

Aquaculture Thematic Methods

Provides the site-level operational layer for aquaculture accounting, extending the physical asset account foundations established in TG-3.9.

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OUTCOME

Upon implementation, practitioners will be able to:

- Classify aquaculture systems according to their operational characteristics, species composition, and environmental setting, using ISIC and ISSCFC frameworks adapted for ocean accounting
- Compile site-level asset accounts tracking cultivated biological resources, production cycles, and stock changes, consistent with [TG-3.1 Asset Accounts](#)
- Quantify environmental interactions including nutrient loading, habitat modification, and genetic impacts on wild populations, complementing [TG-3.4 Flows from Economy to Environment](#)
- Account for feed and resource dependencies linking aquaculture production to wild fish stocks and terrestrial inputs, extending [TG-3.9 Aquaculture Accounts](#)
- Record disease-related losses and biosecurity costs as components of the aquaculture production account, with catastrophic losses treated consistently with SEEA AFF guidance
- Derive policy-relevant indicators for carrying capacity assessment, feed conversion efficiency monitoring, and environmental footprint analysis

Aquaculture thematic methods connect to economy-wide measurement through [TG-2.5 Structure and Function of the Ocean Economy](#), pollution accounting through [TG-2.7 Pollution and Other Flows to Environment](#), and social dependencies through [TG-2.3 Social and Livelihood Dependencies on Ocean Ecosystems](#). Wild-capture methods are in [TG-6.7 Fisheries Accounting: Integrating Stock Assessment](#).

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ABOUT THIS CIRCULAR

RECOMMENDED CITATION

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¶1 ⓘ Framework Position

¶2 TG-6.8 sits within Section 6 (Thematic Methods) and provides the site-level operational layer for aquaculture accounting, extending the physical asset account foundations established in TG-3.9. It connects to the environmental flow accounts in TG-3.4, the ocean economy structure in TG-2.5, and the fisheries accounting methods in TG-6.7 to form a coherent thematic sub-system for aquatic food production.

1. Outcome

¶1 Upon implementation, practitioners will be able to:

- ¶2 **Classify aquaculture systems** according to their operational characteristics, species composition, and environmental setting, using ISIC and ISSCFC frameworks adapted for ocean accounting¹
- ¶3 **Compile site-level asset accounts** tracking cultivated biological resources, production cycles, and stock changes, consistent with **TG-3.1 Asset Accounts**²
- ¶4 **Quantify environmental interactions** including nutrient loading, habitat modification, and genetic impacts on wild populations, complementing **TG-3.4 Flows from Economy to Environment**³
- ¶5 **Account for feed and resource dependencies** linking aquaculture production to wild fish stocks and terrestrial inputs, extending **TG-3.9 Aquaculture Accounts**⁴
- ¶6 **Record disease-related losses and biosecurity costs** as components of the aquaculture production account, with catastrophic losses treated consistently with SEEA AFF guidance⁵
- ¶7 **Derive policy-relevant indicators** for carrying capacity assessment, feed conversion efficiency monitoring, and environmental footprint analysis⁶

¶8 Aquaculture thematic methods connect to economy-wide measurement through **TG-2.5 Structure and Function of the Ocean Economy**, pollution accounting through **TG-2.7 Pollution and Other Flows to Environment**, and social dependencies through **TG-2.3 Social and Livelihood Dependencies on Ocean Ecosystems**. Wild-capture methods are in **TG-6.7 Fisheries Accounting: Integrating Stock Assessment**.⁷

2. Requirements

¶1 This Circular requires familiarity with:

- ¶2 **TG-4.3 Administrative Data Sources** – aquaculture licensing, site consent and production returns are the primary source for the site-level accounts in Section 3.2.
- ¶3 **TG-0.1 General Introduction to Ocean Accounts** – for environmental-economic accounting principles, asset boundaries, and production concepts.
- ¶4 **TG-3.9 Aquaculture Accounts** – for foundational physical asset account methods, including the cultivated versus non-cultivated biological resource distinction.

2.1 Data Requirements

Data source	Description
Aquaculture production statistics	Harvest quantities by species, production system, and site location, typically available from national fisheries agencies and FAO global aquaculture databases ⁸
Licence and site registration data	Permitted sites, lease areas, and production capacity limits, essential for carrying capacity analysis and spatial integration with ecosystem extent accounts ⁹

Data source	Description
Environmental monitoring data	Water quality parameters, nutrient concentrations, and benthic condition assessments, from regulatory agencies, industry reporting, or dedicated surveys ¹⁰ .
Feed and input records	Feed quantities, composition, and source materials; typically maintained by producers but may require survey collection for statistical purposes ¹¹ .
Mortality and escape records	Stock losses from disease, escapes, and other causes; often required under regulatory frameworks though data quality varies across jurisdictions ¹² .

2.2 Statistical Classifications

¶1 Aquaculture activities are classified according to:

- ¶2 **ISIC Division 03:** Specifically Group 032 (Aquaculture) with classes 0321 (Marine aquaculture) and 0322 (Freshwater aquaculture)¹³
- ¶3 **SEEA CF land use and water area categories:** Land used for aquaculture (1.3), including hatcheries (1.3.1) and managed grow-out sites (1.3.2), plus water area categories for inland and coastal waters¹⁴

¶4 Offshore aquaculture in EEZ waters has no discrete numeric sub-category in SEEA CF 2012 Annex I. Where offshore EEZ aquaculture is present, compilers should use the closest applicable coastal water area category and document the extension in supplementary tables, following the national extension guidance in **TG-0.1**.¹⁵

¶5 Marine spatial use classifications for aquaculture sites should be consistent with those applied in **TG-2.3** and the ecosystem extent accounting framework.

3. Guidance Material

3.1 Aquaculture Systems Classification

¶1 The FAO defines aquaculture as:

“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.”¹⁶

¶2 This definition establishes the production boundary determining whether output is recorded as aquaculture or capture fisheries production. It is adopted in SEEA CF para. 5.409 and applied in **TG-3.9**.¹⁷

3.1.1 Marine Cage Systems

¶1 Marine cage aquaculture involves net-pen structures moored in coastal or offshore waters, typically for finfish such as salmon, sea bass, and cobia.

Characteristic	Description
Site boundaries	Defined by lease area coordinates; recorded under the applicable SEEA CF coastal water area category (see Section 2.2) ¹⁸ .

Characteristic	Description
Asset classification	Farmed fish are produced assets – inventories or fixed assets (broodstock) – per SEEA CF para. 5.441 ¹⁹ .
Environmental exposure	Open exchange with surrounding waters means nutrient and disease interactions extend beyond site boundaries; coordinate with TG-3.4 ²⁰ .

¶2 **BSU assignment for offshore aquaculture:** For fixed installations, the BSU should be determined by the centroid of the lease area polygon. For floating installations, by the lease area boundary. Where a lease area straddles two or more BSU boundaries, allocate production to the BSU containing the majority of the stocking area. See **TG-0.1** and **TG-1.2 Marine Spatial Planning** for BSU framework specifications.²¹

3.1.2 Coastal Pond Systems

¶1 Pond-based aquaculture uses constructed enclosures on land or in intertidal areas, commonly for shrimp, tilapia, and milkfish.

Feature	Description
Land area recording	Pond area classified under SEEA CF 1.3.2 (managed grow-out sites on land), enabling integration with terrestrial land use accounts ²² .
Water management	Controlled water exchange enables nutrient budgeting and site-level mass balance calculations ²³ .
Production intensity	Semi-intensive to intensive systems require accounting for feed inputs and aeration costs; intensity affects environmental loading rates per unit production ²⁴ .

3.1.3 Integrated Multi-Trophic Aquaculture

¶1 Integrated multi-trophic aquaculture (IMTA) co-cultures species at different trophic levels, where waste from fed species (e.g., finfish) provides nutrients for extractive species (e.g., seaweed, shellfish). Accounting considerations:

- ¶2 **Nutrient cycling:** Internal recycling reduces net environmental loading. Accounts should distinguish gross and net nutrient flows. Whether net loading is negative depends on site-specific mass balance data and should be verified empirically before recording negative residual flows. Where negative residual flows are recorded, apply the separate recording treatment in **TG-3.4**.²⁵
- ¶3 **Multiple outputs:** Production accounts record outputs from each component species with appropriate allocation of shared inputs, following standard SNA treatment of joint production²⁶

3.1.4 Production Boundary: Aquaculture versus Sea Ranching

¶1 Sea ranching, stock enhancement, and restocking programmes release juveniles into open water without continued ownership or active management. These programmes present a production boundary challenge distinct from the general aquaculture-versus-fisheries distinction.

¶2 The boundary should be determined by two sequential criteria:

1. ¶3 **Ownership after release:** Does the releasing entity retain individual ownership of the stock after it enters open water? Where ownership is held collectively (by a recognised producer association, statutory enhancement body, or public authority), criterion 1 is satisfied provided that (a) the collective holds legally enforceable harvest access rights and (b) maintains records of release quantities and harvest returns. Where neither individual nor collective enforceable

ownership exists, the released stock is classified as a natural resource and excluded from cultivated asset accounts.²⁷

2. ¶4 **Active grow-out intervention:** Does the entity undertake regular feeding, protection, health monitoring, or other active interventions during grow-out? If yes (and criterion 1 is also satisfied), the stock may be classified as a cultivated biological resource. If no, as is typical of open-water sea ranching, the stock is classified as a natural resource, regardless of ownership criterion 1.

¶5 Output released to open water without retained ownership should be classified as natural stock and excluded from cultivated asset accounts. A notation should be made in escape and release records (Section 3.2.4) indicating species, quantities, and intended enhancement purpose. This classification is consistent with SEEA AFF paras. 3.179–3.181 and FAO Technical Guidelines for Responsible Fisheries No. 5, Supplement 4 (2010).²⁷

3.1.5 Species Coverage

¶1 *Table 3.1: Aquaculture species groups and key accounting considerations*

Species Group	Typical Systems	Key Accounting Considerations
Marine finfish	Cages, ponds	Feed-dependent; high nutrient loading
Crustaceans	Ponds, tanks	Disease vulnerability; habitat conversion
Molluscs	Rafts, longlines, on-bottom	Filter-feeding; minimal inputs
Seaweed	Rafts, ropes	Nutrient extraction; carbon sequestration
Other species	Various	Species-specific parameters required

3.2 Site-Level Accounting

3.2.1 Carrying Capacity Assessment

¶1 **Carrying capacity** represents the maximum production intensity that can be sustained without unacceptable environmental degradation. Four dimensions are assessed²⁸:

Dimension	Description
Physical carrying capacity	Maximum stocking density based on water exchange, oxygen availability, and waste assimilation.
Production carrying capacity	Maximum yield achievable given infrastructure and resource constraints.
Ecological carrying capacity	Maximum production compatible with maintenance of ecosystem condition indicators.
Social carrying capacity	Maximum production acceptable to other users and stakeholders.

¶2 Physical, production, and ecological dimensions can be expressed in measurable physical units and recorded as supplementary physical data in the asset account. Social carrying capacity reflects stakeholder preferences and is not a standard SEEA account variable. Record it as a supplementary social indicator consistent with **TG-2.3**.²⁹

¶3 The asset account for aquaculture sites should record carrying capacity estimates as context for stock and production data. The ecological dimension connects to condition accounting in **TG-2.3**, and residual flows should be recorded consistently with **TG-3.4**.

3.2.2 Production Cycle Accounting

¶1 Aquaculture production cycles vary by species and system, from several months (shrimp) to multiple years (salmon). The physical flow account should record:³⁰

¶2 *Table 3.2: Aquaculture physical flow account structure*

Flow Category	Description	Measurement
Opening stock	Biomass at period start	Tonnes live weight
Stocking (seed inputs)	Juveniles or seed transferred in	Numbers and biomass
Natural growth	Biological growth of stock	Tonnes gained
Harvest	Removal for sale	Tonnes live weight
Mortality	Normal and catastrophic losses	Tonnes and numbers
Escapes	Stock lost to environment	Numbers and biomass
Closing stock	Biomass at period end	Tonnes live weight

¶3 Output is measured in live weight equivalent consistent with FAO aquaculture production statistics.³¹

3.2.3 Mortality and Catastrophic Loss Recording

Mortality type	Description
Normal mortality	Predictable losses based on species and system characteristics; recorded as reductions in stock.
Disease outbreaks	Unexpected losses from pathogen events; recorded as catastrophic losses if exceeding normal thresholds (e.g., mortality exceeding two standard deviations above the historical average for the species and system type).
Environmental events	Losses from storms, harmful algal blooms, or temperature extremes; recorded as catastrophic losses.
Predation	Losses to predators (seals, birds); recorded under normal mortality or other reductions.

¶1 The SEEA AFF notes that “unexpected large losses from disease or natural disasters should be recorded as catastrophic losses” (para. 3.185).³²

¶2 Statistical parameters for the catastrophic loss threshold:

1. ¶3 **Reference period:** Calculate historical average and standard deviation using a minimum of five accounting years of site-level mortality data. For sites with fewer than five years of records, use the full period of operation.
2. ¶4 **Reference population:** Use site-specific records where sufficient data are available. Where site-level records are insufficient (fewer than three years), apply a national species-and-system-type average.
3. ¶5 **New sites:** Apply the national species-and-system-type average threshold until a site-specific record is established. Where no national average is available, apply a documented expert judgement threshold and note this in account metadata.

¶6 For a production series with mean μ and standard deviation σ , the threshold is $\mu + 2\sigma$ (example: mean mortality 4.4%, $\sigma = 0.49$ pp, threshold = 5.38%, so observed mortality of 7.2% would be classified as catastrophic). Document the threshold derivation method following **TG-0.7**

Quality Assurance.³³

3.2.4 Escape Recording

¶1 Escapes from aquaculture facilities require reclassification from cultivated to natural stocks. The SEEA AFF acknowledges this complexity:

“Challenges may arise when recording reclassifications of cultivated and natural fish stocks, for example when wild fish are introduced as breeding stock or when cultured seeds are released

into the wild; escapes by fish from aquaculture facilities in river and marine environments can also occur.”³⁴

¶12 Escapes should be recorded as reductions in cultivated stock with corresponding entries in wild population accounts where these are maintained. For consistency with **TG-3.1 Asset Accounts** and **TG-6.7 Fisheries Accounting**, the record of each escape event should include species, estimated numbers and biomass, and whether the species is native to the receiving environment. Where escaped species are not subject to commercial fisheries, the wild stock account entry may be recorded as a supplementary table.³⁵

3.3 Environmental Interactions

¶1 Table 3.3: Aquaculture environmental interaction matrix

Environmental Interaction	Direction	Account Recording	Measurement
Water abstraction	Input from environment	Natural input flow	m ³
Feed use (fish meal)	Input from economy	Intermediate consumption	tonnes
Fish/shellfish output	Output to economy	Production output	tonnes
Nutrient discharge	Output to environment	Residual flow	tonnes N, P
Escapees	Output to environment	Reclassification (to wild)	individuals
Sediment impact	Impact on condition	Condition account	benthic index

3.3.1 Nutrient Loading

¶1 Fed aquaculture systems release nutrients through uneaten feed, faeces, and metabolic excretion. Nutrient loading accounts should record:³⁶

¶2 **Boundary with TG-6.13.** Catchment-derived nutrient loads reaching coastal waters are accounted for in **TG-6.13 Freshwater-Marine Interaction Accounting** Section 3.2. The two accounts partition on the **point of discharge**, not on the industry: a marine cage or other system discharging directly to coastal or marine waters is recorded here, and a land-based pond or hatchery discharging to a river or to sewer is a catchment source recorded under TG-6.13 and excluded from this account. Compilers running both accounts should record which convention each site falls under, so that a site converting from pond to cage production moves between accounts once rather than appearing in both.

¶3 Table 3.4: Nutrient mass balance components for aquaculture

Nutrient Flow	Source	Measurement
Nitrogen inputs	Feed, fertilizer	kg N per tonne production
Phosphorus inputs	Feed, fertilizer	kg P per tonne production
Nitrogen retained	Harvested biomass	kg N in product
Phosphorus retained	Harvested biomass	kg P in product
Net N discharge	Inputs minus retention	kg N released
Net P discharge	Inputs minus retention	kg P released

¶4 The SEEA AFF provides guidance on nutrient budgets: “The basis for measuring nutrient budgets is tracking the nitrogen and phosphorous [sic] cycles... Through consistent measurement of each part of those cycles, an overall indication of change can be obtained along with measures of surpluses or deficits of nitrogen and phosphorus” (para. 4.79).³⁷

¶5 Aquaculture nutrient discharges should be recorded as emissions to water using the residual flow methods in **TG-3.4 Flows from Economy to Environment**.

3.3.2 Habitat Modification

¶1 Aquaculture development can modify marine and coastal habitats through four pathways:

Pathway	Description
Direct conversion	Mangrove clearing for pond construction; seabed modification for on-bottom culture.
Shading effects	Light reduction beneath cage and raft structures affecting benthic communities.
Organic enrichment	Sediment accumulation beneath cage sites altering benthic fauna composition.
Structural provision	Cage structures and shellfish lines providing habitat for associated species.

¶2 Conversions of natural habitats (e.g., mangrove forest, seagrass beds) to aquaculture use should be recorded as land use change, consistent with SEEA EA extent accounting principles. Benthic condition beneath cage sites provides an indicator for the ecological carrying capacity dimension (Section 3.2.1).³⁸

3.3.3 Genetic Impacts

¶1 Escaped farmed fish may interbreed with wild populations, potentially affecting genetic diversity and local adaptation.³⁹ Whilst quantitative genetic accounting methods remain under development, the following information supports qualitative assessment of genetic interaction risks.

Information element	Description
Escape volumes	Numbers and biomass of escaped stock by species, as recorded in Section 3.2.4.
Species overlap	Whether farmed species are native or non-native to the receiving region.
Breeding potential	Whether escapes are reproductively mature or sterile (e.g., triploid stock).

¶2 **Minimum genetic impact recording standard:** For each accounting period where escape events are recorded, compile the following supplementary table and cross-reference it from condition accounts. Cross-reference also from **TG-3.1 Asset Accounts** where condition account linkages are maintained.

¶3 *Table 3.5: Supplementary genetic impact recording template*

Species	Native / Non-native to receiving area	Number of escape events in period	Total estimated escaped biomass (kg)	Proportion with reproductive maturity	Monitoring outcome (interbreeding observed / not observed / not monitored)
[e.g., Atlantic salmon]	[Native / Non-native]	[N]	[kg]	[% or Unknown]	[Observed / Not observed / Not monitored]

3.4 Feed and Resource Use

3.4.1 Fishmeal and Fish Oil Dependency

¶1 Marine ingredients in aquafeed create linkages between aquaculture production and wild fish stocks. The SEEA AFF notes:

*"Fish products... in granule or pellet form... provide nutrition in a stable and concentrated form... 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."*⁴⁰

¶2 Table 3.6: Feed component recording for aquaculture accounts

Feed Component	Source	Measurement
Fishmeal quantity	Reduction fisheries, processing by-products	Tonnes
Fish oil quantity	Reduction fisheries, processing by-products	Tonnes
Vegetable protein	Soy, other crops	Tonnes
Other ingredients	Various sources	Tonnes
Total feed use	All sources	Tonnes per tonne production

¶3 Feed ingredient sourcing should be linked to wild fish stock accounts in **TG-3.9** and **TG-6.7** to enable assessment of net contribution to fish supply.⁴¹

3.4.2 Fish-In Fish-Out Ratios

¶1 The **Fish-In Fish-Out (FIFO) ratio** measures the quantity of wild fish required (as feed ingredients) to produce one unit of farmed fish:

¶2

$$\text{FIFO} = \frac{(\text{Fishmeal quantity} \times \text{FCR}_{\text{meal}}) + (\text{Fish oil quantity} \times \text{FCR}_{\text{oil}})}{\text{Farmed fish output (tonnes)}}$$

¶3 where FCR_meal and FCR_oil are the species-specific wild-fish inclusion factors (kg wild fish per kg of meal or oil) derived from FAO reduction fishery yield ratios. Where fishmeal and fish oil are co-products of the same reduction fishery batch, allocate total wild-fish input between the two products based on their respective mass yield ratios to avoid double-counting.⁴²

¶4 FIFO ratios vary substantially by species and system:

- ¶5 Salmon and marine carnivores: FIFO typically 1.5–3.0
- ¶6 Tilapia and herbivorous species: FIFO typically 0.3–0.8
- ¶7 Filter-feeding shellfish: FIFO = 0 (no feed inputs)

¶8 Declining FIFO ratios reflect increasing substitution of marine ingredients with terrestrial alternatives. For sustainability assessment, present both the ratio and the absolute quantities of wild fish used in feed: a declining ratio accompanied by expanding production may still increase absolute demand on wild fish stocks.⁴³

3.4.3 Feed Sources and Sustainability

Category	Description
Reduction fisheries	Wild fish harvested specifically for fishmeal and fish oil; link to wild stock accounts and deduct from net fish supply contribution.
Processing by-products	Trimings from fish processing; distinguish from dedicated reduction fishery catch in feed composition records.
Terrestrial inputs	Soy, wheat, and other crop-derived ingredients; link to agricultural accounts where available.

3.5 Disease and Biosecurity

3.5.1 Disease-Related Losses

¶1 Table 3.7: Disease loss classification for aquaculture accounts

Disease Category	Examples	Recording Treatment
Endemic diseases	Routine bacterial, parasitic infections	Normal mortality within expected rates
Epidemic events	Viral outbreaks, ISA, VHS	Catastrophic loss if exceeding thresholds
Emerging diseases	Novel pathogens	Catastrophic loss; separate notation

¶2 Disease-caused losses are classified as catastrophic or normal using the two-standard-deviations rule defined in Section 3.2.3.

3.5.2 Treatment Chemical Use

¶1 *Table 3.8: Treatment chemical recording for aquaculture accounts*

Chemical Category	Purpose	Measurement
Antibiotics	Bacterial disease treatment	kg active ingredient
Antiparasitics	Sea lice, parasite control	kg active ingredient
Disinfectants	Biosecurity, equipment treatment	Litres or kg
Vaccines	Disease prevention	Doses administered

¶2 Treatment chemical emissions should be recorded consistent with **TG-3.4 Flows from Economy to Environment** for emissions to water.

3.5.3 Biosecurity Expenditure

Measure type	Description
Infrastructure	Nets, barriers, treatment systems (recorded as GFCF where representing durable investments).
Monitoring	Surveillance, testing, and certification programmes (recorded as intermediate consumption).
Management protocols	Fallowing, single year-class stocking, and area management agreements (costs as intermediate consumption).

¶1 **GFCF boundary for biosecurity infrastructure:** Classification between GFCF and intermediate consumption follows 2025 SNA Chapter 11 capital boundary principles: ⁴⁴

- ¶2 **Service life exceeding 12 months:** Record as GFCF and depreciate over the asset's service life. Applies to purpose-built treatment systems, permanent barriers, and net structures with expected operational life of more than one accounting year.
- ¶3 **Service life of 12 months or less:** Record as intermediate consumption in the period of acquisition or replacement. Applies to biosecurity nets replaced on a cycle of 12 months or less.
- ¶4 **Rolling replacement:** Where nets or other biosecurity components are replaced on a rolling basis, record the full replacement cost in each period as intermediate consumption, regardless of the component's individual service life.

3.6 Compilation Procedure

Step 1: Data assembly and validation

¶1 Assemble aquaculture production data from fisheries agencies, site registration records from licensing authorities, and environmental monitoring data from regulatory programmes. Validate internal consistency between production records and site capacity data. Document data quality issues following **TG-0.7 Quality Assurance**.

Step 2: Site-level asset account compilation

¶1 For each aquaculture site or site cluster, compile a physical asset account (Table 3.2 format) recording opening stock, stocking (seed inputs), natural growth, harvest, mortality, escapes, and closing stock. Aggregate site-level accounts to species groups and production system types. Verify: Closing stock = Opening stock + Stocking + Natural growth - Harvest - Mortality - Escapes.

¶2 Stocking is a positive addition of cultivated biomass to the site, consistent with the SEEA AFF treatment of additions to cultivated biological resources; it is an entry in the physical asset account, not a revaluation. Where a cohort is stocked once at the start of a multi-year production cycle, the stocking term is zero in subsequent years of that cycle but should still be shown explicitly so that the identity is transparent.

Step 3: Environmental flow recording

¶1 Apply nutrient mass balance calculations (Table 3.4) to estimate nitrogen and phosphorus discharges from fed aquaculture systems. Record residual flows following **TG-3.4**. For coastal pond systems, record measured effluent volumes and nutrient concentrations where monitoring data are available.

Step 4: Feed dependency analysis

¶1 Compile feed use data by species and system type. Decompose feed into fishmeal, fish oil, vegetable protein, and other ingredients (Table 3.6). Calculate FIFO ratios using the mass-ratio allocation method (Section 3.4.2). Link fishmeal and fish oil use to wild fish stock accounts in **TG-6.7**.

Step 5: Integration with economy-wide accounts

¶1 Extract aquaculture output, intermediate consumption, and value added from national supply and use tables, following **TG-2.5** Section 3.7. Reconcile physical output quantities from asset accounts with monetary output, applying appropriate unit value factors. Record GFCF in aquaculture infrastructure and equipment.

Step 6: Indicator derivation

- ¶1 **Production efficiency and wild-fish dependency:** FCR and FIFO (Section 3.4.2)
- ¶2 **Environmental intensity:** Nutrient discharge per unit production (kg N per tonne harvest)
- ¶3 **Economic performance:** GVA per unit production, labour productivity, and capital intensity
- ¶4 **Carrying capacity utilisation:** Actual production as percentage of estimated site carrying capacity

3.7 Decision Use Cases

3.7.1 Sustainable Aquaculture Expansion Planning

¶1 **Account inputs:** Site-level asset accounts (Section 3.2), carrying capacity estimates (Section 3.2.1), nutrient loading data (Section 3.3.1), habitat modification records (Section 3.3.2).

¶2 **Analytical outputs:** Production potential by coastal zone, environmental loading relative to assimilative capacity, cumulative impact assessment, spatial optimisation of site allocation.

¶3 **Connection to other circulars:** Carrying capacity links to **TG-2.3**. GVA and employment projections link to **TG-2.5**.

3.7.2 Environmental Footprint Monitoring

¶1 **Account inputs:** Nutrient mass balance (Table 3.4), treatment chemical use (Table 3.8), escape records (Section 3.2.4), benthic condition indicators (Section 3.3.2).

¶2 **Analytical outputs:** Trends in nutrient loading intensity, chemical use per unit production, escape frequency, and benthic impact indices against regulatory limits.

¶3 **Connection to other circulars:** Nutrient discharges aggregate into **TG-2.7 Pollution and Other Flows to Environment**. Habitat impacts connect to **TG-2.8 Climate Change Indicators**.

3.7.3 Feed Conversion Efficiency Tracking

¶1 **Account inputs:** Feed composition (Table 3.6), FIFO ratios (Section 3.4.2), feed conversion ratios, wild fish stock status from **TG-6.7**.

¶2 **Analytical outputs:** Trends in FIFO ratios, share of feed from by-products versus reduction fisheries, actual versus best-practice FCR, net contribution to fish supply.

¶3 **Connection to other circulars:** Wild fish use in feed links to **TG-6.7**. Protein supply links to **TG-2.3**.

4. Worked Example

¶1 This worked example illustrates compilation of a site-level aquaculture account for a hypothetical marine cage salmon farm. The example demonstrates the physical asset account, production flow recording, nutrient loading calculation, and feed use accounting described in Section 3.

4.1 Site Description

¶1 The example site comprises a marine cage salmon farm with 12 net-pen cages located in a coastal embayment. The farm operates on a 24-month production cycle, stocking smolts in Year 1 and harvesting market-size fish in Year 2. The site is classified under ISIC 0321 (Marine aquaculture) and occupies a lease area recorded under the applicable SEEA CF coastal water area category (see Section 2.2).

4.2 Physical Asset Account

¶1 *Table 4.1: Physical asset account – marine cage salmon farm (Year 2 of production cycle)*

Flow Category	Quantity (tonnes live weight)	Notes
Opening stock (1 January)	2,400	Carried from Year 1 closing balance
Stocking (seed inputs)	0	Cohort stocked in Year 1; no smolt input in Year 2
Natural growth	1,800	Biological growth during Year 2
Harvest	-3,600	Removal for sale (Oct–Dec)
Normal mortality	-180	4.5% of mid-year average biomass (estimated at ~4,000 tonnes live weight, reflecting growth before harvest)
Catastrophic loss	0	No disease or environmental events
Escapes	-20	Storm damage to one cage in March
Closing stock (31 December)	400	Remaining unharvested stock

¶2 **Accounting identity verification:** $2,400 + 0 + 1,800 - 3,600 - 180 - 20 = 400$. The account balances.

4.3 Nutrient Loading Estimate

¶1 Using a mass balance approach for nitrogen:

- ¶2 **Feed input:** 4,320 tonnes of feed at 6.5% N content = 281 tonnes N
- ¶3 **Nitrogen retained in biomass gain:** 1,800 tonnes of growth at 2.8% N content = 50 tonnes N (retention is measured on growth, not harvest, because 2,000 tonnes of the harvest were stock carried from Year 1)

- ¶4 **Mortality and escapes:** 200 tonnes, already within the biomass gain (3,600 harvest + 200 mortality and escapes – 2,000 stock drawdown = 1,800), so not deducted again
- ¶5 **Net N discharge to environment:** 281 – 50 = 231 tonnes N

¶6 This net nitrogen discharge of 231 tonnes would be recorded as a residual flow to the marine environment under **TG-3.4 Flows from Economy to Environment**.

¶7 **Loading intensity:** 231 tonnes N / 3,600 tonnes harvest = 64 kg N per tonne production.

4.4 Feed Use and FIFO Calculation

¶1 *Table 4.2: Feed composition and FIFO calculation*

Feed Component	Quantity (tonnes)	Share of Total
Fishmeal	648	15%
Fish oil	432	10%
Vegetable protein (soy)	1,296	30%
Other ingredients	1,944	45%
Total feed	4,320	100%

¶2 Wild fish equivalent in feed, using the mass-ratio allocation FIFO method (Section 3.4.2): fishmeal and fish oil are co-products of the same reduction fishery batch and must be treated as a single joint input. Combined fishmeal and fish oil: 648 + 432 = 1,080 tonnes. Using a combined mass yield of 22.5% (fishmeal) + 5.0% (fish oil) = 27.5% from live weight, following Tacon and Metian (2008) ⁴⁵:

- ¶3 Total wild fish attributed to this feed: 1,080 ÷ 0.275 = 3,927 tonnes
- ¶4 FIFO ratio: 3,927 / 3,600 = 1.09

¶5 This FIFO value reflects the standard mass-ratio allocation method following Tacon and Metian (2008) ⁴⁵ and Jackson (2009) ⁴⁶.

¶6 A FIFO ratio of approximately 1.0 indicates wild-fish input is roughly equivalent to farmed output by weight.

¶7 **Feed conversion ratio (FCR):** 4,320 tonnes feed / 1,800 tonnes biomass gain = 2.4. FCR is computed on biomass gain, not harvest, because most of the harvested fish were grown in Year 1. The illustrative value is above the typical range for salmon cage culture (1.1–1.3); in a real compilation it would prompt a check of the feed and growth records (Step 1).

4.5 Integration with Supply–Use Framework

¶1 *Table 4.3: Integration with ocean economy supply-use table (ISIC 0321 – Marine aquaculture)*

Item	Physical (tonnes)	Monetary (000 USD)	Notes
Output (salmon harvest)	3,600	27,000	At USD 7.50 per kg farmgate price
Intermediate consumption (feed)	4,320	3,456	At USD 0.80 per kg feed price
Intermediate consumption (other)	–	2,160	Fuel, maintenance, services, etc. (excludes labour: compensation of employees is part of GVA)
Gross value added	–	21,384	Output minus intermediate consumption
Employment	–	48	Full-time equivalent workers
GFCF (cage replacement)	–	1,500	Annual capital investment

¶2 The GVA of USD 21.4 million contributes to the aquaculture row in the ocean economy accounts. Labour productivity = USD 445,500 per worker, and capital intensity = 7.0% of GVA.

5. Compilation Considerations

5.1 Data Quality and Availability

¶1 Common data challenges by category:

- ¶2 **Production data:** Generally available from industry reporting and FAO aquaculture statistics, and typically the most complete data category. Verify consistency between national statistical agency records and industry association reports.
- ¶3 **Feed data:** Often commercially sensitive, and may require survey-based collection or estimation using species-specific feed conversion ratios. Document the estimation methodology and associated uncertainty where direct data are unavailable.
- ¶4 **Environmental data:** Variable availability depending on monitoring requirements. Some jurisdictions mandate site-level environmental monitoring, whilst others rely on ambient water quality monitoring that may not capture site-specific impacts.
- ¶5 **Disease data:** May be subject to confidentiality restrictions. Aggregate mortality rates and treatment chemical use statistics may be available where case-level data are restricted.

¶6 Minimum data requirements are production quantities by species and system type, and site location data. Additional data categories enable progressively more complete accounts as described in the phased implementation approach below.

5.2 Phased Implementation

¶1 The phases below define the widening content of an aquaculture account. They sit inside the general readiness and sequencing pathway at **TG-0.8 Implementation Readiness Assessment** Sections 3.1 and 3.2, which is not restated here.

¶2 **Minimum viable account:** A TG-6.8 aquaculture thematic account is considered complete at Phase 2 (environmental interaction accounting). Phase 1 alone represents a partial account consistent with TG-3.9. It does not constitute a complete TG-6.8 compilation. Compilers completing only Phase 1 should label their output “TG-3.9 consistent” and include a note on planned progress toward Phase 2. Document account completeness following **TG-0.7 Quality Assurance** completeness and comparability rating conventions.⁴⁷

1. ¶3 **Phase 1 – Production and asset accounting:** Compile physical quantities of production, stock, and harvest by species and system type, drawing on existing aquaculture production statistics.
2. ¶4 **Phase 2 – Environmental interaction accounting:** Add nutrient loading estimates using mass balance calculations, habitat modification recording, and escape quantification. *Phase 2 represents the minimum complete TG-6.8 account.*
3. ¶5 **Phase 3 – Feed dependency and disease accounting:** Incorporate detailed feed composition, FIFO calculations, disease loss recording, and treatment chemical use.
4. ¶6 **Phase 4 – Full integration with ocean accounts:** Link aquaculture thematic accounts with **TG-3.1 Asset Accounts**, **TG-3.4 Flows from Economy to Environment**, and ecosystem condition accounts.

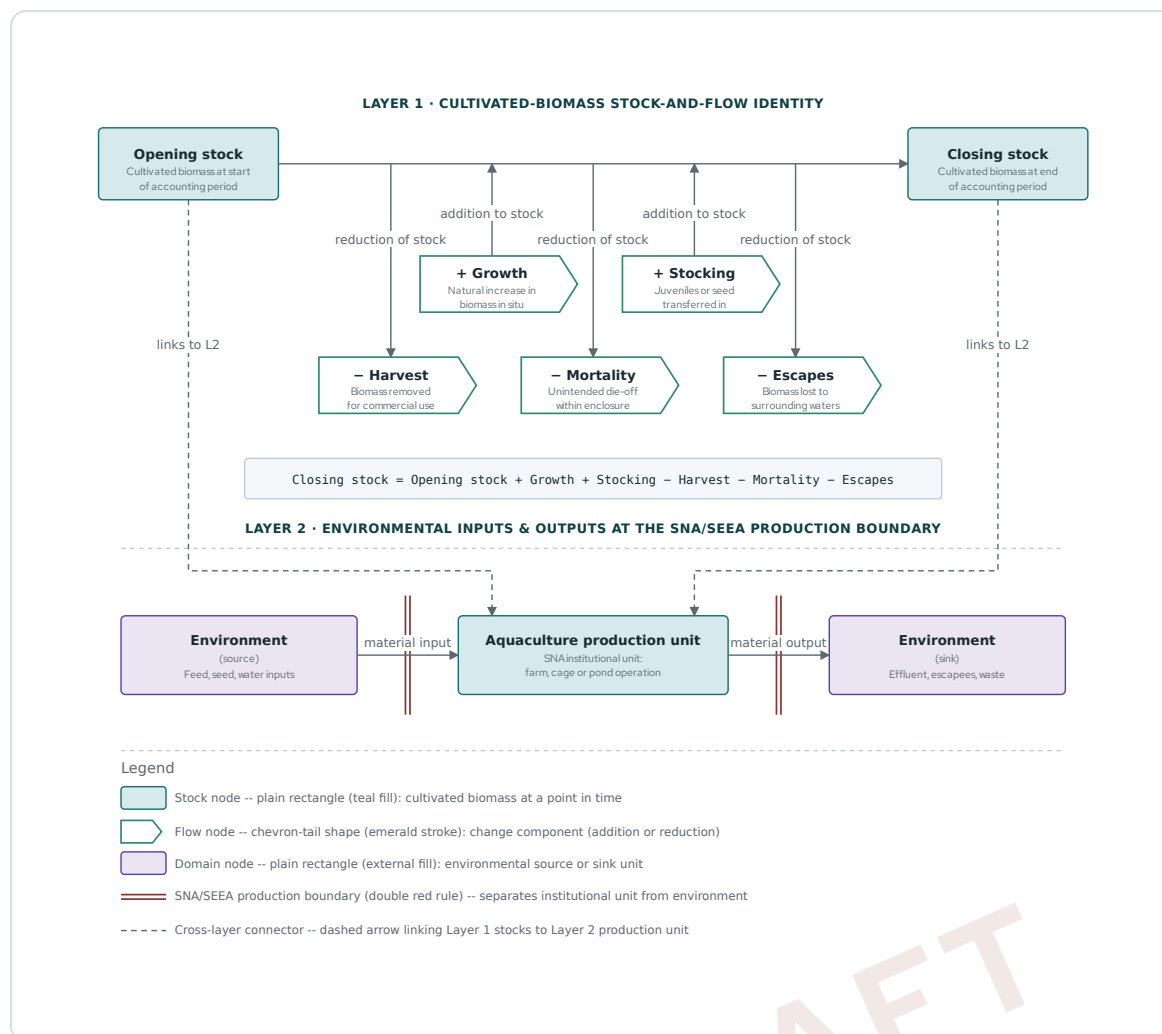


Figure 6.8.1 Two-layer aquaculture stock-and-flow: Layer 1 is the cultivated-biomass identity; Layer 2 places the unit at the SNA/SEEA production boundary. Stocks = plain rectangles; flows = chevron-tail. Mortality and escapes shown disaggregated.

Source: TG-6.8, Section 3 (aquaculture stock-and-flow accounts); SEEA AFF paras. 2.127--2.129; SEEA CF para. 5.1 (asset-account opening/closing stock identity).

6. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

¶3 **Note:** This Circular addresses the thematic methods layer for aquaculture, and extends the foundational aquaculture accounting guidance in TG-3.9.

7. References

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- ¶3 FAO. 2010. *Ecosystem Approach to Aquaculture*. FAO Technical Guidelines for Responsible Fisheries No. 5, Supplement 4. Rome.
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- ¶5 United Nations et al. 2021. *System of Environmental-Economic Accounting – Ecosystem Accounting*. New York.
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FOOTNOTES

1. ¶1 Classification enables consistent aggregation of aquaculture data across sites and jurisdictions, following ISIC and ISSCFC frameworks (SEEA AFF para. 3.156).
2. ¶2 Site-level accounts provide the foundation for national aquaculture statistics and enable analysis of production efficiency and environmental performance.
3. ¶3 Environmental interaction accounting supports assessment of cumulative impacts and sustainable development boundaries.
4. ¶4 Feed dependency tracking links aquaculture to wild fish stocks, addressing concerns about net contribution to fish supply (SEEA AFF para. 3.169).
5. ¶5 Disease and biosecurity accounting enables analysis of production risks and prevention investment returns (SEEA AFF para. 3.185).
6. ¶6 Indicator derivation connects site-level accounts to policy decisions on site allocation, environmental standards, and sustainability certification.
7. ¶7 Integration with broader ocean accounts requires consistent treatment of aquaculture as both an economic activity and source of environmental pressures.
8. ¶8 Production statistics typically available from national fisheries agencies and FAO global aquaculture databases.
9. ¶9 Licence data provides site boundaries and permitted production limits essential for carrying capacity analysis.
0. ¶10 Environmental monitoring data may be obtained from regulatory agencies, industry reporting, or dedicated surveys.
1. ¶11 Feed records typically maintained by producers for production management; may require survey collection for statistical compilation.
2. ¶12 Mortality and escape reporting often required under regulatory frameworks; data quality varies across jurisdictions.
3. ¶13 ISIC Rev.4 defines aquaculture as “the production process involving the culturing or farming (including harvesting) of aquatic organisms... using techniques designed to increase the production of the organisms in question beyond

the natural capacity of the environment.”

4. ¶14 SEEA CF Annex I provides detailed definitions for each land and water use category.
5. ¶15 SEEA Central Framework (2012), Annex I. The SEEA CF water area categories in Annex I cover inland and coastal waters; no discrete EEZ aquaculture sub-category exists at the 4.x level in the published 2012 standard. Compilers developing national extensions for EEZ offshore aquaculture should follow the supplementary tables approach described in TG-0.1.
6. ¶16 FAO Glossary of Aquaculture (2008), adopted in SEEA CF para. 5.409.
7. ¶17 This distinction determines whether output is recorded as aquaculture (cultivated) or fisheries (natural) production (SEEA CF para. 5.409).
8. ¶18 Water area categories extend the SEEA CF land use classification to cover marine spatial use. See Section 2.2 and footnote 14a on EEZ classification.
9. ¶19 SEEA CF para. 5.441: “Aquatic resources farmed in an aquaculture facility are produced assets, either inventories or fixed assets (in the case of breeding stocks).”
0. ¶20 Open cage systems differ fundamentally from closed containment in their environmental interactions, necessitating coordination between site-level accounts and broader environmental flow accounts.
1. ¶21 TG-0.1 General Introduction to Ocean Accounts (Basic Spatial Unit framework); TG-1.2 Marine Spatial Planning (spatial data integration requirements). The centroid-of-lease-area rule for fixed installations is the standard approach in spatial environmental accounting; the majority-area rule for straddling sites follows the SEEA EA recommended allocation principle for account boundaries.
2. ¶22 Land area recording enables integration with terrestrial land use accounts (SEEA CF Annex I).
3. ¶23 Controlled water exchange enables nutrient mass balance calculations at the site level.
4. ¶24 Intensity classification affects environmental loading rates and resource requirements per unit production.
5. ¶25 Integrated systems may show reduced net nutrient loading under specific site conditions; see Nederlof et al. (2022) for empirical evidence on nitrogen retention efficiencies in IMTA systems, which vary widely (up to 56% by retention method) and are highly site- and species-specific. Net uptake exceeding fed-species outputs is most plausible in seaweed-dominant systems at low feed input densities. Compilers should verify this empirically before recording negative residual flows. Negative residual flows (net environmental inputs) require separate recording treatment under TG-3.4 from positive discharges.
6. ¶26 Multiple output recording follows standard SNA treatment of joint production.
7. ¶27 SEEA AFF paras. 3.179–3.181 (boundary between cultivated and natural aquatic resources); FAO Technical Guidelines for Responsible Fisheries No. 5, Supplement 4 (2010).
8. ¶28 Carrying capacity concepts parallel those used for livestock (SEEA AFF para. 3.90) and tourism (SF-MST). Four-dimension framework following McKindsey et al. (2006).
9. ¶29 Social carrying capacity reflects community and stakeholder tolerance levels. It is not a standard SEEA account variable and should be recorded as a supplementary social indicator rather than as part of the formal asset account. See TG-2.3 for social indicator conventions.
0. ¶30 Production cycle accounting follows SEEA AFF physical flow account structure (para. 3.158).
1. ¶31 Live weight equivalent measurement ensures consistency with FAO reporting standards (SEEA AFF para. 3.159).
2. ¶32 SEEA AFF para. 3.185.
3. ¶33 The five-year minimum reference period is consistent with standard statistical practice for rare-event threshold estimation. Site-specific reference populations are appropriate given high variation in mortality rates across system types. Threshold derivation methods should be documented following TG-0.7 Quality Assurance.
4. ¶34 SEEA AFF, paras. 3.185–3.187.
5. ¶35 Cross-reference corrected per EL6.8-05. Cultivated-to-wild reclassification entries belong in TG-3.1 (asset accounts) and TG-6.7 (wild stock implications). Where escaped species are not subject to commercial fisheries, a supplementary table is the appropriate recording vehicle rather than a formal account.
6. ¶36 Nutrient loading calculations adapted from SEEA AFF nutrient budget methodology (Section 4.4).
7. ¶37 SEEA AFF para. 4.79. Note: the quoted SEEA AFF text uses “phosphorous” – this is a misspelling in the source document; the correct noun is “phosphorus” (IUPAC). The [sic] notation indicates the error originates in the cited source.
8. ¶38 Habitat modification recording supports ecosystem extent and condition accounting per SEEA EA.
9. ¶39 Fleming, I.A. et al. (2000). Lifetime success and interactions of farm salmon invading a native population. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 267, 1517–1523. doi:10.1098/rspb.2000.1173.
0. ¶40 SEEA AFF para. 3.169.
1. ¶41 Cross-reference to fisheries and aquaculture accounting circulars ensures consistent treatment of wild fish use in feed across the ocean accounting framework.
2. ¶42 Tacon, A.G.J. and Metian, M. (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. *Aquaculture* 285: 146–158. doi:10.1016/j.aquaculture.2008.08.015. This paper establishes the mass-allocation FIFO methodology including separate fishmeal and fish oil yield fractions. See also Jackson, A. (2009) for the formalised split-allocation formula.
3. ¶43 Declining FIFO ratios are a positive sustainability signal, but absolute quantities of wild fish in feed should also be tracked to account for the effect of production volume growth.

4. ¶44 2025 SNA, Chapter 11 (capital boundary; expected service life criterion for fixed assets). The one-year service life criterion is carried forward from SNA 2008 para. 10.7. Specific 2025 SNA paragraph numbers for the capital boundary criterion should be confirmed against the Chapter 11 PDF (available at: https://unstats.un.org/unsd/nationalaccount/snaupdate/2025/2025SNA_CH11_V5.pdf (https://unstats.un.org/unsd/nationalaccount/snaupdate/2025/2025SNA_CH11_V5.pdf)) before this citation is finalised.
5. ¶45 Tacon, A.G.J. and Metian, M. (2008). *Aquaculture* 285: 146–158. doi:10.1016/j.aquaculture.2008.08.015.
6. ¶46 Jackson, A. (2009). Fish in fish out ratios explained. *Aquaculture Europe*, 34(3). IFFO/EAS conference paper. Available at: https://www.iffco.com/system/files/downloads/EAS%20FIFO%20September2009%202_0.pdf (https://www.iffco.com/system/files/downloads/EAS%20FIFO%20September2009%202_0.pdf). Grey literature; Tacon & Metian (2008) is the primary peer-reviewed citation.
7. ¶47 TG-0.7 Quality Assurance (completeness and comparability standards); TG-3.9 Aquaculture Accounts (foundational account scope).

DRAFT