

# Asset Accounts

Builds asset accounts for ocean resources – the structured records that track what you have, what you gained, what you lost, and what remains.

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|---------------------|------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|------------------|---------|
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## OUTCOME

After working through this Circular, you will be able to build asset accounts for ocean resources – the structured records that track what you have, what you gained, what you lost, and what remains. These capabilities connect directly to the budget processes described in [TG-1.1 OA and National Budget Processes](#), where asset accounts provide the evidence base for allocating public resources to ocean conservation and sustainable use. They also underpin the depletion-adjusted income measures that indicate whether economic growth is coming at the expense of natural capital.

Section 3.5.3 additionally specifies the choices that govern any net present value valuation of an ecosystem asset – perpetuity against finite horizon, and the functional form linking a change in condition to a change in service capacity – together with ecosystem degradation, damage cost, and the offset requirement and restoration equivalence unit that no-net-loss policies rest on. Those specifications are normative for the publication; the service-level valuation methods they discount are in [TG-2.4 Environmental \(including Ecosystem\) Goods and Services](#) Section 3.10.

Ocean accounts answer to two disciplines at once. Accounting requires that numbers balance, whilst ecology describes fish populations whose dynamics resist neat categorisation. This Circular sets out how to satisfy both: maintaining the accounting identities that ensure internal consistency whilst respecting the ecological behaviour of marine systems.

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ABOUT THIS CIRCULAR

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## 1. Outcome

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## 2. Requirements

¶1 **Essential prerequisites:**

- ¶2 **TG-0.1 General Introduction to Ocean Accounts:** conceptual framework and domain structure
- ¶3 **TG-0.2 Overview of Relevant Statistical Standards:** SNA/SEEA accounting architecture

¶4 **Helpful background:**

- ¶5 **TG-0.7 Quality Assurance Principles:** data quality and uncertainty management

### ¶6 Framework Position

¶7 This Circular addresses the stock side of the Ocean Accounts Framework – asset accounts that record the state of marine and coastal assets across all three stock domain groups. SNA produced assets (SG1) are subject to capital formation and depreciation through economic flows (E3). Environmental assets (SG3) supply ecosystem services to the economy (E9) and support intermediate ecological processes (E11). In the Ocean Accounts Framework (TG-0.1 Figure 0.1.2):

| Edge | Direction | Description                                                               |
|------|-----------|---------------------------------------------------------------------------|
| E3   | FG1 ↔ SG1 | Economic flows interacting with SNA assets (Applied)                      |
| E9   | SG3 → FG1 | Environmental assets supplying ecosystem services to economy (Applied)    |
| E11  | FG3 ↔ SG3 | Environmental assets supporting intermediate ecosystem services (Applied) |

¶8 **Scope.** TG-3.1 owns the asset account tables – physical and monetary, individual environmental assets and ecosystem assets – their rows, columns and accounting identities, and the compilation procedure that populates them. It cross-refers for the sector-specific method that produces an entry: fisheries stock assessment and sustainable yield to **TG-6.7**, aquaculture to **TG-3.9** and **TG-6.8**, offshore energy to **TG-3.10** and **TG-6.9**, pelagic delineation to **TG-6.5**; for the measurement of the variables it records to Section 4, in particular **TG-4.1** for extent and **TG-4.8** and **TG-4.9** for condition; and for the service-level valuation methods its NPV calculations discount to **TG-2.4** Section 3.10.

## 3. Guidance Material

¶1 Asset accounts record what you hold and what you have used. They give the stock of marine assets at the beginning and end of an accounting period and every change in between – growth, extraction, natural losses, discoveries, and measurement revisions<sup>1</sup>. This structured bookkeeping allows the central question to be answered: whether ocean capital is being drawn down faster than it regenerates.

¶2 Two complementary accounting frameworks apply to ocean assets. The SEEA Central Framework provides the methodology for accounting for individual environmental assets – fish stocks, seabed minerals, water resources – each tracked separately. SEEA Ecosystem Accounting extends this by treating ecosystems as integrated spatial units: a coral reef or seagrass meadow as a whole rather than only the fish or carbon within it. For ocean accounting, you will typically need both. The individual asset approach records how many tonnes of fish remain, whilst the ecosystem asset approach records whether the reef that supports those fish is expanding or contracting.

¶3 This section examines the structure and accounting entries for physical and monetary asset accounts, before addressing the specific requirements for individual environmental assets (Section 3.4), ecosystem assets (Section 3.5), and produced assets in the ocean domain (Section 3.6). Section 3.2 provides a compilation procedure detailing the steps from data collection to account entry, whilst Section 3.7 presents a worked example with synthetic data demonstrating how to populate asset accounts for a hypothetical coastal area. The methodology presented here provides the basis for the thematic circulars on coral reef accounts (**TG-6.1**), mangrove and wetland accounts (**TG-6.2**), and seagrass accounts (**TG-6.3**).

### 3.1 Physical Asset Accounts

¶1 Physical asset accounts are where you count what you have in tangible units – tonnes of fish, hectares of seagrass, cubic metres of sand. They record whether marine resources are growing or shrinking in physical terms, before any monetary valuation is applied<sup>2</sup>. This matters because price changes can mask physical depletion: a fish stock can be worth more in dollar terms even as the population collapses, since scarcity drives up prices. Physical accounts separate the volume change from the price change.

### Basic structure

¶1 Every physical asset account follows the same logic<sup>3</sup>:

1. ¶2 **Opening stock** – what you had at the start of the year
2. ¶3 **Additions to stock** – everything that increased the stock during the year, including natural growth, discoveries, upward reapraisals, and reclassifications
3. ¶4 **Reductions in stock** – everything that decreased the stock, including extractions, natural losses, catastrophic losses, downward reapraisals, and reclassifications
4. ¶5 **Closing stock** – what you have at the end of the year

¶6 The closing stock must equal the opening stock plus total additions minus total reductions. If it does not balance, something is missing from your records – unreported catch, an unobserved storm event, or a measurement error. This accounting identity is your quality control mechanism: it forces you to account for every change (Figure 3.1.1).

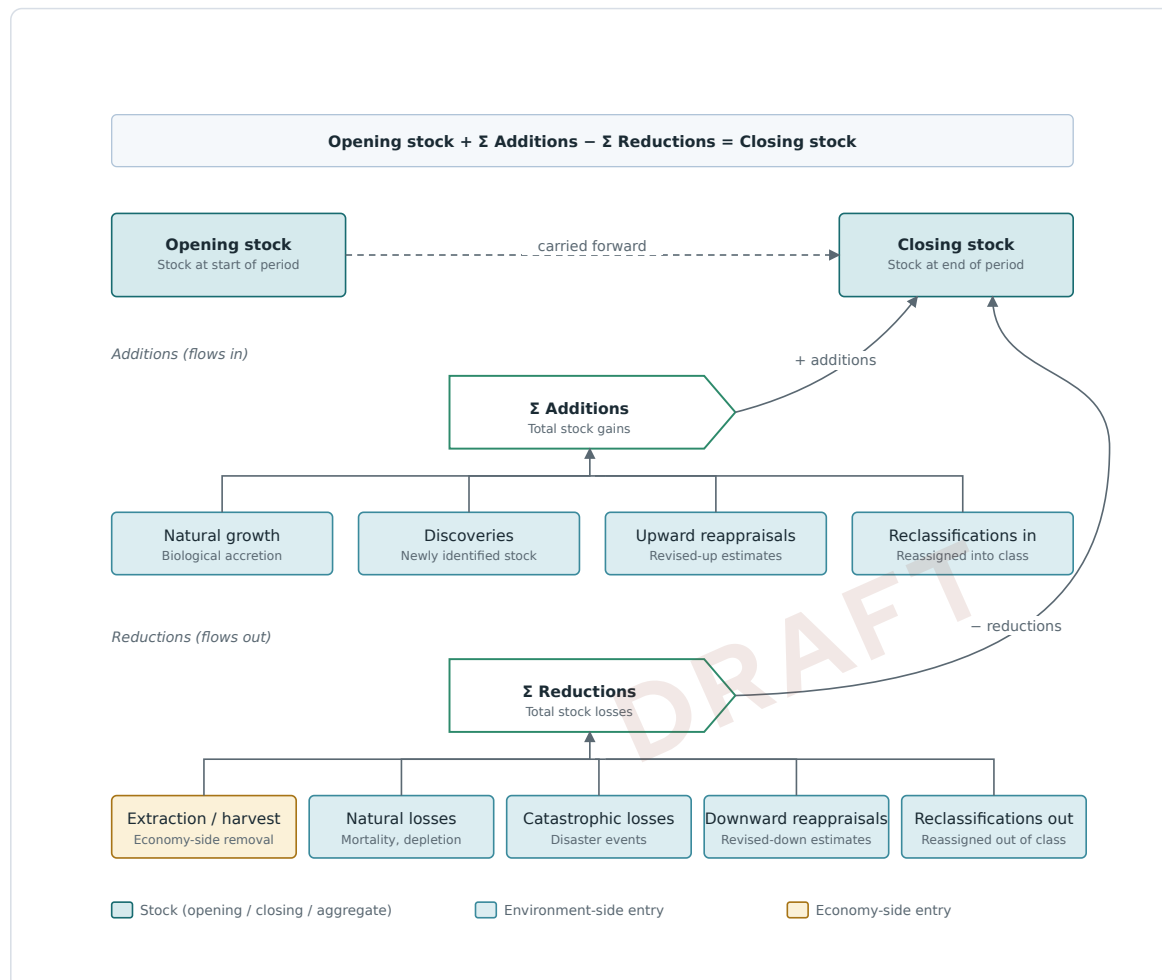


**Figure 3.1.1** SEEA Central Framework environmental-asset accounts follow one stock-flow identity: opening stock plus additions minus reductions equals closing stock. Extraction/harvest is the only economy-side reduction; contrast the ecosystem extent account in Figure 3.1.2.

**Source:** SEEA CF Table 5.2 (physical asset account structure by type of asset); SEEA CF paras 5.43-5.46; TG-3.1.

**Adapted from:** SEEA CF Table 5.2, recast as a stock-flow identity diagram for TG-3.1.

### Additions to stock

¶1 **Natural growth** is the primary addition for renewable resources like fish stocks. It encompasses recruitment – new fish joining the stock – and biomass increase as existing individuals grow<sup>4</sup>. Natural growth is driven by biological processes that vary with environmental conditions, stock size, and species characteristics. For a fisheries manager, natural growth sets the sustainable harvest ceiling: the largest catch that can be taken without reducing the stock's long-term productivity<sup>5</sup>. An accurate measure of natural growth therefore allows harvest limits to be set that keep the stock stable.

¶2 **Discoveries** apply primarily to non-renewable resources. In ocean accounting, this means identification of new oil and gas deposits, seabed mineral resources such as polymetallic nodules and seafloor massive sulphides, and rare earth elements in marine sediments<sup>6</sup>. Discoveries can also apply to aquatic resources when previously unknown fish stocks are identified and assessed – though this is rare in well-surveyed waters.

¶3 **Upward reapraisals** record cases where the estimate of stock size increased but the stock itself did not physically change<sup>7</sup>. The distinction separates a real change in the ocean from an improvement in measurement. For fish stocks, a reappraisal occurs when a stock assessment model is updated with new data and produces a revised biomass estimate. The SEEA CF acknowledges that for fish stocks, "it may not be possible to attribute the changes to natural causes or harvesting activity" and in such cases "only a

regional or national aggregate resource value will be produced”<sup>8</sup>. Compilers should therefore document whether a stock change reflects biological dynamics or improved measurement, even where the boundary between the two is indistinct.

¶4 **Reclassifications** record transfers between asset categories without any physical change<sup>9</sup>. A common ocean example: when a wild fish stock becomes subject to aquaculture operations, it transfers from natural aquatic resources to cultivated aquatic resources. The SEEA CF emphasises that “in cases where stocking with cultured seeds is regularly conducted, as commonly observed in freshwater resources, it is important to include the amount of released seeds as a reclassification from cultivated aquatic resources”<sup>10</sup>. Misclassification matters for policy: it can make wild stocks appear to be growing when they are in fact being supplemented by hatchery production.

### Reductions in stock

¶1 **Extraction** (or harvest, for biological resources) is the removal of natural resources for use in economic activity<sup>11</sup>. For fish stocks, extraction corresponds to gross catch – the total live weight of fish caught, including discarded catch but excluding pre-catch losses<sup>12</sup>. Countries use gross catch rather than landings because discards still remove fish from the ocean, even though they never reach port. The FAO defines the stages of catch as<sup>13</sup>:

- ¶2 *Gross removal*: total live weight of fish caught or killed during fishing operations
- ¶3 *Gross catch*: gross removal less pre-catch losses
- ¶4 *Retained catch*: gross catch less discarded catch
- ¶5 *Landings*: net weight of quantities landed at port
- ¶6 *Nominal catch*: live weight equivalent of landings

¶7 **Normal losses** (natural mortality for biological resources) are decreases from natural processes – death from age, predation, disease, and accidents<sup>14</sup>. For fish stocks, natural mortality is a key parameter in stock assessment models. It must be estimated alongside fishing mortality to understand population dynamics, because a stock with high natural mortality can tolerate less fishing pressure than one where most individuals die of old age.

¶8 **Catastrophic losses** are “exceptional and significant reductions in the natural resource”<sup>15</sup> due to discrete events – storms, disease outbreaks, toxic algal blooms, mass coral bleaching, or oil spills. The distinction from normal losses matters for two reasons. First, if catastrophic losses are increasing in frequency, that is a warning sign that environmental conditions are deteriorating. Second, catastrophic losses are unpredictable and fall outside the scope of normal management, so they need to be tracked separately to avoid distorting assessments of whether routine management is working.

¶9 **Downward reappraisals and reclassifications** mirror their counterparts in additions, recording accounting adjustments from improved information or transfers between categories.

### Depletion

¶1 Depletion is the central sustainability signal in the asset account. It records whether a renewable resource is being harvested faster than it can regenerate, and by how much. For a policy-maker, depletion answers whether current consumption is drawing down the productive base itself.

¶2 For renewable resources, depletion occurs when “the extraction of the natural resource is occurring at a level greater than that of regeneration”<sup>16</sup>. The formula is straightforward:

$$\text{Depletion} = \max(0, \text{Extraction} - \text{Sustainable yield})$$

¶3 When extraction stays at or below sustainable yield, depletion is zero – the stock can absorb the harvest. When extraction exceeds sustainable yield, every tonne above that threshold is depletion – a reduction in the stock’s future productive capacity<sup>17</sup>. For non-renewable resources such as mineral deposits, there is no regeneration, so depletion equals extraction: every barrel of offshore oil extracted is permanently removed from the stock.

¶4 Depletion links the physical and monetary accounts. In the 2025 SNA, depletion of natural resources is treated as a cost of production analogous to depreciation of produced assets, reducing net measures of income and product<sup>18</sup>. A country reporting high GDP from fisheries alongside high depletion is therefore overstating its true income, since part of what appears as earnings is the liquidation of natural capital. The SEEA CF notes that “since the drivers for changes in populations of aquatic resources can only be modelled, it may be difficult to obtain precise and consistent measures of sustainable yield over time”<sup>19</sup>. For methodological guidance on estimating sustainable yield and depletion for fisheries, see **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**.

## 3.2 Compilation Procedure for Asset Accounts

¶1 This section walks through the step-by-step procedure for compiling ocean asset accounts, beginning with the assembly of raw data and ending with balanced accounts that integrate with the broader national accounting system. Following these steps ensures that your accounts are internally consistent and comparable across asset types.

### Step 1: Data collection and source identification

¶1 Start by identifying the data sources you need for each asset type. Different marine assets draw on distinct data sources:

¶2 **For individual environmental assets** (fish stocks, seabed minerals):

- ¶3 **Stock assessment reports** from fisheries management agencies, providing estimates of spawning stock biomass, recruitment, natural mortality, and fishing mortality (see **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**)
- ¶4 **Geological surveys and commercial exploration reports** for mineral and energy resources, including estimates of proven reserves and probabilistic resource classifications (see **TG-3.10 Offshore Energy Accounts**)

- ¶5 **Catch statistics** from fisheries agencies and international databases (FAO FishStatJ), recording landings, gross catch, and discards by species and fishing zone
- ¶6 **For ecosystem assets** (coral reefs, seagrass meadows, mangroves):
  - ¶7 **Remote sensing imagery** (Sentinel-2, Landsat, MODIS) processed to classify ecosystem extent and detect changes over time (see **TG-4.1 Remote Sensing and Geospatial Data**)
  - ¶8 **Field survey data** from ecological monitoring programmes, providing measurements of ecosystem condition variables such as coral cover, seagrass shoot density, mangrove canopy height, and water quality parameters (see **TG-4.2 Survey Methods for Ocean Economic Activity**)
  - ¶9 **National spatial databases** delineating protected areas, coastal zone boundaries, and ecosystem type classifications consistent with the IUCN Global Ecosystem Typology
- ¶10 Assess data quality following **TG-0.7 Quality Assurance Principles**. Pay particular attention to three things: temporal consistency (are opening and closing stocks measured on a comparable basis?), spatial coverage (do the data cover the full accounting area?), and measurement uncertainty (what are the confidence intervals, and are they documented?).

## Step 2: Classification and mapping to asset categories

¶11 Next, map your source data to the asset classification system used in the accounts. Getting this right matters because it determines how your numbers aggregate and compare with other countries. The SEEA CF classifies environmental assets into major categories including aquatic resources, mineral and energy resources, water resources, timber resources, land, and soil resources<sup>20</sup>. For ocean accounting, the relevant categories are:

- ¶12 **Natural aquatic resources** (wild fish, shellfish, and other uncultivated aquatic organisms)
- ¶13 **Cultivated aquatic resources** (farmed fish, shellfish, and seaweed)
- ¶14 **Mineral and energy resources** (offshore oil and gas, seabed minerals, marine aggregates)
- ¶15 **Water resources** (coastal aquifers subject to saltwater intrusion, and seawater abstraction is recorded as an abiotic flow rather than an asset stock)

¶16 SEEA EA ecosystem assets are classified using the IUCN Global Ecosystem Typology. Table 3.2.1 below summarises the marine ecosystem types.

| IUCN GET code                     | Ecosystem types covered                                                            |
|-----------------------------------|------------------------------------------------------------------------------------|
| <b>M1 Marine Shelf</b>            | Seagrass meadows, kelp forests, coral reefs, shellfish beds, subtidal rocky reefs. |
| <b>M2 Pelagic Ocean Waters</b>    | Epipelagic, mesopelagic, bathypelagic zones.                                       |
| <b>M3 Deep Sea Floors</b>         | Abyssal plains, submarine canyons, hydrothermal vents.                             |
| <b>MFT Brackish Tidal Systems</b> | Mangroves, saltmarshes, coastal brackish lagoons.                                  |
| <b>MT Shorelines</b>              | Rocky shores, sandy beaches.                                                       |

¶17 If your country uses a national ecosystem type classification that differs from the IUCN GET, document the correspondence between the two. This ensures that your ecosystem extent can be aggregated to standard categories for international comparison.

## Step 3: Measurement and quantification

¶11 With data sources identified and classifications established, you can quantify opening stocks, additions, reductions, and closing stocks in physical units appropriate to each asset type.

¶12 For **fish stocks**, stock assessment models provide estimates of total biomass (or spawning stock biomass) at the beginning of the accounting period (opening stock). Natural growth is estimated from recruitment models and individual growth rates. Extraction is measured as gross catch from fisheries statistics. Natural mortality is estimated from stock assessment parameters. The accounting identity (opening stock + growth - mortality - catch = closing stock) serves as your reconciliation tool. Where stock assessment provides direct estimates of both opening and closing stock, the identity becomes a consistency check, and discrepancies may indicate data errors or unobserved changes requiring reappraisal entries.

¶13 For **ecosystem extent**, remote sensing analysis provides the primary measurement of opening and closing extent, typically expressed in hectares or square kilometres. Change detection algorithms identify areas where ecosystem type has changed (conversions), distinguishing managed changes (restoration, conversion to aquaculture) from natural changes (storm damage, succession). Ground-truthing surveys validate remotely sensed classifications and provide confidence ratings. The SEEA EA recommends recording extent changes in a structured account showing managed expansion, natural expansion, managed reduction, and natural reduction separately<sup>21</sup>.

¶14 For **ecosystem condition**, the measurement process involves selecting condition variables for each ecosystem type following the SEEA EA Ecosystem Condition Typology (ECT), measuring variable values from field surveys or remote sensing, and normalising these values into indicators relative to reference conditions. Condition accounts record the raw variable values rather than derived indicators, whilst the indicator derivation is addressed in **TG-2.1 Aggregate Biophysical Indicators of Environmental State**.

## Step 4: Account entry and balancing

¶11 Once physical quantities have been measured, enter them into the asset account structure. The account must balance: closing stock = opening stock + total additions - total reductions. Any imbalance signals an error – either a data fault or a missing entry (unreported extraction, unobserved natural changes, or a needed reappraisal adjustment).

¶12 For marine assets, three issues require particular attention:

- ¶13 **Spatial boundaries**: Ensure that opening and closing stocks cover the same geographic area. If jurisdictional boundaries or accounting area definitions changed during the period, record those changes as reclassifications rather than real changes.

Otherwise, you will attribute administrative decisions to ecological processes.

- ¶4 **Unit consistency:** Keep all entries for a given asset in the same measurement unit. For fish stocks, this typically requires converting landings (wet weight) to live weight equivalent, and converting different life stages to a common biomass measure.
- ¶5 **Temporal alignment:** Ensure all entries refer to the same accounting period. Where stock assessments use different time periods or reference dates than the calendar year accounting period, adjustments may be needed.

#### Step 5: Monetary valuation (for monetary accounts)

¶1 For monetary asset accounts, you translate physical stock quantities into monetary values. This is the step where accounting and ecology are most in tension, since pricing a fish stock or a mangrove forest requires assumptions about a future that ecology renders uncertain.

¶2 For fish stocks and other renewable natural resources, the net present value (NPV) of expected future resource rents provides the standard valuation approach<sup>22</sup>. The NPV calculation requires:

1. ¶3 **Resource rent estimation:** Calculate the annual resource rent as the difference between the value of harvest and all costs (including labour, capital, intermediate inputs, and normal return on produced assets). This isolates the economic surplus that the natural resource itself contributes.
2. ¶4 **Discount rate selection:** Determine an appropriate discount rate reflecting the time value of money and asset-specific risk factors (see **TG-1.9 Safe Usage of Monetary Valuation** for detailed guidance). Higher discount rates reduce asset values, so this choice matters for policy.
3. ¶5 **Asset life assumption:** Estimate the expected duration of the resource rent stream. For sustainably managed renewable resources, this may be assumed to be perpetual.

¶6 For ecosystem assets, the monetary value is estimated as the NPV of expected future ecosystem service flows. This requires:

1. ¶7 **Service quantification:** Measure the physical supply of ecosystem services from the asset (see **TG-3.2 Flows from Environment to Economy**)
2. ¶8 **Service valuation:** Apply appropriate valuation methods to estimate unit prices for each ecosystem service
3. ¶9 **NPV calculation:** Discount the stream of future service values to present value

¶10 Changes in monetary value are decomposed into three components:

- ¶11 Changes due to physical volume changes (additions and reductions in stock)
- ¶12 Changes due to updated expectations about future rents or service flows (reappraisals)
- ¶13 Changes due to price movements (revaluations)

¶14 This decomposition matters because it prevents price effects from masking physical depletion. A fish stock can be worth more in dollar terms this year than last, even as the population declines, provided prices rose enough. Separating the two effects keeps the monetary account aligned with the underlying physical change.

#### Step 6: Integration with balance sheets and other accounts

¶1 The final step is integrating asset accounts with national balance sheets and with other ocean accounts. The balance sheet presents the stock of all assets (produced assets, non-produced natural assets, ecosystem assets, financial assets) and liabilities at a single point in time, enabling calculation of net worth<sup>23</sup>. Changes in net worth during the accounting period are explained by saving, capital transfers, and holding gains/losses recorded in the revaluation account.

¶2 For ocean accounting, integration ensures that:

- ¶3 **Depletion entries** in asset accounts correspond to depletion costs in production accounts and adjustments to net domestic product
- ¶4 **Extraction entries** in asset accounts correspond to natural resource inputs in physical supply-use tables (**TG-3.2 Flows from Environment to Economy**)
- ¶5 **Ecosystem service flows** are consistent with the capacity to supply services implied by ecosystem extent and condition (as illustrated in the worked example below)
- ¶6 **Investment in ocean infrastructure** (such as aquaculture facilities and offshore energy) is recorded as gross fixed capital formation in produced assets, enabling joint analysis of natural and produced capital stocks

¶7 Cross-stack connections upward to policy circulars include:

- ¶8 **TG-1.1 National Ocean Budgets** uses asset values and depletion estimates to inform natural capital budgeting
- ¶9 **TG-2.1 Aggregate Biophysical Indicators of Environmental State** derives extent change indicators and condition indices from asset accounts
- ¶10 **TG-2.2 Productivity Indicators** uses fish stock biomass and sustainable yield estimates to calculate indicators of resource productivity

¶11 Cross-stack connections downward to data circulars include:

- ¶12 **TG-4.1 Remote Sensing and Geospatial Data** provides methods for extent mapping that populate ecosystem extent accounts
- ¶13 **TG-4.2 Survey Methods for Ocean Economic Activity** provides protocols for condition variable measurement
- ¶14 **TG-4.3 Administrative Data Sources** provides the spatial framework for delineating ecosystem assets and aggregating data

¶15 Asset accounts therefore operate as an integrated component of the broader ocean accounting system rather than a stand-alone exercise.

### 3.3 Monetary Asset Accounts

¶1 Monetary asset accounts translate the physical stocks and changes described in Section 3.1 into economic values. This translation enables three things that physical accounts alone cannot do: aggregate across different asset types (you cannot add tonnes of fish to hectares of seagrass, but you can add their monetary values), compare environmental assets with produced and financial assets on common terms, and calculate depletion-adjusted income measures that reveal whether economic growth is genuine or is partly the liquidation of natural capital<sup>24</sup>. For detailed guidance on valuation methods applicable to ocean assets, see **TG-1.9 Safe Usage of Monetary Valuation**.

#### Structure of monetary asset accounts

¶1 The structure parallels physical accounts, with one important addition – a revaluation entry<sup>25</sup>:

1. ¶2 **Opening stock value** – the monetary value of the asset at the beginning of the accounting period
2. ¶3 **Additions to stock value** – value of growth, discoveries, and upward reappraisals
3. ¶4 **Reductions in stock value** – value of extractions, normal losses, catastrophic losses, and downward reappraisals
4. ¶5 **Revaluations** – changes in value due to price changes, distinct from physical changes
5. ¶6 **Closing stock value** – the monetary value at the end of the accounting period

¶7 The revaluation entry captures holding gains and losses – changes in asset value attributable to changes in prices rather than physical quantities<sup>26</sup>. This separation is essential: without it, a rise in asset value cannot be attributed to an improvement in the eco-system rather than a shift in market prices.

#### Valuation approaches

¶1 Environmental assets are typically not traded in markets, so no observable price exists. The SEEA CF describes several approaches to address this<sup>27</sup>:

¶2 **Net present value (NPV)** is the preferred approach for valuing natural resources. You estimate the stream of expected future resource rents – the economic surplus accruing to the resource owner after all costs and normal returns are deducted – and discount this stream to the present<sup>28</sup>. For natural resources:

$$\text{Value} = \text{Resource rent} \times \text{Discount factor}$$

¶3 where the discount factor adjusts for the time value of money and the expected duration of the income stream. The SEEA CF describes the discount factor (Omega) as linking “future resource rents to the present value of the asset”<sup>29</sup>. Key considerations for discount rate selection include the real rate of interest, expected asset life, and country-specific factors<sup>30</sup>.

¶4 Discount rate selection can affect asset valuations substantially, particularly for long-lived assets such as fish stocks under perpetual management regimes. A lower discount rate makes long-term sustainability more economically visible, whilst a higher rate assigns less weight to the distant future. The SEEA CF provides extensive guidance on discount rate methodology in Annex A5.2, covering asset life assumptions, risk adjustments, and country-specific factors<sup>31</sup>. For detailed guidance on discount rate selection and its implications for marine asset valuation, see **TG-1.9 Safe Usage of Monetary Valuation**.

¶5 **Market prices** may be used where environmental assets or rights to extract them are traded. For aquatic resources, long-term fishing licences and individual transferable quotas (ITQs) may provide market-based valuations<sup>32</sup>. Markets for environmental assets are, however, often thin or non-existent, and the approach therefore has limited applicability. The SEEA CF notes that “in many cases, where the government hands the access rights to fishermen, trading in these access rights is prohibited and there is therefore no directly observable market valuation”<sup>33</sup>.

#### Deriving resource rent for a wild-capture fishery

¶6 **Resource rent per tonne**. Resource rent is the surplus remaining after deducting all costs of fishing from the gross value of catch. It is estimated as:

¶7

$$\text{Resource rent per tonne} = \frac{\text{Gross value of landings} - (\text{Operating costs} + \text{Depreciation} + \text{Normal return to capital})}{\text{Total catch (tonnes)}}$$

¶8 Normal return to capital is estimated as the risk-free rate applied to the replacement value of the fishing fleet (SEEA CF para 5.114).

¶9 If gross value of landings is USD 28.8 million (24,000 tonnes at USD 1,200 per tonne average price), and total fishing costs are USD 18 million (including labour, fuel, vessel depreciation, normal return to capital), resource rent is USD 10.8 million. Resource rent per tonne is USD 10.8 million / 24,000 tonnes = USD 450 per tonne.

¶10 The rent estimated here is the **total** rent generated by the fishery, only part of which accrues to government as access payments or royalties. Where those receipts are also compiled in the governance revenue tables (**TG-3.7** Table 3.710b), the two must be reconciled rather than added; presenting government rent receipts alongside a depletion-adjusted net income measure without reconciliation double counts the same flow. The budget use of the resulting figure is in **TG-1.1** Section 3.4.

¶11 **Restoration cost** approaches estimate the cost of restoring an ecosystem asset to a reference condition. This approach is described in SEEA EA as a complement to NPV-based valuation, particularly for ecosystem degradation<sup>34</sup>. It answers a different question: the cost of replacing what has been lost, which is distinct from the worth of the ecosystem itself. See **TG-1.9 Safe Usage of Monetary Valuation** for detailed comparison of valuation approaches.

### Structural template – monetary asset account

¶1 Table 1b is the blank counterpart to the physical templates in Section 3.4, for individual environmental assets in monetary terms. The revaluation row is what distinguishes it from the physical account and is the row most often omitted; without it a price movement is indistinguishable from a change in the resource.

¶2 **Table 1b: Monetary asset account – structural template (after SEEA CF Table 5.17)**

| Accounting entry                                | Asset class 1 | Asset class 2 | ... | Total |
|-------------------------------------------------|---------------|---------------|-----|-------|
| Opening stock value                             | [value]       | [value]       | ... | [Σ]   |
| <b>Additions to stock value</b>                 |               |               |     |       |
| – Growth in stock                               | [value]       | [value]       | ... | [Σ]   |
| – Discoveries                                   | [value]       | [value]       | ... | [Σ]   |
| – Upward reappraisals                           | [value]       | [value]       | ... | [Σ]   |
| – Reclassifications in                          | [value]       | [value]       | ... | [Σ]   |
| <i>Total additions</i>                          | [Σ]           | [Σ]           | ... | [ΣΣ]  |
| <b>Reductions in stock value</b>                |               |               |     |       |
| – Extraction                                    | [value]       | [value]       | ... | [Σ]   |
| – Normal losses                                 | [value]       | [value]       | ... | [Σ]   |
| – Catastrophic losses                           | [value]       | [value]       | ... | [Σ]   |
| – Downward reappraisals                         | [value]       | [value]       | ... | [Σ]   |
| – Reclassifications out                         | [value]       | [value]       | ... | [Σ]   |
| <i>Total reductions</i>                         | [Σ]           | [Σ]           | ... | [ΣΣ]  |
| <b>Revaluation</b> (price change only)          | [+/-]         | [+/-]         | ... | [+/-] |
| <b>Net change in value</b>                      | [+/-]         | [+/-]         | ... | [+/-] |
| Closing stock value                             | [value]       | [value]       | ... | [Σ]   |
| <i>Memorandum: depletion at constant prices</i> | [value]       | [value]       | ... | [Σ]   |

¶3 *Table 1b: Structural template of a monetary asset account. The identity is Closing = Opening + total additions – total reductions + revaluation. The memorandum line carries depletion valued at the average of opening and closing prices, which is the figure adjusted in-come measures deduct; it is a memorandum rather than an account entry because its value is already inside the reduction rows.*

### Valuation of depletion

¶1 The monetary value of depletion is calculated by multiplying physical depletion by the appropriate asset price<sup>35</sup>. Following the conventions in the SNA and SEEA CF, depletion should be valued at the average of opening and closing prices:

$$\text{Monetary depletion} = \text{Physical depletion} \times (P_{\text{opening}} + P_{\text{closing}}) / 2$$

¶2 This mid-period valuation “is consistent with the rules in the SNA for the valuation of consumption of fixed capital”<sup>36</sup>: depletion of a fish stock is treated on the same footing as depreciation of a factory. Both represent the using-up of productive capacity, and both should be deducted from income.

## 3.4 Individual Environmental Assets

¶1 Individual environmental assets are “those environmental assets that may provide resources for use in economic activity”<sup>37</sup> – the specific natural resources that can be named and counted, such as fish stocks, oil deposits, and sand reserves. For ocean accounting, the principal categories include aquatic resources (Section 3.4.1), mineral and energy resources (Section 3.4.2), and water resources (Section 3.4.3).

### 3.4.1 Aquatic resources

¶1 **Aquatic resources** include fish, crustaceans, molluscs, shellfish and other aquatic organisms such as sponges and seaweed, as well as aquatic mammals such as whales<sup>38</sup>. These organisms are subject to harvest for commercial, subsistence, and recreational purposes. The SEEA CF distinguishes between:

- ¶2 **Natural aquatic resources** – wild fish and other aquatic organisms not under direct cultivation
- ¶3 **Cultivated aquatic resources** – organisms raised in aquaculture facilities, including fish, shellfish, seaweed, and other species

¶4 This distinction determines how the assets are classified in the accounts: natural aquatic resources are non-produced assets (nature made them), whilst cultivated aquatic resources are produced assets (fixed assets for breeding stocks, and inventories for stocks held for sale)<sup>39</sup>. The distinction matters for policy because the management interventions differ: a wild fishery is managed by controlling extraction, whereas aquaculture is managed by controlling production inputs. Detailed guidance on aquaculture accounting is provided in **TG-3.9 Aquaculture Accounts**.

¶5 **What the asset account requires of a stock assessment.** The account needs four things, whatever method produced them: an opening and a closing estimate of the **total** stock on a consistent basis, natural growth and natural mortality as separate entries, extraction measured as gross catch, and a documented statement of which of these were estimated independently and which were derived. Where the assessment supplies both endpoints directly, the accounting identity becomes a consistency check rather than a derivation, and any residual is entered as a reappraisal rather than absorbed silently.

¶6 Stock assessments commonly distinguish total stock, spawning stock biomass and exploitable stock<sup>40</sup>. The asset account takes the **total** stock; the other two are management reference points, and substituting one for another between periods breaks the time series without any change in the ocean. Where only a relative index such as catch per unit effort is available, the account cannot be closed on that index alone<sup>41</sup> and the limitation must be recorded in metadata; the index still carries a signal, since a declining CPUE trend “may be a signal that the rate of harvest is exceeding the renewal rate of the fish stock”<sup>42, 43</sup>.

¶7 The choice of assessment method – virtual population analysis, surplus production, tag-recapture, acoustic or trawl survey – and the treatment of CPUE standardisation and technological creep are matters for **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**, which also gives the tier mapping from assessment type to the account entries each can support.

¶8 **Classification of catch types.** The SEEA CF recommends using **gross catch** as the measure of extraction from natural aquatic resources<sup>44</sup>. Gross catch is defined as the total live weight of fish caught, comprising:

- ¶9 **Retained catch** – fish brought to shore as landings
- ¶10 **Discarded catch** – fish returned to the water, typically dead or dying

¶11 Using gross catch rather than landings matters because discards still remove fish from the ocean. In some fisheries, discards constitute a substantial fraction of total catch, so ignoring them would understate the impact on fish stocks. The SEEA CF notes that “the measurement of discarded catch is an important contributory factor to a full understanding of the linkages between economic activity and the impact on aquatic resources”<sup>45</sup>. Omitting discards would understate that impact.

¶12 Where direct measurement through at-sea observer programmes is unavailable, discard rates may be estimated using species-specific discard ratios from comparable fisheries, gear-type-specific discard rates from regional studies, or logbook-based self-reporting validated against observer data. For guidance on survey methods applicable to discard estimation, see **TG-4.2 Survey Methods for Ocean Economic Activity**.

¶13 **Physical asset account for aquatic resources.** Table 1 presents the structure of a physical asset account for aquatic resources, distinguishing between cultivated and natural resources.

| Accounting entry           | Cultivated aquatic resources | Natural aquatic resources | Total   |
|----------------------------|------------------------------|---------------------------|---------|
| Opening stock              | 12,000                       | 180,000                   | 192,000 |
| <b>Additions to stock</b>  |                              |                           |         |
| – Growth in stock          | 3,500                        | 28,000                    | 31,500  |
| – Upward reappraisals      | –                            | 5,000                     | 5,000   |
| – Reclassifications        | 200                          | –                         | 200     |
| <i>Total additions</i>     | 3,700                        | 33,000                    | 36,700  |
| <b>Reductions in stock</b> |                              |                           |         |
| – Gross catch/harvest      | 3,200                        | 24,000                    | 27,200  |
| – Normal losses            | 400                          | 15,000                    | 15,400  |
| – Catastrophic losses      | –                            | 2,000                     | 2,000   |
| – Uncompensated seizure    | –                            | 800                       | 800     |
| – Downward reappraisals    | –                            | –                         | –       |
| – Reclassifications        | –                            | 200                       | 200     |
| <i>Total reductions</i>    | 3,600                        | 42,000                    | 45,600  |
| Closing stock              | 12,100                       | 171,000                   | 183,100 |

¶14 *Table 1: Structure of physical asset account for aquatic resources, with illustrative synthetic values in tonnes (adapted from SEEA CF Table 5.22)*<sup>46</sup>

¶15 The table includes “uncompensated seizure” to record illegal fishing by non-residents, following the SEEA CF treatment<sup>47</sup>. In this example the natural aquatic stock is declining (closing stock 171,000 < opening stock 180,000), driven by extraction and losses exceeding growth. Cultivated resources record modest growth, the pattern expected where aquaculture is expanding whilst wild fisheries are under pressure.

### Combined physical asset account template

¶1 Table 1a provides a broader template that compilers can use to record all major categories of marine natural resources within a single accounting structure. It distinguishes natural aquatic resources (fish and other wild aquatic organisms), ecosystem assets (spatially defined marine ecosystem types measured by extent), and mineral and energy resources (seabed deposits). Each asset class follows different dynamics: fish grow and reproduce, ecosystems expand and contract, and minerals only deplete. The template captures these differences.

| Entry                | Natural Aquatic Resources | Ecosystem Assets | Mineral Resources |
|----------------------|---------------------------|------------------|-------------------|
|                      | (tonnes)                  | (hectares)       | (tonnes)          |
| <b>Opening stock</b> | 180,000                   | 72,000           | 5,200,000         |
| <b>Additions</b>     |                           |                  |                   |
| Natural growth       | 28,000                    | N/A              | N/A               |
| Natural expansion    | N/A                       | 120              | N/A               |
| Managed expansion    | N/A                       | 350              | N/A               |
| Discoveries          | 5,000                     | N/A              | 200,000           |

| Entry                   | Natural Aquatic Resources | Ecosystem Assets | Mineral Resources |
|-------------------------|---------------------------|------------------|-------------------|
| Upward reappraisals     | 5,000                     | 80               | 100,000           |
| Reclassifications in    | –                         | 50               | –                 |
| <b>Total additions</b>  | <b>38,000</b>             | <b>600</b>       | <b>300,000</b>    |
| <b>Reductions</b>       |                           |                  |                   |
| Extraction/Harvest      | 24,000                    | N/A              | 180,000           |
| Natural reduction       | 15,000                    | 400              | N/A               |
| Catastrophic losses     | 2,000                     | 600              | N/A               |
| Managed reduction       | N/A                       | 200              | N/A               |
| Downward reappraisals   | –                         | –                | –                 |
| Reclassifications out   | 200                       | 50               | –                 |
| <b>Total reductions</b> | <b>41,200</b>             | <b>1,250</b>     | <b>180,000</b>    |
| <b>Closing stock</b>    | <b>176,800</b>            | <b>71,350</b>    | <b>5,320,000</b>  |
| <b>Derived entries</b>  |                           |                  |                   |
| Sustainable yield       | 22,000                    | N/A              | N/A               |
| Depletion               | 2,000                     | N/A              | 180,000           |

¶12 *Table 1a: Combined physical asset account template for marine natural resources with illustrative synthetic values (integrating SEEA CF Table 5.4, SEEA EA Table 4.1, and SEEA CF Table 5.22)*<sup>48</sup>

¶13 Note: Illustrative values are synthetic. In practice, discoveries of entirely new fish stocks are rare, and stock revisions are typically recorded as reappraisals rather than discoveries.

¶14 The “Derived entries” section highlights depletion as a key sustainability indicator. For renewable resources, depletion occurs only when extraction exceeds sustainable yield (24,000 – 22,000 = 2,000 tonnes in this example). For non-renewable resources, all extraction constitutes depletion – there is no regeneration to offset it. For natural aquatic resources, stock assessment models provide the primary input (see **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**). For ecosystem assets, remote sensing and spatial survey provide extent mapping (see **TG-4.1 Remote Sensing and Geospatial Data**). For mineral resources, geological surveys and commercial assessments provide stock estimates.

¶15 **Sustainable yield and depletion.** For fisheries management, sustainable yield represents the maximum catch that can be taken without reducing the stock’s long-term productivity. When gross catch exceeds sustainable yield, depletion occurs and should be recorded. Conversely, when catch is below sustainable yield, the excess regeneration contributes to stock growth rather than depletion<sup>49</sup>. The practical test: compare your catch to your sustainable yield estimate each year. If the gap is widening, management intervention is needed. The SEEA CF recommends that “estimates from biological models be compared with indicators of stock size, such as CPUE, and also that estimation be carried out on an ongoing basis so that the dynamics of the various populations (natural growth, natural losses, etc.) can be better understood”<sup>50</sup>.

¶16 **Capture fishing by non-residents.** Under the SNA and SEEA CF, production is attributed to the country of residence of the harvesting operation, not the location of the resource<sup>51</sup>. For asset accounts, in contrast, the focus is on changes in the national aquatic resource. The SEEA CF states that “the total catch from the country’s aquatic resources—including any resources on the high seas over which ownership rights exist, regardless of the residency of the harvesting operation”<sup>52</sup> must be recorded as reductions in the national stock. Foreign-flagged vessels fishing in your waters therefore reduce your asset account even though their production appears in another country’s GDP.

¶17 **Illegal fishing.** The SEEA CF addresses illegal fishing explicitly: “If residents harvest aquatic resources beyond the scope of their licence, they are harvesting illegally. Nonetheless, following the principles of the SNA, this harvest should still be recorded as production with an income accruing to the fisherman”<sup>53</sup>. For illegal fishing by non-residents, the physical removals should be recorded as “uncompensated seizures”<sup>54</sup>. Excluding illegal catch from the asset account would overstate the closing stock, since the fish are removed regardless of whether they were caught legally.

¶18 **Monetary valuation of aquatic resources.** The SEEA CF describes two main options for valuing natural aquatic resources<sup>55</sup>:

- ¶19 Using the value of long-term fishing licences and quotas where realistic market values are available
- ¶10 Applying the NPV of expected resource rents

¶11 Where individual transferable quotas (ITQs) are used and traded, the total market value of all quotas may approximate the value of the aquatic resource<sup>56</sup>. Quota markets are, however, often imperfect, and quota values may not reflect the full value of the underlying resource. The SEEA CF notes that “because of market imperfections (barriers to entry in the form of specialized fixed assets, knowledge of fishing grounds, etc.), a lack of liquidity in the markets, and uncertainties in the statistical assumptions required for net present value calculations”, different approaches “are unlikely to give the same result in practice”<sup>57</sup>. Compilers should therefore document which method they used and why, rather than assuming that any single approach yields the “right” answer.

### 3.4.2 Mineral and energy resources

¶1 Mineral and energy resources in the ocean domain include offshore oil and gas deposits, seabed minerals (including polymetallic nodules, cobalt-rich ferromanganese crusts, and seafloor massive sulphides), sand and gravel, and other extractable minerals<sup>58</sup>. Unlike fish stocks, these resources do not regenerate on human timescales – every unit extracted is permanent depletion.

¶2 **Classification of resources.** The SEEA CF classifies mineral resources based on commercial viability, which determines how they enter the accounts<sup>59</sup>. Table 3.4.2 below summarises the three classes.

| Class                                                    | Description                                                     |
|----------------------------------------------------------|-----------------------------------------------------------------|
| <b>Class A – Commercially recoverable</b>                | Economically viable to extract under current conditions.        |
| <b>Class B – Potentially commercially recoverable</b>    | May become viable with technological advances or price changes. |
| <b>Class C – Non-commercial and other known deposits</b> | Not currently viable.                                           |

¶13 This classification matters because movements between classes (a deposit becoming commercially viable as technology improves) are recorded as reclassifications, not discoveries. Understanding this distinction prevents double-counting.

¶14 **Physical asset accounts for minerals.** Asset accounts for mineral and energy resources record the opening stock, discoveries, extractions, reappraisals, and closing stock<sup>60</sup>. Because these are non-renewable resources with no natural growth, depletion equals extraction. Measurement units vary by resource type (barrels for oil, cubic metres for gas, tonnes for minerals).

¶15 For deep-sea minerals in areas beyond national jurisdiction (ABNJ), the regulatory framework under the International Seabed Authority (ISA) continues to develop. The BBNJ Agreement, which entered into force on 17 January 2026, establishes new governance arrangements for biodiversity in ABNJ that may have implications for asset accounting boundaries. Compilers should note that mineral resources in ABNJ are designated as the “common heritage of mankind” under UNCLOS and are administered by the ISA. Asset accounts for ABNJ minerals should reflect the access and benefit-sharing provisions of the applicable regulatory framework. For further guidance on deep-sea and ABNJ accounting, see **TG-6.6 Deep-Sea and ABNJ**.

¶16 **Monetary valuation.** The NPV approach is typically applied, using the expected resource rent – the surplus after all extraction costs and normal returns to produced assets have been deducted<sup>61</sup>. Resource rent can be estimated as a residual from operating surplus or from royalty payments where these approximate market rent. For detailed guidance on resource rent estimation, see **TG-1.9 Safe Usage of Monetary Valuation**.

### 3.4.3 Water resources

¶17 The SEEA CF defines water resources as “freshwater and brackish water in inland water bodies, including groundwater and soil water”<sup>62</sup>. Seawater is excluded from the asset boundary because “the stocks are too large to be meaningful for analytical purposes”<sup>63</sup>. The open ocean is therefore not tracked as an asset, whilst the interfaces between freshwater and marine systems remain important.

¶18 For coastal areas, groundwater in coastal aquifers may be subject to saltwater intrusion, and estuarine systems represent transitional zones where freshwater and marine systems interact. Asset accounts for water resources should capture these coastal dynamics where relevant. The SEEA CF notes that “water is in continuous movement through the processes of precipitation, evaporation, run-off, infiltration and flows to the sea”<sup>64</sup>, and this hydrological connectivity must be considered in coastal accounting. A coastal aquifer losing freshwater to saltwater intrusion is an asset account reduction that directly affects the communities and agriculture that depend on that aquifer.

## 3.5 Ecosystem Assets

¶19 SEEA Ecosystem Accounting extends asset accounting to treat ecosystems as integrated spatial units: the whole living system, of which the fish or minerals within it are components<sup>65</sup>. An **ecosystem asset** is defined as “contiguous spaces covered by a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions”<sup>66</sup>. For ocean accounting, ecosystem assets include coral reefs, mangrove forests, seagrass meadows, kelp forests, coastal wetlands, and the various pelagic and deep-sea ecosystem types.

¶20 This ecosystem-level view captures something that individual asset accounts omit: the interdependence of marine systems. A coral reef supplies coastal protection, supports tourism, sequesters carbon, and maintains biodiversity, alongside its fish. Tracking the reef as a whole records whether these combined services are being sustained or degraded. The relationship between ecosystem assets and the individual environmental assets described in Section 3.4 is addressed in **TG-0.2 Overview of Relevant Statistical Standards**.

### 3.5.1 Ecosystem extent accounts

¶21 **Ecosystem extent** is the size of an ecosystem asset, measured in units of area (or, for some marine ecosystems, length or volume)<sup>67</sup>. Extent accounts answer a basic question: how much of each ecosystem type do you have, and is it growing or shrinking? The extent account uses the same opening-plus-additions-minus-reductions identity as the Central Framework natural-resource account (Figure 3.1.1), but adds an attribution of every addition and reduction by cause – managed change from direct human activity versus unmanaged change from natural processes (Figure 3.1.2).

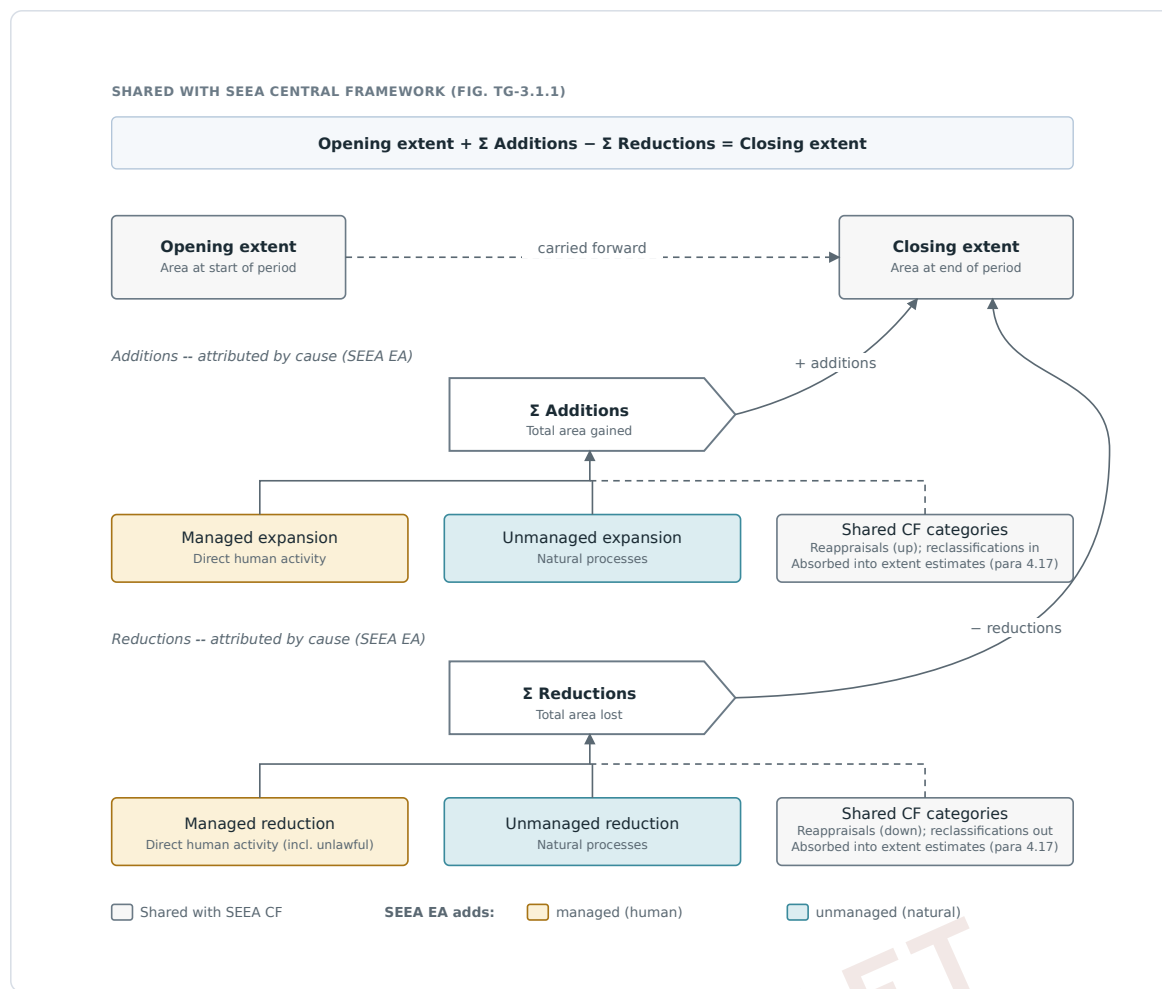


**Figure 3.1.2** SEEA Ecosystem Accounting keeps the Central Framework stock-flow identity and adds managed versus unmanaged cause attribution for each change. Colour marks the cause split on shared CF structure; illustrated for extent (area conversions). Same attribution applies in carbon and monetary ecosystem asset accounts.

**Source:** SEEA EA 2024 para 13.63 (shared CF asset-account form); paras 4.14–4.27 and Table 4.1 (extent account, managed/unmanaged); paras 10.2.2–10.2.3 (enhancement/degradation); TG–3.1.

**Adapted from:** SEEA EA 2024 Table 4.1, recast to highlight the concepts SEEA EA adds to the shared Central Framework asset-account identity for TG–3.1.

¶2 **Structure of extent accounts.** The structure follows the standard asset account format<sup>68</sup>:

| Accounting entry            | Ecosystem Type A | Ecosystem Type B | ... | Total  |
|-----------------------------|------------------|------------------|-----|--------|
| Opening extent              | 15,000           | 8,500            | ... | 72,000 |
| <b>Additions to extent</b>  |                  |                  |     |        |
| – Managed expansion         | 250              | 100              | ... | 350    |
| – Natural expansion         | 80               | 40               | ... | 120    |
| <i>Total additions</i>      | 330              | 140              | ... | 470    |
| <b>Reductions in extent</b> |                  |                  |     |        |
| – Managed reduction         | 150              | 50               | ... | 200    |
| – Natural reduction         | 300              | 100              | ... | 400    |
| <i>Total reductions</i>     | 450              | 150              | ... | 600    |
| Net change in extent        | -120             | -10              | ... | -130   |
| Closing extent              | 14,880           | 8,490            | ... | 71,870 |

¶3 Table 2: Structure of ecosystem extent account with illustrative synthetic values in hectares (adapted from SEEA EA Table 4.1)<sup>69</sup>

¶4 **Structural template – opening/closing extent account (SEEA EA Table 4.1).** Table 2a presents the same account as a blank structural template, ready to be populated. The row structure follows the standard SEEA asset-account logic (opening stock, additions, reductions, closing stock), whilst the columns are the ecosystem types selected for the accounting area<sup>70</sup>. Compilers should populate one column per ecosystem type in the EAA, using a consistent unit of area (e.g., hectares or square kilometres) throughout. The accounting identity is: *Opening extent + Total additions – Total reductions = Closing extent*, and the sum of closing extents across all ecosystem types should equal the total area of the EAA<sup>71</sup>.

¶5 **Table 2a: Opening/closing extent account – structural template (after SEEA EA Table 4.1)**

| Accounting entry                 | Ecosystem type 1 | Ecosystem type 2 | ... | Ecosystem type <i>n</i> | Total                |
|----------------------------------|------------------|------------------|-----|-------------------------|----------------------|
| Opening extent (start of period) | [area]           | [area]           | ... | [area]                  | [Σ area]             |
| <b>Additions to extent</b>       |                  |                  |     |                         |                      |
| – Managed expansion              | [area]           | [area]           | ... | [area]                  | [Σ area]             |
| – Unmanaged expansion            | [area]           | [area]           | ... | [area]                  | [Σ area]             |
| <i>Total additions</i>           | [Σ]              | [Σ]              | ... | [Σ]                     | [ΣΣ]                 |
| <b>Reductions in extent</b>      |                  |                  |     |                         |                      |
| – Managed reduction              | [area]           | [area]           | ... | [area]                  | [Σ area]             |
| – Unmanaged reduction            | [area]           | [area]           | ... | [area]                  | [Σ area]             |
| <i>Total reductions</i>          | [Σ]              | [Σ]              | ... | [Σ]                     | [ΣΣ]                 |
| Net change in extent             | [+/-]            | [+/-]            | ... | [+/-]                   | [+/-]                |
| Closing extent (end of period)   | [area]           | [area]           | ... | [area]                  | [Σ area = total EAA] |

¶6 *Table 2a: Structural template of an ecosystem extent account; cells are left blank to be populated by the compiler with no synthetic values. Row labels follow SEEA EA paras 4.10 and 4.15; column structure follows SEEA EA paras 4.11–4.13.*<sup>70, 71</sup>

¶7 The accounting entries are defined by the SEEA EA as follows (para 4.15)<sup>71</sup>:

- ¶8 **Opening extent and closing extent** – the total area of ecosystem assets for a given ecosystem type at the beginning and end of the accounting period (generally one year).
- ¶9 **Additions to extent** – increases in the area of an ecosystem type, separated where possible into:
  - ¶10 **Managed expansions** – increases due to direct human activity (e.g., land reclamation, reforestation), including the unplanned effects of such activity.
  - ¶11 **Unmanaged expansions** – increases resulting from natural processes (e.g., seeding, sprouting, succession), which may be influenced by human activity (e.g., climate-driven shifts) or result from land abandonment.
- ¶12 **Reductions in extent** – decreases in the area of an ecosystem type, separated where possible into:
  - ¶13 **Managed reductions** – decreases due to direct human activity (e.g., deforestation, urban expansion), including unplanned or illegal activity.
  - ¶14 **Unmanaged reductions** – decreases associated with natural processes (e.g., loss of coral reefs to climate change, abandonment).

¶15 Where data availability does not permit the managed/unmanaged split, SEEA EA para 4.14 advises that it is sufficient to record opening and closing extents and the net change<sup>72</sup>. Revisions arising from updated input data or methods are not recorded as a distinct entry. Instead, opening/closing extents and additions/reductions are altered and time series revised (para 4.17)<sup>72</sup>.

¶16 **Ecosystem conversions.** Changes in ecosystem extent are termed **ecosystem conversions** – situations where “for a given location, there is a change in ecosystem type involving a distinct and persistent change in ecological structure, composition and function”<sup>73</sup>. Conversions may be human-induced (such as clearing mangroves for aquaculture ponds) or natural (such as succession of wetland types). Within the extent account, the total area of all ecosystem types should equal the total ecosystem accounting area: what one type loses, another type gains.

¶17 **Conversions are recorded in the extent account, not beside it.** A conversion changes the ecosystem type of an area that remains inside the accounting area, so it is not a reduction in the same sense as an area lost from the accounting area altogether. Where conversions are material, add a reclassification block to Table 2a between additions and reductions:

| Accounting entry                         | Ecosystem type 1 | Ecosystem type 2 | ... | Total     |
|------------------------------------------|------------------|------------------|-----|-----------|
| <b>Reclassifications</b>                 |                  |                  |     |           |
| – Conversions from other ecosystem types | [area]           | [area]           | ... | [Σ area]  |
| – Conversions to other ecosystem types   | [-area]          | [-area]          | ... | [-Σ area] |
| <i>Net reclassification</i>              | [+/-]            | [+/-]            | ... | 0         |

¶18 *Table 2b: Reclassification block for the ecosystem extent account. Net reclassification sums to zero at the total level: an area converted out of one ecosystem type is an area converted into another.*

¶19 The distinction that governs which row an event enters is whether the area changes **type** or leaves the **accounting area**. Kelp lost to storm damage where the substrate is exposed but not yet colonised is an unmanaged reduction; kelp that becomes an urchin barren is a reclassification, because the area is still accounted for, under a different type. Compilers who cannot yet support a reclassification block should record conversions in a separate ecosystem type change matrix and state in account metadata that they have done so, but the block above is the preferred presentation because it keeps the conversion inside the account that has to balance.

¶20 **Marine ecosystem delineation.** For marine ecosystems, the SEEA EA recommends that within the continental shelf, “ecosystem assets be delineated based on the areas of the different ecosystem types associated with the seabed, for example, seagrass meadows, subtidal sandy bottoms and coral reefs”<sup>74</sup>. This seabed-based approach accommodates the three-dimensional nature of marine ecosystems whilst providing a practical basis for area measurement. The SEEA EA also notes that “marine ecosystems are not concentrated near one surface (i.e. the air-land/water interface) but extend throughout the water column and include the underlying sediment and seabed”<sup>75</sup>. Mapping therefore proceeds from the seabed upward: the seabed type defines the ecosystem boundary, even though the living system extends through the water column above it.

¶21 The IUCN Global Ecosystem Typology (GET) provides the reference classification for marine ecosystem types, with the Marine Shelf biome (M1) encompassing key functional groups including seagrass meadows (M1.1), kelp forests (M1.2), photic coral reefs

(M1.3), shellfish beds and reefs (M1.4), and subtidal rocky reefs (M1.6)<sup>76</sup>. For guidance on mapping marine ecosystem extent using remote sensing and spatial data, see **TG-4.1 Remote Sensing and Geospatial Data**.

¶22 The seabed-based delineation approach presents challenges for pelagic ecosystems that are not clearly associated with specific seabed areas. Epipelagic, mesopelagic, and bathypelagic ecosystem types (IUCN GET M2.1–M2.4) require alternative delineation approaches, potentially using water mass characteristics, depth zones, or biogeochemical provinces as boundaries. These challenges are addressed in **TG-6.5 Pelagic and Open Ocean Accounts**.

### 3.5.2 Ecosystem condition accounts

¶1 **Ecosystem condition** refers to the quality of an ecosystem – how well it is functioning, as distinct from how much of it exists<sup>77</sup>. A hectare of degraded coral reef is still a hectare in the extent account, but its capacity to deliver services (coastal protection, fish habitat, tourism value) may be a fraction of a healthy reef's. Condition accounts capture this quality dimension.

¶2 **Structure of condition accounts.** The SEEA EA describes a three-stage measurement approach<sup>78</sup>, summarised in Table 3.5.2 below.

| Stage                               | Description                                                                                                                                                |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Condition variable accounts</b>  | Record raw values of condition characteristics (e.g., live coral cover percentage, species richness count, water temperature).                             |
| <b>Condition indicator accounts</b> | Transform variables into comparable indicators, typically scaled against a reference condition (e.g., coral cover as a percentage of reference condition). |
| <b>Condition indices</b>            | Aggregate indicators into composite measures for communication to policy-makers (optional).                                                                |

¶3 **Selection of condition variables.** Condition variables should be selected based on their relevance to the ecosystem type, data availability, and connection to ecosystem integrity<sup>79</sup>. For marine ecosystems, the SEEA EA identifies key drivers of condition including bathymetric profile, climate factors (temperature, acidification), substrate type, ocean circulation, salinity, and human pressures<sup>80</sup>. The SEEA EA groups condition characteristics into six classes<sup>81</sup>:

- ¶4 Physical state (including water temperature, salinity)
- ¶5 Chemical state (including ocean acidification, nutrient levels, pollutant concentrations)
- ¶6 Compositional state (including species diversity, community composition)
- ¶7 Structural state (including habitat complexity, biomass)
- ¶8 Functional state (including productivity, ecosystem processes)
- ¶9 Landscape/seascape context (including connectivity, fragmentation)

¶10 For guidance on indicators derived from ecosystem condition accounts, see **TG-2.1 Aggregate Biophysical Indicators of Environmental State**.

### Relationship between extent, condition, and service capacity

¶1 The capacity of an ecosystem to deliver services depends on both its extent and its condition – area multiplied by quality. A large, healthy reef delivers more services than a small, degraded one. SEEA EA Figure 6.1 illustrates this relationship: ecosystem extent determines the spatial scale of potential service delivery, whilst ecosystem condition determines the quality and intensity of service flow per unit area<sup>82</sup>. Together, they determine the overall capacity to deliver ecosystem services, which is then realised through actual service flows to economic units.

¶2 Figure 3.1.3 shows the relationship between ecosystem extent, condition, and service capacity (adapted from SEEA EA Figure 6.1).

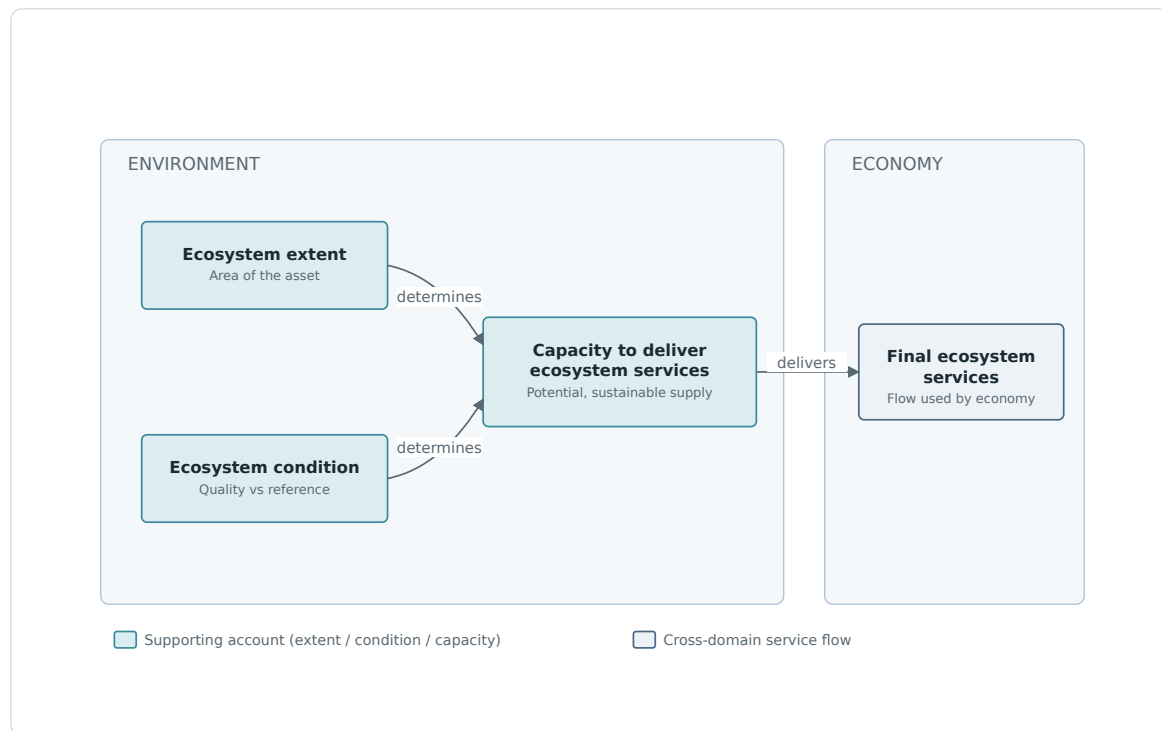


**Figure 3.1.3** Ecosystem extent and condition jointly determine capacity -- the potential sustainable supply realised as final service flows to the economy. Extent, condition, and capacity are supporting accounts; the final service flow crosses the Environment--Economy boundary.

¶13 This framework has direct implications for ocean accounting. A decline in coral reef extent (recorded in the extent account) reduces the total area available for service delivery. Simultaneously, degradation in reef condition (recorded in the condition account) reduces the service flow per hectare. Both effects are captured when compiling ecosystem service flow accounts as described in **TG-3.2 Flows from Environment to Economy**.

#### Illustrative marine condition variables by ECT class

¶11 To support the selection of condition variables for marine ecosystem types, Table 3 maps illustrative variables to the six classes of the SEEA EA Ecosystem Condition Typology (ECT)<sup>83</sup>. The ECT provides a universal structure for organising condition characteristics across all ecosystem types, and groups them into abiotic, biotic, and landscape-level categories.

| ECT Group                 | ECT Class               | Marine condition variables (illustrative)                                                                             |
|---------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>Group A: Abiotic</b>   | A1. Physical state      | Sea surface temperature (°C), salinity (PSU), turbidity (NTU), microplastic concentration (particles/m <sup>3</sup> ) |
|                           | A2. Chemical state      | Ocean pH, dissolved oxygen (mg/L), chlorophyll-a (µg/L), nutrient concentrations (N, P)                               |
| <b>Group B: Biotic</b>    | B1. Compositional state | Species richness (number), abundance of key species (individuals/area), invasive species presence                     |
|                           | B2. Structural state    | Live coral cover (%), seagrass canopy height (cm), mangrove canopy density (%), fish biomass (kg/ha)                  |
|                           | B3. Functional state    | Net primary productivity (gC/m <sup>2</sup> /yr), trophic index, recruitment rates                                    |
| <b>Group C: Landscape</b> | C1. Landscape/seascape  | Habitat connectivity index, fragmentation (patch count), distance to pressure sources (km)                            |

¶12 Table 3: Illustrative marine condition variables structured by ECT class (based on SEEA EA Table 5.1)<sup>83</sup>

¶13 The SEEA EA recommends selecting at least one variable for each of the six ECT classes for each ecosystem type, which sets a minimum level of coverage<sup>84</sup>. Each variable should be compared against a reference condition representing “good” or “natural” state, so that it can be transformed into condition indicators that are comparable across ecosystem types and accounting periods. Based on evaluation of existing ecosystem condition accounts, a set of approximately 6 to 10 well-selected indicators for a given ecosystem type should provide sufficient information to assess the overall condition of an ecosystem asset<sup>85</sup>. For biome-specific indicative variables, including those relevant to marine shelf, pelagic, and deep-sea biomes, compilers should consult the indicative variable sets presented in SEEA EA Table 5.7<sup>86</sup>.

¶14 **Reference conditions.** Condition indicators are typically expressed relative to a reference level representing “good” or “natural” condition<sup>87</sup>. The reference condition may be a historical baseline, a minimally impacted area, or a policy target, and the choice should be clearly documented. A reef measured against a pristine 1950s baseline may record a 60% decline, whilst the same reef measured against a 2010 baseline may appear stable. The choice of reference therefore shapes how the account is interpreted. The SEEA EA links condition to the concept of **ecosystem integrity**: “the ecosystem’s capacity to maintain its characteristic composition, structure, functioning and self-organization over time within a natural range of variability”<sup>88</sup>.

#### The three condition account tables

¶1 The three stages produce three account tables. Compilers should publish all three: the variable account is the auditable record, the indicator account is what can be compared across ecosystem types, and the index is what reaches a policy reader. Publishing only the index hides the choices that produced it.

¶2 **Stage 1 – condition variable account.** Records each selected variable in its own measured units, unrescaled, for the opening and closing of the accounting period, together with the upper and lower reference levels against which it will be rescaled. The reference levels are fixed at the start of the time series and held constant (**TG-4.8** Section 3.1).

¶3 **Table 3a: Ecosystem condition variable account – structural template (after SEEA EA Table 5.2)**

| ECT class              | Condition variable | Unit   | Polarity         | Lower reference <i>L</i> | Upper reference <i>U</i> | Opening value | Closing value |
|------------------------|--------------------|--------|------------------|--------------------------|--------------------------|---------------|---------------|
| A1 Physical state      | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |
| A2 Chemical state      | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |
| B1 Compositional state | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |
| B2 Structural state    | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |
| B3 Functional state    | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |
| C1 Landscape/seascape  | [variable]         | [unit] | Normal / Inverse | [L]                      | [U]                      | [value]       | [value]       |

¶4 *Table 3a: Structural template of an ecosystem condition variable account, one table per ecosystem type in the accounting area. Cells are blank for compiler population. Row structure follows the ECT classes in Table 3; the reference-level and polarity columns carry the parameters the Stage 2 rescaling consumes.*

¶5 **Stage 2 – condition indicator account.** Rescales each variable to a dimensionless 0–1 indicator against its reference levels. **The transformation is not defined here.** It is normative in **TG-2.1 Aggregate Biophysical Indicators of Environmental State** Section 3.4.1 –  $\text{Indicator} = (V - L) / (U - L)$  for normal polarity,  $(L - V) / (L - U)$  for inverse polarity, with the categorical step deduction for pH and other logarithmic-scale variables – and compilers must use that transformation without local variation.

¶6 **Table 3b: Ecosystem condition indicator account – structural template (after SEEA EA Table 5.3)**

| ECT class              | Condition indicator | Opening indicator (0–1) | Closing indicator (0–1) | Change | Data tier |
|------------------------|---------------------|-------------------------|-------------------------|--------|-----------|
| A1 Physical state      | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |
| A2 Chemical state      | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |
| B1 Compositional state | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |
| B2 Structural state    | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |
| B3 Functional state    | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |
| C1 Landscape/seascape  | [indicator]         | [0–1]                   | [0–1]                   | [+/-]  | 1 / 2 / 3 |

¶7 *Table 3b: Structural template of an ecosystem condition indicator account. Every value is dimensionless and bounded on [0, 1], which is what makes rows comparable across ecosystem types and periods. The data tier column carries the quality flag defined in TG-4.8 Section 3.2 and TG-4.9 Section 3.4.*

¶8 **Stage 3 – condition index.** Aggregates the indicators, first to a class-level sub-index and then to a single index for the ecosystem type. SEEA EA describes three aggregation rules in common use: the (weighted) arithmetic mean, the (weighted) geometric mean, and one-out-all-out, in which the index takes the value of its worst-performing indicator. The choice matters and is not neutral: an arithmetic mean lets a strong indicator mask a collapsed one, a geometric mean penalises imbalance, and one-out-all-out is the precautionary rule used in several regulatory regimes. **TG-2.1** Section 3.6 sets the publication default and is normative; the weights and the rule applied must be recorded in the account.

¶9 **Table 3c: Ecosystem condition index – structural template (after SEEA EA Table 5.4)**

| Level                            | Component              | Weight | Opening      | Closing      | Change       |
|----------------------------------|------------------------|--------|--------------|--------------|--------------|
| Class sub-index                  | A1 Physical state      | [w]    | [0–1]        | [0–1]        | [+/-]        |
| Class sub-index                  | A2 Chemical state      | [w]    | [0–1]        | [0–1]        | [+/-]        |
| Class sub-index                  | B1 Compositional state | [w]    | [0–1]        | [0–1]        | [+/-]        |
| Class sub-index                  | B2 Structural state    | [w]    | [0–1]        | [0–1]        | [+/-]        |
| Class sub-index                  | B3 Functional state    | [w]    | [0–1]        | [0–1]        | [+/-]        |
| Class sub-index                  | C1 Landscape/seascape  | [w]    | [0–1]        | [0–1]        | [+/-]        |
| <b>Ecosystem condition index</b> | <b>All classes</b>     | –      | <b>[0–1]</b> | <b>[0–1]</b> | <b>[+/-]</b> |

¶10 *Table 3c: Structural template of an ecosystem condition index. Record the aggregation rule and the weights alongside the table; an index published without them cannot be reproduced or challenged.*

¶11 The closing index in Table 3c is the value the degradation calculation in Section 3.5.3 consumes, and the change column is the index-point decline that formula takes as its input. A compiler who has not produced Table 3c cannot produce a defensible degradation entry.

### 3.5.3 Monetary ecosystem asset accounts

¶1 Monetary ecosystem asset accounts record the value of ecosystem assets in currency units. The SEEA EA presents two main valuation approaches<sup>89</sup>:

1. ¶2 **NPV of ecosystem services** – summing the discounted future flows of all ecosystem services supplied by the asset
2. ¶3 **Restoration cost** – the cost of restoring an ecosystem to a reference condition

¶4 The NPV approach aligns with valuation methods for other natural assets but requires monetary valuation of ecosystem services, which remains methodologically challenging, particularly for non-market services such as coastal protection and biodiversity maintenance. The restoration cost approach provides an alternative that does not require service valuation but may not reflect the full economic value of the asset. A coral reef may cost a certain amount to restore, whilst its actual value to the economy and society may be far higher. For detailed guidance on valuation of ecosystem services, see **TG-1.9 Safe Usage of Monetary Valuation** and **TG-2.4 Ecosystem Goods and Services**.

#### Structure of monetary ecosystem asset accounts

¶1 The SEEA EA monetary ecosystem asset account (Chapter 10) records the monetary values of all ecosystem assets within an ecosystem accounting area at the beginning and end of each accounting period, together with the changes in those values<sup>90</sup>. Table 4 presents the standard structure.

| Accounting entry                   | Ecosystem Type A | Ecosystem Type B | ... | Total   |
|------------------------------------|------------------|------------------|-----|---------|
| Opening value                      | 84,000           | 42,500           | ... | 360,000 |
| Ecosystem enhancement              | 1,200            | 300              | ... | 1,500   |
| Ecosystem degradation              | -2,500           | -800             | ... | -3,300  |
| Ecosystem conversions (additions)  | 400              | 200              | ... | 600     |
| Ecosystem conversions (reductions) | -600             | -250             | ... | -850    |
| Other changes in volume            |                  |                  |     |         |
| – Catastrophic losses              | -1,500           | -400             | ... | -1,900  |
| – Reappraisals                     | 800              | 100              | ... | 900     |
| Revaluation                        | 1,100            | 400              | ... | 1,500   |
| Net change in value                | -1,100           | -450             | ... | -1,550  |
| Closing value                      | 82,900           | 42,050           | ... | 358,450 |

¶2 Table 4: Structure of monetary ecosystem asset account with illustrative synthetic values in thousand currency units (adapted from SEEA EA Table 10.1)<sup>90</sup>

¶3 The account balances on the identity *Closing value = Opening value + enhancement – degradation + conversions (additions) – conversions (reductions) + other changes in volume + revaluation*, and the net change row makes that visible. In this illustration degradation and catastrophic losses together exceed enhancement, reappraisals and holding gains, so the closing value is below the opening value: the accounting area ended the period with less ecosystem wealth than it started with. That is the signal the account exists to carry, and it is the one a compiler should check first.

¶4 The accounting entries distinguish five broad types of change in the monetary value of ecosystem assets<sup>91</sup>:

- ¶5 **Ecosystem enhancement** records increases in monetary value associated with improving condition during the accounting period. This includes the effects of active restoration, reductions in harmful activities that allow recovery, and natural improvements in condition. A positive enhancement entry indicates that investment in ecosystem health is generating economic returns.
- ¶6 **Ecosystem degradation** records decreases in monetary value associated with declining condition. Degradation plays an analogous role to depletion for individual natural resources: it represents a cost that should be deducted in calculating adjusted income measures. Consistently large degradation entries indicate an economy drawing down its ecosystem capital.
- ¶7 **Ecosystem conversions** record additions and reductions resulting from changes in ecosystem type at a given location. When mangroves are cleared for aquaculture, a decrease in value is recorded for mangroves and an increase for the new aquaculture pond ecosystem. There is no expectation that these will be offsetting in monetary terms, as mangroves typically provide far more total ecosystem services than the aquaculture ponds that replace them.
- ¶8 **Other changes in volume** capture two categories: **catastrophic losses**, which are decreases in value due to large-scale, discrete events that cause significant loss in ecosystem condition – significant losses in structure, function or composition – such as a mass bleaching event, a cyclone or an oil spill (SEEA EA paras 10.24, 10.37); and **reappraisals**, which record changes in value due to updated information about expected future demand for ecosystem services or changed expectations about future condition (SEEA EA para 10.38)<sup>92</sup>. Where such an event is severe enough that the ecosystem is considered to have changed its type, the loss is recorded as an **ecosystem conversion**, not as a catastrophic loss (SEEA EA para 10.37). The line therefore turns on whether condition fell or type changed, not on how much extent was affected.
- ¶9 **Revaluation** records changes in monetary value due solely to movements in the unit prices of ecosystem services, distinct from any physical changes in the asset. Following the SEEA CF convention, changes in value resulting from changes in the quantity or quality of future flows of ecosystem services are not revaluations and should be recorded under the appropriate entry above (SEEA EA para 10.41)<sup>93</sup>.

¶10 The distinction between reappraisals and revaluation is essential for interpreting changes in ecosystem asset values.

Reappraisals concern changes in expectations – for example, revised demographic projections that alter the expected future demand for ecosystem services, or rezoning decisions that change the expected pattern of ecosystem use. Revaluations, by contrast, concern changes in unit prices only and are conceptually equivalent to the holding gains and losses recorded for other asset types in the SNA.

¶11 For marine contexts, monetary values of ecosystem assets can be estimated using the NPV of expected future ecosystem service flows. For market services such as fish provisioning and blue carbon sequestration, resource rent methods may be applied. For non-market services such as coastal protection, water purification, and recreational amenity, replacement cost or avoided damage cost methods from the preference hierarchy in **TG-2.4 Environmental (including Ecosystem) Goods and Services** Section 3.10.2 should be used.

¶12 The UN Statistical Commission, in adopting the SEEA EA in 2021, identified “outstanding methodological concerns related to chapters 8 to 11 on valuation” (SEEA EA Preface para 8). Accordingly, the valuation chapters have the status of “internationally recognised statistical principles and recommendations” rather than a full international statistical standard. Compilers should be aware that monetary ecosystem asset valuation methods continue to evolve, and should document the methods and assumptions used in their valuations transparently.

### Horizon and condition-to-service scaling

¶13 Two choices govern any NPV-based ecosystem asset valuation and should be recorded in account metadata.

¶14 **Apply the condition adjustment once.** A condition-adjusted asset value is built by adjusting the *physical service flow* for observed condition – treating a literature-derived or reference-condition service rate as the reference value and scaling it by the composite condition index – and then discounting the resulting condition-adjusted flow. The condition index enters at the service-flow step and **not again** at the discounting step. Applying it at both steps squares the adjustment and understates the asset, and it is a common error because each step looks defensible in isolation. Where condition is on a declining trajectory, project the service flow forward using the trend rather than applying a perpetuity to a single adjusted flow, and record the projected trajectory, its source and the horizon in account metadata.

¶15 **Perpetuity or finite horizon.** A perpetuity is appropriate where there is no foreseeable terminal date for the ecosystem asset, governance arrangements are stable, and any management mandate over the area is continuously renewed. A finite-horizon NPV is required where the arrangement that sustains the service flow has a time-limited mandate, a sunset clause, or uncertain renewal – a protected area designated for a fixed term, or a concession-dependent management regime. The choice materially changes the asset value, and the rationale must be documented.

¶16 **Condition-to-service scaling.** Where a change in the composite condition index is used to infer a change in service flow, **compilers should not assume a linear relationship as a default.** The relationship between condition and service capacity is service-specific: coastal protection, carbon sequestration and fishery support functions each have distinct functional forms, and several are known to be non-linear near ecological thresholds. Compilers should apply the best available ecological or economic evidence for the service in question, and document the functional form and its source. A linear scaling may be used as a screening-level approximation where no calibrated relationship is available, provided it is labelled as such and the direction of likely bias is stated. **TG-1.6 OA and Environmental Impact Assessment** Section 3.5 sets out how an assessor applies these conditions in practice, and why a damage cost must be reported as a range.

### Ecosystem degradation, damage cost and offsets

¶17 Degradation is the decline in the monetary value of an ecosystem asset arising from a decline in its condition during the accounting period. This subsection specifies how it is calculated, when the simplified approach is defensible, and how the same extent-and-condition arithmetic supports offset requirements under no-net-loss policies.

#### Applicability of the simplified linear approximation

¶18 Before applying the degradation formula below, practitioners should confirm that the linear approximation is appropriate for their context. The simplified linear formula is appropriate only where all three of the following conditions are met:

¶19 **(a) Condition decline is 20 percentage points or less**, that is, the absolute change in the condition index does not exceed 0.20. This cut-off is indicative compiler judgement rather than a SEEA-specified threshold, and practitioners should adjust it where domain-specific evidence supports a different value. Larger declines are more likely to involve non-linear service losses.

¶20 **(b) No threshold responses are documented** in the relevant ecosystem literature for the ecosystem type and service combination being valued. If published studies indicate that condition decline triggers disproportionate service loss at any intermediate point within the predicted range, the linear approximation will underestimate damage.

¶21 **(c) A single dominant service type drives asset value** (i.e., one service accounts for more than approximately 70% of total annual service flow value per hectare, an indicative threshold that is not SEEA-specified). Where multiple services of roughly equal weight respond differently to the same condition change, separate service-specific calculations should replace the aggregated formula.

#### Decision checklist:

- ¶23 ☐ Is absolute condition decline 0.20 or less? If no, use an ecosystem-specific biophysical model (see the Guidelines on Biophysical Modelling cited below).
- ¶24 ☐ Does the ecosystem literature document threshold responses within the predicted condition range? If yes, use biophysical model or apply conservative non-linear adjustment (e.g., service loss proportional to condition decline squared). Consult the Guidelines on Biophysical Modelling for Ecosystem Accounting <sup>94</sup>.
- ¶25 ☐ Does one service type account for more than approximately 70% of asset value? If no, calculate degradation separately for each major service.

#### Degradation formula

¶26 Degradation (simplified linear approximation) = (Condition decline) × (Present value of affected service flows)

¶27 **Definition of “condition decline”:** In this formula, “condition decline” means the absolute change in the condition index, expressed in index points. For example, if the condition index falls from 0.72 to 0.60, the condition decline is 0.12 (not the proportional change of 16.7% relative to opening condition). Practitioners must use the absolute index-point change consistently throughout all calculations.

¶28 The formula is applied to project-level impact assessment in **TG-1.6 OA and Environmental Impact Assessment** Section 3.5. Consider a coastal development expected to reduce coral reef condition index from 0.75 to 0.60 (a decline of 0.15 index points) across 100 hectares. If the reef provides coastal protection services valued at USD 10,000/ha/year and biodiversity habitat services valued at USD 2,000/ha/year, and using a 4% discount rate for perpetual service flows (consistent with social discount rates used in several OECD national accounting frameworks, and practitioners should substitute their national treasury or green book rate):

¶29 **Worked calculation:**

- ¶30 Annual service flow per hectare = USD 12,000/ha/year
- ¶31 Asset value per hectare (perpetual annuity) = USD 12,000 / 0.04 = USD 300,000/ha
- ¶32 Total reef asset value (100 ha) = USD 30,000,000
- ¶33 Degradation (0.15 index-point condition decline) = 0.15 × USD 30,000,000 = **USD 4,500,000**

¶34 **Discount rate sensitivity:** As the choice of discount rate affects damage cost estimates, practitioners should present results across a range of rates. For the worked example above (USD 30,000,000 total asset value at 4%, condition decline = 0.15):

| Discount rate | Asset value (100 ha) | Degradation cost (0.15 decline) |
|---------------|----------------------|---------------------------------|
| 2%            | USD 60,000,000       | USD 9,000,000                   |
| 4%            | USD 30,000,000       | USD 4,500,000                   |
| 7%            | USD 17,143,000       | USD 2,571,000                   |

¶35 If engineering solutions to reduce reef impacts would cost USD 4,000,000, the cost-benefit comparison at the 4% rate suggests such measures are economically justified. Discount rate selection is covered in Section 3.3 of this Circular and in **TG-2.4** Section 3.10; **TG-1.9 Safe Usage of Monetary Valuation** sets out how the resulting figures should be presented and caveated.

¶36 **Important methodological considerations:**

¶37 **Service-specific responses:** Different ecosystem services may respond differently to the same condition change. For example, coral cover decline may reduce coastal protection services linearly but reduce biodiversity habitat services exponentially if critical shelter structures are lost. Degradation estimates should separately assess each major service type.

¶38 **Uncertainty:** Both condition predictions and service valuations involve uncertainty. Practitioners should propagate uncertainty through calculations and present results as ranges rather than point estimates where feasible.

#### Offset requirement and restoration equivalence

¶39 Extent and condition accounts provide the quantitative foundation for environmental offset and no-net-loss policies, which apply in a growing number of marine regulatory contexts. The regulatory and procedural side of offsetting is covered in **TG-1.6 OA and Environmental Impact Assessment** Section 3.7; the measurement definitions are set out here so that they are available to compilers and regulators approaching from the accounts. Ecosystem extent and condition accounts establish the quantitative baselines against which offset requirements can be calculated. The offset requirement formula uses the condition index of the habitat that is lost (or degraded), not the condition gain from a restoration action. Consider a port expansion that will result in the loss of 5 hectares of seagrass at condition index 0.80. The offset requirement is:

$$\text{Offset requirement} = (\text{Lost extent}) \times (\text{Condition of lost habitat}) \times (\text{Multiplier})$$

¶40 **Note on the multiplier:** The multiplier is determined by the relevant regulatory authority and is not prescribed by the Ocean Accounts framework. Ocean Accounts provide the input data for the formula (extent and condition metrics) but do not set the multiplier. The illustrative example in this section uses a 2:1 multiplier, whilst the worked example in TG-1.6 Section 3.8 uses a regulator-specified 3:1 multiplier. Practitioners should apply the multiplier required by the applicable regulatory regime.

¶41 Applying a 2:1 multiplier (illustrative only) to account for implementation risk and time lag:

$$\text{Offset} = 5 \text{ ha} \times 0.80 \times 2 = 8 \text{ ha-equivalents of seagrass at reference condition}$$

¶42 The **restoration equivalence unit** for delivery of the offset is defined as:

$$\text{ha-equivalents delivered} = (\text{Restored area}) \times (\text{Condition gain})$$

¶43 where condition gain is the absolute increase in condition index achieved by the restoration action. Using this definition consistently with the requirement formula: restoration of 10 hectares of degraded seagrass from condition 0.60 to 0.80 delivers  $10 \times 0.20 = 2.0$  ha-equivalents, which is insufficient to meet the 8 ha-equivalent requirement. Restoring 10 hectares from 0.50 to 0.80 (gain of 0.30) would deliver  $10 \times 0.30 = 3.0$  ha-equivalents, still insufficient. The offset could instead be achieved through protection of 8 hectares of high-quality seagrass at risk of loss.

¶44 **Side-by-side equivalence check (illustrative seagrass example):**

| Side                | Formula                                              | Values                           | Result                                   |
|---------------------|------------------------------------------------------|----------------------------------|------------------------------------------|
| Requirement         | Lost extent × Condition of lost habitat × Multiplier | 5 ha × 0.80 × 2                  | 8.0 ha-equivalents required              |
| Delivery (option A) | Restored area × Condition gain                       | 10 ha × 0.20 (from 0.60 to 0.80) | 2.0 ha-equivalents delivered (shortfall) |

| Side                | Formula                              | Values                           | Result                                   |
|---------------------|--------------------------------------|----------------------------------|------------------------------------------|
| Delivery (option B) | Restored area × Condition gain       | 10 ha × 0.30 (from 0.50 to 0.80) | 3.0 ha-equivalents delivered (shortfall) |
| Delivery (option C) | Area protected × Condition preserved | 8 ha at reference condition      | 8.0 ha-equivalents (meets requirement)   |

¶45 Both sides of the equivalence calculation must use the same condition metric definition (absolute index points) to produce comparable results. Ecosystem service flow accounts enable assessment of whether proposed offsets adequately compensate for lost service flows, in addition to habitat area. If the 5 hectares of lost seagrass provided coastal stabilisation services valued at USD 2,000/ha/year and fish nursery services valued at USD 1,500/ha/year, the offset must provide equivalent service flows:

$$\text{Required service compensation} = 5 \text{ ha} \times \text{USD } 3,500/\text{ha/year} = \text{USD } 17,500/\text{year}$$

¶46 The offsetting actions must demonstrably provide this level of service flow to achieve functional equivalence. Using the asset valuation approach set out above, the present value of the lost asset is:

$$\text{Lost asset value} = (\text{Annual service flow}) / (\text{Discount rate}) \text{ Lost asset value} = \text{USD } 17,500 / 0.04 = \text{USD } 437,500$$

¶47 This provides a quantitative basis for determining financial compensation where physical offsetting is not feasible.

¶48 **Temporal discounting of offset delivery:** Marine restoration offsets typically take 5–20 years to deliver the promised condition gain, whilst the impact occurs immediately. A nominal 1:1 equivalence at eventual full achievement understates the interim loss of ecosystem services during the restoration period. Some regulatory frameworks address this through temporal discounting provisions or by requiring upfront financial assurance (e.g., surety bonds or in-lieu fee arrangements) that compensate for the time lag. Practitioners should consult their applicable regulatory framework for guidance on whether temporal provisions apply. Where none exist, the multiplier (see above) partly serves this function by requiring over-delivery on the offset.

¶49 Time series data support assessment of whether offsets achieve their intended outcomes over the long term. Post-implementation monitoring should track condition variables and service flows using the same methods as the accounts. This supports objective assessment of offset success and triggers adaptive management responses if targets are not met.

¶50 Countries implementing marine offset policies should ensure that offset accounting is consistent with their broader Ocean Accounts framework to maintain coherence between project-level compensation and national ecosystem reporting<sup>95</sup>.

¶51 The multiplier in the offset requirement is set by the regulator, not by the accounts. Ocean Accounts supply the extent and condition metrics on both sides of the equivalence; the policy parameters – multiplier, temporal discounting of delayed delivery, and whether financial compensation may substitute for physical offset – are matters for the applicable regulatory regime.

¶52 **Degradation.** In SEEA EA, ecosystem **degradation** represents the decline in condition multiplied by the associated loss of future ecosystem service flows, valued in monetary terms<sup>96</sup>. It is the ecosystem equivalent of depletion: the cost of using an ecosystem harder than it can sustain. The SEEA EA states that the approach “involves measuring the value of degradation in terms of loss in future value of ecosystem services due to a decline in ecosystem condition”<sup>97</sup>. For a policy-maker, degradation measures what ecosystem decline is costing the economy.

#### Recording losses from discrete events: catastrophic losses and conversions

¶53 A disaster – a cyclone, a mass bleaching event, an oil spill – is recorded differently from the gradual decline that degradation measures, and the two rules that govern it are the opposite of what intuition suggests.

¶54 **Physical accounts.** The treatment differs between the two account types, and conflating them is a common error. For **individual environmental assets** – fish stocks, timber, mineral resources – the SEEA CF physical asset account carries “Catastrophic losses” as a named line within reductions, covering “exceptional and significant reductions in the natural resource” that result from discrete events (SEEA CF para 5.49(c)). For **ecosystem extent accounts**, SEEA EA provides no standalone catastrophic-losses line: the reductions side is *managed contraction* and *unmanaged contraction*, and catastrophic losses are allocated between them according to whether the reduction was a deliberate management action, though SEEA EA notes they “could be separately identified” as a memorandum component. Report a disaster loss in an extent account as an identified component of unmanaged contraction, so the account still reconciles with the standard structure.

¶55 **A catastrophic loss is a loss of ecosystem condition, not of extent.** SEEA EA records under catastrophic losses the decreases in value due to “large-scale, discrete and recognizable events that cause a significant decline in the condition of an ecosystem asset, that is, significant losses in structure, function or composition”, naming earthquakes, bushfires, cyclones and industrial disasters as the events in scope (paras 10.24, 10.37).

¶56 **Where the event changes the ecosystem type, it is a conversion.** “Where the effects of large-scale events are significant enough for the ecosystem to be considered to have changed its type, this should be recorded as an ecosystem conversion” (para 10.37). Mangrove stand that a cyclone destroys outright, leaving open water or bare mudflat, is a conversion, not a catastrophic loss.

| What the event did                                                                  | Recorded as           |
|-------------------------------------------------------------------------------------|-----------------------|
| Reduced condition of a surviving ecosystem asset (structure, function, composition) | Catastrophic losses   |
| Changed the ecosystem type at that location                                         | Ecosystem conversions |
| Gradual condition decline from ongoing management and use                           | Ecosystem degradation |

¶57 **Degradation is not the disaster line.** Degradation records decline in condition attributable to “the current and expected patterns of ecosystem management and use and expected patterns of environmental variation” (paras 10.22–10.23). A discrete, unforeseeable event is carved out of it precisely because its timing, location and magnitude cannot be anticipated. Routing disaster damage into degradation overstates the entry that feeds adjusted income measures.

¶58 The value recorded for a catastrophic loss is the fall in asset value attributable to the condition decline, derived through the same condition-to-service-flow-to-NPV chain as degradation, above. The value recorded for a conversion is the value of the converted extent, less any value of the ecosystem type that replaces it. Neither represents consumption of fixed capital or depletion: they reduce the value of the asset without arising from its use in production.

### 3.6 Produced Assets in the Ocean Domain

¶1 Whilst this Circular focuses primarily on environmental (non-produced) assets, ocean accounts must also include **produced assets** – the infrastructure, vessels, and equipment built for ocean-based activities. Produced assets are “assets that have come into existence as outputs of production processes”<sup>98</sup>. Recording them alongside environmental assets gives a full account of total ocean wealth and exposes the interdependencies between the two.

#### Types of produced assets in the ocean domain

¶1 Key categories include:

¶2 **Aquaculture fixed assets** – cages, pens, nets, and other infrastructure used for raising cultivated aquatic resources, as well as breeding stocks held as fixed assets<sup>99</sup>. These are produced assets resulting from deliberate investment decisions. For detailed guidance, see **TG-3.9 Aquaculture Accounts**.

¶3 **Offshore energy infrastructure** – platforms, drilling equipment, pipelines, subsea facilities for oil and gas extraction, as well as wind turbines, wave energy converters, and tidal energy devices for marine renewable energy. For detailed guidance, see **TG-3.10 Offshore Energy Accounts**.

¶4 **Port infrastructure** – wharves, jetties, breakwaters, dredged channels, container terminals, and other facilities for maritime transport and trade.

¶5 **Coastal protection structures** – sea walls, groynes, revetments, and other engineered structures designed to protect coastal areas from erosion and flooding. These can be considered alongside the natural coastal protection services provided by ecosystems such as mangroves and coral reefs<sup>100</sup>. Such comparisons often indicate that natural defences are more cost-effective than engineered ones.

¶6 **Vessels** – fishing vessels, cargo ships, cruise ships, offshore service vessels, and other maritime transport equipment.

#### Accounting treatment

¶1 Produced assets are accounted for following standard SNA methodology, with opening stocks, gross fixed capital formation (investment), consumption of fixed capital (depreciation), and closing stocks recorded in physical and monetary terms<sup>101</sup>.

¶2 **Table 10: Produced asset account – structural template (after the SNA capital account)**

| Accounting entry                                  | Vessels  | Aquaculture infrastructure | Offshore energy infrastructure | Port infrastructure | Coastal protection structures | Total |
|---------------------------------------------------|----------|----------------------------|--------------------------------|---------------------|-------------------------------|-------|
| Opening stock (net)                               | [value]  | [value]                    | [value]                        | [value]             | [value]                       | [Σ]   |
| Gross fixed capital formation                     | [value]  | [value]                    | [value]                        | [value]             | [value]                       | [Σ]   |
| Consumption of fixed capital                      | [-value] | [-value]                   | [-value]                       | [-value]            | [-value]                      | [-Σ]  |
| Other changes in volume (incl. catastrophic loss) | [+/-]    | [+/-]                      | [+/-]                          | [+/-]               | [+/-]                         | [+/-] |
| Revaluation                                       | [+/-]    | [+/-]                      | [+/-]                          | [+/-]               | [+/-]                         | [+/-] |
| Closing stock (net)                               | [value]  | [value]                    | [value]                        | [value]             | [value]                       | [Σ]   |
| Memorandum:<br>decommissioning provision          | [value]  | [value]                    | [value]                        | [value]             | [value]                       | [Σ]   |

¶3 *Table 10: Structural template of a produced asset account for the ocean domain. Compiled on standard SNA methodology<sup>101</sup>; the decommissioning memorandum is specific to the ocean domain, where offshore energy and aquaculture infrastructure carry retirement obligations that the net stock does not show. Its treatment is in **TG-3.10 Offshore Energy Accounts** Section 3.6.*

¶4 For ocean accounting, produced assets interact with environmental assets in three ways:

- ¶5 Aquaculture investment creates produced assets (infrastructure) that depend on environmental assets (water quality, marine ecosystems providing supporting services). If the environmental asset degrades, the produced asset becomes less productive.
- ¶6 Offshore oil and gas investment creates produced assets that enable extraction of environmental assets (mineral resources). The produced asset depreciates through use, whilst the environmental asset depletes through extraction.
- ¶7 Coastal infrastructure may protect inland assets but may also affect coastal ecosystem extent and condition – a sea wall can prevent erosion of property whilst destroying the beach ecosystem in front of it.

¶8 These connections should be reflected in integrated accounts that present produced and environmental assets together, enabling analysis of total ocean wealth and its composition. Combined presentations of environmental and economic accounts are addressed in **TG-3.8 Combined Presentations**.

### 3.7 Worked Example: Coastal Ecosystem Asset Accounts

¶1 This section demonstrates how to compile physical and monetary asset accounts for a hypothetical coastal area. The example uses synthetic data for three marine ecosystem types (mangroves, seagrass meadows, and continental shelf waters) and one individual environmental asset (fish stocks), following the compilation procedure from Section 3.2 and the account structures from Sections 3.4 and 3.5. Working through this example demonstrates how the components combine, and how physical declines can be masked by monetary gains.

#### Scenario description

¶1 The accounting area is a coastal zone extending 12 nautical miles offshore and encompassing 500 km<sup>2</sup> of mangrove forest, 200 km<sup>2</sup> of seagrass meadows, and 15,000 km<sup>2</sup> of continental shelf marine waters. The area supports commercial fisheries targeting demersal fish species that depend on mangroves and seagrass as nursery habitat. The accounting period is calendar year 2025.

#### Step 1: Ecosystem extent accounts

¶1 Extent data were compiled from Sentinel-2 satellite imagery processed using supervised classification algorithms, validated by field surveys at 150 ground-truth sites (see **TG-4.1 Remote Sensing and Geospatial Data**). Change detection analysis identified conversions between ecosystem types and losses to non-natural land cover.

#### ¶2 Physical extent account (area in km<sup>2</sup>)

| Accounting entry                              | Mangroves | Seagrass | Shelf Waters | Total  |
|-----------------------------------------------|-----------|----------|--------------|--------|
| Opening extent (1 Jan 2025)                   | 500       | 200      | 15,000       | 15,700 |
| <b>Additions to extent</b>                    |           |          |              |        |
| Managed expansion (restoration)               | 2.5       | 1.2      | 0            | 3.7    |
| Natural expansion                             | 0.8       | 0.3      | 0            | 1.1    |
| <i>Total additions</i>                        | 3.3       | 1.5      | 0            | 4.8    |
| <b>Reductions in extent</b>                   |           |          |              |        |
| Managed reduction (conversion to aquaculture) | 4.0       | 0.5      | 0            | 4.5    |
| Natural reduction (storm damage, erosion)     | 2.5       | 1.8      | 0            | 4.3    |
| <i>Total reductions</i>                       | 6.5       | 2.3      | 0            | 8.8    |
| <b>Net change in extent</b>                   | -3.2      | -0.8     | 0            | -4.0   |
| Closing extent (31 Dec 2025)                  | 496.8     | 199.2    | 15,000       | 15,696 |

¶3 Table 5: Physical ecosystem extent account for coastal zone, 2025

¶4 **Reading the account.** The coastal zone lost 3.2 km<sup>2</sup> of mangroves and 0.8 km<sup>2</sup> of seagrass during 2025. Managed reductions (conversion to aquaculture ponds) exceeded managed expansion (restoration projects); deliberate human decisions drove more loss than restoration could offset. Natural reductions from storm damage and coastal erosion added to the deficit. Continental shelf waters recorded no change in extent because the accounting area boundary remained fixed.

#### Step 2: Ecosystem condition accounts

¶1 Condition data were compiled from 45 monitoring stations distributed across the three ecosystem types, measuring variables in each of the six ECT classes. Measurements were taken quarterly and averaged for the year.

#### ¶2 Condition variable account for mangroves (selected variables)

| ECT class              | Variable               | Unit                 | Polarity | Lower reference <i>L</i> | Upper reference <i>U</i> | Opening value | Closing value |
|------------------------|------------------------|----------------------|----------|--------------------------|--------------------------|---------------|---------------|
| A1 Physical state      | Sedimentation rate     | mm/yr                | Inverse  | 8.0                      | 2.0                      | 3.2           | 3.5           |
| A2 Chemical state      | Soil salinity          | PSU                  | Inverse  | 35                       | 15                       | 18            | 19            |
| B1 Compositional state | Tree species richness  | count                | Normal   | 2                        | 12                       | 8             | 8             |
| B2 Structural state    | Canopy density         | % cover              | Normal   | 20                       | 85                       | 72            | 70            |
| B3 Functional state    | Leaf litter production | g/m <sup>2</sup> /yr | Normal   | 150                      | 550                      | 480           | 465           |
| C1 Landscape/seascape  | Connectivity index     | 0–1                  | Normal   | 0.20                     | 0.80                     | 0.68          | 0.65          |

¶3 Table 6: Ecosystem condition variable account for mangroves, 2025, in the Table 3a format

¶4 **Reading the account.** Every variable sits between its two reference levels, and all but species richness are moving towards the lower one. Canopy density dropped from 72% to 70% against an upper reference of 85%. Connectivity between mangrove patches fell from 0.68 to 0.65, likely because the conversion of mangrove patches to aquaculture created gaps in the landscape. Leaf litter production, a proxy for ecosystem productivity, declined from 480 to 465 g/m<sup>2</sup>/yr.

¶5 **Condition indicator account.** Each variable is rescaled on its own reference levels using the transformation in **TG-2.1** Section 3.4.1 –  $(V - L) / (U - L)$  for normal polarity,  $(L - V) / (L - U)$  for inverse.

| ECT class              | Condition indicator   | Opening | Closing | Change | Data tier |
|------------------------|-----------------------|---------|---------|--------|-----------|
| A1 Physical state      | Sedimentation         | 0.80    | 0.75    | -0.05  | 2         |
| A2 Chemical state      | Soil salinity         | 0.85    | 0.80    | -0.05  | 2         |
| B1 Compositional state | Tree species richness | 0.60    | 0.60    | 0.00   | 1         |

| ECT class             | Condition indicator    | Opening | Closing | Change | Data tier |
|-----------------------|------------------------|---------|---------|--------|-----------|
| B2 Structural state   | Canopy density         | 0.80    | 0.77    | -0.03  | 1         |
| B3 Functional state   | Leaf litter production | 0.83    | 0.79    | -0.04  | 2         |
| C1 Landscape/seascape | Connectivity           | 0.80    | 0.75    | -0.05  | 2         |

¶6 *Table 6a: Ecosystem condition indicator account for mangroves, 2025, in the Table 3b format*

¶7 Worked for one row: canopy density is normal polarity with  $L = 20\%$  and  $U = 85\%$ , so the closing indicator is  $(70 - 20) / (85 - 20) = 50 / 65 = 0.77$ .

¶8 **Condition index.** Aggregated as an unweighted arithmetic mean of the six class indicators – the publication default in **TG-2.1** Section 3.6. With one indicator per class the class sub-index equals the indicator.

| Level                           | Component              | Weight | Opening     | Closing     | Change       |
|---------------------------------|------------------------|--------|-------------|-------------|--------------|
| Class sub-index                 | A1 Physical state      | 1/6    | 0.80        | 0.75        | -0.05        |
| Class sub-index                 | A2 Chemical state      | 1/6    | 0.85        | 0.80        | -0.05        |
| Class sub-index                 | B1 Compositional state | 1/6    | 0.60        | 0.60        | 0.00         |
| Class sub-index                 | B2 Structural state    | 1/6    | 0.80        | 0.77        | -0.03        |
| Class sub-index                 | B3 Functional state    | 1/6    | 0.83        | 0.79        | -0.04        |
| Class sub-index                 | C1 Landscape/seascape  | 1/6    | 0.80        | 0.75        | -0.05        |
| <b>Mangrove condition index</b> | <b>All classes</b>     | –      | <b>0.78</b> | <b>0.74</b> | <b>-0.04</b> |

¶9 *Table 6b: Ecosystem condition index for mangroves, 2025, in the Table 3c format*

¶10 The mangrove condition index fell 0.04 index points over the year. That figure – not a judgement about the variables – is what the degradation entry in Step 4 consumes. Had the aggregation rule been one-out-all-out rather than the arithmetic mean, the index would have been 0.60 in both periods and the change zero, because species richness is both the worst indicator and the only stable one. The rule is doing real work, which is why Section 3.5.2 requires it to be recorded in the account.

### Step 3: Fish stock asset account

¶11 Fish stock data were compiled from stock assessment models for the dominant demersal species complex, using data from commercial catch statistics, fishery-independent trawl surveys, and length-frequency analysis. The stock assessment estimated total biomass, natural mortality, recruitment, and fishing mortality using age-structured models.

#### ¶12 Physical asset account for fish stocks (biomass in tonnes)

| Accounting entry                                   | Value  |
|----------------------------------------------------|--------|
| Opening stock (1 Jan 2025)                         | 42,000 |
| <b>Additions to stock</b>                          |        |
| Natural growth (recruitment + growth)              | 8,500  |
| Upward reappraisals                                | 0      |
| <i>Total additions</i>                             | 8,500  |
| <b>Reductions in stock</b>                         |        |
| Gross catch (commercial fisheries)                 | 7,200  |
| Natural mortality                                  | 4,800  |
| Catastrophic losses (fish kill from hypoxia event) | 500    |
| <i>Total reductions</i>                            | 12,500 |
| Closing stock (31 Dec 2025)                        | 38,000 |
| <b>Derived measures</b>                            |        |
| Sustainable yield (MSY estimate)                   | 6,500  |
| Depletion (catch – sustainable yield)              | 700    |

¶13 *Table 7: Physical asset account for demersal fish stock, 2025*

¶14 **Reading the account.** The fish stock declined by 4,000 tonnes (9.5%) during 2025. Gross catch of 7,200 tonnes exceeded the sustainable yield estimate of 6,500 tonnes by 700 tonnes. That 700 tonnes is depletion, the amount by which the fishery is drawing down its capital base. The stock also experienced a catastrophic loss of 500 tonnes from a hypoxia event in coastal waters during summer, potentially linked to the nutrient loading and habitat fragmentation recorded in the mangrove condition data. The decline was driven by the combination of overfishing and environmental stress.

### Step 4: Monetary valuation

¶11 Monetary values were estimated for ecosystem assets using the NPV of expected future ecosystem service flows, and for fish stocks using the NPV of expected future resource rents.

¶12 **Mangrove ecosystem services valuation** (values expressed per km<sup>2</sup> for this illustrative example):

- ¶13 Coastal protection service: Replacement cost method based on equivalent seawall construction, estimated at USD 12,000 per km<sup>2</sup> per year

- ¶4 Carbon sequestration service: Social cost of carbon (USD 50 per tonne CO<sub>2</sub>) applied to sequestration rate, USD 400 per km<sup>2</sup> per year
- ¶5 Fish nursery service: Productivity change method estimating contribution to commercial fisheries, USD 800 per km<sup>2</sup> per year
- ¶6 Total annual ecosystem service value: USD 13,200 per km<sup>2</sup> per year
- ¶7 Discount rate: 4% real
- ¶8 Asset value (perpetual annuity):  $\text{USD } 13,200 / 0.04 = \text{USD } 330,000$  per km<sup>2</sup> (equivalent to USD 3,300 per hectare)

¶9 **Seagrass ecosystem services valuation** (values expressed per km<sup>2</sup>):

- ¶10 Carbon sequestration: USD 300/km<sup>2</sup>/yr
- ¶11 Water filtration: Avoided treatment cost USD 150/km<sup>2</sup>/yr
- ¶12 Fish nursery: USD 600/km<sup>2</sup>/yr
- ¶13 Total annual service value: USD 1,050/km<sup>2</sup>/yr
- ¶14 Asset value (4% discount):  $\text{USD } 1,050 / 0.04 = \text{USD } 26,250$  per km<sup>2</sup> (equivalent to USD 262.5 per hectare)

¶15 **Fish stock valuation:**

- ¶16 Resource rent per tonne caught: USD 450 (gross value of landings USD 1,200/tonne, less all costs)
- ¶17 Sustainable yield: 6,500 tonnes/yr
- ¶18 Annual sustainable resource rent:  $6,500 \times \text{USD } 450 = \text{USD } 2,925,000$
- ¶19 Asset value (4% discount, perpetual):  $\text{USD } 2,925,000 / 0.04 = \text{USD } 73,125,000$

¶20 **Monetary ecosystem asset account (values in USD thousand)**

| Accounting entry                                                                       | Mangroves  | Seagrass  | Total      |
|----------------------------------------------------------------------------------------|------------|-----------|------------|
| Opening value (500 km <sup>2</sup> x USD 3,300/ha; 200 km <sup>2</sup> x USD 262.5/ha) | 165,000    | 5,250     | 170,250    |
| Ecosystem enhancement (condition improvement from restoration, 2.5 km <sup>2</sup> )   | 825        | 0         | 825        |
| Ecosystem degradation (condition index decline x opening value)                        | -6,600     | -105      | -6,705     |
| Ecosystem conversions (additions)                                                      | 0          | 0         | 0          |
| Ecosystem conversions (reductions: -4.0 km <sup>2</sup> , -0.5 km <sup>2</sup> )       | -1,320     | -13       | -1,333     |
| Catastrophic losses (storm damage value loss)                                          | -825       | -47       | -872       |
| Reappraisals                                                                           | 0          | 0         | 0          |
| Revaluation (5% increase in unit service values)                                       | 8,250      | 263       | 8,513      |
| <b>Net change in value</b>                                                             | <b>330</b> | <b>98</b> | <b>428</b> |
| Closing value                                                                          | 165,330    | 5,348     | 170,678    |

¶21 *Table 8: Monetary ecosystem asset account, 2025*

¶22 **Where the degradation entry comes from.** The mangrove figure is the condition index decline from Table 6b applied to the opening asset value, following Section 3.5.3:  $0.04 \times \text{USD } 165,000 \text{ thousand} = \text{USD } 6,600 \text{ thousand}$ . The seagrass figure is the same calculation on a parallel condition account not reproduced here, whose index fell 0.02 points:  $0.02 \times \text{USD } 5,250 \text{ thousand} = \text{USD } 105 \text{ thousand}$ . Both fall inside the applicability conditions for the simplified linear approximation set out in Section 3.5.3 – the decline is well under 0.20 index points, no threshold response is documented for these ecosystem types in this range, and coastal protection accounts for over 70 per cent of the mangrove service value per hectare. A compiler whose condition decline is larger, or whose asset value is split across services that respond differently, must use the service-specific route instead.

¶23 **Fish stock monetary asset account (values in USD thousand)**

| Accounting entry                                         | Value  |
|----------------------------------------------------------|--------|
| Opening value (1 Jan 2025)                               | 73,125 |
| Additions (natural growth valued at resource rent/tonne) | 3,825  |
| Reductions (extraction and mortality)                    | -5,400 |
| Catastrophic losses (hypoxia event)                      | -225   |
| Reappraisals (revised sustainable yield estimate)        | 0      |
| Revaluation (10% increase in fish prices)                | 7,313  |
| Closing value (31 Dec 2025)                              | 78,638 |

¶24 *Table 9: Monetary fish stock asset account, 2025*

¶25 **Reading the account – and what it can obscure.** Holding gains do most of the work in this account. For mangroves, a 5% increase in unit service values (driven by updated coastal protection valuations following storm damage in a neighbouring region) generated USD 8.25 million, enough to more than offset USD 6.6 million of degradation, USD 1.32 million of conversion loss and USD 0.83 million of catastrophic loss, and to leave the mangrove closing value USD 0.33 million above its opening value. For fish stocks, a 10% price increase generated USD 7.3 million, more than offsetting the value of depletion, so that account too closes higher than it opened.

¶26 Strip the revaluations out and the picture inverts. Mangroves lose USD 7.92 million at constant prices; the ecosystem account as a whole loses USD 8.09 million rather than gaining the USD 0.43 million the closing line reports; and the fish stock loses USD 1.80 million rather than gaining USD 5.51 million. The physical accounts said as much all along – declining fish stocks, shrinking mangroves, a condition index down 0.04 points – and it is the price column, not the ecosystem, that is carrying the closing balance.

¶27 This is why the decomposition is not optional. Adjusted income measures should deduct depletion and degradation at constant prices, and changes in asset value due to price effects must be reported separately as revaluations rather than as real income. The SEEA CF requires depletion to be valued at the average of opening and closing prices to give a neutral mid-period valuation<sup>36</sup>. An account that reports only opening and closing values, without the revaluation line, is capable of showing growth through an entire period of ecosystem collapse.

#### Step 5: Integration and policy implications

¶1 The worked example demonstrates several key linkages in the ocean accounting system:

##### ¶2 Upward linkages to policy (TG-1.x and TG-2.x):

- ¶3 **TG-1.1 National Ocean Budgets:** The USD 6,705 thousand in ecosystem degradation plus USD 315 thousand in fish stock depletion (700 tonnes above sustainable yield at USD 450/tonne resource rent, for a total of USD 7,020 thousand at constant prices) represents the natural capital cost of economic activity during 2025. This cost should be deducted from gross income measures to calculate environmentally adjusted net domestic product.
- ¶4 **TG-2.1 Aggregate Biophysical Indicators of Environmental State:** The 0.025% decline in ecosystem extent (4.0 km<sup>2</sup> loss from 15,700 km<sup>2</sup> total) and 9.5% decline in fish stock biomass provide headline indicators of environmental state for policy monitoring.
- ¶5 **TG-2.4 Ecosystem Goods and Services:** The estimated ecosystem service flows (coastal protection, carbon sequestration, fish nursery) quantified in the valuation step provide inputs to ecosystem service accounts.

##### ¶6 Downward linkages to data (TG-4.x):

- ¶7 **TG-4.1 Remote Sensing and Geospatial Data:** Sentinel-2 imagery provided the primary data source for extent change detection.
- ¶8 **TG-4.2 Survey Methods for Ocean Economic Activity:** Field monitoring at 45 stations provided condition variable measurements. In-situ data remains necessary to complement remote sensing.
- ¶9 **TG-4.3 Administrative Data Sources:** Integration of extent, condition, and stock assessment data within a common spatial framework enabled consistent attribution of ecosystem services to ecosystem assets and analysis of nursery habitat contributions to fisheries.

##### ¶10 Cross-account consistency:

- ¶11 Fish stock depletion of 700 tonnes corresponds to extraction recorded in physical supply-use tables (see **TG-3.2 Flows from Environment to Economy**)
- ¶12 Ecosystem extent changes are reconciled with ecosystem conversion matrices
- ¶13 Monetary degradation and depletion entries correspond to physical condition decline and stock reduction multiplied by appropriate unit values

¶14 This worked example illustrates how asset accounts provide a structured framework for organising diverse data sources, maintaining accounting identities that ensure internal consistency, and deriving policy-relevant measures of sustainability. The procedure can be scaled to national accounting areas and extended to additional asset types following the same logical structure.

#### Implementation Considerations

¶1 For minimum institutional capacity, data infrastructure, and human skills requirements for compiling these accounts, see TG-0.8 Implementation Readiness Assessment. For guidance on adapting these methods to sub-national scales, see TG-3.11 Sub-National Ocean Accounts.

## 4. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

#### FOOTNOTES

1. ¶1 SEEA CF, para 5.42. "Asset accounts record both the opening and the closing stock of assets and the changes over the accounting period."
2. ¶2 SEEA CF, para 5.43
3. ¶3 SEEA CF, para 5.44
4. ¶4 SEEA CF, para 5.72. For renewable biological resources, "natural growth relates to the number of animals... or volume of plants... that have been added to the stock due to natural processes."
5. ¶5 SEEA CF, para 5.82. "For any given population, it is possible to calculate the number of animals or volume of plants by age or size class that may be removed from the population without affecting the capacity of the population to regenerate itself."
6. ¶6 SEEA CF, para 5.180
7. ¶7 SEEA CF, para 5.51. "Reappraisals record changes in estimates of the stock due to revisions in the estimation techniques being applied."
8. ¶8 SEEA CF, para 5.458
9. ¶9 SEEA CF, para 5.52
0. ¶10 SEEA CF, para 5.422
1. ¶11 SEEA CF, para 5.47
2. ¶12 SEEA CF, para 5.429
3. ¶13 SEEA CF, para 5.428
4. ¶14 SEEA CF, para 5.48
5. ¶15 SEEA CF, para 5.50
6. ¶16 SEEA CF, para 2.107
7. ¶17 SEEA CF, Annex A5.1, para A5.28–A5.31
8. ¶18 2025 SNA, Chapter 11, para 11.45
9. ¶19 SEEA CF, para 5.431
0. ¶20 SEEA CF, Chapter 5, Table 5.1. Classification of environmental assets.

1. ¶21 SEEA EA, Table 4.1 and para 4.10–4.22. Ecosystem extent account structure and accounting entries.
2. ¶22 SEEA CF, para 5.103–5.111
3. ¶23 2025 SNA, Chapter 13, paras 13.1–13.15. Balance sheets record stocks of assets and liabilities, with net worth = assets - liabilities.
4. ¶24 SEEA CF, para 5.96
5. ¶25 SEEA CF, para 5.97
6. ¶26 SEEA CF, para 5.102
7. ¶27 SEEA CF, para 5.103–5.111
8. ¶28 SEEA CF, para 5.110. “Net present value is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period.”
9. ¶29 SEEA CF, Annex A5.1, para A5.15
0. ¶30 SEEA CF, Annex A5.2, para A5.42–A5.76
1. ¶31 SEEA CF, Annex A5.2, paras A5.42–A5.76. Discusses discount rate selection including the use of a rate “at the higher end of the range of observable rates on government and high-quality corporate bonds” adjusted for asset-specific risk.
2. ¶32 SEEA CF, para 5.444–5.452
3. ¶33 SEEA CF, para 5.448
4. ¶34 SEEA EA, para 12.30–12.39
5. ¶35 SEEA CF, Annex A5.1, para A5.31
6. ¶36 SEEA CF, Annex A5.1, para A5.27
7. ¶37 SEEA CF, para 5.11
8. ¶38 SEEA CF, para 5.393
9. ¶39 SEEA CF, para 5.395
0. ¶40 SEEA CF, para 5.420–5.422
1. ¶41 SEEA CF, para 5.423
2. ¶42 SEEA CF, para 5.425
3. ¶43 SEEA CF, para 5.457
4. ¶44 SEEA CF, para 5.429
5. ¶45 SEEA CF, para 5.429
6. ¶46 SEEA CF, Table 5.22
7. ¶47 SEEA CF, para 5.436
8. ¶48 Physical asset account template integrating SEEA CF Table 5.4 (general structure of physical asset accounts for environmental assets), SEEA EA Table 4.1 (ecosystem extent account), and SEEA CF Table 5.22 (aquatic resources account).
9. ¶49 SEEA CF, para 5.431–5.432
0. ¶50 SEEA CF, para 5.431
1. ¶51 SEEA CF, para 5.433
2. ¶52 SEEA CF, para 5.434
3. ¶53 SEEA CF, para 5.435
4. ¶54 SEEA CF, para 5.436
5. ¶55 SEEA CF, para 5.442
6. ¶56 SEEA CF, para 5.450
7. ¶57 SEEA CF, para 5.443
8. ¶58 SEEA CF, para 5.173
9. ¶59 SEEA CF, para 5.175–5.178
0. ¶60 SEEA CF, para 5.182–5.183
1. ¶61 SEEA CF, para 5.113–5.114. “Resource rent is the economic rent that accrues in relation to environmental assets, including natural resources.”
2. ¶62 SEEA CF, para 5.474
3. ¶63 SEEA CF, para 5.476
4. ¶64 SEEA CF, para 5.469
5. ¶65 SEEA EA, para 2.6
6. ¶66 SEEA EA, para 2.11
7. ¶67 SEEA EA, para 4.1
8. ¶68 SEEA EA, para 4.10. “The structure of the rows reflects the general logic of asset accounts as described in the SEEA Central Framework.”
9. ¶69 SEEA EA, Table 4.1
0. ¶70 UN SEEA EA (2021), paras 4.10–4.13 and Table 4.1. The row structure of the extent account follows the general asset-account logic of the SEEA Central Framework (opening stock, additions, reductions, closing stock); columns correspond to the classes of the selected ecosystem type classification.
1. ¶71 UN SEEA EA (2021), para 4.15. Definitions of opening/closing extent, managed and unmanaged expansions, and managed and unmanaged reductions. The accounting identity that the sum of areas of all ecosystem types equals the total area of the EAA is stated in para 4.13.
2. ¶72 UN SEEA EA (2021), paras 4.14 (minimum-detail recording where managed/unmanaged split is unavailable) and 4.17 (treatment of revisions arising from updated input data or methods; no distinct revision entry recorded).
3. ¶73 SEEA EA, para 4.23
4. ¶74 SEEA EA, para 3.32
5. ¶75 SEEA EA, para 3.32
6. ¶76 IUCN GET, MI Marine Shelf biome
7. ¶77 SEEA EA, para 2.13
8. ¶78 SEEA EA, para 5.5–5.8
9. ¶79 SEEA EA, para 5.15–5.25
0. ¶80 SEEA EA, para 3.35
1. ¶81 SEEA EA, para 5.32, Table 5.1
2. ¶82 SEEA EA, Figure 6.1 and para 6.18. The capacity to deliver ecosystem services is a function of both the extent and the condition of the ecosystem asset.
3. ¶83 SEEA EA, Table 5.1. Ecosystem Condition Typology (ECT) classes for organising condition characteristics.
4. ¶84 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.”
5. ¶85 SEEA EA, para 5.47. “A set of about 6 to 10 well-selected indicators for a given ecosystem type should provide sufficient information to assess the overall condition of an ecosystem asset.”
6. ¶86 SEEA EA, Table 5.7. Indicative set of ecosystem condition variables for biomes structured in accordance with the ECT.
7. ¶87 SEEA EA, para 5.35–5.48
8. ¶88 SEEA EA, para 5.10
9. ¶89 SEEA EA, Chapter 10
0. ¶90 SEEA EA, Chapter 10, Table 10.1, paras 10.7–10.12. The monetary ecosystem asset account records the NPV of ecosystem services supplied by each ecosystem type.

1. ¶91 SEEA EA, paras 10.15–10.41. Definitions of ecosystem enhancement (para 10.15), ecosystem degradation (para 10.21), ecosystem conversions (para 10.30), other changes in volume (para 10.36), and revaluations (para 10.41).
2. ¶92 SEEA EA, paras 10.36–10.39. Catastrophic losses are “large-scale, discrete and recognizable events that cause a significant loss in the condition of an ecosystem asset” (para 10.37). Reappraisals record changes due to “updated information that permits a reassessment of the expected condition of the ecosystem assets or the future demand for ecosystem services” (para 10.38).
3. ¶93 SEEA EA, para 10.41. “Revaluations are changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services.”
4. ¶94 United Nations Environment Programme (2022). *Guidelines on Biophysical Modelling for Ecosystem Accounting*. UNEP, Nairobi. Provides methods for assessing ecosystem capacity and identifying threshold responses where the linear approximation is not appropriate.
5. ¶95 Countries implementing marine offset policies should ensure that offset accounting is consistent with their broader Ocean Accounts framework, so that project-level compensation and national ecosystem reporting remain coherent.
6. ¶96 SEEA EA, para 11.25
7. ¶97 SEEA EA, para 12.30
8. ¶98 SEEA CF, para 5.34
9. ¶99 SEEA CF, para 5.395
10. ¶100 SEEA EA, para 6.55 on coastal protection as an ecosystem service
11. ¶101 2025 SNA, Chapter 13

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