Monterey Bay Aquarium Seafood Watch®

Seafood Watch® Standard for Aquaculture

Introduction

The Monterey Bay Aquarium is committed to inspiring conservation of the oceans. To this end, Seafood Watch®, a program of the Monterey Bay Aquarium, researches and evaluates the environmental impact of aquaculture products and shares these seafood recommendations with the public and other interested parties in several forms, including regionally specific Seafood Watch pocket guides, smartphone apps and online at www.seafoodwatch.org.

This document houses the Seafood Watch Standard for Aquaculture as approved on February 20-21, 2020 in Monterey, CA. The Standard allows assessment of the relative sustainability of aquaculture operations according to the conservation ethic of the Monterey Bay Aquarium. It includes background and rationale text explaining how the assumptions and Seafood Watch values are reflected within the calculations and scoring options. Wild seafood sources are evaluated with a different standard. The Standard for Aquaculture, the Standard for Fisheries, and the Standard for Salmon, in addition to our assessment process, assessments and recommendations, are all available at www.seafoodwatch.org.

This Standard will be used for all aquaculture assessments beginning April 1st 2020, and consists of:

1. Defined guiding principles
2. Science-based performance criteria that are regularly revised based on the input from aquaculture experts
3. A robust and objective scoring methodology that results in a transparent assessment of an aquaculture operation against the performance criteria

Assessing against the Seafood Watch Standard for Aquaculture results in a Seafood Watch rating of Best Choice (green), Good Alternative (yellow), or Avoid (red). The assessment criteria are used to determine a final numerical score as well as numerical sub-scores and color ratings for each criterion. These scores are translated to a final Seafood Watch color rating according to the methodology described in the table below. The table also describes how Seafood Watch defines each of these categories.

Best Choice	Final Score ≥6.665[1] and ≤10, **and** no Red Criteria, **and** no Critical[2] scores	Wild-caught and farm-raised seafood on the "Best Choice" list are ecologically sustainable, well managed and caught or farmed in ways that cause little or no harm to habitats or other wildlife. These operations align with all of our guiding principles.
Good Alternative	Final score ≥3.335 and ≤6.664, **and** no more than one Red Criterion, **and** no Critical scores.	Wild-caught and farm-raised seafood on the "Good Alternative" list cannot be considered fully sustainable at this time. They align with most of our guiding principles, but there is either one conservation concern needing substantial improvement, or there is significant uncertainty associated with the impacts of this fishery or aquaculture operations.

[1] Each criterion is scored from 1 to 10 based on sub-factor scores, as described in the document below. Criteria scoring ≤3.334 are considered "red" criteria.
[2] Very severe conservation concerns receive "Critical" scores, which result in an Avoid recommendation.

Avoid	Final Score ≥0 and ≤3.334, **or** two or more Red Criteria, **or** one or more Critical scores.	Wild-caught and farm-raised seafood on the “Avoid” list are caught or farmed in ways that have a high risk of causing significant harm to the environment. They do not align with our guiding principles, and are considered unsustainable due to either a Critical conservation concern, or multiple areas where improvement is needed.

Seafood Watch Guiding Principles for Aquaculture

Seafood Watch® defines “sustainable seafood” as seafood from sources, whether fished or farmed, that can maintain or increase production without jeopardizing the structure and function of affected ecosystems.

Sustainable aquaculture farms and collective industries, by design, management and/or regulation, address the impacts of individual farms and the cumulative impacts of multiple farms at the local or regional scale by:

1. **Having robust and up-to-date information on production practices and their impacts available for analysis;**
   Poor data quality or availability limits the ability to understand and assess the environmental impacts of aquaculture production and subsequently for seafood purchasers to make informed choices. Robust and up-to-date information on production practices and their impacts should be available for analysis.
2. **Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level;**
   Aquaculture farms minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry’s waste discharges.
3. **Being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats;**
   The siting of aquaculture farms does not result in the loss of critical ecosystem services at the local, regional, or ecosystem level.
4. **Limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms;**
   Aquaculture farms avoid the discharge of chemicals toxic to aquatic life or limit the type, frequency or total volume of use to ensure a low risk of impact to non-target organisms.
5. **Sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains;**
   Producing feeds and their constituent ingredients has complex global ecological impacts, and the efficiency of conversion can result in net food gains or dramatic net losses of nutrients. Aquaculture operations source only sustainable feed ingredients or those of low value for human consumption (e.g., by-products of other food production), and convert them efficiently and responsibly.
6. **Preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes;**
   Aquaculture farms, by limiting escapes or the nature of escapees, prevent competition, reductions in genetic fitness, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems that may result from the escape of native, non-native and/or genetically distinct farmed species.

7. **Preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites;**
   Aquaculture farms pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites, or the increased virulence of naturally occurring pathogens.
8. **Using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture;**
   Aquaculture farms use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture, or where farm-raised broodstocks are not yet available, ensure that the harvest of wild broodstock does not have population-level impacts on affected species. Wild-caught juveniles may be used from passive inflow, or natural settlement.
9. **Preventing population-level impacts to predators or other species of wildlife attracted to farm sites;**
   Aquaculture operations use non-lethal exclusion devices or deterrents, prevent accidental mortality of wildlife, and use lethal control only as a last resort, thereby ensuring any mortalities do not have population-level impacts on affected species.
10. **Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals;**
    Aquaculture farms avoid the international or trans-waterbody movements of live animals, or ensure that either the source or destination of movements is biosecure in order to avoid the introduction of unintended pathogens, parasites and invasive species to the natural environment.

Seafood Watch Criteria and Scoring Methodology for Aquaculture

Aquaculture is the process of converting resources from one form to another more desirable form via aquatic animals and plants. This definition is intended to highlight the importance of efficiency of conversion of resources used to produce farmed aquatic animals and plants. The end product may be more desirable than the raw resources economically, however there are environmental costs associated with this conversion, and complex social and economic costs and benefits as well. The environmental impact of this conversion is the basis for all Seafood Watch aquaculture assessments, and is the reason we choose this definition of aquaculture. The long-term sustainability of aquaculture depends on a balance and synergy of these costs and benefits. Overall, maximizing the social and economic benefits of aquaculture continues to be the driver for, and focus of, both subsistence and industrial production. These criteria focus on the environmental aspects of aquaculture and provide a tool to assess and highlight the ecological impacts and costs, thereby helping to inform and understand the ecological sustainability of different aquaculture systems. Seafood Watch recognizes the growing importance of social issues and is working to understand how we may include critical social issues as part of our recommendations in the future. We are currently trialing some options that would allow us to recognize the work of others in our process.

Scope

These criteria can be applied to all aquaculture species and production systems at all scales, including those involving multiple species (hereafter termed "polyculture" and inclusive of all multi-species and multi-trophic systems). While the standard criteria can be applied to individual farms, Seafood Watch assessments apply the standards only at a regional, national or international level. Reference is made to "fish" throughout for clarity, with the recognition that this term applies to all species of fish, shellfish, crustaceans, and aquatic plants.

Criterion 1 - Data

Impact, unit of sustainability and principle

- *Impact:* Poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers or enable businesses to be held accountable for their impacts.
- *Unit of sustainability:* The ability to make a robust sustainability assessment.
- *Principle:* Having robust and up-to-date information on production practices and their impacts available for analysis.

Background and Rationale

The Data Criterion recognizes those companies, industries and regulators that make good quality data on their activities and impacts available, or those operations that are well researched.

Seafood Watch will use data that are publicly available or provided privately. Data and information used to justify a score, or interpretations of it, will be included in the report and published.

The practice of assigning low scores in the event that information is "unknown" adheres to Seafood Watch's use of the Precautionary Principle[3] when there is potential for a substantial impact, but information is not available.

The absence of data showing impact does not equate to no impact. (i.e., "No evidence of impact" is not the same as "Evidence of no impact.").

For each of the data categories in Table 2, use the Data Quality and Confidence descriptions in Table 1 to select the appropriate 0-10 Data Quality and Confidence score for each data category. Examples of data quality are provided to determine how effectively the available data or evidence represent the operation and its impacts. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Polyculture Assessments

For assessments concerning polyculture systems, each Data category for each species should be assessed and scored independently.

[3] The use of the Precautionary Principle is not intended to be a blanket response to a lack of information. In a scenario with a potential impact but unknown information, if evidence shows that the risk of the impact is low, Seafood Watch will apply a common sense approach to the scoring of an assessment, rather than a "worst case scenario" Precautionary Principle approach. The Seafood Watch Aquaculture Standard is intended to be functional and produce relatively accurate results in the face of low data. It has been developed as a risk assessment for impacts based on proxies for impact (e.g., openness of a production system as a proxy for impact of disease on wild populations because pathogen/parasite impact to wild populations is generally unknown).

Data -Table 1

Quality	Examples of Data Availability, Quality and Confidence	Score
High	<u>Assessor confidence is high that the operation and its impacts are fully understood, examples include</u>: ▪ Independently verified, peer-reviewed research, official regulatory monitoring results or government statistics ▪ Complete, detailed, and available without averaging or aggregation ▪ Up to date within reason, and covering relevant timeframes ▪ Collected using appropriate methods (e.g., frequency of collection, number of data points, etc.)	10
Moderate-high	<u>Data are considered to give a reliable representation of the operation(s) and/or impacts examples include:</u> ▪ Data quality does not meet the 'High' standards above but are complete and accurate in relation to this assessment ▪ Up to date within reason, and covering relevant timeframes; data gaps may be present but are non-critical ▪ Some non-critical aggregation or averaging may have taken place ▪ Data collection methods (e.g., frequency of collection, number of data points, etc.) are considered robust	7.5
Moderate	<u>Data provide some useful information, but the assessor (subjectively) is uncertain whether data fully represent the farming operations</u> ▪ Data may not be verified ▪ Some loss of relevant information may have occurred through data gaps, averaging or aggregation ▪ Data collection methods are questionable or unknown ▪ Questions or uncertainties remain in key information	5
Low-moderate	<u>Data provide little useful information and are not sufficient to give confidence that the operation and its impacts are well understood</u> ▪ Data probably not verified ▪ Weaknesses in time frames or collection methods; data gaps or aggregation and averaging mean that critical interpretation is not possible ▪ Questions and uncertainties about the data mean it is difficult or impossible to draw reliable conclusions	2.5
Low	<u>Data do not provide useful information and are not considered to represent the operation(s) and/or impacts</u> ▪ Data are incomplete or out of date, unverified, or collection methods are inappropriate	0

Data – Table 2

Category	Data Description	Score 0-10
Production	Industry or farm size and production volumes, species, number and locations of farms or sites, general production methods.	

Management	National, regional, and local laws and regulations and/or industry management measures[4], inclusion of area-based or cumulative impact measures, implementation and enforcement at the individual farm level.	
Effluent	Nutrient waste discharges from farm, water quality and benthic impact monitoring, regulatory control and enforcement.	
Habitat	Farm locations, habitat types, impact assessments, history of conversion, habitat monitoring, habitat/siting regulatory content and enforcement.	
Chemical Use	Type, frequency, dose and discharge characteristics, impact monitoring, regulatory restrictions.	
Feed	eFCR, proximate and ingredient composition of feeds (i.e., inclusion rates of fishmeal and fish oil [including by-products] and of other ingredient groups [vegetable or crop meals and oils, land animal products and by-products, and “alternative” ingredients such as algal, insect, or single-cell ingredients]). Source and sustainability of fisheries supplying marine ingredients.	
Escapes	Numbers and size of animals, recapture or survival rates, genetic and/or competitive impacts of escapees.	
Disease	Disease outbreaks, mortalities, pathogen and parasite levels and treatments, biosecurity characteristics, monitoring or evidence of impacts, regulations and emergency responses.	
Source of stock	Source of farm stocks, use of wild fisheries for broodstock, larvae, juveniles, or other actively-stocked species part of the production system.	
Wildlife mortalities	Predator and wildlife interactions at farms, mortality rates, and evidence of population impacts.	
Escape of secondary species	Trans-waterbody movements of live animal or other potentially non-biosecure materials, biosecurity of sources and destinations.	
	Total Score	

$$\text{Data Criterion Score} = \left(\frac{\text{Total Score}}{11} \right)$$

Final Data Criterion score = _______ (range 0–10)

[4] It is not required that laws, regulations and management measures be provided in English. However if translation capability is limited, the Management category of the Data criterion must be scored in a way that reflects the analyst’s ability to understand the content of the documents in order to determine their relative importance to the assessment, and robustness of their content.

Criterion 2 - Effluent

Impact, unit of sustainability and principle

- *Impact:* Aquaculture species, production systems and management methods vary in the amount of waste produced per unit of production. The combined discharge of farms, groups of farms or industries contribute to local and regional nutrient loads.
- *Unit of sustainability:* The carrying or assimilative capacity of the local and regional receiving waters.
- *Principle*: Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Background and Rationale

The effect of effluent wastes on receiving water bodies is typically related to the total amount of pollutants added over time relative to the carrying capacity of the receiving waters, and not on the concentration of the pollutants, except in situations where concentrations are high enough to have localized impacts (Boyd et al. 2007). The impact of aquaculture wastes, and particularly their contribution to the overall local or regional impacts from all waste sources (i.e., agriculture, domestic waste and so on) varies enormously and is challenging to assess.

This criterion applies to the impacts or risk of impacts from effluent (nutrient-related) discharges from farms in the industry under assessment. These "operational" impacts are different from those related to initial farm construction and farms' physical presence in a space; those impacts (e.g., the mooring of floating net pens, or the construction of ponds) are assessed in Criterion 3 – Habitat. Effluent-related impacts are more likely in the immediate vicinity of the farm or its discharge point, and as such, regulatory or management bodies often govern aquaculture effluent using the concept of an "allowable zone of effect" (AZE). The allowance of varying degrees of impact at varying distances from farms is acknowledged in this criterion, but the intent is to assess the cumulative impact of all effluent discharges on the industry's receiving waterbody/ies.

While it would be preferable to make a direct measurement of effluent impacts resulting from farm discharges, this is generally impossible. The impact typically is not directly related to either the waste produced per ton of fish, the total waste produced by a farm, or the concentration of a pollutant in the wastewater discharged. For example, a small farm can be highly polluting, while a large farm could have a minimal impact. Similarly, a well located and appropriately sized farm could have no impact and a poorly located or poorly sized farm could have a significant[5] impact.

The Effluent criterion therefore uses direct evidence of impacts (or lack of impact) where possible (in the evidence-based assessment option) or a combination of risk factors as outlined below (in the risk-based assessment) to assess the potential for the assessed operations to

[5] In this scenario "significant" can refer to the farm or industry's contribution to cumulative impacts to the receiving waterbody, or it can refer to the farm or industry's impacts that impact wild, native populations beyond the farm site (i.e., effluent may not have an impact cumulatively, but impacts are still occurring at a smaller scale).

exceed the carrying capacity of the receiving waters. The Effluent Criterion covers soluble and particulate fish wastes at both the near- and far-field levels.

Evidence-Based Assessment

The Evidence-Based Assessment is the preferred method of assessment when good research and/or data are available to demonstrate the level of impact (or lack of impact) from effluent wastes. This allows aquaculture operations that can demonstrate that they are operating responsibly to get a good score, and also enables conclusive data or other research evidence on impacts (good or bad) to be the basis of the score.

A Critical score is included in the table to recognize extreme impacts where effluent leads to population-level declines in key species beyond the immediate farm area, or persistent illegal activities take place that contribute to negative ecological impacts (e.g., illegal sludge dumping from ponds contributing to cumulative impacts to a waterbody).

Risk-Based Assessment

The Risk-Based Assessment option is based on the amount of waste discharged per ton of production combined with the effectiveness of the management or regulatory structure to control the total farm discharge and the cumulative impact of multiple farms impacting the same receiving water body.

Factor 2.1 – Waste discharged per ton of fish

While phosphorous may be the main driver of impacts in some environments, particularly freshwater, this criterion uses nitrogen as a proxy indicator of waste due to the ease of calculation based on the greater availability of data for the nitrogen in the protein component of feed or as fertilizer.

The calculation for the amount of nitrogen discharged from the farm (per ton of production) is based on the amount of waste nitrogen produced by the fish (Factor 2.1a), and then the percentage of that waste that actually leaves the farm site (Factor 2.1b). The nitrogen input calculation adds the nitrogen in feed (if used) to the nitrogen in fertilizer (if used) to determine the total kg of nitrogen required to produce one ton of fish. The nitrogen output is determined by the nitrogen available (as protein) in harvested farmed fish. The nitrogen output is then subtracted from the nitrogen input to determine the amount of waste nitrogen produced per ton of farmed fish as effluent.

The percentage of wastes produced by fish that leaves the farm (Factor 2.1b) is calculated such that a score of 1 means 100% of the waste produced by the fish is discharged from the farm; a score of zero means 0% of the waste produced by the fish is discharged from the farm (e.g., a system that assimilates, collects, treats or otherwise appropriately disposes of all wastes).

Adjustments are available for most types of systems to account for different methods of effluent treatment. For example, while fully enclosed recirculation systems do not discharge effluent water from the system, there is removal and disposal of solid wastes from the system which, if disposed of inappropriately, can impact surrounding ecosystems. However, there are adjustments that can be applied if it is known that proper disposal of solids is occurring. Therefore, combinations of different adjustments allow the system discharge score to be zero when all effluent wastes are disposed of appropriately.

For ponds or other systems, Hargreaves (1998), Gross et al. (2000), Jackson et al. (2003), Boyd et al. (2007), and Sonnenholzer (2008) have been the primary data sources (and they largely agree both across studies and across species). For example, Boyd et al. (2007) show 16% N loss in effluent from catfish ponds compared with 17% for shrimp from Sonnenholzer (2008), and 22.6% for sediment accumulation compared to 24% respectively (see Figure 1).

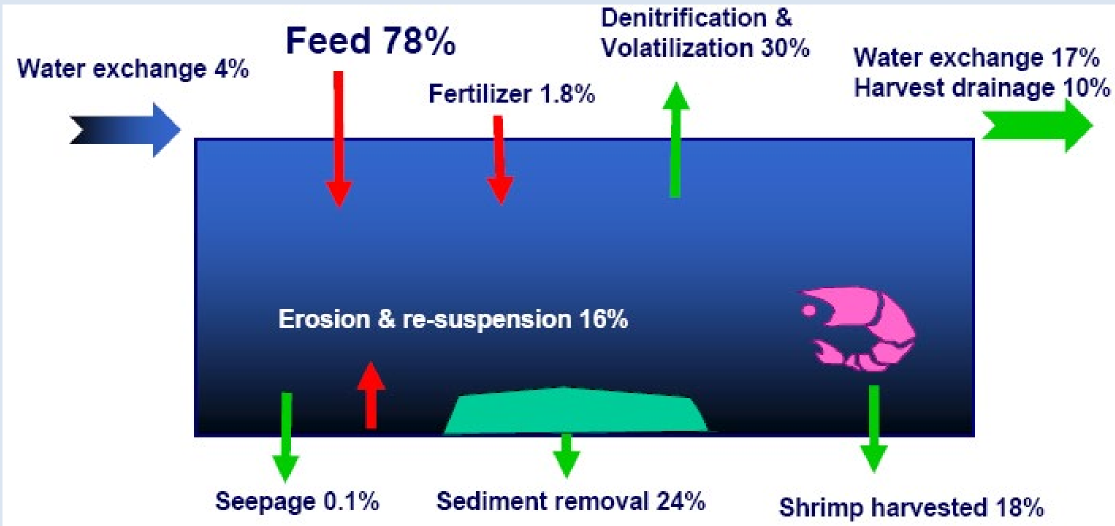

Figure 1 – Shrimp pond nitrogen dynamics, from Sonnenholzer (2008).

The Factor 2.1b scores for ponds are based on Figure 1. The waste outputs with the potential to cause effluent impacts are water exchange (17%) plus harvest drainage (10%) and sediment removal (24%), totaling 51%. This (0.51) is therefore the basic score for daily exchanging ponds (i.e., 49% of the waste produced by the fish is broken down in the pond). Evidence of further waste treatments allow for the reduction of this score according to collection or other appropriate disposal method of the wastes. For example, settling ponds will treat the great majority of the 17% lost in water exchange (therefore the adjustment for the use of settling ponds is -0.17). Similarly, appropriate disposal of pond sludge / sediment allows an adjustment of -0.24.

Tanks and raceways have the potential for 100% of wastes to be discharged; therefore, the basic score is 1. Adjustments allow for the collection or treatment of solid and soluble wastes on the basis of 20% solids, 80% soluble (Roque D'Orbcastel et al. 2008, Schulz et al. 2003).

For net pens, 80% of the waste leaving the production system is soluble effluent waste and the remaining 20% is solid waste that falls below the net pen (Islam 2005, Reid et al. 2009). Impacts from this waste are addressed in the Habitat criterion (Criterion 3). Therefore the Basic Score for net pens is 0.8 (or 80%).

Factor 2.2 – Management of farm-level and cumulative impacts

The above waste score (Factor 2.1) is on a "per ton of production" basis, and therefore does not directly measure the total amount of waste discharged from one or more farms, or the impacts of these wastes. Even aquaculture operations that produce a lot of waste per ton of production can have a minimal overall impact if the farm's size and location, or the concentration and connectivity of multiple farms are well managed or regulated. Similarly, aquaculture operations that discharge relatively small amounts of waste per ton of production could have substantial impacts if the farms are large and/or concentrated.

Factor 2.2 is a measure of the presence and effectiveness of laws, regulations, management control measures, farm-level practices or eco-certification (appropriate to the scale of the industry) to limit the *total* discharge of wastes from farms and the *cumulative* impacts of aquaculture effluent from multiple farms to within the carrying capacity of the receiving environment.

Factor 2.2a – Content of effluent management measures
This factor is intended to assess the strength of management systems in place that regulate aquaculture operations. Seafood Watch considers regulatory systems that manage impacts according to area-based management practices or cumulative impacts to be most appropriate for addressing impacts from aquaculture industries. It is possible for aquaculture operations that produce a lot of waste per ton of production to have a minimal overall impact if the farm's size and location, or the concentration and connectivity of multiple farms are well managed or regulated. Similarly, aquaculture operations that discharge relatively small amounts of waste per ton of production could have substantial impacts if the farms are large and/or concentrated.

Factor 2.2b – Enforcement of effluent management measures
This factor is intended to assess the enforcement and applicability of management systems in place. If a management system exists but is not being enforced, it is not considered to be effective.

Note: "Management system" refers to policies, legislation or regulations, and/or independently verified management measures, codes of practice, Best Management Practices or certification schemes that have the appropriate language[6] and authority for enactment.

The final scoring table for the Effluent Criterion is constructed to recognize the importance of the different characteristics described above. For example, even with very high effluent loads per ton of production, impacts can be minimal if the total discharge is managed effectively. The final score includes a Critical option when the score is zero due to a combination of high waste discharges per ton of production and very weak regulations or management to control the total waste discharge or cumulative impacts.

Area of assessment for Effluent
This criterion applies to effluent impacts at all locations proximal and distant to the farm.

[6] Appropriate language – avoidance of 'should', 'minimize', etc.

For example:

- For net pen farms, Criterion 2 – Effluent applies within and beyond the edge of the net pens or their Allowable Zone of Effect (AZE). It applies to both benthic and water column impacts.
- For pond farms, Criterion 2 – Effluent applies beyond the farm boundary or discharge point, and includes activities such as pond sludge disposal.

Choosing the Evidence-Based or the Risk-Based Assessment

This criterion has two assessment options based on the quality of the effluent data available:

- If good research information and/or data on the ecological impacts are available (i.e., a Criterion 1 – Data score of 7.5 or higher for the Effluent category), use the Evidence-Based Assessment table.
  If the assessed operations do not have good effluent and/or impact data (i.e., a Criterion 1 – Data score of 5 or less for the Effluent category), or they cannot be easily addressed using the Evidence-Based Assessment, the Risk-Based Assessment must be used.

Polyculture Assessments

For assessments concerning polyculture systems, the methodology is dependent on whether there is enough data availability to allocate impacts between all species in the polyculture system. To determine which methodology to use, see Appendix 4 for guidance.

Effluent: Evidence-Based Assessment (based on good data availability and quality)

The Evidence-Based Assessment is the preferred method if good research or data are available (i.e., a Criterion 1 – Data score of 7.5 or higher for the Effluent category). To complete the Evidence-Based Assessment, consider the available data and evidence of impacts, and select the most appropriate score from the examples in the table below. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

In the table, "impacts" are defined as evidence of eutrophication, low dissolved oxygen, high sulfide contents, low redox potential, algae blooms, changes in species diversity or community structure associated with excess nutrients, salinization, dispersal of other farm wastes, or other relevant measurements or indicators of exceeding the carrying capacity of the local or regional environment at any time over multiple production cycles, particularly including periods of peak biomass, harvest and occasional operations (e.g., pond flushing, cleaning or sludge disposal).

Effluent Concern	Effluent or Pollution Examples	Score
Very low	▪ The species produced is extractive, or not provided external feed or nutrient fertilization and has no other effluent or waste impacts ▪ The production system does not discharge wastes[7] ▪ Data show the effluent discharged is of the same quality as the influent water supply	10
Low	▪ Data show no evidence that effluent discharges cause or contribute to cumulative impacts at the waterbody/regional scale	8

[7] Soluble and solid wastes – including solids such as pond sludge, filter solids, uneaten feed, etc.

	and the impacts within the immediate vicinity of the farm are temporary[8].	
Low-moderate	▪ Data show that effluent discharge(s) result in occasional[9] yet temporary impacts within the immediate vicinity of the farm, and there is potential for cumulative impacts at the waterbody or regional scale	6
Moderate	▪ Data show that effluent discharge(s) result in frequent yet temporary impacts within the immediate vicinity of the farm, and there is potential for cumulative impacts at the waterbody or regional scale, or; ▪ Data show only occasional, temporary or minor evidence of impacts beyond the immediate vicinity of the farm or discharge point, or contributions to cumulative local or regional impacts	4
Moderate-high	▪ Data show that effluent discharge(s) result in frequent yet temporary impacts beyond the immediate vicinity of the farm	2
High	▪ Data show effluent discharges cause persistent and/or irreversible impacts	0
Critical	▪ Data show effluent discharges lead to population declines in key indicator species[10] beyond the immediate vicinity of the farm, or result in mortality of protected or endangered species[11]	C

**Note:* intermediate values (i.e., 1,3,5,7 or 9) may be used if needed.

Effluent criterion score = __________ (range 0–10)

If the assessed operation(s) cannot be addressed using these categories, or if the Criterion 1 – Data score is less than 7.5 for the Effluent category, continue to the Risk-Based Assessment and Factors 2.1 and 2.2 below:

Effluent: Risk-Based Assessment (based on poor data availability or quality)

Use this Risk-Based Assessment when the data quality is not good enough to use the Evidence-Based Assessment above; (i.e., when the Criterion 1 – Data score for effluent is 5 or lower).

This criterion estimates the waste produced per ton of fish, then estimates the amount of that waste that is discharged from the farm (Factor 2.1). This is combined with the effectiveness of

[8] Temporary – is reversible through fallowing or other farming strategies to cease or minimize the impact such that the biogeochemical properties of the benthos and water column return to pre-farming conditions.
[9] Occasional, or minor – as a guide, exceedances of regulatory limits or other values occur in less than 10% of the measurements within a year or less than 10% of the total duration of a year, and are not considered to have any lasting impact beyond the exceedance period.
[10] Indicator species are defined by the Encyclopedia of Life as a species that "can signal a change in the biological condition of a particular ecosystem, and thus may be used as a proxy to diagnose the health of an ecosystem." https://education.eol.org/articles/indicator_species.pdf
[11] Species listed as "protected," "vulnerable," "threatened," "endangered" or "critically-endangered" by the IUCN (Red List) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

the regulatory or management scheme to manage the potential cumulative impacts from the total tonnage of any one farm, or from multiple farms (Factor 2.2).

Effluent: Factor 2.1 – Waste discharged per ton of fish

Factor 2.1 is a combination of the waste produced per ton of fish (2.1a) and the proportion of that waste that is discharged from the farm, which is dictated in general by the production system (2.1b).

Factor 2.1a – Biological waste production per ton of fish

a) Protein content of feed = _____ %
b) Economic feed conversion ratio (eFCR[12]) = _____
c) Fertilizer nitrogen input per ton fish produced = _____ kg N t^{-1}
d) Protein content of harvested whole fish = _____ %
e) Protein nitrogen content factor = 0.16 (fixed value; protein is 16% nitrogen)

Nitrogen input per ton of fish produced = (a x 0.16 x b x 10) + c = ______ kg N t^{-1}

Harvested nitrogen per ton of fish produced = (d x 0.16 x 10) = _____ kg N t^{-1}

Waste N produced per ton of fish = N input - harvested N = ____ kg N t^{-1}
Factor 2.1a score = ______ kg N t^{-1}

Factor 2.1b – Production system discharge

This factor assesses how much of the waste produced by the fish is actually discharged from the farm; it acts as a multiplier value (between 0 and 1) for Factor 2.1a.

Select the basic scores and adjustments for the production system from the table below. The pre-selected values are based on the available scientific literature on nutrient dynamics in different aquaculture systems. If specific data are available on waste loss, waste treatment, waste collection or other aspects of the production system that reduce the loss of the nutrients, then use them where possible (marked by "X").

System Characteristic	Basic Score	Adjust
Nets, cages and pens		
1. Open exchange net pens or cages	1.0	
2. Modified cages (e.g., "diapers") – provide data[13] on waste collection	X	
Adjustment – other – provide data		-X
Ponds		
1. Ponds – unknown operation, or operating as a flow-through system (all solid and soluble waste discharged)	1.0	

[12] eFCR = total feed inputs divided by total harvested fish output over the entire production cycle. It should ideally be averaged over multiple production cycles and take account of seasonal differences (e.g., wet or dry season, age of fish). If these data are not readily available, be precautionary and use the best data available.
[13] Information on 'typical' recapture potential for a given system, raw data on known recapture potential, etc.

2. Ponds – average annual daily exchange >3 %	0.51	
3. Ponds – average annual daily exchange <3 %	0.42	
4. Ponds – discharge once per cycle, exchange at harvest	0.34	
5. Zero exchange ponds over multiple cycles	0.24	
6. Ponds – other – provide data	X	
Adjustment (pond average annual daily exchange >3%) – settling pond use (daily use with discharged water; minimum 12 hours retention time)		-0.17
Adjustment (pond average annual daily exchange >3%) – settling pond use (daily use with discharged water; minimum 12 hours retention time)		-0.1
Adjustment (pond average annual daily exchange >3%) – proper sludge disposal adjustment		-0.24
Adjustment (pond average annual daily exchange <3%) – settling pond use (daily use with discharged water; minimum 12 hours retention time)		-0.14
Adjustment (pond average annual daily exchange <3%) – settling pond use (discharged harvest water; minimum 12 hours retention time)		-0.08
Adjustment (pond average annual daily exchange <3%) – proper sludge disposal adjustment		-0.2
Adjustment – other – provide data		-X
Raceways or tanks		
Raceways, tanks – operating as flow-through (solids and soluble waste discharged)	1.0	
Raceways, tanks – flow-through with solids collection AND appropriate disposal (soluble waste discharge)	0.8	
Raceways, tanks – recirculation system, solids collection AND appropriate disposal plus biofiltration treatment (or other) for soluble wastes;	0	
Raceways, tanks – other treatment system – provide data	X	
Adjustment – inappropriate disposal of collected solid wastes		+ 0.2
Adjustment - biofiltration treatment (or other) for soluble wastes		- 0.8
Adjustment – other – provide data		-X
Other systems		
Provide data	X	- X
Other adjustments		
Adjustment - use of IMTA or other nutrient uptake system – provide data on N uptake		- X
Other nutrient adjustments		X

Basic (unadjusted) production system discharge score = _____
Adjustment 1 = _____ (leave blank if no adjustments)
Adjustment 2 = _____
Adjustment 3 = _____

Factor 2.1b: Discharge score = _____ (range 0-1)
Note: the final discharge score must be between 0 and 1 (i.e., between 0 and 100% of the waste produced is discharged).

Factor 2.1 score:
The Factor 2.1 score is the product of the amount of waste produced per ton of fish (kg N ton^{-1} fish) and the percentage of waste that leaves the farm. This value is allocated a 0-10 score based on an aquaculture-relative range from zero kg N ton^{-1} discharge (score 10) to a high discharge of >90 kg N ton^{-1} (Score 0 of 10).

Waste discharged = Waste produced x Production system discharge score
Waste discharged per ton of fish = 2.1a x 2.1b = _______ kg N ton^{-1}

Discharge Description	Value (kg N ton^{-1})	Score
	0	10
Low	0.1 – 9.9	9
	10 – 19.9	8
Low-moderate	20 – 29.9	7
	30 –39.9	6
Moderate	40 – 49.9	5
	50 – 59.9	4
Moderate-high	60 – 69.9	3
	70 – 79.9	2
High	80 – 89.9	1
	> 90	0

Factor 2.1 score = ______ (range 0–10)

Effluent: Factor 2.2 – Management of farm-level and cumulative impacts

This factor is a measure of the presence and effectiveness of laws, regulations, management control measures, farm-level practices or eco-certification (appropriate to the scale of the industry) to limit the ***total*** discharge of wastes from farms and the ***cumulative*** impacts of aquaculture effluent from multiple farms to within the carrying capacity of the receiving environment. It is considered necessary for farms, industries or countries that export farm-raised seafood to be transparent about the environmental management measures and regulations that control the way the exported seafood was produced.

For third party certified farms or other independently verified standards, it is acceptable to answer the questions relating to the relevant standards and inspection/audit process where these are considered to be more robust than the regulatory (or other) system.

Factor 2.2a – Content of effluent management measures
Consider the content of relevant management measures such as:

- National[14], regional and local effluent regulations.
- Applicable industry codes of good practice.
- Applicable area-based or producer organization agreements, or farm-level management systems.
- Any other management measures relating to effluent.

Contact relevant management agencies and in-country NGO, academic or industry experts and decide the appropriate content score from the broad descriptions in the following table:

Content	Description	Score
Comprehensive	An area-based, cumulative management system is in place for multiple industries including aquaculture, with effluent limits set for aquaculture in combination with other industries[15]. Limits are based on the carrying capacity of the receiving waterbody.	5
Robust	An area-based, cumulative management system is in place for aquaculture effluents, with limits defined and applied at the farm-level appropriate to the receiving waterbody.	4
Moderate	Management system sets effluent limits, based on relevant ecological factors at the site level but not at the cumulative or area level. Limits cover the entire production cycle and cover peak events (e.g., max biomass, harvest, sludge disposal etc.).	3
Limited	Management system does not set site-specific effluent limits, or the limits are not based on ecological principles, or the limits do not cover the entire production cycle and cover peak events (e.g., harvest, sludge disposal etc.).	2
Minimal	Unknown or unclear management structure for aquaculture, or the effluent limits set are not specific or relevant to aquaculture or the receiving water.	1
Absent	No relevant management systems in place for aquaculture effluents	0

Factor 2.2a score = _____ (0–5)

Factor 2.2b – **Enforcement of effluent management measures**
Even comprehensive regulations or management measures are not effective without appropriate enactment and enforcement. Consider the available information on the enforcement of the effluent management measures apparent in Factor 2.2a above and decide the appropriate enforcement score from the broad descriptions in the following table. If an assessed operation's third-party certification is the most relevant example of management, then apply the questions to the inspection/auditing and certification process.

Enforcement	Description	Score
Highly Effective	Enforcement organizations are identifiable and contactable, and resources are appropriate to the scale of the industry. Enforcement is active at the area-based scale, and covers the entire production cycle	5

[14] Use the relevant FAO National Aquaculture Legislation Overview (NALO) country factsheet if necessary.
[15] E.g., agriculture, manufacturing or domestic wastes.

	and peak events. Evidence of monitoring and compliance, and evidence of penalties for infringements are available.	
Effective	As Highly Effective above, but with minor limitations to any aspect.	4
Moderate	Enforcement organizations are identifiable and active, but have limitations in resources or activities that reduce effectiveness. Some gaps in monitoring or compliance data.	3
Limited	Enforcement measures are limited, do not cover the complete production cycle or do not cover peak effluent events. Monitoring or compliance data are limited.	2
Minimal	Enforcement organizations and their activities are difficult to identify. Little evidence of monitoring or compliance data, or limited evidence of penalties for infringements.	1
Ineffective	No evidence of effective enforcement activity. Persistent illegal activities occurring.	0

Factor 2.2b score = ______ (0–5)

Factor 2.2 score = (2.2a x 2.2b) / 2.5
Factor 2.2 effluent management score = _______ (range 0–10)

Final Effluent criterion score
Although reducing waste produced per ton of production is important, the total or cumulative amount of waste produced by the farms and the industry is typically more important. The effectiveness and enforcement of the management regime is most relevant to controlling farm size, total waste discharge and cumulative industry impact. The scoring matrix below therefore favors a low waste discharge per ton of production, but also values the effectiveness of management to control cumulative impacts.

Select the final Effluent score from the table using the waste discharge (Factor 2.1) and management (Factor 2.2) scores.

		Management score (Factor 2.2)										
		10	**< 10**	**< 9**	**< 8**	**< 7**	**< 6**	**< 5**	**< 4**	**< 3**	**< 2**	**< 1**
Waste discharge score (Factor 2.1)	**10**	10	10	10	10	10	10	10	10	10	10	10
	9	10	10	9	9	9	8	8	7	7	7	6
	8	10	9	9	8	8	7	7	6	6	5	5
	7	10	9	8	7	7	6	6	5	5	4	4
	6	10	9	8	7	6	6	5	5	5	4	3
	5	10	8	7	6	6	5	5	5	4	4	3
	4	10	8	7	6	5	5	4	4	4	3	2
	3	10	8	7	6	5	4	4	4	3	2	1
	2	10	7	6	5	4	4	3	3	2	1	0
	1	10	7	6	4	3	3	2	2	1	0	0
	0	10	6	5	3	2	2	1	1	0	0	0

Final Effluent criterion score = ______ (range 0–10) (Zero score = Critical)

Criterion 3 – Habitat

Impact, unit of sustainability and principle

- *Impact:* Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats as well as to the critical "ecosystem services" they provide.
- *Unit of sustainability:* The ability to maintain the critical ecosystem services relevant to the habitat type.
- *Principle:* Being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats.

Background and Rationale

The Habitat Criterion assesses the impacts, or risk of impacts, of farm construction and operation/presence on the habitats in which farms are sited (Factor 3.1) and the scope and effectiveness of management or regulatory systems that govern them (Factor 3.2). This criterion is inclusive of the physical impacts of the farm's presence at both the acute and cumulative industry scales, and can include plastics, feed bags, nets, ropes, etc. where relevant. Nutrient-related impacts, both near and far-field, are assessed in Criterion 2 – Effluent.

The effects of farm siting on habitat are challenging to quantify because the establishment of farms has a *de facto* deleterious impact on the existing terrestrial or aquatic ecosystem relative to baseline conditions. The degree of impact must then be ascribed relative to the change in ecosystem structure and function.

In most cases, our current scientific understanding of the structure and function of ecosystems is not sufficiently complete to have accurate *a priori* knowledge of how species declines or changes in network structure or complexity will affect an ecosystem's overall resilience. Similarly, we cannot currently predict where systems will encounter ecological tipping points – although we know that such dynamics regularly exist (Ellis et al. 2011, Scheffer et al. 2009).

The Habitat Criterion must also cater to the diversity of aquaculture production systems used (i.e., the differing impacts of floating pens, or constructed ponds), the global scope of potential habitats (from open ocean to coastal to freshwater to terrestrial), and also consider the complexities of historic and recent habitat conversion (e.g., for agriculture) and subsequent secondary conversion for aquaculture.

In addition to the technical complexity of assessing habitat impacts, expert opinion also varies widely. Considering the satellite photo in Figure 2 (of shrimp farms in Thailand), expert comments have concluded this to be either a heavily-impacted area of coastal habitat with greatly reduced ecosystem services that should be given a low habitat score, or conversely, as an area already heavily-impacted by human activity in general and therefore a good place to concentrate aquaculture to avoid further impacts to pristine habitats (worthy of a high habitat score).

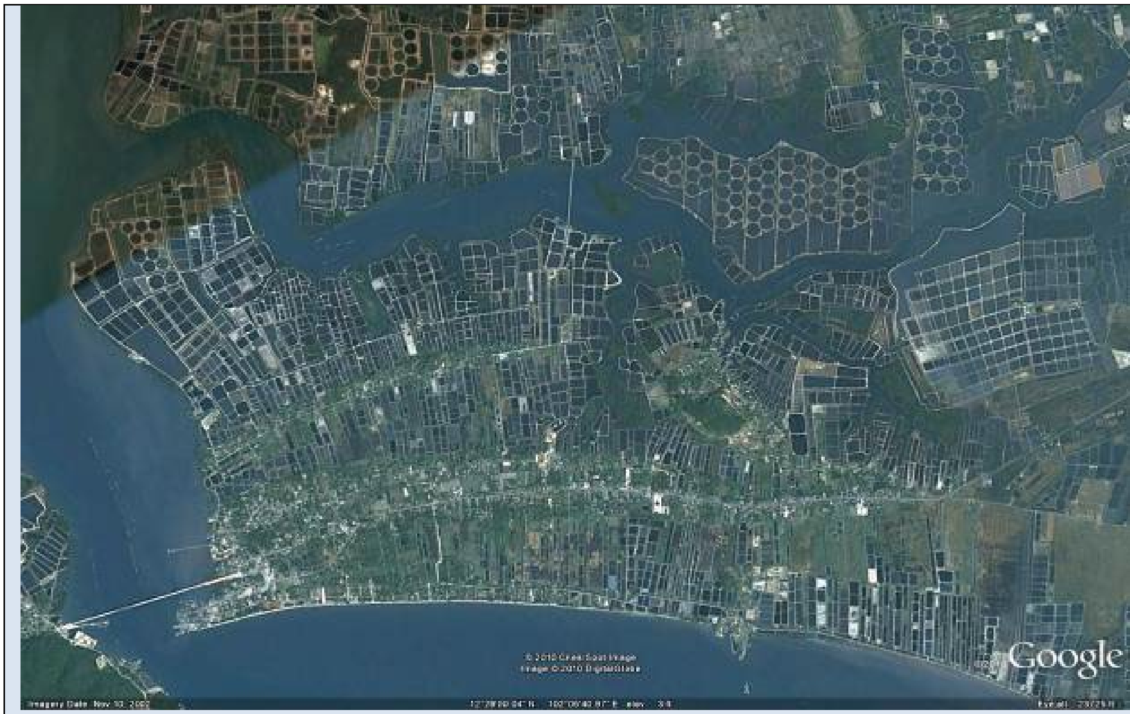

Figure 2 – Shrimp farms in Eastern Thailand, showing impacts to coastal, estuarine and terrestrial habitats, and evidence of historic conversion of original pristine habitats for rice culture and urban development and subsequent re-conversion to shrimp ponds. Image captured using Google Earth.

Given these constraints, this criterion is based on the evidence of change in the provision of ecosystem services that results from habitat conversion or modification for aquaculture. The change in ecosystem services supply has been increasingly used to assess the impact of land use change (Metzger et al. 2006). The flexibility of this framework allows its appliance to the different terrestrial and aquatic ecosystems in which aquaculture operations are located.

The Habitat Criterion includes two parts: habitat conversion and function (F3.1) and farm siting management effectiveness (F3.2). Factor 3.1 estimates the impact of habitat conversion to aquaculture in terms of ecosystem function by using indicators for assessing changes in the provision of ecosystem services. While Factor 3.1 assesses the impact at the farm level, Factor 3.2 deals with the existence and enforcement of management and regulations that limits the expansion and cumulative impact of multiple farms on the provision of ecosystem services.

Factor 3.1 – Habitat functionality

This factor is intended to describe whether the assessed industry has maintained functionality of ecosystem services in the habitats where it operates, or has contributed to a loss of ecosystem services historically (prior to 1999), in the recent past (since 1999), or is having an ongoing impact. The year 1999 was chosen as the threshold date for "historical" or "recent" due to the pivotal Resolution VII.21, *Enhancing the conservation and wise use of intertidal wetlands*[16], of the Contracting Parties to the Convention on Wetlands (colloquially known as

[16] https://www.ramsar.org/sites/default/files/documents/library/key_res_vii.21e.pdf

the Ramsar Convention). Although Ramsar is specific to wetland habitat, we would suggest that it serves as an appropriate industry-wide threshold date, after which existed a rapidly building awareness of the importance of functioning habitats and the increasing consensus that ongoing conversion of pristine habitats is unacceptable.

Habitat conversion for aquaculture purposes is measured through the effect on the provision of ecosystem services. Ecosystems provide life support functions as well as other valuable services, many of which are essential to human welfare and for all practical purposes, non-substitutable. For instance, coastal ecosystems generate a wide range of ecosystem services including protection from wave damage and flooding, habitat for fish and shellfish (i.e., food production), improvements to water quality, and the enhancement of recreational, tourism, aesthetic, spiritual and cultural values. The maintenance of critical ecosystem service provision after the conversion to aquaculture is considered optimal, and the degree of impact is assessed through the maintenance/loss of different ecosystem services.

Different indicators have been developed to monitor the status and trends in ecosystem services provision. Biological indicators, such as land cover, presence of keystone species, and biodiversity indexes, are used frequently (Feld et al. 2009). Indicators can be measured in “pristine” or minimally impacted conditions and then compared with the aquaculture site (Borja et al. 2012), or can be estimated through ecological models, remote sensing, or GIS. As the relationship between a given ecosystem service and particular structural components of the ecosystem may be non-linear (Barbier et al. 2008, Ellison 2008), indicators should be useful to identify if a system is moving towards or has already passed a threshold of functionality. Gradually changing conditions, such as habitat fragmentation or loss of diversity, can surpass threshold levels, triggering the loss of an ecosystem service. Recovering the ecosystem service can be complex, and sometimes impossible. The restoration of the system to its previous state requires a return to environmental conditions well before the point of collapse. This pattern is known as “hysteresis” and it implies that the recovery time is usually longer than the duration of the impact (Scheffer & Carpenter 2003).

If there is evidence of loss of functionality (i.e., the provision of one or more critical ecosystem services is lost), then the Factor 3.1 score will depend on how long ago the original ecosystem was converted to aquaculture production and on the type of ecosystem. If the farms were established prior to 1999 in original (or “pristine”) ecosystem, or more recently in a habitat that had previously lost functionality prior to 1999 (e.g., rice fields, pastures, dammed lakes/reservoirs), then the score will be higher (between 4 and 6 depending on the original habitat value) than if the aquaculture farm has been established after 1999 in a pristine habitat. This classification seeks to penalize the damage that resulted from aquaculture conversion, but avoids holding aquaculture industries responsible for previous or historic habitat conversions. Furthermore, the score depends on the type of the original habitat. Habitats are classified into high-, moderate-, and low-value according to the quantity and quality of critical ecosystems services that they provide. Ongoing conversion of high-value habitats resulting in a loss of functionality results in a zero score, and ongoing loss of habitat functionality due to illegal siting activity results in a Critical score.

Factor 3.2 – Management effectiveness

The impact of habitat conversion can be considered cumulatively and proximally, with individual farms contributing incrementally to effects at the landscape level, likely having the greater overall impact. However, Seafood Watch believes it important to consider both levels of impact. In order to determine the cumulative impact of aquaculture on habitat function, Factor 3.2 assesses the existence and enforcement of regulations that control and/or limit aquaculture industry size and concentration, or in their absence, effective industry management measures. Aquaculture siting management requires a regional, ecosystem-based approach focused on the assimilative capacity determined by baseline conditions. An appropriate farm siting involves in-depth knowledge of the environment, as well as an understanding of different institutional factors (Longdill et al. 2008). The ecosystem approach should consider the aquaculture operation within the wider ecosystem (Soto et al. 2008), by protecting community resources, and promoting the rehabilitation of degraded habitats. Therefore, the siting process should be part of wider zoning plans such as Integrated Coastal Zone Management (Primavera 2006). Furthermore, the siting and regulation process not only has to be based on ecological principles, but should be consistent, transparent, and objective (King & Pushchak 2008).

Factor 3.2a – Content of management measures

This factor is intended to assess the strength of management systems in place that regulate or effectively manage aquaculture operations. It is the assumption of Seafood Watch that regulatory systems managing impacts according to area management practices or cumulative impacts are most appropriate for addressing impacts from aquaculture industries, as it is possible for aquaculture operations that are managed at the farm level to overlook potential cumulative habitat impacts. However, it is also possible for aquaculture to be managed in a way that has a minimal overall impact if the farm's size and location, or the concentration and connectivity of multiple farms, are well managed or regulated. Furthermore, the ability for area-based management systems to mitigate cumulative impacts is still being determined.

Factor 3.2b – Enforcement of management measures

This factor is intended to assess the enforcement and applicability of management systems in place. It is the view of Seafood Watch that a management system is only as strong as its enforcement mechanism. If a management system exists but is not being enforced, it is not considered to be effective.

The final score for F3.2 results from the multiplication of these two factors (3.2a and 3.2b). By doing this, a high score is only achieved if both factors present high values (i.e., good regulations and good enforcement). Alternatively, even if the regulatory and management effectiveness is good, a lack of enforcement will result in a low overall score for Factor 3.2.

It is recognized that the regulatory or management effectiveness and enforcement (although it is actually considered to be the controlling factor in large-scale habitat and ecosystem impacts of aquaculture) is typically not in the direct control of the aquaculture operations being assessed. Aquaculture operations do have control of the specific site selection and the habitats directly impacted; therefore Factor 3.1 is given a double weighting compared to Factor 3.2 in the final score.

Scoring of the Habitat criterion as Critical occurs when the Factor 3.1 Habitat conversion and function score is 0 of 10 meaning that there is ongoing conversion of high-value habitats due to illegal siting activities that results in the loss of ecosystem services.

Scoring of the Habitat criterion as Critical also occurs if the Final score for the Criterion is 0 of 10. This is the result of scores of 0 of 10 in Factors 3.1 Habitat conversion and function and 3.2 Farm siting regulation and management.

Polyculture Assessments
For assessments concerning polyculture systems, consider the impacts of the entire production system on the occupied habitat.

Habitat: Factor 3.1 – Habitat conversion and function

A categorical measure of habitat impact taking account of the ongoing functionality of affected habitats and the historic or ongoing nature of the habitat conversion for aquaculture.

Definitions:

- Maintaining functionality – aquaculture has not caused the loss of any critical ecosystem services.
- Loss of functionality – aquaculture has caused "major" habitat impacts, defined as the loss of one or more critical ecosystem services.
- Critical ecosystem services are those that:
    - society depends on or values;
    - are undergoing (or are vulnerable to) rapid change;
    - have no technological or off-site substitutes.

Note: Because the Seafood Watch Aquaculture Standard assesses all production systems in various habitats in all locations around the world, a single, specific definition of "critical" ecosystem services may not be universally applicable. The three principles that are outlined above are intended to guide analysts in evaluating which ecosystem services in the area of the assessment are critical.

Assessment Instructions:

Step 1

- Determine the appropriate habitat type for the farm, farms, region or industry being assessed. Use "average" habitat types where necessary, or split the assessment into different recommendations if habitat types lead to different scores and overall ranks.

Step 2

- With consideration of the overall scale and intensity of the industry in any one habitat type, determine if key ecosystem services continue to function, and the degree of functionality remaining.
    - If all critical ecosystem services are maintained[17], the habitat is considered to be "maintaining full functionality".
    - If all critical ecosystem services are maintained to some degree, the habitat is considered to be "maintaining functionality" and the score will depend on the degree of impact.

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[17] For aquaculture located in modified habitats such as reservoirs, dammed lakes or canals, agricultural lands etc., consider the ecosystem services provided by the modified habitat and the impacts of aquaculture upon them.

  - If any critical ecosystem service has been lost, the habitat is considered to have lost functionality.
- If the habitats are considered to be maintaining functionality, then use Table 1 and the examples in the Appendix to determine the appropriate score.
- If the habitat is considered to have lost functionality, go to Step 3.

Step 3
- If the habitats are considered to have lost functionality, then consider the scores in Table 2 along with the timeframe of historic and/or ongoing habitat loss
- Use the habitat values in Table 3 where necessary.

Habitat: Table 1 – Maintaining habitat functionality

Habitat Functionality	Impact on Habitat Functionality	Score
Maintaining functionality	Maintaining full functionality	10
	Minimal impacts	9
	Minor-moderate impacts	8
	Moderate impacts	7
Loss of functionality	Major impacts	Go to Table 2

Habitat: Table 2 – Loss of habitat functionality

Timeframe of Habitat Loss	Habitat Value	Score
Historic loss of functionality occurred prior to 1999	Low	6
Historic loss of functionality occurred prior to 1999	Moderate	5
Historic loss of functionality occurred prior to 1999	High	4
Loss of functionality occurred after 1999, or ongoing loss of functionality	Low	3
Loss of functionality occurred after 1999, or ongoing loss of functionality	Moderate	2
Loss of functionality occurred after 1999	High	1
Ongoing loss of habitat functionality	High	0
Ongoing loss of habitat functionality due to illegal siting activity	High	Critical

Habitat: Table 3 – Habitat value[18]

High	Moderate	Low
Coastal intertidal Coastal/terrestrial shoreline Estuaries Tidal wetlands and forests Freshwater wetlands Coral reefs	Coastal inshore sub-tidal[19] Riparian land and floodplains Temperate broadleaf and mixed forests	Open ocean/offshore[20] Coniferous forests Grasslands, savanna and shrublands Desert and dry shrublands Modified habitat[21]

[18] The designations of value for each of the habitats listed in Table 3 are generalizations, and if data support a higher or lower value of a particular habitat within the scope of an assessment, that value shall supercede the generalization.
[19] Inshore sub-tidal = approximately from zero to three nautical miles from the main coastline.
[20] Open ocean/offshore = greater than three nautical miles offshore.
[21] For example, reservoirs, dammed lakes or canals, agricultural lands, etc.

Seagrass/algae beds Freshwater lakes Rivers and streams Tropical broadleaf and mixed forests		

Factor 3.1 score = ______ (range 0–10)

Habitat: Factor 3.2 – Farm siting regulation and management

Ecosystem impacts are driven largely by the cumulative effects of multiple farms in a location, habitat type, region or a country, and on their separation distances, connectivity and overall intensity. This factor (3.2) is a measure of the presence and effectiveness of regulatory or management measures appropriate to the scale of the industry, and therefore a measure of confidence that the cumulative impacts of farms sited in the habitats declared in Factor 3.1 above are at appropriate spatial scales.

Regulations or management measures relates to policies, legislation or regulations, aquaculture zoning, zonal management, and/or independently verified management measures such as codes of practice, Best Management Practices or certification schemes that have the appropriate language[22] and authority for enactment.

Assessment instructions
Consider the content of relevant management measures such as:

- National[23], regional or local habitat regulations.
- Applicable industry codes of good practice.
- Applicable area-based or producer organization agreements, or farm-level management systems.
- Any other management measures relating to habitat.

Contact relevant management agencies and in-country NGO, academic or industry experts and decide the appropriate content score from the broad descriptions in the following table:

For third-party certified farms or other independently verified standards, it is acceptable to answer the questions relating to the relevant standards and inspection/audit process where these are considered to be more robust than the regulatory (or other) system at controlling impacts from multiple farms.

Factor 3.2a – Content of habitat management measures
Decide the appropriate content score from the broad descriptions in the following table:

Content	Description	Score
Comprehensive	Area based, cumulative management system is in place with aquaculture farm siting integrated with other industries based on	5

[22] Designed for, or applicable to aquaculture – as opposed to regulations designed for fisheries, agriculture or other activities or industries that are poorly related to the needs of aquaculture regulation. Appropriate language – avoidance of "should", "minimize", etc.
[23] Use the relevant FAO National Aquaculture Legislation Overview (NALO) country factsheet if necessary.

	maintaining ecosystem functionality of the affected habitats. Future expansion is addressed accordingly, and if relevant[24], restoration of former high value habitats is required.	
Robust	Area based, cumulative management system is in place for aquaculture farm siting based on maintaining ecosystem functionality of the affected habitats, or acceptable habitat impacts are defined within an ecosystem- and area-based habitat management system. Future expansion is addressed accordingly, and if relevant, restoration of former high value habitats is encouraged.	4
Moderate	The management system requires farms to be sited according to ecological principles and/or environmental considerations (e.g., EIAs may be required for new sites), but there are limited considerations of cumulative habitat impacts and loss of ecosystem services.	3
Limited	The management system may be based on ecological principles, but do not account for habitat connectivity and cumulative impacts on ecosystem services.	2
Minimal	Unknown or unclear management system for aquaculture, or the management system is not based on ecological principles.	1
Absent	No relevant management systems in place for aquaculture siting and habitat impacts.	0

Factor 3.2a score = ______ (range 0–5)

Factor 3.2b – Enforcement of habitat management measures
Consider the available information on the enforcement of the habitat management measures apparent in Factor 3.2a above and decide the appropriate enforcement score from the broad descriptions in the following table.

Enforcement	Description	Score
Highly Effective	Enforcement organizations are identifiable and contactable, and their resources are appropriate to the scale of the industry. Enforcement is active at the area-based or habitat scale, the permitting or licensing process is transparent[25], and evidence of penalties for infringements are available.	5
Effective	As Highly Effective above, but with minor limitations to any aspect.	4
Moderate	Enforcement organizations are identifiable and active, but have limitations in resources or activities that reduce effectiveness. Cumulative habitat impacts may not be fully addressed, and some gaps in transparency or compliance data may be apparent.	3
Limited	Enforcement measures are limited, do not cover cumulative habitat impacts, or transparency and compliance data are limited.	2

[24] Restoration is relevant if high value habitats (as defined in Section 3.1) have been converted for aquaculture or ecosystem services have been lost.
[25] For example, public availability of farm locations and sizes, EIA reports, zoning plans, etc.

Minimal	Enforcement organizations and their activities are difficult to identify. Little evidence of monitoring or compliance data, or limited evidence of penalties for infringements.	1
Ineffective	No evidence of enforcement activity. Persistent illegal siting activities occurring[26]	0

Factor 3.2b score = _______ (range 0–5)

Factor 3.2 Siting management score = (3.2a x 3.2b) / 2.5 = _______ (range 0–10)

Final Habitat Criterion score = [(2 x Factor 3.1) + (Factor 3.2)] / 3
Habitat Criterion score = ________ (Range 0–10) (Zero score = Critical)

Criterion 4 – Chemical Use

Impact, unit of sustainability and principle

- *Impact:* The use of chemical treatments can impact non-target organisms and lead to ecological and human health concerns due to the acute or chronic toxicity of chemicals and the development of chemical-resistant organisms.
- *Unit of sustainability:* Non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to treatments.
- *Principle:* Limit the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Background and Rationale

A wide range of chemicals are used in aquaculture systems for a variety of purposes, but most importantly they are applied for disease treatment and pest management. The most common classes of chemicals used include pesticides (parasiticides, piscicides), disinfectants, antibiotics/antimicrobials, antifoulants, anesthetics, and herbicides. The potential effects of chemical use on natural ecosystems and human health have raised growing awareness about the need for responsible practices (Cabello et al. 2013, Cole et al. 2008, Rico et al. 2012). Although the improvement of management practices in some production systems (e.g., Norwegian farmed salmon - Figure 4) has resulted in a multi-decadal reduction in chemical use, especially in antimicrobials, fish farmers still use chemicals on a regular basis in their operations (Milanao et al. 2011, Rico et al. 2012).

[26] E.g., Farm siting in MPAs, evidence of widespread illegal farm siting

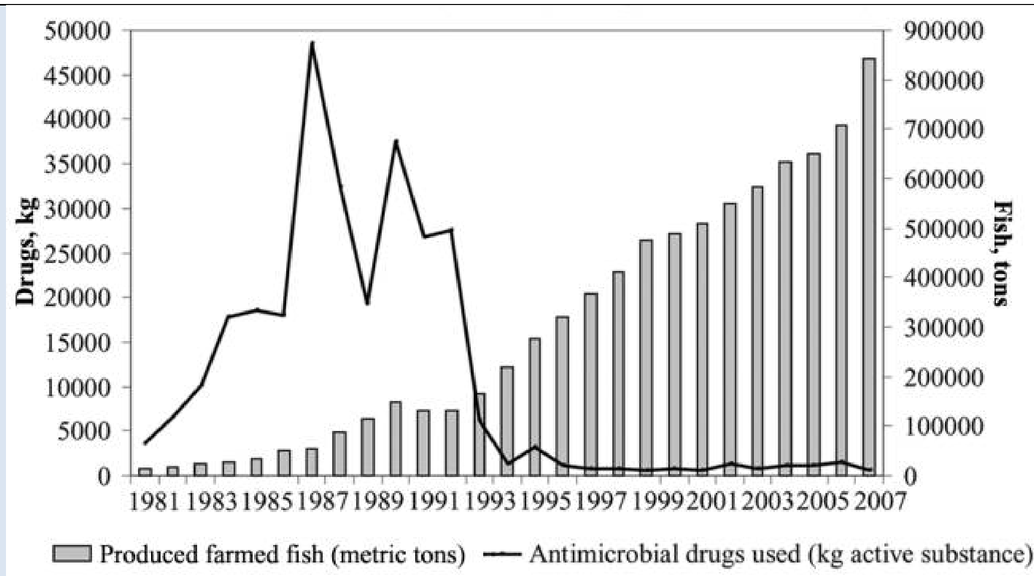

Figure 4 — Antimicrobial drug use, and farmed Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) production in Norway. From Heuer et al. (2009).

The potential negative ecological impacts associated with the use of chemicals are related to their toxicity and/or long term impacts to non-target organisms, and to other organisms such as bacteria, that may alter biogeochemical processes. Chemicals used in aquaculture operations can also reach wild fish and shellfish surrounding aquaculture sites. For instance, residues of antimicrobials were found in the tissue of two wild fish species near salmon farms in Chile (Fortt et al. 2007). Exposure to other chemicals such as copper can also cause adverse health effects in aquatic organisms (Santos et al. 2009). Some chemicals such as hydrogen peroxide break down rapidly in the environment into harmless components and are therefore of lower concern from an environmental perspective.

The improper use of antimicrobials, several of which are persistent in the environment, generally results in the emergence and spread of resistance against the drug (Buschmann et al. 2012). Millanao et al. (2011) demonstrate that the major concern with excessive antimicrobial use is the development of resistance by bacterial populations, particularly those listed as “Critically Important” for human medicine according to the World Health Organization (WHO, 2011). It is clear that any and every use of antimicrobials selects for resistance (Davies, 2010), and it is therefore essential that antimicrobial use is minimized and that they are used prudently.

The emergence of antimicrobial resistance among fish pathogens undermines the effectiveness of the prophylactic use of antimicrobials in aquaculture (Baquero et al. 2008). Resistance can be transmitted to bacteria of the terrestrial environment, including human pathogens (Cabello et al. 2006, Sapkota et al. 2008). The development of antimicrobial resistance in bacteria causing infections in humans may result in (1) an increased number of infections, and (2) an increased frequency of treatment failures and increased severity of infection (Heuer et al. 2009).

In the case of pesticide “therapeutants”, there is evidence of loss of sensitivity in sea louse to emamectin benzoate in at least Chile (Bravo et al. 2008) and Canada (Jones et al. 2013, Burridge and Van Geest, 2014), and to cypermethrin in Norway, Scotland, and Ireland as a consequence of their overuse in Atlantic salmon farms (Sevatdal et al. 2005).

The impact of chemical use depends on the extent to which these chemicals reach the environment. Therefore, the degree of openness of culture facilities ultimately determines the risk associated with chemical use. Open systems such as cages or frequently exchanging ponds inherently carry the highest risks, as unconsumed food and fish waste, both of which will contain antimicrobial residues, are directly released to the environment. According to Christensen et al. (2006), 70-80% of the antimicrobials administered as medicated pelleted feed are released into the aquatic environment via urinary and fecal excretion and in unconsumed medicated food. In contrast, closed systems present the lowest risk of releasing these chemicals into the environment (Tal et al. 2009).

Unfortunately, robust data on chemical use (type, toxicity, frequency of use, dose, discharge, decomposition, dilution, etc.) are rarely available. Furthermore, there is little consistency (i.e., pattern of chemical use) between different production species, production systems, or countries. The use of chemicals is regulated by the legislation of each country, and thus, a chemical that is legal in one country can be considered illegal in other country. Regulations related to the requirement to publically report chemical use are also inconsistent among countries (Burridge et al. 2010).

Existing regulatory controls or management measures on chemical use are typically restricted to the types of treatments permitted and their method of use (e.g., “responsible” use under veterinary supervision), but often do not limit the frequency or total use of chemicals. Seafood Watch will not defer to regulations or other management measures as a proxy for “sustainable” chemical use unless they include robust limits on total use, or the permitted use of those chemicals has been justified by monitoring and assessment of ecological impacts.

The score of this criterion is based on the evidence of the use of chemicals, and the risk of their incorporation into the receiving environment, dictated by the openness of the facilities. Closed production systems that do not discharge chemicals or their by-products, systems that present evidence of no use of chemicals over the most recent three consecutive production cycles (or years, for cycles longer than one year) and have a demonstrably low need for chemical use, or systems in which effluent treatment does not allow chemical discharge to present concern, earn the highest score (10 out of 10) in the scoring table. In contrast, the use of illegal chemicals, the use of antimicrobials highly important for human medicine in unknown quantities, or a negative impact on non-target organisms beyond an allowable zone of effect register the lowest score (0 out of 10).

Criterion 4 may be scored as Critical if there is a) evidence of pathogens with developed clinical resistance to antimicrobials that are highly important or critically important for human medicine; b) there is use of critically important antimicrobials in significant or unknown quantities, or c) if there is illegal use of chemicals that results in negative ecological impact.

Trend adjustment

This criterion assesses current chemical use and does not assess the risk that chemical use *could* increase in the future (for example, in response to a future disease outbreak). In addition, the trend adjustment option recognizes decreasing trends in chemical use while still reflecting the overall quantity and frequency of use of chemicals in an industry. If data show a decline in chemical use over time sufficient to give confidence that improving management practices are leading to clear reductions in use and the risk of impacts, a positive adjustment of up to 2 points can be applied based on the duration and rate of the decline and the current level of use where a clear reduction in concern is justified. For example, an assessment scoring 2 out of 10 due to "Occasional, temporary or minor evidence of impacts to non-target organisms beyond an allowable zone of effect" could increase their score to 4 out of 10 if it is demonstrated that there is an ongoing decreasing trend in the quantity and frequency of use of chemicals over the last decade that signifies improvements in management practices.

There is a minimum of 5 years for a trend adjustment to be applicable based on the assumption that any timeframe less than 5 years could be considered "coincidence." Continued decrease in chemical use between 5-10 years can be recognized with increasing adjustment up to 2 points. The trend adjustment does not apply to a Critical base score.

Assessment Guide
The criterion is structured flexibly to allow for the typical poor availability and low confidence in chemical use data.

Chemical treatments of concern relevant to this criterion are broadly defined as those products used in aquaculture to kill or control aquatic organisms, and/or whose use may impact non-target organisms or raise concerns relevant to human health. It does not include chemicals such as mercury, PCBs, dioxins or other environmental contaminants associated with feed ingredients and those are not assessed in the Seafood Watch Aquaculture Standard. Chemicals such as anti-foulants, anesthetics and others can be accounted for in this assessment when there is evidence of impacts.

If data on chemical use (e.g., types, quantity) or evidence of impacts (e.g., development of resistance, impacts to non-target species) are available, use it to determine the appropriate score from the following table. If robust data are not available, use the options based on the species or production system characteristics as a proxy for an assessment of risk.

Consider **ALL** the options in the following table and determine the appropriate level of concern before scoring. If chemical use (e.g., type or quantity) and/or impacts are unknown, use the production system-based options. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Polyculture systems
For assessments concerning polyculture systems, conduct multiple assessments (one for each species in the system) with impacts or risk of impacts allocated to the species for whom chemical treatment/application is intended. If more than one species is treated, then impacts are allocated accordingly to each treated species. If data are not available to determine which species are treated and which are not, all species in the system will receive the score appropriate for the chemical use that is known.

Trend adjustment

If data show a decline in chemical use over time sufficient to give confidence that improving management practices are leading to clear reductions in use and the risk of impacts, a positive adjustment of up to 2 points can be made based on the duration and rate[27] of the decline and the current level of use where a clear reduction in concern is justified.

The trend adjustment does not apply to a Critical base score.

Concern	Chemical Use Examples	Score
Very low	▪ The production system is closed and does not discharge active chemicals or by-products (e.g., antibiotic/antimicrobial resistant bacteria), or; ▪ The data score for chemical use is 7.5 or 10 of 10 and data show that chemical treatments have not been used for the most recent three consecutive production cycles or three consecutive years for cycles longer than one year, and the species or production system has a demonstrably low need for chemical use, or; ▪ The method of treatment does not allow active chemicals or by-products to be discharged, or;	10
Low	▪ The data score for chemical use is 7.5 or 10 of 10 and data show that chemical treatments are used on average less than once[28] per production cycle or once per year for longer production cycles, or; ▪ The production system does not discharge water over multiple production cycles, or; ▪ Evidence of no impacts on non-target organisms, or;	8
Low-moderate	▪ Specific data may be limited, but the species or production systems have a demonstrably low need for chemical use, or; ▪ Evidence of only minor impacts on non-target species within the allowable zone of effect (i.e., no population-level impacts), or; ▪ The production system has very infrequent or limited discharge of water (e.g., once per production cycle or < 1% per day).	6
Moderate	▪ Occasional, temporary or minor[29] evidence of impacts to non-target organisms beyond an allowable zone of effect, or; ▪ Some evidence or concern of clinical resistance[30] to chemical treatments, or; ▪ Regulations, management or mitigation measures with demonstrated effective enforcement are in place that limit the frequency of use and/or total use of chemicals, or their impacts	4

[27] Duration and rate definition: for example, a 5-year trend with a rate of decline sufficient to give confidence that improving management practices are leading to clear reductions in chemical use and the risk of impacts = 1 point; 10 years = 2 points

[28] A treatment is a single course of medication given to address a specific disease issue and that may last a number of days. For sites with multiple production units, the number of treatments is scoped to the unit that treatment courses are administered and which have their own production cycle.

[29] Refers to impacts to individual animals only (no population level impacts).

[30] Clinical resistance is defined as a level of antimicrobial activity associated with high likelihood of therapeutic failure; typically evidenced by a documented reduced efficacy of treatment. The focus of concern is in veterinary applications.

Moderate-high	▪ Chemicals are known to be used on multiple occasions each production cycle and the treatment method allows their release into the environment, or; ▪ Chemical use (type and/or volume) is unknown but the production viability is considered to be dependent on chemical intervention, and the treatment method allows their release into the environment, or; ▪ Regulatory limits on chemical type, frequency and/or dose exist with unknown enforcement effectiveness[31], or; ▪ Confirmed cases of clinical resistance to chemical treatments with no effective mitigation measures, or; ▪ Evidence indicates antimicrobials highly important for human medicine[32] are being used in significant[33] quantities.	2
High	▪ Illegal chemicals (as defined by the country of production) are used beyond exceptional cases[34], or; ▪ Evidence indicates antimicrobials highly important for human medicine are being used in unknown quantities, or; ▪ Negative impacts of chemical use seen on non-target organisms beyond an allowable zone of effect.	0
Critical	▪ Evidence of developed clinical resistance to antimicrobials (e.g., loss of efficacy of treatments) that are highly important or critically important for human medicine, or; ▪ Illegal activities with demonstrable, persistent, negative environmental impacts. ▪ Evidence indicates antimicrobials critically important for human medicine[35] are being used in significant or unknown quantities.	C

**Note:* Intermediate values (i.e., 1, 3, 5, 7, or 9) may be used when justified or needed.

Chemical Use score = _______ (range 0–10 or Critical)
Trend adjustment =_________ (range 0-2)
Final Chemical Use criterion score = ________ (range 0-10 or Critical)

[31] While limits may exist, Seafood Watch does not defer to regulation as a proxy for ecological conservation
[32] Highly important antimicrobials listed in - https://apps.who.int/iris/bitstream/handle/10665/312266/9789241515528-eng.pdf?ua=1have been used in the current or previous production cycle.
[33] Significant definition: the average frequency of use of the farms being assessed is more than once per production cycle, or if data on the total volume of antimicrobial use (if this is the only data available) imply the same (estimated).
[34] Exceptional cases definition: use is clearly limited to a small minority of producers in an industry, or the frequency of use at the farm-level is no more than once in a three year period.
[35] Critically important antimicrobials listed in: https://apps.who.int/iris/bitstream/handle/10665/312266/9789241515528-eng.pdf?ua=1

Criterion 5 - Feed

Impact, unit of sustainability and principle

- *Impact:* Feed consumption, feed type, ingredients used, and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and the efficiency of conversion can result in net food gains or dramatic net losses of nutrients.
- *Unit of sustainability:* The amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.
- *Principle:* Sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Background and Rationale

Feed continues to be a major factor affecting the sustainability of aquaculture, especially in intensive systems that rely entirely on external feeding. The globalization of the aquaculture industry requires that feed ingredients are often sourced from locations distant to the aquaculture operations (Lebel et al. 2002), and while marine ingredients have traditionally been the focus of concern (Naylor & Burke, 2005), the production and common use of terrestrial ingredients (crop and livestock-derived) and emerging use of 'alternative' ingredients (e.g., insect meals/oils, algal meals/oils, single-cell proteins, etc.) also have impacts on the environment. As the substitution of marine ingredients in aquaculture feeds increases, it becomes more important to account for their impacts (Boissy et al. 2011).

The Seafood Watch Feed Criterion assesses three core aspects of feed use:

1. The use of wild fish
2. The net protein gain or loss
3. The 'global impact' of feed production

The combination of these three aspects allows a thorough assessment of the ecological impacts of feed use in aquaculture. For example, the structure of the equations allow the following variety of practical feed aspects to be assessed:

- The efficiency of using wild fish to produce farmed fish
- The sustainability of the sources of fishmeal and fish oil
- The use of crop, animal, and emerging 'alternative' ingredients to replace fishmeal and fish oil
- The net gain or loss of protein from the aquaculture operation
- The global warming potential of feed ingredient production and use

Feed formulations are still typically considered proprietary and ingredient sources change frequently; therefore, this criterion must work with very limited data if necessary, but also encourage greater data availability by rewarding access to better feed composition information. These core aspects and their components are designed to work within the practical limits of data availability and allow a comprehensive assessment of feed use in aquaculture at any scale.

The Seafood Watch Feed Criterion is only applied to production systems that provide external feeds of some kind; species such as bivalve shellfish or fish or shrimp grown in extensive ponds with no additional feed are scored 10 out of 10.

By-product and non-edible feed ingredients

Robustly assessing the use of by-product ingredients (e.g., fisheries or land-animal by-products) in aquaculture feeds is enormously complex. The factors associated with their determination as by-products (i.e., something produced incidentally to the production process) or as co-products (any of two or more product outputs from a production process) are complex, as are the factors determining the ecological impact of their harvest (i.e., the ecological value of fish viscera versus fish fillets of low/high economic value respectively). The economic value of poultry by-products is low, whereas the ecological cost of production is high (i.e., chicken feed is needed to make both chicken breasts and chicken viscera). Both have high nutritional values.

A similarly complex debate revolves around the “edible” or “non-edible” nature of feed ingredients with regard to their suitability for human consumption either in their original form (e.g., Peruvian anchovy or soybeans) or their processed forms (fish meal or oil, and soybean meal or oil), and the use of land to grow “edible” food or feed-grade crops. Many, if not all, feed ingredients are considered physically or culturally inedible due to their inputs and/or processing (e.g., feed-grade soybean meal, dried distillers grains, feather meal, fishmeal sourced from by-products, insect meal fed food wastes, methanotrophic microbes, etc.). On the other hand, when considering the opportunity cost of production, it is possible to argue that all of these ingredients may be considered edible (e.g., growing and/or processing food-grade crops, extracting edible protein from animal and vegetable “wastes”, etc.).

While focusing on ecological impacts, Seafood Watch does not intend to perversely incentivize the use of one feed ingredient over another, and in recognition of the complexities described, Seafood Watch assesses all ingredients, inclusive of those considered “by-products”, “co-products”, “edible” or “inedible”.

Seafood Watch uses the “economic allocation” of impact for feed ingredients, whereby the ecological impact of a process is proportionately allocated between its co-products based on their economic value. While this approach is imperfect–economic value is both temporally and spatially variable–“economic allocation between co-products reflects the rationale for which producers create environmental burdens” and is commonly applied in assessing agriculture systems (Poore and Nemecek, 2018). From a conservation perspective, it makes good sense that the primary economic driver of an activity bears the primary ecological burden of that activity.

Allocation criteria are based on relationships that link system inputs and co-product outputs and reflect material flows logically, and causality is generally “the most appropriate relational property” for determining allocation criteria (Pelletier and Tyedmers 2011). Economic allocation is driven by socioeconomic causality (e.g., poultry are farmed for edible meat, not viscera, thus allocation of more impact to the meat), whereas other allocation methods have been proposed in attempt to more accurately reflect the physical causality within agricultural systems, often referred to as “biophysical allocation”. While the developing alternatives to economic allocation are promising, the debate over how to allocate between co-products in these types of systems is ongoing, and to date, proposed methodologies have not resolved “the problem of mixing socioeconomic causality with physical causality", a major criticism of economic allocation (Mackenzie et al. 2017; Pelletier and Tyedmers 2011; Ayer et al. 2007). Despite its well-documented shortcomings, a major advantage of economic allocation is that is can be applied consistently across complex systems (Eady et al. 2012), and given the complexity of global feed ingredient production, economic allocation is applied where appropriate in Criterion 5. Seafood Watch intends to revisit this decision as consensus in the scientific community emerges.

Factor 5.1 – Wild Fish Use

This factor combines the amount of wild fish used in feeds with the sustainability of the source fishery to give a measure of "wild fish use".

While it is acknowledged that the common measures of whole fish use (i.e., the Feed Fish Efficiency Ratio, FFER) are not perfect, Seafood Watch uses the "academic" equation (e.g., Naylor et al. 2009) as opposed to the "industry" equation (e.g., Jackson, 2009). This equation provides a simple measure from first principles of the number of tons of wild fish that must be caught to produce one ton of farmed fish. This calculation is inclusive of both whole fish and by-product fishmeal and fish oil ingredients.

As described in the previous section, Seafood Watch assesses all ingredients, regardless of their consideration as by-products or co-products. Fishmeal and fish oil sourced from fishery and aquaculture processing by-products (skin, offal, bone, etc.) have an ecological cost of production, despite relatively low economic value and minor to negligible contribution to the economic viability of the activity from which they are sourced. Literature indicates that seafood processing by-products generally represent <5% of the total economic value of the process, but can represent 40-70% of the mass balance (Newton et al. 2013; Ayer et al. 2007). In recognition of this, 5% of the byproduct fishmeal and fish oil inclusion(s) is considered in the FFER calculation. This fraction reflects the economic value of these byproducts relative to the economic value of the activity, alongside the notion that from a conservation perspective, the primary driver of an activity (in this case, fishing or aquaculture for food production) should bear the primary ecological burden.

After an FFER has been calculated, the sustainability of the source fishery is assessed; this is a basic assessment that uses commonly available metrics that avoid the need for an independent fishery assessment.

Due to the importance of sustainably using marine feed ingredients in aquaculture, Factor 5.1 has several Critical decision points (listed for all criteria at the end of this standard) based on the use of highly unsustainable sources of fishmeal and fish oil, or the combination of a high use of marine ingredients and low protein conversion efficiency.

Factor 5.2 – Net Protein Gain or Loss

Seafood Watch principles note the importance of efficiently converting feed into seafood products. Aquaculture typically results in an overall net loss of protein of varying degrees depending on the species farmed, the feed formulation, and the production system. Crompton et al. (2010) concluded that aquaculture (in their case salmon) can be a net producer of fish protein and oil, but the authors only considered the fish protein inputs (ignoring all the other sources of protein in the feed). By considering all the other sources of protein included in the feed (in addition to fish protein), this criterion will demonstrate that in many forms of fed aquaculture, there is an overall (and frequently substantial) net loss of protein. A Critical score is assigned if there is a net loss of protein >90% (i.e., score 0 of 10 for Factor 5.2), or a loss of ≥80% of the protein where the FFER is >3. The equations for the net protein efficiency of the fish farming process are based on the feed protein inputs and the harvested fish protein outputs.

Factor 5.3 – Feed Footprint

Factor 5.3 uses the feed ingredient composition to determine the inclusion levels of each ingredient (or basic groups of ingredients – aquatic, crop, land animal) and estimate the global warming potential (CO_2-eq including land use change (LUC)) of the feed (at the ingredient farm-gate) used to produce one kilogram of seafood protein.

This factor utilizes life cycle assessment (LCA) data from the Global Feed Lifecycle Institute (GFLI)[36] database, a publicly available database[37] which provides high quality data covering cultivation, processing, and logistics for nearly 1,000 unique feed ingredient products. The GFLI is a feed industry initiative that arose in 2016 out of the need to measure the environmental impact of the feed and livestock sectors with a global scope, and its members include major feed and ingredient manufacturers[38],[39]. The GFLI methodology follows guidelines developed by the FAO Livestock Environmental Assessment and Performance (LEAP) Partnership, and Product Environmental Footprint (PEF) methodology guidelines developed by the European Commission, ensuring compliance with recognized LCA methodology requirements.

The background datasets included in this database are the United States Life Cycle Inventory (USLCI) and European reference Life Cycle Database (ELCD), with data included from additional datasets proven to be compliant with GFLI methodology. While this database is continuously being updated (as of February 2020, most recently in July 2019), there are still gaps – such as datasets covering Asian feed ingredient production. Despite these current gaps, this database is currently the strongest publicly available reference for feed ingredient LCA data and is used to assess global warming potential of feed ingredients in this Factor.

Feed Criterion Final Score

The final score is the average of the three factor scores with a double-weighting on the wild fish use factor (Factor 5.1). The double-weighting is used because Seafood Watch considers the direct harvest of wild fish to be the primary environmental concern of aquaculture feeds compared to the terrestrial production of feed ingredients from crops and land animals. If Factor 5.1 or Factor 5.2 has scored Critical (see "Overall score and final recommendation" on page 65 for listing of all Critical decision points), the final score for the Feed criterion will be Critical and the final recommendation of the assessment will be Avoid.

[36] http://globalfeedlca.org/
[37] https://tools.blonkconsultants.nl/tool/gfli/
[38] http://globalfeedlca.org/gfli-members/our-members/
[39] http://globalfeedlca.org/wp-content/uploads/2017/03/full-paper-GFLI-food-LCA-2016-final.pdf

Assessment instructions:

This criterion is only applied to those aquaculture operations that use external feed. If no external feed is applied, the score is 10 out of 10. Please refer to Appendix 3 for additional guidance regarding the calculations in this Criterion.

Polyculture systems

For assessments concerning polyculture systems, the methodology is dependent upon whether there is enough data availability to allocate feed impacts between all species in the polyculture system. To determine which methodology to use, see Appendix 4 for guidance.

Step 1

- Determine the appropriate feed crude protein, economic feed conversion ratio (eFCR) and feed ingredient composition for the industry being assessed, and fill in the table below. Use "average" feed composition(s) where necessary, or split the assessment into different recommendations if feed types lead to different scores and overall ratings.

Feed crude protein: _____ %
Economic feed conversion ratio (eFCR): _____

Feed ingredients (list ingredient, country of origin, and gear type if relevant)	**Feed type 1** Ingredient inclusion %	**Feed type 2** Ingredient inclusion %	Add columns as necessary
Fishmeal			
Fishmeal from by-products			
(add rows as necessary)			
Fish oil			
Fish oil from by-products			
(add rows as necessary)			
Vegetable/crop ingredient(s)			
(add rows as necessary)			
Land animal ingredient(s)			
(add rows as necessary)			
Alternative ingredient(s) (e.g., insect meal, microbe meal, algae oil, etc.)			
(add rows as necessary)			

Feed: Factor 5.1 – Wild fish use

A measure of the amount of wild fish used to produce farmed fish, combined with the sustainability of the fisheries from which they are sourced. Factor 5.1 combines the amount of wild fish used (Factor 5.1a) with the sustainability of the source fishery (Factor 5.1b) to give a score from 0-10 for "wild fish use".

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)
A measure of the dependency on wild fisheries for feed ingredients using the ratio of the amount of wild fish used in feeds to the harvested farmed fish.[40]

Use the best available (most recent or relevant) data:

a) Fishmeal (from whole fish) inclusion level*† = _____ %
b) Fishmeal (from by-products) inclusion level† = _____ % × .05[41] = _____ %
c) Fish oil (from whole fish) inclusion level*† = _____ %
d) Fish oil (from by-products) inclusion level† = _____ % × .05[41] = _____ %
e) Fishmeal yield % = _____ (use 22.5[42] if value is unknown)
f) Fish oil yield % = _____ (use 5.0[34] if value is unknown
g) Economic FCR[43] = _____

Note on the use of whole (unprocessed) or "trash" fish for feed* **– If whole fish are used as feed, the eFCR effectively determines the FFER value. Use eFCR as the FFER value (or entering 22.5 as the FM inclusion level and 5 for FO in the equations along with the eFCR will give the same result).

†*Note on fishmeal and fish oil inclusions* **–** Use the actual inclusion percentage of both whole fish and by-product fishmeal and fish oil. For example, if a feed contains 20% fishmeal, and 50% of fishmeal is from by-products, (a) would be 10% and (b) would be 10%, as 10% of the feed is whole fish fishmeal, and 10% is by-product fishmeal.

<u>Fishmeal and fish oil yield values:</u>
The calculation of the FFER requires the input of the yield values for fishmeal and fish oil. Yield values that are commonly used in key literature and by industry are 22.5% for fishmeal and 5% for fish oil (Peron 2010, Tacon & Metian 2008). Where data specific to the ingredients used in the assessment are not available, these default values should be used.

$$FFER_{FishMEAL} = \frac{(a+b) \times g}{e} =$$

$$FFER_{Fish\ OIL} = \frac{(c+d) \times g}{f} =$$

Final FFER value = the greater value of $FFER_{FishMEAL}$ or $FFER_{Fish\ OIL}$
Final FFER value = _______

Factor 5.1b – Source fishery sustainability

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[40] Also commonly referred to as the FFDR – Forage Fish Dependency Ratio or FIFO – Fish In : Fish Out Ratio
[41] This value is intended to capture the ecological cost of production associated with by-products. Please refer to the Background and Rationale for a detailed explanation.
[42] Yield values from Tacon and Metian (2008). Other (similar) values are possible from Peron et al. (2010), but data clarity is not sufficient for a robust quantification of fishery landings.
[43] Economic FCR or eFCR = total feed used divided by total harvest of fish.

A simple measure of the sustainability of the fisheries providing fishmeal and fish oil.

Step 1:
Using an average, or annual weighted estimate of the fishery sources used in a typical feed, decide or calculate the appropriate sustainability score according to the table below. When calculating a weighted average, total fishmeal and fish oil inclusions are the sum of the values determined in Factor 5.1a (e.g., fishmeal: a + b; fish oil: c + d).

Score	Fishery Sustainability Examples
10	SFW Green. Demonstrably sustainable.[44] FishSource scores all > 8. Fishery exceeds all reference points and has no significant concerns.
8	MSC certified without conditions. All FishSource scores ≥ 6 and must be ≥ 8 on "Stock Health". Fishery meets or is close to all reference points with only minor concerns.
6	SFW Yellow. All FishSource scores ≥ 6. MSC certified with conditions. Fishery does not meet all reference points or has some concerns.
4	IFFO certified 'Responsible'. FAO Code of Conduct compliant (independently verified). One FishSource score < 6.
2	SFW Red. More than one FishSource score < 6. Unknown sustainability. Fishery does not meet reference points or has significant concerns regarding bycatch or ecosystem impacts.
0	Unknown source fishery. Demonstrably unsustainable (e.g., overfished with overfishing occurring). Fishery source information deliberately withheld. Evidence that source of terrestrial ingredients from agriculture is known to destroy high value habitat.
Critical	SFW Red with a Critical score. Evidence that 25% or more of fishery is illegal, unregulated or unreported[45]. Fishery has unacceptable bycatch or ecosystem impacts. The assessed aquaculture operations generate or cumulatively contribute to unacceptable fishery practices (e.g., small mesh mixed trawl fisheries).

Source fishery sustainability score = ______ (range 0 to 10)

[44] On a realistic and pragmatic basis – i.e., the best current understanding of fishery sustainability (accepting that ecosystem-based forage fishery management is not yet fully developed).
[45] These fisheries are likely cited by peer reviewed literature, government reports, etc. Analyst can also refer to Seafood Watch report on that fishery for information.

If the source fishery sustainability score of any inclusion(s) of fishmeal or fish oil is Seafood Watch Red-rated (a score of 2), recalculate the FFER using only those ingredients. If the FFER resulting from Seafood Watch Red-rated fishery inclusions is ≥ 1, do not proceed to Step 2, and score Factor 5.1b Critical.

Step 2:
The final Wild Fish Use score is determined by selecting the appropriate score from the tables using the FFER value and the Sustainability Score.

	FFER Value																				
SS	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**
10	10	9.78	9.56	9.33	9.11	8.89	8.67	8.45	8.22	8.00	7.78	7.56	7.34	7.11	6.89	6.67	6.34	6.00	5.67	5.34	5.01
9	10	9.04	8.88	8.67	8.51	8.30	8.13	7.97	7.76	7.60	7.39	7.23	7.02	6.86	6.65	6.39	6.02	5.70	5.39	5.02	4.70
8	10	8.30	8.20	8.00	7.90	7.70	7.60	7.50	7.30	7.20	7.00	6.90	6.70	6.60	6.40	6.10	5.70	5.40	5.10	4.70	4.40
7	10	7.95	7.85	7.70	7.60	7.45	7.35	7.25	7.10	7.00	6.84	6.62	6.35	6.14	5.87	5.55	5.19	4.87	4.55	4.19	3.87
6	10	7.60	7.50	7.40	7.30	7.20	7.10	7.00	6.90	6.80	6.67	6.34	6.00	5.67	5.34	5.01	4.67	4.34	4.01	3.67	3.34
5	10	7.25	7.15	7.05	6.90	6.94	6.72	6.50	6.29	6.07	5.84	5.50	5.17	4.84	4.51	4.17	4.14	3.87	3.60	3.19	2.82
4	10	6.90	6.80	6.70	6.50	6.67	6.34	6.00	5.67	5.34	5.01	4.67	4.34	4.01	3.67	3.34	3.60	3.40	3.20	2.70	2.30
3	10	5.70	5.50	5.35	5.10	5.01	4.77	4.40	4.09	3.72	3.40	3.04	2.72	2.35	2.04	1.67	1.80	1.70	1.60	1.35	0.00
2	10	4.50	4.20	4.00	3.70	3.34	3.20	2.80	2.50	2.10	1.80	1.40	1.10	0.70	0.40	0	0	0	0	0	C
1	10	3.50	3.10	2.75	2.35	1.92	1.60	1.40	1.25	1.05	0	0	0	0	0	C	C	C	C	C	C
0	10	2.50	2.00	1.50	1.00	0.50	0.00	0.00	0	0	C	C	C	C	C	C	C	C	C	C	C
C	10	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

	FFER Value																			
SS	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**3.9**	**4.0**
10	4.67	4.34	4.01	3.67	3.34	3.01	2.67	2.34	2.01	1.68	1.34	1.00	0.67	0.33	0	0	0	0	0	C
9	4.39	3.87	3.60	3.29	3.02	2.70	2.39	2.12	1.80	1.49	1.22	0.90	0.58	0.32	0	0	0	0	0	C
8	4.10	3.40	3.20	2.90	2.70	2.40	2.10	1.90	1.60	1.30	1.10	0.80	0.50	0.30	0	0	0	0	0	C
7	3.65	3.10	2.80	2.50	2.20	1.90	1.55	1.30	0.95	0.65	0.55	0.40	0.25	0.15	0	0	0	0	0	C
6	3.20	2.80	2.40	2.10	1.70	1.40	1.00	0.70	0.30	0	0	0	0	0	0	0	0	0	0	C
5	2.50	2.10	1.65	1.30	0.85	0.70	0.50	0.35	0.15	0	0	0	0	0	C	C	C	C	C	C
4	1.80	1.40	0.90	0.50	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C
3	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
2	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
1	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

Factor 5.1 – Wild fish Use Score = _____ (range 0–10)

Feed: Factor 5.2 – Net protein gain or loss

A measure of the net protein efficiency of the fish farming process based on the feed protein inputs and the harvested fish protein outputs.

The net protein gain or loss is calculated according to the following basic equation:

Net Protein = (Harvested Protein Output – Feed Protein Input) / Feed Protein Input

Where:

- Feed Protein Input = % crude protein content of feed (*h*) x eFCR
- Harvested Protein Output (*b*) = % protein content of whole harvested fish

The crude protein content of feed should be readily available from the feed company or technical data sheets (and printed on every feed bag), or relevant examples should be available in the scientific literature. The feed protein content can vary considerably over the production cycle; ideally, a weighted average feed protein content would be used for the full cycle. Alternatively, use the protein content from the main (i.e., bulk) growout feeds. The protein contents of whole harvested fish are available from the literature.

Net protein gain is indicated by a positive result, and net protein loss is indicated by a negative result.

Final Factor 5.2 Calculation

Net Protein= $\frac{[b - (h \times eFCR)]}{(h \times eFCR) \times 100}$

Net protein gain = ______ % (indicated by positive result) OR
Net protein loss = ______ % (indicated by negative result)

	Protein Gain or Loss (%)	Score
Net protein gain	> 0	10
Net protein loss	0.1–9.9	9
	10–19.9	8
	20–29.9	7
	30–39.9	6
	40–49.9	5
	50–59.9	4
	60–69.9	3
	70–79.9	2
	80–89.9	1
	> 90	0

Factor 5.2 score = ______ (range 0–10). This is Critical if the score = zero

Feed: Factor 5.3 – Feed footprint

An approximate measure of the global resources used to produce aquaculture feeds based on the global warming potential (CO_2-eq including land use change (LUC)) of the feed ingredients necessary to grow one kilogram of farmed seafood protein.

Use the best available (most recent or relevant) data:

a) Economic feed conversion ratio (eFCR[46]) =
b) Whole harvested fish protein content: _____ %

Fill out the ingredient composition table below, using the Global Feed Lifecycle Institute (GFLI) database (economic allocation)[47] and feed composition as a reference.

Feed ingredients (≥2% inclusion) (please list ingredient and country of origin)	**GWP (incl. LUC)** kg CO2 eq / kg product	**Feed type 1** Ingredient inclusion %	**GWP (incl. LUC)** kg CO2 eq / mt feed
Example	= y	= z	= y × z × 10
Fishmeal			
Fishmeal from by-products			
(add rows as necessary)			
Fish oil			
Fish oil from by-products			
(add rows as necessary)			
Vegetable/crop ingredient(s)			
(add rows as necessary)			
Land animal ingredient(s)			
(add rows as necessary)			
Alternative ingredient(s) (e.g., insect meal, microbe meal, algae oil, etc.)			
(add rows as necessary)			
	Sum of total	= (c)	= (d)

If an individual crop, animal, and/or alternative ingredient is not found in the GFLI database, please refer to the aggregated value(s) for these categories (e.g., “Total vegetable meals”) in the database. If there is no appropriate category, do not include this ingredient inclusion in the calculation.

If an individual crop, animal, and/or alternative ingredient is found in the GFLI database and the origin is known but not found in the database, please refer to the aggregated value(s) for these categories (e.g., “Total vegetable meals”) in the database. If an individual crop, animal, and/or

[46] Economic FCR or eFCR = total feed used divided by total harvest of fish.
[47] The GFLI database can be accessed as an Excel file and downloaded here (with free registration) https://tools.blonkconsultants.nl/tool/gfli/. Download the “List of impacts (ReCiPe) (July 2019)” or more recent version, and select the “Economic Allocation” worksheet.

alternative ingredient is found in the GFLI database but the origin is not known, use an average value between the listed "GLO" value and the worst value for that ingredient.

To complete this Factor, the following calculation is performed. An example calculation for this Factor can be found in Appendix 3.

$$\frac{(a)}{(b)} \times \frac{[(d)\times 10]}{(c)} = \text{kg } CO_2 \text{ eq kg}^{-1} \text{ farmed seafood protein}$$

This value is considered the estimated total feed global warming potential (GWP). The score for Factor 5.3 is determined by selecting the appropriate score from the table below using the total feed global warming potential (GWP).

Impact	kg CO_2-eq kg^{-1} farmed seafood protein	Score
Zero	0	10
Low	0.1 - 4.4	9
	4.5 - 8.8	8
Low-moderate	8.9 - 13.2	7
	13.3 - 17.6	6
Moderate	17.7 - 22.0	5
	22.1 - 26.4	4
Moderate-high	26.5 - 30.8	3
	30.9 - 35.2	2
High	35.3 - 39.9	1
Very high	≥40	0

Factor 5.3 score = _______ (range 0–10)

Final feed criterion score = [(2 x Factor 5.1 score) + Factor 5.2 score + Factor 5.3 score] / 4
= _________ (range 0–10)

Criterion 6 – Escapes

Impact, unit of sustainability and principle

- *Impact:* Competition, altered genetic composition, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations.
- *Unit of sustainability:* Affected ecosystems and/or associated wild populations.
- *Principle:* Preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Background and Rationale

There is a growing body of evidence which demonstrates the negative impacts of the escape of some aquaculture species. The introduction of native or non-native escapees from aquaculture sites can threaten ecosystem integrity. Despite its importance, the specific impacts of escapees are usually difficult to predict because of the inherent difficulty in accurately documenting the number of escapes and, furthermore, assessing their impacts (Naylor et al. 2001, Simberloff 2005).

Robust data on escape numbers are rarely available due the difficulty of counting total numbers of fish at stocking and harvest and knowing what proportion of any loss is due to mortalities versus escapes. Data collection and reporting of escapes (both escape 'events' and chronic trickle losses) are very rarely robust, and monitoring for the presence of escapees in the wild is typically rare. In addition, many farmed species are broadcast spawners and spawning during the production cycle represents a potentially significant source of escapees in open systems.

The Escapes Criterion is therefore developed to assess the risk of escape from the production system, and the risk of invasiveness and potential ongoing impact to the surrounding ecosystem of those escapes.

Factor 6.1
Factor 6.1 assigns a level of risk to each type of production system based on the ability of farmed species to escape the system and enter the surrounding ecosystem. Production system escape risks are categorized as Low to High based on openness, management practices, escape trends, and vulnerability to environmental factors (e.g., tsunami, flood, predator damage, etc.).

Systems that are more open to the environment have an inherently higher risk of escape, however, it is recognized that improved technologies and management practices can result in lowering that risk. For example, adjustment of a "moderate-high" risk (Red) to a "moderate" risk (Yellow) can be employed if it can be demonstrated that improved technology and management of high-risk systems has resulted in a decrease of escapes to a level that does not pose a threat to wild, native populations.

In addition, an adjustment can be made to the Escape Risk score, of up to 10 points, to allow for the recapture of escapes where evidence shows that the reduction in escape numbers occurs before they have an impact[48], or where the reduction would lead to a reduced risk of impact. There is enormous complexity in determining risk reduction resulting from recapture, particularly for a multi-species and globally-applied standard. Though imperfect, the numerical adjustment to the base Factor 6.1 score correlates to the percentage of escapees that are recaptured.

Factor 6.2

[48] For example, if the main impact of farmed salmon escaping from sea cages occurs when they migrate into rivers, then mortality prior to reaching rivers can be included where it demonstrably leads to a reduction in the overall impact of the escapes.

Invasiveness, referred to as the risk of competitive and genetic interactions (CGI), is defined as "*…the degree to which an organism is able to spread from site of primary introduction, to establish a viable population in the ecosystem, to negatively affect biodiversity on the individual, community, or ecosystem level and cause adverse socioeconomic consequence"* (Panov et al. 2008). According to this definition, Factor 6.2 considers both the short-term and long-term ecological impacts of escape. This factor has been adapted (and greatly simplified) from the Marine Fish Invasiveness Screening Kit (MFISK) (and other similar tools developed by Copp et al. [2007, 2009]), and from the Global Aquaculture Performance Index (GAPI)'s similar use and adaptation of the same tools (Volpe et al. 2013).

The risk of impacts resulting from repeated escapes of farmed stock (regardless of their ability to establish), or the risks resulting in the establishment of escapees differs according to species-specific characteristics, and particularly between native and non-native species. While the escape of native species is often considered to be less harmful to the environment than the escape of non-native species, this characteristic alone is not enough to estimate the extent of their impacts.

Native

In the case of native species, the Competitive and Genetic Interactions (CGI) impact of their escape is related to the genetic differences between farm-origin escapees and their wild conspecifics, and also to other direct ecological impacts such as competition, predation, and spawning competition or disturbance. Native farmed species differ genetically from wild populations as a function of the number of generations that separates them from wild individuals and are a result of the artificial selection of traits that are beneficial to aquaculture producers. Selection for few, specific aquaculture-related traits typically results in phenotypic changes such as body size or age at sexual maturity and a lower diversity of traits that are beneficial to wild fish (i.e., the balance of growth rate, disease resistance, reproductive success, predator avoidance, etc.). Genetic introgression of farm-origin fish into wild genotypes can result in a loss of balance in these fitness-related traits, which may subsequently alter the overall fitness and dynamics of wild populations. Therefore, if farmed fish are of one generation of domestication or less (i.e., naturally-settled shellfish spat, wild-captured juvenile finfish), the escapees will pose no threat to altering the genetic make-up of the still-wild population. In contrast, the escape of fish raised in hatcheries for more than one generation presents higher concerns as a result of their potential to impact the genetic structure and demographic dynamics of wild populations (Kostow 2009). The increase in the number of captive-bred generations results in a greater degree of deliberate (and unintended) artificial selection, and thus, greater genetic differences between farmed and wild conspecifics are expected. Ultimately, genetic introgression resulting from escaped farm-origin fish may have two possible consequences: (1) the homogenization of genetic differences between populations that might reduce the long-term persistence of the wild populations, or (2) a reduction in fitness, and thus, a reduced productivity of offspring from parents (Bartley & Martinn 2004).

Non-native

The Competitive and Genetic Interactions (CGI) risk of non-native species is based on their potential for imposing negative impacts to wild organisms in the receiving environment resulting from their predation on wild stocks, habitat alteration, competition for feed sources, reproductive hybridization, or disruption of reproductive processes of wild fish. Additional risk occurs when non-native species present traits that favor ecological establishment, such as a tolerance to a broad suite of environmental conditions and rapid growth (Diana 2009), and in these cases, the potential of escaped, non-native species to become ecologically established is high. For example, there is increasing evidence of the negative impacts of farm-origin tilapia (in areas they are not native to) on the biodiversity of the environment into which they escape (Canonico et al. 2005).

It is noted, however, that in some cases non-native species are unable to survive or establish viable populations in the wild. In the case of Atlantic salmon in British Columbia for example, despite numerous escape events (and intentional introduction attempts for fishing), the establishment of breeding populations is uncertain (Bisson 2006, in Thorstand et al. 2008), and monitoring of rivers has not recently yielded reports of Atlantic salmon reproduction (Noakes 2011). Surveys using multiple types of traps in areas with a high probability for Atlantic salmon presence have yielded none of any life stage (DFO, 2013).

Seafood Watch recognizes that in some areas, intentional introduction of non-native species for purposes other than aquaculture has resulted in ecological establishment of non-native populations. In these cases, where viable populations were established in the wild prior to commercial aquaculture production of the species being assessed, or ongoing intentional introductions of conspecifics with identical genotypes are occurring, it is often considered that escapes of non-native species from aquaculture facilities will not have an additional ecological impact. This assumption does *not* apply where commercial aquaculture production has resulted in the ecological establishment of the species being assessed.

Ecological impacts of native and non-native species

Seafood Watch recognizes that in cases where establishment of an escaped non-native species does not occur, or genetics of native farmed species and their wild conspecifics are similar, repeated escapes from farms can still have ongoing impacts to ecosystems in a similar way that establishment of the species would (e.g., ongoing habitat alteration, predation on wild populations, competition for habitat and feed, etc.) (Fleming et al. 2000). Therefore, this factor assesses the frequency and intensity of escape events and their associated impact on wild populations (e.g., a small number of large-scale escape events of a species known to be unable to survive and establish populations in the wild could have less impact than ongoing small-scale escape events of a species known to be highly predatory.) A Critical score in Factor 6.2 results in a Critical score for Criterion 6.

Final scoring of Criterion 6 – Escapes

The final score is a combination of the scores for Factor 6.1 and Factor 6.2. A final numerical score of ≤1 of 10 results in a Critical score for the criterion, as it represents high escape numbers that are damaging to vulnerable or endangered wild populations.

Assessment scale

This criterion combines two factors; Factor 6.1 assesses the risk of escapes from a “typical” farm based on characteristics of the production system used. Factor 6.2 assesses the potential for escaped species to establish and have ongoing impacts to the ecosystem.

Polyculture Systems

For assessments concerning polyculture systems, conduct multiple assessments (one for each species in the system) and assign a score to each species.

Escapes: Factor 6.1 – Escape Risk Score

A measure of the escape risk (for the species being farmed) inherent in the production system, accounting for improvements in production system technology and management techniques when these changes have demonstrably resulted in low or no escapes.

Assessment Guidance
Consider the characteristics of the assessed production system, or the characteristics of a typical, representative or "average" production system in the industry being assessed. Also consider any available data on escapes, and then select the most appropriate score from the following table of examples. Consider all the options in the table below; while every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate Escape Risk score.

When assessing a single farm or a small portion of an industry, the escape score should be the typical score for the industry unless the assessed farms have demonstrably different production practices than the industry norm.

Concern	Escape Risk Examples	Score
Very low	▪ No connection to natural water bodies (i.e., fully biosecure), or; ▪ Tank based recirculation systems (≥ 80% reuse) with appropriate (multiple) screens, water treatment, and secondary capture devices.	10
Low	▪ Tank based recirculation systems (any % reuse) with (multiple) screens, water treatment, and secondary capture devices (but less robust than those resulting in score of 10), or; ▪ Static ponds with no water discharge (including at harvest) over multiple production cycles; not vulnerable[49] to flood, storm or tsunami damage, or; ▪ Robust data[50] on fish counting and escape records indicate escapes (catastrophic or trickle) do not occur (e.g., in the last 5 years), or; ▪ Independent monitoring data show that escapees are not present in the wild.	8
Low-moderate	▪ Any "Moderate concern" system (as defined in this table) that also uses multiple or fail-safe escape prevention methods, or active Best Management Practices for design, construction, and management of escape prevention (biosecurity), or;	6

[49] Not vulnerable – as a guide, not located in areas vulnerable to floods or tsunamis (including increasing risk due to sea level rise or storm severity), e.g., above or beyond 100-year flood event boundaries, or construction is based on 100-year flooding events
[50] Robust data – the escapes score in the Data Criterion is 7.5 or more, or the analyst has confidence that the data are either independently collected or verified, or are otherwise trustworthy.

	▪ Any "Low concern" system (as defined in this table) with uncertainty or evidence questioning the robustness of escape prevention measures, or of monitoring data, or; ▪ Ponds with low average annual daily exchange 0–3% not prone to flood damage, or; ▪ Monitoring data indicate only occasional detection of low numbers[51] of escapees in the wild.	
Moderate	▪ Ponds with moderate average annual daily exchange (e.g., 3–10%) or that drain externally at harvest, or; ▪ Ponds with a moderate risk[52] of vulnerability to flooding events, or; ▪ Flow-through (i.e., single-pass) tanks or raceways, or: ▪ Open systems going beyond[53] "Best Management" in system design, construction and maintenance, or; ▪ Open systems with documented track record of low escapes (as defined in footnote 51) or failures for at least 10 years, or justifiable evidence[54] for a lower level of concern, or; ▪ Any "Moderate-high concern" pond system (average annual daily exchange >10%) with multiple or fail-safe escape prevention methods, or; ▪ Monitoring data indicate infrequent detection of large numbers[55] of escapees present in the wild, or moderately frequent detection of low numbers.	4
Moderate-high	▪ Production systems vulnerable to large escape events or frequent trickle losses, or; ▪ Open systems with effective Best Management Practices for design, construction, and management of escape prevention (biosecurity), or; ▪ Any "Moderate concern" system (as defined in this table) with uncertainty or evidence questioning the robustness of escape prevention measures, or; ▪ Large escapes (≥5% of the holding unit) or frequent trickle losses (≥5% cumulatively) have occurred in the last 10 years, or; ▪ Ponds with high average annual daily exchange > 10%, or; ▪ Monitoring data indicate escapees are frequently detected in the wild.	2

[51] 'Low' numbers of escapees – insufficient numbers to produce population level impacts to wild species in the receiving environment.
[52] Moderate risk – ponds or tanks may be located at the limits or edges of flood or tsunami zones, or constructed to withstand 50 year events
[53] e.g., exceeding regulatory requirements or the industry's best management practices in design and construction
[54] e.g., Adaptations to net pen technology or other equivalent that reduces risk of escape
[55] Escape numbers capable of producing population level impacts to wild species in the receiving environment

High	▪ Open systems (e.g., net pens, cages, ropes) vulnerable to escape, without effective Best Management Practices for design, construction and management of escape prevention (biosecurity), or; ▪ Large escapes or frequent trickle losses have occurred in the last 10 years, and no corrective action has been taken, or corrective actions taken have not been adequate, or; ▪ Ponds in flood-prone areas or vulnerable to flooding events, or: ▪ Production systems that do not safeguard against reproduction (egg/fry/juvenile) escapes, or; ▪ Monitoring data indicate frequent occurrence of large numbers[56] of escapees in the wild	0

**Note:* Intermediate values (i.e., 1,3,5,7 or 9) may be used if needed.

The Escape Risk score can be adjusted to allow for the recapture of escapes where evidence shows that the reduction in escape numbers occurs before they can have an impact, or where the reduction would lead to a reduced risk of impact. The numerical adjustment directly correlates to the percentage of escapees that are recaptured (prior to having an impact) and therefore reduces the 'risk gap' otherwise demonstrated by the base Factor 6.1 score.

For example, if the base score for Factor 6.1 is 4 out of 10, and evidence shows 50% of escapes are recaptured, then the 'gap' between the base score of 4 and a full score of 10 (i.e., 6) can be reduced by 50% and the final Escape Risk score could be improved to 7 out of 10.
i.e.,: $\{[(10 - 4) \times 0.50] + 4\} = 7$

Initial escape risk score = _____ (range 0–10)
Recapture adjustment = _____ (range 0-10)

Final escape risk score (cannot be greater than 10) = _____ (range 0–10)

Escapes: Factor 6.2 Competitive and genetic interactions

A trait-based measure of the likelihood of genetic and/or ecological disturbance from escapees based on their native or non-native status, and/or their domestication and ecological characteristics. Note – even if a species was unable to become established in the wild, repetitive introductions into the wild from escapes can have the same ecological impacts.

Assessment Guide
Consider the species being farmed, its likely survival after escape, and the potential impacts were it to escape. Select the most appropriate score from the following table of examples. Consider all the options in the table: while every eventuality may not be covered, use the examples as guidelines to determine the most appropriate Invasiveness score. Select the lowest relevant score; for example if the farmed species would unable to breed with wild populations if it were to

[56] Escape numbers capable of producing population level impacts to wild species in the receiving environment

escape (score 10), but could have population level impacts by preying on or competing with wild populations (score 0) then the score for this factor would be zero.

Concern	Characteristics of farmed stock (i.e., the potential escapees)	Score
Very low	▪ Wild caught or naturally settled from the same water body, or; ▪ Will not compete with, breed with, predate on, disturb, or otherwise impact wild species, habitats or ecosystems[57], or; ▪ The receiving environment characteristics[58] mean that escapees will not or cannot cause additional ecological impacts, or; ▪ Post-escape mortality of farmed species has been robustly demonstrated to occur to a degree that satisfies the conditions above for a very low risk of impact.	10
Low	▪ Native and high genetic similarity to wild conspecifics (e.g., one generation domesticated), or; ▪ Non-native - fully ecologically[59] established in the production region prior to aquaculture, or; ▪ Has a low risk of competition, predation, disturbance or other impacts to wild species, habitats or ecosystem, or; ▪ Post-escape mortality of farmed species has been robustly demonstrated to occur to a degree that satisfies the conditions above for a low risk of impact.	8
Low-moderate	▪ Native - some genetic differentiation is likely, e.g., more than one generation domesticated, or; ▪ Non-native - not present in the wild, or present and not established, and highly unlikely[60] to establish viable populations, or; ▪ Non-native - became fully ecologically established in the production region as a result of aquaculture > 10 years ago, or; ▪ Post-escape mortality of farmed species has been robustly demonstrated to occur to a degree that satisfies the conditions above for a low-moderate risk of impact.	6
Moderate	▪ Native - minor evidence of phenotypic differences[61] from selective breeding, or hatchery raised for three generations, or; ▪ Non-native - not yet present in the wild (or present in the wild and not yet established[62]), but establishment is possible, or;	4

[57] For example, the species is environmentally benign, reproductively sterile, or physically unable to interact with wild populations (e.g., farm is located in a manmade waterbody with no connection to wild populations)
[58] For example, identical fish are deliberately stocked into the same environment such that additional farm escapes will not have any additional impact.
[59] Ecologically established in the environment which means it is capable of actively reproducing in wild areas as opposed to commercially established production in the region
[60] As a guide, introductions of the species (multiple and/or over extended timeframes) have been unsuccessful more often than successful or the species reproductive tolerance, behavior or habitat requirements are not suited to the escape location.
[61] For example, changes in growth rate, disease resistance, body shape, behavior or other changes.
[62] Repeated introductions of farm escapees into the wild can have a similar potential for impacts as actual ecological establishment of the species in the wild.

	▪ Competition, predation, disturbance or other impacts to wild species, habitats or ecosystem may occur, but are not considered likely to affect the population status of the wild species, or; ▪ Some post-escape mortality of farmed species has been robustly demonstrated to occur, but only to a degree that still presents a moderate concern for impact as defined above.	
Moderate-high	▪ Native - genetically distinct from wild conspecifics (e.g., clear evidence of selected characteristics) with evidence or potential for genetic introgression, or; ▪ Non-native - not yet present in the wild (or present in the wild and not yet established[63]), but the same or similar species have already established elsewhere, or; ▪ Non-native - partly established, with the potential to extend the species range (and impact)[64], or; ▪ Competition, predation, disturbance or other impacts to wild species, habitats or ecosystem occur, and have the potential to affect the population status of impacted wild species, or; ▪ Some post-escape mortality of farmed species has been demonstrated to occur, but only to a degree that still presents a moderate-high concern for impact as defined above.	2
High	▪ Native - genetically distinct from wild conspecifics (e.g., clear evidence of selected characteristics) with evidence or potential for genetic introgression, and relevant wild stocks are considered vulnerable or endangered[65], or; ▪ Evidence of population-level impacts to wild species through genetic interactions, competition, predation or other disturbance, or; ▪ The species has a high potential for impact (e.g., on the invasive species lists[66], competitive, predatory, habitat modifying etc.) and is farmed in an area where it is not yet established, or an increase in range is possible, or; ▪ No or little evidence of post-escape mortality of farmed species, and a high concern for impact exists as defined above.	0
Critical	▪ Population impacts occur to endangered or protected species.	C

Factor 6.2 score

Competitiveness and genetic interactions (CGI) score = _____ (range 0–10)

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[63] Repeated introductions of farm escapees into the wild can have a similar potential for impacts as actual ecological establishment of the species in the wild.

[64] For example, the species is present or partly established in the wild (e.g., in a limited area) and has the potential to cause additional impact as it becomes fully established over a greater range, OR as aquaculture extends its range into new areas.

[65] Species listed as protected, vulnerable, threatened, endangered or critically-endangered by the IUCN (Red list) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

[66] The Global Invasive Species Database (GISD) http://www.iucngisd.org/gisd/about.php

Final Escapes criterion score

Select the final escape score from the table using the "Risk of escape" (6.1) and the "CGI" (6.2) scores (e.g., if the CGI score = 7.5, look in the < 8 column).

		Competitive and genetic interactions (Factor 6.2)										
		10	9	8	7	6	5	4	3	2	1	0
Risk of escape (Factor 6.1)	10	10	10	10	10	10	10	10	10	10	10	10
	9	10	9	8	8	7	6	6	5	4	4	3
	8	10	8	8	7	7	6	6	5	4	4	3
	7	10	8	7	7	6	6	5	5	4	3	2
	6	10	7	7	6	6	5	4	4	3	3	2
	5	10	7	6	6	5	5	4	4	3	2	1
	4	10	6	6	6	5	4	4	3	3	2	1
	3	10	6	5	5	4	3	3	3	2	2	1
	2	10	5	5	4	4	3	3	2	2	1	0
	1	10	5	4	4	3	3	2	2	1	1	0
	0	10	5	4	4	3	2	1	0	0	0	0

Final Escape criterion score = ______ (range 0–10)
Escape criterion is Critical if the score is ≤ 1.

Criterion 7 – Disease, pathogen and parasite interaction

Impact, unit of sustainability and principle

- *Impact:* Amplification of local pathogens and parasites on fish farms and their transmission or retransmission to local wild species that share the same water body.
- *Unit of sustainability:* Wild populations susceptible to elevated levels of pathogens and parasites.
- *Principle:* Preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Background and Rationale

**Note:* Use of the term "disease" refers to pathogens and parasites.

All farming operations risk, and often demonstrate, the amplification of naturally-occurring pathogens and parasites and their associated clinical outbreaks of disease. Depending on the nature of the production system, elevated levels of pathogens and parasites can represent a risk to wild species residing in or passing through the area in which the farms are sited. In many cases, the initial infection of the farm stock will come from wild fish populations, but the amplification of pathogens and/or parasites on the farm and their subsequent retransmission to the same (or other) populations of wild fish can potentially affect the abundance and/or fitness of those wild populations in the surrounding ecosystem. The cross-infection of neighboring aquaculture sites also represents a major production limitation and both aspects require effective biosecurity regulations or management measures.

The impacts of diseases on wild fish are generally poorly understood or underestimated, as it is commonly believed that significant[67] epizootics rarely occur in wild populations. Furthermore, limited research has been undertaken on diseases of wild populations, as well as on the exchange of pathogens between farmed and wild fish. Therefore, direct evidence for transmission from farmed fish to wild populations is scarce. In some cases, however, evidence suggests that such transmission does take place with the potential for considerable impacts. For instance, it is now clear that wild salmonids (e.g., salmon, sea trout, or char) are infected by sea lice originating from salmon farms, and that other diseases have been spread to wild populations from salmonid farming activities (Ford & Myers 2008, Krkosek et al. 2011).

Because of the limited conclusive research, the Disease Criterion offers two methods of assessment: an Evidence-Based Assessment and a Risk-Based Assessment. The Evidence-Based Assessment can be used only when the Data score for the Disease criterion is 7.5 of 10 or higher. This option assesses known impacts (or demonstrated lack of impact) to ecosystems (i.e., wild populations, wild individuals, etc.). A Critical score is assigned when data show population declines in wild species with populations unable to recover, or when data show that there are population-level impacts to wild species considered endangered, vulnerable, etc. The Risk-Based Assessment is to be used when the Data score for the Disease Criterion is 5 of 10 or lower. This option assesses the operation using evidence of disease/pathogen outbreaks on a "typical" farm, and the openness of the farm system as a proxy for impact to wild populations. A Critical score is assigned when there is a high disease concern and affected wild stocks are considered endangered, vulnerable, etc.

Choosing the Evidence-Based or the Risk-Based Assessment

This criterion has two assessment options based on the quality of the effluent data available:

- If good research or data on the impacts are available (i.e., a Criterion 1 – Data score of 7.5 or higher for the Disease category), use the Evidence-Based Assessment table.
- If the assessed operations do not have good Disease and/or impact data (i.e., a Criterion 1 – Data score of 5 or less for the Disease category), or they cannot be easily addressed using the Evidence-Based Assessment, use the Risk-Based Assessment.

Polyculture systems

For assessments concerning polyculture systems, conduct multiple assessments (one for each species in the system) and assign a score to each species.

[67] Having population level impacts (as opposed to impacting individual animals only).

Disease: Evidence-Based Assessment

Consider evidence of impacts to wild fish, shellfish or other populations in the farming locality or region.

Concern	Pathogen and Parasite Interaction Risk Examples	Score
Very low	▪ Data show that there is no transmission of parasites or pathogens from the farm to wild species, or; ▪ Data show wild species are not affected by transmitted pathogens or parasites	10
Low	▪ Disease transmission may occur, but data show that pathogens or parasite numbers on wild species are not amplified above background levels, or; ▪ Disease transmission occurs, but pathogens or parasites do not cause morbidity to wild species	8
Low-moderate	▪ Pathogens or parasites cause morbidity to wild species but do not result in mortality	6
Moderate	▪ Pathogens or parasites cause mortality to wild species but have no population-level impact	4
Moderate-high	▪ Disease transmission occurs, and due to low population size[68] and/or low productivity (or other measure of vulnerability), and/or high mortality numbers, it negatively impacts the affected species' population size or its ability to recover	2
High/Critical	▪ Data show population declines in wild species with populations unable to recover, or; ▪ Data show evidence of population-level impacts to wild species considered vulnerable, endangered, IUCN red list, etc[69].	0

Disease: Risk-Based Assessment

Consider **ALL** the descriptions or examples below and select the most appropriate score given the available information. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Concern	Pathogen and Parasite Interaction Risk Examples	Score
Very low	▪ The production system is fully biosecure and all discharged water is treated or has no possibility for further impact, or; ▪ The production system has no connection to wild populations	10

[68] The population size is below the point where recruitment or productivity is impaired.
[69] Species listed as "protected", "vulnerable", "threatened", "endangered" or "critically-endangered" by the IUCN (Red List) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

Low	▪ The production system has very limited discharge of water (e.g., farms do not discharge water over multiple production cycles[70]), or; ▪ Production practices do not increase the likelihood of pathogen amplification compared to natural populations, e.g., natural stocking density, water quality, feed type, behavior, etc.[71] ▪ Robust[72] fish health and biosecurity management measures[73] are in place and are properly enforced, preventing the occurrence and spread of disease between farm sites, and from farm sites to wild species.	8
Low-moderate	▪ Fish health management measures result in low, temporary or infrequent[74] occurrences of infections or mortalities at the "typical" farm level, or; ▪ The production system only discharges water once per production cycle, or; ▪ Independently audited, scientifically robust limits[75] are in place, and available data show that pathogen or parasite levels are consistently below the limits over multiple production cycles, or; ▪ Robust biosecurity protocols are in place that limit the discharge of pathogens at the farm level	6
Moderate	▪ Some disease-related mortalities occur on farms, or on-farm survival is occasionally reduced for unknown reasons, and production systems discharge water on multiple occasions during the production cycle without relevant treatment, or; ▪ The production system has some biosecurity protocols in place, yet is still open to introductions of local pathogens and parasites (e.g., from water, broodstock, eggs, fry, feed, local wildlife, etc.) and is also open to the discharge of pathogens	4
Moderate-high	▪ Where there is a known pathogen/parasite transfer risk, fish health and biosecurity regulations or management measures do not exist, or are in place but implementation and enforcement is unknown ▪ The farming system is open to the environment, or exchanges water on multiple occasions during the production cycle and suffers from high disease or pathogen related infection and/or mortality	2

[70] Multiple production cycles – as a guide, the normal production practice is to maintain the same water on the farm throughout one complete production cycle and reuse it for the next production cycle without discharge at any time.
[71] Consider examples of naturally settled shellfish, or extensive fish or shrimp ponds.
[72] Robust protocols must include disease monitoring and reporting, disposal of mortalities, emergency disease response, quarantine procedures, active vector or boundary controls, treatment of diseased water, etc.
[73] Fish health and biosecurity measures designed for applicability at the farm, waterbody and industry scale.
[74] Low, temporary or infrequent – as a guide, available data show diagnosed clinical disease is present in less than 5% of stock, for less than 5% of the time, or combined diagnosed plus undiagnosed mortalities do not exceed 5% over multiple production cycles.
[75] Scientifically robust limits – controls on the number or occurrence of pathogens or parasites are primarily intended to protect wild populations or other ecosystem functions, or to apply a precautionary approach where research is inconclusive.

High	▪ Discharge of water from farms with known disease events occurs, with wild hosts that are considered "vulnerable", "endangered", IUCN Red List, etc.	0
Critical	▪ There is a high disease concern and the affected wild stocks are considered "vulnerable", "endangered", IUCN Red List, etc.	C

**Note:* Intermediate values (i.e., 1, 3, 5, 7, or 9) may be used if needed.

Final Disease criterion score = _______ (range 0–10 or Critical)

Criterion 8X – Source of Stock – Independence from wild fish stocks

Impact, unit of sustainability and principle

- *Impact:* The removal of fish from wild populations
- *Unit of Sustainability:* Wild fish populations
- *Principle:* Using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture.

A measure of the aquaculture operation's independence from active capture of wild fish for on-growing, broodstock or other species raised with the primary stock (e.g., cleaner fish).

Background and Rationale
This Criterion (8X) is defined as an exceptional criterion that may not be relevant to all aquaculture production, yet can be a significant concern for those production practices where it is relevant. Whereas all other criteria or factors score positively and contribute to the overall score total, the exceptional criteria are given a negative score which is subtracted from the final total score for those aquaculture operations where it is a concern.

The Source of Stock criterion is a single factor based on the independence of the farming operation from wild fisheries and their associated impacts, and is assessed using the percentage of production that is sourced from hatchery-raised broodstock (i.e., the percentage of the farm's production that is independent from the direct wild capture of fish).

The criterion does not intend to penalize the historic capture of wild fish for the establishment of domesticated broodstocks. It is based on the assumption that the majority of aquaculture operations worldwide are operating as closed life cycles with broodstock no longer originating from wild populations. This is now considered best practice, and therefore should not be given a positive score if it is being upheld. It will, however, be penalized if best practice is not being met. A score of Critical is assigned if there is sourcing of wild juveniles and/or broodstock that are considered endangered.

**Note:* The use of domesticated stocks leads to a good score in this criterion, whereas increasing domestication can be associated with the increased potential for impacts of escapes in Criterion 6 – Escape (native). This is an unavoidable conflict within aquaculture production, and the role of these criteria is to highlight the impacts (and promote better alternatives) associated with whichever production option the farm or industry chooses. It is, however, possible to score well in both Criterion 6 and Criterion 8X if the stock being farmed is sufficiently genetically separate from the wild population that it cannot interbreed, or it is sterile.

**Note:* The collection of wild fingerlings, seed or other life stages for supplying aquaculture will often be from depressed species or fisheries. With the exception of sources that would otherwise not survive (for example, ephemeral mussel spat), Seafood Watch considers that capturing wild fish, even from a sustainable fishery, and raising them on a farm is a net loss of resources and ecosystem services. This criterion is based on the reality that wild fish have more comprehensive ecological value than farmed fish, whose scope of benefits is very narrow (i.e., solely for human consumption). It is preferable for wild aquatic resources to continue to be part of a functioning natural ecosystem (while still maintaining a sustainable fishery, where possible) than to remove them and raise them solely in farms.

Polyculture systems
For assessments concerning polyculture systems (inclusive of the use of cleanerfish), conduct multiple assessments (one for each species in the system) and utilize the **lowest** score.

Guidance
Source of stock score = the percentage of production that originates from, or is dependent on, either:

1. Wild-caught juveniles or seed, unless they are from passive influx or natural settlement (e.g., shellfish)
2. Wild-caught broodstock unless the number used and the sustainability of the source can be demonstrated to be of minimal concern (i.e., score of ≥ 6 in Fishery Sustainability Examples table in Factor 5.1b Source Fishery Sustainability
3. Other wild-caught species actively stocked but not intended for human consumption (e.g., cleaner fish) unless the number used and the sustainability of the source can be demonstrated to be of minimal concern (i.e., score of ≥ 6 in Fishery Sustainability Examples table in Factor 5.1b Source Fishery Sustainability.)

Production from Wild Juveniles or Broodstock or Co-stocked Wild Species (%)	Score
Sourcing of endangered[76] species or Seafood Watch Red/Avoid fishery	Critical
100	-10
90–99.9	-9
80–89.9	-8
70–79.9	-7
60–69.9	-6
50–59.9	-5
40–49.9	-4
30–39.9	-3
20–29.9	-2

[76] Species listed as “protected”, “vulnerable”, “threatened”, “endangered” or “critically-endangered” by the IUCN (Red List) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

10–19.9	-1
0–9.9	0

Final Source of Stock criterion score = ________ (range 0 to -10, Critical)

Criterion 9X –Wildlife Mortalities

Impact, unit of sustainability and principle

- *Impact:* Mortality of predators or other wildlife caused or contributed to by farming operations
- *Unit of Sustainability:* Wildlife or predator populations
- *Principle:* Preventing population-level impacts to predators or other species of wildlife attracted to farm sites.

Background and Rationale

This Criterion (9X) is defined as an exceptional criterion that may not be relevant to all aquaculture production, yet it can be a concern for those production practices where it is relevant. Whereas all other criteria or factors score positively and contribute to the overall score total, the exceptional criteria are given a negative score which is subtracted from the final total score for those aquaculture operations where it is a concern.

Aquaculture operations can directly or indirectly cause the death of predators or other wildlife that are attracted by the concentration of cultured aquatic animals. Wild animals such as crustacea, reptiles, birds, fish, and mammals can be predators of the aquatic cultured populations (e.g., Sanchez-Jerez et al. 2008). Predation can have a significant economic impact on aquaculture operations and also cause injuries and stress to farm fish, and contribute to the spread of parasites and diseases. For that reason, aquaculture operations seek to minimize the impact of predators by using different control methods. These methods can accidentally or deliberately result in mortalities (Engle 2009).

Different control measures are taken by farmers against predators. These methods can be classified into (1) exclusory, (2) frightening, and (3) lethal. Exclusory devices are physical barriers that seek to exclude predators by screens and nets. These can vary from simple, temporary nettings, to the complete enclosure of the entire facility. Methods to frighten predators are typically based on sounds or visual stimuli that discourage predators from remaining at a site by making them believe the site is dangerous or “unpleasant”. Lethal control methods may include shooting, trapping, or toxic chemicals, and may be legally permitted in some circumstances. Predator control methods can be enhanced through facility design. For example, a raceway can be more easily covered than a pond, and small ponds are more easily protected than large ponds. The design of ponds and raceways with covers or fences can discourage vertebrate predators (Masser 2000).

Although different aquaculture operations attract a variety of predators and wildlife (e.g., starfish and crabs to shellfish aquaculture, birds to ponds, and otters, seals and other marine mammals to sea cages), the impacts of mortalities (from shooting, trapping, entanglement, drowning, etc.) vary depending on the population status, species vulnerability or productivity, and the numbers killed. Substantial numbers of fish may also be trapped as juveniles and grow within the farm until harvest.

This criterion is therefore a measure of the effects of deliberate or accidental mortality on the populations of predators or other wildlife. It is based on the assumption that aquaculture production worldwide has progressed to the degree that operations are not often having population-level impacts on wildlife or predators, and it is considered best practice that management strategies minimize the amount of interaction between wildlife/predators and farmed stocks that results in mortality of wild animals.

The criterion must consider greatly-varying numbers of potential mortalities, and the vastly-differing real and perceived "values" of the species affected. For example, it must be able to differentiate between the mortality of a thousand rats, or twenty birds, or one endangered marine mammal. Therefore, the score depends on the potential to affect the population status of the relevant species. While the use of non-harmful predator control methods gets the highest score, the evidence of mortality of endangered or protected populations is considered a Critical concern.

The term "Wildlife" refers to any species of wildlife (including predators), other than vermin, residing on, or interacting with, the farm site during production. It does not cover impacts to wildlife during farm construction or expansion due to habitat disturbance.

Select the most appropriate score from the table below. Select the lowest (worst) score that is applicable to the aquaculture operations being assessed. Use time frames relevant to the impacted wild species. As a guide, use the number of years to reach first maturity (for example, consider average mortalities of Stellar sea lions over the last five years).

Choosing the Evidence-Based or the Risk-Based Assessment
This criterion has two assessment options based on the quality of the data available:
If good research or data on mortality numbers and/or the impacts to the population are available (i.e., a Criterion 1 – Data score of 7.5 or higher for the Wildlife Mortality category), use the Evidence-Based Assessment table. If the assessed operations do not have good wildlife mortality and/or impact data (i.e., a Criterion 1 – Data score of 5 or less for the Wildlife Mortality category), or they cannot be easily addressed using the Evidence-Based Assessment, use the Risk-Based Assessment.

Polyculture Assessments
For assessments concerning polyculture systems, conduct multiple assessments (one for each species in the system) with impacts allocated to the species responsible for the impacts. If data are not available to determine which species are responsible for the impact, all species in the system will receive the score appropriate for the impact that is known.

Wildlife Mortalities: Evidence-Based Assessment

While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score according to what the data or other evidence shows.

Concern	Evidence Examples of Impacts to Wildlife	Score
Very low	▪ Data show there is no direct or accidental mortality of wildlife due to the assessed operations.	-0
Low	▪ Data show wildlife mortalities are limited to exceptional[77] cases that do not significantly affect the population size.	-2
Low-moderate	▪ Data show wildlife mortalities occur beyond exceptional cases; but represent less than 10 % of the PBR[78] (or equivalent concept).	-4
Moderate	▪ Data show wildlife mortalities affect the population size; for example, mortalities represent less than 50 % of the PBR[79] (or equivalent concept).	-6
Moderate-high	▪ Data show wildlife mortalities substantially impact the population size; for example, mortalities exceed 50 % of the PBR (or equivalent concept), but do not exceed PBR. ▪ Data show wildlife mortalities substantially contribute to exceeding PBR; for example, PBR is exceeded and aquaculture mortality represents between 10 and 50% of PBR. ▪ Data show wildlife mortalities exceed regulatory limits.	-8
High	▪ Data indicate wildlife mortalities exceed the PBR (or equivalent concept) of the affected population.	-10
Critical	▪ Data show wildlife mortalities exceed, or substantially contribute to exceeding, the PBR (or equivalent concept) of a highly vulnerable species[80].	C

**Note:* Intermediate values (i.e., 1,3,5,7 or 9) may be used when justified or needed.

Wildlife Mortalities: Risk-Based Assessment

Concern	Risk Examples of Impacts to Wildlife	Score
Very low	▪ The production system is isolated from wildlife, or otherwise not vulnerable to wildlife interaction and/or deliberate or accidental mortality. ▪ Effective management practices for the non-harmful exclusion of wildlife are in place, and deliberate lethal wildlife control is not used or permitted.	-0

[77] Mortalities occur very infrequently, or occur only in exceptional circumstances; for example, when worker safety is immediately threatened, or as a last resort when euthanizing is an act of mercy.
[78] The Potential Biological Removal (PBR) level is defined as the maximum number of animals, not including in natural mortalities, that may be removed annually from a population while allowing that population to reach or maintain its optimal sustainable population level.
[79] The Potential Biological Removal (PBR) level is defined as the maximum number of animals, not including in natural mortalities, that may be removed annually from a population while allowing that population to reach or maintain its optimal sustainable population level.
[80] Species listed as protected, vulnerable, threatened, endangered or critically-endangered by the IUCN (Red list) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

Low	▪ Effective regulations or management practices for non-harmful exclusion or control of wildlife are in place, such that accidental mortalities are likely to be limited to exceptional cases and/or are considered highly unlikely to affect the health of the population[81]. ▪ Deliberate lethal wildlife control is not used or permitted.	-2
Low-moderate	▪ Regulations and management practices for non-harmful exclusion and control are in place, but accidental mortalities (e.g., entanglement) cannot be prevented, and mortality numbers are unknown. ▪ Lethal control is only used, or only permitted to be used, in exceptional cases[82] or based on species' PBR (or equivalent concept).	-4
Moderate	▪ Exclusion or control methods are unknown, and mortality numbers are unknown. ▪ Regulations or management measures are in place that aim to generally limit wildlife mortalities, but enforcement is weak or unknown, or mortality numbers are unknown. ▪ The population size or PBR are not known, but mortality numbers may affect the health of the population.	-6
Moderate-high	▪ Lethal wildlife control is known to be used or the system is known to be vulnerable to entanglement or other accidental mortality, and mortality numbers are unknown. ▪ Regulations or management measures are not in place and their content and enforcement is unknown. ▪ The population size or PBR are not known, but mortality numbers are considered highly likely to affect the health of the population size.	-8
High	▪ The production system is known to interact with highly vulnerable species[83] but mortalities numbers (if any) are unknown.	-10
Critical	▪ The production system is known to interact with highly vulnerable species, mortalities are known to occur, but numbers are unknown.	C

**Note:* Intermediate values (i.e., 1,3,5,7 or 9) may be used when justified or needed.

Criterion 9X score = -_______ (range 0 to -10)

[81] Health of the population: Utilizing information such as life history characteristics (e.g., fecundity, age at maturity) and presence, absence, or degree of other pressures on the population (e.g., commercial or otherwise significant harvest of the species), together with mortality numbers, the impact to the population can be pragmatically estimated to not manifest across time (e.g., is not multi-generational) or space (e.g., local mortalities are not observable in species abundance distant to those mortalities).

[82] Exceptional circumstances; for example, when worker safety is immediately threatened, or as a last resort when euthanizing is an act of mercy.

[83] Species listed as protected, vulnerable, threatened, endangered or critically-endangered by the IUCN (Red list) or by a national or other official list with equivalent categories. However, more recent or more regional/stock specific data can override these determinations.

Criterion 10X – Introduction of Secondary Species

Impact, unit of sustainability and principle

- *Impact:* Movement of live animals resulting in introduction of unintended species
- *Unit of Sustainability:* Wild native populations
- *Principle:* Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals.

A measure of the escape risk (introduction to the wild) of alien species ***other than the farmed species*** are introduced to an ecologically-distinct waterbody (i.e., one in which they are not native or present)**.** This could include pathogens, parasites, or other secondary species unintentionally transported during live animal movements (e.g., eggs, juveniles or broodstock, cleaner fish, etc.), or the movements of other non-biosecure materials (e.g., baitfish or other unprocessed feed ingredients, farming equipment, etc.).

Background and Rationale

This Criterion (10X) is defined as an exceptional criterion and will not be relevant to the majority of aquaculture production, yet it can be a concern for those production practices where it is relevant. Whereas all other criteria and factors score positively and contribute to the overall score total, the exceptional criteria are given a negative score, which is subtracted from the final score for those aquaculture operations where it is a concern.

The movement of animals (live or dead) between ecologically-distinct areas without inspection, quarantine, or other appropriate management procedures has inevitably led to the simultaneous introduction of unintentional accompanying animals during live animal shipments, other than the principal species being transported. The range of potentially transferable species by this way is significant, especially when different life stages (e.g., eggs, larvae or juveniles) are considered.

Criterion 10X addresses the aquaculture operation's dependence on trans-waterbody movements of animals (Factor 10Xa) and the biosecurity of both the source and the destination of the species transported during live fish shipments (Factor 10Xb).

Trans-waterbody movements take place when the source waterbody is ecologically distinct from the destination (farming) waterbody, such that the live animal movements represent a risk of introducing species (pathogens, parasites, other secondary species) not present in the destination waterbody. The scoring table uses the approximate percentage of production reliant on the ongoing trans-waterbody movement within one generation of the farmed product. It does not include historic introductions of broodstock, as our concern is focused on the ongoing dependency on live animal movements or movement of non-biosecure (e.g., unprocessed) materials, such as forage fish used as feed. If aquaculture production does not rely, to any degree, on trans-waterbody movements of these animals or materials, it is considered that there is no risk of movement of secondary species and the score for Factor 10Xa is 10 of 10, and Factor 10Xb is not necessary to complete.

The biosecurity assessment (Factor 10Xb) is based on fundamental system biosecurity, best management practices, regulations, and codes of conduct – particularly the ICES Code of

Practice on the Introductions and Transfers of Marine Organisms (ICES 2004). The biosecurity of the source or origin of animal shipments determines the risk for secondary species entering shipments, and the biosecurity of the destination determines the risk for introducing them into the wild. The final scoring for Factor 10Xb is the higher of the two biosecurity scores – source or destination.

Polyculture systems
For assessments concerning polyculture systems, conduct multiple assessments (one for each species in the system) and utilize the **lowest** score.

Factor 10Xa – **International or trans-waterbody animal shipments**
Approximate percentage of production reliant on the ongoing trans-waterbody movement of broodstock, eggs, larvae, or juveniles within one generation of the farmed product, or the transport of unprocessed feed or other non-biosecure materials.

Note: Trans-waterbody movement is defined with the source waterbody being ecologically distinct from the destination (farming) waterbody, such that the animal movements represent a risk of introducing species not native to or present in the destination waterbody. While conducting a complete analysis of the biological diversity of the source and the destination of animal or other material movements is impractical, a reasonable effort to determine the degree of distinctiveness of the ecosystems/environments in question should be made.

Do not include historic introductions of broodstock for establishing domesticated stocks, etc.

Reliance on Animal Movements	% of production	Score
Zero	0	10
Low	0.1–9.9	9
	10–19.9	8
Low-moderate	20–29.9	7
	30–39.9	6
Moderate	40–49.9	5
	50–59.9	4
Moderate-high	60–69.9	3
	70–79.9	2
High	80–89.9	1
	> 90	0

Factor 10Xa score = ______ (range 0–10)

If Factor 10Xa has a score of 10 out of 10 (no trans-waterbody movements of animals) do not complete Factor 10Xb.

Factor 10Xb – **Biosecurity of source and destination (for introduced species)**
Considering the types of species–inclusive of all life stages–potentially being transported unintentionally during trans-waterbody movements of the principal farmed species, use the table below ***twice*** to assess the biosecurity risk; once for the source of animal movements (e.g.,

hatchery or wild seed bed, etc.) and once for the farm destination. Consider that biosecurity procedures for the principal farmed species may not prevent the introduction of smaller, unintentionally-transported pathogens, parasites, plants, animals or their various life stages arriving with live fish shipments. SPF/SPR animals may be free of certain pathogens but are not guaranteed to be free of all pathogens.

The score for Factor 10Xb is the ***highest*** score (i.e., most biosecure) of either the source or destination. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Concern	Biosecurity and Escape Risk Examples for Source and Destination	Score
Very low	▪ No connection to natural water bodies (i.e., fully biosecure)	10
Low	▪ Tank based recirculation systems (≥ 80% reuse) with appropriate (multiple) screens, water treatment, and secondary capture devices. ▪ Static ponds with no water discharge (including at harvest) over multiple production cycles, not vulnerable to flood/storm/tsunami damage	8
Low-moderate	▪ Any "Moderate risk" system with multiple or fail-safe escape or entry prevention methods, or active Best Management Practices for design, construction, and biosecurity management ▪ Any "Low risk" system with uncertainty or evidence questioning the robustness of biosecurity measures ▪ Ponds with low average annual daily exchange 0–3% per day	6
Moderate	▪ Ponds with moderate average annual daily exchange 3–10% per day ▪ Static ponds that drain externally at harvest or do not screen effluent water ▪ Any ponds or tanks located at the limits or edges of flood or tsunami zones, or constructed to withstand 50 year events ▪ Flow-through tank or raceways	4
Moderate-high	▪ Any "High risk" system with effective best management practices for design, construction, and biosecurity management ▪ Any "Moderate risk" system with uncertainty or evidence questioning the robustness of biosecurity prevention measures ▪ High exchange ponds with average annual daily > 10% per day	2
High	▪ Open systems (e.g., net pens) or wild caught sources (e.g., dredged mussel spat) ▪ Ponds in low-lying valley areas, wetlands, river flood plains, or coastal tsunami zones. ▪ Systems that do not safeguard against reproduction based egg/fry dispersal ▪ System vulnerable (with evidence) to predator damage	0

Note: Intermediate values (i.e., 1,3,5,7 or 9) may be used if needed.

Biosecurity score of the source of animal movements = ______ (range 0–10)
Biosecurity score of the farm destination of animal movements = ______ (range 0–10)

Criterion 10Xb score = highest biosecurity score = ______ (range 0-10)

Criterion 10X score = [(10 - 10Xa) x (10 - 10Xb)] / 10 = -______ (range 0 to -10)
Note: This is a negative score that will be subtracted from the overall final score total of the other criteria.

Exceptional Criterion 10X score = - _____ (range 0 to -10)

Overall score and final recommendation

Numerical score

The Final numerical score = [(Sum of C1–C7 scores) + (C8X + C9X + C10X)]/7
= ______ (range 0–10)

Number of Red Criteria

Any criterion in C1–C7 with a score lower than 3.335, or lower than -6.665 for C8X, C9X and C10X, is considered "Red".

Total number of Red criteria or factors = ______ (0–10)

Number of Critical Scores

A number of criteria or factors have one or more "Critical" characteristics:

- Effluent C2 Evidence-based assessment score = Critical
- Effluent C2 Risk-based assessment score = 0 (high effluent discharge and poor management)
- Habitat C3.1 score = Critical
- Habitat C3 score = 0
- Chemical use C4 score = Critical (i.e., evidence of pathogens with developed resistance to antimicrobials highly- or critically-important for human medicine) OR; illegal activity with demonstrable negative environmental impacts OR; evidence indicates antimicrobials critically important for human medicine are being used in significant or unknown quantities
- Feed F5.1 FFER value is greater than 4 (actual FFER value, not the FFER score)
- Feed F5.1b Source fishery sustainability score is Critical
- Feed 5.1b is zero and FFER value is ≥1.0
- Feed 5.1b is 1 out of 10 and FFER value is ≥1.0
- Feed 5.1b is 2 out of 10 and FFER value is ≥2.0
- Feed 5.1b is 3 out of 10 and FFER value is ≥2.5
- Feed 5.1b is 4 out of 10 and FFER value is ≥3.0
- Feed 5.1b is 5 out of 10 and FFER value is ≥3.5
- Feed 5.1b is SFW Red (score of 2 out of 10) and FFER associated with these inclusions is ≥1.0
- Feed F5.1 FFER value (not score) > 3 and F5.2 PRE score < 2 (i.e., a high amount of wild fish is used in the feed and most of the fed nutrients are wasted)
- Feed F5.2 PRE score = 0 (i.e., > 90% of the protein provided in the feed is wasted)

- Escapes Factor 6.2 score = Critical
- Escapes C6 score ≤ 1 (i.e., escape numbers are very high and damaging to wild populations) and the affected wild populations are vulnerable, endangered, IUCN listed, etc.
- Disease C7 Evidence-based assessment score = 0
- Disease C7 Risk-based assessment score = Critical
- Source of Stock 8X = Critical (Sourcing of endangered wild juveniles and/or broodstock (e.g., IUCN listed, etc.), or from a fishery rated red/Avoid by Seafood Watch)
- Wildlife mortalities C9X score of -10 = Critical

Number of Critical scores = _______

Criterion	Score (0-10)	Red? (Y/N)	Critical? (Y/N)
C1 Data			N/A
C2 Effluent			
C3 Habitat			
C4 Chemical Use			
C5 Feed			
C6 Escapes			
C7 Disease			
C8X Source of Stock	-		
C9X Wildlife Mortalities	-		
C10X Secondary Introductions	-		
Overall score = (0-10)			
Number of Red Criteria =			
Number of Critical Scores =			

Final Seafood Watch Recommendation

The overall recommendation is as follows:

- Best Choice = Final score ≥6.665 and ≤10, **and** no Red criteria, **and** no Critical scores.

- Good Alternative = Final score ≥3.335 and ≤6.664, **and/or** one Red criterion, **and** no Critical scores.

- Avoid = Final score ≥ 0 ≤ 3.334, **or** more than one Red criterion, **or** one or more Critical scores.

Final Recommendation = _______

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Appendix 1 – Habitat examples

The following additional examples or indicators are provided to help the assessor determine the maintenance or loss of habitat functionality, and/or the level of impact to functioning habitats. Indicators of habitat damage vary between habitat types, are difficult to quantify for some habitats, and may not provide linear measures of damage or scores. Use any relevant indicator of habitat impact for which data or evidence are available.

Type of Conversion	Remaining Mangrove/ Wetland Area (%)	Index of Biotic Integrity	Habitat Disturbance or Fragmentation	Examples or Indicators
Maintains full functionality	100	>90%	Undisturbed	Undisturbed
Minimal impact	90–100	75–90%	Minimal habitat fragmentation	Little impact on ecosystem service delivery, habitat usability, resource delivery/support Little impact on extractive capacity, such as fisheries catch or crop yield (e.g., reduced C sequestration)
Minor impacts	70–90	70–75%	Minor habitat fragmentation	Some impact on ecosystem service delivery, habitat usability, resource delivery/support Some impact on extractive capacity, such as fisheries catch or crop yield (e.g., reduced effect on hazard control, higher soil conductivity, loss of juvenile habitat)
Moderate impacts	50–70	65–70%	Significant but not irreversible habitat fragmentation	Some impact on ecosystem service delivery, habitat usability, resource delivery/support Some impact on extractive capcity, such in fisheries catch or crop yield

				(e.g., loss of soil fertility, changes in species abundance)
Major impacts – loss of functionality	0–50	<65%	Major and irreversible fragmentation	Major impact on ecosystem service delivery, habitat usability, resource delivery/support Major impact on extractive capcity, such in fisheries catch or crop yield (e.g., loss of hazard control capacity, changes in species diversity, significant amount of C release, loss of fisheries, loss of functional diversity)

Appendix 2 – Additional guidance for the Habitat Criterion

Historic loss of functionality

- If the farms were established historically (prior to 1999), the score will (typically, unless otherwise justifed) be between 4 and 6, depending on the original habitat value.
- If the farms were established after 1999 in habitats that had previously lost functionality prior to 1999, the score will (typically, unless otherwise justified) be between 4 and 6, depending on the original habitat value.
- If the farms or industry are still expanding into habitats that had previously lost functionality (prior to 1999), the score will (typically, unless otherwise justified) be between 4 and 6, depending on the original habitat value.

Recent and ongoing habitat damage resulting in loss of functionality

- If the farms have recently been established (after 1999) without maintaining critical ecosystem services, the score will be between 1 and 3, depending on the original habitat value.
- If the farms are still expanding into functioning habitat (i.e., there is a continuing loss of ecosystem services), then the score will be between 0 and 3, depending on original habitat value.
- If the farms were recently established (after 1999), or are still expanding into habitat that had previously lost functionality prior to 1999, the score will be between 4 and 6, depending on the original habitat value.

Appendix 3 – Additional guidance for the Feed Criterion

Table A1

If data on protein content of whole harvested farmed fish cannot be found use the table below:
Whole-fish Protein Content examples

Species	Protein %	Reference
Tilapia	14	Boyd 2007
Salmon	18.5	Boyd 2007
Catfish	14.9	Boyd 2007
White shrimp (L. vannamei)	17.8	Boyd 2007
Tiger shrimp (P. monodon)	18.5	Boyd 2007
Rainbow trout	15.6	Boyd 2007
Other	18	

Feed Calculation Guidance

Scenario 1: Single Feed Type

When a single feed type is being assessed and its inclusion levels are known, reference this section (Scenario 1) to understand the steps, equations and methods used to complete the calculations for each Factor in Criterion 5 – Feed.

Factor 5.1 – Wild fish use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Step 1: Calculate the FFER for fishmeal and fish oil.

(Eq. 1)

$$FFER_{FM} = \frac{\left[\mathrm{FM}_{wf} + (FM_{bp} \times 0.05)\right] \times eFCR}{e}$$

$$FFER_{FO} = \frac{\left[FO_{wf} + (FO_{bp} \times 0.05)\right] \times eFCR}{f}$$

Where:

FM_{wf} = fishmeal whole fish inclusion level
FM_{bp} = fishmeal by-product inclusion level
eFCR = economic feed conversion ratio
e = fishmeal yield

FO_{wf} = fish oil whole fish inclusion level
FO_{bp} = fish oil by product inclusion level
f = fish oil yield

Factor 5.1b – Sustainability of the Source of Wild Fish

The following steps are done to calculate a final 5.1b score for a single feed type and various sources of marine ingredients (i.e., fishmeal and fish oil):

1. Determine the sustainability score for each source fishery.
2. Calculate whole fish and by-product 5.1b Source Fishery Sustainability scores.
3. Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.
4. Calculate a final Factor 5.1b score by weighting the overall fishmeal and fish oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

Step 1: Determine the sustainability score for each source fishery.

Follow the instructions from the standard (page 39) to determine the sustainability score for each source fishery.

Step 2: Calculate whole fish and by-product 5.1b Source Fishery Sustainability scores.

To determine a single F5.1b Source Fishery Sustainability score for fishmeal and fish oil sourced from whole fish and byproducts, the following equation is used:

(Eq. 5)

$$S_{FM\text{-}wf} = \sum[(K_n/\alpha_{FM-wf}) \times F_n]$$

$$S_{FM\text{-}bp} = \sum[(K_n/\alpha_{FM-bp}) \times F_n]$$

$$S_{FO\text{-}wf} = \sum[(K_n/\alpha_{FO-wf}) \times F_n]$$

$$S_{FO\text{-}bp} = \sum[(K_n/\alpha_{FO-bp}) \times F_n]$$

Where:

K_n = Inclusion (%) of each source fishery

α_n= Total fishmeal or fish oil inclusion from whole fish or by-product

F_n = SFW 5.1b sustainability score for each source fishery

Step 3: Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.

Using the fishmeal and fish oil sustainability score values for whole fish and by-products calculated in Step 2, the following equation is then used to calculate the weighted overall sustainability scores for total fishmeal and fish oil (Eq. 6):

(Eq. 6)

$$S_{FMtotal} = (S_{FM-wf} \times 0.95) + (S_{FM-bp} \times 0.05)$$

$$S_{FOtotal} = (S_{FO-wf} \times 0.95) + (S_{FO-bp} \times 0.05)$$

Where:

S_{FM-wf} = weighted sustainability score for fishmeal (whole fish)

S_{FM-bp} = weighted sustainability score for fishmeal (by-product)
S_{FO-wf} = weighted sustainability score for fish oil (whole fish)
S_{FO-bp} = weighted sustainability score for fish oil (by-product)

Step 4: Calculate a final Factor 5.1b score by weighting the total fishmeal and fish oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

(Eq. 7)

$$Final\ 5.1b\ score\ = \frac{(FFER_{FM}\ \times\ S_{FMtotal}) +\ (FFER_{FO}\ \times\ S_{FOtotal})}{(FFER_{FM}\ +\ FFER_{FO})}$$

Factor 5.2 – Net protein gain or loss

Step 1: Calculate the net protein gain or loss using the following equation:

(Eq. 8)

$$\text{Net Protein} = \frac{[\text{b} - (\text{h} \times \text{eFCR})]}{(\text{h} \times \text{eFCR}) \times 100}$$

Where:

b = % protein content of whole harvested fish
h = feed protein content %

Factor 5.3 – Feed Footprint

Step 1: Calculate the total global warming potential (GWP) for each category (i.e., fishmeal and fish oil from whole fish and by-products, terrestrial crop ingredients, animal ingredients and other) by using the following equations:

(Eq. 9)

$$GWP_{FM-wf} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{FM-bp} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{FO-wf} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{FO-bp} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{terrestrial\ crop\ ingredients} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{terrestrial\ animal\ ingredients} = \sum(K_n \times \mu_n\ \times 0.01)$$

$$GWP_{other} = \sum(K_n \times \mu_n\ \times 0.01)$$

Where:

K_n = Inclusion (%) of each source fishery
μ_n = GFLI Economic allocation – EF3.1, values from Climate change (kg CO_2-eq / ton

product) column; *note these values are not published in SFW assessments due to licensing agreements.*

Step 2: Sum the total global warming potential (GWP) for all categories (i.e., fishmeal and fish oil from whole fish and by-products, terrestrial crop ingredients, animal ingredients and other).

(Eq. 10)

$$d = (GWP_{FM\text{ - }wf} + GWP_{FM - bp} + GWP_{FO\text{-}wf} + GWP_{FO - bp} + GWP_{terrestrial\ crop\ ingredients} + GWP_{terrestrial\ animal\ ingredients} + GWP_{other})$$

Step 3: Calculate the estimated total feed global warming potential (GWP) using the following equation:

(Eq. 11)

$$\rho = \frac{(eFCR)}{(b)} \times \frac{(d) \times 10}{(c)}$$

Where:

eFCR = the reported eFCR associated with each feed

b = % protein content of whole harvested fish

c = the total ingredient inclusion for each feed, ideally is 100%

d = Total GWP/mt of feed, as calculated in Step 2

ρ = Est. kg CO_2-eq/kg of farmed seafood protein

Scenario 2: Multiple Feed Types

When multiple feed types are being assessed and their inclusion levels are known, reference this section (Scenario 2) to understand the steps, equations and methods used to complete the calculations for each Factor in Criterion 5 – Feed.

Factor 5.1 – Wild fish use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Step 1: Calculating a weighted average for total fishmeal and fish oil inclusions.

(Eq. 1)

$$FM_{avg} = (X\%_{FM\ 1} \times X\%_{share\ 1}) + (X\%_{FM\ 2} \times X\%_{share\ 2}) + \cdots$$

$$FO_{avg} = (X\%_{FO\ 1} \times X\%_{share\ 1}) + (X\%_{FO\ 2} \times X\%_{share\ 2}) + \cdots$$

Where:

$X\%_{FM\ n}$ = average of fishmeal inclusion levels reported for each feed

$X\%_{FO\ n}$ = average of fish oil inclusion levels reported for each feed

$X\%_{share\ n}$ = estimated market share or proportion of total use for each feed

Step 2: Calculating a weighted average for by-product fishmeal and fish oil inclusions.

(Eq. 2)

$$FM_{bp} = (X\%_{FM\ bp\ 1} \times X\%_{share\ 1}) + (X\%_{FM\ bp\ 1} \times X\%_{share\ 2}\%) + \cdots$$

$$FO_{bp} = (X\%_{FO\ bp\ 1} \times X\%_{share\ 1}) + (X\%_{FO\ bp\ 1} \times X\%_{share\ 2}\%) + \cdots$$

Where:

$X\%_{FM\ bp\ n}$. = average of fishmeal by-product inclusion levels reported for each feed.

$X\%_{FO\ bp\ n}$. = average of fish oil by-product inclusion levels reported for each feed.

$X\%_{share\ n}$ = estimated market share or proportion of total use for each feed

Step 3: Calculating whole fish inclusion levels by the difference between the by-product percentages, as shown above, and 100% of each respective input.

(Eq. 3)

$$FM_{wf} = (X\% - FM_{bp})$$

$$FO_{wf} = (\mathrm{X}\% - FO_{bp})$$

Step 4: Calculate the FFER for fishmeal and fish oil.

(Eq. 4)

$$FFER_{FM} = \frac{[\mathrm{FM}_{wf} + (FM_{BP} \times 0.05)] \times eFCR}{e}$$

$$FFER_{FO} = \frac{[FO_{wf} + (FO_{bp} \times 0.05)] \times eFCR}{f}$$

Where:

FM_{wf} = fishmeal whole fish inclusion level
FM_{bp} = fishmeal by-product inclusion level
eFCR = economic feed conversion ratio
e = fishmeal yield

FO_{wf} = fish oil whole fish inclusion level
FO_{bp} = fish oil by product inclusion level

f = fish oil yield

Factor 5.1b – Sustainability of the Source of Wild Fish

The following steps are done to calculate a final 5.1b score when multiple feed types are used and there are many sources of marine ingredients (i.e., fishmeal and fish oil):

1. Determine the sustainability score for each source fishery.
2. Calculate whole fish and by-product 5.1b Source Fishery Sustainability scores.
3. Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.
4. Calculate a final Factor 5.1b score by weighting the overall fishmeal and fish oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

Step 1: Determine the sustainability score for each source fishery.

Follow the instructions from the standard (page 39) to determine the sustainability score for each source fishery.

Step 2: Calculate whole fish and by-product 5.1b Source Fishery Sustainability scores.

To determine a single F5.1b Source Fishery Sustainability score for fishmeal and fish oil sourced from whole fish and byproducts across multiple separate feed types, the following equation are used:

(Eq. 5)

$$S_{FM\text{-}wf} = (\frac{FM_{wf1} \times X_{share\,1} \times C_{FM-wfn}}{W_{FM-wf}} + (\frac{FM_{wf2} \times X_{share\,2} \times C_{FM-wfn}}{W_{FM-wf}} + (\frac{FM_{wf3} \times X_{share\,3} \times C_{FM-wfn}}{W_{FM-wf}} + \cdots)/100$$

$$S_{FM\text{-}bp} = (\frac{FM_{bp1} \times X_{share\,1} \times C_{FM-bpn}}{W_{FM-bp}} + (\frac{FM_{bp2} \times X_{share\,2} \times C_{FM-bpn}}{W_{FM-bp}} + (\frac{FM_{bp3} \times X_{share\,3} \times C_{FM-bpn}}{W_{FM-bp}} + \cdots)/100$$

$$S_{FO\text{-}wf} = (\frac{FO_{wf1} \times X_{share\,1} \times C_{FO-wfn}}{W_{FO-wf}} + (\frac{FO_{wf2} \times X_{share\,2} \times C_{FO-wfn}}{W_{FO-wf}} + (\frac{FO_{wf3} \times X_{share\,3} \times C_{FO-wfn}}{W_{FO-wf}} + \cdots)/100$$

$$S_{FO\text{-}bp} = (\frac{FO_{bp1} \times X_{share\,1} \times C_{FO-wfn}}{W_{FO-bp}} + (\frac{FO_{bp\,2} \times X_{share\,2} \times C_{FO-wfn}}{W_{FO-bp}} + (\frac{FO_{bp\,3} \times X_{share\,3} \times C_{FO-wfn}}{W_{FO-bp}} + \cdots)/100$$

Where:

FM_{wfn} = Total fishmeal inclusion from whole fish for each feed type

FM_{bpn} = Total fishmeal inclusion from by-products for each feed type

FO_{wfn} = Total fish oil inclusion from whole fish for each feed type

FO_{bpn} = Total fish oil inclusion from by-products for each feed type

$X_{share\ n}$ = estimated market share or proportion of total use for each feed type

$$W_{FM-wf} = \sum\left[\left(FM_{wfn} \times X_{share\ n}\right)/_{100}\right]$$

$$W_{FM-bp} = \sum\left[\left(FM_{bpn} \times X_{share\ n}\right)/_{100}\right]$$

$$W_{FO-wf} = \sum\left[\left(FO_{wfn} \times X_{share\ n}\right)/_{100}\right]$$

$$W_{FO-bp} = \sum\left[\left(FO_{bpn} \times X_{share\ n}\right)/_{100}\right]$$

$$C_{FM-wfn} = \sum\left[\left(K_n/FM_{wfn}\right) \times F_n\right]$$

$$C_{FM-bpn} = \sum\left[\left(K_n/FM_{bpn}\right) \times F_n\right]$$

$$C_{FO-wfn} = \sum\left[\left(K_n/FO_{wfn}\right) \times F_n\right]$$

$$C_{FO-wfn} = \sum\left[\left(K_n/FO_{bpn}\right) \times F_n\right]$$

Where:

K_n= the given percentage of each source fishery for whole fish or by-product for each feed type

F_n = SFW 5.1b sustainability score of each source fishery for fishmeal or fish oil whole fish or by-product for each feed

W = the weighted inclusion across the feeds for fishmeal or fish oil whole fish or byproducts

C = the weighted sustainability score of each feed for fishmeal or fish oil whole fish or byproducts

Step 3: Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.

Using the fishmeal and fish oil sustainability score values for whole fish and by-products calculated in Step 2, the following equation is then used to calculate the weighted overall sustainability scores for total fishmeal and fish oil (Eq. 6):

(Eq. 6)

$$S_{FMtotal} = (S_{FM-wf} \times 0.95) + (S_{FM-bp} \times 0.05)$$

$$S_{FOtotal} = (S_{FO-wf} \times 0.95) + (S_{FO-bp} \times 0.05)$$

Where:

S_{FM-wf} = weighted sustainability score for fishmeal (whole fish)
S_{FM-bp} = weighted sustainability score for fishmeal (by-product)
S_{FO-wf} = weighted sustainability score for fish oil (whole fish)
S_{FO-bp} = weighted sustainability score for fish oil (by-product)

Step 4: Calculate a final Factor 5.1b score by weighting the total fishmeal and fish oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

(Eq. 7)

$$\text{Final 5.1b score} = \frac{(FFER_{FM} \times S_{FMtotal}) + (FFER_{FO} \times S_{FOtotal})}{(FFER_{FM} + FFER_{FO})}$$

Factor 5.2 – Net protein gain or loss

Step 1: Calculate the net protein gain or loss using the following equation:

(Eq. 8)

$$\text{Net Protein} = \frac{[\text{b} - (\text{h} \times \text{eFCR})]}{(\text{h} \times \text{eFCR}) \times 100}$$

Where:

b = Harvested fish protein content %
h = feed protein content %

Factor 5.3 – Feed Footprint

Step 1: For each feed, calculate the total global warming potential (GWP) for each category (i.e., fishmeal and fish oil from whole fish and by-products, terrestrial crop ingredients, animal ingredients and other) by using the following equations:

(Eq. 9)

$$GWP_{FM-wf} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{FM-bp} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{FO-wf} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{FO-bp} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{terrestrial\ crop\ ingredients} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{terrestrial\ animal\ ingredients} = \sum(K_n \times \mu_n \times 0.01)$$

$$GWP_{other} = \sum(K_n \times \mu_n \times 0.01)$$

Where:

K_n = Inclusion (%) of each ingredient
μ_n = GFLI Economic allocation – EF3.1, values from Climate change (kg CO2 eq / ton product) column *note these values are not published in SFW assessments due to licensing agreements.*

Step 2: For each feed, sum the total global warming potential (GWP) for all categories (i.e., fishmeal and fish oil from whole fish and by-products, terrestrial crop ingredients, animal ingredients and other).

(Eq. 10)

$$d = (GWP_{FM - wf} + GWP_{FM - bp} + GWP_{FO\text{-}wf} + GWP_{FO - bp} + GWP_{terrestrial\ crop\ ingredients} + GWP_{terrestrial\ animal\ ingredients} + GWP_{other})$$

Step 3: For each feed, calculate the estimated total feed global warming potential (GWP) of each feed using the following equation:

(Eq. 11)

$$\rho = \frac{(eFCR)}{(b_n)} \times \frac{(d_n) \times 10}{(c_n)}$$

Where:

eFCR = the reported eFCR associated with each feed

b_n = the whole harvested fish protein content of the species under scope

c_n = the total ingredient inclusion for each feed, ideally is 100%

d_n = Total GWP/mt of feed for each feed, as calculated in Step 2

ρ = Est. kg CO2-eq/kg of farmed seafood protein

Step 4: To determine a single feed footprint a weighted average is calculated between the scores, using the following equation:

(Eq. 12)

$$\text{Weighted kg } CO_2\text{-eq / kg farmed seafood protein} = [(\rho_1 \times X_{share\ 1}) + (\rho_2 \times X_{share\ 2}) + (\rho_3 \times X_{share\ 3}) + \cdots]/100$$

Where:

ρ_n = Est. kg CO_2-eq/kg of farmed seafood protein

$X_{share\ n}$ = estimated market share or proportion of total use for each feed

Calculating Feed Factor 5.3 Feed Footprint Example
Sample calculation of Factor 5.3 using hypothetical feed composition for salmon.
Data values are hypothetical and are not reproduced from the GFLI database.

a) Economic feed conversion ratio (eFCR) = 1.3
b) Whole harvested fish protein content: 18.5 %

Feed ingredients (≥2% inclusion) (please list ingredient and country of origin)	**GWP (incl. LUC)** kg CO2 eq / kg product	**Feed type 1** Ingredient inclusion %	**GWP (incl. LUC)** kg CO2 eq / mt feed
Example	= y	= z	= y × z × 10
Fish meal (Peru, unknown species)	1.522	26	395.72
Fish oil (unknown location, unknown species)	0.693	10	69.3
Soybean meal (Brazil)	2.897	12	347.64
Maize gluten (Europe)	1.322	7	92.54
Wheat gluten (Europe)	1.212	5	60.6
Sunflower seed meal (Denmark)	0.778	12	93.36
Whole wheat (US)	0.633	20	126.6
Rapeseed oil (US)	4.321	5	216.05
Vitamins and minerals (unknown origin)	1.072	2	21.44
	Sum of total	99 = (c)	1423.25 = (d)

$$\frac{(a)}{(b)} \times \frac{[(d)\times 10]}{(c)}$$ = kg CO_2 eq kg^{-1} farmed seafood protein

$$\frac{1.3}{18.5} \times \frac{[1423.25\times 10]}{99} =$$ **10.10** kg CO2-eq kg-1 farmed seafood protein

Impact	kg CO_2-eq kg^{-1} farmed seafood protein	Score
Zero	0	10
Low	0.1 - 4.4	9
	4.5 - 8.8	8
Low-moderate	8.9 - 13.2	7
	13.3 - 17.6	6
Moderate	17.7 - 22.0	5
	22.1 - 26.4	4
Moderate-high	26.5 - 30.8	3
	30.9 - 35.2	2
High	35.3 - 39.9	1
Very high	≥40	0

The final score for Factor 5.3 is 7 out of 10.

Appendix 4 – Polyculture Assessment Methodology for Effluent and Feed

For assessments concerning polyculture systems, the methodology is dependent on whether there is enough data availability to differentiate and/or allocate impacts between all species in the polyculture system. To determine which methodology to use, see the Polyculture Effluent Criterion Methodology and the Polyculture Feed Criterion Methodology below.

Fed species are all species in the production system that are known or assumed to be directly consuming feed inputs (e.g., salmon, tilapia, shrimp, etc.).

Unfed species are all species in the production system that do not directly consume feed inputs (e.g., autotrophs, bivalves, etc.). For extractive species such as sea cucumbers and urchins, consider them unfed unless data indicate otherwise.

Polyculture Effluent Criterion Methodology

<u>For assessments where there are robust data available to identify and allocate waste discharges to individual species within the system, conduct individual assessments of the waste discharges of that/those species.</u>

- Factor 2.1a: Allocate waste discharges based on the total discharge and the relative contributions by each species, resulting in individual scores for each species.
    - For example, if 100 kg N are discharged from the system and data indicate that species A contributes 80 kg N and species B contributes 20 kg N, score each species based on their individual contributions.
- Factor 2.1b: Assess as normal, where the total biological waste production per ton of fish is modified by the basic production system discharge.

<u>For assessments where there are not robust data available to identify and allocate waste discharges to individual species within the system **and** there is a physical boundary between the production system and the environment, then conduct a weighted assessment of the feed consumption of the fed species in the system, and all other (i.e., unfed) species are given a final Effluent score of 10:</u>

- Factor 2.1a: The characteristics of the fed species (i.e., protein content of feed applied, eFCR, and protein content of harvested whole fish) are used to estimate the biological waste production per ton of fish. Where fertilizers are used, the nitrogenous fertilizer input to the entire system should be divided by the harvested biomass of the fed species only to achieve the required nitrogen-per-ton-of-production value.
    - If there are multiple fed species, conduct the assessment with values calculated on a weighted basis.
        - Protein content: Protein content of the feed applied, or weighted protein content relative to all feeds applied, or crude average of protein content of all feeds applied.
        - eFCR: Total feed input divided by total fed species harvest.
        - Fertilizer: Total nitrogenous fertilizer applied per ton of total fed species harvested.

        - Protein content of harvested fish: weighted protein content relative to all fed species harvested, or crude average of protein content of all fed species harvested.
- Factor 2.1b: The total biological waste production per ton of fish that is produced by the fed species is modified by its basic production system discharge **and** the nutrient uptake (e.g., nitrogen assimilation) of the unfed species in the system where data allow.
    - Nutrient (nitrogen) uptake by the unfed species in the system can be estimated by using the total harvested biomass of the unfed species and the total harvested protein content of the unfed species.

<u>For assessments where there are not robust data available to allocate effluent impacts to individual species within the system and there is **no** physical boundary between the production system and the environment, conduct a weighted assessment of the effluent discharges of the fed species and all other (i.e., unfed) species are given a final Effluent score of 10.</u>

- Factor 2.1a: The characteristics of the fed species (i.e., protein content of feed applied, eFCR, and protein content of harvested whole fish) are used to estimate the biological waste production per ton of fish. Where fertilizers are used, the nitrogenous fertilizer input to the entire system should be divided by the harvested biomass of the fed species only to achieve the required nitrogen-per-ton-of-production value.
    - If there are multiple fed species, conduct the assessment with values calculated on a weighted basis.
        - Protein content: Protein content of the feed applied, or weighted protein content relative to all feeds applied, or crude average of protein content of all feeds applied.
        - eFCR: Total feed input divided by total fed species harvest.
        - Fertilizer: Total nitrogenous fertilizer applied per ton of total fed species harvested.
        - Protein content of harvested fish: weighted protein content relative to all fed species harvested, or crude average of protein content of all fed species harvested.
- Factor 2.1b: The total biological waste production per ton of fish that is produced by the fed species is modified by its basic production system discharge.

Polyculture Feed Criterion Methodology

<u>For assessments where there are robust data available to identify feed application and use by individual species within the system, conduct individual assessments of the feed consumption of that/those species; if more than one species is fed and data show each species consumes only the feed applied/intended for it, conduct an assessment for each species and the feed it consumes. All other (i.e., unfed) species are given a final Feed score of 10.</u>

- Factor 5.1: Assess as normal utilizing the fed species' eFCR (i.e., divide the feed input to that species by the harvested biomass of that species) and the marine ingredient inclusions of the feed(s) applied (on a weighted basis if multiple feeds are applied to that species).
- Factor 5.2: Assess as normal with the protein input attributes defined by the feed(s) applied (on a weighted basis if multiple feeds are applied to that species) and the protein outputs of the fed species.

- Factor 5.3: Assess utilizing the weighted protein attributes (and feed inputs if multiple feeds are applied) determined in Factor 5.2.

For assessments where there are not robust data available to determine which fed species within the system consume the applied feeds, conduct a system-wide feed assessment with weighted values where relevant and available. All other (i.e., unfed) species are given a final Feed score of 10.

- All feeds used in the system are considered. A system-wide eFCR must be determined and feed ingredient sustainability is considered on a weighted basis relative to the feeds applied. The system-wide eFCR should be calculated by dividing the total amount of feed applied by the total amount of fed seafood harvested, and used for all calculations in this Criterion.
    - Factor 5.1: Use a calculated system-wide FFER (Factor 5.1a) and combine with a weighted evaluation of marine ingredient sustainability (Factor 5.1b).
        - For Factor 5.1a, the fishmeal and fish oil inclusions should be determined on a weighted basis (i.e., relative to the feeds applied) to create a single fishmeal and a single fish oil inclusion. For Factor 5.1b, determine a single sustainability score on a weighted basis.
    - Factor 5.2: Consider the crude protein content of all feeds applied and the harvested protein outputs of the fed species, both on a weighted basis, to create a single protein in and single protein out.
    - Factor 5.3: Use the system harvested protein output calculated in Factor 5.2 and conduct an assessment for each feed applied to obtain a global warming potential value for each fed species (kg CO_2 eq kg^{-1} farmed seafood protein). Combine the calculated values on a weighted basis to obtain a final Factor 5.3 score.

Appendix 5 – Document Revision History Summary

Calculation guidance was added to VA4.0 of the standard in April 2023 as summarized below. The resulting document remains VA4.0 (this document).

Criterion 5 – Feed

- Changed equation formatting in Factor 5.2 – Net protein gain or loss to align with Appendix 3.

Appendix 3 – Additional guidance for the Feed Criterion

- Inserted detailed guidance for calculating each Factor in Criterion 5 – Feed, including equations for assessing both single and multiple feed types.

Calculation guidance was added to VA4.0 of the standard in November 2022 as summarized below. The resulting document remains VA4.0 (this document).

Criterion 5 – Feed

- Clarified guidance for using the Global Feed Lifecycle Institute (GFLI) database.

Appendix 3 – Additional guidance for the Feed Criterion

- Inserted guidance for calculating Factor 5.1 – Wild fish use, including equations for weighting multiple feed types and multiple ingredients within each feed.

VA3.2 of the standard was revised in February 2020 as summarized below. The resulting document is VA4.0 (this document).

All Criteria

- Changed scoring table concern column "no concern" indicator to "very low".

Criterion 2 – Effluent and Criterion 3 – Habitat

- The scope of Effluent was modified such that all effluent discharges from farms (including those from net pens) are now considered in Criterion 2 – Effluent, regardless of the distance of that impact from the farm. Previously, net pen effluent discharges impacting the benthos were split between the two criteria, with impacts outside an allowable zone of effect (AZE) considered in Criterion 2 – Effluent and impacts within an AZE considered in Criterion 3 – Habitat. The intent of this change is to assess the cumulative nutrient-related impacts of any industry under Criterion 2 – Effluent, and assess the cumulative physical impacts (e.g. physical impacts of farm structures, habitat fragmentation, plastics, etc.) under Criterion 3 – Habitat.

Criterion 2 – Effluent

- Inserted some guidance for assessing polyculture systems with further guidance in Appendix 4. This guidance intends to ensure basic nutrient dynamics associated with multi-species systems can be accounted for in the calculation of likely impact from discharges of such systems. Guidance for polyculture has also been inserted into other criteria, as well as the scope of assessment in the standard's introduction, but the most substantial change has been its incorporation into Criterion 2 and Criterion 5.

Criterion 4 – Chemical Use

- Modified language for a score of 10 out of 10 to require that chemical treatments have not been used for the most recent three consecutive production cycles or three consecutive years for cycles longer than one year, and the species or production system has a demonstrably low need for chemical use.
- Modified language such that the use of antimicrobials critically important for human medicine in significant quantities (defined as more than once per production cycle) or unknown quantities to be considered a Critical conservation concern. A Critical concern drives the overall rating to a red Avoid regardless of how the rest of the criteria are scored.
- Modified language such that the use of antimicrobials highly important for human medicine in significant quantities (defined as more than once per production cycle) remains at a score of 2 out of 10, but the use of those products in unknown quantities is

now considered a score of 0 out of 10.

Criterion 5 – Feed

- Inserted guidance for assessing polyculture systems (inclusive of cleaner fish and multi-trophic systems) and is further described in Appendix 4.

- Factor 5.1 – Wild Fish Use
  - Increasing the weighting of the sustainability of the source fisheries for marine ingredients, and partially including the use of by-product fishmeal and fish oil in the calculation of FFER.

- Factor 5.2 – Net Protein Gain/Loss
  - Simplifying the 'protein budget' calculation to a simple "all protein in, all protein out"; this is in recognition of the incredibly complex determinations (as a result of often-conflicting ecological, economic, and social values) of the 'edibility' of ingredients used in aquafeeds.

- Factor 5.3 – Feed Footprint
  - The transition from a crude Earth-area-based metric to the utilization of a new, robust, and publicly- available life cycle assessment database to estimate the global warming potential (via CO2-equivalents) of feed production on a per-kg of harvested fish protein basis.

Criterion 8X – Source of Stock

- Provided explicit guidance that the use of any species actively stocked to be a part of the farming system, including those not otherwise the primary harvestable species (e.g. cleaner fish used in salmon farming systems), must be scored in Criterion 8X.

- Modified language such that sourcing of Seafood Watch Red/Avoid fishery products for species actively stocked to be a part of the system is now considered a Critical conservation concern.

Criterion 9X – Wildlife Mortalities

- Restructured to allow for both Evidence-based and Risk-Based Assessment options, depending on data availability. Incorporating the concept of Potential Biological Removal, this will allow data on the impact of any aquaculture-related wildlife mortalities, where they exist, to be more robustly used. This also allowed scoring options for when robust data are not available to be more distinguishable from one another and result in clearer risk-based scoring decisions.