

Seagrass Ecosystem Accounting

Provides seagrass-specific guidance for ecosystem accounts, covering subtidal mapping, species-dependent service parameters and the blue carbon storage–sequestration distinction.

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OUTCOME

This circular provides seagrass-specific guidance for ecosystem accounts. It addresses the distinct challenges of subtidal mapping, species-dependent service parameters, and the blue carbon storage–sequestration distinction.

Upon implementation, countries will be able to: (a) compile seagrass extent accounts; (b) develop condition accounts using seagrass-specific indicators; (c) quantify ecosystem service flows, with emphasis on carbon sequestration, nursery habitat, and coastal protection; and (d) apply monetary valuation and integrate seagrass accounts within national ocean accounting frameworks.

Carbon stock and sequestration methods align with the parallel blue carbon guidance for mangroves and coastal wetlands in [TG-6.2 Mangrove and Coastal Wetland Accounting](#).

Framework Position

This Circular owns the extent, condition, service and asset accounts for IUCN GET M1.1 seagrass meadows, and the seagrass-specific measurement problems: subtidal optical limits and deep-meadow undercoverage, species-dependent service parameters, and the carbon storage–versus–sequestration distinction.

It cross-refers for the account structure and the NPV and condition-adjustment rules ([TG-3.1](#)), extent and condition measurement ([TG-4.1](#), [TG-4.8](#), [TG-4.9](#)) and indicator derivation ([TG-2.1](#), [TG-2.4](#)).

The carbon pricing rule is not this Circular’s: it is owned by [TG-6.2](#) Section 3.6 and applies unchanged to seagrass. This matters because seagrass credits trade almost entirely on the voluntary market, which that rule excludes.

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ABOUT THIS CIRCULAR

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DRAFT

1. Outcome

¶1 This circular provides seagrass-specific guidance for ecosystem accounts. It addresses the distinct challenges of subtidal mapping, species-dependent service parameters, and the blue carbon storage–sequestration distinction.¹

¶2 Upon implementation, countries will be able to: (a) compile seagrass extent accounts; (b) develop condition accounts using seagrass-specific indicators; (c) quantify ecosystem service flows, with emphasis on carbon sequestration, nursery habitat, and coastal protection; and (d) apply monetary valuation and integrate seagrass accounts within national ocean accounting frameworks.²

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¶6 It cross-refers for the account structure and the NPV and condition-adjustment rules (**TG-3.1**), extent and condition measurement (**TG-4.1**, **TG-4.8**, **TG-4.9**) and indicator derivation (**TG-2.1**, **TG-2.4**).

¶7 The **carbon pricing rule is not this Circular's**: it is owned by **TG-6.2** Section 3.6 and applies unchanged to seagrass. This matters because seagrass credits trade almost entirely on the voluntary market, which that rule excludes.

2. Requirements

2.1 Prerequisite Knowledge

¶1 This Circular requires familiarity with:

- ¶2 **TG-0.1 General Introduction** – ocean accounts framework and terminology.
- ¶3 **TG-0.7 Quality Assurance** – applied to deep-meadow undercoverage (Section 3.1.2) and the compilation procedure (Step 8).
- ¶4 **TG-2.1 Biophysical Indicators** – indicator-selection framework and the normalisation formula applied in Section 3.2.
- ¶5 **TG-2.4 Ecosystem Goods and Services** – service identification methodology applied in Section 3.3.
- ¶6 **TG-2.8 Climate Change Indicators** – climate-account linkages for carbon services (Sections 3.3.2, 3.4.1).
- ¶7 **TG-3.1 Asset Accounts** – extent and condition account templates applied throughout Section 3.
- ¶8 **TG-4.1 Remote Sensing and Geospatial Data** – satellite platforms, water-column correction, and mapping QA, supplemented by acoustic methods in Section 3.1.3 below.

¶9 **TG-1.9 Valuation** is not a direct prerequisite (physical accounts may be compiled without monetary valuation), but is required where Section 3.4 is applied.³

2.2 Institutional and Technical Requirements

¶1 Coordination across NSO, marine environment agency, and fisheries authority follows **TG-0.1**. Technical capacity is required for: (a) optical satellite classification and acoustic survey for extent mapping (Section 3.1); (b) field measurement of shoot density, canopy height, percent cover, and epiphyte load; (c) carbon stock estimation following Fourqurean et al. (2012) and Howard et al. (2014); and (d) biophysical modelling per the SEEA EA guidelines.⁴

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

3. Guidance Material

3.1 Extent Accounting

¶1 The extent account structure (opening stock, additions, reductions, closing stock) follows **TG-3.1** Section 3.4. This section addresses seagrass-specific issues: subtidal detection limits, species-level stratification, and the acoustic methods required for deep meadows.⁵

3.1.1 Classification Framework

¶1 Seagrass meadows correspond to IUCN GET functional group **M1.1 Seagrass meadows** (Marine Shelf biome M1). The GET hierarchy and national crosswalk requirement are in **TG-4.1** Section 3.2.4.⁶ National classifications should disaggregate by:

- ¶2 **Dominant species** (e.g., *Posidonia*, *Zostera*, *Thalassia*, *Halophila*): a required stratification, since carbon, productivity, and service parameters differ by up to an order of magnitude across genera (Section 3.2)
- ¶3 **Depth zone** (intertidal versus subtidal)
- ¶4 **Density class** (sparse, moderate, dense)

3.1.2 Mapping Challenges

¶1 Optical remote sensing is limited to approximately 10–15 m depth in clear waters and less in turbid coastal environments.⁷ Meadows below that limit are undetectable by standard optical methods and require the acoustic methods in Section 3.1.3. In exceptionally clear waters they reach 40–60 m. Additional constraints include spectral confusion with macroalgae and bare sediment,⁸ seasonal biomass variation (30–50% in temperate regions, so imagery acquisition should be timed consistently across years), and fragmented patch distributions that demand higher-resolution imagery.

¶2 As TG-4.1 focuses on optical and bathymetric platforms, this circular serves as the interim GOAP reference for acoustic survey methods pending a dedicated acoustic circular.

3.1.3 Mapping Methods

¶1 Tiered approach following GOAP convention:⁹

¶2 **Tier 1 – Global data products.** UNEP-WCMC Global Distribution of Seagrasses, Allen Coral Atlas benthic classes (see **TG-4.1** Section 3.2.2), and regional initiatives. Indicative only, with insufficient temporal consistency for formal accounts.¹⁰

¶3 **Tier 2 – Satellite classification.** Sentinel-2 (10 m visible bands, 5-day revisit) and Landsat with supervised classification, object-based analysis, water-column correction, and multi-temporal compositing. Platform specifications in **TG-4.1** Section 3.1.1. Field ground-truthing is required.

¶4 **Tier 3 – Integrated multi-source mapping.** Optical satellite combined with aerial/UAV imagery, **acoustic surveys** (sidescan sonar or multibeam echosounder at 100–500 kHz, detecting seagrass-sediment contrast beyond 30 m depth¹¹), underwater video transects, and diver surveys. Acoustic protocols and calibration must be documented to enable reproducibility across accounting periods.

3.1.4 Recording Extent Changes

¶1 Extent change categories follow SEEA EA Table 4.2:

Change category	Description
Managed expansion	Restoration, transplanting, or facilitated recovery through pressure reduction.
Managed reduction	Dredging, coastal development, infrastructure.
Natural expansion	Colonisation of suitable substrates, recovery from disturbance.
Natural reduction	Storm damage, disease, grazing.
Catastrophic losses	Marine heatwaves, sediment burial, toxic algal blooms, oil spills.

¶12 Anthropogenic pressure-driven loss is recorded under “Other reductions – degradation” (SEEA EA Table 4.2), with optional memorandum sub-rows attributing the pressure category. The principal pressure categories from the seagrass-loss literature (Waycott et al. 2009; Dunic et al. 2021) are eutrophication, sediment loading from coastal development, physical disturbance (anchoring, propeller scarring, dredging), destructive fishing gear, coastal engineering, marine heatwaves, and wasting disease.¹² The memorandum-row convention is demonstrated in Section 3.6 Step 1.

3.2 Condition Assessment

¶1 The SEEA EA three-stage approach (variables → indicators → optional composite) and the normalisation formula are defined in **TG-3.1** Section 3.5.2 and **TG-2.1** Section 3.4.1. The measurement protocols for the variables themselves – how each is observed, at what frequency and to what tolerance – are owned by **TG-4.8 Physical Condition Measurement** and **TG-4.9 Biological Condition Measurement**; this Section selects and interprets them for seagrass meadows.

¶2 **Species identity is a stratification variable, not a condition indicator.** *Posidonia oceanica*, *Thalassia testudinum*, *Zostera marina*, *Halophila* spp., and *Enhalus acoroides* differ in morphology, longevity, and carbon density by up to an order of magnitude, so reference values and service coefficients must be selected per genus.

¶3 **Sediment organic carbon stock is an asset attribute, not a condition variable**, and is treated in Section 3.3.2 to avoid double counting. Where a sediment-carbon condition signal is desired, use a process metric (observed sediment accumulation rate against a reference rate) rather than the stock.

3.2.1 Condition Variables

¶1 Candidate variables fall into four groups: structural (shoot density, canopy height, percent cover, above- and below-ground biomass), sediment process (grain size, accumulation rate, sulphide concentrations), water quality (Kd, Secchi depth, nutrient and chlorophyll-a concentrations), and associated biota (epiphyte load, mesograzers abundance, fish community).¹³ The recommended minimum set for international comparability is in Table 3.2.1.

¶2 Table 3.2.1: Recommended minimum condition variables for seagrass ecosystem accounts

Condition Variable	Measurement	Indicator Direction	Reference Condition	Data Source
Percent cover	% bottom covered	Positive (higher = better)	Site-specific historical	Remote sensing, transects
Shoot density	Shoots/m ²	Positive (higher = better)	Species-specific	Quadrat sampling
Canopy height	cm	Positive (higher = better)	Species-specific	Field measurement
Epiphyte load	% coverage	Inverse (lower = better)	Low (indicative default: < 10%)	Visual assessment
Species diversity	Species count	Positive (higher = better)	Site-specific	Surveys

¶3 **QA check:** indicators should fall within [0, 1]. Values outside this range indicate a direction or reference-level error.

3.2.2 Reference Conditions

¶1 Few pristine seagrass meadows remain and historical baselines are typically unavailable. Compilers should apply the SEEA EA reference-condition hierarchy on a document-and-justify basis: natural reference preferred, historical baseline where natural is undeterminable, best observed as fallback, and policy target where mandated for regulatory reporting.¹⁴ Sources include protected marine areas, historical photographs and traditional knowledge, palaeoecological sediment cores, and scientific literature on relatively pristine systems.

3.2.3 Condition Indicators

¶1 The illustrative table below uses the Table 3.2.1 minimum set. The simplified ratio shown is for introductory purposes only.

Variable	Reference Value	Current Value	Indicator
Percent cover	60%	45%	0.75
Shoot density	800 shoots/m ²	560 shoots/m ²	0.70
Canopy height	40 cm	28 cm	0.70
Epiphyte load (inverse)	< 10% (VH); 50% (VL)	18%	0.80
Species diversity	7 species	5 species	0.71

¶2 Note: The percent cover, shoot density, canopy height, and species diversity rows use the simplified ratio of current value to reference value, equivalent to the full normalisation formula (defined in **TG-2.1 Biophysical Indicators for Ocean Accounts** Section 3.4.1) only when VL = 0. The epiphyte load row is an inverse indicator. Compilers should apply the full formula with site-specific VL values, as demonstrated in the worked example (Section 3.6) and the compilation procedure (Step 4). Where additional indicators are illustrated outside the minimum set (e.g., light at depth, sediment process metrics), they should be flagged as supplementary.

3.2.4 Composite Condition Indices

¶1 Where condition indicators are aggregated into a single composite index, compilers may apply one of four documented approaches:

Approach	Strength	Limitation
Equal-weight (documented default)	Transparent, no training data required, easily replicated	Treats unequal-signal metrics as equivalent; can dilute the dominant structural indicator
Local-expert weighting	Captures site-specific ecological knowledge; prioritises relevant structural indicator	Subjective; reduced inter-jurisdiction comparability
Data-driven (PCA / factor analysis)	Empirically derived from pressure-response data; objective	Requires large multi-site training dataset; weights not easily transferable
Regulatory-endorsed multimetric	Comparable across reporting unit; pre-validated thresholds	Fixed metric set restricts updating; jurisdiction-bounded

¶2 GOAP does not endorse a single index. Worked examples in the published literature include SEQI (Indonesia), POMI and BiPo (W Mediterranean), PREI (France WFD), SQI (UK WFD), GBR MMP Seagrass Condition Index, and Chesapeake Bay SAV scorecard.¹⁵ Compilers selecting an equal-weight default should specify which structural indicator (shoot density or canopy cover) anchors the composite, document any metric excluded or down-weighted, and defer to regulatory indices

where the accounting unit overlaps a regulatory reporting unit. The worked example in Section 3.6 uses the equal-weight default for illustrative purposes.

3.3 Ecosystem Services

¶1 Services are organised per SEEA EA classification. The general identification and measurement framework is in **TG-2.4**.

¶2 ① **Recording rule – coastal protection service**

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

3.3.1 Provisioning Services

¶1 **Biomass provisioning.** Seagrass-attributable fish catch is estimated through catch data from associated fishing grounds, bio-economic models linking extent to productivity, meta-analysis of seagrass-fishery relationships,¹⁶ or trophic-based seagrass dependency (TB-SGd), a food-web network analysis tracing the proportion of each trophic level's biomass originating from seagrass as a primary producer (Addamo et al. 2024).¹⁷ TB-SGd is more rigorous than habitat-area ratios where trophic data are available.

¶2 Only the ecosystem contribution should be attributed (excluding labour, capital, technology). Residual value and simulation methods are in SEEA EA and **TG-2.4 Environmental (including Ecosystem) Goods and Services** Section 3.10.¹⁸ The seagrass-attributable share may appear small (Addamo et al. estimate ~1% for a Mediterranean model), yet the entire dependent catch is at risk if seagrass disappears. Compilers may record this broader 'flow at risk' as a supplementary memorandum entry distinct from the directly attributed flow.¹⁹

¶3 **Raw biomass provision (prospective service).** Stranded seagrass leaves (banquettes) have potential uses as biofuel feedstock, soil amendments, and composite materials.²⁰ Conservative valuation uses the avoided cost of removal and disposal (approx. EUR 30–155 per tonne; Di Gennaro 2018; Balata and Tola 2016). Record as prospective, and flag species-specific leaf-turnover and local waste-management costs.

¶4 **Other provisioning.** Traditional uses (thatching, fertiliser, crafts) are typically minor in economic terms.

3.3.2 Regulating and Maintenance Services

¶1 **Global climate regulation – carbon sequestration and storage.** Two distinct services:

- ¶2 **Carbon sequestration** (Cseq) – annual flux into long-term storage, recorded as service flow (tonnes CO₂e/ha/yr). Mean long-term burial rates 48–138 g C/m²/yr (1.8–5.1 t CO₂e/ha/yr), distinct from total NPP (>400 g C/m²/yr but not equivalent to sequestration).²¹
- ¶3 **Carbon storage** (Cstor) – long-term sediment stock (up to 140 Mg C/ha in top 1 m, with ~90% of total seagrass carbon held in soils), recorded as asset stock attribute. Cstor accumulates over centuries to millennia and can be permanently released if meadows are destroyed.²²

¶4 The three-pool measurement framework (above-ground biomass, below-ground biomass, sediment organic carbon) and IPCC Wetlands Supplement Tier framework are in **TG-6.2 §3.3**. Species-appropriate values must be used: *Posidonia* stocks and rates exceed *Halophila* by up to an order of magnitude.

¶5 Where meadows are being lost, the climate regulation entry records both annual sequestration flow and the emissions associated with degradation. Condition–service linkage may be quantified

through regression of shoot density or percent cover against carbon accumulation rates per the SEEA EA biophysical-modelling guidelines.²³

¶6 **Coastal and sediment stabilisation.** Seagrass canopies attenuate wave energy at 20–40% per 100 m of meadow width (Ondiviela et al. 2014²⁴). Measured through wave-attenuation rates, sediment trapping, and erosion comparisons between protected and unprotected coastlines. Valuation by replacement cost / avoided damage per Section 3.4.2 and **TG-1.9**.

¶7 **Water purification and nutrient cycling.** Denitrification in seagrass sediments can exceed un-vegetated rates by 2–4x.²⁵ Nutrient-removal capacity exhibits non-linear threshold and hysteresis behaviour: where epiphyte cover exceeds the Table 3.2.1 threshold (indicative default: 10%), apply a condition-adjusted service flow scaling capacity by canopy health. Where eutrophication has caused meadow collapse, record as zero. Compilers with local evidence for a different threshold should document and cite it.

¶8 **Nursery population and habitat maintenance.** Seagrass meadows are nursery habitat for snapper, sea bream, mullet, prawns, blue swimmer crabs, scallops, queen conch, and megafauna (dugongs, green turtles).²⁶ The nursery-as-intermediate-service double-counting method follows **TG-6.2 §3.5. GOAP default for seagrass:** where stage-structured production-function data are unavailable, assign the full seagrass-attributable fisheries contribution to biomass provisioning (Section 3.3.1). Where such data exist, the contribution may be apportioned between nursery habitat and biomass provisioning, with the partitioning method documented and verified to sum without overlap.

3.3.3 Cultural Services

¶1 **Recreation and tourism.** Snorkelling, diving, recreational fishing, and megafauna viewing (dugongs, manatees, turtles). Measured via visitor numbers, expenditure, or travel cost / revealed preference studies. **Seagrass-density and megafauna-density proxies:** where direct visitor data are unavailable, shoot density (proxy for dive-site attractiveness) and dependent-megafauna density rank recreation opportunity into high/medium/low classes with per-visit net benefit values. Addamo et al. (2024) demonstrate this for the Mediterranean using logit (visit probability) and Poisson (visit frequency) models with landscape and demographic covariates.²⁷ The full nature-based recreation value associated with seagrass-dependent megafauna may be at risk if seagrass disappears, even where direct attribution is small (flow-at-risk concept, see Section 3.3.1).

¶2 **Education and research.** Sites for marine education and scientific research. Such sites are difficult to quantify but support knowledge generation.

3.4 Valuation Methods

¶1 The exchange-value preference hierarchy is in **TG-2.4 Environmental (including Ecosystem) Goods and Services** Section 3.10 and **TG-3.2 Flows from Environment to Economy**. The seagrass-specific application follows below.

3.4.1 Valuing Carbon Sequestration

¶1 The carbon pricing rule is common to all blue carbon ecosystems and is owned by **TG-6.2 Mangrove and Coastal Wetland Accounting** Section 3.6, which applies the SEEA EA two-component model: the **social cost of carbon** for the retention (stock) component, and **compliance market prices** for the sequestration (flow) component.²⁸ It is not restated here.

¶2 Two points bear on seagrass specifically. Voluntary carbon market prices are **not** used for SEEA-EA-aligned monetary accounts, which matters more for seagrass than for mangroves because seagrass credits are traded almost entirely on the voluntary market and seagrass-specific methodologies remain under development.²⁹ And the price must be the same one applied to mangroves, salt-marsh and terrestrial sinks in the same account: a national account that prices mangrove carbon at

the social cost of carbon and seagrass carbon at a voluntary credit price is internally inconsistent (**TG-2.8**).

3.4.2 Replacement Cost Approaches

¶1 **Coastal protection.** Replacement-cost / avoided-damage method including seawall unit costs and annualisation is in **TG-3.2 Flows from Environment to Economy** Section 3.5. The seagrass-specific parameter is wave-attenuation capacity (20–40% per 100 m of meadow width; Ondiviola et al. 2014²⁴). Document protected-coastline length and attenuation rate in the service flow record.

¶2 **Water purification.** Tertiary-treatment unit costs vary by orders of magnitude across jurisdictions. Derive them from national wastewater cost data and document the source.

¶3 Replacement-cost approaches assume the engineered alternative would actually be built and provides equivalent benefits.³⁰

3.4.3 Fisheries Contribution

¶1 Per the GOAP default (Section 3.3.2), the full seagrass-attributable contribution is recorded under biomass provisioning, valued as the seagrass-attributable share of landed catch (ex-vessel price × physical share). Where stage-structured production-function data exist, apportion between nursery and biomass provisioning, documenting the partitioning and verifying no overlap. Methods: **production function** (econometric models of extent–catch relationship),³¹ **resource rent** apportioned between stocks and habitat (see **TG-3.1** Section 3.3), and **benefit transfer** with context adjustment.³²

3.4.4 Asset Valuation

¶1 The NPV method, the perpetuity-or-finite-horizon choice, and the rule that the condition index is applied **once** – at the physical service flow stage, not again at discounting – are set out in **TG-3.1 Asset Accounts** Section 3.5.3 and are not restated here.³³ In this Circular the single application is at Step 3 of the compilation procedure, where the literature-derived service rate is treated as a reference-condition value and scaled by the composite condition index; Step 4 then discounts that condition-adjusted flow directly.

¶2 A perpetuity is defensible for seagrass assets under effective protection and management. It is not defensible for a meadow on a documented declining trajectory, which is the more common case: project the service flow forward on the trend instead, and state the assumption. Discount-rate choice matters more for seagrass than for most marine assets because carbon storage dominates the service mix and has the longest horizon; the rate must be the one used for other natural assets in the same national accounts.³⁴

3.5 Compilation Procedure

Step 1: Delineate EAA and stratify by species

¶1 Delineate the EAA per **TG-4.1** Section 3.4, Step 1. Classify to GET M1.1 and **stratify by dominant species** (*Posidonia*, *Thalassia*, *Zostera*, *Halophila*) as a default, not “where data permit”, since species drives carbon, productivity, and service parameters. Disaggregate further by depth zone (Section 3.1.1) and document the national-to-GET crosswalk.

Step 2: Map extent using tiered approach

¶1 Select Tier 1, 2, or 3 (Section 3.1.3). Where acoustic or diver data are unavailable for deep meadows (beyond ~10–15 m), record mapped extent as a lower bound with a quality-statement note documenting the estimated deep-meadow proportion from bathymetric and habitat suitability data. Where feasible, apply a regional-study-based coverage correction. Validate against ground-truth with confusion matrices (**TG-4.1** Section 3.5.1) and the **TG-0.7** quality framework.

Step 3: Populate extent account

¶1 Compare opening and closing maps, then classify changes per Section 3.1.4. Anthropogenic pressure-driven loss is recorded under “Other reductions – degradation” (SEEA EA Table 4.2) with memorandum sub-rows attributing the pressure.

Step 4: Measure condition variables and derive indicators

¶1 Sample sites stratified by species, depth, and pressure exposure. Measure the Table 3.2.1 minimum set. Normalise using the **TG-2.1** Section 3.4.1 formula. Tag each variable as **standard** or **inverse** in a direction column before applying. Optionally aggregate using one of the Section 3.2.4 approaches. Equal weighting is the documented default, with the dominant structural indicator (shoot density or cover) anchoring the composite.

Step 5: Quantify service flows in physical units

¶1 For carbon sequestration: measure sediment accumulation rates from dated cores (Pb-210 or Cs-137), then multiply extent × species-appropriate rate × composite condition index to obtain observed-condition flow (tonnes CO₂e/yr). Condition adjustment is applied once, here, so Step 7 uses the condition-adjusted total without a further multiplier (Section 3.4.4).

¶2 For coastal protection: model wave attenuation per Ondiviela et al. (2014)²⁴, then document protected coastline length and implied attenuation rate.

¶3 For fisheries: apply the GOAP default (full seagrass-attributable contribution to biomass provisioning) unless stage-structured production-function data permit partitioning (Section 3.3.2).

¶4 For water purification: where epiphyte load exceeds the Table 3.2.1 threshold, apply a condition-adjusted nutrient-removal service flow. Where eutrophication has caused meadow collapse, record as zero.

¶5 Record physical quantity and natural spatial unit (hectares, kilometres, tonnes) per SEEA EA Table 7.1.

Step 6: Apply monetary valuation (optional)

¶1 Apply Section 3.4 methods. Ensure carbon-price and discount-rate consistency with other blue carbon and natural-asset accounts. Record in SEEA EA Table 9.3.

Step 7: Compile asset valuation and degradation accounts

¶1 Apply the NPV formula from Section 3.4.4. For first-time compilations, the opening NPV uses current observed-condition flows (no degradation charge unless condition or extent changes within the period).

¶2 Degradation = Opening asset value – Closing asset value (at opening-period prices and discount rate). Record separately: (a) revaluations from price or discount-rate changes, and (b) within-period condition and extent decline. Where significant losses occurred, disaggregate by driver (eutrophication, storm damage, dredging). Standard structure: SEEA EA Chapter 10 / Table 10.5.

Step 8: Document methods and quality assurance

¶1 ISO 19115 metadata + **TG-0.7** framework. Include coherence checks across extent, condition, and services accounts.

Annex: SEEA EA table cross-reference for compilation steps

Step	SEEA EA Table	Purpose
Step 3	Table 4.2	Standard ecosystem extent account format
Step 4	Table 5.2	Condition indicator standardisation

Step	SEEA EA Table	Purpose
Step 5	Table 7.1	Ecosystem services flow account
Step 6	Table 9.3	Monetary ecosystem services supply table
Step 7	Chapter 10 / Table 10.5	Monetary ecosystem asset account

3.6 Worked Example

¶1 This worked example demonstrates the compilation of seagrass ecosystem accounts for a hypothetical 12,000-hectare seagrass meadow system spanning temperate and tropical waters. The example follows the extent-condition-services-valuation sequence presented in Section 3 and illustrates the key accounting entries and calculations. All monetary values are illustrative composites and should not be used as benchmarks for specific national contexts.

¶2 **Setting:** The ecosystem accounting area (EAA) is a two-embayment coastal zone of approximately 450 km². Within this geographic frame, seagrass (M1.1 Seagrass meadows) occupies 12,000 hectares as the opening-year asset stock. The EAA is larger than the seagrass extent, with the remaining EAA area comprising unvegetated soft sediment and mixed benthic habitat. The seagrass stock comprises temperate *Posidonia* beds (7,500 ha, to 15 m depth) and tropical *Thalassia-Halophila* meadows (4,500 ha, to 12 m depth), distributed across the two embayments.

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

Accounting entry	Seagrass extent (hectares)
Opening extent (year t)	12,000
Additions to extent	
– Managed expansion (restoration transplanting)	50
– Natural expansion (colonisation of adjacent substrate)	80
<i>Total additions</i>	130
Reductions in extent	
– Managed reduction (dredging for port expansion)	60
– Natural reduction (storm scour, wasting disease)	120
– Other reductions – degradation	150
<i>of which: eutrophication-related light limitation (memorandum)</i>	150
<i>Total reductions</i>	330
Closing extent (year t+1)	11,800

¶4 Step 2: Condition account

¶5 Condition indicators are derived from field survey data using species-specific reference levels from protected reference sites. The variable set matches the Table 3.2.1 minimum set:

Condition variable	Observed value	VH (reference)	VL (degraded)	Indicator score
Percent cover	45%	60%	5%	0.73
Shoot density	520 shoots/m ²	800	100	0.60
Canopy height	30 cm	45 cm	10 cm	0.57
Epiphyte load (inverse)	18%	5% (VH)	50% (VL)	0.71
Species diversity	5 species	7	1	0.67

¶6 Note: For epiphyte load, a lower value indicates better condition. VH = 5% is the load observed at the protected reference sites, within the Table 3.2.1 indicative default (< 10%). Using the inverse normalisation formula (see **TG-2.1** Section 3.4.1): $(50 - 18) / (50 - 5) = 0.71$.

¶7 Composite condition index (equal-weight default per Section 3.2.4): $(0.73 + 0.60 + 0.57 + 0.71 + 0.67) / 5 = 0.66$

¶8 Step 3: Ecosystem services (annual flows)

Service	Physical quantity	Monetary value (USD, illustrative)
Carbon sequestration	27,720 t CO ₂ e/yr (42,000 t CO ₂ e/yr reference-condition flow x condition index 0.66)	2,218,000 (at USD 80/t CO ₂)
Biomass provisioning (fisheries; default per Section 3.3.2)	1,800 t seagrass-attributable landed catch	3,200,000 (ex-vessel composite at ~USD 1,780/t; illustrative)
Sediment stabilisation	65 km coastline stabilised	4,100,000 (avoided damage/replacement cost; illustrative)
Water filtration (nutrient removal)	480 t N removed/yr	1,900,000 (replacement cost; illustrative)
Total valued services		11,418,000 (illustrative)

¶9 Notes:

- ¶10 The carbon sequestration rate of 3.5 t CO₂e/ha/yr is a mid-range reference-condition value within the 1.8–5.1 t CO₂e/ha/yr range given in Section 3.3.2 (Fourqurean et al. 2012 synthesis). Compilers should select species- and site-specific values with citation. Within the cited range, 1.8 represents a conservative lower bound and 5.1 an upper bound.
- ¶11 The reference-condition flow (12,000 ha x 3.5 = 42,000 t CO₂e/yr) is adjusted by the composite condition index at Step 3: 42,000 x 0.66 = 27,720 t CO₂e/yr. This convention treats the literature rate as a reference-condition value and applies the condition adjustment once, at the physical flow stage. The Step 4 asset valuation uses the condition-adjusted annual service total (USD 11,418,000) without a further condition multiplier, avoiding double-counting. See Section 3.4.4. For periods with significant extent change, compilers may use the mean of opening and closing extent.
- ¶12 The fisheries entry applies the GOAP default rule (Section 3.3.2): the full seagrass-attributable fisheries contribution is assigned to biomass provisioning, not split between nursery habitat and biomass provisioning. Compilers with stage-structured production-function data may apportion per Section 3.4.3, documenting the partitioning method.
- ¶13 Monetary values for sediment stabilisation and water filtration are illustrative composites. Published seawall replacement costs (USD 1,000–10,000 per linear metre) and tertiary nutrient-removal unit costs vary by orders of magnitude across jurisdictions. Compilers must derive their own unit prices from national engineering or wastewater cost data and document the calculation.

¶14 Step 4: Asset valuation

¶15 Apply the NPV formula from Section 3.4.4 using the condition-adjusted annual service total from Step 3 (USD 11,418,000). Because the condition index has already been applied at the physical flow stage (Step 3), no further condition multiplier is applied here, since doing so would double-count the condition adjustment:

Annual service value (condition-adjusted at Step 3): USD 11,418,000

Perpetuity (indefinite horizon, $r = 4\%$): Asset value = $11,418,000 / 0.04 = \text{USD } 285,450,000$ (illustrative)

25-year finite horizon: Asset value = $11,418,000 \times AF$, where $AF = [1 - (1 + r)^{-T}] / r = [1 - (1.04)^{-25}] / 0.04 = 15.62$

Asset value (25-year) = $11,418,000 \times 15.62$ = *approximately USD 178,349,000 (illustrative)*

¶16 Compilers should recalculate the annuity factor (AF) using their national discount rate. Where condition is declining, compilers should project forward service flows using trend data rather than applying the perpetuity formula directly.

¶17 This worked example illustrates the full accounting sequence for seagrass ecosystems. Actual compilations will require country-specific data, species-appropriate reference levels, and primary valuation studies for each service type. The carbon price of USD 80/t CO₂ is illustrative and should be replaced with the prevailing compliance market price or social cost of carbon applicable in the compiler's jurisdiction. The eutrophication-related decline is classified under "Other reductions – degradation" per SEEA EA Table 4.2, with a memorandum sub-row attributing the pressure, consistent with the guidance in Sections 3.1.4 and 3.5 Step 3.

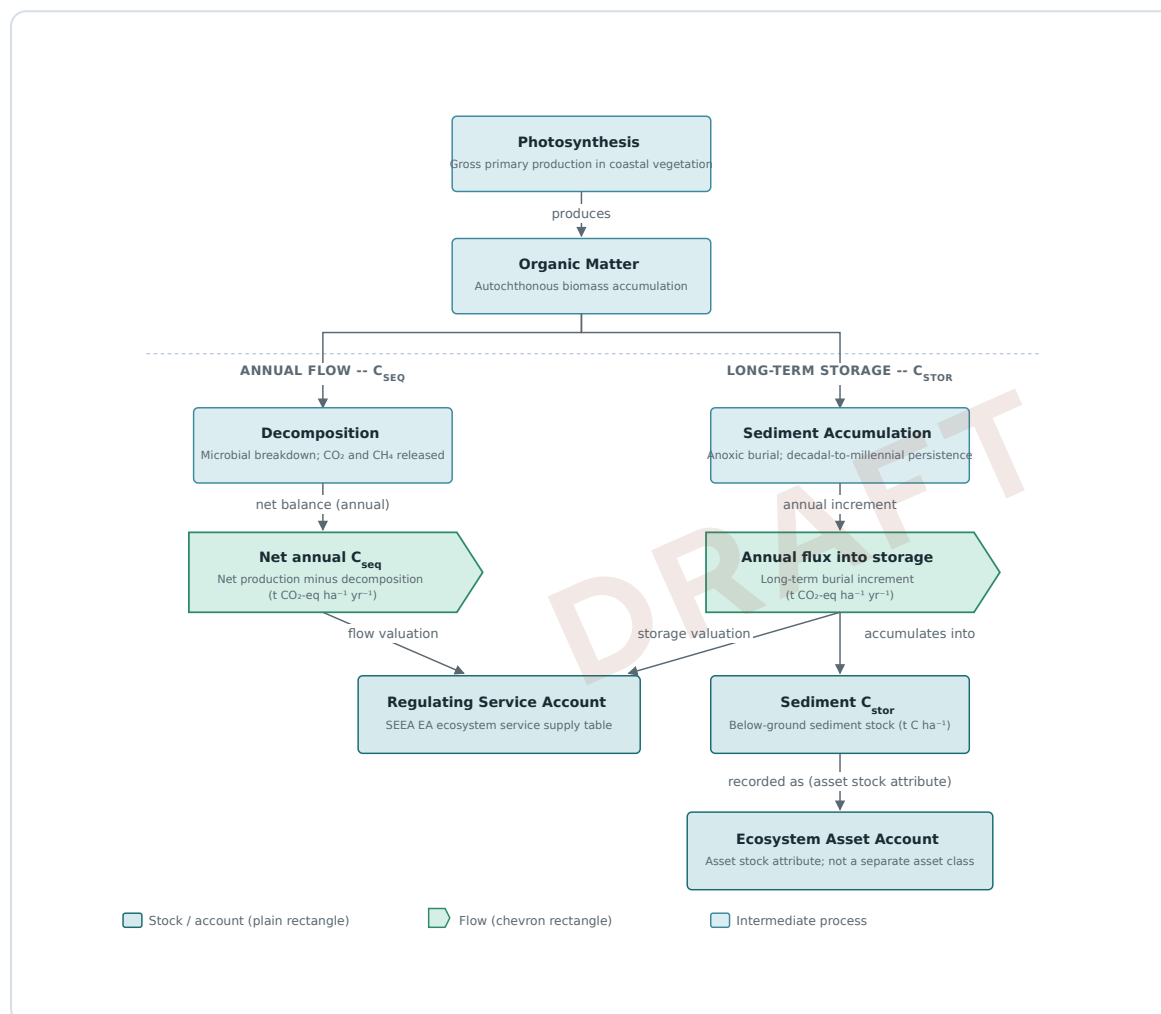


Figure 6.3.1 In a vegetated coastal habitat, C_{seq} is an annual regulating-service flow while C_{stor} is the accumulated sediment stock attribute. Flow and permanence valuations are alternatives -- not summed. Rectangles: chevron-tail = flows; plain = stocks.

Source: TG-6.3, Section 3.3.2 (carbon sequestration and storage); SEEA EA 2024, paras. 10.20-10.40 (ecosystem carbon pools and asset accounting).

4. Acknowledgements

¶1 This guidance draws on the conceptual framework and methodological recommendations of the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA) and its sup-

porting technical materials. The IUCN Global Ecosystem Typology provides the ecosystem classification framework. Scientific understanding of seagrass ecosystem services draws on extensive research literature, including foundational works by Costanza et al., Duarte et al., Fourqurean et al., and the global seagrass research community.

¶2 **Authors:** [To be confirmed]

¶3 **Reviewers:** [To be confirmed]

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- ¶15 Van der Heide, T., Govers, L.L., de Fouw, J., et al. (2012). 'A three-stage symbiosis forms the foundation of seagrass ecosystems'. *Science* 336(6087): 1432–1434.

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FOOTNOTES

1. ¶1 Keith et al. (2020), M1.1 Seagrass meadows: "Seagrasses are the only subtidal marine flowering plants and underpin the high productivity of these systems."
2. ¶2 United Nations (2021), SEEA EA Chapters 4-11.
3. ¶3 Countries may compile physical seagrass accounts without monetary valuation as a first step. See TG-1.9.
4. ¶4 United Nations (2022), *Guidelines on Biophysical Modelling for Ecosystem Accounting*.
5. ¶5 Keith et al. (2020), M1.1 Key Ecological Drivers – maximum depth limited by light attenuation; minimum depth by wave orbital velocity, tidal exposure, and wave energy.
6. ¶6 Keith et al. (2020), Section M1.1.
7. ¶7 Beer-Lambert; coastal K_d typically 0.1–0.5 m^{-1} .
8. ¶8 Water-column correction (e.g., Lyzenga 1981; Maritorena 1996) requires accurate optical-property data.
9. ¶9 GOAP tiered approach; see TG-4.1 for the general framework.
0. ¶10 Global seagrass datasets underestimate extent in data-poor regions and have significant temporal lags.
1. ¶11 Kenny et al. (2003), *ICES J. Mar. Sci.* 60(2): 411-418.
2. ¶12 Waycott et al. (2009) and Dunic et al. (2021) provide the canonical global loss synthesis.
3. ¶13 Van der Heide et al. (2012) describe the three-stage seagrass-lucinid-bacteria symbiosis underpinning meso-grazer and microbial controls.
4. ¶14 SEEA EA para 5.30-5.35.
5. ¶15 Worked examples of seagrass composite condition indices: SEQI (Wahyudin et al. 2021, *Sci. Total Environ.*); POMI (Romero et al. 2007, *Mar. Pollut. Bull.*); BiPo (Lopez y Royo et al. 2010, *Ecol. Indic.*); PREI (Gobert et al. 2009); SQI (Foden & Brazier 2007; Neto et al. 2013, *Ecol. Indic.*); GBR MMP Seagrass Condition Index (GBRMPA Marine Monitoring Program annual reports); Chesapeake Bay SAV scorecard (Chesapeake Bay Program SAV technical synthesis); Tampa Bay Seagrass Assessment (TBEP / SIMM reports).
6. ¶16 Heck et al. (2003), *Mar. Ecol. Prog. Ser.* 253: 123-136 – fish densities in seagrass are typically 2–5x higher than in adjacent unvegetated areas.
7. ¶17 Addamo et al. (2024) define trophic-based seagrass dependency (TB-SGd) as the product of diet-contribution proportions ($DCFG_x \rightarrow FG_y$) for all prey–predator pairs across trophic levels linking seagrass to the target species, multiplied by prey biomass. Applied to seven Mediterranean fish species, the estimated seagrass contribution averaged approximately 1% of total landed biomass, though the entire trophic chain was considered at risk in the absence of seagrass. Species-specific trophic parameters for the Mediterranean are provided in Piroddi et al. (2017, 2022).
8. ¶18 SEEA EA Chapter 7 and NCAVES/MAIA (2022) describe residual-value and simulation approaches.
9. ¶19 The "flow at risk" concept distinguishes (a) the direct seagrass-attributable share of a service (e.g. 1% of fish biomass directly traceable through the trophic web) from (b) the total service value that would be lost if seagrass disappeared (e.g. the entire trophic chain collapses). Compilers recording only the attributable share may significantly understate the economic dependency on seagrass. A memorandum row in the supply table labelled "flow at risk – seagrass dependency" can record this broader exposure without double-counting the attributable flow.
0. ¶20 Mediterranean seagrass species (primarily *Posidonia oceanica*) shed leaves seasonally; annual leaf-turnover rates provide the biophysical basis for raw biomass estimates. Cebrian et al. (1997) provide above-ground biomass estimation methods applicable to multiple Mediterranean species. Alternative uses for stranded seagrass biomass (banquettes) include biofuel feedstock (Masri et al. 2017), composite materials (Scaffaro et al. 2018), and animal fodder; current regulatory status varies by Mediterranean jurisdiction.
1. ¶21 Fourqurean et al. (2012), *Nature Geoscience* 5: 505-509 – synthesis of 946 meadows; sediment stocks up to 140 Mg C/ha (top 1 m), ~90% of total carbon in soils, global stock to 19.9 Pg C. Burial rates 48-138 g C/m²/yr (1.8-5.1 t CO₂e/ha/yr) reflect long-term sequestration, distinct from NPP >400 g C/m²/yr.
2. ¶22 Addamo et al. (2024) operationalise this distinction in their Mediterranean supply table, recording carbon sequestration and carbon storage as separate line items. Carbon storage (Cstor) from *Posidonia oceanica* sediment stocks may represent centuries of accumulation and is not recoverable on human timescales once a meadow is destroyed; this asymmetry between sequestration flow and storage stock has implications for degradation accounting (see Step 7 of the compilation procedure).
3. ¶23 United Nations (2022), Section 4.3.
4. ¶24 Ondiviela et al. (2014), *Coastal Engineering* 87: 158-168 – 20–40% wave attenuation per 100 m of meadow width.
5. ¶25 Reynolds et al. (2016), *Restoration Ecology* 24(5): 583-588.
6. ¶26 Keith et al. (2020), M1.1 Ecological Traits.
7. ¶27 Addamo et al. (2024) apply a logit model for visit probability and a weighted Poisson regression for visit frequency across 137 Mediterranean NUTS3 coastal regions, using landscape composition, marine protected area presence, and GDP as covariates. The per-visit net benefit value of EUR 15.02 (lower bound) to EUR 37.28 (upper bound) is drawn from Stebbings et al. (2021). This approach is transferable to other regions with appropriate recalibration of the visit-prediction models using local survey data.
8. ¶28 US EPA Interagency Working Group (2023) – central SCC ~USD 190/t CO₂ at 2.0% near-term discount rate; values exceed USD 300 under some specifications.

9. ¶29 Verra VCS methodologies exist for mangrove and salt marsh; seagrass-specific methodologies remain under development.
0. ¶30 SEEA EA para 9.49–9.52.
1. ¶31 Production-function approaches require detailed habitat-recruitment-yield ecological data.
2. ¶32 Benefit transfer requires adjustments for ecological, social, and economic context.
3. ¶33 SEEA EA Chapter 10.
4. ¶34 SEEA EA Annex A10.1.

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