

Aquaculture Accounts

Provides guidance on compiling accounts for aquaculture within ocean accounting frameworks.

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OUTCOME

This Circular provides guidance on compiling accounts for aquaculture within ocean accounting frameworks, addressing the distinction between cultivated biological resources (produced assets within the SNA production boundary) and natural biological resources (wild fisheries). Aquaculture is a large and growing component of global seafood production, with distinct accounting requirements that differ markedly from wild-capture fisheries.

Aquaculture accounts serve several decision use cases for governments managing blue food systems and coastal development. They inform sustainable aquaculture planning by quantifying production capacity, tracking environmental pressures from aquaculture operations (nutrient loading, habitat conversion), and identifying trade-offs between aquaculture expansion and ecosystem conservation. They support carrying capacity assessment by comparing actual production against environmental limits. This enables authorities to set appropriate licensing thresholds for coastal zones and marine areas. They enable GBF Target 10 reporting by tracking area under sustainable aquaculture management and documenting environmental impacts that must be minimised under the Kunming-Montreal Global Biodiversity Framework. They also provide the evidence base for blue economy investment decisions by showing whether aquaculture growth is economically productive whilst remaining within ecological boundaries. These functions connect directly to the policy frameworks described in [TG-1.2 OA and Marine Spatial Planning](#) and [TG-1.5 OA and Fisheries Management](#), where aquaculture accounts provide quantitative evidence for balancing food security objectives against environmental sustainability.

The guidance covers production boundary treatment, asset classification for aquaculture stocks, carrying capacity and sustainable production considerations, and environmental interactions including feed inputs and waste outputs. This Circular provides the accounting foundation for the thematic methodologies in [TG-6.8 Aquaculture Thematic Methods](#).

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ABOUT THIS CIRCULAR

RECOMMENDED CITATION

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¶1 ⓘ Framework Position

¶2 TG-3.9 sits within Section 3 (Accounts Compilation) and provides the aquaculture-specific application of the produced-asset accounting principles introduced in TG-3.1. It is the primary compilation reference for aquaculture and the direct methodological foundation for TG-6.8.

1. Outcome

¶1 This Circular provides guidance on compiling accounts for aquaculture within ocean accounting frameworks, addressing the distinction between cultivated biological resources (produced assets within the SNA production boundary) and natural biological resources (wild fisheries). Aquaculture is a large and growing component of global seafood production, with distinct accounting requirements that differ markedly from wild-capture fisheries¹.

¶2 Aquaculture accounts serve several decision use cases for governments managing blue food systems and coastal development. They inform sustainable aquaculture planning by quantifying production capacity, tracking environmental pressures from aquaculture operations (nutrient loading, habitat conversion), and identifying trade-offs between aquaculture expansion and ecosystem conservation. They support carrying capacity assessment by comparing actual production against environmental limits. This enables authorities to set appropriate licensing thresholds for coastal zones and marine areas. They enable GBF Target 10 reporting by tracking area under sustainable aquaculture management and documenting environmental impacts that must be minimised under the Kunming-Montreal Global Biodiversity Framework. They also provide the evidence base for blue economy investment decisions by showing whether aquaculture growth is economically productive whilst remaining within ecological boundaries. These functions connect directly to the policy frameworks described in **TG-1.2 OA and Marine Spatial Planning** and **TG-1.5 OA and Fisheries Management**, where aquaculture accounts provide quantitative evidence for balancing food security objectives against environmental sustainability.

¶3 The guidance covers production boundary treatment, asset classification for aquaculture stocks, carrying capacity and sustainable production considerations, and environmental interactions including feed inputs and waste outputs. This Circular provides the accounting foundation for the thematic methodologies in **TG-6.8 Aquaculture Thematic Methods**.

2. Requirements

¶1 This Circular requires familiarity with:

- ¶2 **TG-0.1 General Introduction to Ocean Accounts**: conceptual framework and key components of Ocean Accounts
- ¶3 **TG-0.2 Overview of Relevant Statistical Standards**: methodological foundations in SNA 2025, SEEA CF, and SEEA EA
- ¶4 **TG-3.1 Asset Accounts**: general methodology of physical and monetary asset accounts
- ¶5 **TG-3.3 Economic Activity Relevant to the Ocean**: industry classification framework for aquaculture

¶6 **Related Circulars**:

- ¶7 **TG-1.5 OA and Fisheries Management**: broader fisheries management context
- ¶8 **TG-3.2 Flows from Environment to Economy**: natural resource inputs used by aquaculture
- ¶9 **TG-3.4 Flows from Economy to Environment**: aquaculture residual flows to the environment
- ¶10 **TG-2.7 Pollution Flows**: nutrient and chemical emission accounting

3. Guidance Material

¶1 Aquaculture has grown rapidly worldwide, with production exceeding wild-capture fisheries for human consumption in recent years². This expansion creates accounting challenges that differ from those of traditional fisheries. Whilst wild-capture fisheries extract natural biological resources from common-pool stocks, aquaculture involves deliberate cultivation under the direct control, responsibility and management of institutional units. This placement of aquaculture within the production boundary of the national accounts carries substantial implications for how aquaculture stocks and their changes are recorded.

¶2 This Circular is foundational for **TG-6.8 Aquaculture Thematic Methods** and complements **TG-3.1 Asset Accounts**, addressing the interface between produced and non-produced assets that is particularly complex in the marine domain. The relationship between aquaculture accounting and fisheries management is addressed in **TG-1.5 OA and Fisheries Management**, which clarifies how cultivated and natural aquatic resources interact within integrated ocean accounting frameworks.

¶3 This section examines the production boundary treatment (Section 3.1), compilation procedures for aquaculture accounts (Section 3.2), asset classification for aquaculture stocks (Section 3.3), carrying capacity considerations for sustainable production (Section 3.4), and environmental interactions (Section 3.5). Section 3.6 presents worked examples demonstrating account compilation with synthetic data. The guidance presented here aligns with the SEEA Central Framework, the SEEA Agriculture, Forestry and Fisheries (SEEA AFF), and the 2025 SNA treatment of cultivated biological resources.

3.1 Production Boundary Treatment

¶1 The distinction between aquaculture and wild-capture fisheries governs their accounting treatment. The distinction rests on the **production boundary**—the demarcation between economic activity treated as production and natural processes that fall outside the production boundary³. For guidance on the relationship between natural and produced assets, see **TG-3.1 Asset Accounts** Section 3.4.1 (Aquatic resources) and Section 3.6 (Produced Assets in the Ocean Domain).

The production boundary and aquaculture

¶1 The SEEA Central Framework establishes that “the production boundary includes all activities carried out under the responsibility, control and management of a resident institutional unit in which labour and assets are used to transform inputs of goods and services into outputs of other goods and services”⁴. Applying this principle to aquatic resources, the SEEA CF states that “the growth of fish in fish farms and other aquaculture facilities is treated as a process of production”⁵.

¶2 The FAO definition of aquaculture, adopted in the SEEA CF, provides the operational basis for this distinction:

“Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms that are harvested by an individual or corporate body that has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms that are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of fisheries.”⁶

¶3 This definition establishes three criteria for treating aquatic production as aquaculture: (1) intervention in the rearing process; (2) ownership of the stock; and (3) ownership throughout the rearing

period. These criteria provide a practical basis for classification, though edge cases remain. For extensive pond culture systems with minimal intervention, or ranching programmes with delayed harvest, SEEA AFF paragraphs 2.127–2.129 provide additional guidance on distinguishing natural from cultivated processes. Where a clear institutional unit exercises control over the growth process—even if that control is limited to stocking and harvesting—the activity should be treated as aquaculture⁷. Figure 3.9.1 traces how the three criteria are applied in sequence to route an aquatic stock to one of four accounting terminals.

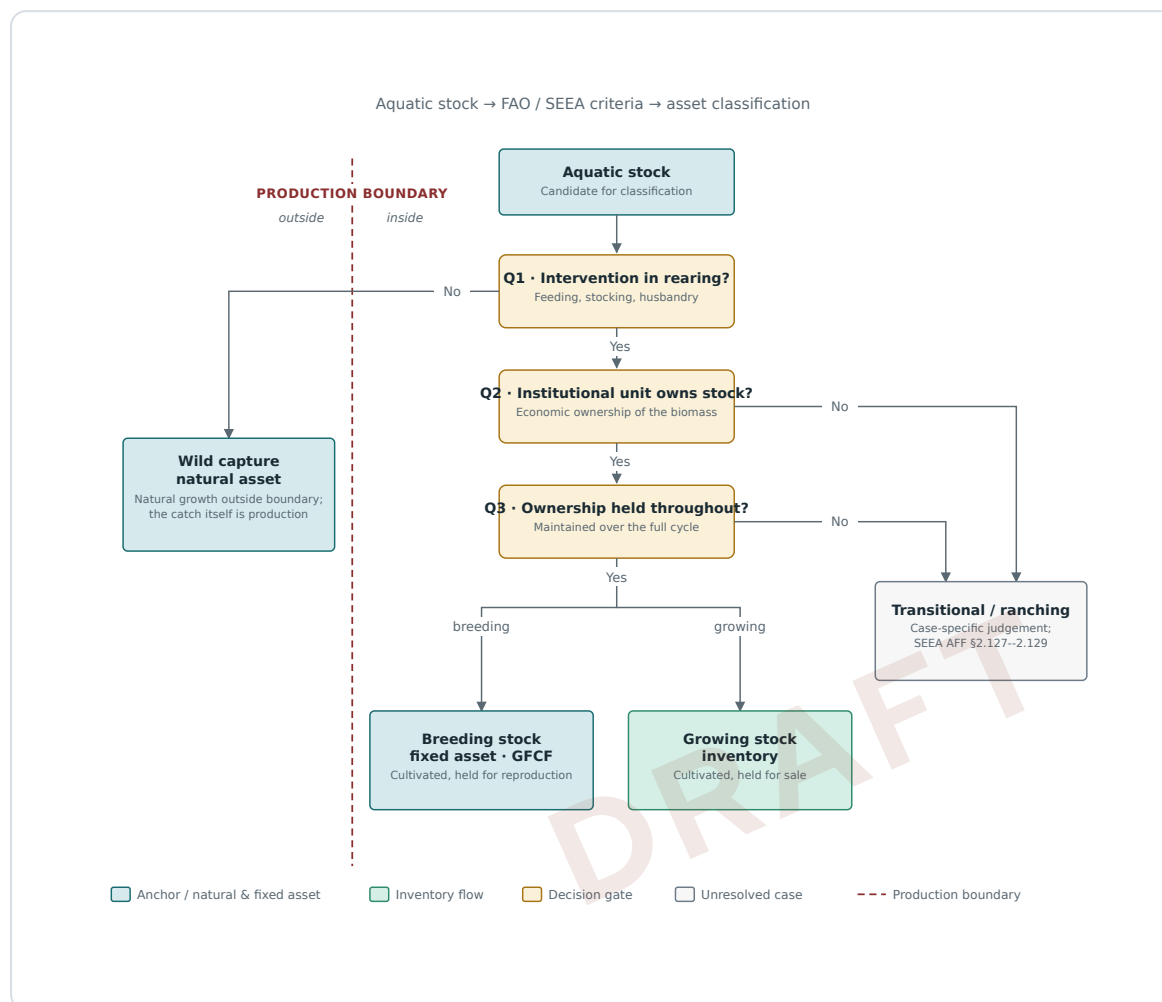


Figure 3.9.1 Three FAO/SEEA criteria route an aquatic stock to wild capture, breeding stock, growing stock, or a transitional case. Wild capture sits outside the production boundary; breeding stock is fixed capital and growing stock is inventory.

Source: TG-3.9 Section 3 (FAO / SEEA production-boundary criteria); SEEA AFF §2.127--2.129 (transitional and stock-enhancement cases).

Adapted from: SNA 2025 production-boundary treatment of cultivated biological resources and natural growth, applied to FAO aquaculture vs capture-fisheries definitions.

¶4 *Table 3.9.1: Aquaculture production boundary decision criteria*

Characteristic	Natural Aquatic Resource	Cultivated Aquatic Resource
SNA classification	Non-produced asset	Produced asset
Control over growth	No direct control	Active management
Feeding	Natural food web	Supplementary feeding
Stocking	Natural recruitment	Deliberate stocking
Harvest timing	Market/quota driven	Growth cycle driven

Characteristic	Natural Aquatic Resource	Cultivated Aquatic Resource
Asset account	Environmental asset account	Fixed asset/inventory account
Output recording	Extraction from nature	Agricultural output

¶5 This decision table summarises the distinguishing characteristics that determine whether aquatic resources fall on the natural or cultivated side of the production boundary. In practice, some operations exhibit characteristics from both columns, requiring case-by-case assessment against the three criteria established above.

Implications for accounting treatment

¶1 The placement of aquaculture within the production boundary has several implications:

¶2 **Output measurement.** The growth of aquaculture organisms constitutes **output** in the national accounts sense. This growth is recorded as production of the aquaculture industry, contributing to GDP and value added. In contrast, the natural growth of wild fish stocks is not treated as production and does not contribute directly to economic output—only the extraction (harvest) enters the economic accounts⁸. For guidance on how natural resource extraction is treated, see **TG-3.2 Flows from Environment to Economy**. The industry classification of aquaculture within the ocean economy is addressed in **TG-3.3 Economic Activity Relevant to the Ocean**.

¶3 **Asset classification.** Aquaculture stocks are classified as **produced assets** rather than natural resources. This contrasts with wild fish stocks, which are classified as natural (non-produced) assets subject to depletion accounting. The distinction between produced and non-produced assets affects balance sheet treatment and the calculation of depletion-adjusted income measures⁹. The framework for natural aquatic resource accounting is presented in **TG-3.1 Asset Accounts** Section 3.4.1.

¶4 **Capital formation.** Investment in aquaculture stocks is recorded as **gross fixed capital formation** (for breeding stocks) or **changes in inventories** (for stocks being raised for harvest). This treatment parallels the accounting for livestock in agriculture, where breeding cattle are treated as fixed assets and animals raised for slaughter are treated as inventories¹⁰.

¶5 For mixed and transitional cases (ranching, stock enhancement, IMTA), see the reclassification guidance in Section 3.3.

3.2 Compilation Procedure

¶1 This section provides a step-by-step procedure for compiling aquaculture accounts, integrating production accounts, asset accounts, and environmental flow accounts. The procedure assumes that countries have established coordination mechanisms between statistical offices, aquaculture regulatory agencies, and environmental authorities as described in **TG-4.7 National Data Coordination Architectures**.

Step 1: Delineate aquaculture operations and classify systems

¶1 Identify all aquaculture operations within the national accounting boundary and classify them according to:

¶2 a) **System type**—open systems (cage culture, net-pens, on-bottom culture), closed systems (tanks, raceways, recirculating aquaculture systems), or semi-intensive systems (pond culture, integrated systems);

¶3 b) **Species or species groups**—finfish (salmon, sea bass, tuna), crustaceans (shrimp, prawns), molluscs (oysters, mussels), aquatic plants (seaweed);

¶4 c) **Salinity**—marine aquaculture (operating in coastal waters or offshore), brackish water aquaculture, or freshwater aquaculture (the latter is outside the ocean accounting boundary but may be

included in national aquaculture accounts; see the note on freshwater aquaculture scope at the end of this step);

¶5 d) **Purpose**—food production, ornamental species, stock enhancement/ranching (see Section 3.1 for treatment of transitional cases).

¶6 Data sources include aquaculture licensing registries, fisheries statistical databases (FAO FishStatJ; see **TG-4.10 Extending Fisheries Statistics** Section 3.8.1 for full database description, including coverage, refresh frequency, and limitations), remote sensing analysis for spatial extent of cage culture operations (**TG-4.1 Remote Sensing and Geospatial Data**), and industry census data from statistical offices.

¶7 **Freshwater aquaculture scope note:** Freshwater aquaculture (catfish, tilapia, carp, and other freshwater species) falls outside the ocean accounting boundary but is within scope for SNA national production accounts and should be compiled using the same methodology described in this Circular. Within ocean accounts, freshwater aquaculture production should appear as a memorandum item or in a supplementary “All Aquaculture” table that includes freshwater alongside marine and brackish production, with clear delineation by salinity category. The national total should be reconcilable to FAO FishStatJ national aquaculture production figures, which include all systems, to support cross-country comparability and external validation.

Step 2: Compile production accounts

¶1 Assemble aquaculture production data following the Supply and Use Table (SUT) framework described in **TG-3.3 Economic Activity Relevant to the Ocean**:

¶2 a) **Output**—Record aquaculture production in physical terms (tonnes live weight) and monetary terms (value at basic prices). Output includes both harvest for sale and intermediate transfers between hatcheries and grow-out operations.

¶3 b) **Intermediate consumption**—Record feed inputs (fishmeal, fish oil, plant-based feeds), fingerlings/juveniles purchased from hatcheries, veterinary services, energy inputs, and other operational inputs. Feed inputs from wild fisheries should be separately identified to enable calculation of fish-in-fish-out ratios (Section 3.5).

¶4 c) **Value added**—Calculate gross value added as output minus intermediate consumption. This measures the aquaculture sector’s contribution to GDP.

¶5 d) **Employment**—Record full-time equivalent employment in aquaculture to enable productivity analysis.

¶6 Data sources include aquaculture production surveys, business censuses, industry association reports, feed sales data, and energy consumption statistics.

Step 3: Compile physical asset accounts for aquaculture stocks

¶1 Construct physical asset accounts for cultivated aquatic resources following the structure in Section 3.3 below:

¶2 a) **Opening stock**—Determine stock biomass at the beginning of the accounting period using the following tiered data source hierarchy: (1) facility biomass records as the primary source; (2) regulatory production returns where facility records are absent or unreliable; (3) statistical survey estimates where regulatory returns are unavailable; (4) model-based estimates using licensed area multiplied by species-specific average stocking density norms sourced from national fisheries authority technical tables, as a last resort. Compilers must flag fallback methods (sources 3 and 4) in metadata following **TG-0.7 Quality Assurance** conventions. For breeding stocks, record number of broodstock by species. For growing stocks, record total biomass by species and cohort/size class where data permit.

¶3 b) **Additions to stock**—Record natural growth (biomass increase from feeding and maturation), hatchery production or purchases of juveniles (additions to growing stocks), and reclassifications from natural resources (wild-caught organisms introduced for fattening or broodstock).

¶4 c) **Reductions in stock**—Record harvest (sales or transfers to processing), normal losses (routine mortality from disease, predation, environmental stress), catastrophic losses (disease outbreaks, harmful algal blooms, storm damage), escapes (reclassifications to natural resources), and culling (removal of unproductive broodstock).

¶5 d) **Closing stock**—Verify that closing stock equals opening stock plus additions minus reductions. Reconcile discrepancies through data quality audits.

¶6 Data sources include aquaculture facility production records, hatchery sales records, veterinary health reports, loss event reporting systems, and regulatory compliance data. For data quality considerations, see **TG-0.7 Quality Assurance**.

Step 4: Compile monetary asset accounts

¶1 Value aquaculture stocks following standard SNA principles for produced assets, applying the following method hierarchy:

¶2 a) **Inventory valuation**—Where active markets for live organisms exist and reliable price data are available, market price valuation is the preferred method, as it aligns with SNA balance sheet conventions for traded assets. Apply current market prices to biomass estimates, adjusted for size class where market prices vary by size. Revaluation entries (holding gains or losses) must be recorded separately from volume changes to avoid confounding the two in the monetary account. Where market prices are absent—for immature growth stages with no comparable market, or for species with no live trade—use the cost accumulation method described in the 2025 SNA treatment of work-in-progress (Chapter 11), recording costs incurred (feed, juveniles, labour, capital services) as inventory builds up over the growth cycle. Table 3.9.2 (monetary account columns) illustrates how revaluation entries are separated from volume changes.

¶3 b) **Breeding stock valuation**—Value breeding stocks based on expected future economic benefits from their reproductive capacity. Depreciation schedules should be based on the documented productive lifespan of the species drawn from biological literature or established industry norms. Straight-line depreciation over that productive lifespan is the default method. For operations involving mass replacement cycles—where an entire broodstock cohort is written off and replaced after a fixed number of spawning seasons (e.g., salmon broodstock replaced after 2–3 spawning cycles)—the cohort write-down and new cohort acquisition should both appear in the same accounting period as gross fixed capital formation (GFCF) and consumption of fixed capital (CFC). Market values for replacement broodstock may be used where active markets exist.

¶4 c) **Revaluations**—Record holding gains or losses reflecting price changes during the accounting period, separate from volume changes.

¶5 For valuation methodology, see **TG-3.1 Asset Accounts** Sections 3.3 (monetary asset accounts) and 3.6 (produced assets).

Step 5: Compile environmental flow accounts

¶1 Record flows between aquaculture operations and the environment following the methodology in **TG-3.2 Flows from Environment to Economy** and **TG-3.4 Flows from Economy to Environment**:

¶2 a) **Natural inputs**—Record abstraction of marine or coastal water for land-based systems (cubic metres). The following decision rule applies for water use recording: water use is recorded as abstraction when water is actively diverted from its natural course into a controlled facility, involving measurable pump intake volume. Passive water exchange through nets or tidal action in open cage culture is not abstraction and should not be recorded. Recirculating aquaculture systems (RAS) and

closed land-based systems with pump intake are clearly within scope as abstraction cases. These should be recorded following SEEA-Water definitions of abstraction¹¹. Record wild fish equivalent of feed inputs as a supplementary satellite or memo item (not as a main natural input entry; see Section 3.5 and SEEA AFF para 3.169), and where quantifiable, ecosystem services supporting aquaculture (water quality maintenance, nursery habitat provision).

¶3 b) **Residual outputs**—Record nutrient emissions (nitrogen and phosphorus from uneaten feed, faeces, excretion—measured in tonnes N and P), chemical releases (therapeutants, antifoulants—kilograms active ingredient), organic waste deposition (tonnes organic matter), and escapes (number or biomass, classified by species).

¶4 c) **Spatial attribution**—Assign emissions and environmental pressures to receiving ecosystems or management zones to enable integration with ecosystem condition accounts (**TG-3.1 Asset Accounts** Section 3.5.2).

¶5 Data sources include environmental monitoring programs, aquaculture environmental impact assessments, nutrient budget models for cage culture operations, veterinary chemical use records, and escape event reporting systems. See **TG-2.7 Pollution Flows** for emission accounting methodology.

Step 6: Assess carrying capacity and sustainability indicators

¶1 Integrate aquaculture accounts with ecosystem accounts to assess sustainability:

¶2 a) **Stocking density analysis**—Compare actual stocking levels against recommended carrying capacity thresholds for different system types and species. Excessive stocking reduces growth rates, increases disease risk, and elevates environmental pressures.

¶3 b) **Feed conversion efficiency**—Calculate feed conversion ratios (FCR—mass of feed per mass of production) and fish-in-fish-out ratios (FIFO—mass of wild fish in feed per mass of farmed output) as indicators of resource efficiency. See **TG-2.11 Resource Efficiency** for indicator methodology.

¶4 c) **Environmental pressure indicators**—Calculate nutrient loading per unit area of coastal zone, sediment organic enrichment indices beneath cage sites, and chemical loading. Compare against water quality standards or ecosystem health thresholds from **TG-2.1 Biophysical Indicators**.

¶5 d) **Habitat conversion tracking**—Where aquaculture expansion involves coastal habitat conversion (mangrove clearance for pond construction, seagrass loss beneath cage moorings), record extent changes in ecosystem accounts for affected habitats. See **TG-6.2 Mangrove and Coastal Wetland Accounting** for mangrove accounting methodology.

¶6 e) **GBF Target 10 alignment**—Report area under sustainable aquaculture management regimes to track progress towards ensuring all aquaculture is under effective management that minimises impacts on biodiversity and ecosystem functions¹². For statistical purposes, the minimum criterion for classifying an operation as “under sustainable management” is that it operates under a licence or permit that includes binding environmental performance conditions: nutrient discharge limits, escape prevention requirements, and habitat protection obligations. Third-party certified operations (e.g., ASC, BAP) constitute a subset of this definition and may be reported separately. This criterion aligns with FAO Voluntary Guidelines for Small-Scale Fisheries and CBD COP16 guidance on GBF monitoring framework implementation. It is intended as an interim operational definition pending further international agreement on Target 10 monitoring methodology.

Step 7: Integration and consistency checks

¶1 Ensure internal consistency and integration across account types:

¶2 a) **Production-asset consistency**—Verify that harvest recorded in production accounts equals reductions from harvest in asset accounts. Reconcile discrepancies through improved measurement or identification of unrecorded flows.

¶3 b) **Feed flow consistency**—Ensure that wild fish used for feed recorded in aquaculture intermediate consumption matches extractions recorded in fisheries accounts (**TG-1.5 OA and Fisheries Management**).

¶4 c) **Ecosystem integration**—Link aquaculture environmental pressures (nutrient loading, habitat conversion) to changes in ecosystem condition indicators for receiving ecosystems. Declining condition in coastal ecosystems may signal that aquaculture intensity exceeds ecological carrying capacity.

¶5 d) **Temporal consistency**—Maintain consistent time series by adjusting for changes in system boundaries, classification, or measurement methodology. Document adjustments in metadata following **TG-0.7 Quality Assurance** standards.

¶6 This compilation procedure provides the foundation for policy-relevant analysis. It allows governments to assess whether aquaculture expansion is sustainable, identify environmental pressure points requiring management intervention, and track progress towards blue economy and biodiversity targets.

3.3 Asset Classification

¶1 The classification of aquaculture assets must distinguish between different types of aquaculture systems and different categories of aquaculture stocks within those systems. This section builds on the general asset classification framework in **TG-3.1 Asset Accounts** Section 3.2 (Step 2).

Classification of aquaculture stocks

¶1 Within aquaculture operations, stocks must be classified according to their function in the production process:

¶2 **Breeding stocks (fixed assets)**. Aquatic organisms maintained for reproduction purposes are treated as **fixed assets** in the SNA classification¹³. These resources yield repeat products (eggs, juveniles, milt) over multiple production cycles. In asset accounts, they are recorded separately from stocks held for sale, and their growth is recorded as gross fixed capital formation. The 2025 SNA confirms that “animal resources yielding repeat products” include “aquatic resources maintained for controlled reproduction”¹⁴.

¶3 **Growing stocks (inventories)**. Organisms being raised for eventual harvest and sale are treated as **inventories**, specifically as **work-in-progress**¹⁵. The growth of these organisms over the accounting period represents additions to inventory, whilst harvest represents withdrawals. The SEEA CF notes that “the majority of changes in the stock of cultivated aquatic resources should be accounted for as changes in inventories”¹⁶.

¶4 **Hatchery output**. The treatment of hatchery production requires specific attention, and the correct recording depends on the institutional structure of the operation. For transactions between separate institutional units, juvenile organisms produced by a hatchery and sold to a grow-out operation represent output of the hatchery industry. The transaction should be recorded as a **sale and purchase of goods** (intermediate consumption by the grow-out operation), rather than as a reclassification between asset categories, since ownership changes hands through a market transaction¹⁷. For vertically integrated enterprises where a single institutional unit owns both the hatchery and grow-out facilities, no market transaction occurs. Intra-unit transfers are recorded as internal movements of work-in-progress inventory, with no output generated at the hatchery stage. Recording intra-unit transfers as sales would double-count output and distort gross value added estimates for the aquaculture sector. Compilers should apply the institutional unit identification approach consistent with **TG-3.3 Economic Activity Relevant to the Ocean** and the treatment of intra-enterprise transfers described in 2025 SNA Chapters 6 and 7¹⁸.

¶5 **Integrated multi-trophic aquaculture (IMTA)**. In IMTA systems, extractive species (mussels, seaweed, sea cucumbers) are co-cultivated with fed species and derive part of their growth from

organic waste generated by those fed species. For asset classification purposes, extractive species in IMTA should be classified and accounted following the same cultivated biological resource framework as other aquaculture stocks (as produced assets: fixed assets or inventories depending on their function). The waste assimilation function performed by the extractive species constitutes an intra-sector ecosystem service flow, with waste from one aquaculture activity becoming a production input for another. This flow should be recorded in a supplementary physical flow account. The monetary value of the nutrient removal service may be estimated using the avoided-cost methodology described in **TG-2.4 Ecosystem Goods and Services**. The accounting treatment of IMTA is an active methodological development area. Compilers should flag IMTA entries in metadata and consult **TG-6.8 Aquaculture Thematic Methods** for further guidance as it becomes available.

¶6 **Ornamental aquaculture.** Ornamental species (marine fish, corals, live rock) classified under purpose category (d) in Step 1 are within scope for aquaculture accounts and should be compiled using the same cultivated biological resource framework. The specific data challenge for ornamentals is that production is not recorded in FAO FishStatJ food production databases, which cover food and feed species. Compilers should use national licensing registries and trade data (import/export statistics for live ornamental species) as primary data sources. The production boundary criterion applies in full: cultivated classification requires ownership and control throughout the rearing period. Wild-caught marine organisms held temporarily for resale do not qualify as aquaculture and should not be included in cultivated asset accounts (the ownership-throughout-rearing criterion in SEEA CF para 5.409 is not satisfied) and their extraction is therefore recorded under natural resource use per SEEA CF para 5.407¹⁹.

Physical asset account structure

¶1 Table 3.9.2 presents the structure of a physical asset account for cultivated aquatic resources, following the format in SEEA CF Table 5.22.

¶2 *Table 3.9.2: Structure of physical asset account for cultivated aquatic resources*

Accounting entry	Breeding stocks (fixed assets)	Growing stocks (inventories)	Total cultivated
Opening stock	Number/tonnes	Tonnes	Tonnes
Additions to stock			
– Growth in stock	Natural increase	Biomass gain	
– Purchases/hatchery production	Broodstock acquisitions	Juvenile stocking	
– Reclassifications (from natural)	Wild-caught broodstock	Wild-caught for fattening	
<i>Total additions</i>			
Reductions in stock			
– Harvest	–	Sales/processing	
– Normal losses	Routine mortality	Routine mortality	
– Catastrophic losses	Disease/environmental events	Disease/environmental events	
– Culling	Unproductive broodstock	–	
– Reclassifications (to natural)	–	Escapes/releases	
<i>Total reductions</i>			
Closing stock	Number/tonnes	Tonnes	Tonnes

¶3 **Note on monetary account columns:** Where monetary columns are added to Table 3.9.2, revaluation entries (holding gains/losses from price changes) must be presented as a separate line

item distinct from the volume change entries above, to avoid confounding volume and price effects in the time series. See Step 4 for the method hierarchy governing monetary valuation.

¶4 **Note on breeding stock depreciation illustration:** For a cohort replaced after two spawning cycles (typically two years for Atlantic salmon), a compiler would record in Year 1: GFCF for the new cohort acquisition; in Year 2: CFC (consumption of fixed capital) through the year as productive capacity declines, and at end of Year 2: the remaining book value written down simultaneously with new cohort GFCF. Both entries appear in the same accounting period when mass replacement occurs.

¶5 This structure parallels the asset account for natural aquatic resources presented in **TG-3.1 Asset Accounts** Table 1, enabling side-by-side comparison and consolidation of total aquatic resource accounts.

¶6 **Growth in stock** encompasses both increase in numbers (through hatching, natural reproduction where relevant) and increase in biomass (growth of individual organisms). For breeding stocks, only the growth of the breeding population is recorded. The juveniles produced are recorded as additions to growing stocks.

¶7 **Reclassifications** record transfers between natural and cultivated categories. Introduction of wild-caught organisms as broodstock or seed represents a reclassification from natural to cultivated resources. Release of cultured organisms for ranching or enhancement programmes, and escapes from aquaculture facilities, represent reclassifications from cultivated to natural resources²⁰.

¶8 **Harvest** records the removal of organisms from growing stocks for sale or processing. For breeding stocks, animals removed for slaughter (culling of unproductive or excess broodstock) are recorded as reductions.

¶9 **Normal losses** include mortality from routine causes such as disease, predation, and environmental stress within normal operating parameters.

¶10 **Catastrophic losses** record exceptional losses from disease outbreaks, harmful algal blooms, extreme weather events, or other unexpected events beyond normal operating expectations²¹.

Monetary valuation

¶1 Aquaculture stocks are valued following standard SNA principles for produced assets. For inventory valuation, the 2025 SNA treatment of work-in-progress recognises that cost accumulation methods may not provide satisfactory results where growth is non-linear²². Similar challenges arise for aquaculture, where growth is not linear and substantial mortality may occur. For guidance on valuation approaches, see **TG-1.9 Valuation**.

¶2 For breeding stocks (fixed assets), valuation should reflect the expected future economic benefits from the breeding capacity. Depreciation is recorded for the decline in value as breeding animals age and their productive capacity declines²³.

3.4 Carrying Capacity Considerations

¶1 Aquaculture production occurs within environmental constraints that determine the sustainable level of production. Accounting for these constraints supports assessment of the long-term viability of aquaculture operations and their interactions with marine ecosystems.

Concept of carrying capacity in aquaculture

¶1 The concept of **carrying capacity** in aquaculture contexts refers to the maximum production that can be sustained in a given environment without causing unacceptable environmental impacts or production failures. The FAO definition of aquaculture (see footnote ⁶) describes aquaculture as involving “some form of intervention in the rearing process to enhance production,” whilst ISIC

Rev.4 Group 032 describes aquaculture as involving “some form of intervention in the rearing process... Farming also implies individual or corporate ownership of the stock being cultivated”²⁴.

¶2 Drawing on aquaculture science literature and applying the carrying capacity concept recognized in SEEA AFF para 3.90, several dimensions of carrying capacity are relevant for accounting purposes. Table 3.4.1 below summarises these dimensions.

Dimension	Description
Physical carrying capacity	The maximum stocking density or production that can be achieved given physical and biological constraints (space, oxygen, water flow, etc.).
Production carrying capacity	The level of production at which marginal costs equal marginal revenues – the economically optimal production level given input costs and output prices.
Ecological carrying capacity	The level of production that can be sustained without causing unacceptable impacts on the surrounding environment or wild populations. Particularly relevant for open aquaculture systems that interact with marine ecosystems.
Social carrying capacity	The level of production that is acceptable given competing uses of coastal and marine space and community concerns about environmental and aesthetic impacts.

¶3 The Statistical Framework for Measuring the Sustainability of Tourism (SF-MST) provides a parallel treatment of carrying capacity in its discussion of tourism environmental limits (para 4.103), supporting the broader applicability of carrying capacity concepts within environmental-economic accounting²⁵. The SEEA AFF notes that asset accounts “can be used to better understand the carrying capacity of agricultural areas with respect to livestock, for example, the number of cattle per hectare”²⁶. This is a direct statistical precedent for applying carrying capacity analysis to cultivated biological resources.

Authoritative sources for carrying capacity thresholds

¶1 For statistical compilation purposes, national statistical offices (NSOs) should adopt carrying capacity thresholds published by national competent authorities (principally aquaculture licensing agencies and environmental regulators) where such thresholds have been formally established. These published regulatory thresholds provide the most replicable and institutionally consistent basis for the sustainability assessments in Step 6. Where no national thresholds exist, NSOs should use FAO Technical Guidelines for Responsible Fisheries No. 5 (Aquaculture Development) or peer-reviewed species-specific benchmarks from the scientific literature as reference values, flagging these as provisional in metadata consistent with **TG-0.7 Quality Assurance** conventions. The NSO’s role is to compile and report against established thresholds, not to derive or adjudicate carrying capacity values independently. For thematic methodological detail on carrying capacity assessment methods, see **TG-6.8 Aquaculture Thematic Methods**.

Accounting implications

¶1 For accounting purposes, carrying capacity considerations affect the interpretation of production levels and the assessment of sustainability:

¶2 **Stock assessment.** The opening and closing stocks of cultivated aquatic resources should be assessed against the carrying capacity of the facilities and environment. Stocking at levels that exceed carrying capacity may lead to reduced growth rates, increased mortality, disease outbreaks, and environmental degradation.

¶3 **Sustainable yield.** Whilst the concept of maximum sustainable yield (MSY) is traditionally applied to wild fisheries (see **TG-6.7 Fisheries Stock Assessment**), analogous concepts apply to aquaculture in open systems. Production that exceeds ecological carrying capacity may degrade the supporting ecosystem, reducing its capacity to support future production.

¶4 **Environmental condition.** For open aquaculture systems operating within marine ecosystems, the ecosystem condition accounts described in **TG-3.1 Asset Accounts** Section 3.5.2 should capture changes in environmental quality that affect or are affected by aquaculture operations.

Integration with ecosystem accounts

¶1 The SEEA Ecosystem Accounting framework provides a basis for linking aquaculture accounts with ecosystem condition and service accounts. Key linkages include:

¶2 **Supporting services.** Marine ecosystems provide water quality maintenance, waste assimilation, and habitat functions that support aquaculture production. Degradation of these supporting services may reduce carrying capacity and production potential.

¶3 **Provisioning services.** In some extensive aquaculture systems, natural productivity contributes directly to fish growth, representing a flow of ecosystem services to the aquaculture activity.

¶4 **Regulating services.** Ecosystems regulate water temperature, disease prevalence, and harmful algal blooms, all of which affect aquaculture production.

¶5 For guidance on ecosystem service accounting, see **TG-3.2 Flows from Environment to Economy** and **TG-2.4 Ecosystem Goods and Services**.

3.5 Environmental Interactions

¶1 Aquaculture, particularly in open marine systems, interacts substantially with the surrounding environment. These interactions must be captured in ocean accounts to record the aquaculture sector's environmental dependencies and impacts in full. This section complements the general guidance on environmental flows in **TG-3.2 Flows from Environment to Economy** and **TG-3.4 Flows from Economy to Environment**.

Inputs from the environment

¶1 Aquaculture operations draw upon environmental inputs that should be recorded in physical supply and use accounts:

¶2 **Water abstraction.** Land-based aquaculture systems (tanks, ponds, raceways) may abstract large volumes of freshwater or seawater. These abstractions should be recorded in water accounts following the methodology in SEEA-Water¹¹. For marine cage culture, passive water exchange through nets or tidal action is not abstraction and should not be recorded. Only pumped intake into a controlled facility qualifies (see the decision rule in Step 5a). Water quality requirements for cage culture operations should be noted as context for ecosystem condition assessment.

¶3 **Feed from wild fisheries.** A material environmental interaction is the use of fish meal and fish oil derived from wild-caught fish as feed inputs for carnivorous aquaculture species²⁷. The SEEA AFF notes that "fish products provide nutrition in a stable and concentrated form, which enables the fish to feed efficiently and grow to their full potential. Many of the intensively farmed fish are carnivorous, including, among others, Atlantic salmon, trout, sea bass and turbot. In line with the emergence of modern aquaculture in the 1970s, fish meal and fish oil have become major components of feed for those species"²⁸.

¶4 The relationship between aquaculture feed and wild fish stocks requires careful treatment to avoid double-counting in linked accounts. In most commercial operations, aquaculture operators purchase commercially processed fishmeal and fish oil as intermediate inputs, not raw wild fish directly. The wild fish extraction that generates this fishmeal is already recorded in the fisheries supply account at the point of harvest. Compilers should not record the fishmeal content of purchased feed as a separate "natural input" in the aquaculture accounts, as this would double-count the same fish stock depletion. Commercially purchased fishmeal and fish oil appear in the supply and use table as purchased goods (intermediate consumption by the aquaculture industry), not as direct flows from nature²⁹. The analytical relationship between fishmeal use and wild fish extraction is

captured by the **fish-in-fish-out ratio** (FIFO)—the ratio of wild fish equivalent embedded in feed per unit of farmed output produced. This is an analytical indicator rather than a separate accounting entry. Where NSOs wish to show the wild fish equivalent of purchased feed, it should be presented as a supplementary satellite table or memo item, aligned with SEEA AFF para 3.169. The **feed conversion ratio** (FCR)—the ratio of feed input to fish output—is a key efficiency indicator and should be reported alongside FIFO in resource efficiency analysis. FIFO ratios vary substantially by species and have been declining over time with improvements in feed technology and partial replacement of fishmeal by plant-based proteins³⁰. For supply and use accounting, the feed inputs (measured in tonnes) should be recorded as intermediate consumption. For resource efficiency analysis, see **TG-2.11 Resource Efficiency**.

¶5 **Ecosystem services.** As noted in Section 3.4, aquaculture benefits from ecosystem services including water quality maintenance, disease regulation, and larval supply (for some species). These services represent flows from the environment to the economy that may be captured in ecosystem service accounts.

Outputs to the environment

¶1 Aquaculture operations generate outputs to the environment that should be recorded in residual flow accounts:

¶2 **Nutrient loading.** Aquaculture releases nutrients (primarily nitrogen and phosphorus) through uneaten feed, faeces, and metabolic excretion. In open systems, these nutrients are released directly to the marine environment and may contribute to eutrophication in poorly flushed areas³¹. Nutrient releases should be recorded in emission accounts following the SEEA CF methodology for residual flows. For guidance on pollution flow accounting, see **TG-2.7 Pollution Flows**.

¶3 **Organic matter.** Feed waste and faeces settling beneath cage sites can alter benthic conditions, affecting sediment chemistry and benthic communities.

¶4 **Chemical releases.** Aquaculture may involve use of therapeutants (antibiotics, parasiticides), antifoulants, and other chemicals that are released to the environment. These should be recorded following standard emission accounting principles. Chemical treatments for parasites (e.g., hydrogen peroxide, azamethiphos) are quantifiable where veterinary chemical use records are maintained and should appear in the chemical releases row with a species/compound breakdown where data permit.

¶5 **Escapes.** Organisms that escape from aquaculture facilities represent a flow from the economy to the environment. As noted in Sections 3.1 and 3.3 (Table 3.9.2), these should be recorded as reclassifications from cultivated to natural aquatic resources “in cases where the fish are able to integrate into natural fish stocks”³². Where integration is not possible (e.g., non-native species in unsuitable environments), escapes should be recorded as losses.

¶6 **Pathogen and parasite pressure.** Aquaculture operations may transmit pathogens and parasites to wild populations, an interaction with documented ecosystem condition effects. Where quantification is possible (for example, sea lice counts per fish from regulatory reporting in salmon-producing countries, or volumes of antiparasitic chemicals used), these should be recorded in ecosystem condition accounts as pressure indicators linked to **TG-2.1 Biophysical Indicators**. Quantifiable chemical treatments (e.g., antiparasitic compound volumes) should appear in the chemical releases row of Table 3.9.3 with a species/compound breakdown. The transmission of biological parasites or pathogens to wild populations is not currently quantifiable within standard SEEA accounting structures and is flagged as a methodological development area for future revision.

Recording environmental interactions

¶1 Table 3.9.3 presents a framework for recording the principal environmental interactions of aquaculture in physical terms.

¶2 Table 3.9.3: Framework for recording environmental interactions of aquaculture

Flow type	Category	Measurement unit	Relevant account	Cross-reference
Inputs				
Water abstraction	Natural input	Cubic metres	Water accounts	TG-3.2
Wild fish for feed (memo item)	Supplementary	Tonnes wild fish equivalent	Satellite/memo table	TG-3.2
Ecosystem services	Service flow	Various	Ecosystem service accounts	TG-2.4
Outputs				
Nutrient releases (N, P)	Residual	Tonnes	Emission accounts	TG-3.4, TG-2.7
Chemical releases (incl. antiparasitics)	Residual	Kilograms	Emission accounts	TG-3.4
Organic waste	Residual	Tonnes	Waste accounts	TG-3.4
Escapes	Reclassification	Number/tonnes	Asset accounts	TG-3.1
Pathogen/parasite pressure	Ecosystem condition indicator	Various (lice counts, chemical volumes)	Ecosystem condition accounts	TG-3.1 Section 3.5.2

Integration with flows accounts

¶1 The environmental interactions of aquaculture should be integrated with the flow accounts described in **TG-3.2 Flows from Environment to Economy** and **TG-3.4 Flows from Economy to Environment**. This integration enables:

- ¶2 Calculation of resource efficiency indicators (e.g., water use per tonne of production, feed conversion ratios)—see **TG-2.11 Resource Efficiency**
- ¶3 Assessment of environmental pressures relative to ecosystem carrying capacity
- ¶4 Linking of aquaculture activity to changes in ecosystem condition—see **TG-2.1 Biophysical Indicators**
- ¶5 Derivation of sustainability indicators for aquaculture management

¶6 For detailed methodological guidance on site-specific assessment and integration with ecosystem accounts, see **TG-6.8 Aquaculture Thematic Methods**. The broader relationship between aquaculture and fisheries within ocean accounting is addressed in **TG-1.5 OA and Fisheries Management**, which discusses how aquaculture and wild-capture fisheries interact in contributing to ocean-based food production and how both are treated within integrated fisheries governance frameworks.

3.6 Worked Examples

¶1 This section presents three worked examples with synthetic data demonstrating the compilation of aquaculture accounts for common scenarios: a shrimp farm production account, a coastal zone mangrove conversion tracking system, and a salmon cage culture nutrient loading assessment.

Example 1: Coastal shrimp farm production and asset accounts

¶1 **Context:** A coastal nation operates intensive shrimp aquaculture in converted mangrove areas. The example demonstrates production account compilation, asset account structure for growing stocks, and feed flow tracking.

¶2 **Scenario parameters** (synthetic data for accounting year 2025):

- ¶3 Total shrimp farm area: 500 hectares
- ¶4 Growing stocks opening biomass: 800 tonnes
- ¶5 Stocking during year: 1,200 tonnes of juveniles at nursery stocking size (assumed average individual weight: 0.3 g, equivalent to approximately 4.0 billion individuals. This refers to post-larvae at PL20 or larger nursery stage, not newly hatched post-larvae)³³
- ¶6 Biomass growth: 3,500 tonnes (from feeding and maturation)
- ¶7 Harvest: 3,800 tonnes (market-size shrimp)
- ¶8 Normal losses: 600 tonnes (mortality from disease, predation)
- ¶9 Catastrophic losses: 100 tonnes (disease outbreak in one farm cluster)
- ¶10 Closing biomass: 1,000 tonnes
- ¶11 Feed inputs: 6,000 tonnes commercial feed (25% fishmeal content = 1,500 tonnes fishmeal from wild fisheries)
- ¶12 Production value: USD 38 million at basic prices
- ¶13 Intermediate consumption: USD 22 million (feed USD 15 million, PL USD 3 million, other USD 4 million)
- ¶14 Value added: USD 16 million

¶15 *Table 3.9.4: Shrimp aquaculture physical asset account, 2025*

Accounting entry	Growing stocks (tonnes live weight)	Growing stocks (millions of individuals – memo)
Opening stock	800	–
Additions to stock		
– Growth in stock	3,500	–
– Purchases (PL stocking)	1,200	4,000
– Reclassifications (from natural)	0	0
<i>Total additions</i>	4,700	
Reductions in stock		
– Harvest	3,800	–
– Normal losses	600	–
– Catastrophic losses	100	–
– Reclassifications (to natural)	0	0
<i>Total reductions</i>	4,500	
Closing stock	1,000	–

¶16 **Note on PL stocking unit:** Post-larvae (PL) are commercially traded in millions of individuals. The 1,200 tonnes figure represents nursery-stage juveniles at approximately 0.3 g average body weight (approximately 4,000 million individuals or 4.0 billion PL). Where the primary data source is in units of millions of individuals, compilers should convert to biomass using the average individual weight at stocking, which should be documented in facility records or species-specific industry norms. The memo column above illustrates this parallel recording.

¶17 **Verification:** Closing stock (1,000) = Opening stock (800) + Additions (4,700) – Reductions (4,500). Account balances correctly.

¶18 **Feed conversion and efficiency indicators:**

- ¶19 Feed conversion ratio (FCR) = Feed input / Biomass growth = 6,000 / 3,500 = 1.71 (industry benchmark for intensive shrimp: 1.5–2.0)

- ¶20 Fish-in-fish-out ratio (FIFO) = Wild fish equivalent of fishmeal / Harvest = (1,500 / 0.225) / 3,800 = 6,667 / 3,800 = 1.75, at the standard fishmeal yield of 22.5 per cent of raw fish³⁴ (net consumer of wild fish, as FIFO > 1.0)

¶21 ⓘ **Corrected 24 September 2026**

¶22 FIFO was previously computed as fishmeal ÷ harvest (0.39, “net contributor”); on the circular’s own definition it is wild fish equivalent ÷ farmed output, which at a 22.5 per cent fishmeal yield is 1.75, so the farm is a net consumer of wild fish. FCR is now computed on biomass growth (production), as defined in Section 3.2, Step 6.

¶23 **Production account linkages:** The 3,800 tonnes harvest recorded as reduction in asset account should match output recorded in supply table for ISIC 0321 (Marine aquaculture). The USD 3 million PL purchases appear as intermediate consumption in the shrimp farm production account and as output in the hatchery industry production account.

¶24 **Environmental flow implications:** The 1,500 tonnes of fishmeal embodied in purchased feed, about 6,700 tonnes of wild fish equivalent, represents a wild fish equivalent analytical indicator (FIFO). This should be presented as a satellite table or memo item rather than as a direct natural input in the main accounts, consistent with the double-counting avoidance rule described in Section 3.5 and SEEA AFF para 3.169.

Example 2: Mangrove conversion tracking for shrimp pond expansion

¶1 **Context:** The same coastal nation experienced shrimp aquaculture expansion from 2020–2025, involving conversion of mangrove ecosystems to pond culture. The example demonstrates integration of aquaculture asset accounts with ecosystem extent accounts.

¶2 **Scenario parameters** (synthetic data):

- ¶3 Mangrove extent 2020: 12,000 hectares
- ¶4 Mangrove extent 2025: 11,500 hectares
- ¶5 Shrimp pond extent 2020: 300 hectares
- ¶6 Shrimp pond extent 2025: 500 hectares
- ¶7 Documented mangrove-to-pond conversion 2020–2025: 200 hectares
- ¶8 Other mangrove losses (erosion, development): 300 hectares

¶9 *Table 3.9.5: Ecosystem extent account for mangrove and shrimp pond ecosystems, 2020–2025*

Accounting entry	Mangrove (hectares)	Shrimp pond (hectares)
Opening extent (2020)	12,000	300
Extent additions		
– Managed expansion	0	200
– Natural regeneration	0	0
<i>Total additions</i>	0	200
Extent reductions		
– Conversion to aquaculture	200	0
– Conversion to other uses	300	0
– Coastal erosion	0	0
<i>Total reductions</i>	500	0
Closing extent (2025)	11,500	500

¶10 **Cross-account consistency:** The 200 hectares of mangrove-to-pond conversion appears as a reduction in the mangrove extent account and as an addition to the shrimp pond (produced asset) area. This reclassification tracks the transformation of natural ecosystem assets into cultivated aquaculture infrastructure.

¶11 **Policy implications:** The 4.2% loss of mangrove extent over five years signals environmental pressure from aquaculture expansion. Mangrove ecosystem service losses include carbon sequestration capacity (estimated 3–5 tonnes CO₂e/ha/yr), coastal protection value, and nursery habitat for wild fisheries. See **TG-6.2 Mangrove and Coastal Wetland Accounting** for mangrove accounting methodology, including valuation of ecosystem services lost through conversion.

¶12 **GBF Target 10 relevance:** Countries reporting under the Kunming-Montreal Global Biodiversity Framework must track area under sustainable aquaculture. The 200-hectare mangrove conversion would need to be balanced by demonstrating that the resulting shrimp farms meet environmental sustainability criteria to avoid negative reporting against biodiversity targets.

Example 3: Salmon cage culture nutrient loading to coastal ecosystem

¶1 **Context:** A temperate coastal nation operates salmon cage culture in fjords and sheltered coastal waters. The example demonstrates compilation of nutrient emission accounts and integration with ecosystem condition assessment.

¶2 **Scenario parameters** (synthetic data for accounting year 2025):

- ¶3 Salmon production: 150,000 tonnes live weight harvest
- ¶4 Feed input: 195,000 tonnes (FCR = 1.3)
- ¶5 Feed composition: 30% protein, 20% fat, nitrogen content 4.8% of feed, phosphorus content 0.9%
- ¶6 Estimated nutrient releases applying **illustrative** release fractions (see note below):
 - ¶7 Nitrogen: 195,000 tonnes feed × 0.048 × 0.65 (illustrative N release fraction) = 6,084 tonnes N
 - ¶8 Phosphorus: 195,000 tonnes feed × 0.009 × 0.70 (illustrative P release fraction) = 1,229 tonnes P
- ¶9 Receiving coastal ecosystems: 15 fjord systems, total surface area 450 km²

¶10 **Note on release fractions:** The nitrogen (0.65) and phosphorus (0.70) release fractions used in this example are illustrative scenario parameters, not authoritative emission factors. They fall within the upper range of published values for intensive fed-finish systems. Compilers should use release fractions from their national regulatory framework, environmental monitoring programmes, or established reference sources (e.g., HELCOM PLC-Water Guidelines, which specify aquaculture nutrient thresholds for the Baltic Sea, or FAO reference values³⁵). Published release fractions vary by feed composition, species, and production system type. Table 3.9.6 illustrates this range:

¶11 *Table 3.9.6: Published range of nutrient release fractions by aquaculture system type (illustrative)*

System type	N release fraction (range)	P release fraction (range)	Source basis
Intensive fed finfish (cage)	0.55–0.75	0.60–0.75	Holmer (2010) ³¹ ; HELCOM
Semi-intensive pond	0.30–0.55	0.40–0.60	Literature range
Recirculating aquaculture (RAS)	0.10–0.30	0.15–0.35	Technology-dependent

¶12 *Table 3.9.7: Nutrient emission account for salmon aquaculture, 2025*

Residual type	Measurement unit	Quantity	Receiving ecosystem	Relevant standard
Nitrogen (N)	Tonnes N	6,084	Fjord coastal waters	SEEA CF Table 3.2
Phosphorus (P)	Tonnes P	1,229	Fjord coastal waters	SEEA CF Table 3.2

¶13 **Nutrient loading intensity:**

- ¶14 Nitrogen loading = 6,084 tonnes / 450 km² = 13.5 tonnes N/km²/yr
- ¶15 Phosphorus loading = 1,229 tonnes / 450 km² = 2.7 tonnes P/km²/yr

¶16 **Ecosystem condition linkages:** These nutrient loading rates should be assessed against water quality standards and ecosystem condition indicators from **TG-2.1 Biophysical Indicators**. Indicators might include:

- ¶17 Dissolved oxygen levels in bottom waters (hypoxia threshold: < 2 mg/L)
- ¶18 Chlorophyll-a concentrations (eutrophication indicator)
- ¶19 Benthic community condition indices beneath cage sites

¶20 **Carrying capacity assessment:** If condition indicators show declining trends (increasing hypoxia, benthic degradation), this signals that aquaculture intensity may exceed the ecological carrying capacity of the receiving fjord systems. Authorities may need to adjust licensing to reduce stocking density or redistribute farms to less-impacted areas.

¶21 **Data sources:** Nutrient release estimates are typically derived from mass-balance models combining feed input data (from industry records), feed composition (from nutritional analysis), and empirically-determined release fractions (from scientific literature or site-specific monitoring). For emission accounting methodology, see **TG-2.7 Pollution Flows** and **TG-3.4 Flows from Economy to Environment**.

¶22 **Cross-stack connections:** These worked examples demonstrate integration across the accounting stack:

- ¶23 **Upward to TG-1.x policy:** Mangrove conversion and nutrient loading evidence informs decisions on aquaculture zoning, licensing thresholds, and environmental performance standards (**TG-1.2 OA and Marine Spatial Planning**, **TG-1.5 OA and Fisheries Management**).
- ¶24 **Lateral to TG-2.x indicators:** FCR and FIFO ratios feed into resource efficiency indicators (**TG-2.11**), and nutrient loading drives water quality indicators (**TG-2.1**).
- ¶25 **Downward to TG-4.x data:** Extent mapping requires remote sensing and geospatial analysis (**TG-4.1**). Nutrient budget models require data integration from production statistics, feed composition databases, and field monitoring (**TG-4.6 Data Harmonisation and Interoperability**).

3.7 Provisioning-Service Quantification: Linking Aquaculture Output to Ecosystem

Service Accounts

¶1 Aquaculture production accounts (Sections 3.2–3.3) measure cultivated output as a produced asset within the SNA production boundary. They do not, by themselves, quantify the **provisioning ecosystem services** that supporting marine and coastal ecosystems contribute to that output, nor do they quantify the wild-capture and gleaning flows that often coexist with aquaculture in the same coastal zone. Practitioners may consider compiling complementary provisioning-service accounts following SEEA EA Chapter 6, particularly where aquaculture sits alongside wild-capture fisheries, gleaning, or mangrove fuel-wood collection in an integrated coastal accounting area³⁶.

¶2 The candidate workflows below are presented as parallel quantification pipelines: aquaculture production accounting (covered in Sections 3.2–3.3), wild-capture catch accounting, gleaning, and wood/non-timber forest product (NTFP) provisioning. Each pipeline produces a physical supply table and, where feasible, a monetary supply table. Practitioners may select the workflows applicable to their accounting area and tier their implementation according to data availability.

3.7.1 Aquaculture production accounting (reference)

¶1 The physical asset and production accounts compiled per Sections 3.2–3.3 directly populate the provisioning-service entry for cultivated aquatic resources. Output recorded in tonnes live weight by species and system type may be cross-tabulated against the supporting ecosystem (coastal waters, brackish ponds converted from mangrove, offshore cage sites) to indicate the

spatial distribution of cultivated provisioning supply. Monetary valuation follows the produced-asset method hierarchy in Step 4 (market price; cost-accumulation fallback). FAO aquaculture statistics, reported through FAO FishStatJ, provide the national benchmark against which compiled accounts may be reconciled³⁷.

3.7.2 Wild-capture catch accounting (parallel workflow)

¶1 Wild-capture fisheries operating in the same coastal zone as aquaculture should be accounted as a distinct provisioning service flow drawn from natural (non-produced) aquatic resources. Practitioners may consider the following candidate pipeline, adapted from SEEA EA Section 6.1:

¶2 a) **Physical measurement.** Compile total annual landed catch (kg/yr) from national or regional fisheries agency records, supplemented where coverage is thin by structured fisher surveys. Disaggregate by (i) species or species group; (ii) gear type; and (iii) ecosystem association (typically coral reef, seagrass, mangrove, or pelagic) using species-habitat associations from peer-reviewed literature, validated against local fisher knowledge where feasible. Where landing surveys cover only a fraction of trips, practitioners may calibrate coverage against provincial or regional statistics to derive an extrapolation factor.

¶3 b) **Monetary valuation: resource rent.** Resource rent is computed following the method defined in **TG-3.2 Flows from Environment to Economy** Section 3.5. A negative residual indicates that fishing costs exceed revenue under prevailing conditions and may be reported as a zero ecosystem service value with the negative figure disclosed in metadata. The resource rent method is consistent with the FAO Code of Conduct for Responsible Fisheries principles on economic sustainability of fisheries³⁸ and with the SEEA EA treatment of market-based provisioning services³⁹.

¶4 c) **Tiered implementation.** Practitioners may begin at Tier 1 (national aggregate catch statistics with global or regional unit values transferred from comparable contexts) and progress to Tier 2 (locally compiled landings disaggregated by species, gear, and ecosystem, with domestically sourced cost data) or Tier 3 (vessel-level production accounts with site-specific capital stock valuation). Value-transfer accuracy is limited and may not be acceptable beyond preliminary accounts. Practitioners may consider flagging Tier 1 entries as indicative.

¶5 d) **Data sources.** FAO FishStat global capture production records provide the international benchmark⁴⁰. National fisheries authority landings registers, port samplers, and structured artisanal-fisher surveys provide the disaggregated detail required for ecosystem attribution.

3.7.3 Gleaning (intertidal hand-collection)

¶1 Gleaning (the hand-collection of molluscs, crustaceans, echinoderms, and seaweeds from intertidal mudflats, reef flats, and mangrove edges) is a provisioning flow often missed by both aquaculture and conventional fisheries statistics, despite its importance for coastal household food security and women's livelihoods. Practitioners may consider a parallel candidate workflow:

¶2 a) **Physical measurement.** Where direct catch records are unavailable, household survey instruments may be used to estimate per-collector annual harvest (kg/yr) by target species group. Aggregate across the eligible population within accessible distance of the providing ecosystem. Spatial proxy models – in which collection is modelled as a function of distance to the resource edge, accessible standing stock, and household demand parameters – may be used to extrapolate where survey coverage is incomplete.

¶3 b) **Monetary valuation.** Where gleaned products enter local markets, first-sale prices may be used to compute gross revenue and a resource rent computed analogously to wild-capture fisheries (Section 3.7.2). Where collection is predominantly for subsistence with no observed market transaction, practitioners may consider a substitute-cost approach – valuing the catch against the market price of the nearest commercial equivalent – and recording the result as a Category V (non-market) valuation in metadata.

¶4 c) **Use table.** Gleaning output typically flows to subsistence households rather than the formal fisheries sector. The use table should record this allocation distinctly to preserve the distributional information needed for livelihood and food-security analysis.

3.7.4 Wood and non-timber forest product (NTFP) provisioning from mangroves

¶1 Where aquaculture operations are sited in or adjacent to mangrove ecosystems – a common pattern for brackish-water shrimp and milkfish ponds – the mangrove area that remains intact may continue to provide wood and NTFP provisioning services (fuel wood, building poles, charcoal feedstock, honey, dye, traditional medicine) to surrounding communities. The provisioning-service account for mangrove wood is conceptually independent from the aquaculture account but should be compiled in the same accounting area to enable trade-off analysis between mangrove conversion for ponds and retained mangrove provisioning value.

¶2 a) **Physical measurement.** Where direct household survey data on fuel-wood collection are unavailable, practitioners may consider a spatial proxy model estimating per-household extraction as a function of distance from household to mangrove edge, accessible deadwood stock, and a baseline household demand parameter drawn from peer-reviewed literature. Aggregation across eligible households within an accessible distance band yields total annual collection. Practitioners may flag the use rate against a sustainable yield benchmark (commonly expressed as a function of standing biomass and rotation length) to check consistency with mangrove extent accounts.

¶3 b) **Monetary valuation – substitute-cost.** Where collected wood does not enter formal markets, the candidate primary method is substitute-cost: total annual collection converted to energy equivalent and valued at the market price of the displaced commercial fuel (typically LPG or kerosene). Air-dried biomass is converted to MJ using species-appropriate calorific values. Bark and leaves are typically excluded.

¶4 c) **Monetary valuation – resource rent (stumpage value).** Where mangrove wood is marketed (sold as timber, poles, or firewood), practitioners may instead use the stumpage-value resource rent method: market price at point of sale less harvesting and transport costs. This yields a directly observed market-based exchange value consistent with SEEA EA monetary valuation hierarchy⁴¹.

¶5 d) **Cross-account consistency.** The use rate implied by the physical account must be cross-checked against extent and condition accounts for the providing mangrove ecosystem. A use rate exceeding sustainable yield implies declining mangrove biomass, and that decline should be reflected in the extent or condition account and metadata. Practitioners may consider flagging districts where mangroves have been substantially converted to aquaculture as excluded from the provisioning model.

3.7.5 Data quality and limitations

¶1 Provisioning-service quantification in coastal contexts is sensitive to several recurring data-quality issues that practitioners may consider documenting in account metadata:

- ¶2 Limited cost-survey data or low response rates in artisanal contexts may yield unreliable resource rent estimates. Practitioners may consider increasing survey effort, supplementing with focus groups, or flagging the entry as data-deficient.
- ¶3 Subsistence catch and gleaning are difficult to value at market prices. Recording them separately, with a noted data gap, preserves the physical signal.
- ¶4 Species-habitat allocations drawn from regional literature may not reflect local ecological conditions and may require validation with local fishers.
- ¶5 Spatial proxy models for wood and NTFP provisioning are sensitive to literature-derived distance elasticity and use-rate parameters. Sensitivity analysis on these parameters is good practice.
- ¶6 Charcoal and processed-product value streams may be material but are often excluded from primary proxy models. Practitioners may consider supplementary accounts for these flows.

¶7 This subsection presents candidate workflows. Practitioners may select among them according to the structure of the accounting area, the data available, and the policy questions the account is intended to support. The SEEA EA framework permits parallel compilation of cultivated and natural provisioning accounts in a single physical supply and use table, with monetary entries compiled where data permit⁴².

4. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

¶3 **Note:** This circular addresses a priority addition identified in the February 2025 modular structure revision.

5. References

1. ¶1 FAO (2024), *The State of World Fisheries and Aquaculture 2024*, reports that aquaculture production has exceeded wild-capture fisheries for food use since 2020.
2. ¶2 FAO SOFIA 2024 confirms aquaculture's expanding share of global seafood production.
3. ¶3 SEEA CF, para 2.84-2.86
4. ¶4 SEEA CF, para 5.408
5. ¶5 SEEA CF, para 5.408
6. ¶6 SEEA CF, para 5.409, citing FAO (2008) Glossary of Aquaculture
7. ¶7 SEEA AFF, para 2.127-2.129 on distinguishing natural from cultivated processes
8. ¶8 SEEA CF, para 5.407-5.408
9. ¶9 2025 SNA, Chapter 11, para 11.206-11.208
0. ¶10 2025 SNA, para 11.214-11.216
1. ¶11 SEEA-Water provides comprehensive guidance on water abstraction accounting
2. ¶12 Kunming-Montreal Global Biodiversity Framework, Target 10: "Ensure that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity..."
3. ¶13 SEEA CF, para 5.418
4. ¶14 2025 SNA, para 11.215
5. ¶15 SEEA CF, para 5.415
6. ¶16 SEEA CF, para 5.418
7. ¶17 2025 SNA, para 11.216 (treatment of sales of livestock between establishments applies analogously to arm's-length hatchery sales)
8. ¶18 2025 SNA, paras 6.23-6.27 (vertically integrated enterprises and the valuation of deliveries between their stages) and paras 7.94, 7.96 and 7.114 (goods produced and used within one establishment are not output; intra-enterprise deliveries are recorded only where the receiving establishment decides its own supply and prices).
9. ¶19 SEEA CF, para 5.409 (FAO ownership-throughout-rearing criterion); SEEA CF, para 5.407 (natural resource extraction vs. production boundary); ISIC Rev.4, Group 032
0. ¶20 SEEA CF, para 5.416
1. ¶21 SEEA CF, para 5.417
2. ¶22 2025 SNA, Chapter 11, on the valuation of work-in-progress with non-linear growth profiles. The principle applies to aquaculture inventory valuation.
3. ¶23 2025 SNA, para 11.216
4. ¶24 ISIC Rev.4, Group 032 Aquaculture
5. ¶25 SF-MST, para 4.103, on the application of carrying capacity concepts in environmental-economic accounting
6. ¶26 SEEA AFF, para 3.90
7. ¶27 Tacon, A.G.J. and Metian, M. (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds. *Aquaculture* 285: 146-158.
8. ¶28 SEEA AFF, para 3.169
9. ¶29 SEEA AFF, para 3.169; SEEA CF Chapter 3 (supply and use tables). Commercially purchased fishmeal and fish oil appear as intermediate consumption (purchased goods) in the aquaculture supply and use table. The wild fish equivalent embedded in feed is an analytical indicator (FIFO ratio) and should appear only as a supplementary satellite table or memo item to avoid double-counting the same extraction already recorded in fisheries accounts.
0. ¶30 Ytrestoyl, T., Aas, T.S. and Asgard, T. (2015). Utilisation of feed resources in production of Atlantic salmon (*Salmo salar*) in Norway. *Aquaculture* 448: 365-374.

1. ¶31 Holmer, M. (2010). Environmental issues of fish farming in offshore waters: perspectives, concerns and research needs. *Aquaculture Environment Interactions* 1: 57–70.
2. ¶32 SEEA CF, para 5.416
3. ¶33 FAO FishStatJ (FAO global fisheries and aquaculture production database). Average post-larval shrimp weight at nursery stocking size (PL20 or equivalent) is typically 0.1–0.5 g per individual; the assumed 0.3 g in this example should be replaced by species- and farm-specific stocking weight documentation in real compilations.
4. ¶34 Jackson, A. (2009). Fish in – fish out ratios explained. *Aquaculture Europe* 34(3): 5–10. IFFO computes FIFO as (fishmeal inclusion rate / fishmeal yield) x FCR, with a standard fishmeal yield of 22.5 per cent of raw fish.
5. ¶35 HELCOM PLC-Water Guidelines (2022) specify aquaculture nutrient thresholds for the Baltic Sea (phosphorus: 8 g/kg fish produced; nitrogen: 70 g/kg fish produced). FAO Technical Guidelines for Responsible Fisheries No. 5 (Aquaculture Development) provide species-specific reference ranges applicable more broadly.
6. ¶36 UN et al. (2021). *System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA)*, Chapter 6 (Ecosystem Service Accounts), Section 6.1 on provisioning services.
7. ¶37 FAO. *FishStatJ – software for fishery and aquaculture statistical time series* (aquaculture production database). FAO Fisheries and Aquaculture Division, Rome.
8. ¶38 FAO (1995). *Code of Conduct for Responsible Fisheries*, Article 7 (Fisheries Management) on the economic, social and environmental sustainability of fisheries.
9. ¶39 SEEA EA, Section 6.3 on monetary valuation of ecosystem services, including the resource rent method for provisioning services.
0. ¶40 FAO. *FishStat – global capture production database*. FAO Fisheries and Aquaculture Division, Rome.
1. ¶41 SEEA EA, Section 6.3 on stumpage-value resource rent as a directly observed exchange-price method for wood provisioning.
2. ¶42 SEEA EA, Section 6.2 on the structure of ecosystem service supply and use tables, permitting joint recording of cultivated and natural provisioning flows.

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