity and responsive to the pressures or management interventions of interest. For marine ecosystems, indicators should capture characteristics relevant to ocean-specific processes such as productivity, biodiversity, water quality, and habitat structure.
Scientific validity	Indicators should be based on sound scientific understanding of ecosystem function and established relationships between measured characteristics and ecosystem health. Where possible, indicators should align with validated assessment frameworks such as Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) ¹⁴ .
Measurability	Indicators should be based on data that can be collected consistently across space and time using available methods and resources. For many marine ecosystems, this implies prioritising indicators that can be derived from remote sensing, systematic surveys, or monitoring networks with established protocols.
Sensitivity	Indicators should be sensitive to changes in ecosystem state at policy-relevant timescales, neither so volatile as to reflect noise rather than signal, nor so stable as to miss important changes.
Comparability	Indicators should be constructed in ways that enable meaningful comparison across different areas, ecosystem types, and time periods. The use of common reference conditions and standardised normalisation approaches supports comparability.
Transparency	The methods for constructing indicators should be fully documented, enabling independent verification and facilitating understanding of what the indicator does and does not capture.
Uncertainty documentation	Indicators should be accompanied by information on the uncertainty associated with their values, including measurement uncertainty in the underlying data, model uncertainty in the normalisation process, and sensitivity to methodological choices such as reference condition selection and aggregation weights. The quality management principles in TG-0.7 Quality Assurance apply directly to indicator construction and should inform the documentation of confidence levels and data quality ratings for published indicators.

3.1.4 The normalised 0-1 condition index pattern

¶1 The normalisation of a raw condition variable against a reference level to produce a dimensionless score on a 0-1 scale is the standard biophysical-indicator pattern used throughout ocean accounting. Compilers should treat this pattern as the default form for any indicator derived from a condition variable, regardless of the ecosystem type, ECT class, or measurement units of the underlying observation.

¶2 The pattern has three conceptual components:

- ¶3 **A condition variable** measured in its native units (concentration, percentage cover, count, temperature, index, etc.).
- ¶4 **A reference level** that defines what the indicator is being compared against. The reference level is anchored at one end of the scale (the value corresponding to “reference condition” or good state) and bounded at the other end (the value corresponding to fully degraded condition). The choice of reference level is a separate methodological decision addressed in Section 3.4.2.
- ¶5 **A normalised indicator** expressed on a fixed 0–1 scale, where 1 represents the reference condition and 0 represents the fully degraded state. Values between 0 and 1 represent intermediate states, interpretable as the proportional distance from degraded to reference condition.

¶6 Adopting this pattern as the standard form for biophysical indicators delivers several benefits. It places indicators derived from different variables, ECT classes, and ecosystem types onto a common scale, so they can be presented side by side, compared across spatial units and time, and aggregated into composite indices without unit conversion. The empirical measurement (the variable) is held separate from the normative or scientific judgement embedded in the reference level, so both elements remain visible and revisable. Traceability from the headline indicator back to the underlying observation is preserved, because the variable value, reference level, and polarity assignment are all recorded explicitly in metadata. For downstream users (policy audiences, MPA managers, SDG reporters), the pattern fixes a consistent interpretive convention: a score closer to 1 always indicates better condition relative to the chosen reference, irrespective of which characteristic is being measured.

¶7 The pattern should be applied consistently across all condition-derived indicators in ocean accounts. Section 3.4.1 sets out the formula and parameters used to implement the pattern, including the treatment of variables with inverse polarity (where higher measured values indicate lower condition). Section 3.4.2 addresses the selection and documentation of reference levels. Section 3.4.3 addresses aggregation of normalised indicators into composite indices, which is only well-defined because all contributing indicators share the 0–1 scale established by this pattern.

¶8 Some indicators are not derived through normalisation against a reference level and should not be forced onto the 0–1 scale. These include extent indicators expressed in absolute area units, and stock status indicators expressed relative to fishery reference points (B/B_{MSY}, F/F_{MSY}). The pattern applies specifically to indicators derived from ecosystem condition variables as defined in the SEEA EA Ecosystem Condition Typology.

3.2 Compilation Procedure for Aggregate Indicators

¶1 This section outlines the step-by-step procedure for compiling aggregate biophysical indicators from ocean accounts.

¶2 All computed indicator values should be rounded to two decimal places using standard rounding (0.5 rounds up) and this convention applied consistently across all worked tables and published outputs.

Step 1: Identify indicator set and policy requirements

¶1 The compilation process begins with identifying which indicators are needed to serve the intended policy use cases. This involves reviewing policy commitments (SDG targets, national conservation strategies, MPA management plans) to determine reporting requirements, consulting with decision-makers and stakeholders to understand their information needs, and assessing data availability and quality to ensure feasibility.

¶2 For ocean accounting, priority indicator sets typically include those summarised in Table 3.2.1 below.

Indicator Set	Description
Extent change indicators	For ecosystem types covered by international targets (mangroves, coral reefs, seagrass meadows).
Condition indicators	Spanning all six ECT classes to provide full assessment coverage.
Combined extent-condition indicators	For ecosystems that deliver critical services (coastal protection, fish nursery habitat, carbon sequestration).
Headline composite indices	For high-level communication in state-of-environment reports and ocean health scorecards.

¶3 The selection process should be documented in a technical specification that records the rationale for each indicator, its intended use, and the accounts from which it will be derived.

Step 2: Source data from accounts

¶1 With the indicator set identified, the next step is to extract the required data from the underlying asset accounts compiled following **TG-3.1 Asset Accounts**. For extent indicators, this involves extracting opening and closing extent values from ecosystem extent accounts, calculating net change, and expressing change as both absolute values (hectares) and relative values (percentage change from opening extent).

¶2 For condition indicators, the process involves extracting condition variable values from condition variable accounts for opening and closing periods, retrieving reference condition values for each variable, and checking that measurement units are consistent across accounting periods. The data extraction should preserve links to the spatial units (ecosystem assets or BSUs) from which the data originate. These links enable disaggregated analysis when needed.

¶3 Data quality ratings from **TG-0.7 Quality Assurance** should be carried forward from the accounts to the indicators, documenting the fitness-for-purpose of the underlying data.

Step 3: Apply reference conditions

¶1 Reference conditions establish the benchmark against which current ecosystem state is measured¹⁵. For each condition variable, the compiler must:

1. ¶2 **Select the reference condition** from the SEEA EA framework in Section 3.4.2 – for a natural ecosystem, an undisturbed or minimally-disturbed, historical, least-disturbed or contemporary condition – and record it separately from the method used to estimate it
2. ¶3 **Justify the choice** based on data availability, scientific understanding, and policy requirements
3. ¶4 **Document the reference value** with its source and any assumptions
4. ¶5 **Establish polarity** (whether high measured values indicate high or low condition) following the polarity decision protocol described in Section 3.4.1

¶6 The strengths and limitations of each reference type for ocean accounting are summarised in Section 3.4.2. Climate-related considerations for reference condition selection are discussed in Section 3.4.2.

Step 4: Compute indicators

¶1 Normalise each variable using the min–max rescaling formula described in Section 3.4.1. The computation should be performed for each condition variable, for each ecosystem asset or spatial unit, and for both opening and closing accounting periods. The results populate the ecosystem condition indicator account, enabling comparison across variables, ecosystem types, and time periods.

Step 5: Validate indicators

¶1 Before aggregation, individual indicators should be validated to ensure they produce reasonable results. Validation checks include:

- ¶2 **Range check:** All indicator values should fall within [0, 1] unless deliberately allowed to exceed reference condition
- ¶3 **Consistency check:** Indicators derived from the same underlying process (e.g., coral cover and reef structural complexity) should show correlated patterns
- ¶4 **Sensitivity check:** Indicators should respond to known pressures or management interventions in expected directions
- ¶5 **Comparison with external assessments:** Where available, indicators should be compared with independent condition assessments from scientific literature or management reports

¶6 Indicators that fail validation checks should be investigated before aggregation. Common issues include incorrect reference condition selection, data entry errors, or inappropriate choice of variable for the ecosystem type.

Step 6: Aggregate into composite indices (optional)

¶1 Choose an aggregation method following the criteria in Section 3.4.3. The SEEA EA describes aggregation as optional but notes that composite indices are often required for policy communication¹⁶. Aggregation can occur at several levels: across indicators within the same ECT class (e.g., a composite structural state index for coral reefs), across all ECT classes for a single ecosystem type (e.g., an overall coral reef condition index), or across ecosystem types for the entire accounting area (e.g., a national marine ecosystem condition index). Higher levels of aggregation increase communication efficiency but reduce transparency and may mask critical thresholds in specific characteristics or ecosystem types.

Step 7: Disseminate with metadata

¶1 The final compilation step is to package indicators with full metadata and disseminate them to intended users. Table 3.2.2 below summarises the metadata elements that should accompany every published indicator.

Metadata Element	Description
Source accounts	Which extent and condition accounts provided the underlying data.
Reference conditions	What reference type and values were used for each variable.
Normalisation method	The formula and parameters used to transform variables to indicators.
Aggregation method	If composite indices were created, how indicators were weighted and combined.
Polarity decisions	The polarity assigned to each variable and the rationale, particularly for contextually ambiguous variables.
Spatial coverage	The proportion of the accounting area covered by observed versus imputed condition values, the imputation method applied, and whether a quality flag has been applied (see Section 3.6.1).
Uncertainty	Confidence intervals, data quality ratings, and sensitivity to methodological choices.
Limitations	What the indicator does and does not capture, and appropriate uses.

¶2 **Indicator versioning:** All published indicators must carry a version number and release date. When a revision is made, the nature of the revision must be classified as:

- ¶3 **Type 1** – data correction (source data corrected after publication)
- ¶4 **Type 2** – reference condition update (reference values revised following new scientific assessment)
- ¶5 **Type 3** – methodology change (normalisation formula, aggregation method, or classification scheme revised)

¶6 Revisions that affect trend direction or cross a policy threshold (for example, a change that moves MPA condition from above to below a management target) require a revision note in the metadata and back-casting of the affected time series. This revision classification approach follows standard national statistics revision policy and ensures that changes to published figures can be traced and explained¹³.

3.3 Extent-Based Indicators

¶1 Extent-based indicators measure the spatial dimension of marine ecosystems: where they are, how much area they cover, and how coverage is changing over time.

3.3.1 Ecosystem extent change

¶1 The primary extent indicator is change in ecosystem extent over the accounting period, measured in absolute terms (hectares gained or lost) or relative terms (percentage change from opening extent)¹⁷. For marine ecosystems, extent change indicators capture:

- ¶2 Loss of ecosystem area due to conversion, degradation, or sea-level change
- ¶3 Gain of ecosystem area due to expansion, restoration, or natural succession
- ¶4 Net change combining losses and gains

¶5 The SEEA EA recommends recording extent changes through a structured account that distinguishes managed and natural drivers of change¹⁸. The ecosystem extent account structure records opening extent, additions (managed expansion, natural expansion), reductions (managed reduction, natural reduction), and closing extent. This structure enables indicators to distinguish anthropogenic drivers (e.g., coastal development converting mangroves) from natural processes (e.g., storm damage to coral reefs).

¶6 For ocean accounting, priority extent indicators include:

Ecosystem Type	Indicator	Data Source
Coral reefs	Reef area (km ²) and change	Remote sensing, field surveys
Seagrass meadows	Meadow extent (ha) and change	Remote sensing, in situ mapping
Mangrove forests	Forest area (ha) and change	Satellite imagery, land cover mapping
Kelp forests	Canopy extent (ha) and change	Remote sensing, dive surveys
Salt marshes	Marsh area (ha) and change	Coastal mapping, remote sensing
Offshore waters	Area by water column depth zone	Bathymetry, oceanographic data

¶7 Thematic circulars provide detailed guidance on extent accounting for specific ecosystem types: **TG-6.1 Coral Reef Accounts**, **TG-6.2 Mangrove and Coastal Wetland Accounting**, **TG-6.3 Seagrass Accounts**, and **TG-6.5 Pelagic and Open Ocean Accounts**.

3.3.2 Ecosystem conversion

¶1 Beyond net extent change, conversion indicators track the transformation of one ecosystem type into another¹⁹. The ecosystem type change matrix records flows between ecosystem types, enabling construction of indicators such as:

- ¶2 Area of natural ecosystems converted to artificial or managed types (e.g., mangrove to aquaculture pond)
- ¶3 Area restored from degraded to natural condition
- ¶4 Area of coastal land converted to marine area (coastal erosion) or vice versa (land reclamation)

¶5 Conversion indicators are particularly important for understanding the drivers of extent change and the implications for ecosystem services. Conversion of mangroves to aquaculture ponds, for

example, involves loss of coastal protection and carbon storage services even if total coastal ecosystem extent is maintained through expansion elsewhere. These service implications are addressed in **TG-2.4 Ecosystem Goods and Services**.

¶6 The SEEA EA defines ecosystem conversion as occurring when “for a given location, there is a change in ecosystem type involving a distinct and persistent change in ecological structure, composition and function”²⁰. For marine ecosystems, determining when a change in condition constitutes conversion to a different ecosystem type (rather than degradation within the same type) requires careful application of this standard.

¶7 **Conversion versus degradation decision framework:** A compiler should assess conversion when condition evidence suggests a persistent change in ecological structure, composition, and function consistent with SEEA EA para 4.23, confirmed over at least two consecutive accounting periods. A change is considered distinct if it is assessed as not reversible within the normal accounting cycle, based on condition evidence documented in the ecosystem condition account. This determination cannot rest on a single condition metric or a fixed numerical threshold. Instead, the compiler must document the specific condition metric(s) and decision criterion used, drawing on local reference distributions or national ecological assessment standards. Any reclassification from degradation to conversion must be submitted to national technical committee approval before being recorded in the extent account. Guidance on marine ecosystem classification is provided in **TG-3.1 Asset Accounts** and **TG-0.2 Standards Overview**²¹.

3.3.3 Extent indicators for policy targets

¶1 Extent indicators align directly with international policy targets. SDG target 14.5 set a 2020 deadline for conserving at least 10% of coastal and marine areas, measured by indicator 14.5.1 (coverage of protected areas in relation to marine areas)²². The Kunming-Montreal Global Biodiversity Framework Target 3 has since set a more ambitious target of protecting at least 30% of marine areas by 2030²³. Extent accounts for marine protected areas, combined with condition accounts assessing protection effectiveness, provide the ‘data foundation’ for national reporting against these targets. The application of ocean accounts to MPA assessment is addressed in detail in **TG-1.3 OA and Marine Spatial Management**.

¶2 SDG 15.3.1 measures land degradation, including coastal areas, through an approach that integrates extent and condition information²⁴. This methodology could be extended to marine ecosystems as “ecosystem degradation neutrality” indicators – the degraded-area classification for GBF Target 2 in **TG-2.10** Section 3.3 is the nearest existing guidance for marine contexts.

3.4 Condition-Based Indicators

3.4.1 Deriving condition indicators from variables

¶1 **Reference condition parameters:** The following definitions apply throughout this section and in the normalisation formula:

- ¶2 **Reference condition** (general concept) – the benchmark state of the ecosystem used to contextualise current condition. For a natural ecosystem SEEA EA offers an undisturbed or minimally-disturbed, historical, least-disturbed or contemporary condition; anthropogenic ecosystems draw on a separate set ending in best-attainable condition (see Section 3.4.2, which is normative).
- ¶3 **U (upper reference value)** – the formula parameter representing good condition. This is the value of the condition variable associated with the chosen reference condition.
- ¶4 **L (lower reference value)** – the formula parameter representing degraded condition. This is the minimum acceptable or fully degraded value of the condition variable.

¶5 The transformation from condition variables to condition indicators involves normalisation against these reference levels. The SEEA EA describes a linear transformation approach²⁵:

¶6 **Indicator = (Variable value – L) / (U – L)**

¶7 Where U is the upper reference value (high condition) and L is the lower reference value (degraded condition). The resulting indicator takes values between 0 (fully degraded) and 1 (reference condition). Any reference type (natural, historical, policy target, or best observed) may serve as U, provided the compiler documents the choice in Step 7 metadata.

¶8 For some variables, high measured values indicate high condition (e.g., species richness, coral cover), whilst for others, high measured values indicate low condition (e.g., pollutant concentration, invasive species abundance). The polarity of the transformation must be adjusted accordingly to ensure consistent interpretation of indicator values²⁶. The inverse-polarity formula is:

¶9 **Indicator = (L – Variable value) / (L – U)**

¶10 **Polarity decision protocol:** Compilers must assign a polarity (Normal or Inverse) to each condition variable before computing indicators and record this assignment in Step 7 metadata. The following decision sequence should be applied:

1. ¶11 If the variable has a clear monotonic relationship with ecosystem health in the target ecosystem type (e.g., coral cover: more = better), assign Normal or Inverse polarity accordingly.
2. ¶12 If the variable has context-dependent polarity, consult the reference table below for the recommended default and note any override with justification.
3. ¶13 If polarity cannot be determined from published ecological evidence, flag the variable as requiring expert review before publication.

Variable	Recommended Default Polarity	Notes on Override
Chlorophyll-a concentration	Inverse (eutrophication indicator)	Override to Normal if used as primary productivity proxy in oligotrophic open-ocean systems; document context
Turbidity	Inverse (reduces light penetration)	Override to Normal in estuarine nursery habitats where moderate turbidity supports feeding; document context
Dissolved inorganic nitrogen	Inverse	No standard override
Water temperature	Inverse (thermal stress context)	Override to Normal in cold-water ecosystems where warming improves productivity; document context

¶14 **Example (normal polarity):** For a coral reef ecosystem, coral cover percentage might be transformed as follows:

- ¶15 U (upper reference, high condition): 50% coral cover
- ¶16 L (lower reference, degraded condition): 5% coral cover
- ¶17 Observed value: 35% coral cover
- ¶18 Indicator = $(35 - 5) / (50 - 5) = 30 / 45 = 0.67$

¶19 This indicator value of 0.67 indicates the coral reef is at 67% of reference condition based on the coral cover characteristic.

¶20 **Example (inverse polarity):** For a coastal water body, dissolved inorganic nitrogen concentration is an inverse indicator: higher values indicate lower condition. The transformation adjusts polarity accordingly:

- ¶21 U (upper reference, high condition): 0.1 mg/L (low nutrient level characteristic of unpolluted waters)
- ¶22 L (lower reference, degraded condition): 1.5 mg/L (eutrophic level)
- ¶23 Observed value: 0.6 mg/L
- ¶24 Indicator = $(L - \text{Observed}) / (L - U) = (1.5 - 0.6) / (1.5 - 0.1) = 0.9 / 1.4 = 0.64$

¶25 This indicator value of 0.64 indicates the water body is at 64% of reference condition based on nutrient concentration, with the inverse polarity ensuring that lower pollutant levels correspond to

higher indicator scores.

¶26 Variables measured on a logarithmic scale

¶27 The linear transformation above assumes that equal changes in the variable represent equal changes in condition. That assumption fails for variables measured on a logarithmic scale, of which pH is the case most often encountered in ocean accounts. A shift from pH 8.2 to pH 8.0 is a rise of roughly 58 per cent in hydrogen ion concentration, yet the linear transformation registers it as a small deviation and understates the ecological significance of acidification.

¶28 For pH, compilers should therefore apply a **categorical step deduction** in place of the linear formula:

¶29 **Indicator = 1.00 – (0.10 × n)**, where **D** is the deviation in pH units below the reference value and **n** is the number of complete 0.05-unit steps in **D** – that is, the largest integer satisfying **n × 0.05 ≤ D**.

¶30 The indicator is clamped at 0 and capped at 1.00 where observed pH equals or exceeds the reference. The resulting bands are:

Deviation below reference (D)	Indicator
D < 0.05	1.00
0.05 ≤ D < 0.10	0.90
0.10 ≤ D < 0.15	0.80
0.15 ≤ D < 0.20	0.70
0.20 ≤ D < 0.25	0.60
each further 0.05	deduct a further 0.10, to a floor of 0

¶31 **A note for implementers.** Determine *n* by comparison in whole hundredths of a pH unit, not by floating-point division. In IEEE-754 double precision $0.15 / 0.05$ evaluates to 2.9999999999999996, so a literal `floor(D / 0.05)` returns 2 and yields 0.80 where the band table gives 0.70 – and D = 0.15 is a value that occurs in the worked example in TG-1.3 Section 3.6.

¶32 *Example:* reference pH 8.2, observed pH 8.03. D = 0.17, which contains three complete 0.05-unit steps ($0.15 \leq 0.17 < 0.20$), so *n* = 3 and the indicator = $1.00 - 0.30 = \mathbf{0.70}$.

¶33 Compilers should document the reference pH value, its source (historical baseline, pristine-site comparison, or ecological modelling), and the step size applied. Where a national programme has evidence supporting a different step size, it may be substituted provided the choice is documented and applied consistently across periods.

¶34 This treatment is applied to the pH rows of the marine protected area condition accounts in **TG-1.3 OA and Marine Spatial Management** Section 3.6.

3.4.2 Reference conditions

¶1 The choice of reference condition is one of the most consequential methodological decisions in condition indicator construction. Reference conditions establish the benchmark against which current ecosystem state is measured¹⁵. SEEA EA Appendix A5.2 separates two decisions that this Circular previously ran together, and they are chosen independently of one another:

- ¶2 **which state** is taken as the benchmark – the *reference condition*; and
- ¶3 **how that state is quantified** – the *estimation method*.

¶4 The axes are orthogonal. A historical reference condition may be quantified from palaeo-environmental data, from a model, from expert opinion, or from a combination of these. Treating an estimation method as though it were a kind of reference condition produces reference levels that cannot be documented against the standard, because the two are recorded separately.

¶5 **The natural state is the recommended default.** SEEA EA takes the reference condition to be the state at which ecological integrity is maximal, and states that using the natural state “is preferred and recommended” (para 5.70)¹⁵. The benchmark is deliberately independent of management objectives: the natural state “may not be related to supply of ecosystem services and may not be the target of current legislation, policy or ecosystem management objectives” (para 5.69). Measuring distance from the natural state is what allows the degree of ecosystem change to be seen at all.

¶6 **Table 3.4.2: Assessment framework for selecting a reference condition**, reproduced from SEEA EA Table A5.2.1²⁷

Ecosystem class	Reference condition	Definition
Natural	Undisturbed or minimally-disturbed	The condition of an intact ecosystem with maximal ecological integrity and no or minimal disturbance.
Natural	Historical	The condition at some point or period in its history considered to represent the stable natural state – for example the pre-industrial period.
Natural	Least-disturbed	The currently best available condition of the ecosystem.
Natural	Contemporary	The condition at a point or period in its recent history for which comparable data are available.
Anthropogenic	Historical	As above, but representing the stable socio-ecological state.
Anthropogenic	Least-disturbed	The currently best available condition of the ecosystem.
Anthropogenic	Contemporary	The condition at a point or period in its recent history for which comparable data are available.
Anthropogenic	Best-attainable	The expected condition under best possible management practices, attaining a stable socio-ecological state.

¶7 Natural ecosystems are those predominantly influenced by natural ecological processes, whose condition ranges within its natural variability; anthropogenic ecosystems are those predominantly influenced by human activities, where a stable natural state is unobtainable. In **semi-natural or lightly managed** ecosystems any of the five conditions may be used, provided the choice is explicit and its rationale explained.

¶8 Two consequences follow for marine accounts. First, coral reef, seagrass, mangrove, kelp forest, pelagic and deep-sea systems are **natural** ecosystems under SEEA EA, so the four natural-ecosystem conditions are the ones available to them; **best-attainable condition is not**, being confined to anthropogenic systems such as artificial waterbodies and other anthropogenic marine systems. Second, each of the four is a *state of the ecosystem*, not a management objective.

¶9 **Table 3.4.3: Methods for estimating a reference condition**, reproduced from SEEA EA Table A5.2.2²⁸

¶10 A mark indicates that the method can be used to estimate that reference condition.

Estimation method	Undisturbed / minimally-disturbed	Historical	Least-disturbed	Contemporary	Best-attainable
1. Reference sites	x	x	x	x	
2. Modelled reference conditions	x	x	x		x
3. Statistical approaches based on ambient distributions			x		x
4. Historical observations and palaeo-environmental data		x			

Estimation method	Undisturbed / minimally-disturbed	Historical	Least-disturbed	Contemporary	Best-attainable
5. Contemporary data				x	
6. Prescribed levels					x
7. Expert opinion	x		x		x

¶11 Method 8 is a combination of the above and is not a separate column. SEEA EA directs that **methods 1–4 are considered first**, as the approaches that best describe and quantify the reference condition and the upper and lower reference levels. Methods 5–7 are alternatives where methods 1–4 cannot be applied, or where policy or legislative drivers require method 5 or 6. Method 7 is noted as particularly relevant to capturing Indigenous knowledge and perspectives; where it is used, the consent, attribution and data-governance requirements in **TG-3.6 Traditional Knowledge** apply.

¶12 **Where a policy target sits.** Prescribed levels – method 6 – estimate only the best-attainable condition, and best-attainable is available only to anthropogenic ecosystems. A level prescribed in policy or legislation therefore has no cell in the natural-ecosystem columns of Table 3.4.3. SEEA EA makes the same point from the other direction: globally agreed reference conditions support comparison between countries, but “some of these reference conditions may incorporate aspects concerning policy targets and hence may not fully reflect the conceptual basis for a reference condition for ecosystem accounting” (para 5.73). Section 3.4.1 permits any reference type to serve as U provided the choice is documented; where that type is a policy target applied to a natural ecosystem, compilers should record it as a departure from Table 3.4.2 and state the reason, so that the series can be reconciled if the target is later revised.

¶13 The SEEA EA emphasises that reference conditions should be “clearly defined, scientifically based, and consistent with the purpose of the assessment”²⁹. For marine ecosystems, establishing natural reference conditions is particularly challenging due to the long history of human fishing pressure and the “shifting baseline syndrome” whereby each generation accepts the degraded state they first observe as normal³⁰.

¶14 For marine ecosystems subject to climate change, reference conditions may need to incorporate considerations of climate adaptation and novel ecosystem states, and a reference condition that is periodically updated against monitored reference sites is one way SEEA EA contemplates handling this.

¶15 Climate change introduces a methodological challenge for reference condition selection. Fixed reference conditions (whether natural or historical) enable tracking of total change in ecosystem state, including climate-driven change, and support assessment of cumulative human impact. Adjusted reference conditions that account for inevitable climate-driven shifts enable assessment of the additional impact of local pressures beyond background climate change. In practice, compilers may present both fixed and adjusted reference conditions in parallel, allowing users to distinguish between total change and locally manageable change.

¶16 **Climate adjustment decision box:** When a compiler chooses to use an adjusted reference condition to account for climate change, the following specifications apply:

- ¶17 **Recommended scenario:** SSP2-4.5 (intermediate emissions pathway) is the default. Where a country has adopted a specific national NDC scenario for official environmental reporting, that scenario may be used as an alternative with documented justification.
- ¶18 **Adjustment time horizon:** The baseline-period median projected change to the accounting year, derived from the selected scenario.
- ¶19 **Acceptable data sources:** CMIP6 multi-model ensembles are the primary source, whilst downscaled regional climate model outputs are acceptable where available and peer-reviewed.

- ¶20 **Step 7 metadata record (mandatory):** The scenario identifier, data source citation, and the numerical adjustment value applied to each reference condition must be recorded and published with the indicator.

¶21 Where adjusted reference conditions are used, these specifications must be followed to enable comparison across assessments and time periods.

3.4.3 Condition indices

¶1 Ecosystem accounts connect extent, condition, services in physical and monetary terms, and monetary asset accounts. Those connections illustrate why condition indices occupy a central position in the accounting framework. Condition accounts both depend on extent information and inform the measurement of ecosystem services, creating an integrated chain of measurement.

¶2 Figure 2.1.3 shows the connections between ecosystem accounts (adapted from 2025 SNA Figure 35.3)³¹.

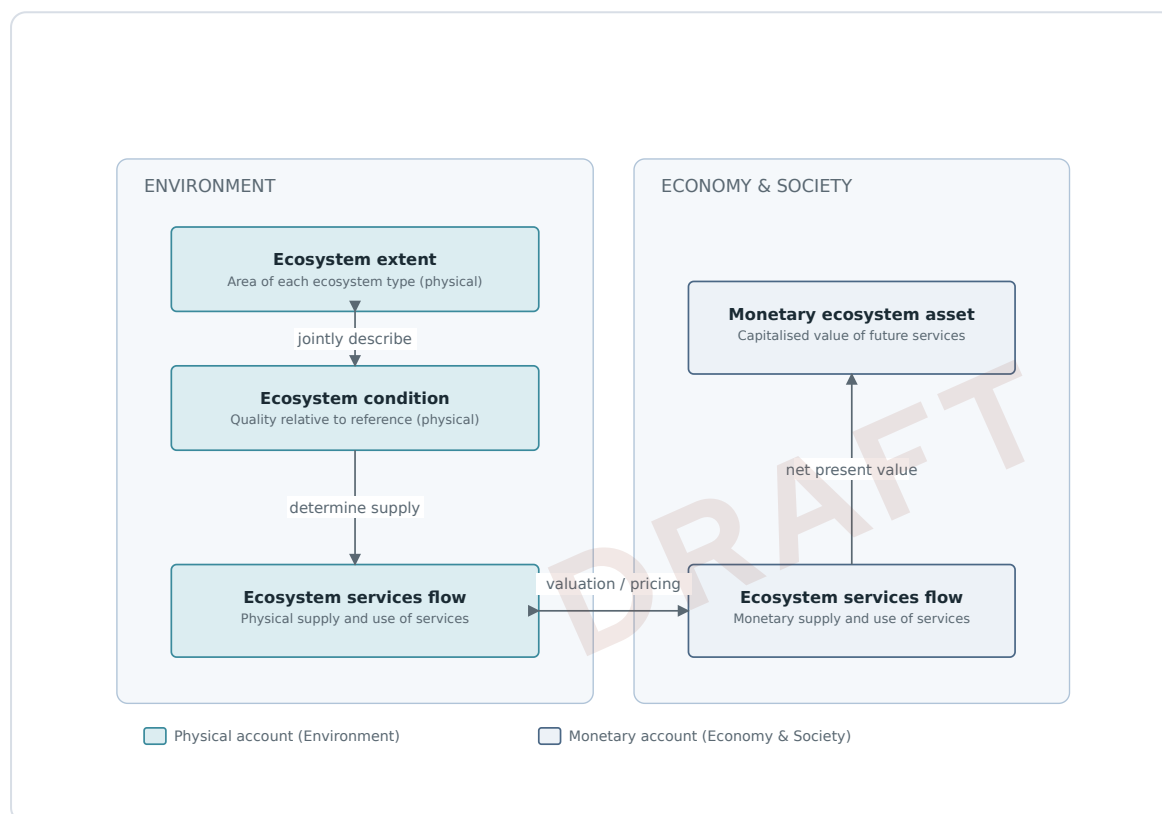


Figure 2.1.3 Five SEEA EA ecosystem accounts connect: extent and condition determine physical service flows that value into monetary accounts. Physical flows link by valuation to monetary service flows, which accumulate as NPV into the monetary asset account.

¶3 Ecosystem condition indices aggregate individual condition indicators into composite measures that summarise overall ecosystem health¹⁶. Index construction involves decisions about which indicators to include, how to weight them, and what aggregation function to apply.

¶4 **Arithmetic mean:** The simplest aggregation approach, giving equal weight to all included indicators. An ecosystem condition index calculated as the arithmetic mean of n indicators would be:

¶5 **ECI = $(1/n) \times \text{Sum of all indicator values}$**

¶6 This approach is transparent and easy to calculate but assumes substitutability between indicators: improvement in one characteristic can compensate for decline in another.

¶7 **Geometric mean:** Gives more emphasis to low values, such that a low score on any indicator reduces the overall index substantially. This approach reflects the view that ecosystem health

requires adequate performance across all characteristics, with weak-link characteristics constraining overall condition.

¶8 **Weighted mean:** Assigns different weights to indicators based on their importance for ecosystem function, data quality, or policy relevance. Weighting can be based on expert elicitation, statistical approaches (e.g., principal components analysis), or ecosystem modelling. Weights should be transparent and justified³². For a set of n indicators with weights w_i summing to 1, the weighted mean ECI is:

¶9 **ECI = Sum of ($w_i \times \text{Indicator}_i$) for $i = 1$ to n**

¶10 The structure of ecosystem condition accounting described in SEEA EA allows for aggregation in several ways: across indicators within the same ECT class, across classes of characteristics in the ECT, or across ecosystem types³³. For example:

- ¶11 An aggregate index for “structural state” of coral reefs (combining coral cover, rugosity, colony size distribution)
- ¶12 An overall condition index for coral reefs (combining structural, compositional, physical, chemical, functional, and seascape indicators)
- ¶13 A national marine ecosystem condition index (combining condition indices for coral reefs, seagrass, mangroves, and other marine ecosystem types, weighted by area)

¶14 The SEEA EA notes that “where it is undertaken, a clear link should be established to information on movements in individual indicators”³⁴. That link ensures that aggregate indices do not obscure important changes in component variables.

3.5 Worked Example: Coastal Ecosystem Condition Indicators

¶1 This section presents a worked example demonstrating how to compile and aggregate biophysical indicators for a hypothetical coastal area. The example uses synthetic data for two marine ecosystem types (mangroves and coral reefs) to illustrate the compilation procedure described in Section 3.2 and the normalisation and aggregation methods presented in Sections 3.3 and 3.4. All indicator values are rounded to two decimal places using standard rounding.

Scenario description

¶1 The accounting area is a coastal zone containing 450 km² of mangrove forest and 180 km² of coral reef ecosystems. The accounting period is calendar year 2025. Condition monitoring data were collected at 25 field sites (15 mangrove, 10 reef) distributed across the accounting area, with quarterly sampling throughout the year.

Step 1: Source data from condition accounts

¶1 Condition variable data were extracted from the ecosystem condition variable accounts compiled following **TG-3.1 Asset Accounts**. Table 1 presents selected condition variables for mangroves, with values at the opening (January 2025) and closing (December 2025) of the accounting period.

¶2 *Table 1: Ecosystem condition variables for mangroves, 2025*

ECT Class	Variable	Polarity	Unit	Opening Value	Closing Value	Upper Reference (U)	Lower Reference (L)
A1 Physical	Sedimentation rate	Inverse	mm/yr	3.2	3.5	2.0	5.0
A2 Chemical	Soil salinity	Inverse	PSU	18	19	15	25
B1 Compositional	Tree species richness	Normal	count	8	8	12	4

ECT Class	Variable	Polarity	Unit	Opening Value	Closing Value	Upper Reference (U)	Lower Reference (L)
B2 Structural	Canopy density	Normal	% cover	72	70	85	40
B3 Functional	Leaf litter production	Normal	g/m ² /yr	480	465	550	200
C Seascape	Connectivity index	Normal	0–1	0.68	0.65	0.80	0.30

¶3 Table 2 presents condition variables for coral reefs:

¶4 *Table 2: Ecosystem condition variables for coral reefs, 2025*

ECT Class	Variable	Polarity	Unit	Opening Value	Closing Value	Upper Reference (U)	Lower Reference (L)
A1 Physical	Water temperature	Inverse	C	27.2	27.8	26.5	30.0
A2 Chemical	pH (ocean acidification)	Normal	pH units	8.05	8.03	8.20	7.8
B1 Compositional	Coral species richness	Normal	count	42	41	60	20
B2 Structural	Live coral cover	Normal	% cover	35	32	50	10
B3 Functional	Recruitment rate	Normal	recruits/m ² /yr	12	11	20	5
C Seascape	Reef connectivity	Normal	index 0–1	0.52	0.50	0.75	0.1

Step 2: Apply reference conditions and compute indicators

¶1 For each variable, indicators were computed using the linear normalisation formula described in Section 3.4.1 with U (upper reference) and L (lower reference) as defined in Table 1 and Table 2. The exception is pH, which takes the categorical step deduction in Section 3.4.1 against the reference pH of 8.20: D = 0.15 at opening and 0.17 at closing, so n = 3 in both periods and the indicator is 0.70 in both.

¶2 For variables with normal polarity (higher values = better condition): **Indicator = (Observed – L) / (U – L)**

¶3 For variables with inverse polarity (higher values = worse condition): **Indicator = (L – Observed) / (L – U)**

¶4 *Table 3: Mangrove condition indicators, 2025 (indicator values, 0–1 scale)*

ECT Class	Variable	Opening Indicator	Closing Indicator	Change
A1 Physical	Sedimentation rate	0.60	0.50	-0.10
A2 Chemical	Soil salinity	0.70	0.60	-0.10
B1 Compositional	Species richness	0.50	0.50	0.00
B2 Structural	Canopy density	0.71	0.67	-0.04
B3 Functional	Leaf litter production	0.80	0.76	-0.04
C Seascape	Connectivity	0.76	0.70	-0.06

¶5 Table 4: Coral reef condition indicators, 2025 (indicator values, 0–1 scale)

ECT Class	Variable	Opening Indicator	Closing Indicator	Change
A1 Physical	Temperature stress	0.80	0.63	-0.17
A2 Chemical	Ocean pH	0.70	0.70	0.00
B1 Compositional	Species richness	0.55	0.53	-0.02
B2 Structural	Coral cover	0.63	0.55	-0.08
B3 Functional	Recruitment	0.47	0.40	-0.07
C Seascape	Connectivity	0.54	0.50	-0.04

¶6 **Interpretation:** Both ecosystem types record declining condition across most indicators during 2025. Mangrove condition declined moderately, with the largest decreases in sedimentation rate (increased sediment loading) and soil salinity (increased salinity stress). Coral reef condition also declined, with the largest decrease in the temperature stress indicator, where warming water temperatures approached bleaching thresholds.

Step 3: Aggregate into composite condition indices

¶1 Composite condition indices were calculated for each ecosystem type using three aggregation methods to illustrate their differences:

¶2 **Arithmetic mean:** Simple average of all six indicators **Geometric mean:** nth root of the product of all indicators **Weighted mean:** Weighted average with structural state (B2) receiving double weight (reflecting its importance for ecosystem services), giving weight vector $w = [1/7, 1/7, 1/7, 2/7, 1/7, 1/7]$ for the six indicators in the order A1, A2, B1, B2, B3, C.

¶3 The weighted mean ECI for each ecosystem type and period is computed as:

¶4 $ECI = (w_{A1} \times I_{A1}) + (w_{A2} \times I_{A2}) + (w_{B1} \times I_{B1}) + (w_{B2} \times I_{B2}) + (w_{B3} \times I_{B3}) + (w_C \times I_C)$

¶5 For coral reefs opening: $(1/7 \times 0.80) + (1/7 \times 0.70) + (1/7 \times 0.55) + (2/7 \times 0.63) + (1/7 \times 0.47) + (1/7 \times 0.54) = (0.80 + 0.70 + 0.55 + 1.26 + 0.47 + 0.54) / 7 = 4.32 / 7 = 0.62$.

¶6 Table 5: Composite ecosystem condition indices for mangroves and coral reefs, 2025

Aggregation Method	Mangroves Opening	Mangroves Closing	Coral Reefs Opening	Coral Reefs Closing
Arithmetic mean	0.68	0.62	0.62	0.55
Geometric mean	0.67	0.61	0.61	0.54
Weighted mean (B2 x2; $w = [1/7, 1/7, 1/7, 2/7, 1/7, 1/7]$)	0.69	0.63	0.62	0.55

¶7 **Interpretation:** All three aggregation methods produce similar results. Each indicates a condition decline for both ecosystem types. The geometric mean produces slightly lower values than the arithmetic mean, as it places more emphasis on low-scoring indicators. The weighted mean that emphasises structural state produces values equal to or slightly higher than the arithmetic mean and is consistent with the stated weight vector.

Step 4: Calculate realm-specific and area-weighted condition indices

¶1 Under the IUCN Global Ecosystem Typology v2.1, mangroves belong to the Marine Freshwater-Terrestrial (MFT) realm and coral reefs belong to the Marine realm. Because the SEEA EA (para 5.87) cautions against aggregation across ecosystem types from different realms, compilers should present condition indices by realm as their primary outputs. Cross-realm aggregation requires explicit documentation of purpose and limitations.

¶2 Separate realm indices (primary output):

- ¶3 MFT realm (mangroves only): Opening ECI = 0.68, Closing ECI = 0.62
- ¶4 Marine realm (coral reefs only): Opening ECI = 0.62, Closing ECI = 0.55

¶5 Cross-realm combined index (illustrative; for use only when explicitly documented):

¶6 When a single national marine summary is required for state-of-environment reporting, an area-weighted aggregate may be computed alongside the separate realm indices:

¶7 National Marine ECI = (Extent_mangroves x ECI_mangroves + Extent_coral x ECI_coral) / Total Marine Extent

¶8 Using the arithmetic mean indices and extent values:

- ¶9 Mangroves: $450 \text{ km}^2 \times 0.62 = 279$
- ¶10 Coral reefs: $180 \text{ km}^2 \times 0.55 = 99$
- ¶11 Total: $(279 + 99) / (450 + 180) = 378 / 630 = 0.60$

¶12 Compilers presenting a cross-realm combined index must document: (a) the realm classification of each ecosystem type, (b) the specific purpose for which the combined index is required, and (c) the limitation that the aggregate conceals divergent trends across realms. The separate realm indices must be published alongside the combined figure.

Step 5: Link to extent indicators and policy targets

¶1 The worked example can be extended to link condition indicators with extent indicators to assess progress toward policy targets. If the accounting area's marine protected area (MPA) coverage target is 30% by 2030 (following the Kunming-Montreal Global Biodiversity Framework Target 3), and current MPA coverage is 25% (158 km² of the 630 km² total marine area), the question arises: is the protected area in good condition?

¶2 Cross-tabulating MPA coverage with ecosystem condition reveals:

¶3 Table 6: MPA coverage by ecosystem type and condition status

Ecosystem Type	Total Extent (km ²)	MPA Extent (km ²)	MPA Coverage (%)	Avg Condition in MPAs	Avg Condition Outside MPAs
Mangroves	450	115	26%	0.68	0.60
Coral reefs	180	43	24%	0.60	0.53
Total	630	158	25%	0.66	0.58

¶4 **Note on derivation of Table 6 condition values:** The average condition within and outside MPAs is computed by spatially disaggregating the condition variable accounts to MPA polygon boundaries and computing separate area-weighted condition indices for each spatial stratum. The "Avg Condition in MPAs" values therefore require that condition data are available at a spatial resolution finer than the MPA boundary. For coral reefs, the area-weighted check is: $(43 \times 0.60 + 137 \times 0.53) / 180 = (25.80 + 72.61) / 180 = 98.41 / 180 = 0.55$, consistent with the whole-ecosystem closing ECI.

¶5 **Interpretation:** The accounting area has achieved 25% MPA coverage, approaching the 30% target. Ecosystems within MPAs exhibit better condition than those outside (average ECI 0.66 vs 0.58). This gap points to a positive effect of protection. Even protected ecosystems, however, remain well below reference condition (0.66 vs 1.0): MPA designation alone is insufficient to maintain ecosystem health, and broader pressures such as climate change and upstream pollution also require management. This analysis demonstrates how aggregate indicators derived from accounts can inform policy discussions about the quality of protection, and not area alone.

Analytical insights

¶1 This worked example illustrates several key features of aggregate indicator compilation:

1. ¶2

Transparency and comparability: Normalised indicators improve both transparency and cross-ecosystem comparability by exposing the underlying reference conditions and aggregation choices, enabling traceability from headline index to source condition variable.

2. ¶3

Aggregation sensitivity: Different aggregation methods produce similar but not identical results. That divergence points to the importance of documenting and justifying the chosen approach.

3. ¶4

Policy relevance: The linked analysis of MPA coverage and condition demonstrates how aggregate indicators can directly inform questions about conservation effectiveness and target achievement.

4. ¶5

Communication efficiency: The separate realm indices and the illustrative combined national ECI of 0.60 together serve different audiences: technical analysts can investigate realm-specific trends whilst non-technical audiences receive an accessible headline figure.

3.6 Aggregation Approaches

3.6.1 Spatial aggregation

¶1 Spatial aggregation combines condition indicators from individual ecosystem assets or grid cells into summary measures for larger areas such as management zones, provinces, or entire countries. Key considerations include:

¶2 **Area weighting:** Larger ecosystem assets should typically contribute more to aggregate indicators than smaller assets. The standard approach weights each unit's condition score by its area (area-weighting formula: Section 3.5 Step 4)³⁵. This area-weighted approach ensures that the aggregate indicator reflects conditions across the full spatial extent of the ecosystem type.

¶3 **Default aggregation method:** Where data or policy requirements do not indicate otherwise, the **arithmetic mean** of the component indicators is the default method for combining condition indicators within an ecosystem type. Section 3.4.3 and the worked example in Section 3.5 Step 3 set out the geometric and weighted alternatives and their implications for interpretation. Compilers should state which method has been applied wherever a composite index is published.

¶4 **Sub-account aggregation within a single accounting area:** Where an accounting area contains more than one habitat type – for example a marine protected area holding coral reef, seagrass and pelagic sub-accounts – the area-level index is the area-weighted mean of the sub-type indices:

¶5 **Area ECI = Sum over sub-types of (Sub-type ECI x Sub-type area) / Total area of the sub-types included**

¶6 Sub-type indices should be **published alongside** the area-level aggregate, not only as inputs to it. An aggregate can conceal divergent trends between habitat types that a manager needs to act on separately, and the sub-type series is the one that supports habitat-specific intervention. Where a habitat present in the accounting area is excluded from the aggregate for want of data, the excluded area and the reason should be stated with the index.

¶7 **Representativeness:** Aggregate indicators are only meaningful if the underlying spatial units adequately represent the full range of ecosystem conditions within the accounting area. Sampling bias can distort aggregate indicators, for example if monitoring sites are concentrated in accessi-

ble or well-managed areas. The SEEA EA recommends that “hierarchical aggregation schemes should contain a description of how missing indicators or subindices are handled”³⁶.

¶8 **Missing data protocol:** Compilers will routinely encounter spatial units with no condition monitoring data (for example, remote offshore reefs or areas with monitoring gaps). Where condition data are unavailable for some spatial units, the following protocol applies:

- ¶9 The compiler documents the proportion of the accounting area covered by observed versus imputed condition values in Step 7 metadata.
- ¶10 Where imputation is applied, the method and rationale must be recorded. Permissible imputation methods are: (a) carry-forward from the prior accounting period, (b) regional mean from adjacent spatial units within the same ecosystem type, and (c) spatial interpolation from neighbouring monitored units.
- ¶11 A quality flag is applied to the aggregate indicator when the imputed area exceeds the observed area (i.e., imputed proportion > 0.5 of total area). This flag signals to users that the aggregate rests primarily on estimated rather than observed values.
- ¶12 No GOAP minimum coverage threshold is prescribed. Coverage adequacy is a matter of national statistical judgment. Compilers must document their assessment of whether the observed coverage is sufficient to support the published aggregate and communicate limitations transparently.

¶13 **Connectivity:** For some purposes, spatially connected ecosystem assets may warrant different aggregation treatment than fragmented assets. Landscape/seascape indicators that capture connectivity and fragmentation can complement simple area-weighted aggregation.

¶14 Spatial considerations for marine ecosystems are addressed in more detail in **TG-4.1 Remote Sensing Data** and **TG-4.3 Geospatial Data Integration**.

3.6.2 Projecting a condition trajectory under a management scenario

¶1 Scenario analysis in planning and appraisal circulars requires a projected condition index, not only an observed one. Accounts do not record the immediate effect of a management action: the efficacy of a decision becomes visible over successive accounting periods as the condition variables are re-measured, and for many marine ecosystems a change in the composite index takes three to five years or more to emerge. Projection is therefore a modelling step layered on the accounts, and its outputs must be labelled as projections rather than account entries.

¶2 The procedure is:

1. ¶3 Identify the primary pressure that the management action addresses (fishing pressure, sediment input, thermal stress, nutrient loading).
2. ¶4 Select the condition variables most sensitive to that pressure – for fishing pressure, compositional state variables such as fish community diversity, and structural state variables such as coral cover or seagrass canopy height.
3. ¶5 Estimate the expected rate of change in each selected variable per accounting period under the proposed regime, from ecological recovery literature or from regional time series for comparable sites.
4. ¶6 Apply the per-period rate to derive a projected trajectory for each variable across the scenario horizon.
5. ¶7 Normalise each projected variable value against its upper and lower references (Section 3.4.1) and aggregate to a composite index for each period using the method in Section 3.6.1.
6. ¶8 Record the projected index values as the scenario condition trajectory, with an uncertainty range, and state that actual condition change will be verified through successive account compilations.

¶9 Variables that respond on different timescales should not be projected on a common rate. Structural complexity and apex predator recovery lag compositional measures substantially, and a composite projected from a single recovery rate will overstate near-term improvement.

¶10 This procedure supports the scenario comparison in **TG-1.2 OA and Marine Spatial Planning** Section 3.5 and the sustainability scenarios in **TG-1.4 OA and Sustainable Ocean Planning** Section 3.6.

3.6.3 Temporal aggregation

¶1 Temporal aggregation produces indicators for periods longer than the basic accounting period or enables comparison across non-contiguous time points. Considerations include:

¶2 **Time series averaging:** Multi-year averages smooth short-term variability, which may obscure important trends but provides more reliable indicators when inter-annual variation is high due to natural cycles or measurement noise.

¶3 **Trend indicators:** Change over time may be more policy-relevant than absolute condition levels. Trend indicators express the rate of improvement or decline in condition, often calculated using statistical approaches such as linear regression over the available time series.

¶4 **Baseline comparison:** Indicators expressed relative to a baseline year enable tracking of progress (or regress) from a defined starting point, which is often required for policy reporting.

3.6.4 Aggregation across ecosystem types

¶1 For summary indicators at the national or regional level, aggregation across different marine ecosystem types may be desirable. The SEEA EA provides guidance on creating an overall ecosystem condition index where “aggregation can take the form of a condition index applied to each ecosystem type, weighted by the area of the ecosystem type within the EAA, then summed for all ecosystem types in the EAA to derive an overall ecosystem condition index”³⁷.

¶2 Combining condition indices for ecosystem types that belong to different IUCN GET v2.1 realms is discouraged unless compilers explicitly document the purpose and limitations. The primary published outputs should be separate condition indices by realm or ecosystem type. Where a cross-realm combined index is presented, compilers must state the realm classification of each contributing ecosystem type, explain why a combined figure is required, and note the limitation that the aggregate may conceal divergent trends across realms³⁸. This requirement reflects SEEA EA para 5.87, which cautions against aggregation across fundamentally different ecosystem types.

¶3 Within a single realm, aggregation across ecosystem types follows the area-weighted approach described in Section 3.5 Step 4, with the same requirements for documentation, quality flags, and linkage to disaggregated component indices.

¶4 Combined presentations that integrate biophysical indicators with economic accounts are addressed in **TG-3.8 Combined Presentations**.

3.7 Marine-Specific Applications

3.7.1 Coral reef health indicators

¶1 Priority condition variables for coral reef accounts include³⁹:

ECT Class	Variable	Indicator Description
Structural state	Coral cover	Live coral as % of substrate
Structural state	Rugosity	Three-dimensional complexity
Compositional state	Fish biomass	Reef fish density (kg/ha)
Compositional state	Coral diversity	Species richness, community composition

ECT Class	Variable	Indicator Description
Chemical state	Carbonate saturation	Aragonite saturation state
Physical state	Sea surface temperature	Thermal stress exposure
Functional state	Recruitment rate	Coral larvae settlement

¶12 Aggregate reef condition indices combine these variables with appropriate weighting. The Reef Check methodology, for example, produces summary indicators from standardised survey protocols⁴⁰. The Ocean Health Index includes a “biodiversity” subgoal that incorporates habitat condition for coral reefs and other marine habitats⁴¹.

¶13 Detailed guidance on coral reef accounting, including extent measurement and condition indicators, is provided in **TG-6.1 Coral Reef Accounts**.

3.7.2 Fish stock indicators

¶11 Fish stock condition provides indicators of both individual environmental asset status (treated in **TG-3.1 Asset Accounts**) and ecosystem compositional state. The SEEA EA treats fish stocks primarily as non-cultivated biological resources recorded in asset accounts⁴². Compilers should apply the following decision boundary when assigning fish-related variables to account categories:

¶12 **Decision boundary – fish stock and fish community indicators:**

- ¶13 **Asset account (not condition index):** Fish stock status indicators based on biomass relative to reference points (B/B_{MSY}) and exploitation rate (F/F_{MSY}) belong in the ecosystem asset account and in SDG 14.4.1 reporting tables. Including these indicators in condition indices would double-count information already captured in the asset account and would introduce fisheries management performance, an outcome of human exploitation decisions, into what should be a biophysical ecosystem state measure.
- ¶14 **Condition account, B1 compositional state class:** Fish community indicators such as mean trophic level of the fish assemblage, functional diversity, and size spectrum belong in the B1 compositional state class of condition accounts. These variables characterise the ecosystem’s biotic composition independent of stock-specific exploitation status.
- ¶15 **Condition account, habitat condition:** Habitat quality metrics for fish nursery areas, such as coral cover, seagrass density, and mangrove canopy density, belong in the relevant habitat condition account (coral reef, seagrass, or mangrove). These are structural state (B2) variables for those ecosystems and should not be entered as fish stock indicators.

¶16 Stock status indicators include:

¶17 **Biomass relative to reference points:** Current spawning stock biomass (B) relative to the biomass at maximum sustainable yield (B_{MSY}) or unfished biomass (B₀). Stocks with B > B_{MSY} are considered within biologically sustainable limits⁴³.

¶18 **Exploitation rate indicators:** Fishing mortality (F) relative to the fishing mortality at maximum sustainable yield (F_{MSY}). Stocks with F < F_{MSY} are not experiencing overfishing.

¶19 **Trophic level indicators:** Mean trophic level of fish communities, tracking changes in ecosystem structure that may indicate “fishing down the food web”⁴⁴.

¶10 SDG indicator 14.4.1 measures the proportion of fish stocks within biologically sustainable levels⁴⁵. National ocean accounts can directly support reporting on this indicator by tracking the status of assessed fish stocks relative to MSY-based reference points. At global level, FAO estimates that the proportion of stocks fished within biologically sustainable levels declined from 90% in 1974 to 65.8% in 2017⁴⁶.

¶11 For detailed guidance on integrating fish stock assessment with ocean accounts, see **TG-1.5 OA and Fisheries Management** and **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**.

3.7.3 Water quality indicators

¶1 Water quality condition is fundamental to marine ecosystem function and is directly connected to land-based sources of pollution. Table 3.7.3 below summarises priority water quality variables for marine condition accounts.

Variable	Description
Nutrient concentrations	Dissolved nitrogen and phosphorus levels, which at elevated concentrations can cause eutrophication, algal blooms, and hypoxia ⁴⁷ .
Dissolved oxygen	Oxygen levels in the water column, with low oxygen (hypoxia) indicating degraded condition and threat to marine life.
Chlorophyll concentration	A proxy for primary productivity and phytoplankton abundance, which at excessive levels may indicate eutrophication. Note that chlorophyll-a has context-dependent polarity (see the polarity reference table in Section 3.4.1) and the compiler must document the polarity assignment and its ecological rationale.
Ocean acidification	Sea water pH and carbonate saturation state, tracking the impacts of atmospheric CO ₂ absorption on marine chemistry.
Pollutant levels	Concentrations of heavy metals, persistent organic pollutants, plastics, and other contaminants.

¶2 The SDG framework includes indicator 14.1.1 (Index of coastal eutrophication and floating plastic debris density), which aggregates water quality and pollution variables into a composite measure⁴⁸. National ocean accounts can provide the underlying data and support disaggregation of this aggregate indicator.

¶3 Links between water quality indicators and flows from the economy to the environment are addressed in **TG-3.4 Flows Economy to Environment**.

3.7.4 Integrated marine indicators

¶1 Several existing indicator frameworks integrate multiple dimensions of marine ecosystem condition:

¶2 **Essential Ocean Variables (EOVs)**: Defined by the Global Ocean Observing System (GOOS), EOVs provide a standardised set of variables spanning physics (temperature, salinity, currents), biogeochemistry (nutrients, oxygen, pH), and biology/ecosystems (phytoplankton, zooplankton, fish abundance, marine habitat)⁴⁹. Alignment between ocean accounts and EOVS frameworks enhances data interoperability.

¶3 **Ocean Health Index (OHI)**: The OHI assesses ocean health across ten goals reflecting the diverse benefits people derive from the ocean⁵⁰. The OHI incorporates condition indicators for coral reefs, seagrass, mangroves, and other habitats within its “biodiversity” and “carbon storage” goals.

¶4 **Marine Biodiversity Observation Network (MBON) indicators**: MBON promotes standardised biodiversity observation. Its indicators of marine species diversity and community composition can inform the compositional state component of ecosystem condition accounts⁵¹.

¶5 **Taskforce on Nature-related Financial Disclosures (TNFD)**: The TNFD framework recommends disclosure of metrics on ecosystem condition relevant to business dependencies and impacts, including marine ecosystems⁵². Ocean accounts can provide standardised condition indicators suitable for corporate nature-related disclosure – see **TG-2.2 Macro-economic Dependencies** and **TG-1.7 OA and Multilateral Development Finance**.

3.7.5 Climate-related marine indicators

¶1 Climate-related indicators bridge the boundary between pressure indicators (measuring driving forces) and state indicators (measuring ecosystem response). Compilers are encouraged to include

climate-related variables within the relevant ECT classes of their condition accounts, rather than treating climate indicators as a separate category.

¶2 **Ocean warming indicators:** Sea surface temperature anomalies, marine heatwave frequency and intensity, and thermal stress accumulation (degree heating weeks) provide condition indicators for the physical state class of the ECT. These indicators are relevant across all marine ecosystem types and directly inform coral bleaching risk assessment and species distribution shifts.

¶3 **Ocean acidification indicators:** Sea water pH decline and aragonite saturation state track the chemical impacts of atmospheric CO₂ absorption. These indicators are particularly consequential for calcifying organisms (corals, molluscs, and planktonic foraminifera) and can be incorporated into the chemical state class of condition accounts.

¶4 **Sea level indicators:** Relative sea level change affects coastal ecosystem extent directly, driving landward migration of intertidal ecosystems and inundation of low-lying habitats. Sea level indicators connect to both extent accounts (through ecosystem conversion) and condition accounts (through salinity and inundation stress).

¶5 **Extreme event indicators:** The frequency and severity of marine heatwaves, tropical cyclones, and hypoxic events can be recorded as condition-relevant pressures. Where these events cause measurable changes in ecosystem condition variables, they contribute to explaining temporal patterns in condition indicators.

4. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

5. References

1. ¶1 United Nations. (2021). *System of Environmental-Economic Accounting–Ecosystem Accounting*. Chapter 14, Figure 14.1. The information pyramid concept organises statistical products into a hierarchy from data and statistics through frameworks and accounts to indicators.
2. ¶2 SEEA EA, para 5.1.
3. ¶3 United Nations. (2021). *System of Environmental-Economic Accounting–Ecosystem Accounting*. Para 5.14, Table 5.1.
4. ¶4 SEEA EA, para 5.5–5.8. “The measurement of ecosystem condition in SEEA EA follows a three stage approach: (i) recording of values of ecosystem condition variables... (ii) deriving ecosystem condition indicators... (iii) aggregating indicators into ecosystem condition indices.”
5. ¶5 SEEA EA, para 4.1–4.5. Ecosystem extent accounts record the area of ecosystem assets.
6. ¶6 SEEA EA, para 5.55–5.64. Condition indicators are derived from variables through normalisation.
7. ¶7 SEEA EA, Table 5.1. The SEEA Ecosystem Condition Typology organises characteristics into six classes.
8. ¶8 SEEA EA, para 5.79–5.87. Discussion of aggregation across indicators and ecosystem types.
9. ¶9 United Nations. (2025). *System of National Accounts 2025*. Figure 35.2. General ecosystem accounting framework showing relationships between environment, ecosystem assets, services, and society.
0. ¶10 SEEA EA, Table 5.2. Structure of ecosystem condition variable account.
1. ¶11 SEEA EA, Table 5.3. Structure of ecosystem condition indicator account.
2. ¶12 SEEA EA, Tables 5.4–5.6. Presentation of ecosystem condition indices.
3. ¶13 OECD. (2003). *Environmental Indicators: Development, Measurement and Use*. Reference paper.
4. ¶14 Global Ocean Observing System. (2019). Essential Ocean Variables. www.goosocean.org/eov (<http://www.goosocean.org/eov>); GEO BON. (2018). Essential Biodiversity Variables.
5. ¶15 SEEA EA, para 5.35–5.48. Discussion of reference conditions.
6. ¶16 SEEA EA, para 5.79–5.87. Section on ecosystem condition indices.
7. ¶17 SEEA EA, para 4.15–4.22. Recording ecosystem extent changes.
8. ¶18 SEEA EA, Table 4.1. Structure of ecosystem extent account.
9. ¶19 SEEA EA, para 4.23–4.28. Ecosystem type changes and conversion matrix.
0. ¶20 SEEA EA, para 4.23.
1. ¶21 SEEA EA, para 4.23–4.28; SEEA EA, Table 4.1.

2. ¶22 United Nations. (2017). *Global Indicator Framework for the Sustainable Development Goals*. A/RES/71/313. Indicator 14.5.1.
3. ¶23 Convention on Biological Diversity. (2022). *Kunming-Montreal Global Biodiversity Framework*. Target 3.
4. ¶24 UNCCD. (2017). SDG 15.3.1 Good Practice Guidance: Proportion of land that is degraded over total land area.
5. ¶25 SEEA EA, para 5.61. The formula for linear transformation of variables to indicators.
6. ¶26 SEEA EA, para 5.60. "For some condition variables, there is an inverse relationship between the value of the variable and the condition score."
7. ¶27 SEEA EA, Table A5.2.1. Assessment framework for selection of reference condition.
8. ¶28 SEEA EA, Table A5.2.2. Summary of methods for estimating possible reference condition for natural and managed ecosystems.
9. ¶29 SEEA EA, para 5.45.
0. ¶30 Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution*, 10(10), 430.
1. ¶31 United Nations. (2025). *System of National Accounts 2025*. Figure 35.3. Connections between ecosystem extent, condition, services (physical and monetary), and monetary asset accounts.
2. ¶32 Nardo, M., et al. (2005). *Handbook on constructing composite indicators: methodology and user guide*. OECD Statistics Working Papers 2005/03.
3. ¶33 SEEA EA, para 5.82. "Aggregation is possible across indicators within the same ECT class, across classes of characteristics in the ECT or across ecosystem types."
4. ¶34 SEEA EA, para 5.79.
5. ¶35 SEEA EA, para 5.83. "Aggregation can take the form of a condition index applied to each ecosystem type, weighted by the area of the ecosystem type."
6. ¶36 SEEA EA, para 5.80.
7. ¶37 SEEA EA, para 5.83.
8. ¶38 SEEA EA, para 5.79. "Where aggregation is undertaken, a clear link should be established to information on movements in individual indicators."
9. ¶39 Hughes, T.P., et al. (2017). Coral reefs in the Anthropocene. *Nature*, 546, 82-90.
0. ¶40 Reef Check Foundation. www.reefcheck.org (<http://www.reefcheck.org>). Standardised reef monitoring protocols.
1. ¶41 Ocean Health Index. (2023). Methods. www.oceanhealthindex.org (<http://www.oceanhealthindex.org>)
2. ¶42 SEEA EA, para 7.18-7.30. Fish stocks as non-cultivated biological resources in asset accounts.
3. ¶43 FAO. (2020). *The State of World Fisheries and Aquaculture 2020*. SDG 14.4.1 methodology.
4. ¶44 Pauly, D., et al. (1998). Fishing down marine food webs. *Science*, 279(5352), 860-863.
5. ¶45 United Nations. (2017). *Global Indicator Framework*. Indicator 14.4.1.
6. ¶46 FAO. (2020). *SOFIA 2020*. Global fish stock sustainability assessment.
7. ¶47 Diaz, R.J. & Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. *Science*, 321(5891), 926-929.
8. ¶48 United Nations. (2017). *Global Indicator Framework*. Indicator 14.1.1.
9. ¶49 GOOS. (2019). *Essential Ocean Variables*. Global Ocean Observing System.
0. ¶50 Halpern, B.S., et al. (2012). An index to assess the health and benefits of the global ocean. *Nature*, 488, 615-620.
1. ¶51 Duffy, J.E., et al. (2013). Toward a coordinated global observing system for marine biodiversity. *Frontiers in Ecology and the Environment*, 11(7), 354-361.
2. ¶52 TNFD. (2023). *Recommendations of the Taskforce on Nature-related Financial Disclosures*. Appendix 2: Core global disclosure metrics.