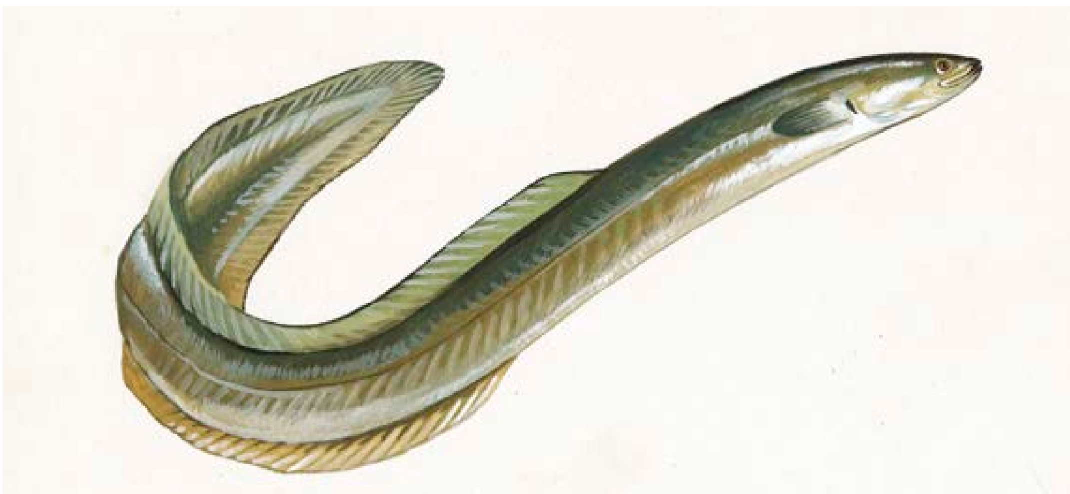
Monterey Bay Aquarium Seafood Watch®

Freshwater Eel (Unagi)

Anguilla anguilla, Anguilla japonica and *Anguilla rostrata*



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China, Japan, Republic of China (Taiwan), and Republic of Korea

Ponds (outdoor, greenhouse and flow-through)

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About Seafood Watch®

The Monterey Bay Aquarium Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the North American marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's mission is to engage and empower consumers and businesses to purchase environmentally responsible seafood fished or farmed in ways that minimize their impact on the environment or are in a credible improvement project with the same goal.

Each sustainability recommendation is supported by a seafood report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's sustainability criteria to arrive at a recommendation of "Best Choice," "Good Alternative," or "Avoid." In producing the seafood reports, Seafood Watch utilizes research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch research analysts also communicate with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying seafood reports will be updated to reflect these changes. Both the detailed evaluation methodology and the scientific reports, are available on seafoodwatch.org.

For more information about Seafood Watch and seafood reports, please contact the Seafood Watch program at Monterey Bay Aquarium by calling 1-877-229-9990 or visit online at seafoodwatch.org.

Seafood Watch and seafood reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture must possess to be considered sustainable by the Seafood Watch program:

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the 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 beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use.
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- Promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture.

1 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy intensive production systems (e.g., promoting more energy intensive closed recirculation systems).

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Are well managed and caught or farmed in environmentally friendly ways.

Good Alternatives/Yellow: Buy, but be aware there are concerns with how they're caught or farmed.

Avoid/Red: Take a pass on these. These items are overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation — China

European Eel, Japanese Eel, American Eel, Unagi

Anguilla anguilla, Anguilla japonica, Anguilla rostrata

Pond (still, greenhouse, flow-through)

FINAL RANK	RED

OVERALL RANKING	
Final Score	0.72
Initial rank	RED
Red Criteria	6
Intermediate Rank	RED
Critical Criteria?	NO

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.06	RED	n/a
C2 Effluent	2.00	RED	NO
C3 Habitat	4.46	YELLOW	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	5.26	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	2.00	RED	NO
C8 Source	0.00	RED	n/a
C9X Wildlife mortalities	-6.00	YELLOW	NO
C10X Introduced species escape	-8.00	RED	n/a
Total	5.78		
Final Score	0.72		

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary

The final numerical score for eel (*Anguilla anguilla, Anguilla japonica,* and *Anguilla rostrata*) farmed in pond culture systems in China is 0.72. The low numerical score along with six red criteria resulted in an overall red ranking.

Final Seafood Recommendation — Japan

European Eel, Japanese Eel, American Eel, Unagi

Anguilla anguilla, Anguilla japonica, Anguilla rostrata

Pond (still, greenhouse, flow-through)

FINAL RANK	RED

OVERALL RANKING	
Final Score	1.25
Initial rank	RED
Red Criteria	5
Intermediate Rank	RED
Critical Criteria?	NO

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.06	RED	n/a
C2 Effluent	2.00	RED	NO
C3 Habitat	4.70	YELLOW	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	5.26	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	2.00	RED	NO
C8 Source	0.00	RED	n/a
C9X Wildlife mortalities	-6.00	YELLOW	NO
C10X Introduced species escape	-8.00	RED	n/a
Total	10.02		
Final Score	1.25		

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary

The final numerical score for eel (*Anguilla anguilla, Anguilla japonica,* and *Anguilla rostrata*) farmed in pond culture systems in Japan 1.25, and with 5 red criteria the final ranking is red overall.

Final Seafood Recommendation – Republic of China (Taiwan)

European Eel, Japanese Eel, American Eel, Unagi

Anguilla anguilla, Anguilla japonica, Anguilla rostrata

Pond (still, greenhouse, flow-through)

FINAL RANK	RED

OVERALL RANKING	
Final Score	0.70
Initial rank	RED
Red Criteria	6
Intermediate Rank	RED
Critical Criteria?	NO

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.06	RED	n/a
C2 Effluent	2.00	RED	NO
C3 Habitat	4.29	YELLOW	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	5.26	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	2.00	RED	NO
C8 Source	0.00	RED	n/a
C9X Wildlife mortalities	-6.00	YELLOW	NO
C10X Introduced species escape	-8.00	RED	n/a
Total	5.61		
Final Score	0.70		

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary

The final numerical score for eel (*Anguilla anguilla, Anguilla japonica,* and *Anguilla rostrata*) farmed in pond culture systems in Taiwan is 0.70. The low numerical score along with six criteria resulted in an overall red ranking.

Final Seafood Recommendation – South Korea

European Eel, Japanese Eel, American Eel, Unagi

Anguilla anguilla, Anguilla japonica, Anguilla rostrata

Pond (still, greenhouse, flow-through)

FINAL RANK	RED

OVERALL RANKING	
Final Score	1.21
Initial rank	RED
Red Criteria	5
Intermediate Rank	RED
Critical Criteria?	NO

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.06	RED	n/a
C2 Effluent	2.00	RED	NO
C3 Habitat	4.40	YELLOW	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	5.26	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	2.00	RED	NO
C8 Source	0.00	RED	n/a
C9X Wildlife mortalities	-6.00	YELLOW	NO
C10X Introduced species escape	-8.00	RED	n/a
Total	9.72		
Final Score	1.21		

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary

The final numerical score for eel (*Anguilla anguilla, Anguilla japonica,* and *Anguilla rostrata*) farmed in pond culture systems in South Korea is 1.21, and with five red criteria the final ranking is red overall.

European Eel, Japanese Eel, American Eel, Unagi

Anguilla anguilla, Anguilla japonica, Anguilla rostrata

Pond (still, greenhouse, flow-through)

Criterion	China	Japan	Taiwan	South Korea
C1 Data	3.06	3.06	3.06	3.06
C2 Effluent	2.00	2.00	2.00	2.00
C3 Habitat	4.46	4.70	4.29	4.40
C4 Chemicals	0.00	4.00	0.00	4.00
C5 Feed	5.26	5.26	5.26	5.26
C6 Escapes	3.00	3.00	3.00	3.00
C7 Disease	2.00	2.00	2.00	2.00
C8 Source	0.00	0.00	0.00	0.00
C9X Wildlife mortalities	-6.00	-6.00	-6.00	-6.00
C10X Introduced species escape	-8.00	-8.00	-8.00	-8.00
Total	5.78	10.02	5.61	9.72
Final Score	0.72	1.25	0.70	1.21

Summary

This table compiles the scores from the four previous tables so as to facilitate comparison between the four countries included in this assessment. Upon closer review, it becomes evident that the only two criteria that vary between countries are Habitat (C3) and Chemicals (C4). The final scores for all four countries vary by only 0.55 and every country receives a red AVOID ranking overall.

Executive Summary

Since the late 1950s, aquaculture has played a growing role in the supply of eel products, and now accounts for over 95% of global eel production by volume. In 2010, over 270,000 metric tons (mt) of farmed eel[2] were produced globally, and China, Japan, Taiwan and Korea accounted for approximately 96% of this production. Pond systems, including outdoor, greenhouse, and flow-through ponds are the predominant production systems employed in these countries and, hence, are the focus of this assessment. The United States ranks as the 6th largest importer of eel products worldwide, but total US imports are less than one tenth (by quantity) of those of the top importers.

A lack of complete, detailed, and independent data available in English presented a significant challenge in conducting this assessment. Some valuable data were collected from government websites, academic literature, grey literature, and personal communications with experts involved in international eel trade and aquaculture. From these multiple sources, sufficient summaries of eel aquaculture practices in Asia were analyzed and informed this assessment. Nonetheless, Seafood Watch is open to reviewing this assessment in the future should more data become available.

Criterion C2 (effluent) scored 2 out of 10, due to the high discharge rate of pond culture systems (10%–35% daily exchange) and the presence of an established regulatory system that lacks transparency and evidence of enforcement in all four countries. Similarly, Criterion C3 (habitat) received an overall score ranging from 4.29 to 4.70 out of 10 because eel aquaculture in ponds is shown to have low habitat conversion rates, however, the regulatory and management regimes in place are lacking in transparency and enforcement, which lead to a low effectiveness score for Factor 3.2b. The final score for Criterion C3 is reported as a range because slight variability in the management regimes across regions necessitated individual country-specific analysis to be conducted for this criterion.

Two assessments were conducted for Criterion C4 (chemical use) due to significant differences in practices applied in various countries. For China and Taiwan, a score of 0 (red ranking) is the result of the use of banned chemical substances (e.g., Malachite green) in farmed eel products. For eel cultured in Japan and South Korea, the chemical criterion receives a score of 4 (yellow) because, although there is evidence that a significant amount of chemicals are used, there have been no reports of the use of banned chemical substances or development of microbial resistance. The high-exchange pond systems employed in eel culture, however, do risk the release of chemicals into the surrounding environment.

Criterion C5 (feed) received a final score of 5.26 (yellow), due to the moderate degree of wild fish used in eel feed (score of 6.53 for Factor 5.1), the 32.9% net protein loss that occurs in eel

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[2]Data from FAO FishStatJ 2013. Many aspects of the international trade of eels, in particular the lack of identification to the species level, make it challenging to accurately record the industry's production statistics, but this is the most robust number available.

farming (score of 6 for Factor 5.2), and the relatively high feed footprint (22.96 hectares) resulting principally from the large area of ocean appropriated for feed production (score of 2 for Factor 5.3). These scores are driven by a relatively high aquatic feed inclusion rate (62.5%), however, much of this (84%) is sourced from processing byproducts as opposed to whole fish, resulting in a moderate score for the Feed criterion.

The impact of escapes from eel culture ponds in Asia was determined to be high (score of 3, red) due to a ‘moderate-high’ escape risk associated with high-exchange pond culture systems. Recent and ongoing reports on non-native eel species in streams and rivers in Japan, China and Taiwan lead to a ‘moderate’ invasiveness score.

Eel diseases and pathogens are reported with relatively high frequency in each of the four assessed countries, and the nature of the production systems employed (pond and/or flow-through) allow for significant amounts of water to exchange into the natural environment, suggesting that release of pathogens or disease from farm sites is likely. Resultantly, Criterion C7 (pathogens) scored 2 overall and received a red ranking.

Criterion C8 scored 0 overall, and ranked red because the eel aquaculture industry remains fully reliant on wild-caught broodstock due to the ongoing challenges to close the lifecycle of eel species for domestication.

No information on wildlife and predator mortalities was available at the time of this report, however, it is reasonable to presume that wildlife interact with eel ponds and that some mortality is likely to occur. Exceptional Criterion 9X scores -6 out of -10 based on unknown species status and unknown population-level impacts of mortalities.

Exceptional Criterion 10X (introduced species escapes) received a score of -8 due to the high dependency on international or trans-waterbody live animal shipments and high biosecurity concerns of both the source (wild-caught glass eels) and destination (pond culture systems) of the animal shipments.

The variation in scores for the Chemical Use and the Habitat Criterions resulted in a slight discrepancy in the final numerical scores for eel cultured in each of the four countries, with China scoring 1.35, Japan scoring 1.88, Taiwan scoring 1.33, and South Korea scoring 1.84. Despite this nominal variation in numerical scoring, the final ranking for eel culture in pond systems in China, Taiwan, Japan and South Korea was red, and the overall recommendation is ’Avoid.’

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European eel *(Anguilla anguilla),* Japanese eel *(Anguilla japonica),* American eel *(Anguilla rostrata)*

Geographic coverage
China, Japan, Republic of China (Taiwan) and Republic of Korea

Production Methods
Eels are raised in a variety of production systems, from earthen ponds to highly technical recirculating aquaculture systems (RAS). RAS are used predominantly in Europe, and global production volumes from these systems are minimal compared to pond production in Asia; as such this assessment focuses on eel cultured in pond systems (including outdoor, greenhouse and flow-through ponds), which are the predominant production systems employed in China, Japan, Taiwan and South Korea.

Species Overview

There are 19 species and sub-species classified under the genus *Anguilla*, most of which are catadromous, meaning that they migrate from rivers and other inland water sources to the sea in order to breed. Of these 19 species and sub-species, only three are currently of interest to this assessment due to their dominance in the US market place: *A. anguilla* (European eel), *A. japonica* (Japanese eel), and *A. rostrata* (American eel). It should be noted that as the dynamics of the global trade in *Anguilla* juveniles (known as "glass eels") continues to shift due to change in species availability. Additionally, a greater diversity of eel species are starting to be farmed in Asia, including *A. marmorata, A. bicolor*, *A. mossambica*, and *A. luzonesis,* and while these are likely to become more common in the US marketplace in coming years (Crook & Nakamura, 2013), current production levels are small and these species are not covered in the scope of this assessment.

Eels have an extremely complex lifecycle and exhibit broad geographic distributions, which have made them difficult to research and vulnerable to overexploitation. The Japanese eel is distributed across East Asia, inhabiting rivers and streams of China, Japan, Taiwan, Korea, and the northern Philippines during the freshwater component of its lifecycle and subsequently migrating some 3000 km to their spawning grounds west of the Mariana Islands in the mid-Pacific (Ottolenghi et al. 2004). The European eel and American eel are both believed to spawn in the Sargasso Sea (mid-Atlantic Ocean), but disperse to European and American coasts and rivers, respectively.

The newly-hatched larval form of eels is known as a leptocephalus and is a marine planktonic stage. As they enter the continental shelf from their deep-sea spawning grounds, leptocephali metamorphose into glass eels (juveniles), a transparent stage that more closely resembles the adult form. Glass eels become progressively more pigmented, a life stage known as "elvers." Once the eels enter freshwater, several adult stages (known as "yellow" and "silver" eels) lead ultimately to sexual maturation.

The migration pattern of each species differs in their seasonality and duration. For example, the Japanese eel will typically disperse in coastal areas and rivers as elvers within one year of hatching, while European eels will spend approximately three years at sea as leptocephali before migrating to coastal areas and freshwater (Ottolenghi et al. 2004). The European eel will spawn in winter and spring, while the American eel spawns in the fall (Ottolenghi et al. 2004).

The Japanese eel and the European eel have been the most commercially important *Anguilla* species to date, with modest contributions to global production from the American eel and the short finned eel (*A. australis*) (Ottolenghi et al. 2004, Crook 2010). Increased fishing pressure along with deteriorating environmental conditions have caused significant declines in global eel populations over the past 30 years (Casselman and Cairns 2009).

The European eel is currently listed as Critically Endangered on the IUCN Red List and in 2007 it was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Japanese eel has been under assessment by the IUCN for the past year and was listed as endangered in June 2014[3]. This species has also been designated as endangered by the Japanese Environment Ministry[4/5] and is considered to be of critical concern by the East Asia Eel Resource Consortium[6]. Similarly, the American eel has been listed as threatened by Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC)[7] and is currently under review by the US Fish and Wildlife Services[8] for inclusion on their endangered species list.

Production statistics

Eels are harvested for global trade and consumption at all stages of their lifecycle. Since the late 1950s, aquaculture has played a growing role in the supply of eel products and now accounts for over 95% of global eel production for food trade by volume (Food and Agriculture Organization (FAO) 2013). Despite the fact that capture fisheries represent a small portion of overall eel production by volume, they still play an important role in the industry, as eel aquaculture remains entirely dependent on wild-caught broodstock. As such, capture fisheries now target predominantly glass eels and elvers to supply aquaculture operations. Crook and

[3] http://www.iucnredlist.org/details/166184/0
[4] http://japandailypress.com/japanese-eel-added-to-environment-ministrys-vulnerable-list-1412167/
[5] http://www.japantimes.co.jp/life/2013/02/02/environment/ministry-officially-classifies-japanese-eel-as-species-at-risk-of-extinction/#.UpKiTdKsiM4
[6] http://easec.info/EASEC_WEB/index_files/EASECdeclarations(Final).pdf
[7] http://www.cosewic.gc.ca/eng/sct1/searchdetail_e.cfm?id=891
[8] http://www.fws.gov/northeast/newsroom/eels.html

Nakamura (2013) note that prior to 1990 eel farming was mostly carried out using species of local provenance, however, a sharp decline of Japanese eel populations in the late 1990s prompted the development of an international trade in glass eels. Today, instability in the supply of glass eels has made them an extremely valuable product; so much so that one anecdotal account in a seafood industry magazine reported a market price of US$35,000/kg (approximately US$7 per individual) for glass eels in 2012[9], however, this value was subsequently questioned by other industry experts.

In 2010, over 270,000 metric tons (mt) of farmed eel were produced globally. According to FAO (2013), China accounted for over 78% of that production and a single species (*A. japonica*) is said to have accounted for 95% of globally farmed eel. Although there is likely some truth to these figures, many aspects of the international trade of eels make it particularly challenging to accurately record the industry's production statistics. For example, it is known that eel farmers in Asia will stock different species depending on market availability and price, however, all production either gets recorded as Japanese eel (*A. japonica*) or simply is not recorded to a species-specific level (Crook pers. comm., Ringuet et al. 2002). These examples of gaps and deficiencies in the data are simply a reality within the eel trade; as such, the author would like to preface this report by acknowledging that production statistics included herein are unlikely to be completely reflective of current practices, but they are as accurate as possible given the available data.

Asia has been a dominant player in eel aquaculture with China, Japan, Taiwan and Korea accounting for over 96% of global farmed eel production in 2010 (FAO, 2013). Europe is the second largest production region where the Netherlands, Denmark and, to a lesser extent, Spain are the top producing countries in that region.

Import and export sources and statistics

Eels have yet to become a popular food fish in the United States and, as a result, the market for them remains relatively small. The largest single market for eels continues to be for Japanese 'kabayaki' (marinated, grilled eel). The United States ranks as the 6th largest importer of eel products worldwide, but note that US imports are less than one tenth (by quantity) of those of the top importers (FAO 2013). Overall, an estimated 1 575 mt of mixed eel products were imported into the US in 2013, which was valued at $29 million (USDA 2014). A vast majority of eel imports are sourced from China (86%), while Taiwan, Japan, South Korea, Vietnam and Canada supply product to a lesser extent (Agricultural Resource Marketing Center 2013). Note that Vietnam acts as a point of re-exportation, as they do not typically farm eel themselves and, hence, Vietnam is not included in this assessment. Similarly, eel products being imported from Canada are sourced from capture fisheries and are being imported mostly as live elvers (USDA 2013).

In 2013, the US exported approximately 1,559 mt of eel products valued at $47 million (USD) (USDA 2013). Live elvers or frozen fillets made up the majority of exported eel products by

[9] http://www.gaalliance.org/mag/2012/Nov-Dec/download.pdf

weight, however, the export of live elvers accounted for 90% of exports by value. Exports of live elvers go primarily to Hong Kong, South Korea, and Belgium, while exports of frozen fillets are destined for South Korea, the Netherland and Brazil (USDA 2013).

Common and market names

Freshwater eel, river eel, common eel, kabayaki, unagi.

Product forms

Farmed eel is typically sold as fillets, either fresh or frozen. Fillets are most commonly marinated and grilled in Japanese cuisine (unagi and kabayaki).

Note that *unagi* refers to freshwater eels of the genus *Anguilla*, while *anago* is prepared from conger eels (family Congridae), which are exclusively marine (Halpin 2007). This report covers only freshwater eels and does not cover conger eels.

Analysis

Scoring guide

- With the exclusion of the Exceptional Criteria (C9X and C10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.seafoodwatch.org/cr/cr_seafoodwatch/content/media/mba_seafoodwatch_aquaculturecriteramethodology.pdf
- The full data values and scoring calculations are available in Appendix 1.

Criterion 1: Data quality and availability

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, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment.*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	5	5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Chemical use	Yes	2.5	2.5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Predators and wildlife	Yes	0	0
Other – (e.g., GHG emissions)	no	Not relevant	n/a
Total			**27.5**

C1 Data Final Score	**3.06**	**RED**

Brief Summary
Scientific, publically available data pertaining to the eel aquaculture industry are limited. The few peer-reviewed articles analyzed, in conjunction with government reports, FAO documents, and direct communications with producers have informed this assessment. However, overall data availability is poor and Criterion 1 – Data receives a score of 3.06 out of 10.

Justification of Ranking
Despite the growing importance of aquaculture to both Asia and the global market, robust and reliable data about production levels and farming practices in Asia remain disparate at best. This is particularly true for eel aquaculture because, although it is highly lucrative, it represents a small portion of the overall aquaculture industry in the region. The reliability of government reporting has been brought into question since the Chinese production statistics had to be revised and corrected in the FAO State of the World Fisheries and Aquaculture 2010. The complexity of eel trade and lack of an appropriate traceability system has further challenged the ability to accurately record the species of eels being farmed, production volumes, and typical trade routes (Crook 2010, Crook & Nakamura 2013).

The majority of the data included in this assessment were sourced from government documents, academic literature, and grey literature (typically reports from the Food and Agriculture Organization). None of the data categories assessed, with the exception of production statistics, had well-defined data sets or a significant volume of independent, peer-reviewed literature. Rather, the information and resulting scores are more a patchwork of data from multiple sources that were brought together to inform the assessment. The Effluent (C2) and Habitat (C3) criteria, for example, were informed primarily by environmental laws and regulations available on government websites, while the academic literature provided one-off observations or case studies applicable to these criteria. In the case of predator interactions (C9X) the complete absence of data required that the assessment be informed by insights gleaned from pond culture systems more generally, as well as an applicable precautionary approach.

The Chemical Use (C4), Escapes (C6), and Disease (C7) criteria were informed first and foremost by academic literature that provided snap-shots into what might be typical practice around these points. For Chemical Use (C4), further insights were gathered from the Food and Drug Administration (FDA) shipment inspections and other similar international import control measures. Data for the Feed Criterion (C5) were sourced from an FAO report, academic literature and personal communications with two of the largest eel feed producers in Europe. Although these data provide the best general assessment for the feed criterion, the geographic and temporal differences in feed formulations and the lack of transparency and reporting of specific feed formulations from feed companies present a serious challenge when assessing the feed criterion. A precautionary approach was adopted in light of data gaps, and it was expected that increased data availability would result in an improvement in the feed score. The Source of Stock (C8) criterion received a moderate data quality score because researchers and farmers have yet to be able to fully domesticate eel broodstock, which indicates that all eel aquaculture is dependent on wild fisheries. There remains, however, much ambiguity around the source of wild glass eels for aquaculture in Asia as a result of decreased capture landings and increased cost for certain *Anguilla* species, which has forced farmers to source glass eels from new populations (Crook 2010, Crook and Nakamuta 2013).

Overall, the lack of complete, detailed and independent monitoring (or data collection) for aquaculture in China, Japan, Taiwan and South Korea challenges the ability to carry out an environmental assessment that is adequately informed and appropriately representative of on-the-ground practices. The growing importance of Asian aquaculture to the global market, however, implores the need to consolidate all currently available information so as to highlight areas that require greater transparency.

It should be noted that one of the main challenges in conducting this assessment was the language barrier such that the author of this report has little knowledge of the primary languages spoken in China, Japan, Taiwan or South Korea. Hence, it is possible that more robust data does exist but that it is not available in English at this time. The author did make numerous attempts to contact government employees, researchers, academics and non-governmental organizations in each of the countries included in this assessment via email and phone, however, the vast majority of information requests went unanswered. As a result of the lack of data available at this time, the final data quality score is 3.06 out of 10. Should more data become available in the future these scores will be updated.

Criterion 2: Effluents

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations 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 beyond the immediate vicinity of the farm.*

Criterion 2 Summary

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	84.32		
F2.1b Waste discharged from farm (%)	75		
F2 .1 Waste discharge score (0-10)		3	
F2.2a Content of regulations (0-5)	4		
F2.2b Enforcement of regulations (0-5)	0.75		
F2.2 Regulatory or management effectiveness score (0-10)		1.2 – 1.95	
C2 Effluent Final Score		**2.00**	**RED**
Critical?	NO		

Brief Summary

It was calculated that 84.32 kg of nitrogen waste are produced per ton of eel. As 75% of waste is discharged in effluent from flow-through and high-exchange ponds, the waste discharge score is 3 out of 10. While some regulation and management of effluent-related impacts are apparent, evidence of compliance and enforcement is lacking and warrants a precautionary approach. The numerical score for Criterion 2 – Effluent is 2 out of 10.

Justification of Ranking

Factor 2.1 Waste discharge score

The typical feed formulations for eel farming in Asia maintain a protein content of 48% and farming practices result in an economic feed conversion ratio (eFCR) of 1.4[10]. Based on these values, it was calculated that 84.32 kg of nitrogen is produced per ton of eel farmed. The degree to which this waste is discharged varies significantly based on the production system used. For flow-through pond systems it is considered that 100% of the waste produced is discharged into the surrounding environment, whereas pond culture systems that exhibit a daily exchange are considered to discharge only 51% of the waste produced; the remaining 49%

[10] See Criterion 5 for further details

of waste produced remains within the immediate footprint of the farm and is considered in Criterion 3 – Habitat. As both flow-through ponds and ponds with daily exchange (with minimal water retention) are used to a similar degree for eel culture in China, Japan, Taiwan, and South Korea, an average waste discharge rate of 75% was applied to this assessment. As such, 63.24 kg of nitrogen is calculated to be discharged from eel aquaculture ponds as effluent, corresponding to a score of 3 out of 10 for Factor 2.1.

Factor 2.2 Regulatory or management effectiveness score
The regulation and management effectiveness for effluent controls are outlined below—due to variability in national legislative regimes, each country is presented individually. Despite these variations, all four countries received very similar scores for Factor 2.2, wherein they ranged from 1.2 to 1.95.

China
In China, management of effluent from aquaculture is addressed by a number of laws and regulations including the *Fisheries Law*, *Regulation for the Implementation of the Fisheries Law*, *Law on Prevention and Control of Water Pollution*, and the *Marine Environment Protection Law*. In accordance to the aforementioned laws and regulations, the *Water Quality Standards for Fisheries* (1989) was developed and set out specific quantitative standards for 32 different water pollution indicators. These laws and regulations are national standards that are applied by the Bureau of Fisheries, which is a department under the Ministry of Agriculture, but they are typically supplemented by more specific rules and regulations set out by the fisheries departments of specific provinces, autonomous prefectures, counties and cities (FAO 2013b). Fisheries administrations, at or above the county level, are responsible for permitting, monitoring and enforcing regulations of aquaculture operations, which are to be carried out as per the state defined rules and regulations. Unfortunately, the author was not able to retrieve these more regional rules and regulations, but it is likely that these regional rules provide more site-specific regulations for the 32 different water pollution indicators set out by the national regulations, and may provide some control measures to address cumulative impact of effluent. However, in absence of the exact language of regional legislation and regulation, the management effectiveness factors were scored conservatively (2.25 out of 5) as per the available national legislation. According to a 2001 FAO document, there were 2,100 fisheries law enforcement agencies with 30,000 enforcement staff throughout China at the end of 1999. More recent published literature (e.g., Cao et al*.* 2007; Zhang 2007; Miao & Jiang 2007) denounces the environmental implications of aquaculture waste production in China, which brings into question the ability of enforcement to demonstrably result in compliance. This resulted in a lower overall score (1.25 out of 5) for the enforcement level of effluent regulations. Overall, the management regime for effluent control from aquaculture in China scored 1.75 out of 10 due to the lack of evidence of effective monitoring and enforcement.

Japan
In Japan, effluent discharges are regulated under the *Water Pollution Control Law* (WPCL) (1970) for which the Ministry of the Environment (MoE) is the responsible authority. As per

chapter 2 of the WPCL, the MoE has set out national effluent standards in an effort to prevent the pollution of public waters. Furthermore, under the Basic Environmental Law (1993) the MoE established environmental quality standards (EQS) for water pollution of which there are two kinds: those that aim to protect human health and those that aim to protect the living environment. The EQS provide quantitatively set limits for 26 substances and five ecological indicators, which are to be achieved by the governors of each prefecture by the establishment of a "Plan for Reduction of Total Pollution Load"[11]. The listed laws and regulations above suggest that there are control measures for effluent regulations that are applicable to aquaculture operations in Japan, however, it is unclear whether these control measures lead to site-specific discharge limits. The requirement for each prefecture to develop a "plan for reduction of total pollution load" suggests that the control measures likely consider cumulative effects, however, the specific language of the prefecture-level plans could not be found and hence this factor was scored moderately.

Chapter III of the WPCL also makes prefecture governments responsible for continuous monitoring of the conditions of water pollution, of which the results are to be reported back to the MoE. Any industry found to be discharging effluent that exceeds acceptable EQS could be held liable to compensate for damages as per Chapter IV of the WPCL, however, it is not clear how strict enforcement is within the country. In addition to these broad regulations, the Law to Ensure Sustainable Aquaculture Production was passed in 1999 which requires the Fisheries Cooperative Associations—the local governing bodies for fisheries and aquaculture—to develop and implement "aquaculture ground improvement programmes" (FAO 2013*c*). Unfortunately, at the time of this writing, these programs and plans were not publicly available in English, but Yokoyama (2003) identified that the program, although based in legislation, is voluntary and that enforcement has not resulted in full compliance to date.

Overall, the regulatory and management effectiveness for effluent control in Japan scored 1.5 out of 10.

Taiwan

The Environmental Protection Administration (EPA) serves as the lead organization responsible for regulating aquaculture effluent in Taiwan. The national organization houses a department of water quality protection, a department of environmental sanitation, and toxic substance management, as well as a bureau of environmental inspection. Each city and county government also established an environmental protection bureau to enhance the work of the EPA (EPA 2010). The guiding piece of legislation specific to effluent management is the *Water Pollution Control Act (1974,* as amended), under which there is a suite of regulations such as the *Effluent Standard Regulations* (1987, as amended), the *Surface Water Classification and Water Quality Standards* (1985, as amended), and the *Water Pollution Control Measures and Test Reporting Management Regulations* (2006, as amended) that outline specific regulations and discharge limits for various industries, including aquaculture. Under Article 80 of the *Water*

[11] see http://www.env.go.jp/en/water/wq/wp.pdf

Pollution Control Measures and Test Reporting Management Regulations (2006, as amended), general fish farming enterprises are required to keep monthly reports that record the date that wastewater is discharged, method of disposal, quantity of wastewater discharged and the dissolved oxygen level of wastewater at time of disposal. In addition, all aquaculture operations must report the pH, water temperature, biological oxygen demand, chemical oxygen demand, and suspended solids concentration for effluent every six months (Article 83). The *Surface Water Classification and Water Quality Standards* set out additional standards for surface water used for aquaculture. These latter standards include limits for ammonia and total phosphorous concentrations.

Despite the seeming thoroughness of these numerous regulations and legislations, it has been repeatedly highlighted that the lack of an appropriate regulatory regime has had serious implications for the industry (Liao 1998, Liao 2005, Liao & Chao 2007). Liao & Chao (2007) state, "the proliferation of aquaculture ponds was not regulated until several serious problems were encountered that resulted in the collapse of the industry as a whole" (p.167). Given that most of the effluent related legislations and regulations have been in place since the mid-1980s, it is perhaps the lack of enforcement that has undermined the ability of the legislations outlined above to effectively manage the impact of effluent from the aquaculture industry. The EPA and environmental protection bureaus work together to conduct annual water pollution inspections, which are subsequently reported on the Taiwan Environment Data Warehouse[12]. In 2012, 3,159 water pollution inspections were completed across the country and over $8 million (USD) was collected in fines. Unfortunately, inspection reports are aggregated by geographic region and, hence, it is not known how many (if any) inspections took place on aquaculture sites. Overall, the regulatory and management effectiveness for effluent control in Taiwan scored 1.95 out of 10.

South Korea

The regulation and management of aquaculture effluent in Korea is guided primarily by the *Water Quality and Ecosystem Conservation Act (1997)* and the *Enforcement Decree of the Water Quality and Ecosystem Conservation* Act (1997). Together, these two pieces of legislation aim to preserve the quality of public waters (including rivers, lakes, marshes, harbors, ports and coastal waters) from pollution that would be damaging to human health and the environment. The *Water Quality and Ecosystem Conservation Act (1997)* sets out discharge standards for 31 pollution indicators, including organic matter, suspended solids, phosphorous, nitrogen, and chemical pollutants (Republic of Korea Ministry of Environment, n.d.). These standards are applicable to all wastewater discharge facilities, which are defined as "facilities, machines, equipment and other objects that release water quality pollutants" (Article 2-11, *Water Quality and Ecosystem Conservation Act*). The standards are applied "in accordance with the amount of discharged wastewater from facilities by region" (Republic of Korea Ministry of Environment, n.d.), which suggest that they account for cumulative impacts on a regional scale and are likely to lead to site-specific discharge limits. As per the *Enforcement Decree of the Water Quality and*

[12] http://edw.epa.gov.tw/eng/reportStatisticEN.aspx?StatDataID=37

Ecosystem Conservation Act (1997), the Minister of the Environment is responsible for publishing the target water quality and the total amount of water quality pollutants that are to be regulated for specific regions and river systems. Local authorities (the Mayor/governor) can, however, publish more specific water quality regulations for their jurisdiction by submitting a detailed application to the minister of environment. As these acts do not speak specifically to aquaculture, it is unclear how regularly aquaculture effluent is being monitored and if control measures cover all aspects of the production cycle. However in 2003 a Pollutant Discharge Levy Program was initiated that charges business establishments for each pollution unit discharged for 19 different pollutants, including nitrogen and phosphorous. If discharge facilities exceed their allotted loading quantity, they may be required, under Article 9 of the *Enforcement Decree of the Water Quality and Ecosystem Conservation* Act (1997), to install monitoring gauges that automatically transmit measured discharge quantities to the Tele-Monitoring System Control Center.

Enforcement of water quality regulations is carried out by the Water Environment Management Bureau, for which the organizational structure and contact information is available online[13]. There are no data currently available, however, that speak specifically to monitoring or enforcement of aquaculture sites. Due to the lack of transparency in enforcement and uncertainty as to the effectiveness of the established management regime, South Korea received a score of 1.2 (out of 10) for this factor overall.

Summary

Overall, the high discharge rate of pond culture systems combined with a lack of evidence of effective regulatory and management regimes in all four countries resulted in a final score of 2 (out of 10) for the effluent criterion.

[13] http://eng.me.go.kr/content.do?method=moveContent&menuCode=abo_org_contact

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 and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		6.00	
F3.2a Content of habitat regulations	1.75		
F3.2b Enforcement of habitat regulations	1.25		
F3.2 Regulatory or management effectiveness score		0.875 – 2.1	
C3 Habitat Final Score		**4.29 – 4.70**	**YELLOW**
Critical?	NO		

Brief Summary

The eel aquaculture industry initially developed with little regulatory oversight or planning, however, most ponds are built on former agricultural lands as opposed to virgin ecosystems. While there are shown to be moderate habitat impacts, due to the high density and input-requirements of eel ponds there is little evidence of permanent loss of ecosystem services. Content and enforcement of legislation in place to mitigate habitat impacts is moderate and the final score for Criterion 3 – Habitat is a range of 4.29 to 4.70 out of 10.

Justification of Ranking

Factor 3.1. Habitat conversion and function

Criterion 3 aims to assess the direct habitat impacts that occur as a result of siting aquaculture farms. These impacts may arise from the direct conversion of pristine habitat for aquaculture purposes or the rezoning of previously used habitat. Habitat conversion for the purpose of aquaculture is of concern because it results in a loss of ecosystem services, which may in turn limit the functionality of that ecosystem. Note that this criterion is only concerned with the impacts observed at the farm site and within the allowable zone of effect (AZE). Far-afield impacts resulting from the release of effluent are assessed in criterion C2.

The rapid growth of the eel farming industry in Asia that has occurred over the past two decades transpired with little to no regulatory oversight, particularly in the early years (Liao & Chao 2007). Many small-scale producers started their business by transforming agricultural land into pond culture systems and there is little evidence that this has resulted in permanent loss of ecosystem services. Hall et al. (2011) found that inland eel pond culture can cause far-field eutrophication of surrounding water bodies, however, this is believed to be reversible with fallowing. Typically, this would be considered a moderate impact on habitat functionality and result in a score of 7 (out of 10), but some concerns have been raised regarding the intensive use of freshwater in eel pond culture, which is amplified by the inadequate degree of planning and lack of regulatory oversight during the initial phases of industry development. In some regions, like Taiwan, the persistent drawing of groundwater has resulted in massive land subsidence, sometimes upwards of three meters (Chang 2010, Taiwan Review 2009, Wu 1999). Damage from land subsidence may be rectified by infilling, but it is believed to have a long-lasting negative impact on communities, particularly with the looming threats of sea-level rise and increased flooding associated to climate change. In circumstances where land subsidence does occur, it would be considered a major impact to overall habitat functionality, however, this does not occur in all instances of eel aquaculture development in Asia. As such, this factor results in a median score of 6 (out of 10) in order to maintain an average assessment that is reflective of the eel aquaculture in Asia industry as a whole.

Factor 3.2. Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

China

In China, land and water resources are state owned and, as such, states are responsible for having overall land utilization plans and implementing a system of water withdrawal permits. Under the Regulations for Implementation of the *Fisheries Law* (1987), natural spawning, breeding and feeding grounds of fish, shrimp, crab, shellfish and algae, migration passages, and other environmentally sensitive habitats are protected from aquaculture siting. Additionally, in 2003, the *Environmental Impact Assessment Law* came into effect and expanded the requirement for environmental impact assessments (EIA) to encompass government planning for developments including, but not limited to, aquaculture, animal husbandry and agriculture (FAO, 2013*b)*. Despite the growing legislative environmental protection that speaks to aquaculture siting in China, there have also been continuous efforts to promote the growth and development of the industry. Some have argued that the growth of the industry has occurred at a rate that exceeds the ability of government policies, legislation and enforcement to ensure its sustainable development (Cao et al. 2007, Zhang 2007, Miao & Jiang 2007). Luo, Zhu, & Bao (2009), for example, reported that pre-construction EIAs were still lacking for new farms. The regulatory and management effectiveness received a moderate score of 2.75 out of 5 for having clear regulations requiring EIAs and protection of high-valued habitat, but limited consideration of cumulative impacts, and the industry's future expansion limits remain unaddressed. The siting regulatory or management enforcement factor received a lower score (1.38 out of 5) because, although there are designated responsible government authorities, there is no transparency in the enforcement process nor is there evidence that the limits or defined control measures are being achieved. The overall score was 1.38 out of 10 for China's habitat and farm siting management effectiveness.

<u>Japan</u>

The *Law of Fisheries* (1949, as revised in 1962) provides a national legislative framework for fisheries production systems—where “fisheries” refers to gathering, catching and culturing of aquatic animals and plants. There exists an environmental impact assessment Law, which came into force in 1997, however, this law does not speak to aquaculture directly. In 1999, the *Law to Ensure Sustainable Aquaculture Production* was passed with the intent to prevent self-induced environmental deterioration around fish farms. Subsequent to the passing of this law, the Ministry of Agriculture, Forestry and Fisheries developed basic voluntary guidelines for water quality, for sediment condition on the bottom of aquaculture grounds, and for the health condition of culture fish (Takeda, 2010). To the extent of the author’s knowledge, this law, does not speak specifically to siting guidelines for aquaculture or habitat protection, however, it was not fully available in English at the time of writing. The *Basic Environmental Law* (1993) does, however, set out general principles for environmental protection.

More specific aquaculture regulations are set out at the prefecture level of government and the regional fisheries coordination committees are responsible for administering aquaculture rights in their respective prefecture (Arsenault, Beigbeder, Johnson, & Pearce 2002). The committees are made up of fifteen members, with representatives from local fisherman, and other persons knowledgeable of the regional fishing industry. The application for an aquaculture right can be submitted only by a fisheries cooperative association and must include all the details of the proposed facility. If approved, the aquaculture right is valid for five years, after which another application is required for renewal. Given the regional scale at which aquaculture is managed and regulated in Japan, there is likely to be significant variation between the management regimes of the 47 prefectures that make up the country. The lack of information specifically applicable to aquaculture siting, on the one hand, raises concern about the effectiveness of regulation while, on the other hand, there is also no evidence to support the conclusion that the management regime is ineffective. Resultantly, this factor was scored moderately with a final score of 2.1 out of 10 namely due to the lack of transparency in monitoring and enforcement of set regulations.

<u>Taiwan</u>

The regulatory and management regime for aquaculture in Taiwan remains ill defined. The national Council of Agriculture hosts a fisheries agency (FA) branch, which in turn houses the Aquaculture Fisheries Division (AFD). The AFD is supposedly responsible for the planning, promotion, supervision and management of aquaculture (Fisheries Agency 2012), however, the acts and regulations that govern the Fisheries Agency and its divisions are heavily focused on capture fisheries and speak minimally to aquaculture. The *Fisheries Act* (1929, as amended) is one the most foundational pieces of legislation and it touches on aquaculture only briefly in Article 69, wherein it designates the municipality/county/city as the competent authority for the registration and management of inland aquaculture. Resultantly, it appears that the environmental protection bureaus (EPB), which are regional outposts of the Environmental Protection Administration (EPA), have overseen much of the aquaculture siting.

As per Article 17 in the *Standards for Determining Specific Items and Scope of Environmental Impact Assessments for Development Activities* (1995, as amended), an environmental impact assessment (EIA) is required for the construction of fish farms or fish ponds if the proposed site is: 1) located in a wildlife preserve or an important wildlife habitat environment, 2) located on a wetland, 3) located in a nature preserve, 4) located in an underground water control area, or 5) is expected to be greater than 50 hectares in size. The *Environmental Impact Assessment Act* (1994, as amended) and the *Environmental Impact Assessment Act Enforcement Rules* (1995, as amended) together outline the roles and responsibilities of the developer and central competent government authority as they pertain to carrying out an EIA. Neither of these outline standards specifically for aquaculture siting, nor do they speak to cumulative impacts of any industries. The *Environmental Impact Assessment Act* together with the *Basic Environment Act* (2002) provide legislative protection of high-valued environments and habitats.

It is unclear at this time how common it is for aquaculture sites to undergo an EIA. The EPA does report the total number of EIA cases accepted on an annual basis through the Taiwan Environment Data Warehouse, however, there are no details or descriptions of which industries the EIAs were conducted for. Given the lack of transparency in the enforcement process, it is unknown how effective the control measures and management regime is in mitigating the habitat impacts of aquaculture sitings. Over the past five years, records from the Taiwan Environment Data Warehouse show that 666 EIA cases were accepted, of which only seven were not approved and another 110 were approved with conditions. As mentioned in Criterion 2 for Taiwan, there have been many reports stating that the early years of aquaculture development came at significant environmental cost (Liao & Chao 2007, Liao 1998, Liao 2005, Chang 2010, Taiwan Review 2009, Wu 1999). Resultantly, the factors for assessing the regulatory and management effectiveness were scored conservatively and a final score of 0.875 (out of 10) was awarded.

<u>South Korea</u>

In South Korea, the *Fisheries Act* (1990, as amended) provides the basic regulatory framework for aquaculture in the country and requires that all persons cultivating seaweed, shellfish or other marine animals be licensed through the local government. All licenses are issued within the limits of fishing ground utilization and the development plan set out by the Ministry of Marine Affairs and Fisheries (MMAF) (FAO 2013*d*). The *Act on Assessment of Impacts of Works on Environment, Traffic, Disasters and Population* (1999) sets out the guidelines for which projects require EIAs, and outlines that these include projects that, *among other things,* result in the development of water resources and the cultivation and reclamation of public waters (FAO 2013*d*). This would suggest that aquaculture sites are required to undergo EIAs, however, there is no evidence or record to suggest that this has been done. A number of environmental protection legislations are in place—such as the *Wetlands Conservation Act* (1999), *Public Water Management Act* and the *Basic Environmental Policy Act* (1990)—which together protect high-value habitat (such as wetlands) from development. This industry's total size and future expansion does not appear to be limited, but, on the contrary, is generally being promoted at this time through the *Culture-Based Fishery Promotion Act* (2002) and the *Aquaculture Ground Management Act* (2000). The *Culture-Based Fisheries Promotion Act* (2002) requires the government to establish a framework that will promote culture-based fisheries every five years, but there is no evidence that either of these acts takes into consideration the cumulative effects of multiple farms. An aquaculture license is valid for typically ten years and upon expiration the license-holder must restore the area by removing all facilities installed.

The ministry responsible for fisheries in Korea has changed a number of times as of late. Originally the MMAF was the responsible ministry, however, in 2008 a reorganization of ministries saw the duties transferred to the Ministry for Food, Agriculture, Forestry and Fisheries, and, subsequently, in 2013 the Ministry of Oceans and Fisheries was established. Resultant of these changes, it is difficult to determine the enforcement process that is currently in place. Overall, the management and regulations in place to control habitat impacts of aquaculture siting in South Korea were found to be minimally effective and scored 1.2 out of 10.

Summary

The slight variability in management scores for the habitat criterion led to a range of final scores for Criterion C3. Overall, scores between 4.29 – 4.70 (out of 10) were awarded to the four countries because eel aquaculture in ponds was shown to have a low habitat conversion rate, however, the regulatory and management regimes in place are lacking in transparency and enforcement.

Criterion 4: Evidence or Risk of 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.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments.*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Criterion 4 Summary

China and Taiwan

Chemical Use parameters	Score	
C4 Chemical Use Score	**0.00**	
C4 Chemical Use Final Score	**0.00**	**RED**
Critical?	NO	

Japan and South Korea

Chemical Use parameters	Score	
C4 Chemical Use Score	**4.00**	
C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

Brief Summary

The use of banned chemicals, most notably malachite green, is shown to occur in Chinese and Taiwanese eel aquaculture, resulting in a score of 0 out of 10 for these two countries. There is no evidence of such banned chemical use in Korea or Japan, however, there are demonstrably significant amounts of chemicals used in eel farming and the production systems employed, risking the release of said chemicals into the surrounding environment. The score for Korea and Japan is 4 out of 10.

Justification of Ranking

Two assessments are provided for this criterion as a result of demonstrable differences in the practice of chemical use between countries.

China and Taiwan

The use of chemicals such as nitrofurans, fluoroquinolones and malachite green in aquaculture have been prohibited by the Chinese authorities since 2002, however, eel exports containing these substances are still being reported with relative frequency. Since 2001, the US FDA continues to find residues of these and other chemical therapeutants in shipments of eel and related products from China[14] (FDA 2012). In 2005, the Korea Food & Drug Administration found malachite green in imported Chinese eel and related products (Gwang-lip 2005). Similar reports have been cited for eel imported into Japan from China in 2005, 2006 and 2007 (Mori, Nabeshima & Yamada 2013). In 2007, Japan went as far as to place restrictions on eel imports from China, due to the presence of malachite green, and Singapore now requires all eels and freshwater fish imported from China to undergo pre-export testing (Pandey 2005). Violations have been cited for the excessive use of sulfanilamide (Yu-Tzu, 2003), malachite green[15] (FDA, 2009) and nitrofurans for eel product sourced from Taiwan. (Hedlund 2006).

Several scientists have noted that despite the many laws, standards and policies in place to monitor chemical use in China, the efficiency of these regulations are weak due to the challenges of management, implementation and enforcement (Broughton & Walker 2010, Zhang 2007, Ming 2006, Tam & Yang 2005). Some of the major issues include: the uncoordinated nature of food regulations, the narrow scope of the laws (e.g., the regulatory framework does not consider the early stages of production, whereby banned pharmaceutical agents and other inputs could be in use), lax enforcement by inspectors, and minimal penalties issued for infringements. In Taiwan, although there are a number of regulations relating to water quality, the release of toxic substances, marine pollution, and specific regulations relating to the use of chemicals in aquaculture are not readily available. To that point, Liao & Chao (2007) noted that most inland aquaculture remains unregulated.

China and Taiwan have been noted to use a particularly high degree of chemical application in aquaculture due to the poor water quality resulting from sewage, industrial waste and agricultural runoff (including pesticides), as well as the increasing stocking density that has come with intensification of aquaculture practices (Chen, Lee & Lao 2007; Zhang 2007). Due to evidence of use of banned chemical substance in farmed aquaculture product (described above), China and Taiwan both received a score of zero (out of 10) for the Chemical Use criterion.

Korea and Japan

Both Japan and Korea have very low eel export volumes and, so far, none of these consignments have been rejected and/or detained for malachite green or other banned substances by the FDA or other regulatory bodies. Japan has a number of regulations to manage chemical use in aquaculture: Law to Ensure Sustainable Aquaculture Production (1999), Water Pollution Control Law (1970, as amended), Agricultural Chemicals Regulation Law (1948, as amended), Food Safety Basic Law (2003), Food Sanitation Law (1947, as amended). As such, there appears to be a certain degree of control over the use of banned chemicals and substances (FAO 2013*c*). For Korea, only limited information was available on the use chemicals and veterinary drugs used by the aquaculture industry (FAO 2013*d*, Joh et al. 2011, Joh et al.

[14] http://www.accessdata.fda.gov/cms_ia/importalert_33.html
[15] http://www.accessdata.fda.gov/cms_ia/importalert_27.html

2007). Applicable legislations that are believed to regulate chemical use in the aquaculture industry include the Culture-Based Fishery Promotion Act (2002), the Public Water Management Act (1961, as amended), the Water Quality Conservation Act (1990, as amended), and the Fishery Products Quality Control Act that came into effect 1 September 2001 (FAO 2013*d*). The latter regulation was developed to improve food safety and harmonize with international standards of food quality.

Both Japan (Usiui 1974, Miyai 2004) and Korea (Joh et al. 2011, Joh et al. 2007) have documented outbreaks of diseases relating to pond systems and their external environment. Eels in particular are known to be prone to parasites such as *Heterosporis anguillarum* (Joh et al. 2007). As both countries employ predominantly outdoor pond and flow-through systems for eel farming, there remains great potential for chemicals and antibiotics to be released to the environment. Resultantly, Korea and Japan received a score of 4 because the production method and history of disease outbreaks suggest that a significant amount of chemicals are used in eel farming and the production systems employed risk the release of these chemicals into the surrounding environment.

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 their 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.*
- *Sustainability unit: 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: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	1.12	7.20	
F5.1b Source fishery sustainability score		-6.00	
F5.1: Wild Fish Use		6.53	
F5.2a Protein IN	15.83		
F5.2b Protein OUT	10.62		
F5.2: Net Protein Gain or Loss (%)	-32.94	6	
F5.3: Feed Footprint (hectares)	22.96	2	
C5 Feed Final Score		**5.26**	**YELLOW**
Critical?	NO		

Brief Summary

Eel farming in Asia utilizes a commercial feed with high levels of fishmeal, 84% of which is derived from processing byproducts as opposed to whole fish. Eel feeds contain 4% fish oil inclusion and the eFCR of the industry is shown to be 1.4:1. Eel farming is shown to result in a 32.9% net loss of protein. A total ocean and land area of 22.96 hectares is calculated to be necessary to produce the feed ingredients required to grow one ton of farmed eel. The numerical score for Criterion 5 – Feed is 5.26 out of 10.

Justification of Ranking

Note that for this criterion, if a range of values is reported in the literature, the median value was applied in the assessment to ensure typical farming practices were represented.

Factor 5.1. Wild Fish Use

With the intensification of eel aquaculture, it has become common practice to provide high-energy, protein-rich, commercial feeds through all culture phases (Ottolenghi et al. 2004). In the grow-out phase, feeds are delivered as paste, dough or pellets. Feeds typically have a high protein content, ranging from 45% (Weimin & Mengqing 2007) to 50% (FAO 2013). The high protein content is derived predominantly from fishmeal, for which inclusion levels range between 55% (Tacon & Metian 2008) and 62% (Weimin & Mengqing 2007). The report by Weimin & Mengquing (2007) includes a “practical feed formulation for eel” that was provided by a feed producer from the Guangdong province of China, in which 84% of the fishmeal is sourced from byproduct. China is one of the main eel feed producers with over 100 feed mills that produce over 350,000 tons of feed (Weimin & Mengquing 2007), however, given the volatility in sources of fishmeal, it is uncertain how common the practice is to include such a high degree of fishmeal byproduct. Despite this uncertainty, this value was used in the assessment, as there was no evidence or data to counter it. Fish oil inclusion rates in eel feed are relatively low ranging from 3.5% to 5% (Tacon and Metian 2008); a fish oil inclusion level of 4% was utilized in the assessment.

Ottolenghi et al. (2004) reported that the feed conversion ratio (FCR) for Asian and European intensive eel farming operations ranged from 0.9 to 1.9:1. To date, there appear to have been few advances in improving the FCR efficiency, as a more recent report by Krikegaard (2010) stated that typical FCRs in European culture were between 1.6 and 1.7:1. Tacon & Metian (2008) provide the most specific estimates of FCRs in Asia, whereby they report an FCR of 1.4 in Korea and 1.7 in Taiwan. This latter report also goes on to estimate that in 2010 the average FCR for eel farming would be 1.4. An FCR value of 1.4 was applied to all calculations herein as it the average value of all those found in the literature.

Applying the figures above, FIFO ratio was calculated to be 0.58 for fishmeal and 1.12 for fish oil, which scores 7.20 out of 10 in the Seafood Watch methodology. A FIFO of 1.12 means that from first principles, 1.12 tons of wild fish would need to be caught and processed to supply sufficient fish oil to grow one ton of farmed salmon in land-based closed containment recirculating aquaculture systems.

An adjustment score can be applied based on the relative sustainability of the source fisheries from which fishmeal and fish oil are derived. Given the globalization of the fishmeal industry, lack of traceability through supply chains and the major role that Asia plays in commercial feed production, the source fisheries for fishmeal and fish oil are unknown. According to the Seafood Watch criteria, an adjustment score of -6 out of -10 is applied for the unknown sustainability of the source fisheries.

When the adjustment score is applied, the resulting numerical score for Factor 5.1 is 6.53.

Factor 5.2. Net Protein Gain or Loss

Applying the data provided by Weimin & Mengquing (2007) in the “practical feed formulation for eel,” it was found that 67% of protein in the feed was from nonedible sources (fishmeal byproduct), while the remaining 33% were sourced from edible crops such as fishmeal, soybean and cassava starch.

Typical protein content of whole harvested eel ranges from 14% to 17% (Heinsbroek et al. 2007, FAO 2001), while the edible yield rate can range from 60% to 75%, depending on the processing method (Crapo et al. 1993, Venugopal 2005).

Overall, these values are used in a series of calculations (see Appendix 1) that conclude that eel farming results in a net protein loss of 32.9%. This loss corresponds to a numerical score of 6 out of 10 for Factor 5.2.

Factor 5.3. Feed Footprint

According to the feed formulation in the report by Weimin & Mengquing (2007), no land animal products are included in commercially produced eel feeds. Personal communications with representatives from BioMar and Skretting, two of the leading producers of eel feed in Europe, also claim to have a zero percent inclusion of land animal products. Aside from the high degree of marine resource inclusion (fishmeal and fish oil combined represent 62.5% of feed ingredients), the remainder of formulated eel feeds (37.5%) is made up of crop feed ingredients such as wheat, soy, and/or cassava. These values were utilized in the calculation to determine that the production of one metric ton of farmed eel requires the appropriation of 22.76 hectares of ocean area and 0.20 hectares of land area (see Appendix 1 for calculations). This 22.96-hectare feed footprint corresponds to a score of 2 out of 10.

Summary

The scores for Factors 5.1, 5.2 and 5.3 are combined to result in a final Criterion 5 – Feed score of 5.26 out of 10. This score is driven by the moderate degree of wild fish use in eel feed, the net protein loss that occurs in eel farming, and the relatively high feed footprint resulting from the large area of ocean appropriated for feed production.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, 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.*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		4	
C6 Escape Final Score		**3.00**	**RED**
Critical?	NO		

Brief Summary

Eel farming ponds have high daily water exchange rates and inherent connectivity to natural water bodies. No evidence exists of recapture or direct mortality of escapees. Though non-native eels are cultured throughout Asia and have been encountered in the wild, the scientific evidence suggests that they are not established and are unlikely to establish viable populations.

Justification of Ranking

Factor 6.1a. Escape risk

Eels in Asia are cultured primarily in a variety of pond systems (greenhouse, still and/or flow-through). These systems typically have high flushing rates ranging from 15% to 35% water exchange per day (Heinsbroeck 1991, Nielsen & Prouzet 2008); the Seafood Watch criteria classify these systems as a moderate-high escape risk due to inherent connectivity to natural water bodies. Each of the countries included in this assessment have basic environmental legislation and/or fisheries laws that speak to the importance of protecting wild native species, but no specific legislation or best management practices could be found with respect to minimizing the escape of species from aquaculture systems. Each of the countries included here also have legislation governing the import of exotic species, however, these regulations speak almost exclusively to minimizing the risk of disease transfer upon entry of the exotic species.

It may be possible that best management practices specific to minimizing aquaculture escapes do exist and simply are not available to the author due to language barriers, however, the growing number of reports of escaped non-native eel species in Japan, China and Taiwan (see Factor 6.1b) suggest that, even if best management practices are in place, they are not effective at this time.

The initial escape risk score is 2 out of 10. This score may be adjusted upward if evidence exists of recapture or direct mortality of escapees. No such evidence was available at the time of this report and, as such, no recapture/mortality adjustment is applied and the numerical score for Factor 6.1 is 2 out of 10.

Factor 6.1b. Invasiveness

As a result of inconsistent availability of *A. japonica* glass eels, it has become common practice for eel aquaculturists in Asia to source non-native glass eels and elvers (particularly European eels (*A. anguilla*) and American eels (*A. rostrata*)) for grow-out (Crook et al. 2010, Casselman & Cairns 2009, Ottolenghi 2004). Due to the lack of species-specific labeling of eel products through the complex international trade system, it is not possible at this time to identify what proportion of current farmed stock is of native or non-native species. The recent listing of *A. anguilla* in Appendix II of CITES is anticipated to decrease the amount of European eel being farmed in Asia, however, some have speculated that this will in turn increase the import of other non-native species (*A. rostrata, A. australis*, *A. bicolor*, and *A. mossambica*) because recent catches of *A. japonica* glass eel are simply not sufficient to supply the demand (Crook 2010, Miller and Casselman, in press). Although non-native species do not represent 100% of the current farmed stock in Asian eel aquaculture, there is sufficient evidence to suggest that non-native eel species are commonly cultured (Crook, pers. comm.; Ringuet et al. 2002). Due to the inconsistency of reporting production statistics and import/export data to a species-specific level (i.e., most data is simply recorded as *Anguilla sp.*), it is not possible to determine what percentage of stock may be native versus non-native. As such this factor has been scored for stock that is non-native as this represents a realistic worst-case scenario.

The academic literature contains several examples of non-native eel species being encountered in the wild across Asia. Han et al. (2002) reported the first identification of exotic eels in Taiwan in 2002 when six American eels (*A. rostrata*) were found in the Kaoping River. Additionally, a Japanese survey conducted in 2000 found that European eels accounted for 93.5% of the 98 specimens sampled in the Uono River (Aoyama et al. 2000). A more comprehensive survey was conducted in Japan in 2006 and it was found that only 6.8% of the eels collected from 16 sites in Japan were European eels (Okamura et al. 2007). Many of the captured non-native European eels had metamorphosed into migratory silver eels suggesting they had the ability to initiate spawning, however, the researchers concluded that it was unlikely for them to establish due to the observed decline in European eel presence at these sites (Okamura et al. 2007). It is uncertain how successful non-native eel species will be at self-propagating in Asian waters, but many have suggested that the potential for these species to establish new spawning grounds in Asia cannot be overlooked (Han et al. 2002, Aoyama et al. 2000). As such, the current non-native farmed stock is deemed to be present in the wild but not established and not likely to establish viable populations (score of 1.5 out of 2.5 for Factor 6.1b Part B).

The ongoing escape of non-native eel species from culture ponds presents a moderate to high impact for the natural ecosystem, as escapees have been documented to compete with wild native populations for food and habitat and may act as additional predation pressure for some prey (Aoyama et al. 2000, Okamura et al. 2007). There is no evidence at this time that non-native eel species have interbred with the native Japanese eel, however both Okamura et al. (2007) and Han et al. (2002) note that there is potential for interspecific hybridization should non-native eel species begin to spawn in the Mariana Islands which is the natural spawning ground for the native Japanese eel. The life history and nature of non-native eel species do not differ greatly from that of native eel species and as such escapees are not anticipated to modify habitats to the detriment of other species. Part C in Factor 6.1b scored 2.5 out of 5 because escaped eel from aquaculture sites in Asia pose a moderate invasiveness risk to natural ecosystems. When the score for Parts B and C are combined, the numerical score for Factor 6.1b is 4 out of 10.

Overall, the impact, or risk of impact, of escapes from eel culture ponds in Asia was determined to be high. Criterion 6 – Escapes receives a numerical score of 3 out of 10 and is driven by a moderate-high escape risk and a moderate invasiveness score.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body.*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	2.00	
C7 Disease; pathogen and parasite Final Score	**2.00**	**RED**
Critical?	**NO**	

Brief Summary

A variety of pathogens and diseases occur on eel farms in Asia and result in mortalities of farm stock. The pond production systems exhibit high daily water exchange rates (10-35% per day according to Nielsen and Prouzet 2008) and present a high concern for release of pathogens into the surrounding environment. The numerical score for Criterion 7 – Disease is 2 out of 10.

Justification of Ranking

Disease, particularly of bacterial origin, is a major cause of economic loss in the eel aquaculture industry (Joh et al., 2013). Some of the common pathogens include *Edwardsiella tarda* (Chen & Kou, 1992; Joh et al., 2011), *Listonella anguillarum* (Austin & Austin, 1999), *Vibriovulnificus serovar* (Hoi, Dalsgaard, DePaola, Siebeling, & Dalsgaard 1998; Austin & Austin, 1999), *Aeromonas hydrophila* (Hah, Hong, Oh, Fryer, & Rohovec, 1988; Yoo, Kwon, Yoon, Park, & Choi, 1990), and *Pseudomonas anguilliseptica* (Haenen & Dvvidse, 2001; Berthe, Michel, & Bernadette, 1995).

Many of these diseases are believed to thrive when environmental conditions are unbalanced, such as high water temperature, poor water quality and high organic content, which are common in pond culture systems (Wang, Zhang, & Austin, 2010). Some of the diseases seen in eel aquaculture, such *E. tarda* and some *Aeromonas spp*., pose a direct risk to human health as they are known human pathogens that can cause gastrointestinal and extra-intestinal infections (Janda & Abbott, 1993; Gutierrez et al., 1993). Due to this risk of transferability, particular attention should be given to prevent risk factors associated with *E. tarda* infections in humans (Joh et al., 2011; Joh et al., 2013).

There is also growing evidence that many eel diseases can affect multiple species and may be easily transferred across geographic regions. For example, the parasite *Anguillicoloides crassus* and the swim-bladder nematode (*A. globiceps*), are known to affect farmed and wild populations of both Japanese European eels (Ottolenghi et al., 2004). Outbreaks of *A. crassus* occurred in Europe (Molnár, Székely, & Baska, 1991) and North America (Barse & Secor, 1999) in the 1980's, which were found to originate from Japanese eels that were imported live from Asia for aquaculture. More recently *A.* crassus has also been found in eels in the St. Lawrence River System in Canada (Casselman, unpublished data).

<u>China</u>

Examples of pathogens and parasites impacting Chinese eel aquaculture include *E. tarda*, which has caused mortalities in Chaozhou, Guangdong Province (Quanzhang & Xinling, 1994) and the parasite *A. crassus* (Ottolenghi et al., 2004). A recent study on bacterial diversity in coastal mariculture farms of Southeast China (Zeng et al., 2010) found evidence of pathogenic entities including *Escherichia, Aeromonas, Bacillus* and *Vibrio* (Zeng et al., 2010). The study also found high quantities of the antibiotic streptomycin in some of the water samples, and the authors indicate that there is a risk that bacteria, such as *Vibrio sp*., are becoming resistant to this drug (Zeng et al., 2010). In addition to causing diseases within cultured ponds, this bacterium could also negatively affect the natural composition of bacteria in the surrounding environments (Zeng et al., 2010).

<u>Japan</u>

Several viral, bacterial, fungal, and other parasitic diseases have been reported in Japanese eel farms including *Saprolegnia* fungal infection caused by a pathogenic bacterium (Lee, Nomura & Miyazaki, 1999), and *Edwardsiellosis*, caused by *E. tarda* (Hoshina, 1962). Other Introduced pathogens include the parasitic nematode *Ichthyophthirius multifilis* (Oka, & S. Egusa, cited in Münderle et al., 2006), the brachial trematode, *Gyrodactylus anguillae* (Ogawa & Egusa, 1980), and the fungus, *Dermocystidium anguillae* (Hatai, Hirose, Hioki, Miyakawa & Egusa, 1979). It has been suggested that the ongoing documentation of non-native eel species in Japanese waters is likely due to escaped stock from production ponds (Aoyama, Watanabe, Ishikawa, Nishida, & Tsukamoto, 2000; Okamura et al. 2008), which highlights this as an important introduction pathway for diseases to the natural environment (Miyai et al., 2004).

<u>Taiwan</u>

In addition to earlier mentioned pathogens and bacterium, other parasites recorded at Taiwanese eel aquaculture sites include *Pleistophora anguillarum* (Kou & Lou, 1994), enteritis type bacterial diseases, fungal diseases, gill diseases, and diseases caused by water quality, deformity, nutritional disease, and drug injuries which evolve into diseases (Shih, Lu & Chen, 1993). Infectious Pancreatic Necrosis Virus (IPNV) (Hsu, Chen & Wu 1993) and Eel Herpesvirus in Formosa (EHVF) are also found in Taiwanese cultured eels (Ottolenghi, 2004). Additionally, as observations of non-endemic European eels (*Anguilla* anguilla) in the wild become more common (likely due to escapes from eel farms), there is an increased risk that new and/or foreign pathogens may be introduced. Some studies, for example, have indicated that European eels appear to be more susceptible to *Anguillicoloides crassus* than the Japanese eel (Münderle et al., 2006).

South Korea

There have been several reports of *E. tarda*, *A. hydrophila*, and *Vibrio spp*. in Korean eel aquaculture (Hah et al., 1984; Yoo et al., 1990; Kim, Ok, Kim, & Oh, 2011; Joh et al., 2011). A study conducted between 2003 and 2010 on 621 diseased eels from 26 eel farms supported earlier research in that *E. tarda* was one of the most important bacterial pathogens in eels (Joh et al., 2011). This study also noted that the infection rates varied greatly from farm to farm, indicating a wide variation in the sanitary management of farms (Joh et al., 2011). Infections caused by the parasite *Heterosporis anguillarum* have caused significant economic losses in Korea and elsewhere, as the transmission rate within ponds is high (Suh & Chun, 1998, cited in Joh et al., 2007). As pathogenic risk to cultured eels both in South Asia and internationally is high, it is recommended that this specific parasite be consistently monitored with continual stringent management of production systems (Joh et al., 2007)

Summary

Overall, the relative frequency with which diseases are reported in each of these four countries suggests that pathogens are of significant concern in eel farming operations. The nature of the production systems employed (pond and/or flow-through) allow for significant amounts of water to be released into the natural environment, suggesting that introduction of pathogens or disease from farm sites is likely. This is of particular concern in the case of eel farming because wild Japanese eel stocks are currently considered threatened and the risk of transferring diseases and pathogens may place further stress on these stocks. There is, however, no evidence at this time that eel aquaculture is actually resulting in an amplification of pathogens and parasites in the natural environment. As a result, Criterion 7 – Disease scores 2 out of 10.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture*

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	0	
C8 Source of stock Final Score	**0.00**	**RED**

Brief Summary

Despite significant research efforts, eels are unable to be hatched and raised in hatcheries. All eels grown by the aquaculture industry are sourced from wild populations, and as such the industry is completely dependent on wild stocks. As such, Criterion 8 – Source of Stock scores 0 out of 10.

Justification of Ranking

Despite significant efforts in research since the 1930s, there has been little success in closing the lifecycle and raising any of the *Anguilla* species in hatcheries. In 1974 Yamamoto and Yamauchi were the first researchers to successful obtain fertilized eggs and larvae from the Japanese eel using hormone treatments, however the larvae did not survive past a two-week rearing period (Tanaka et al, 2003). Since this time, artificial sexual maturation has been induced in *A. anguilla, A. rostrata, A. dieffenbachii* and *A. australis* to obtain eggs and larvae, but no further development has been successful (Minegishi et al., 2012). The Japanese eel (*A. japonica*) has seen the greatest achievements to date whereby in 2003 Tanaka et al successfully reared larvae into the glass eel stage. This success appears to be most attributable to advances in developing a specialized diet that support the larvae beyond the depletion of their yolk and oil droplet stores in the preleptocephalus larvae stage (Tanaka et al. 2003). Although this study was determined to be a huge advance in the domestication of eels, many challenges still persist including high mortality rates, reduced growth rates, and the inability to date to foster spontaneous gametogenesis and spawning in captivity (Tanaka et al., 2003; Minegishi et al., 2012).

Due to the ongoing challenges in the domestication of eel, the aquaculture industry remains fully reliant on wild-caught brood stock and hence Criterion 8 – Source of Stock scores 0 out of 10.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**-6.00**	**GREEN**
Critical?	NO	

Brief Summary
While no information on wildlife interactions with eel ponds was available for analysis, it is reasonable to presume interactions do occur. As no further data on wildlife mortalities, species status, or population-level impacts are available, this Exceptional Criterion is scored on a precautionary basis according to the Seafood Watch criteria and results in an adjustment score of -6 out of -10.

Justification of Ranking
The high density of fish in outdoor pond culture systems presents a prime foraging opportunity for wildlife and predators. It has been repeatedly noted, for example, that water birds will forage at aquaculture sites (Ma 2011, Ma 2004, Price 1995) to the extent that the year-round food supply provided by extensive aquaculture systems may even cause behavioral and migration pattern changes (Tucker, Hargreaves & Boyd 2008). No information could be found, at the time of this writing, on the exclusion practices used by fish farmers in any of the four countries included in this report, nor is there any evidence of direct or incidental mortalities of predators on aquaculture sites. However, it is presumed that wildlife and predators do interact with eel ponds and, as such, some level of mortality is reasonable to expect. As the species status or impacts at the population level are unknown, a score of -6 out of -10 is applied to this Exceptional Criterion.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	0.00	
F10Xb Biosecurity of source/destination	2.00	
C10X Escape of unintentionally introduced species Final Score	**-8.00**	**RED**

Brief Summary
Eel aquaculture relies heavily on international and trans-waterbody shipment of animals. As juvenile eels are sourced from wild populations, the biosecurity of the source is considered negligible and an area of high concern as other species besides eels have the potential to be caught and transported with the juvenile eels. The biosecurity of the source ponds is also a high concern as high daily water exchange rates create the potential for the release of an unintentionally introduced species. The numerical score for the Exceptional Criterion 10X is -8 out of -10.

Justification of Ranking

Factor 10Xa International or trans-waterbody live animal shipments
Eel aquaculture is completely dependent on wild-caught glass eels and elvers for the farm stock (FAO 2013*e,* Crook 2010, Casselman & Cairns 2009). Historically, eel farming was mostly carried out using species of local provenance, but, as previously noted, the inconsistent supply of local species led to the development of international trade in glass eels of many different *Anguilla* species. Given the significant challenges observed with traceability and labeling of eel products, it is not possible at this time to determine what proportion of eel farmed in Asia is dependent on international or trans-waterbody live animal shipments. However, the declining wild stocks of the local eel species (*A. japonica*) suggest, that a realistic worst-case scenario would be that more that 90% of the farmed stock would be reliant on international or trans-waterbody live animal shipments. As such, the score for Factor 10Xa is 0 out of 10.

Factor 10Xb Biosecurity of source/destination
In the case of the eel aquaculture industry, there is a heavy reliance on international or trans-waterbody live animal shipments for glass eels and elvers, which are stocked for growout in aquaculture ponds. Glass eels and elvers are harvested from the wild where no biosecurity measures exits, and therefore the biosecurity score of the source of animal movements is of

high concern and received a score of 0. The biosecurity score of the destination is of moderate-high concern and received a score of 2 because eel aquaculture in Asia is predominantly carried out in pond systems (greenhouse, still, or flow-through) with daily water exchange rates between 10% and 35% per day (Nielsen & Prouzet 2008).

Overall, this criterion received a score of -8 due to the high dependency on international (or trans-waterbody live animal shipments) and high biosecurity concerns of both the source and destination of the animal shipments.

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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Data points and all scoring calculations

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	5	5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	0	0
Chemical use	Yes	2.5	2.5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Other – (e.g. GHG emissions)	No	Not Relevant	N/A
Total			**27.5**

C1 Data Final Score	3.05	RED

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	48
eFCR	1.4
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	14.5
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	107.52
N in each ton of fish harvested (kg)	23.2
Waste N produced per ton of fish (kg)	**84.32**

Factor 2.1b - Production System discharge score

Basic production system score	0.75
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0

Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.75**

80% of the waste produced by the fish is discharged from the farm

2.2 – Management of farm level and cumulative impacts and appropriateness to the scale of the industry

China

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Moderately	0.5
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Partly	0.25
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Moderately	0.5
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	No	0
		2.25

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Moderately	0.5
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Moderately	0.5
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Moderately	0.5
4 - Does enforcement demonstrably result in compliance with set limits?	Partly	0.25
5 - Is there evidence of robust penalties for infringements?	no	0
		1.75

F2.2 Score (2.2a*2.2b/2.5)	**1.575**

C2 Effluent Final Score	**2.00**	**RED**
	Critical?	NO

Japan

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score

1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Moderately	0.5
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Yes	1
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Moderately	0.5
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	No	0
		3

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Moderately	0.5
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Partly	0.25
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Partly	0.25
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	Partly	0
		1.25

F2.2 Score (2.2a*2.2b/2.5)	**1.5**

C2 Effluent Final Score	**2.00**	**RED**
	Critical?	NO

Taiwan

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Moderately	0.5
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Mostly	0.75
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Moderately	0.5
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Moderately	0.5

		3.25

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Moderately	0.5
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Partly	0.25
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	N0	0
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	Mostly	0.75
		1.5

F2.2 Score (2.2a*2.2b/2.5)	1.95

C2 Effluent Final Score	2.00	RED
	Critical?	NO

<u>**South Korea**</u>

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Mostly	0.75
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Yes	1
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Yes	1
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Partly	0.25
		4

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Mostly	0.75
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	No	0

3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	No	0
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	No	0
		0.75

F2.2 Score (2.2a*2.2b/2.5)	**1.2**

C2 Effluent Final Score	**2.00**	**RED**
	Critical?	NO

Criterion 3: Habitat

3.1 Habitat conversion and function

F3.1 Score	**6.00**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

China

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Moderately	0.5
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Partly	0.25
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	no	0
		2.75

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	no	0

5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	no	0
		1.375

F3.2 Score (2.2a*2.2b/2.5)	**1.38**

C3 Habitat Final Score	**4.46**	**YELLOW**
	Critical?	NO

Japan

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Moderately	0.5
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Yes	1
		3.5

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Mostly	0.75
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	No	0
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	No	0
		1.5

F3.2 Score (2.2a*2.2b/2.5)	**2.10**

C3 Habitat Final Score	**4.70**	**YELLOW**
	Critical?	NO

Taiwan

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Mostly	0.75
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	no	0
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	No	0
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	no	0
		1.75

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Partly	0.25
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	No	0
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Partly	0.25
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		1.25

F3.2 Score (2.2a*2.2b/2.5)	**0.875**

C3 Habitat Final Score	**4.29**	**YELLOW**
	Critical?	NO

South Korea

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	No	0
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	No	0

4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Yes	1
		3

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	No	0
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	No	0
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	No	0
		1

F3.2 Score (2.2a*2.2b/2.5)	**1.20**

C3 Habitat Final Score	**4.40**	**YELLOW**
	Critical?	NO

Criterion 4: Evidence of Risk of Chemical Use

China and Taiwan

Chemical Use parameters	Score	
C4 Chemical Use Score	**0.00**	
C4 Chemical Use Final Score	**0.00**	**RED**
Critical?	NO	

South Korea and Japan

Chemical Use parameters	Score	
C4 Chemical Use Score	**4.00**	
C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

Criterion 5: Feed

5.1 Wild Fish Use

Factor 5.1a – Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	58.5
Fishmeal from byproducts (%)	84
% FM	9.36
Fish oil inclusion level (%)	4
Fish oil from byproducts (%)	0
% FO	4
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.4
FIFO fishmeal	0.58
FIFO fish oil	1.12
Greater of the 2 FIFO scores	1.12
FIFO Score	**7.20**

Factor 5.1b – Sustainability of the Source of Wild Fish (SSWF)

SSWF	-6
SSWF Factor	-0.672

F5.1 Wild Fish Use Score	**6.53**

5.2 Net Protein Gain or Loss

Protein INPUTS		
Protein content of feed		48
eFCR		1.4
Feed protein from NON-EDIBLE sources (%)		67
Feed protein from EDIBLE CROP soruces (%)		33
Protein OUTPUTS		
Protein content of whole harvested fish (%)		15.5
Edible yield of harvested fish (%)		68.5
Non-edible byproducts from harvested fish used for other food production		0
Protein IN		15.83
Protein OUT		10.6175
Net protein gain or loss (%)		-32.9435
	Critical?	NO
F5.2 Net protein Score	**6.00**	

5.3 Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	62.5
eFCR	1.4
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	22.76

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

Inclusion level of crop feed ingredients (%)	37.5
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	1.4
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.20

Value (Ocean + Land Area)	**22.96**

F5.3 Feed Footprint Score	**2.00**

C5 Feed Final Score	**5.26**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

Factor 6.1a – Escape Risk

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**2**

Factor 6.1b – Invasiveness

Part B – Non-Native Species

Score	1.5

Part C – Native and non-native species

Question	**Score**	
Do escapees compete with wild native populations for food or habitat?	yes	1
Do escapees act as additional predation pressure on wild native populations?	yes	1

Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some Extent	0.5
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No	0
Do escapees have some other impact on other native species or habitats?	No	0
	2.5	2.5

F 6.1b Score	**4.0**

Final C6 Score	**3.00**	**RED**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	**Score**	
C7 Biosecurity	2.00	
C7 Disease; pathogen and parasite Final Score	**2.00**	
Critical?	NO	**RED**

Criterion 8: Source of Stock

Source of stock parameters	**Score**	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	0	
C8 Source of stock Final Score	**0**	
		RED

Exceptional Factor 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	**Score**	
F3.3X Wildlife and Predator Final Score	**-6.00**	**YELLOW**
Critical?	NO	

Exceptional Factor 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	**Score**	
F6.2Xa International or trans-waterbody live animal shipments (%)	0.00	
F6.2Xb Biosecurity of source/destination	10.00	
F6.2X Escape of unintentionally introduced species Final Score	**-8.00**	
		RED