

Coral Reef Ecosystem Accounting

Provides guidance on compiling ecosystem accounts for coral reef ecosystems within the SEEA Ecosystem Accounting framework.

Version 0.8.1 **Status** Draft **Stability** Applied

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

Drafting AI-assisted drafting from GOAP Secretariat source materials; source list to be published at the close of consultation.

OUTCOME

This Circular provides guidance on compiling ecosystem accounts for coral reef ecosystems within the SEEA Ecosystem Accounting framework. Coral reefs are among the most extensive coastal and marine ecosystem types globally.

Coral reef accounts support four priority decision contexts: MPA effectiveness monitoring (tracking condition changes inside protected areas relative to baseline); tourism carrying capacity analysis (quantifying visitor use relative to ecosystem condition); bleaching damage quantification for insurance (valuing condition losses from mass bleaching events to support parametric insurance products – the Section 3.4 subsection on reef accounts and disaster risk financing sets out the damage-formula and DHW linkage); and reef restoration return on investment (comparing restoration costs against expected service value gains). These functions connect to the policy processes in [TG-1.3 OA and Marine Spatial Management](#).

The accounting framework here provides the foundation for [TG-6.4 Kelp Forest and Temperate Reef Accounting](#) and [TG-6.5 Pelagic and Open Ocean Accounting](#). Valuation methods follow [TG-1.9 Valuation](#), spatial data inputs draw on [TG-4.1 Remote Sensing and Geospatial Data](#), and asset account structures follow [TG-3.1 Asset Accounts](#). Biophysical indicators are addressed in [TG-2.1 Biophysical Indicators](#).

Framework Position

This Circular owns the extent, condition, service and asset accounts for IUCN GET M1.3 photic coral reefs, and the reef-specific judgements a compiler cannot take from the generic method: the catastrophic-loss criterion for bleaching mortality, the conversion-versus-condition test, and the climate-adjusted service trajectory.

It cross-refers for the account structure and the degradation and NPV identities ([TG-3.1](#)), extent mapping ([TG-4.1](#)), condition measurement protocols ([TG-4.8](#), [TG-4.9](#)), service classification ([TG-2.4](#)) and valuation principles ([TG-1.9](#)).

Three boundaries are easy to cross by accident. Cold-water and deep-sea coral ecosystems (M3.4, M3.5) are [TG-6.6](#). Submerged artificial structures are M4.1 and belong to [TG-6.9](#) Section 3.5.2, even when colonised by reef-building corals. The produced-asset side of coastal protection is [TG-6.11](#); this Circular records the protection service flow.

CONTENTS

1. Outcome	3
2. Requirements	3
3. Guidance Material	3
3.1 Extent Accounting	4
3.2 Condition Assessment	6
3.3 Ecosystem Services	9
3.4 Valuation Methods	11
3.5 Compilation Procedure	13
3.6 Worked Example	14
4. Supplementary Materials	18
4.1 Data Sources	18
5. Acknowledgements	18
6. References	19
Footnotes	19

ABOUT THIS CIRCULAR

RECOMMENDED CITATION

Coral Reef Ecosystem Accounting (2026) (GOAP Technical Guidance on Ocean Accounting, TG-6.1, v0.8.1). GOAP Secretariat.
<https://guidance.oceanaccounts.org/circulars/section-6/6-1-coral-reef/>

© 2026 Global Ocean Accounts Partnership. Licensed under CC BY-NC 4.0.

DRAFT

1. Outcome

¶1 This Circular provides guidance on compiling ecosystem accounts for coral reef ecosystems within the SEEA Ecosystem Accounting framework. Coral reefs are among the most extensive coastal and marine ecosystem types globally.

¶2 Coral reef accounts support four priority decision contexts: **MPA effectiveness monitoring** (tracking condition changes inside protected areas relative to baseline); **tourism carrying capacity analysis** (quantifying visitor use relative to ecosystem condition); **bleaching damage quantification for insurance** (valuing condition losses from mass bleaching events to support parametric insurance products – the Section 3.4 subsection on reef accounts and disaster risk financing sets out the damage-formula and DHW linkage); and **reef restoration return on investment** (comparing restoration costs against expected service value gains). These functions connect to the policy processes in **TG-1.3 OA and Marine Spatial Management**.

¶3 The accounting framework here provides the foundation for **TG-6.4 Kelp Forest and Temperate Reef Accounting** and **TG-6.5 Pelagic and Open Ocean Accounting**. Valuation methods follow **TG-1.9 Valuation**, spatial data inputs draw on **TG-4.1 Remote Sensing and Geospatial Data**, and asset account structures follow **TG-3.1 Asset Accounts**. Biophysical indicators are addressed in **TG-2.1 Biophysical Indicators**.

¶4 ⓘ Framework Position

¶5 This Circular owns the extent, condition, service and asset accounts for **IUCN GET M1.3 photic coral reefs**, and the reef-specific judgements a compiler cannot take from the generic method: the catastrophic-loss criterion for bleaching mortality, the conversion-versus-condition test, and the climate-adjusted service trajectory.

¶6 It cross-refers for the account structure and the degradation and NPV identities (**TG-3.1**), extent mapping (**TG-4.1**), condition measurement protocols (**TG-4.8**, **TG-4.9**), service classification (**TG-2.4**) and valuation principles (**TG-1.9**).

¶7 Three boundaries are easy to cross by accident. Cold-water and deep-sea coral ecosystems (M3.4, M3.5) are **TG-6.6**. Submerged artificial structures are M4.1 and belong to **TG-6.9** Section 3.5.2, even when colonised by reef-building corals. The produced-asset side of coastal protection is **TG-6.11**; this Circular records the protection service flow.

2. Requirements

¶1 This Circular requires familiarity with **TG-0.1 General Introduction to Ocean Accounts**, **TG-3.1 Asset Accounts**, **TG-1.9 Valuation**, and **TG-4.1 Remote Sensing and Geospatial Data**. Readers should also be familiar with **TG-2.1 Biophysical Indicators** (for the condition variables in Section 3.2) and **TG-2.4 Environmental Goods and Services** (for the service classification in Section 3.3).

¶2 **Readiness and sequencing**. Whether a country is positioned to compile this account at all – mandate, data architecture, capacity and the order in which to build – is assessed under **TG-0.8 Implementation Readiness Assessment**, and is not restated here.

3. Guidance Material

¶1 Coral reef ecosystems are classified within the IUCN Global Ecosystem Typology as **M1.3 Photic coral reefs** (Marine Shelf biome, M1)^{1, 2}. The SEEA EA treats coral reefs as **ecosystem assets**: contiguous areas of a specific ecosystem type delineated “based on the areas of the different ecosystem types associated with the seabed, for example, seagrass meadows, subtidal sandy bottoms and coral reefs”^{3, 4}.

¶2 This section examines extent accounting (Section 3.1), condition assessment (Section 3.2), ecosystem services (Section 3.3), and valuation methods (Section 3.4). Section 3.5 provides the com-

pilation procedure and Section 3.6 presents a worked example. Account linkages are illustrated in Figure 6.11⁵.

¶3 This Circular focuses exclusively on photic (warm-water) coral reefs classified under IUCN GET M1.3. Cold-water and deep-sea coral ecosystems differ from photic reefs in their ecological characteristics, depth distributions, and data requirements. Such ecosystems include those classified under M3.5 (Deepwater biogenic beds) and those found on M3.4 (Seamounts, ridges and plateaus). Accounting for deep-sea ecosystems, including cold-water coral formations, is addressed in **TG-6.6 Deep Sea and ABNJ Accounting**.

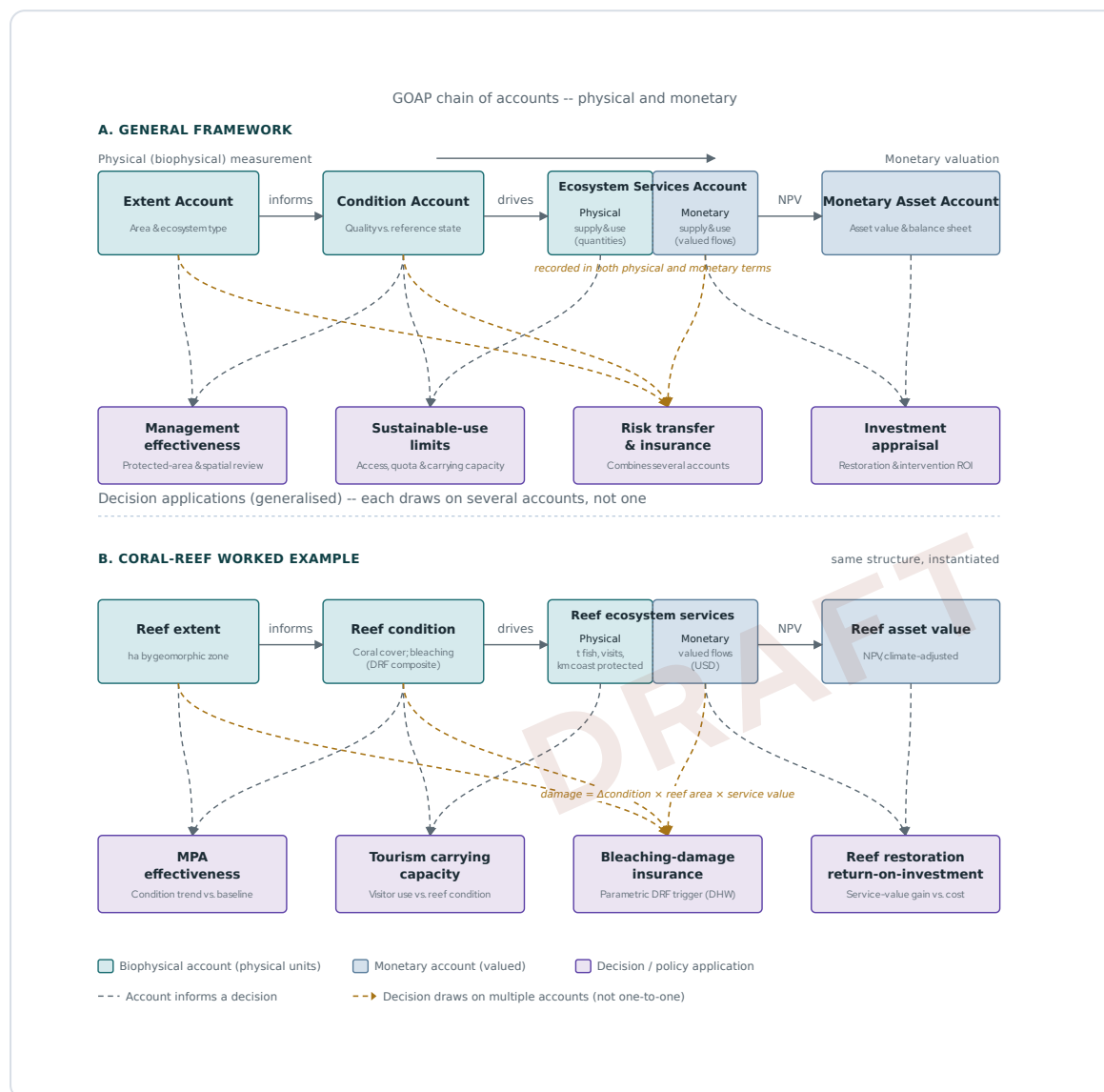


Figure 6.11 Two-panel GOAP account chain: Extent informs Condition, which drives Ecosystem Services into the Monetary asset account; Panel B instantiates coral reefs. Decision applications draw on several accounts, not one-to-one.

Source: TG-6.1, Section 1 (decision contexts), Sections 3.1--3.4 (account chain), 3.4 reef-accounts-and-disaster-risk-financing (damage formula), Table 3 (physical and monetary services columns); account-chain logic consistent with SEEA EA 2021, Chapter 4 (extent), Chapter 5 (condition), Chapters 6--7 (ecosystem services, physical and monetary supply-and-use), Chapters 9--10 (monetary valuation).

3.1 Extent Accounting

¶1 Ecosystem extent accounts record the total area of each ecosystem type within an ecosystem accounting area (EAA), along with additions and reductions during the accounting period⁶.

For coral reefs, extent is typically measured in hectares or square kilometres of reef surface area. Accurate delineation of reef extent provides the foundation for condition assessment and services quantification.

¶12 The asset account structure presented in **TG-3.1 Asset Accounts** applies directly to coral reef ecosystem assets. The key accounting entries (opening stock, additions, reductions, and closing stock) capture changes in reef extent over the accounting period.

Mapping coral reef extent

¶11 Coral reef extent mapping combines remote sensing with in-situ validation⁷. Primary approaches: (1) **satellite imagery** – the Allen Coral Atlas (v2.0, 2022) provides standardised reef mapping at ~5 m resolution globally, whilst Landsat and Sentinel-2 provide recurring observations (see **TG-4.1 Remote Sensing and Geospatial Data** for processing guidance); (2) **aerial photography and drone surveys** – for patchy reefs and complex geomorphology (see **TG-4.2 Survey Methods**); (3) **bathymetric surveys** – acoustic and LiDAR for three-dimensional structure; (4) **in-situ surveys** – dive transects, manta tows, and drop cameras for validation. Document data sources, resolution, and temporal coverage to ensure reproducibility.

Classification within IUCN GET

¶11 Coral reefs are classified as **M1.3 Photoc coral reefs** within the IUCN Global Ecosystem Typology (Marine Shelf biome, M1). For the GET realm/biome/EFG hierarchy and the national crosswalk obligation, see **TG-4.1 Remote Sensing and Geospatial Data** Section 3.2.4.⁸

¶12 For national accounting purposes, coral reef ecosystem types may be further disaggregated based on geomorphological class (fringing, barrier, atoll, patch), depth zone (reef flat, reef crest, fore-reef slope), or dominant benthic community (hard coral dominated, soft coral dominated, algal dominated)⁹, following SEEA EA paragraphs 3.22–3.24¹⁰.

Disaggregation by geomorphic zone

¶11 Where reef geomorphic zones (fringing, barrier, atoll rim, patch) face materially different pressures or provide distinct service profiles, condition and service accounts should be compiled separately for each zone. Fringing reefs typically experience higher sediment and nutrient pressures from terrestrial runoff, whilst outer barrier and patch reef positions experience greater thermal exposure and wave energy. Where land-based sediment or nutrient pressure on fringing reefs is documented in national monitoring data, separate fringing-reef condition accounts are recommended even where data for other zones are aggregated. Where data do not support zone-level compilation, a single spatially aggregated condition score is acceptable, but the aggregation approach and its implications for hiding inter-zone heterogeneity should be documented in account metadata so that downstream users can interpret the composite indicator appropriately.

What is coral-specific about the extent account

¶11 The account structure – opening extent, managed and unmanaged additions and reductions, the reclassification block, and the closing identity – is the standard one and is set out once in **TG-3.1 Asset Accounts** Section 3.5.1¹¹. A worked coral reef extent account appears at Section 3.6 below. What follows is only what a compiler must decide differently for reefs.

¶12 **Additions** are primarily unmanaged (natural growth and recovery). Managed expansion (coral gardening, larval enhancement) typically represents small additions¹². Placed artificial structures are **not** an addition to M1.3 extent, even where corals colonise them: they are a distinct ecosystem type, IUCN GET M4.1 Submerged artificial structures, and are recorded in their own extent entry under the rule in **TG-6.9 Offshore Energy Thematic Methods** Section 3.5.2, which owns the treatment of submerged artificial structures for this publication. Recording the same hectares as both M1.3 and M4.1 would double-count them. **Reductions** may be managed (coastal development, dredging, land reclamation) or unmanaged (storm damage, bleaching-induced mortality, chronic

degradation). Climate-driven bleaching mortality is classified as an unmanaged reduction because it is not the result of a deliberate management decision¹³.

¶3 Bleaching-induced mortality should be recorded as a **catastrophic loss** in the extent account, rather than a routine unmanaged reduction, when both of the following procedural criteria are satisfied: (1) the mortality is attributable to a discrete, identifiable thermal stress event, as identified by NOAA Coral Reef Watch degree heating week (DHW) alerts at Alert Level 1 or higher over the reef area; and (2) the event is documented in peer-reviewed literature or national monitoring reports as exceptional – that is, not part of routine expected annual losses. Gradual mortality that cannot be attributed to a single discrete event is classified as an unmanaged reduction. This procedural rule follows the SEEA CF definition of catastrophic losses as “large-scale, discrete and recognizable events” that are unexpected and exceptional¹⁴. No published standard (SEEA CF, SEEA EA, GCRMN, NOAA, IUCN) specifies a quantitative percentage mortality threshold for the classification, and the guidance here is therefore indicative.

Restoration interventions

¶1 Coral gardening, larval enhancement and substrate stabilisation produce managed additions to extent and, where successful, condition gains. Where the intervention is a nature-based solution, its counterfactual tier, survival adjustment, permanence risk and lifecycle cost are recorded in parallel under **TG-6.15 Ocean Accounting for Nature-based Solutions** Section 3.2. Reef restoration has among the lowest recorded survival rates of any marine restoration type, so the survival adjustment in that Circular’s Section 3.4 does material work here and an extent entry taken at planted area will overstate the gain.

Reef conversions

¶1 Reef conversions are recorded in the reclassification block of the extent account (**TG-3.1** Section 3.5.1, Table 2b), not in a separate change matrix¹⁵. The transitions that matter for reefs are coral reef to algal-dominated rubble after a mortality event, coral reef to seagrass meadow, and degraded reef to recovering reef. A reef that loses live coral but retains its carbonate structure and is still classified M1.3 has changed **condition**, not type, and belongs in Section 3.2 rather than here – this is the judgement compilers most often get wrong, because the ecological loss feels like a conversion.

3.2 Condition Assessment

¶1 Ecosystem condition accounts record the quality or health of coral reef ecosystems relative to a reference condition. The SEEA EA defines condition as “the quality of an ecosystem measured in terms of its abiotic and biotic characteristics”¹⁶. The principles for selecting and interpreting biophysical indicators are addressed in **TG-2.1 Biophysical Indicators**. This section applies those principles to coral reefs. The measurement protocols for the variables themselves – how each is observed, at what frequency and to what tolerance – are owned by **TG-4.8 Physical Condition Measurement** and **TG-4.9 Biological Condition Measurement**; this Section selects and interprets them for photic coral reefs.

Condition variables for coral reefs

¶1 The SEEA EA organises condition variables within the Ecosystem Condition Typology (ECT). Table 3.2.1 maps ECT classes to reef-relevant variables¹⁷.

ECT class	Reef-relevant variables
Class A1: Physical state	Abiotic characteristics (water temperature, pH, turbidity, dissolved oxygen).
Class A2: Chemical state	Nutrient concentrations, pollutant levels, aragonite saturation state.

ECT class	Reef-relevant variables
Class B1: Compositional state	Species composition, functional diversity, presence of indicator species.
Class B2: Structural state	Coral cover, rugosity, reef accretion rates.
Class B3: Functional state	Primary productivity, nutrient cycling, bioerosion rates.
Class C1: Landscape and seascape characteristics	Connectivity, patch size, fragmentation.

¶2 The following variables are recommended for coral reef condition assessment¹⁸. Reference levels are indicative, and compilers should adapt them to regional baselines (Caribbean, Indo-Pacific, Red Sea conditions differ substantially).

¶3 Table 2 includes a **Direction** column flagging whether each variable is “standard” (higher value = higher condition) or “inverse” (higher value = lower condition). Both normalisation formulas are defined in **TG-2.1** Section 3.4.1. Compilers must check the Direction column before applying the formula.

Condition variable	ECT class	Direction	Measurement approach	Reference level guidance
Live hard coral cover (%)	B2 Structural	Standard	Transect surveys, remote sensing	Upper: historical baseline (preferred) or 40% (default); Lower: 5%
Coral species richness	B1 Compositional	Standard	Species inventories	Reference site diversity
Fish species richness	B1 Compositional	Standard	Visual census surveys	Reference site diversity
Herbivore fish biomass (kg/ha)	B2 Structural	Standard	Underwater visual census	Upper: 50 kg/ha; Lower: 5 kg/ha
Macroalgae cover (%)	B2 Structural	Inverse	Transect surveys	Upper (good): 5%; Lower (poor): 40%
Coral recruitment density	B3 Functional	Standard	Settlement tile surveys	Regional norms
Reef rugosity index	B2 Structural	Standard	Chain intercept, 3D photogrammetry	Upper: 2.0; Lower: 1.2
Bleaching prevalence (%)	A1 Physical state	Inverse	Bleaching surveys	Upper (good): 0%; Lower (poor): 50%
Water quality index	A2 Chemical	Standard	Water sampling	Jurisdiction standards
Aragonite saturation state	A2 Chemical	Standard	Carbonate chemistry	Upper: 4.0; Lower: 3.0

¶4 *Table 2: Condition variables for coral reef ecosystems. The Direction column indicates whether the standard or inverse normalisation formula (defined in **TG-2.1** Section 3.4.1) should be applied.*

Reference levels and condition indicators

¶1 For coral reefs, reference conditions may be established based on the four options summarised in Table 3.2.2 below.

¶2 **Table 3.2.2: Reference condition options for coral reef ecosystems**

Reference type	Description
Historical baselines	Documented reef condition from historical records, photographs, or palaeoecological evidence (e.g., pre-1950 baseline).
Contemporary reference sites	Condition observed at minimally impacted reference reefs within the same biogeographic region.

Reference type	Description
Scientific thresholds	Ecologically meaningful boundaries such as the 30% coral cover threshold commonly associated with reef functionality and ecosystem service provision.
Policy targets	Condition levels consistent with management objectives (e.g., national marine park standards).

¶3 Regional variation requires context-specific reference level selection¹⁹. For live hard coral cover, a site-specific historical baseline is the preferred upper reference where pre-disturbance data exist. The default 40% applies when no historical data are available. Document the data source, survey year, and spatial coverage in account metadata.

Aggregation and weighting of condition indicators

¶1 Indicator-level scores are combined into a composite condition index following the principles described in SEEA EA paragraphs 5.77–5.88, which discuss weighted averaging and other combination methods²⁰. For coral reefs specifically, peer-reviewed literature treats live hard coral cover (B2 Structural) as the primary structural indicator of reef condition²¹. Where expert ecological judgement is available, live hard coral cover should be assigned the largest single weight in the composite index, indicatively at least 0.30, with the remaining weight distributed across compositional, functional, and other structural indicators according to local management priorities. Where expert weighting is not feasible, equal weighting is acceptable as a documented default. The weighting approach (whether expert-derived, equal, or PCA-derived) is a methodological choice that materially affects the composite score, and should be documented in account metadata alongside the rationale for any departure from equal weights.

¶2 **Two-composite framing for routine reporting versus disaster risk financing.** Compilers should maintain two composite variants where reef accounts are used to support disaster risk financing (DRF) applications. The **routine composite** (live hard coral cover, herbivore fish biomass, macroalgae cover, and reef rugosity, with the weights described above) is appropriate for general reporting on reef condition. It excludes bleaching prevalence. A composite score derived under routine weights therefore will not respond to a bleaching event, and is not suitable for any application that uses the damage formula $\text{Damage} = (\text{Condition}_{\text{pre}} - \text{Condition}_{\text{post}}) \times \text{area} \times \text{unit service value}$ (see the Section 3.4 subsection on reef accounts and disaster risk financing). For DRF applications, a **DRF-composite** that includes bleaching prevalence (or post-bleaching mortality) alongside the four routine variables must be used. Indicative weights for the DRF-composite are: live hard coral cover 0.30, bleaching prevalence 0.20, and the three remaining variables (herbivore fish biomass, macroalgae cover, reef rugosity) 0.167 each, summing to 1.000 ($0.30 + 0.20 + 3 \times 0.167 = 1.001$, with one of the 0.167 terms rounded down to 0.166 so the displayed weights sum to exactly 1.000). Compilers may adjust these weights provided live hard coral cover retains the primary weight and bleaching prevalence carries a non-trivial weight, so that the composite index responds materially to bleaching events.

Bleaching as a condition indicator

¶1 Coral bleaching is the expulsion of symbiotic zooxanthellae in response to thermal stress, and is a primary condition indicator for reefs^{22, 23}. Bleaching may be recorded using any of the four metrics in Table 3.2.3.

Metric	Description
Bleaching prevalence	Percentage of colonies affected.
Bleaching severity	Degree of tissue colour loss using standardised colour charts.
Post-bleaching mortality	Percentage of colonies that died following bleaching.
Recovery status	Return to baseline coloration following bleaching.

¶2 NOAA Coral Reef Watch provides satellite-derived bleaching alerts and degree heating week (DHW) products that can be integrated with in-situ monitoring data²⁴.

¶3 Where bleaching leads to substantial mortality, it may also be recorded as a **catastrophic loss** in extent accounts following the two-criterion procedural rule in Section 3.1²⁵.

Structure of condition accounts

¶1 Condition accounts may be presented at the three levels of aggregation summarised in Table 3.2.4 below²⁶.

Account level	Description
Variable accounts	Tracking individual condition variables over time (SEEA EA Table 5.3).
Indicator accounts	Presenting normalised indicators derived from variables (SEEA EA Table 5.4).
Index accounts	Aggregating indicators into composite condition indices (SEEA EA Table 5.5).

¶2 The aggregation approach should follow the weighting guidance above and the principles in SEEA EA paragraphs 5.77–5.88.

3.3 Ecosystem Services

¶1 Ecosystem services accounts record flows from coral reef ecosystems to economic units and households²⁷. The methodology for identifying and measuring services is in **TG-2.4**

Environmental Goods and Services.

¶2 ⓘ Recording rule – coastal protection service

¶3 This Circular is the recording point for the coastal protection service supplied by coral reefs. **TG-6.11 Coastal Infrastructure Accounting** Section 3.3.2 records the produced-asset side – the capital cost and depreciation of engineered and hybrid works – and cross-refers here for the service; it does not estimate a second protection value for the same area. **TG-6.15** Section 3.8 supplies the method for comparing the two.

Provisioning services

¶1 **Fisheries provisioning** – Coral reefs support fisheries for reef fish, invertebrates (lobster, sea cucumber, trochus), and associated pelagic species²⁸. The ecosystem service is the reef's contribution to fish production, distinct from human inputs (fishing effort, gear, vessels). Key physical metrics: fish biomass on reefs (kg/ha), sustainable yield estimates (tonnes/year), actual retained catch (tonnes), and species composition. For fisheries accounting detail, see **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**.

¶2 **Genetic and biochemical resources** – Coral reef organisms provide sources of pharmaceuticals, cosmetics, and other biochemical products. Whilst difficult to quantify, these potential services represent option value for future applications.

¶3 **Ornamental resources** – Live coral, reef fish, and other organisms collected for the aquarium trade represent a distinct provisioning service flow. Physical units should follow CITES trade database conventions (see Section 3.3 services account, Table 3): live ornamental fish in number of specimens, and live ornamental corals and invertebrates in number of colonies or kg.

Regulating services

¶1 **Coastal protection** – Coral reefs attenuate wave energy, reducing coastal erosion and flood risk^{29, 30}. The value of this service depends on reef extent, condition, and the exposure of coastal assets. Degraded reefs provide less wave attenuation than healthy reefs³¹. Physical metrics: wave energy attenuation (% reduction in wave height), avoided damage costs (currency/year), length of coastline protected (km), and population in protected zones.

¶2 **Water quality regulation** – Reef ecosystems contribute to water quality regulation through several distinct biological and physical mechanisms, which should be disaggregated in Table 3 rather than reported under an ambiguous single “volume filtered” entry:

1. ¶3 **Sponge-mediated biofiltration** – Reef sponges actively pump and filter water, and remove dissolved and particulate organic matter through the “sponge loop”. Quantification follows the indicative metric “sponge biofiltration rate (L/h/m²) x reef area”. The metric draws on per-individual pumping-rate measurements scaled by sponge density from benthic surveys. No internationally standardised reef-area-normalised protocol is currently published, so this metric should be reported as indicative and the underlying density and pumping-rate sources documented in account metadata.
2. ¶4 **Turbidity reduction** – Wave attenuation and particle trapping in reef structures reduce water-column turbidity over the reef and adjacent seagrass beds. This sub-service is quantifiable as the difference in nephelometric turbidity units (NTU) across a reef cross-section.
3. ¶5 **Nutrient uptake** – Coral symbionts and other reef autotrophs assimilate dissolved nutrients, with quantification through mass-balance approaches.

¶6 Compilers should select the sub-service(s) that match available monitoring data and avoid the unqualified “volume filtered” unit, which is more appropriate to oyster and seagrass systems than to coral reefs³².

¶7 **Carbon cycling** – Coral reefs are widely considered net carbon sources at the ecosystem scale because calcification releases CO₂, even though photosynthesis by zooxanthellae, associated seagrass beds, and algal turf can sequester carbon over short timescales^{33, 34}. There is no default presumption of net sequestration for coral reefs, and net flux entries implying net uptake require site-specific evidence. Compilers should not transfer the blue-carbon sequestration presumption from mangrove/seagrass systems (see [TG-6.2 Mangrove and Coastal Wetland Accounting](#)) to reef accounts.

¶8 For accounting purposes, compilers should avoid combining reef carbon into a single ambiguous figure and should instead record it as **two distinct entries**:

- ¶9 A **stock** entry: carbon stored in the reef framework structure (tC), recorded in the asset/balance sheet at opening and closing of the accounting period.
- ¶10 A **flow** entry: net annual carbon flux (tC/year) attributable to the combined effects of calcification (release) and net photosynthetic production (uptake), reported with an explicit sign convention (positive = net uptake by the reef, negative = net release to the atmosphere).

¶11 Where the net annual flux is negative (the reef is a net CO₂ source over the period), the negative value must be recorded as a negative service flow rather than suppressed or reset to zero, so that monetary valuation does not systematically overstate reef carbon services. The monetary value applied to the flux entry uses an explicit carbon price source, typically the domestic emissions trading scheme price where one exists, or the national social cost of carbon. That price source must be documented alongside the entry.

Cultural services

¶1 **Recreation and tourism** – Coral reefs support diving, snorkelling, and coastal tourism^{35, 36}. Physical metrics: visitor numbers (annual person-visits), trip expenditure attributable to reef access, consumer surplus, and recreation days. See valuation in Section 3.4 (simulated exchange value method)³⁷.

¶2 **Cultural heritage and spiritual values** – Traditional fishing grounds, spiritual sites, and elements of cultural identity are recorded qualitatively or through participatory valuation.

¶3 **Education and research** – Research expenditure and educational outcomes attributable to reef access.

Structure of services accounts

¶1 Ecosystem services flow accounts record the quantity and, where feasible, the monetary value of services provided during the accounting period³⁸:

Ecosystem service	Physical quantity	Physical units	Monetary value (USD thousand)
Provisioning services			
– Reef fisheries	750	tonnes	2,250
– Ornamental fish (live trade)	11,500	number of specimens	60
– Ornamental corals and invertebrates (live trade)	1,200	kg (or number of colonies)	25
– Genetic resources	(qualitative)	(qualitative)	(not valued)
Regulating services			
– Coastal protection	42	km protected	8,200
– Water quality regulation: sponge biofiltration	1,200	sponge biofiltration rate (L/h/m ²) x reef area, ML/yr equivalent	120
– Water quality regulation: turbidity reduction	8	NTU reduction across cross-section	40
– Water quality regulation: nutrient uptake	18	tN/yr	20
– Carbon cycling: stock (reef framework)	32,400	tC stored (balance sheet entry)	(stock, not flow)
– Carbon cycling: net annual flux	-150	tC/yr (positive = net uptake; negative = net release) ³⁹	-8
Cultural services			
– Recreation and tourism	115,000	person-visits	4,950
– Cultural and spiritual	(qualitative)	(qualitative)	(not valued)
– Education and research	(qualitative)	(qualitative)	(not valued)
Total valued service flows			15,657

¶2 Table 3: Structure of ecosystem services flow account for coral reefs with illustrative synthetic values (adapted from SEEA EA Table 7.1). Ornamental species are reported in two sub-rows aligned with CITES trade database conventions⁴⁰. Carbon cycling is split between a stock balance-sheet entry and an annual flux flow entry, with negative flux values retained rather than suppressed.

3.4 Valuation Methods

¶1 Monetary valuation follows the exchange-value preference hierarchy in **TG-2.4 Environmental (including Ecosystem) Goods and Services** Section 3.10 and **TG-3.2 Flows from Environment to Economy**⁴¹, ⁴². The applicable methods for coral reef services are summarised below.

Valuation of ecosystem services

¶1 **Fisheries services** – Resource rent (gross revenue minus costs of labour, capital, and other inputs)⁴³. For the worked example derivation, see Section 3.6 Step 3. For small-scale fisheries where the input-subtraction method yields near-zero or negative resource rent, apply the net price method (SEEA EA para. 9.42) and document the comparator source. See **TG-6.7 Fisheries Accounting** for the fisheries-specific application.

¶2 **Tourism and recreation** – The tourism expenditure this draws on is compiled as an industry segment in **TG-6.14 Marine and Coastal Tourism Accounting**; a compiler running both should take the

reef-attributable expenditure from that segment rather than estimating it twice. For accounting purposes, methods yielding exchange values consistent with SNA principles are preferred^{44, 45}. Applicable approaches: market-based methods (tourism expenditure and producer margins), travel cost methods, contingent valuation, and simulated exchange values.

¶3 **Simulated exchange value for reef tourism.** “Simulated exchange value” as used in reef tourism accounting refers to a specific construct from SEEA EA Chapter 9. It equals the tourism-related expenditure attributable to reef access multiplied by the reef ecosystem share of the tourist experience:

$$\text{Simulated exchange value} = (\text{Tourism expenditure attributable to reef access}) \times (\text{Reef ecosystem share})$$

¶4 The **reef ecosystem share** is estimated by subtracting the value of human-provided services to reef tourists (accommodation, transport, guiding services, gear hire) from total reef-related tourist expenditure and attributing the residual to the ecosystem. This residual approach ensures that the recorded value reflects only the ecosystem’s contribution rather than the gross tourism turnover. The simulated exchange value derivation is set out in SEEA EA paras. 9.52–9.59⁴⁶. Compilers unfamiliar with this construct should not substitute gross visitor expenditure (which overstates the ecosystem contribution) or consumer surplus (which is a welfare measure not consistent with the exchange-value basis of the accounts).

¶5 **Coastal protection** – Avoided damage cost methods compare expected damages with and without the reef⁴⁷. These methods require hazard modelling, exposure mapping, vulnerability assessment, and scenario comparison. Alternative approaches: replacement cost (engineered equivalents such as seawalls) and hedonic pricing (property value premiums).

¶6 **Non-use values** – Non-use values (existence, bequest, option) fall outside the exchange-value scope of the SEEA EA⁴⁸ but may be compiled as complementary welfare estimates (stated preference methods) in supplementary tables, clearly distinguished from core account entries. See **TG-1.9 Valuation** for the exchange-value/welfare-value distinction.

Valuation of ecosystem assets

¶1 The NPV method for ecosystem assets, the discount-rate choice, the perpetuity-or-finite-horizon decision, the rule that the condition adjustment is applied **once** at the service-flow step, and the degradation identity are all set out in **TG-3.1 Asset Accounts** Section 3.5.3, and are not restated here^{49, 50, 51}. Restoration cost as a complement to NPV is covered in the same place^{52, 53}.

¶2 What is reef-specific is the **service trajectory**. A stable-flow NPV that assumes service flows continue at the opening-period level for the whole projection horizon will substantially overstate the asset value of reefs facing documented bleaching risk under IPCC AR6 warming scenarios: reefs are among the few ecosystem assets for which a published, quantified condition decline is already available at national scale. Where a bleaching risk assessment exists – NOAA Coral Reef Watch projections, national climate scenarios, regional downscaled models – use it to project the condition trajectory forward and derive a declining service flow, rather than applying a perpetuity to the opening-period flow.

¶3 Two consequences follow. Present the climate-adjusted NPV **and** the stable-flow baseline, the latter as a sensitivity scenario, noting that the climate-adjusted estimate is a prudent lower bound for accounting purposes. And record the condition trajectory used, its source and the projection horizon in account metadata, because the trajectory is doing more work in the reef asset value than the discount rate is.

Reef accounts and disaster risk financing

¶1 Reef accounts directly support **parametric insurance** and other disaster risk financing instruments for bleaching damage, an application identified in the Outcome section. The monetary damage from a discrete bleaching event is calculated by combining the condition account with the services account:

$$\text{Damage} = (\text{Condition}_{\text{pre}} - \text{Condition}_{\text{post}}) \times \text{Reef area} \times \text{Annual service value per unit area}$$

¶2 where Condition_{pre} and Condition_{post} are the composite condition index scores immediately before and after the bleaching event, Reef area is the affected extent (ha), and Annual service value per unit area is drawn from the services account in Section 3.3. This damage estimate can serve as the indemnity in parametric insurance products where NOAA Coral Reef Watch **degree heating week (DHW)** thresholds are used as the trigger: for example, Alert Level 1 (4 DHW) for moderate bleaching and Alert Level 2 (8 DHW) for severe bleaching with widespread mortality risk⁵⁴. Compilers intending to use reef accounts for insurance purposes should align the bleaching prevalence condition variable in Table 2 with the DHW trigger levels used in the relevant insurance product, so that the condition-based damage estimate and the parametric trigger refer to the same underlying ecological event. Existing reef insurance products (e.g., the Quintana Roo Coastal Zone Management Trust) demonstrate the operational feasibility of this approach⁵⁵.

¶3 The Condition_{pre} and Condition_{post} values used in the damage formula must be drawn from the **DRF-composite** introduced in Section 3.2 (which includes bleaching prevalence or post-bleaching mortality), not the routine four-variable composite used for general condition reporting. A routine composite that omits bleaching will not respond to a bleaching event, so substituting it into the damage formula would yield Condition_{pre} approximately equal to Condition_{post} and an indemnity of zero regardless of the severity of the underlying ecological loss. Use of the DRF-composite for any insurance, parametric trigger, or disaster risk financing calculation is therefore mandatory, whilst the routine composite remains acceptable for general reporting.

3.5 Compilation Procedure

Step 1: Data collection and source identification

¶1 Primary data sources include:

¶2 Extent data:

- ¶3 Satellite imagery (Sentinel-2, Landsat, Planet) for reef extent classification
- ¶4 Allen Coral Atlas v2.0 for standardised reef mapping
- ¶5 National benthic habitat mapping programmes
- ¶6 Historical reef extent records for baseline establishment

¶7 Condition data:

- ¶8 Field survey data from reef monitoring programmes (transects, manta tows, photo quadrats)
- ¶9 NOAA Coral Reef Watch for thermal stress and bleaching alerts
- ¶10 GCRMN regional reports for comparative condition benchmarks
- ¶11 Water quality monitoring data from coastal stations

¶12 Services data:

- ¶13 Fisheries catch statistics from national agencies
- ¶14 Tourism visitation data from protected area authorities
- ¶15 Coastal infrastructure inventories for protection service valuation
- ¶16 Expenditure surveys for recreation service measurement

¶17 Data quality should be assessed following **TG-0.7 Quality Assurance**, with attention to temporal consistency, spatial coverage, and measurement uncertainty.

Step 2: Reef extent classification and mapping

¶1 Classify reef extent using IUCN GET M1.3, with optional sub-classification by geomorphology (fringing, barrier, atoll, patch) or depth zone (reef flat, crest, slope). Validate remote sensing classifications using field survey data. See **TG-4.1 Remote Sensing and Geospatial Data** for classification workflows.

Step 3: Condition variable measurement

¶1 Measure condition variables from Table 2 for each reef ecosystem asset (or spatially aggregated unit), calculating area-weighted averages at opening and closing periods. The SEEA EA recommends at least one variable per ECT class⁵⁶.

Step 4: Reference condition establishment and indicator derivation

¶1 Establish reference levels from historical baselines, reference sites, or scientific thresholds. Derive indicators using the standard and inverse normalisation formulas (Direction column of Table 2, with the formulas defined in **TG-2.1** Section 3.4.1). Aggregate into a composite index following the weighting guidance in Section 3.2 (live hard coral cover indicatively weighted at least 0.30; equal weighting as a documented default). Document reference level rationale, including data source, year, and spatial coverage where a site-specific historical baseline is used.

Step 5: Ecosystem service quantification

¶1 Quantify service flows in physical units using the classification in Table 3: harvest statistics for provisioning services, and biophysical models and survey methods for regulating and cultural services. Include the disaggregated water-quality sub-services and the split carbon stock/flow entries (Section 3.3). Link service flows to extent and condition, and validate against administrative data.

Step 6: Monetary valuation

¶1 Estimate monetary values using the methods in Section 3.4 and **TG-2.4 Environmental (including Ecosystem) Goods and Services** Section 3.10, applying resource-rent decomposition for fisheries and the simulated exchange value construct for tourism. Calculate NPV asset values at opening and closing periods, presenting both climate-adjusted and stable-flow scenarios where bleaching risk is documented.

Step 7: Account integration and balance sheet compilation

¶1 Compile extent, condition, services, and monetary asset accounts into the standard SEEA EA formats (Sections 3.1–3.4). Verify accounting identities (closing = opening + additions - reductions), cross-check physical and monetary consistency, and integrate reef accounts with national ocean accounts.

3.6 Worked Example

¶1 This worked example demonstrates the compilation of coral reef ecosystem accounts for a hypothetical atoll system representative of a Pacific small island developing state. The example follows the extent-condition-services-valuation sequence and illustrates the key accounting entries and calculations.

¶2 **Setting:** A national EAA containing an atoll with 4,850 hectares of coral reef ecosystem classified as M1.3 Photoc coral reefs. The reef system includes fringing reefs (2,900 ha), patch reefs (1,200 ha), and barrier reef sections (750 ha). National monitoring data document persistent sediment and nutrient pressure on the fringing reef component from terrestrial runoff. Consistent with the guidance in Section 3.1, a separate fringing-reef condition account is compiled alongside the

spatially aggregated atoll-wide account presented below, with both reported in the published account metadata.

Step 1: Extent account (year t to t+1)

Accounting entry	Coral reef extent (hectares)
Opening extent (year t)	4,850
Additions to extent	
– Managed expansion (restoration)	15
– Unmanaged expansion (natural recovery)	20
<i>Total additions</i>	35
Reductions in extent	
– Managed reduction (port development)	25
– Unmanaged reduction (cyclone damage + bleaching mortality)	65
<i>Total reductions</i>	90
Closing extent (year t+1)	4,795

¶1 *Net loss: 55 ha (1.1%). The bleaching component of the 65 ha unmanaged reduction satisfies both criteria for catastrophic loss classification (Section 3.1) and is recorded under the catastrophic-loss line item in the account workbook.*

Step 2: Condition account

¶1 Condition indicators are derived from field survey data using the reference levels and direction conventions in Table 2:

Condition variable	Direction	Observed value	VH	VL	Formula	Indicator score
Live hard coral cover	Standard	32%	40%	5%	$(V-VL)/(VH-VL)$	0.77
Herbivore fish biomass	Standard	38 kg/ha	50	5	$(V-VL)/(VH-VL)$	0.73
Macroalgae cover	Inverse	12%	5%	40%	$(VL-V)/(VL-VH)$	0.80
Reef rugosity index	Standard	1.72	2.0	1.2	$(V-VL)/(VH-VL)$	0.65

¶2 Composite condition index (live hard coral cover weighted 0.30 as the primary structural indicator, with the remaining weight of 0.70 distributed equally across three variables at $7/30 \approx 0.2333$ recurring each, so that weights sum to exactly 1.000):

$$\text{Composite} = 0.30 \times 0.77 + 0.2333 \times 0.73 + 0.2333 \times 0.80 + 0.2334 \times 0.65 = 0.231 + 0.170 + 0.187 + 0.152 = 0.74$$

¶3 For comparison, an equal-weighted composite (0.25 each) yields $(0.77 + 0.73 + 0.80 + 0.65) / 4 = 0.74$. For this dataset, the weighting choice does not materially shift the headline composite, but the weighting choice and its rationale are nevertheless documented in account metadata.

¶4 **DRF-composite (alongside the routine composite above).** Where the reef accounts are used to support parametric insurance or other disaster risk financing instruments, the bleaching-inclusive DRF-composite introduced in Section 3.2 is computed in parallel. The worked example uses an

illustrative bleaching prevalence observation of 8% with VH = 0% (good) and VL = 50% (poor). These reference values give an inverse-direction indicator of $(50 - 8) / (50 - 0) = 0.84$:

Condition variable	Direction	Indicator score	DRF weight
Live hard coral cover	Standard	0.77	0.30
Bleaching prevalence	Inverse	0.84	0.20
Herbivore fish biomass	Standard	0.73	0.167
Macroalgae cover	Inverse	0.80	0.167
Reef rugosity index	Standard	0.65	0.166

$$\begin{aligned} \text{DRF-composite} &= 0.30 \times 0.77 + 0.20 \times 0.84 + 0.167 \times 0.73 + 0.167 \times 0.80 + 0.166 \times 0.65 = \\ &0.231 + 0.168 + 0.122 + 0.134 + 0.108 = \mathbf{0.76} \end{aligned}$$

¶5 The DRF-composite (0.76) is marginally higher than the routine composite (0.74) for this worked example because the illustrative bleaching prevalence is low (8%, well below the VL of 50%). Under a discrete bleaching event raising prevalence post-event to, say, 40%, the bleaching indicator would fall to $(50 - 40) / 50 = 0.20$, and, with the other four indicators held constant, the DRF-composite would fall to $0.30 \times 0.77 + 0.20 \times 0.20 + 0.167 \times 0.73 + 0.167 \times 0.80 + 0.166 \times 0.65 = 0.2310 + 0.0400 + 0.1219 + 0.1336 + 0.1079 = 0.63$. This Condition_pre = 0.76 to Condition_post = 0.63 change (– 0.13) drives the damage formula in the Section 3.4 subsection on reef accounts and disaster risk financing. The routine composite, which excludes bleaching prevalence, would remain at 0.74 across the same event and would yield zero damage.

¶6 *Composite condition: 0.74. Rugosity is the limiting factor, indicating historical loss of three-dimensional reef architecture.*

Step 3: Ecosystem services (annual flows)

Service	Physical quantity	Monetary value (USD)
Reef fisheries	750 tonnes	2,250,000 (resource rent: see derivation below)
Coastal protection	42 km coastline	8,200,000 (avoided damage)
Recreation and tourism	115,000 person-visits	4,950,000 (simulated exchange value)
Total valued services (3 major)		15,400,000

¶1 Resource rent sub-calculation for reef fisheries:

Line item	Value (USD)
Gross revenue (750 t at USD 5,000/t)	3,750,000
less: Vessel operating costs	(600,000)
less: Labour costs	(700,000)
less: Capital consumption	(200,000)
Resource rent	2,250,000

¶2 Simulated exchange value sub-calculation for tourism:

Line item	Value (USD)
Total reef-related tourist expenditure (115,000 visits x USD 110 average)	12,650,000
less: Accommodation, transport, guiding (human-provided services)	(7,700,000)
Reef ecosystem share (simulated exchange value)	4,950,000

¶3 **Coastal-protection avoided-damage sub-derivation.** Coastal protection is the largest single service in this worked example (USD 8.2 million, 53% of the headline value) and is derived as the sum of a storm-avoidance component and chronic erosion- and flood-risk-avoidance components, both scaled by a reef-condition multiplier consistent with Ferrario and others (2014)⁵⁷.

Line item	Value (USD)
Storm component (1-in-50-year design event)	
Coastal capital at risk in the affected zone	410,000,000
Loss share without reef attenuation (12%)	49,200,000
Annualised over 50-year recurrence interval (EAD _{no-reef})	984,000
Loss share with reef attenuation at condition 0.74 (2.2%, per Ferrario 2014 wave-attenuation parameters)	9,020,000
Annualised over 50-year recurrence interval (EAD _{with-reef})	180,000
<i>Storm avoided-damage component (EAD_{no-reef} – EAD_{with-reef})</i>	<i>804,000</i>
Chronic erosion- and flood-risk-avoidance components	
Avoided chronic shoreline erosion and recurrent nuisance-flood damages referenced to the national coastal-asset register	7,400,000
Total coastal protection (storm + chronic, at condition 0.74)	8,204,000
Rounded value reported in the headline services table	8,200,000

¶4 The value scales linearly with reef condition via the multiplier (Condition / 0.74): a reef condition of 0.50 would reduce the coastal-protection service to USD 8,200,000 x (0.50 / 0.74) = USD 5,540,000, and a fully degraded reef (Condition = 0) would reduce it to zero. The chronic erosion and recurrent flood components are referenced to the national coastal-asset register, and the loss-share parameters follow Ferrario and others (2014)⁵⁷.

¶5 Additional services from Table 3, including ornamental fish/corals (USD 85,000), water-quality sub-services (USD 180,000), and net carbon flux (USD –8,000), are excluded from the headline asset valuation for simplicity but appear in the full services account in Section 3.3.

Step 4: Asset valuation – stable-flow and climate-adjusted scenarios

¶1 Applying a 4% social discount rate over a 25-year projection horizon:

¶2 **Stable-flow baseline (Service_t = USD 15,400,000 for all t):**

Asset value = 15,400,000 x present value annuity factor (4%, 25 years) Asset value = 15,400,000 x 15.62 = USD 240,550,000

¶3 **Climate-adjusted scenario.** NOAA Coral Reef Watch and national climate scenarios for this atoll project a decline in composite condition from 0.74 at t = 0 to approximately 0.55 at t = 25 under a SSP2–4.5 trajectory, with a roughly linear interpolation in intervening years. Applying Service_t = 15,400,000 x (Condition_t / 0.74) and discounting at 4%:

Climate-adjusted asset value ~ USD 211–216 million

¶4 The derivation: Condition_t declines linearly from 0.74 at t = 0 to 0.55 at t = 25, giving Condition_t / 0.74 values from 1.000 (year 0) down to 0.743 (year 25). Service_t = 15,400,000 x (Condition_t / 0.74) is summed as a discounted annuity at 4% over 25 years. The midpoint of the trajectory gives a discounted service sum of approximately USD 213 million. The +/- 3 million range reflects alternative endpoint assumptions: USD 211 million uses Condition₂₅ = 0.53 (lower bound

of the national scenario range) and USD 216 million uses Condition₂₅ = 0.57 (upper bound). Only one trajectory shape (linear decline) is modelled. Compilers with non-linear condition projections should substitute the appropriate Condition_t path.

¶5 Both values are recorded in the asset account, with the climate-adjusted figure flagged as the prudent lower bound. The Condition_t trajectory source and projection horizon are documented in metadata.

¶6 *The ~10–15% reduction under the climate-adjusted scenario reflects projected service-capacity decline. The reef carbon stock of 32,400 tC (Table 3 balance-sheet entry) is not included in the NPV, which captures annual service flows only. Including the carbon stock would double-count against approaches that draw on that figure separately.*

Step 5: Integration with national accounts

- ¶1 Extent decline (1.1%) and condition index (0.74) feed into **TG-2.1 Biophysical Indicators** as headline reef health metrics.
- ¶2 Annual service flow (USD 15.4 million) contributes to **TG-2.4 Ecosystem Goods and Services**.
- ¶3 Protected coastline (42 km) links to **TG-1.3 OA and Marine Spatial Management** for MPA effectiveness analysis.
- ¶4 The bleaching-damage formula (Section 3.4) connects condition and service accounts to disaster risk financing.
- ¶5 Reef fisheries (750 tonnes) cross-references **TG-6.7 Fisheries Accounting**.
- ¶6 Extent data sourced from Sentinel-2 imagery (**TG-4.1**), and condition variables from 35 monitoring site transects (**TG-4.2 Survey Methods**).

4. Supplementary Materials

4.1 Data Sources

¶1 Key data sources for coral reef ecosystem accounting include:

- ¶2 **Allen Coral Atlas** (allencoralatlas.org) – global reef extent and geomorphic mapping at approximately 5-metre resolution derived from Planet satellite imagery, version 2.0 released 2022
- ¶3 **Global Coral Reef Monitoring Network (GCRMN)** – standardised reef condition monitoring protocols and regional reports, sixth global status report published 2021
- ¶4 **NOAA Coral Reef Watch** (coralreefwatch.noaa.gov) – satellite-derived bleaching alerts, sea surface temperature, and degree heating weeks, updated daily
- ¶5 **Reef Check** – volunteer reef monitoring data using standardised protocols
- ¶6 **World Resources Institute Reefs at Risk** – global threat and value assessments
- ¶7 **National reef monitoring programmes** – country-specific monitoring systems (e.g., Australian Institute of Marine Science Long-Term Monitoring Program)
- ¶8 **FAO fisheries statistics** – reef-associated catch data
- ¶9 **CITES Trade Database** (managed by UNEP-WCMC) – international trade data for live corals (kg) and ornamental fish (number of specimens) consistent with the Table 3 ornamental species units

5. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

6. References

¶1 See the SEEA Ecosystem Accounting framework (2021) and related technical guidance for detailed methodological specifications. Key references include:

- ¶2 United Nations and others (2021). *System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA)*.
- ¶3 NCAVES and MAIA (2022). *Monetary valuation of ecosystem services and ecosystem assets for ecosystem accounting: Interim Version 1st edition*.
- ¶4 Keith, D.A. and others (2020). *IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*.
- ¶5 Sheppard, C., Davy, S., Pilling, G. and Graham, N. (2018). *The Biology of Coral Reefs*. Second Edition. Oxford University Press.
- ¶6 Ferrario, F., Beck, M.W., Storlazzi, C.D., Micheli, F., Shepard, C.C. and Airolidi, L. (2014). The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature Communications*, 5, 3794.
- ¶7 GCRMN (2021). *Status of Coral Reefs of the World: 2020*. Global Coral Reef Monitoring Network/International Coral Reef Initiative.
- ¶8 Allen Coral Atlas (2022). *Allen Coral Atlas v2.0*. Vulcan Inc./Arizona State University. Available at allencoralatlas.org.
- ¶9 Hughes, T.P. and others (2017). Coral reefs in the Anthropocene. *Nature*, 546, 82–90.
- ¶10 Beck, M.W. and others (2018). The global flood protection savings provided by coral reefs. *Nature Communications*, 9, 2186.
- ¶11 de Goeij, J.M. and others (2013). Surviving in a marine desert: the sponge loop retains resources within coral reefs. *Science*, 342, 108–110.

FOOTNOTES

1. ¶1 IUCN GET M1.3 Photic coral reefs describes coral reefs as ecosystems “found in warm, shallow (rarely >60 m deep), clear, relatively nutrient-poor, open coastal waters” where temperatures vary between 17–34 degrees C. See Keith, D.A. and others (2020), *IUCN Global Ecosystem Typology 2.0*.
2. ¶2 SEEA EA para. 3.12 and Appendix A3.2 recognise the alignment between SEEA ecosystem type classification and the IUCN Global Ecosystem Typology.
3. ¶3 SEEA EA para. 3.5 defines ecosystem assets as “contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions.”
4. ¶4 SEEA EA para. 3.12.
5. ¶5 This figure illustrates the conceptual linkages between the four account types compiled for coral reef ecosystems, following the accounting sequence described in SEEA EA Chapters 3, 4, 5, and 7–8.
6. ¶6 SEEA EA Chapter 4 (paras. 4.1–4.30) provides the methodology for ecosystem extent accounts.
7. ¶7 For remote sensing methods applicable to coral reef mapping, see [TG-4.1 Remote Sensing and Geospatial Data](#) and SEEA EA para. 4.10 on the use of Earth observation data.
8. ¶8 IUCN GET M1.3 and SEEA EA Table 3.2.
9. ¶9 SEEA EA para. 3.22–3.24 discusses national adaptation of ecosystem type classifications, including zone- or community-based sub-classifications applicable to coral reefs.
0. ¶10 SEEA EA paras. 3.22–3.24.
1. ¶11 SEEA EA Table 4.1 presents the standard ecosystem extent account format.
2. ¶12 SEEA EA para. 4.14–4.17 distinguishes managed and unmanaged additions and reductions.
3. ¶13 SEEA EA para. 4.17. The classification of climate-driven bleaching mortality as an unmanaged reduction follows the SEEA EA distinction between managed changes (resulting from deliberate decisions) and unmanaged changes (associated with natural processes, including those influenced by anthropogenic pressures).
4. ¶14 SEEA CF para. 5.49 and Chapter V define catastrophic losses procedurally as “large-scale, discrete and recognizable events” that are unexpected and exceptional; no quantitative mortality percentage is specified in SEEA CF, SEEA EA, GCRMN, NOAA, or IUCN guidance.
5. ¶15 SEEA EA Table 4.2 and paras. 4.20–4.28 present the ecosystem type change matrix format and methodology.
6. ¶16 SEEA EA para. 2.26 and 5.3.
7. ¶17 SEEA EA para. 5.29–5.40 and Table 5.2 present the Ecosystem Condition Typology (ECT).
8. ¶18 Adapted from SEEA EA Table 5.7 examples for marine ecosystems. Reference levels are indicative and should be calibrated to regional baselines.
9. ¶19 SEEA EA para. 5.68.

0. ¶20 SEEA EA paras. 5.77–5.88.
1. ¶21 Live hard coral cover is treated as the primary structural indicator of reef condition in the peer-reviewed literature; see Hughes, T.P. and others (2017), “Coral reefs in the Anthropocene”, *Nature*, 546, 82–90. The indicative minimum weight of 0.30 is an editorial recommendation and a methodological choice that compilers must document; it is not prescribed in SEEA EA paras. 5.77–5.88 or any specific weighting study.
 2. ¶22 Coral bleaching is a well-documented indicator of thermal stress; see Sheppard, C., Davy, S., Pilling, G. and Graham, N. (2018), *The Biology of Coral Reefs*, Oxford University Press.
 3. ¶23 IUCN GET M1.3 Photic coral reefs.
 4. ¶24 NOAA Coral Reef Watch provides satellite coral bleaching monitoring products at coralreefwatch.noaa.gov.
 5. ¶25 SEEA CF Chapter V, section on catastrophic losses (para. 5.49), describing “exceptional and significant reductions in the natural resource due to discrete events”. See footnote 14a.
 6. ¶26 SEEA EA Tables 5.3, 5.4, and 5.5 present variable, indicator, and index account formats.
 7. ¶27 SEEA EA Chapter 6–7 (paras. 6.1–7.46) provide the methodology for ecosystem services accounts.
 8. ¶28 SEEA EA para. 6.43–6.52 addresses provisioning services.
 9. ¶29 SEEA EA para. 6.73–6.81 discusses regulating services for coastal protection.
 0. ¶30 SEEA EA Table 6.3 lists coastal protection among regulating ecosystem services.
 1. ¶31 The relationship between reef condition and coastal protection capacity is documented in the scientific literature; see Ferrario et al. (2014) “The effectiveness of coral reefs for coastal hazard risk reduction and adaptation”, *Nature Communications*.
 2. ¶32 Sponge biofiltration on coral reefs is documented by de Goeij, J.M. and others (2013), “Surviving in a marine desert: the sponge loop retains resources within coral reefs”, *Science*, 342, 108–110. Reef-area-normalised sponge biofiltration rates are not yet standardised in published GCRMN, AIMS, or equivalent monitoring protocols; the metric “sponge biofiltration rate (L/h/m²) x reef area” should therefore be reported as indicative, with the underlying sponge density and per-individual pumping-rate sources documented. SEEA EA paras. 6.73–6.81 cover regulating services.
 3. ¶33 SEEA EA Chapter 13 and Table 13.4 identify core ocean statistics for biogeochemical cycling by ecosystem type.
 4. ¶34 Ware, J.R., Smith, S.V. and Reaka-Kudla, M.L. (1992). Coral reefs: sources or sinks of atmospheric CO₂? *Coral Reefs*, 11(3), 127–130. See also SEEA EA para. 6.82–6.90 on global climate regulation services and the distinction between carbon storage stocks and carbon sequestration flows.
 5. ¶35 SEEA EA para. 6.91–6.105 addresses cultural services including recreation.
 6. ¶36 SEEA EA para. 13.81.
 7. ¶37 SEEA EEA Technical Recommendations para. 4.103.
 8. ¶38 SEEA EA Table 7.1 presents the standard ecosystem services supply and use account format.
 9. ¶39 The negative net annual carbon flux is retained as a negative service flow rather than suppressed, so that monetary valuation does not systematically overstate reef carbon services. The carbon price applied is the domestic emissions trading scheme price where one exists, or the national social cost of carbon reference value, and is documented in account metadata.
 0. ¶40 CITES Trade Database (managed by UNEP-WCMC) records live corals in kilograms and ornamental fish in number of specimens; these conventions are applied to the Table 3 ornamental species sub-rows to ensure inter-country comparability.
 1. ¶41 SEEA EA Chapter 9–10 and the NCAVES/MAIA Valuation Guidance provide detailed valuation methodology.
 2. ¶42 SEEA EA para. 9.14.
 3. ¶43 SEEA EA para. 9.37–9.45 discusses resource rent approaches. The net price method for small-scale fisheries with near-zero or negative input-subtraction resource rent follows SEEA EA para. 9.42.
 4. ¶44 SEEA EA para. 9.52–9.60 addresses valuation of cultural services.
 5. ¶45 SEEA EEA Technical Recommendations para. 5.41.
 6. ¶46 SEEA EA paras. 9.52–9.59 (verify exact paragraph numbering against the SEEA EA 2021 PDF before final publication). The simulated exchange value construct for recreation/tourism is corroborated in the applied valuation literature; see Hein and others (2015), *Ecological Economics*, 139, 140–149, and Remme and others (2022), *Ecosystem Services*, 54.
 7. ¶47 SEEA EA para. 9.62–9.70 discusses avoided damage cost and related approaches.
 8. ¶48 SEEA EA para. 2.53.
 9. ¶49 SEEA EA para. 10.17–10.35 presents the net present value approach for ecosystem asset valuation.
 0. ¶50 SEEA CF para. 5.137 on the discount factor.
 1. ¶51 SEEA EA para. 10.71–10.80 addresses the measurement of ecosystem degradation (paragraph range to be verified against the SEEA EA 2021 PDF before publication).
 2. ¶52 SEEA EA para. 10.45–10.52 discusses restoration cost approaches.
 3. ¶53 SEEA EA para. 10.46.
 4. ¶54 NOAA Coral Reef Watch degree heating week (DHW) products and alert level thresholds are documented at coralreefwatch.noaa.gov. Alert Level 1 (4 DHW) is associated with significant bleaching risk; Alert Level 2 (8 DHW) with widespread bleaching and mortality risk.
 5. ¶55 Beck, M.W. and others (2018). The global flood protection savings provided by coral reefs. *Nature Communications*, 9, 2186 (DOI: 10.1038/s41467-018-04568-z). The Quintana Roo Coastal Zone Management Trust (Mexico) provides an operational example of parametric reef insurance triggered on wind speed and reef condition.

6. ¶56 SEEA EA para. 5.46. “Ideally, the compilation of ecosystem condition accounts should ensure that for each ecosystem type, at least one variable is selected for each of the six ECT classes.”
7. ¶57 Ferrario, F., Beck, M.W., Storlazzi, C.D., Micheli, F., Shepard, C.C. and Airoldi, L. (2014). “The effectiveness of coral reefs for coastal hazard risk reduction and adaptation”, *Nature Communications*, 5, 3794. The 2.2% reef-at-tenuated loss share applied at condition 0.74 is an illustrative figure consistent with the wave-energy and wave-height attenuation parameters reported in that paper; compilers should derive country-specific values from their national coastal hazard modelling using the Ferrario parameter ranges as a guide.

DRAFT