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 September 30, 2015 by the Seafood Watch Multi-Stakeholder Group. 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. Both the Standard for Aquaculture and the Standard for Fisheries, in addition to our assessment process, assessments and recommendations, are available at www.seafoodwatch.org.

This Standard will be used for all aquaculture assessments beginning January 1 2016, 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 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 ≥6.66[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.

[1] Each criterion is scored from 1 to 10 based on sub-factor scores, as described in the document below. Criteria scoring <3.3 are considered "red" criteria.

[2] Very severe conservation concerns receive "Critical" scores, which result in an Avoid recommendation.

Good Alternative	Final score ≥3.331 and ≤6.66, **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.
Avoid	Final Score ≥0 and ≤3.33, **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 ~~non-target~~ 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 from individual farms to regional, national and international industries. 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.

Scale of Assessment

Seafood Watch conducts assessments at a variety of scales from individual farms to country level industries. The criteria are applied consistently across these scales depending on the data that are available. For all scales of assessment their relative contributions to the cumulative impacts of neighboring farms and the larger scale industry are addressed where relevant.

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 publically available.

<u>Background and Rationale</u>

Aquaculture frequently operates in the public domain or "the commons", but farm level records, independent monitoring data, and industry production data are typically sparse or unavailable unless aggregated or anonymous. While Freedom of Information claims allow access to some sources, the ability to make informed environmental performance assessments of these industries is often limited.

The Data Criterion is intended to reward those responsible companies, industries and regulators that make data on their activities and impacts available, or those operations that are well researched (accepting that research may be focused on some of the worst impacts or performers). It is understood that not all areas of data will be applicable to each assessment; in these cases, a "not applicable" option is available that avoids penalizing assessments for not having data that are not relevant to the particular industry/region under assessment. The calculation determining the final Data Criterion score will reflect only the number of applicable data categories.

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.

Data quality and availability are addressed in this criterion as well as individually in key areas of several of the other criteria through the use of low scores for "unknown" information. 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 significant[4] impact, but information is not available.

**Note:* 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.")

Assessment scale

- Farm-level assessments – apply this criterion to the farm being assessed, or at a broader level, where relevant (e.g., regulations or enforcement).

- Regional or national assessments – apply to regional or national statistics, or relevant impacts. Use "typical" or "average" farms within the region or country, where necessary.

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. While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Data -Table 1

Quality	Examples of Data Availability, Quality and Confidence	Score
High	Assessor confidence is high that the operation and its impacts are fully understood, examples include: ▪ 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	Data are considered to give a reliable representation of the operation(s) and/or impacts examples include:	7.5

[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).

[4] Generally refers to population level impacts (as opposed to impacts to individual animals).

	▪ 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	
Moderate	Data provides some useful information, but the assessor (subjectively) is uncertain whether data fully represent the farming operations ▪ 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	Data provide little useful information and are not sufficient to give confidence that the operation and its impacts are well understood ▪ 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	Data do not provide useful information and are not considered to represent the operation(s) and/or impacts ▪ Data are incomplete or out of date, unverified, or collection methods are inappropriate	0

Data – Table 2

Category	Data Description	Score 0-10 or n/a
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[5], inclusion of area-based or cumulative impact measures, implementation and enforcement at the individual farm level	
Effluent	Water quality testing, impact monitoring, regulatory control and enforcement	

[5] 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.

Habitat	Farm locations, habitat types, impact assessments, history of conversion, habitat monitoring, habitat regulatory control and enforcement	
Chemicals	Type, frequency, dose and discharge characteristics, impact monitoring, regulatory restrictions	
Feed	eFCR, inclusion rates of fishmeal and oil (including by-products) and of other ingredient groups[6] (vegetable or crop meals and oils, land animal products and by-products). Sustainability of fisheries supplying marine ingredients	
Escapes	Numbers and size of animals, recapture or survival rates, 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	Source of farm stocks, use of wild fisheries for broodstock, larvae or juveniles	
Predators Wildlife	Predator and wildlife mortality rates and evidence of population impacts	
Introduced species	International or trans-waterbody live animal movements, species and domestication status, biosecurity of sources and destinations	
Energy Use	Electricity, fuel use, etc.	
	Total Score	

$$\text{Data Criterion Score} = \left(\frac{\text{Total}}{12 - \text{sum(n/a)}} \right)$$

Final data criterion score = _______ (range 0–10)

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 beyond the farm or its allowable zone of effect.
- *Principle:* Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level..

[6] Seafood Watch recognizes the proprietary nature of feed formulations and does not expect these to be made available, but data on basic inclusion levels of key ingredient groups is an essential starting point for assessing feed sustainability.

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 effluent effects outside the farm boundary or beyond an allowable zone of effect. Effluent impacts within the farm's boundary, immediate area or allowable zone of effect are addressed in Criterion 3 – Habitat.

While it would be preferable to make a direct measurement of effluent impacts resulting from farm discharges, this is generally impossible. The impact is typically 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[7] 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 exceed the carrying capacity of the receiving waters. The Effluent Criterion primarily focuses on soluble and particulate fish wastes but can also include plastics, feed bags, nets, ropes, etc. where relevant.

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

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).

[7] 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).

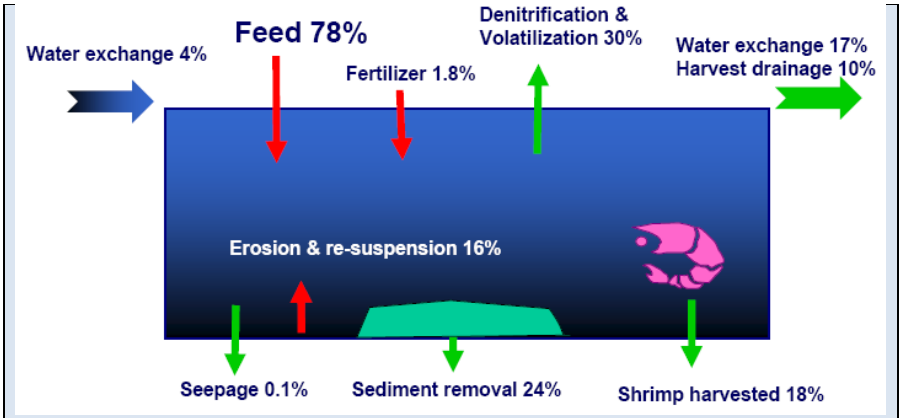

Figure 1 – Shrimp pond nitrogen dynamics, from Sonnenholzer (2008).

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

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 - 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 - 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[8] 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 effects outside the farm boundary or beyond an allowable zone of effect. Impacts within the farm's boundary, immediate area or allowable zone of effect are addressed in Criterion 3 – Habitat. While relevant distances or boundaries of AZEs will vary, 30m is suggested as an initial distance for this assessment unless other information is available.

For example:

- For net pen farms, Criterion 2 – Effluent applies beyond the edge of the net pens (initially suggested as 30 m from the edge of the pens), or beyond an Allowable Zone of Effect (AZE).

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

It applies to both benthic and water column impacts. Criterion 3 – Habitat applies to benthic impacts under the net pens and within 30 m or the AZE.

- 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.

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
No concern	▪ 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[9] wastes ▪ 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
Low-moderate	▪ Data show no evidence that effluent discharge impacts beyond the immediate vicinity of the farm or discharge point[10], but there is	6

[9] Soluble and solid wastes – including solids such as pond sludge, filter solids, plastic wastes etc.
[10] Immediate vicinity – as a guide, beyond 30 m from the farm, or beyond an allowable zone of effect

	potential for cumulative impacts at the waterbody or regional scale	
Moderate	▪ Data show only occasional, temporary or minor[11] 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 evidence of frequent impacts beyond the immediate vicinity of the farm or discharge point, or contributions to cumulative local or regional impacts	2
High	▪ Data show discharges cause persistent and/or irreversible impacts beyond the immediate vicinity of the farm or discharge point, and/or contribute to cumulative local or regional impacts	0
Critical	▪ Data show discharges from aquaculture operations lead to population declines in key indicator species beyond the immediate vicinity of the farm or discharge point, or result in mortality of protected or endangered species	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 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).

[11] Occasional, temporary 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.

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	0.8	
2. Modified cages (e.g., 'diapers') – provide data on waste collection	X	
Adjustment – other – provide data		-X
Ponds		
1. Ponds – unknown operation, or operating as a flow-through raceway system	1.0	
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 adjustment (daily use with discharged water; minimum 12 hours retention time)		-0.17

Commented [LT1]: This additional language is purely for clarification and does not change any scoring.

It is to clarify that we assess water exchange rates as an average, annual, daily rate over an entire grow out cycle, rather than on a day-to-day basis, which the earlier language could be interpreted to mean.

[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.

Adjustment (pond average annual daily exchange >3%) – use of settling pond for discharged harvest water		-0.1
Adjustment (pond average annual daily exchange >3%) – proper sludge disposal adjustment		-0.24
Adjustment (pond average annual daily exchange <3%) – settling pond adjustment (daily use with discharged water; minimum 12 hours retention time)		-0.14
Adjustment (pond average annual daily exchange <3%) – use of settling pond for discharged harvest water		-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[13], regional or 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:

[13] Use the relevant FAO National Aquaculture Legislation Overview (NALO) country factsheet if necessary.

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[14]. 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 ~~farm-specific~~ effluent limits ~~set~~, 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

Commented [LT2]: Text added to clarify the intent of the score 3 out of 5 with relation to scores 2 and 4 out of 5. This does not result in any changes to scoring, just clarification of intent and justification.

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 and peak events. Evidence of monitoring and compliance, 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. Some gaps in monitoring or compliance data.	3

[14] E.g. agriculture, manufacturing or domestic wastes.

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, within the farm boundary or an Allowable Zone of Effect (Factor 3.1) and the scope and effectiveness of management or regulatory systems which govern them (Factor 3.2). 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.

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 (>15 years ago), in the recent past (<15 years), or is having an ongoing impact. Fifteen years was chosen as the threshold date for 'historical' or 'recent' due to the adoption of the mission of the RAMSAR Convention by its Parties in 1999 ("the conservation and wise use of all wetlands…"). 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 even 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 more than 15 years ago in original (or "pristine") ecosystem, or less than 15 years ago in a habitat that had previously lost functionality (e.g. rice fields, pastures), then the score will be higher (between 4 and 6 depending on the original habitat value) than if the aquaculture farm has been recently established (less than 15 years) in a pristine habitat. This classification seeks to penalize the damage that resulted from aquaculture conversion, but avoids making 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.

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:

<u>Step 1</u>

- 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.

<u>Step 2</u>

- 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, 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.
    - 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.

<u>Step 3</u>

- 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 > 15-years ago	Low	6
Historic loss of functionality occurred > 15 years ago	Moderate	5
Historic loss of functionality occurred > 15 years ago	High	4
Loss of functionality occurred < 15 years ago, or ongoing loss of functionality	Low	3
Loss of functionality occurred < 15 years ago, or ongoing loss of functionality	Moderate	2
Loss of functionality occurred < 15 years ago	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

High	Moderate	Low
Coastal intertidal Coastal/terrestrial shoreline Estuaries Tidal wetlands and forests Freshwater wetlands Coral reefs Seagrass/algae beds Freshwater lakes Rivers and streams	Coastal inshore sub-tidal[15] Riparian land and floodplains Temperate broadleaf and mixed forests	Open ocean/offshore[16] Coniferous forests Grasslands, savanna and shrublands Desert and dry shrublands

[15] Inshore sub-tidal = approximately from zero to three nautical miles from the main coastline.
[16] Open ocean/offshore = greater than three nautical miles offshore.

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[17] and authority for enactment.

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

- National[18], 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

[17] 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.
[18] Use the relevant FAO National Aquaculture Legislation Overview (NALO) country factsheet if necessary.

Comprehensive	Area based, cumulative management system is in place with aquaculture farm siting integrated with other industries based on maintaining ecosystem functionality of the affected habitats. Future expansion is addressed accordingly, and if relevant[19], restoration of former high value habitats is required.	5
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[20], 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

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

Limited	Enforcement measures are limited, do not cover cumulative habitat impacts, or transparency and 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 enforcement activity. Persistent illegal siting activities occurring[21]	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:* Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to 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 important 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.

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

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, 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 antibiotics, fish farmers still use chemicals on a regular basis in their operations (Milanao et al. 2011, Rico et al. 2012).

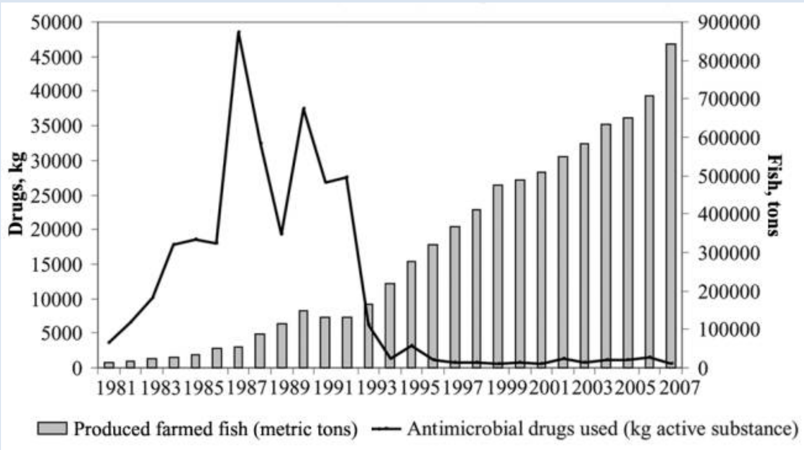

Figure 4 — Antimicrobial drug use, and farmed Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) production in Norway. From Heuer et al. (2009).

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 antibiotics 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 antibiotics, 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 antibiotic use is the development of resistance by bacterial populations, particularly those listed as “Critically

Important" for human medicine according to the World Health Organisation (WHO, 2011). It is clear that any and every use of antibiotics selects for resistance (Davies, 2010), and it is therefore essential that antibiotic use is minimized and that they are used prudently.

The emergence of antibiotic resistance among fish pathogens undermines the effectiveness of the prophylactic use of antibiotics in aquaculture (Baquero et al. 2008). The antibiotic 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 antibiotics, are directly released to the environment. According to Christensen et al. (2006), 70 -80% of the antibiotics 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, <u>or</u> 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 no discharge chemicals or their by-products, systems that present evidence of no use of chemicals over multiple production systems, or systems in which effluent treatment does not allow chemical discharge present no concern, having the highest score (10 out of 10) in the scoring table. In contrast, the use of illegal chemicals, or the use of chemicals that have a high risk to human health, 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 evidence of pathogens with developed resistance to chemicals that are highly important or critically important to human health. The Chemical Use criterion is also scored Critical 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.

Commented [LT3]: This clarifies that the trend adjustment, which was added as part of the Seafood Watch Aquaculture Standard update in 2015, cannot be applied if the base score for Criterion 4 is Critical.

This functions to ensure that if ongoing activities are egregious enough to warrant a Critical score, a decline in chemical use will not improve the score and sweep those activities under the rug.

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.

Scale:

- Farm level assessments – apply this criterion to the farm being assessed but consider the farms contribution to cumulative impacts relative to neighboring farms.
- Regional or national assessments – apply to relevant regional, national, or eco-certification statistics or impacts, or use data from "typical" or "average" farms.

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.

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[22] 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
No concern	▪ The production system is closed and does not discharge active chemicals or by-products (e.g. antibiotic 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 over multiple production cycles, 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 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[23] evidence of impacts to non-target organisms beyond an allowable zone of effect, or; ▪ Some evidence or concern of resistance to chemical treatments, or;	4

[22] 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
[23] Refers to impacts to individual animals only (no population level impacts).

	▪ ~~Regulations or management measures with demonstrated effective enforcement are in place that limit the frequency of use and/or total use of chemicals.~~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	
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[24], or; ▪ ~~Confirmed cases of resistance to chemical treatments, or;~~Confirmed cases of resistance to chemical treatments with no effective mitigation measures, or; ▪ Chemicals highly important to human health[25] are being used in significant[26] or unknown quantities.	2
High	▪ Illegal chemicals (as defined by the country of production) are used beyond exceptional cases[27], or; ▪ Chemicals critically important to human health[28] are being used in significant[29] or 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 chemicals (e.g. loss of efficacy of treatments) that are highly important or critically important to human health, or; ▪ Illegal activities with demonstrable, long-term, negative environmental impacts.	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)

Commented [LT4]: Proposed change to language to make this scoring option applicable to management measures for limits on frequency of use, total use, and mitigation measures (as seen in the proposed update in score 2 out of 10 below).

Commented [LT5]: This text is added to make this scoring option more appropriate to a score of 2 out of 10. It is intended to be applied in scenarios where there is confirmed resistance, and management measures are either not in place or are ineffective. In a scenario where there is a case of resistance and management measures effectively mitigate that resistance a higher score would be applied.

Commented [LT6]: This added text is intended to decrease subjectivity and clarify the intent of this scoring option.

This scoring option is intended for long-term negative impacts from illegal chemical use.

The original wording could have been incorrectly interpreted as applying to a scenario where a one-time illegal activity had a minimal, short-term ecological impact.

---

[24] While limits may exist, Seafood Watch does not defer to regulation as a proxy for ecological conservation
[25] Highly important chemicals listed in - http://www.who.int/foodborne_disease/resistance/cia/en/ have been used in the current or previous production cycle.
[26] 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 antibiotic use (if this is the only data available) imply the same (estimated).
[27] 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 less than once in a three year period.
[28] Critically important chemicals listed in - http://www.who.int/foodborne_disease/resistance/cia/en/ have been used in the current or previous production cycle.
[29] 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 antibiotic use (if this is the only data available) imply the same (estimated).

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. Feed use is considered to be one of the defining factors of aquaculture sustainability.
- *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 use of terrestrial ingredients (crop and livestock-derived) also have impacts on the environment. As the latter are increasingly used as substitutes for marine ingredients in aquaculture feeds, 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 ‘footprint’ of feed production

The combination of these three aspects allows a thorough assessment of the driving forces leading to more sustainable practices. 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 net benefit from using fishmeal and oil from non-edible by-products or processing wastes
- The use of sustainable or unsustainable sources of fishmeal and oil
- The use of whole ‘trash’ fish for feed
- The use of terrestrial crop and animal ingredients to replace aquatic fishmeal and oil
- The net gain or loss of edible protein from the aquaculture operation
- The net benefit from using non-edible crop and by-product animal ingredients

- The gain in protein biological value from converting crop ingredients to fish muscle
- The edible yield of farmed fish (i.e. the benefit from consuming a greater portion of the harvested fish).
- The use of the non-edible by-products from farmed fish after harvest

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. That is, species such as bivalve shellfish or fish or shrimp grown in extensive ponds with no additional feed are given a score of 10 out of 10.

<u>By-product feed ingredients</u>
Seafood Watch supports the use of by-product ingredients (e.g. fisheries or land-animal by-products) in aquaculture feeds, but also recognizes the ecological costs of their production and harvest, which are arguably the same as their counterpart co-products (e.g. fillets or edible meat). This criterion currently does not include fishery by-products in the Wild Fish Use Factor, or land animal by-products in the Protein Retention Factor because this might dis-incentivize their use in favor of whole ingredients, but they are included in the Feed Footprint Factor.

Factor 5.1 – Wild Fish Use
This factor combines the amount of whole 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) 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 would need to be caught to produce one ton of farmed fish.

The sustainability of the source fishery is a basic assessment that uses commonly available metrics that avoid the need for an independent fishery assessment. It applies an increasingly large negative adjustment to the wild fish use score for an increasingly unsustainable source fishery. In this way, Seafood Watch takes the position that using sustainable sources of fishmeal and oil should be the minimum acceptable baseline, and a penalty is applied for unsustainable sources.

Factor 5.1a Wild Fish Use is scored as Critical if the Feed Fish Efficiency Ratio (FFER) value is >4. If the FFER value is >3 and there is a net protein loss resulting in a score <2 of 10 (i.e., there is a net protein loss >80% and most of the fed nutrients are wasted) in Factor 5.2, the Factor 5.1 score is also Critical.

Factor 5.1b Sustainability of the source of wild fish in feeds scores Critical if it is found that wild fish are being caught using illegal, unreported and unregulated fishing (IUU). This factor also scores Critical if the fishery has egregious bycatch or ecosystem impacts[30], and/or cumulative contributions to unacceptable fishery practices (i.e., while a single fishery may not have a large impact, the industry as a whole contributes cumulatively to unacceptable practices).

Factor 5.2 – Net Protein Gain or Loss
Aquaculture typically results in an overall net loss of edible protein of varying degrees depending on the species farmed, the feed formulation, and the production system. Crompton et al. (2010) concluded that aquaculture (in this 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 edible 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). The equations for the net protein efficiency of the fish farming process are based on the edible protein inputs and the total utilized protein outputs.

Factor 5.3 – Feed Footprint
This factor recognizes that all feed ingredients have an ecological cost of production, and while those made from by-products (e.g. fishmeal from fish filleting wastes or poultry feather meal) are not scored in previous factors, they have a similar ecological impact of production as their more economically valuable co-products (e.g. fish fillets or chicken meat).

The factor uses simple feed inclusion levels of three groups of ingredients (aquatic, crop, and land animal) to estimate the global footprint (ocean + land) required to produce them. Typical ocean productivity values are used for marine ingredients, and data from life cycle assessments are used to estimate crop areas, and also for the areas of crop used to produce land animals.

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 (F5.1). The double-weighting is used because the directed harvest of wild fish is still considered 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, the overall Final score for the Feed criterion will be Critical.

---

[30] Per SFW Standard for Fisheries "The fishery targets and/or regularly retains overfished, depleted, endangered or threatened species, and the fishery is a substantial contributor to mortality of the species, and management lacks in adequate rebuilding or recovery strategy and/or effective practices practices designed to limit mortality of these species (for example, overfishing is occurring)" or the (fishery uses destructive practices such as explosives or poison, e.g. cyanide).

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.

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.[31]

Use the best available (most recent or relevant) data:
a) Fishmeal inclusion level* = _____ %
b) Fish Oil inclusion level* = _____ %
c) Fishmeal yield % = _____ (use 22.5[32] if value is unknown)
d) Fish oil yield % = _____ (use 5.0[34] if value is unknown)
e) Economic FCR[33] = _____

Note on fish processing by-products, trimmings, etc.* **– Feed ingredients from trimmings, by-products or other processing wastes are NOT scored in this equation as it measures direct dependence on wild fisheries. If data are available for these ingredients, they can be subtracted from the inclusion levels used in the FFER calculation (lines a and b above). E.g., if total fishmeal inclusion level is 40% and one-quarter of the fishmeal comes from trimmings or by-products, the final inclusion level = 30%.

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).

Fishmeal and fish oil yield values:
The calculation of the FFER ratio 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). A FFER of less than 1 is given a high (or 'green') score (before applying the factor that penalizes the use of unsustainable sources of FM and FO) shown in Factor 5.1b.

---

[31] Also commonly referred to as the FFDR – Forage Fish Dependency Ratio or FIFO – Fish In : Fish Out Ratio
[32] 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.
[33] Economic FCR or eFCR = total feed used divided by total harvest of fish.

$$FFER_{FishMEAL} = \frac{a \times e}{c} = \_\_\_\_\_\_$$

$$FFER_{Fish\ OIL} = \frac{b \times e}{d} = \_\_\_\_\_\_$$

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

FFER score = 10 - (2.5 x FFER)
FFER score = ________ (range 0–10)

Factor 5.1b – Source fishery sustainability

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

This factor applies a negative adjustment to the FFER score with an increasing penalty for decreasing sustainability. Using sustainable sources results in no penalty.

Using an average, or annual weighted mass-balance estimate of the fishery sources used in a typical feed, decide the appropriate sustainability score according to the following descriptions and examples.

Score	Fishery Sustainability Examples
0	Demonstrably sustainable.[34] MSC certified without conditions. Fishsource scores all > 8. SFW Green. Fishery exceeds all reference points and has no significant concerns.
-2	MSC certified with minor 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.
-4	All Fishsource scores ≥ 6. MSC certified with major conditions. SFW Yellow. Fishery does not meet all reference points or has some significant concerns.
-6	IFFO certified 'Responsible'. FAO Code of Conduct compliant (independently verified). One Fishsource score < 6.
-8	More than one Fishsource score < 6.

[34] 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).

	Unknown sustainability. SFW Red. Fishery does not meet reference points or has significant concerns regarding bycatch or ecosystem impacts.
-10	Unknown source fishery. Demonstrably unsustainable (e.g., overfished with overfishing occurring) SFW Red with a Critical score. Fishery source information deliberately withheld Evidence that source of terrestrial ingredients from agriculture is known to destroy high value habitat.
Critical	Evidence that 25% or more of fishery is illegal, unregulated or unreported[35]. 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)

Factor 5.1 Wild fish use score = FFER score + [(FFER value x [2 x Sustainability score]) / 10]

**Note:* Negative values are possible with this equation, but in these cases the score for this factor is zero.

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 edible protein inputs and the utilized protein outputs. Note "edible" in this context relates to feed ingredients that would be suitable (or equivalent to those suitable) for human consumption.

The net gain or loss in edible or utilized protein is calculated according to the following base equation:

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

Where:

- Edible Feed Protein Input = % Edible Protein Content of Feed x eFCR
- Harvested Protein Output = % Protein Utilized from Whole Harvested Fish

Net protein gain is indicated by a positive result, and net protein loss is indicated by a negative result. The equation will function with very limited data if necessary, but the following additional types of information will reward transparency and a greater amount of data availability from the aquaculture producers or their feed companies.

[35] 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.

Calculating Edible Feed Protein Input
Fish feeds typically contain a mix of edible and non-edible ingredients (from a human consumption perspective). The Edible Feed Protein Input value is based on the percentage of the total feed that is edible protein.

The % 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.

Factor 5.2 is broken down into two assessment options for calculating the protein input (choose the appropriate option):

Option 1 is based on the availability of information on the quantity and type of crop and land animal ingredients included in feed. This option is designed to reward transparency with feed formulations by often allowing better scores to be obtained due to known use of sources of protein non-edible to humans in aquaculture feeds (i.e. non-edible crop ingredients, non-edible land animal ingredients). In this option, the analyst will determine the type of ingredient (crop or land animal), its inclusion level in the feed, the protein content of the ingredient (See Appendix 3 Table A2), and whether the ingredient is considered to be edible or non-edible for humans (See Appendix 3 Table A2). Using these values along with the total protein content of the feed, the analyst will determine the percentages of edible and non-edible protein in the feed. Calculations are included below.

Option 2 is based on the fact that feed formulations are often considered proprietary information by feed companies, and this information is not shared. In this scenario, all protein from non-marine ingredients is considered to be from edible crops, which are considered to be the least efficient source of protein in aquaculture feeds (compared to the biological value of land animal proteins and marine proteins).

Option 1: Crop and land animal ingredients and inclusion levels are KNOWN
To determine whether an ingredient is considered edible or non-edible use Appendix 3 Table A2.

Analysts can calculate the % of protein in feed from each individual ingredient (See Appendix 3 Table A2) and then combine those into edible and non-edible (to populate lines j and k below) **OR** add up the inclusion rates of edible crops, non-edible crops, edible land-animal ingredients and non-edible ingredients and populate lines j and k using average yield values from Appendix 3 Table A3.

Using the protein yield values in Appendix 3 Table A3 calculate (individually for each line f-I using tool in the scoring platform):

a. Protein content of feed
b. Ingredient inclusion level
c. Ingredient protein yield (See Appendix 3 Table A3)
d. % of feed that is protein from ingredient (calculated by analyst: b x c = d)
e. % of protein in feed that is from ingredient (calculated by analyst: d/a = e)

f. Percent of total feed protein that is from edible crop ingredients _______
g. Percent of total feed protein that is from non-edible crop ingredients _______
h. Percent of total feed protein that is from edible land animal ingredients _______
i. Percent of total feed protein that is from non-edible land animal ingredients _______

Combined total of protein contents (between 90 and 110, and ideally close to 100%) _______

Option 1 Summary of edible and non-edible protein inputs:

j. Percent of total protein from edible sources (marine, crop, land animal) _______
k. Percent of total protein from non-edible sources (marine, crop, land animal) _______

- Adjusted percent of total feed protein from edible sources _______
  (100/combined total protein content) x total protein from edible sources
- Adjusted percent of total feed protein from non-edible sources _______
  (100/combined total protein content) x total protein from non-edible sources

Total adjusted protein (should equal 100%) _______

**Note:* Lines j and k above, as well as the adjusted values, are calculated automatically in the scoring platform.

Edible Feed Protein Input = (% Total Protein Content of Feed x Adjusted % of Total Protein from Edible Sources / 100) x eFCR

Overall;
Edible Feed Protein Input = _________ kg protein/100kg fish production

Option 2: Crop and land animal ingredients and inclusion levels are UNKNOWN
Without any specific data on crop or land animal ingredients in feed, the following calculation assumes that all protein that does not come from marine ingredients comes from edible crop ingredients.

Percent of total feed protein from edible crops = 100 - % protein from whole fish - % protein from marine byproducts _______

**Note:* The percent of total feed protein from whole fish and from marine byproducts is automatically calculated in the scoring platform. The % of total feed protein from edible crops is also automatically calculated in the scoring platform. Analysts will not need to complete these calculations during the assessment.

Option 1 Summary of edible and non-edible protein inputs:
Percent of total feed protein from edible sources (marine, edible crops) _______
Percent of total feed protein from non-edible sources (marine) _______

Edible Feed Protein Input = (% Total Protein Content of Feed x % of Total Protein from Edible Sources / 100) x eFCR

Overall;
Edible Feed Protein Input = __________ kg protein/100kg fish production

Calculating Harvested Protein Output

Call For Public Comment
As seen below, one of the assumptions currently made in Seafood Watch's calculation of protein gain/loss is that 100% of the by-products generated during processing harvested farmed fish (i.e. the materials often considered non-edible, such as skin, viscera, head and rack, etc.) are used for further protein production, unless it is known that such products are not utilized. We are requesting constructive comment on this assumption, and welcome specific suggestions for an alternative value that is representative of the global aquaculture industry's further use of harvesting by-products. **Please note that this assumption is not applicable to unfed species or systems (i.e. shellfish), as those species/systems are automatically awarded a Feed Criterion score of 10 out of 10.*

The Harvested Protein Output is based on the % protein content of the harvested fish. Use a value from the Table A1 in Appendix 3, or a specific value if available. This value is then combined with the amount of the total harvested protein that is utilized and not wasted.

The initial equation is:

Utilized Harvested Protein Output (unadjusted)= (% protein content of whole harvested fish x % protein utilized)/100

Seafood Watch considers it to be common practice for all the protein in the harvested fish to be utilized– i.e. after filleting, the by-products (viscera, skin, head etc.) are processed and utilized for further protein production. The "% protein utilized" is therefore considered to be 100% unless it is known that by-products are not utilized; in which case the value can be adjusted accordingly as shown below:

Commented [LT7]: Please see yellow box above asking for public comment feedback on this assumption.

% Protein Utilized = % Edible Yield + By-products Utilized
Where:

- Edible yield = the % of whole fish utilized for human consumption.

And:

- By-products utilized = [(100 - Edible Yield %) x % of By-products Utilized[36]]/100

Overall:
Harvested Protein Output (unadjusted) = _______ kg protein/100kg fish production (also see adjustment for protein quality below)

<u>Recognizing the protein quality of harvested fish</u>
The protein in harvested fish is of a higher nutritional value to humans than that in crop ingredients due to the amino acid profile of proteins in fish. The conversion of crop ingredients to harvested fish is therefore beneficial for human consumption, and can be recognized if data are available. If data are available on the amount of protein that comes from crops (i.e. the remaining protein after marine and land-animal sources), they can be used to adjust the Harvested Protein Output value as follows:

For purposes of this adjustment:

a. Utilized protein outputs (unadjusted)
b. Protein content of feed
c. Percent of total feed protein from edible crops
d. Percent of total feed protein from non-edible crops
e. eFCR

Protein Quality Adjustment = a*b*(c + d) * e/100 * 1.4/100

Adjusted protein output value (kg protein per 100 kg harvested farmed fish) = _________

Final Factor 5.2 Calculation

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

[36] The % of by-products utilized is the percentage of the by-products from harvested fish that are utilized for other purposes, e.g. processed into meals or oils for other animal feed uses. E.g. if only half of the by-products are used, the value is 50%. If three-quarters are used, it is 75%.

	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 ocean and land area used to produce the feed ingredients necessary to grow one ton of farmed fish.

Factor 5.3a – Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

a) Inclusion level of aquatic feed ingredients* = FM% + FO% = ____ %
b) eFCR = _____
c) Average primary productivity (carbon) required for aquatic feed ingredients = 69.7 tC t^{-1}
d) Average ocean productivity for continental shelf area = 2.68 t C ha^{-1}

*Include all aquatic ingredients; i.e., by-products or other processing wastes ARE INCLUDED in this calculation.

Ocean area appropriated = [(a / 100) x b x c] / d = _____ ha ton^{-1} of farmed fish

Factor 5.3b - Land area appropriated by feed ingredients per ton of production

a) Inclusion level of crop feed ingredients = ____ %

b) Inclusion level of land animal products = ____ %

- If both the inclusion level of crop and animal ingredients are unknown, assume all non-aquatic ingredients are from crop sources.
- If either the inclusion level of crop ingredients OR land animal ingredients is known, use the inclusion of aquatic ingredients and simple arithmetic to calculate the remaining ingredients (assuming all ingredients add up to 100%).

c) Conversion ratio of crop ingredients to land animal products (e.g. feather meal, pig by-product meal) = 2.88 (fixed value)
d) eFCR of the farmed fish = _____
e) Average yield (per hectare) of major feed ingredient crops = 2.64 tons crops ha^{-1} (fixed value)

Land area appropriated (per ton of farmed fish) = [(a + (b x c)) x 0.01 x d] / e

Land area appropriated = _____ ha ton^{-1} of farmed fish

Total global area appropriated per ton of farmed fish = Ocean area + Land area

Total area = ______ ha ton^{-1} of farmed fish

Total Area	ha ton^{-1}	Score
Zero	0	10
Low	0.1–2.9	9
	3–5.9	8
Low-moderate	6–8.9	7
	9–11.9	6
Moderate	12–14.9	5
	15–17.9	4
Moderate-high	18–20.9	3
	21–23.9	2
High	24–26.9	1
Very high	> 27	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[37], or where the reduction would lead to a reduced risk of impact.

Factor 6.2
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)

[37] 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.

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

- For farm level assessments: apply this criterion to the farm being assessed, or use average or typical data from similar production systems and species if necessary. It is necessary to take into account the farm's contribution to a cumulative level impact, i.e. if the industry in a region consists of a single farm the impact of escapes may be lower than the impact of escapes from a single farm within a larger industry where escapes occur from other farms as well.

For regional or national assessments: apply to relevant regional, national, or eco-certification statistics or impacts, or use typical or average data for the production system or species. Assess impacts of escapes cumulatively.

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.

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[38] to flood, storm or tsunami damage, or; ▪ Robust data[39] 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

[38] 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

[39] 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.

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; ▪ 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[40] of escapees in the wild.	6
Moderate	▪ Ponds with moderate average annual daily exchange (e.g. 3–10%) or that drain externally at harvest, or; ▪ Ponds with a moderate risk[41] of vulnerability to flooding events, or; ▪ Flow-through (i.e. single-pass) tanks or raceways, or: ▪ Open systems going beyond[42] "Best Management" in system design, construction and maintenance, or; ▪ Open systems with documented track record of low escapes (as defined in footnote 41) or failures for at least 10 years, or justifiable evidence[43] 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 indicates infrequent detection of large numbers[44] 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;	2

Commented [LT8]: Addition of scoring option in order to maintain consistency with scoring options in other scores. This was an oversight in the previous iteration of the Seafood Watch Aquaculture Standard, and should be rectified here.

[40] 'Low' numbers of escapees – insufficient numbers to produce population level impacts to wild species in the receiving environment.
[41] 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
[42] For example, exceeding regulatory requirements or the industry's best management practices in design and construction,
[43] e.g. Adaptations to net pen technology or other equivalent that reduces risk of escape
[44] Escape numbers capable of producing population level impacts to wild species in the receiving environment

	▪ Monitoring data indicate escapees are frequently detected in the wild.	
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[45] 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. For example if evidence shows all escapes are recaptured then the Escape Risk score could be improved to 10 out of 10.

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

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

relevant score; for example if the farmed species would unable to breed with wild populations if it were to 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[46], or; ▪ The receiving environment characteristics[47] 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[48] 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[49] 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[50] from selective breeding, or hatchery raised for three generations, or;	4

[46] 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)
[47] For example, identical fish are deliberately stocked into the same environment such that additional farm escapes will not have any additional impact.
[48] 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
[49] 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.
[50] For example, changes in growth rate, disease resistance, body shape, behavior or other changes.

	▪ Non-native - not yet present in the wild (or present in the wild and not yet established[51]), but establishment is possible, or; ▪ 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[52]), 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)[53], 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	▪ 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[54], 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[55] species.	C

Factor 6.2 score

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

Final escape criterion score

[51] 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.

[52] 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.

[53] 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.

[54] The Global Invasive Species Database (GISD) http://www.issg.org/database/welcome/

[55] Listed as endangered or threatened by government, non-government, or conservation organizations (e.g. IUCN, World Wildlife Fund, etc.)

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	<10	<9	<8	<7	<6	<5	<4	<3	<2	<1
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[56] 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.

Assessment scale

- Farm level assessments – apply this criterion to the farm being assessed, or use data from similar production systems and species if necessary.
- Regional or national assessments – apply to relevant regional or national statistics or use "typical" or "average" data for the production system or species.

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.

[56] 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
No concern	▪ 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 physiological impacts to wild species	8
Low-moderate	▪ Pathogens or parasites cause physiological impacts to wild species but do not result in mortality	6
Moderate	▪ Pathogens or parasites cause morbidity or mortality in wild species but have no population-level impact	4
Moderate-high	▪ Disease transmission occurs, and due to low population size[57] 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.	0

Disease: Risk-Based Assessment

Consider **<u>ALL</u>** 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
No concern	▪ 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

[57] The population size is below the point where recruitment or productivity is impaired.

Low	▪ The production system has very limited discharge of water (e.g. farms do not discharge water over multiple production cycles[58]), 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.[59] ▪ Robust[60] fish health and biosecurity management measures[61] 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[62] 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[63] 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	2

[58] 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.
[59] Consider examples of naturally settled shellfish, or extensive fish or shrimp ponds.
[60] 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.
[61] Fish health and biosecurity measures designed for applicability at the farm, waterbody and industry scale.
[62] 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.
[63] 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. The values are not contested by conservation organizations.

	suffers from high disease or pathogen related infection and/or mortality ▪ Discharge of water from farms with known disease events occurs, with vulnerable wild hosts	
High	▪ Wild species are highly susceptible to the pathogens from farms and vulnerable to population-level impacts	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 for growing to harvest size in farms
- *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 or for broodstock.

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 for the harvested farm stock).

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 growout in farms 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.

Assessment scale

- Farm level assessments – apply this criterion to the farm being assessed, or use data from similar production systems and species if necessary.
- Regional or national assessments – apply to relevant regional or national statistics, or use "typical" or "average" data for the production system or species.

Guidance

Source of stock score = the percentage of production that originates from 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 ≥ -4 in Fishery Sustainability Examples table in Factor 5.1b Source Fishery Sustainability

Production from Wild Juveniles or Wild-caught Broodstock (%)	Score
Sourcing of Endangered Species[64]	Critical
100	-10

[64] Listed as endangered or threatened by government, non-government, or conservation organizations (e.g. IUCN, World Wildlife Fund, etc.)

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
10–19.9	-1
0–9.9	0

Final source of stock criterion score = ________ (range 0 to -10, Critical)

Criterion 9X – Predator and 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.

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).

Assessment scale

- For farm level assessments: apply this factor to the farm being assessed
- For regional or national assessments: apply to relevant regional, national, or eco-certification statistics or impacts, or use data from "typical" or "average" farms.

While every eventuality may not be covered in the table, use the examples as guidelines to determine the most appropriate score.

Concern	Examples of Impacts on Predators or Other Wildlife	Score
No concern	▪ No direct or accidental mortality of predators or wildlife.	-0

Low	▪ Aquaculture operation may attract or interact with predators or other wildlife, but effective management and prevention measures limit mortalities to exceptional cases.	-2
Low-moderate	▪ Wildlife mortalities occur (beyond exceptional cases), but due to high population size[65] and/or high productivity[66] and/or low mortality numbers[67], they do not significantly impact[68] the affected species' population size.	-4
Moderate	▪ Mortalities are known to occur but the species' status or impacts on the population size are unknown	-6
Moderate-high	▪ Wildlife mortalities occur; due to low population size[69] and/or low productivity (or other measure of vulnerability), and/or high mortality numbers, they negatively impact the affected species' population size or its ability to recover.	-8
High / Critical	▪ Affected species are protected, endangered, threatened (or other relevant classification) and mortalities contribute to further declines or prohibit recovery.	-10

**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)

Criterion 10X – Escape of ~~non-target~~ secondary species

Commented [LT9]: We are proposing to change the term "non-target" to "secondary" where it appears in Criterion 10X.

There has been confusion over the interpretation of "non-target," and we believe "secondary" better captures the intent, which is to describe species that are unintentionally moved along with the target species.

An example would be in the transport of shrimp post larvae (target species). Any pathogens that are unintentionally transported along with the post larvae would be considered secondary.

If public comment yields more appropriate terminology we will gladly consider it.

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 non-target 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.*** This could include pathogens, parasites, or other ~~non-target~~secondary species unintentionally transported during live animal shipments (e.g. eggs, juveniles or broodstock), or dead animal movements (e.g. baitfish or other unprocessed feed ingredients).

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

[65] Population is at or near its historic high or virgin biomass, or the population size is above the point where recruitment or productivity is impaired.
[66] Marine mammals, turtles, sharks, seabirds and other birds are considered to have low productivity.
[67] Mortality is low compared to natural mortality or mortality from other sources.
[68] Mortalities are at or below a level that will not reduce population productivity.
[69] The population size is below the point where recruitment or productivity is impaired.

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 mass transfer of animals (live or dead) 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 principal farmed species. 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 international or 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 non-native species (pathogens, parasites, other ~~non-target~~secondary species). The scoring table uses the approximate percentage of production reliant on the ongoing international or 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. If aquaculture production does not rely, to any degree, on international or trans-waterbody movements of live animals, it is considered that there is no risk of movement of ~~non-target~~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 live animal shipments determines the risk for non-target species entering shipments, and the biosecurity of the destination determines the risk for releasing them into the wild. The final scoring for Factor 10Xb is the higher of the two biosecurity scores – source or destination.

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

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 non-native species.

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 international or 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 international or 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 escape 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 management of escape and entry prevention (biosecurity) ▪ Any "Low risk" system with uncertainty or evidence questioning the robustness of entry or escape prevention 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 management of escape or entry prevention (biosecurity) ▪ Any "Moderate risk" system with uncertainty or evidence questioning the robustness of escape or entry 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 escapes ▪ 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 3.3, or less than -6.6 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 bad management)
- Habitat C3.1 score = Critical
- Habitat C3 score = 0
- Chemical use C4 score = Critical (i.e., evidence of pathogens with developed resistance to chemicals important to human health) OR; illegal activity with demonstrable negative environmental impacts
- Feed F5.1 FIFO value is greater than 4 (actual FIFO value, not the FIFO score)
- Feed F5.1b Source fishery sustainability score is Critical
- Feed F5.2 PRE score = 0 (i.e., > 90% of the protein provided in the feed is wasted)
- Feed F5.1 FIFO value (not score) > 3 and F5.3 PRE score < 2 (i.e., a lot of wild fish is used in the feed and most of the fed nutrients are 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 = Critical
- 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.))
- Predator/ wildlife mortalities C9X Predators 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	-		
C10X 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 > 6.66 and ≤10, **and** no Red criteria, **and** no Critical scores.
- **Good Alternative** = Final score > 3.33 and ≤6.66, **and/or** one Red criterion, **and** no Critical scores.
- **Avoid** = Final score ≥ 0 ≤ 3.33, **or** more than one Red criterion, **or** one or more Critical scores.

Final Recommendation = ______

References

Andres, B (2015) Summary of reported Atlantic salmon *(Salmo salar)* catches and sightings in British Columbia and results of field work conducted in 2011 and 2012. Department of Fisheries and Oceans Canada, Canadian Technical Report of Fisheries and Aquatic Sciences 3061.

Baquero, F, J-L Martinez, R Canton (2008) Antibiotics and antibiotic resistance in water environments. Current Opinion in Biotechnology 19: 260–265.

Barbier, EB, EW Koch, BR Silliman et al. (2008) Coastal Ecosystem–Based Management with Nonlinear Ecological Functions and Values. Science 319: 321-323.

Bartley, DM, F Marttin (2004) Introduction of Alien Species/Strains and Their Impact on Biodiversity. In: MV Gupta, DM Bartley, BO Acosta (Eds.) Use of genetically improved and alien species for aquaculture and Conservation of Aquatic Biodiversity in Africa. World Fish Center, Penang, pp. 17-21.

Bisson, P (2006) Assessment of the risk of invasion of national forest streams in the Pacific Northwest by farmed Atlantic salmon. Olympia, WA, Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Boissy, J, J Aubin, A Drissi, HMG van der Werf, GJ Bell, SJ Kaushik (2011) Environmental impacts of plant-based salmonid diets at feed and farm scales. Aquaculture 321: 61-70.

Borja, A, DM Dauerb, A Gremarec (2012) The importance of setting targets and reference conditions in assessing marine ecosystem quality. Ecological indicators 12 (1): 1-7.

Boyd, CE, C Tucker, A McNevin, K Bostick, J Clay (2007) Indicators of Resource Use Efficiency and Environmental Performance in Fish and Crustacean Aquaculture. Reviews in Fisheries Science 15: 327-360.

Bravo, S, S Sevatdal, TE Horsberg (2008) Sensitivity assessment of *Caligus rogercresseyi* to emamectin benzoate in Chile. Aquaculture 282 (1-4): 7-12.

Burridge, L, J Van Geest (2014) A review of potential environmental risk associated with the use of pesticides to treat Atlantic salmon against infestations of sea lice in Canada. Fisheries and Oceans Canada, Science.

Burridge, L, JS Weis, F Cabello, J Pizarro, K Bostick (2010) Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. Aquaculture 306 (1-4): 7-23.

Buschmann, AH, A Tomova, A López, MA Maldonado, LA Henríquez et al. (2012) Salmon Aquaculture and Antimicrobial Resistance in the Marine Environment. PLoS ONE 7(8): e42724. doi:10.1371/journal.pone.0042724

Cabello, FC (2006) Heavy use of prophylactic antibiotics in aquaculture: a growing problem for human and animal health and for the environment. Environmental Microbiology 8: 1137–1144.

Cabello, FC, Godfrey, HP, Tomova, A, Ivanova, L, Dölz, H, Millanao, A, Buschmann, AH (2013) Antimicrobial use in aquaculture re-examined: its relevance to antimicrobial resistance and to animal and human health. Environmental microbiology, 15(7), 1917-1942.

Canonico, GC, A Arthington, JK McCrary, ML Thieme (2005) The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine Freshwater Ecosystem 15: 463–483.

Christensen, AM, F Ingerslev, A Baun (2006) Ecotoxicity of mixtures of antibiotics used in aquacultures. Environmental Toxicology and Chemistry 25: 2208–2215.

Cole, DW, R Cole, SJ Gaydos, J Gray, G Hyland, ML Jacques, N Powell-Dunford, C Sawhney, WW Au (2008) Aquaculture: Environmental, toxicological, and health issues. International Journal of Hygiene and Environmental Health 212 (4): 369-377.

Copp GH, L Vilizzi, D Cooper, A South (2007) MFISK: Marine Fish Invasiveness Scoring Kit. [Internet]. Lowestoft (Suffolk): Cefas, Salmon & Freshwater Fisheries Team [cited 2009 September 19]. Available from: http://www.cefas.co.uk/projects/risks-andimpacts-of-non-native-species/decision-support-tools.aspx

Copp, GH, L Vilizzi, J Mumford, GV Fenwick, MJ Godard, RE Gozlan (2009) Calibration of FISK, an Invasiveness Screening Tool for Nonnative Freshwater Fishes. Risk Analysis 29: 457–467.

Davies, J., and D. Davies. 2010. Origins and Evolution of Antibiotic Resistance. Microbiology and Molecular Biology Reviews 74:417-433.

Diana, J (2009) Aquaculture Production and Biodiversity Conservation. BioScience 59: 27-38.

Ellis, BK, JA Stanford, D Goodman, CP Stafford, DL Gustafson, DA Beauchamp, DW Chess, JA Craft, MA Deleray, BS Hansen (2011) Long-term effects of a trophic cascade in a large lake ecosystem. Proceedings of the National Academy of Sciences 108 (3): 1070-1075.

Ellison, AM (2008) Managing mangroves with benthic biodiversity in mind: Moving beyond roving banditry Journal of Sea Research 59: 2-15.

Engle, CR (2009) Mariculture, Economic and Social Impacts. In: JH Steele, KK Turekian, SA Thorpe (eds.). Encyclopedia of Ocean Sciences 2nd Edition. Elsevier, pp. 545-551.

Feld, CK, PM da Silva, JP Sousa, F de Bello, R Bugter, U Grandin, D Hering, S Lavorel, O Mountford, I Pardo, M Partel, J Rombke, L Sandin, B Jones, P Harrison (2009) Indicators of biodiversity and ecosystem services: a synthesis across ecosystems and spatial scales. Oikos 118: 1862-1871.

Fleming, IA, K Hindar, IB Mjolnerod, B Jonsson, T Balstad, A Lamberg (2000) Lifetime success and interactions of farm salmon invading a native population. Proceedings of the Royal Society B 267: 1517-1523.

Ford JS, RA Myers (2008) A global assessment of salmon aquaculture impacts on wild salmonids. PLoS Biol 6(2): e33. doi:10.1371/journal.pbio.0060033

Fortt, A, F Cabello, A Buschmann (2007) Residues of tetracycline and quinolones in wild fish living around a salmon aquaculture center in Chile (in spanish). Revista Chilena de Infectología 24 (1): 14-18.

Gross, A, CE Boyd and CW Wood (2000) Nitrogen transformations and balance in channel catfish ponds. Aquaculture Engineering 24(1): 1-14.

Hargreaves, JA (1998) Nitrogen biogeochemistry of aquaculture ponds. Aquaculture 166 (3-4): 181-212.

Heuer, OE, H Kruse, K Grave, P Collignon, I Karunasagar, FJ Angulo (2009) Human health consequences of use of antimicrobial agents in aquaculture. Clinical Infectious Diseases 49: 1248–1253.

ICES (2004) Code of Practice on the Introductions and Transfers of Marine Organisms. The International Council for the Exploration of the Sea.
http://www.ices.dk/reports/general/2004/icescop2004.pdf

Jackson, C, N Preston, PT Thompson and M Burford (2003) Nitrogen budget and effluent nitrogen components at an intensive shrimp farm. Aquaculture 218 (1-4): 397–411.

Jackson, A (2009) Fish In Fish Out Ratios Explained. Aquaculture Europe 34(3): 5-10.

Jones, P, K Hammell, G Gettinby, C Revie (2013) Detection of emamectin benzoate tolerance emergence in different life stages of sea lice, *Lepeophtheirus salmonis,* on farmed Atlantic salmon, *Salmo salar* L. Journal of Fish Diseases 36: 209-220.

King, SC, R Pushchak (2008) Incorporating cumulative effects into environmental assessments of mariculture: Limitations and failures of current siting methods. Environmental Impact Assessment Review 28: 572–586.

Kostow, K (2009) Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Reviews in Fish Biology and Fisheries 19(1): 9-31.

Krkosek, , M, BM Connors, A Morton, MA Lewis, LM Dill, R Hilborn (2011) Effects of parasites from salmon farms on productivity of wild salmon. Proceedings of the National Academy of Sciences doi: 10.1073/pnas.1101845108.

Lebel, L, NH Tri, A Saengnoree, S Pasong, U Buatama, LK Thoa (2002) Industrial transformation and shrimp aquaculture in Thailand and Vietnam: pathways to ecological, social, and economic sustainability? Ambio 31: 311–323.

Longdill, PC, TR Healy, KP Black (2008) An integrated GIS approach for sustainable aquaculture management area site selection. Ocean & Coastal Management 51: 612–624.

Masser, MP (2000) Pests and predators. In: RR Stickney (ed.) Encyclopedia of Aquaculture. John Wiley, New York, pp. 671-676.

Metzger, MJ, MDA Rounsevell, L Acosta-Michlik, R Leemans, D Schrote (2006) The vulnerability of ecosystem services to land use change. Agriculture, Ecosystems and Environment 114: 69–85.

Millanao BA, HM Barrientos, CC Gómez, A Tomova, A Buschmann, H Dölz and FC Cabello (2011) Injudicious and excessive use of antibiotics: public health and salmon aquaculture in Chile (in Spanish). Revista Medica de Chile 139 (1): 107-118.

Naylor, RL, SLWilliams, DR Stron (2001) Aquaculture—A Gateway for Exotic Species. Science 294: 1655-1656.

Naylor, RL, M Burke (2005) Aquaculture and ocean resources: Raising Tigers of the Sea. Annual Review of Environmental Resources 30: 185–218.

Naylor, R, RW Hardy, DP Bureau, A Chiu, M Elliott, AP Farrell, I Forster, DM Gatlin, RJ Goldburg, K Hua, PD Nichols (2009) Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences 106:15103-15110.

Noakes, D (2011) Impacts of salmon farms on Fraser River sockeye salmon: results of the Noakes investigation. Cohen Commission Technical report 5C, Vancouver, BC.

Panov, VE, B Alexandrov, K Arbaciauskas et al. (2008) Assessing the Risks of Aquatic Species Invasions via European Inland Waterways: From Concepts to Environmental Indicators. Integrated Environmental Assessment and Management 5 (1): 110–126

Peron, G, J Mittaine, B Le Gallic (2010) Where do fishmeal and fish oil products come from? An analysis of the conversion ratios in the global fishmeal industry. Marine Policy doi:10.1016/j.marpol.2010.01.027

Primavera, JH (2006) Overcoming the impacts of aquaculture on the coastal zone. Ocean & Coastal Management 49: 531–545.

Rico, A, K Satapornvanit, MM Haque, J Min, PT Nguyen, T Telfer and PJ van den Brink (2012) Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture 4: 75–93.

Roque d'Orbcastel, E , J-P Blancheton, T Boujard, J Aubin, Y Moutounet, C Przybyla and A Belaud (2008) Comparison of two methods for evaluating waste of a flow through trout farm. Aquaculture 274 (1): 72-79.

Sanchez-Jerez, P, D Fernandez-Jover, J Bayle-Sempere, C Valle, T Dempster, F Tuya, F Juanes. 2008. Interactions between bluefish *Pomatomus saltatrix* (L.) and coastal sea-cage farms in the Mediterranean Sea. Aquaculture 282(1-4): 61-67.

Santos, EM, JS Ball, TD Williams, H Wu, F Ortega, R van Aerle, I Katsiadaki, F Falciani, MR Viant, JK Chipman, CR Tyler (2009) Identifying Health Impacts of Exposure to Copper Using Transcriptomics and Metabolomics in a Fish Model. Environmental Science & Technology 44 (2): 820-826.

Sapkota, A, AR Sapkota, M Kucharski, J Burke, S McKenzie, P Walker, R Lawrence (2008) Aquaculture practices and potential human health risks: current knowledge and future priorities. Environtal International 24: 1215–1226.

Scheffer, M, J Bascompte, WA Brock, V Brovkin, SR Carpenter, V Dakos, H Held, EH van Nes, M Rietkert, G Sugihar (2009) Early-warning signals for critical transitions. Nature 461: 53-59.

Scheffer, M, SR Carpenter (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. Trends in Ecology and Evolution 18(12): 848-656.

Schulz, C, J Gelbrecht and B Rennert (2003) Treatment of rainbow trout farm effluents in constructed wetland with emergent plants and subsurface horizontal water flow. Aquaculture 217 (1–4): 207–221.

Sevatdal, S, L Copley, C Wallace, D Jacksonm TE Horsberg (2005) Monitoring of the sensitivity of sea lice (Lepeophtheirus salmonis) to pyrethroids in Norway, Ireland and Scotland using bioassays and probit modeling. Aquaculture 244 (1-4): 19-27.

Simberloff, D (2005) Non-native species do threaten the natural environment! Journal of Agricultural and Environmental Ethics 18 (6): 595-607.

Sonnenholzer, S (2008) Effluent impact assessment: water quality monitoring vs nutrient budget. WWF Shrimp Aquaculture Dialogue, Guayaquil, Ecuador.

Soto, D, J Aguilar-Manjarrez, C Brugère, D Angel, C Bailey,K Black, P Edwards, B Costa-Pierce, T Chopin, S Deudero, S Freeman, J Hambrey, N Hishamunda, D Knowler, W Silvert, N Marba, S Mathe, R Norambuena, F Simard, P Tett, M Troell, A Wainberg (2008) Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In: D Soto, J Aguilar-Manjarrez, N Hishamunda (eds) Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. pp. 15–35

Tacon AGJ, M Metian (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285 (1-4): 146-158.

Tal, Y, HJ Schreier, KR Sowers, JD Stubblefield, AR Place and Y Zohar (2009) Environmentally sustainable land-based marine aquaculture. Aquaculture 286: 28–35.

Volpe, J, J Gee, V Ethier, M Beck, A Wilson, J Stoner (2013) Global Aquaculture Performance Index (GAPI): The First Global Environmental Assessment of Marine Fish Farming. Seafood Ecology Research Group, Victoria, Canada.

WHO. 2011. Critically important antimicrobials for human medicine. 3rd revision - 2011. World Health Organization.

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.

Wetland ecosystems (mangroves, brackish and freshwater)

Type of Conversion	Remaining Mangrove/ Wetland Area (%)	Other Example or Indicators
Maintains full functionality	100	Undisturbed
Minimal impact	90–100	Little impact on fisheries catch
Minor impacts	70–90	Decrease in fisheries catch Reduced effect on hazard control Loss of juvenile habitat
Moderate impacts	50–70	Changes in species abundance
Major impacts – loss of functionality	0–50	Loss of hazard control capacity Changes in species diversity Significant amount of C release Loss of fisheries Loss of functional diversity

Ocean/ marine ecosystems

Note: benthic marine impacts are typically rapidly reversible, therefore impacts are considered relatively less severe and allocated to different impact groups accordingly.

Type of Conversion	Examples or Indicators				
	(EcoQ)[70]	H'	AMBI	Diversity	Effects
Maintains full functionality	High	H'>4	AMBI≥1.2	90–100% of reference station value	Undisturbed
Minimal impacts	Good	3<H'≤4	1.2<AMBI≤ 3.3	70–90% of reference station value	Slightly disturbed
Minor impacts	Moderate	2<H'≤3	3.3<AMBI≤ 4.3	50–70% of reference station value	Moderately disturbed
Moderate impacts	Poor	1<H'≤2	4.3<AMBI≤ 5.5	30–50% of reference station value	No irreversible impacts on benthic communities (disturbance is rapidly reversed by fallowing) Oxygen depletion Toxic effect of H_2S
Major impact – loss of functionality	Bad	H'≤1	AMBI>5.5	Less than 30% of reference station value	Some evidence of far-field effects Irreversible impacts

<u>Freshwater ecosystems</u>

Note: benthic freshwater impacts are typically rapidly reversible, therefore impacts are considered less severe and allocated accordingly.

Type of conversion	Index of Biotic Integrity	Effects
Maintains full functionality	>90%	Undisturbed
Minimal impacts	75–90%	Slightly disturbed
Minor impacts	70–75%	Moderately disturbed

[70] EcoQ = Biotic biodiversity status

Moderate impacts	65–70%	No irreversible impacts (disturbance is rapidly reversed by fallowing)
Major impact – loss of functionality	<65%	Some evidence of far-field effects

Terrestrial ecosystems

Type of Conversion	Land Cover	Salinization	Effects
Maintains full functionality	70–100 %		
Minor impacts	50–70 %		Reduced C sequestration
Moderate impact	30–50%	Higher soil conductivity	Significant habitat fragmentation
Major impact –loss of functionality	0–30%	Reduced crop yields Loss of soil fertility	

Appendix 2 – Additional guidance for the Habitat Criterion

Historic loss of functionality

- If the farms were established historically (more than ten years ago), the score will be between 4 and 6, depending on the original habitat value.
- If the farms were established less than ten years ago in habitats that had previously lost functionality more than ten years ago, the score will 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 more than ten years ago, the score will 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 (less than ten years ago) 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, or are still expanding into habitat that had previously lost functionality more than ten years ago, 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	

Table A2

Crop and Land Animal Product Protein Content Examples

Protein source	Protein %	Edible?
Feather meal	84.9	no
Meat and bone meal. Defatted 45	42.7	no
Poultry byproduct meal	58.7	no
Blood meal	79.8	no
Maize glutenmeal 60	60.7	yes
Wheat Distillers grains dehy	28.32	no
Maize distillers grains dehy	21.6	no
Soybean meal solv extr 48	45.8	yes
Soybean meal solv extr 44	44.6	yes
Wheat middlings	16.4	no
Wheypowder cattle	13.3	yes
Hard Wheat bran	15.6	yes
Maize yellow	9.6	yes

Table A3

Average Fishmeal, Land Animal and Crop Ingredients Protein Contents

Ingredient	Average Protein content %
Fishmeal	66.5
Land animal ingredients	55.9
Crop ingredients	28.4