Monterey Bay Aquarium
Seafood Watch

Farmed Seaweed

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Worldwide

All Production Systems

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Final Seafood Recommendation

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.25	YELLOW	
C2 Effluent	9.00	GREEN	NO
C3 Habitat	6.18	YELLOW	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8 Source	10.00	GREEN	
9X Wildlife mortalities	0.00	GREEN	NO
10X Introduced species escape	0.00	GREEN	
Total	**63.43**		
Final score	**7.93**		

OVERALL RANKING

Final Score	7.93
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

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 seaweeds farmed in open water systems worldwide is 7.93, which is in the green range. Three criteria (data, habitat and escapes) received yellow rankings; however, this did not affect the overall green ranking.

Executive Summary

Around the world, particularly in Asia, seaweed is commercially produced on coastal farms. These farms can vary in size, with very large farms producing millions of metric tons of seaweed per year. Seaweeds covered under this assessment include both the edible "sea vegetables," as well as seaweeds that are produced for other uses (i.e., additives in foods). Seaweed farming, unlike many other forms of aquaculture, results in little impact, or risk of impact, to the surrounding natural environment. As a primary producer, seaweed does not require inputs of feed because it grows by photosynthesizing energy from the sun and absorbing carbon dioxide (CO_2) and inorganic nutrients directly from the water.

Data availability and quality for seaweed farming is limited. Information about the industry, trade, and regulation is particularly lacking in the public domain. There is a significant number of academic articles about seaweed farming, with most of them emphasizing the overall sustainability of the practice and the need for effective management in order to responsibly develop the industry. Direct contact with industry and academic representatives was an especially valuable source of information for this assessment, as many of these experts were able to provide information that was not available elsewhere.

Due to the general nature of seaweed culture, there are low concerns regarding potential impacts from effluents, feed, chemical use, disease, predator interactions and the use of wild populations for broodstock or seed. Two areas where a moderate concern remains are the potential impacts of large scale seaweed farming on habitats, and the potential spread of non-native species. Due to the high intensity of seaweed farming in some areas around the world, there can be impacts on the surrounding habitat. For example, if areas are cleared of natural seagrasses or other components of the environment to make room for the seaweed farm. Secondly, many cultured species are not native to the area where they are being farmed. The open water system used by seaweed farms provides little control of escapes (by natural reproduction and dispersion) and it is possible that they may colonize an area where they were previously not found, potentially disrupting natural ecosystems. Today, due to increased regulation, it is much less likely that a species would be allowed to be farmed in a non-native area.

Despite these concerns, seaweed farming is shown to have minimal environmental impacts, as outlined in the remainder of this assessment.

Overall, international seaweed farming in open water production systems received a high score of 7.93 out of 10, with no red criteria; therefore, the final Seafood Watch recommendation is "Green – Best Choice."

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Introduction

Scope of the analysis and ensuing recommendation

This report evaluates the environmental impacts of globally farmed seaweed species that are available to consumers in the United States. The seaweed species included in this report are commonly referred to as sea vegetables and can be directly consumed. Seaweed species that are grown solely for their extractive components (i.e., agar, carrageenan, alginates, bioactives and secondary metabolites) are also covered under this assessment as all of these species have similar production methods. The focus of this report will be on seaweed farms in Asia, which is where most global seaweed production takes place, however the resulting recommendation is valid for all farmed seaweed irrespective of country.

Species

"Seaweeds" include a diversity of large marine macroalgae (Redmond et al. 2014). Macroalgae can be classified into three distinct classes: brown algae (Phaeophyta), green algae (Chlorophyta), or red algae (Rhodophyta). Seaweeds differ from true plants because they lack true roots, stems and leaves. Instead, they have holdfasts, midribs (in some cases), and fronds, all of which differ in their structure and function when compared to true plants (Fredericq 2003). Brown and red algae are the most commonly produced and consumed as human food. In the United States, the most popular, directly consumed seaweed is undoubtedly the red algae, *Porphyra* spp. or *Pyropia* spp. (nori) used in sushi, but other species with similar open water production methods will also be evaluated in this report (Table 1).

Seaweeds grow primarily in intertidal or sub-littoral (beyond the low-tide mark) coastal waters where they can be attached to the bottom but still have access to enough light for photosynthesis (Dhargalkar and Pereira 2005). They are extractive organisms, meaning they remove CO_2 and nutrients from the seawater around them and can store them or convert these compounds into biomass (Fredericq 2003, Fei 2004, Lynn Cornish, personal communication). Seaweeds act as an important component of marine ecosystems, providing oxygen, food, and habitat for fish and invertebrates. Seaweeds can reproduce sexually (which includes complicated life cycles) and some species are capable of asexual reproduction (fragmentation).

Table 1. Farmed seaweed species forming the focus of this assessment.

Species	Common Name
Porphyra spp. or *Pyropia* spp.	Nori or purple laver
Saccharina japonica (formerly Laminaria japonica)	Japanese kelp
Undaria pinnatifida	Wakame
Gracilaria spp.	Gracilaria
Saccharina latissima	Sugar kelp
Laminaria digitata	Horsetail
Alaria esculenta	Winged kelp
Sargassum fusiforme	Hijiki
Eisenia bicyclis	Arame
Monostroma spp. and *Ulva* spp.	Aonori or green laver or sea lettuce
Eucheuma denticulatum	Eucheuma
Kappaphycus striatum	Eucheuma
Kappaphycus alvarezii	Eucheuma

Geographic coverage

This report focuses on Asian countries that produce seaweeds. The overwhelming majority of global seaweed production occurs in these countries and seaweed is a culturally important food in these areas. Seaweed production methods are often very similar between countries, and as such, this report considers multiple species and countries within one assessment and the resulting recommendation is considered to be applicable globally.

Production Methods

There are two distinct phases in seaweed farming: (1) the indoor hatchery phase and (2) the sea-based grow-out phase. During the indoor hatchery phase, the microscopic life stages of the seaweeds are nurtured and grow-out rafts, nets or ropes are seeded. In the sea-based grow-out phase the seaweed rafts, nets or ropes are moved to coastal waters where the seaweeds grow to maturity (Figure 1 and 2). There are several different raft, net and rope culture methods that are used in the grow-out phase; however, they are all similar in that they are suspended off the bottom and seaweeds grow in the water column (Food and Agriculture Organization (FAO) online resources). This report addresses the grow-out phase for all forms of suspended raft, net and rope culture in coastal waters, as well as land-based tank culture systems (although this method produces only a small amount of seaweed currently). Both sea- and land-based methods are viewed as activities that have low environmental impacts and that can offer employment and independence for coastal communities (Redmond et al. 2014).

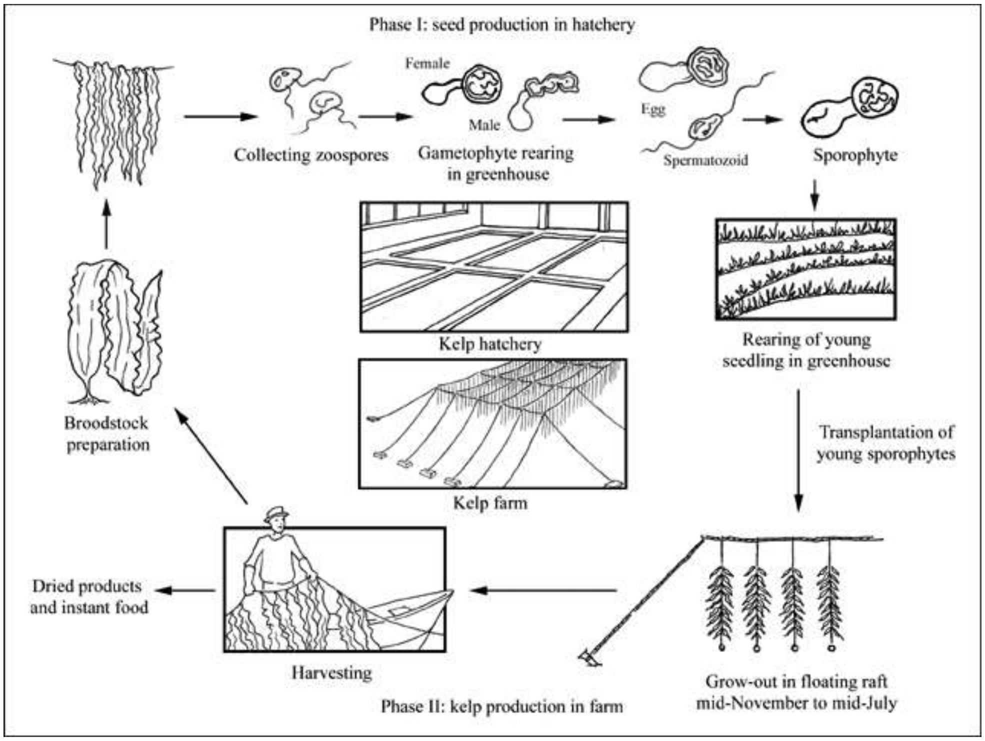

Figure 1. *Laminaria* spp. production cycle (source: www.fao.org)

Figure 2. Nori (*Porphyra* spp.) growing on rope nets (source: Jiaxin Chen, personal communication)

Additionally, seaweeds are an important component of integrated multi-trophic aquaculture (IMTA) systems. This method for seaweed growth still utilizes suspended off-the-bottom techniques, but grows seaweed and shellfish alongside fed aquaculture systems: the shellfish extract organic particulate nutrients and the seaweeds absorb dissolved inorganic nutrients from the downstream effluent of the fish. IMTA is considered an ecologically-based method for producing fish and other products from aquaculture and can contribute to healthier ecosystems and more responsible aquaculture production (Neori et al. 2007, Redmond et al. 2014).

Species Overview

Seaweed (sometimes referred to as aquatic plants by organizations like the FAO) production worldwide can be described by country, weight, value, or species. Most seaweed production is described by its classification as brown, red or green algae. Therefore, it is useful to know which species fall under each classification. Table 2 provides some examples of the most commonly produced seaweeds and their classification.

Table 2. Examples of red, brown, and green seaweeds.

Classification	**Species**
Red Seaweeds	*Porphyra* spp., *Pyropia* spp., *Gracilaria* spp., *Kappaphycus* spp., *Eucheuma* spp.
Brown Seaweeds	*Laminaria* spp., *Sacharrina* spp., *Undaria* spp., *Sargassum* spp.
Green Seaweeds	*Monostroma* spp., *Ulva* spp.

Production statistics.

Seaweeds are traditionally consumed and produced on a large scale in Asia but are becoming more and more popular as a food in western countries (Forster 2011). Redmond et al. (2014) summarizes global seaweed production well:

> … there is an ever increasing amount of seaweed production from aquaculture, principally in Asia and South America (Chile). Seaweed aquaculture makes up a significant portion of organisms cultured worldwide (~19 million metric tons) with a value of ~US $5.65 billion (FAO 2012). Aquaculture production is dominated by kelps (*Saccharina japonica* and *Undaria pinnatifida*), tropical red algal species (carrageenophytes species including *Kappaphycus* and *Eucheuma*), nori (including *Porphyra* and *Pyropia* species), and the red algal agarophyte species known as *Gracilaria*. China is the world's top producer of cultured seaweeds, though other countries in Asia (Japan, Korea, and the Philippines) and in Europe (France, Ireland, Norway, Scotland, and Spain) also grow seaweed. In North America, the seaweed industry is comprised of small wild harvest cottage operations located along the East and West Coasts of Canada and the United States. Recent developments in culture technologies, however, have led to the development of a small sugar kelp industry in the Northeast.

Numerical figures on aquaculture production can be found through the FAO and the National Marine Fisheries Service (NMFS). Globally, red seaweeds have the highest production volume and the highest value, with brown seaweeds following in both production and value; green seaweeds have very low production and value but there are a few species that are consumed by humans (i.e., *Ulva* spp. and *Caulerpa* spp.) (Figure 3 and 4). Asia is by far the largest producer of aquatic plants (including seaweeds), producing approximately 23.6 million metric tons (mt) in 2012, worth approximately 6.3 billion USD (FAO 2014). Africa produced the next highest volume at approximately 161,000 mt in 2012, but the Americas' seaweed production has the second highest value at approximately 25 million USD in 2011, dropping to approximately 10 million in 2012 (FAO 2014).

Within Asia, China produces the highest quantity of aquatic plants, at approximately 12.8 million mt in 2012, followed by Indonesia and the Philippines at approximately 6.5 and 1.8 million mt, respectively (FAO 2014). Indonesia and the Philippines primarily culture species that are not typically consumed directly (i.e., *Kappaphycus* and *Eucheuma* species) (Valderrama 2012). Japan produced approximately 441,000 mt in 2012(FAO 2014). China's production is worth approximately 2.9 billion USD, followed by Indonesia and Japan at approximately 1.3 and 1.3 billion USD respectively (FAO 2014).

China produces primarily brown seaweeds (almost 6 million mt), followed by miscellaneous (2.9 million mt) and red seaweeds (2.6 million mt). Indonesia produces primarily red seaweeds (5.17 million mt). Japan produces primarily red seaweeds at almost 300,000 mt. Korea (both Dem. People's Rep. and the Republic of Korea) produces primarily brown seaweeds. The Philippines produce primarily red seaweeds (1.8 million mt).

Asia produces approximately 11 million mt of red seaweeds and approximately 7 million mt of brown seaweeds. Red seaweeds from Asia are worth approximately 3 billion USD while brown seaweeds are worth approximately 1 billion USD.

Import and export sources and statistics

The US imports about 6,400 mt (this is likely a dry weight figure, which would amount to approximately 60,000 mt wet weight, John Forster, personal communication) of edible seaweed and algae, which is worth approximately 62 million USD (NMFS 2013). The US exports only about 1,233 mt of edible seaweed and algae, worth about 14 million USD (NMFS 2013). Exact figures on the products or species of seaweed that are being imported and exported by the US and Asian countries do not exist, however, nori (red seaweed, *Porphyra* spp. and *Pyropia* spp.) seems to be the most popular seaweed product among US consumers, with kelps (brown seaweed, *Saccharina* spp. (sometimes referred to as *Laminaria* spp.) and *Gracilaria* spp. becoming more popular (Charles Yarish, personal communication).

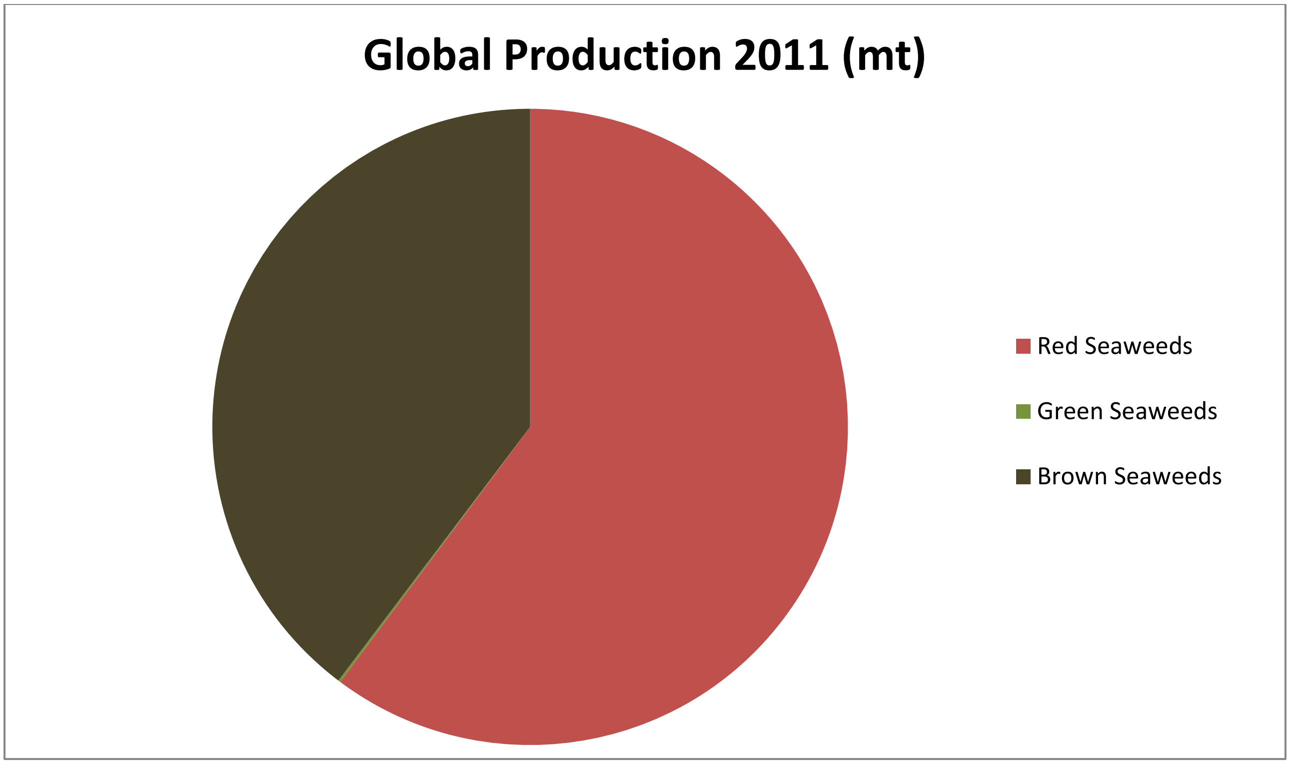

Figure 3. Global production of red, brown, and green seaweeds by weight in 2011.

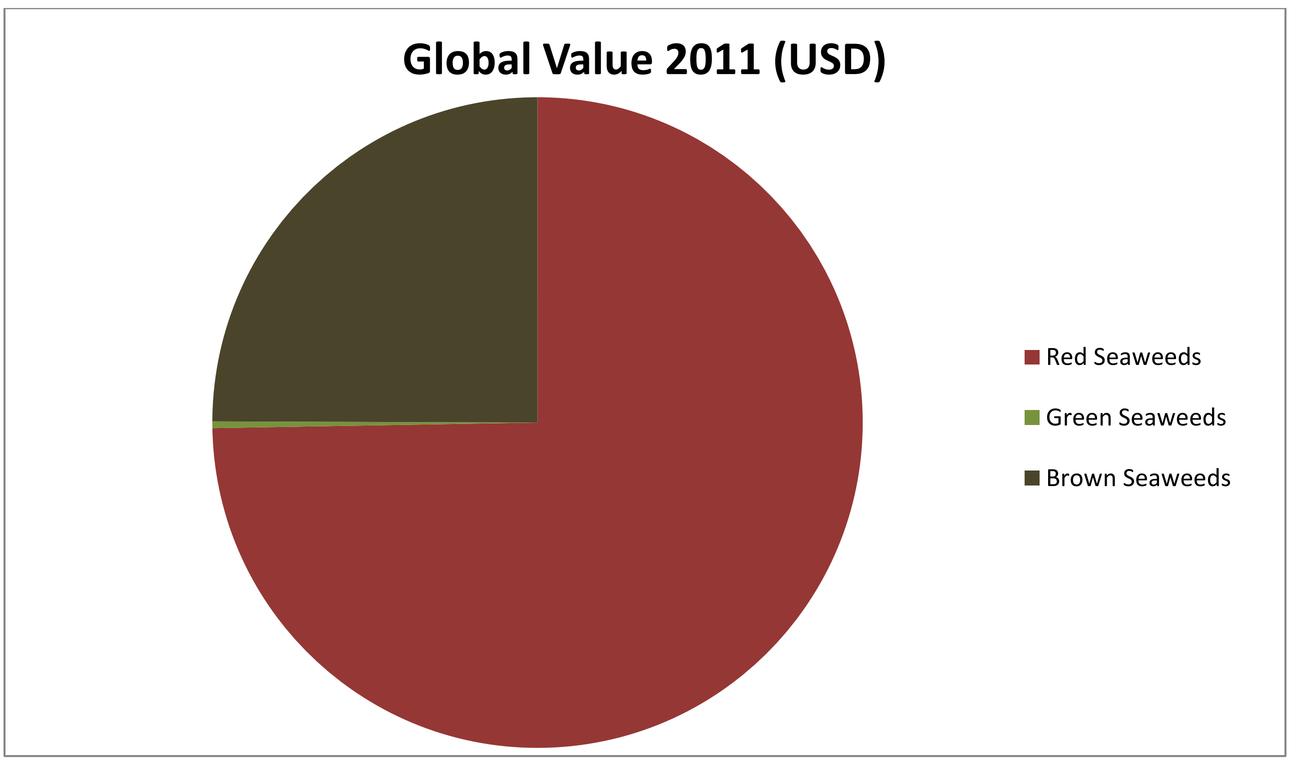

Figure 4. Global value of red, brown, and green seaweeds in US Dollars in 2011.

Common and market names

Scientific Name	*Porphyra* spp. and *Pyropia* spp.
Common Name	Nori, Laver
United States	Nori
Chinese	Zicai
Japanese	Nori
Korean	Gim

Scientific Name	*Saccharina japonica* (formerly *Laminaria japonica*)
Common Name	Kelp
United States	Kelp
Chinese	Haidai
Japanese	Kombu
Korean	Dashima

Scientific Name	*Undaria pinnatifida*
Common Name	Wakame
United States	Japanese kelp, Asian kelp, apron-ribbon vegetable, wakame
Chinese	Ito-wakame, Kizami-wakami, Qundai-cai
Japanese	Wakame, Ito-wakame, Kizami-wakame, Nambu wakame
Korean	Miyeok, Ito-wakame, Kizami-wakami

Scientific Name	*Gracilaria* spp.
Common Name	Gracilaria
United States	Ogo
Chinese	Jiangli
Japanese	Ogonori

Scientific Name	*Saccharina latissima*
Common Name	Sugar kelp
United States	Sugar kelp

Scientific Name	*Laminaria digitata*
Common Name	Horsetail
United States	Horsetail

Scientific Name	*Alaria esculenta*
Common Name	Winged kelp

United States	Winged kelp
Chinese	Cizao

Scientific Name	*Sargassum fusiforme*
Common Name	Hijiki, Hiziki
United States	Hijiki
Chinese	Yagqicai
Japanese	Hijiki

Scientific Name	*Eisenia bicyclis*
Common Name	Arame, Sea Oak
United States	Arame
Japanese	Arame

Scientific Name	*Eucheuma denticulatum*
Common Name	Eucheumoid algae, Guso
United States	Eucheuma
Philippines	Guso

Scientific Name	*Kappaphycus alvarezii*
Common Name	Eucheumoid algae
United States	Eucheuma
Philippines	Guso

Scientific Name	*Kappaphycus striatum*
Common Name	Eucheumoid algae
United States	Eucheuma
Philippines	Guso

Although Hijiki is included in the above tables, many food agencies, including the United States Department of Agriculture, have advised against its consumption due to potentially harmful levels of inorganic arsenic that can be found in the food (USDA 2004).

Product forms.

Seaweeds can be consumed fresh, dried (flakes or sheets), frozen, cooked, in baked goods or in soups. Nori sheets for preparing sushi rolls are readily available in American grocery stores and are a commonly consumed product in China, Japan and Korea (Yang et al. 2010, Zava and Zava 2011). Wakame is also an important food in Chinese, Japanese and Korean cultures (Yang et al. 2010, Zava and Zava 2011). Specifically, wakame is used in the traditional miso soup (dashi stock), as a salad vegetable, with rice, in pickles, and as a natural remedy for variety of ailments (Naylor 2006).

Additionally, seaweeds are used as an additive in foods. Specifically, *Kappaphycus* and *Eucheuma* species are cultivated to extract carrageenan, a gelling agent in foods (i.e., pudding) (Hayashi n.d.).

Analysis

Scoring guide

- With the exception of the exceptional factors (9X and 10X), 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 factors 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.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in Appendix 1.

Production system

The production systems considered under the scope of this global seaweed assessment include both raft, net, and rope systems located in coastal, open waters and land-based tank systems.

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	2.5	2.5
Effluent	Yes	5	5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	7.5	7.5

Chemical use	Yes	7.5	7.5
Feed	No	10	n/a
Escapes, animal movements	Yes	5	5
Disease	Yes	7.5	7.5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**50**

C1 Data Final Score	**6.25**	**YELLOW**

Brief Summary

This assessment includes all countries and all cultured seaweed species. Although data availability and quality for each country or species may be lacking, the overall environmental impacts of seaweed farming tend to be minimal, which can excuse the lack of data in some areas. The most valuable sources of information in most cases were personal communications with individual researchers and industry contacts. These experts have experience studying seaweed farming and in many cases have comprehensive knowledge of Asia's seaweed production. Due to the lack of information in some areas, but the overall low environmental impact of seaweed aquaculture, the criterion for data quality and availability scored 6.25 out of 10.

Justification of Ranking

Industry and production statistics were often broad, grouping many seaweed species under one category, and sometimes outdated (i.e., more than 10 years old). Additionally, it is nearly impossible to get reliable trade data on seaweeds (personal experience; Charles Yarish, personal communication). Information on effluent, habitat, wildlife, chemical use, escapes, disease and source of stock were available in the literature and online resources (i.e., Naylor et al. 2001, Tang et al. 2009, FAO documents and online resources, The Seaweed Site, etc.). However, some sources may have been either very broad (for example covering many species) or very specific (only one species) and many are considered to be outdated. Most of the time, if there was information available on only one species, the findings were extrapolated to other species that have very similar biological and production characteristics.

The final score for Criterion 1 – Data is 6.25 out of 10.

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

Evidence-Based Assessment

C2 Effluent Final Score	**9.00**	**GREEN**

Brief Summary

An evidence-based assessment was used to assess the effluent criterion for seaweed aquaculture. As an extractive species, there is no risk that seaweed culture can cause impacts due to effluent discharge. While there is some concern over the release of epiphytes into the water during cleaning and harvesting of the farmed seaweed species, there is very limited evidence to suggest that this produces a harmful effect on the extended environment. Seaweed aquaculture is more commonly regarded as being beneficial to marine ecosystems because it removes pollution-loaded nutrients from the water, which often originate from land-based pollution sources (i.e., sewage and agricultural run-off) (Fei 2004). For these reasons, the criterion for effluent scored 9 out of 10.

Justification of Ranking

Seaweed production differs from many other forms of aquaculture because there is no feed requirement and very limited (if any) use of fertilizers (FAO 2003, Charles Yarish, personal communication). If fertilizers are used, as is done in the Yellow Sea with Japanese kelp production, the added nutrients are quickly absorbed by the seaweed and little is lost to the surrounding environment (FAO 2003). Additionally, and in contrast to the culture of many animals, there is no organic waste associated with seaweed farming. This is because seaweeds are extractive and have been shown to improve water quality in some cases, removing ammonia and phosphorous and releasing oxygen into the water (Goldburg et al. 2001).

There is an abundance of research focused on the ability of seaweeds to extract inorganic nutrients, particularly for the purpose of mitigating the impacts of fed aquaculture systems that produce effluent (i.e., salmon aquaculture) (Naylor et al. 2000). Most commonly referred to as integrated multi-trophic aquaculture (IMTA), fed aquaculture species may be grown alongside seaweeds and shellfish (to extract inorganic and organic nutrients , respectively, in the effluent) to reduce overall impacts from the fish effluent on the environment (Naylor et al. 2000, Chopin et al. 2001).

Interestingly, the world's largest reported algae bloom occurred off the coast of Qingdao, China in 2008. This bloom and others like it have been incorrectly attributed (by some researchers and reporters) to activities related to *Porphyra yezoensis* farming in Jiangsu Province (Liu et al. 2009, Liu et al. 2010, Jacobs 2013, Ling 2013). *Ulva prolifera* (sometimes referred to by its former name, *Enteromorpha prolifera*) is a green alga that grows on the rafts used for the farming of *Porphyra*. It is often removed from the rafts during cleaning and harvesting, and allowed to drift in the water, where it can continue growing— it does not need to remain attached to the bottom to grow. While the farming of *Porphyra* was taking place approximately 180 km away from the coast of Qingdao, it was hypothesized (and since disproven) that favorable oceanographic conditions (temperature, wind and current) allowed for the quick growth and transport of the green algae from Jiangsu Province to Qingdao. This was also the first case where aquaculture of seaweeds was suggested as the cause of an algal bloom (Liu et al. 2009, Liu et al. 2010). It was suggested by Liu et al. (2009) that algal blooms from *Porphyra* farming could easily be prevented in the future by not disposing of green algae into the sea during harvesting and cleaning of culture rafts.

Further and more recent research suggests that *Porphyra* farming was not the source of the algae bloom in 2008 (Pang et al. 2010, Charles Yarish, personal communication). Instead, morphologic and molecular data point to on-land animal aquaculture ponds in Jiangsu Province as the source of the bloom. On-land animal aquaculture ponds have high nutrient levels in the water and they discharge effluents containing *Ulva* into coastal water year-round.
While there is no definitive evidence that seaweed farming has any impacts beyond the immediate vicinity of the farm, seaweed culturing and the increase in natural seaweed growth due to coastal eutrophication have been identified as sources of seaweed waste in the oceans (Tang et al. 2009). It is important to consider the amount of seaweed waste in the environment and the ability for that waste to be decomposed by microorganisms. Again, reducing seaweed waste from seaweed farming could be easily managed by proper disposal of waste products.

There is very little evidence suggesting an impact on the environment outside of the allowable zone of effect. It has been suggested that discarded epiphytes from seaweed farms may continue to grow in the open ocean and could potentially be linked to algal blooms; however, this hypothesis has been refuted and remains unproven.

The final score for Criterion 2 – Effluent is 9 out of 10.

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		9.00	
F3.2a Content of habitat regulations	0.75		
F3.2b Enforcement of habitat regulations	1.75		
F3.2 Regulatory or management effectiveness score		0.53	
C3 Habitat Final Score		**6.18**	**YELLOW**
Critical?	NO		

Brief Summary

Seaweed farms can be extremely large operations, with the potential to alter the physical characteristics and habitat surrounding them. This being said, there is very little evidence to suggest that seaweed farms have serious consequences for the surrounding habitat. Although effective management is often not apparent for seaweed farms, it could play an important role in ensuring that seaweed farms are operated in a manner that mitigates any environmental impacts. The criterion for habitat scored 6.18 out of 10.

Justification of Ranking
Factor 3.1. Habitat conversion and function

Seaweed farms can be very large operations with thousands of seaweed lines or nets in each farm, especially in Asia where most seaweed farms are located. Indeed, some farms can take up entire bays, with the largest farm being in Jiaozhou Bay, near Qingdao, China and apparently producing almost half of the global seaweed production in this one single location (Manufactured landscapes 2009) (Figure 6). Despite the large farms present in some areas, there is little evidence that there are negative impacts on the environment (Jiaxin Chen, personal communication).

Figure 6. Jiaozhou Bay seaweed farm, near Qingdao, China (photo retrieved from http://hhaldenby.wordpress.com/seaweeds-role-in-society/)

Seaweeds are known to be habitat-creators, forming refuges and feeding grounds for a variety of fishes and invertebrates (Limbaugh 1955). For example, *Eucheuma* spp. farming has been shown to increase fish and shellfish populations in surrounding areas (Crawford 2002).

Additionally, it has been suggested that seaweed farms provide ecosystem services by removing pollution-loaded nutrients from seawater, which originate primarily from on-land pollution sources. This ecosystem service could be considered especially valuable in highly populated regions of Asia, which is indeed where most seaweed farming takes place, because the seaweeds counteract the high nutrient inputs from land in those areas (Fei 2004,; Charles Yarish, personal communication; Jiaxin Chen, personal communication). There is no existing evidence that seaweed farming results in wider scale nutrient depletion. However, it has been suggested that it is possible that diversion of nutrients through macroalgae instead of phytoplankton could have implications for the nutrient cycle and secondary productivity (Phillips 1990).

However, intensive, large-scale seaweed farming could have impacts on the physical environment, such as changes in patterns of sedimentation, changes in water movement, erosion, depletion of nutrients, competition with native primary producers for nutrients, alteration of habitat prior to farming, shading of the benthos (especially corals), and addition of detritus from decaying seaweed (De Silva 1999, as cited in Crawford 2002; Tang and Fang 2002).

There is also some debate about the effects of seaweed farming on seagrass beds. Eklof et al. (2006) found that off-bottom seaweed farming negatively affected one native seagrass species in Tanzania, but not another. It was then concluded that although seaweed farming may have some effect on the environment, it is far less detrimental than many other forms of aquaculture, such as shrimp aquaculture. Still, seaweed farmers may engage in activities, such as uprooting seagrass to make room for farms, and also place seaweed farms on top of seagrass beds, which could have serious effects on the health of seagrass beds (de la Torre-Castro and Rönnbäck 2004).

Due to the fact that seaweed farms appear to have few negative effects on local habitats, Factor 3.1 receives a score of 9 out of 10 for habitat conversion and function.

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

A description of relevant legislations and regulations governing seaweed aquaculture in some of the principal production countries is presented below.

<u>China</u>
Chinese aquaculture is managed under the Bureau of Fisheries. There are concerns about the effectiveness of regulation and enforcement in China (Chen et al. 2011; FAO China; Jiaxin Chen, personal communication). There are no specific laws for aquaculture site selection, however, there are many other comprehensive laws dealing with fisheries and the environment, such as the Fisheries Law of People's Republic of China (1986, 2000, 2004), the Regulation Law for Sea Area Usage (2001), and many other standards and policies (Chen et al. 2011). Although there is a legal framework present for aquaculture in many cases, enforcement remains to be an issue, particularly due to the large number of rural and small aquaculture operations in China and the government's desire to maintain or grow production in the industry (Chen et al. 2011). Specific regulations for seaweed farming are not apparent.

<u>Japan</u>
Japanese aquaculture is managed by the Fisheries Agency under the Ministry of Agriculture, Forestry, and Fisheries. There are concerns about the effectiveness of regulation and enforcement in Japan (FAO Japan). In 1999 the Law to Ensure Sustainable Aquaculture Production was enacted; however, there is no indication that seaweed farming is addressed through this law (Yokoyama 2003). Fisheries cooperatives in Japan are the only associations allowed to harvest wild seaweed in Japan, which is unlike the USA where harvesting is typically done by industrial firms or contractors. These fisheries cooperatives are also the management and protective bodies for the resource (Wildman, nd; Ifremer 2011).

Korea

In Korea, fisheries and aquaculture are largely regulated by fishing village cooperatives (Ifremer 2011), but this industry has become more individualized and privatized since the decrease in reliance on fishing (Cheong 2010). Now, sites are often leased by village cooperatives to individuals for "unspecified aquaculture" (Cheong 2010). This has resulted in a lack of regulation and enforcement of aquaculture activities from higher levels of government.

USA

The United States does not have specific regulations or legislation pertaining to seaweed farming, except in the state of Connecticut (Charles Yarish, personal communication; State of Connecticut 2013).

While it is recognized that there is a relatively low risk of habitat damage for seaweed farming, it is also apparent that there is some concern and lack of clarity on the regulation and enforcement of seaweed farming in many of the producing countries. As such, Factor 3.2 receives a score of 0.53 out of 10 due to low management/regulatory effectiveness.

The final score for Criterion 3 – Habitat is 6.18 out of 10, and acknowledges the very large scale of production in some areas.

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

Chemical Use parameters	Score	
C4 Chemical Use Score	**10.00**	
C4 Chemical Use Final Score	**10.00**	**GREEN**
Critical?	NO	

Justification of Ranking

There is no evidence that chemicals toxic to aquatic life (e.g., pesticides, antibiotics or disinfectants) are used in seaweed farming, nor any apparent application for their potential use should this lack of evidence and the subsequent assumption be incorrect. The score for this criterion is therefore 10 out of 10.

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

C5 Feed Final Score		**10.00**	**GREEN**
Critical?	NO		

Justification of Ranking

Seaweeds farming does not require feed; therefore, Criterion 5 – Feed scores 10 out of 10.

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		6.00	
C6 Escape Final Score		**4.00**	**YELLOW**
Critical?	NO		

Brief Summary

The escape risk for farmed seaweed is high because non-native species may be cultured, and the system is open with little evidence to show that there are management systems in place to prevent escapes. While it is unlikely that all of the factors would be present to allow establishment of the new seaweed species, it is possible and introduced seaweeds (i.e., *Undaria pinnatifida* in the Mediterranean Sea) have been demonstrably invasive in the past. For these reasons, Criterion 6 – Escapes scored 4 out of 10.

Justification of Ranking

Factor 6.1a. Escape risk

Seaweed introductions are little understood because the mechanism of introduction is often not certain. Most scientific studies to date have been in reaction to the discovery of introductions, rather than to understand or prevent introductions (Schaffelke et al. 2007).

Due to the dispersive nature of seaweed reproduction, seaweed aquaculture systems are considered open systems with no physical separation between the culture area and the wider marine environment. Additionally, management structures to prevent escapes are often not present, or not apparent. Therefore, the high risk of escape inherent in the production system mandates a precautionary management approach. The score for Factor 6.1 is 2 out of 10.

Factor 6.1b. Invasiveness

The "invasiveness" portion of this evaluation examines the potential impact of escapes on the surrounding ecosystem. Invasive species are species that are introduced to an area and have harmful ecological and/or economic effects (Boudouresque and Verlaque 2002). Introduced seaweeds can have negative effects, such as altered competitive relationships in the invaded habitat, changes in biodiversity, effects on fish and invertebrates, toxic effects on other species, and changes to habitat structure (Wikström and Kautsky 2004, Schaffelke and Hewitt 2007).

Seaweeds are sometimes introduced to new areas primarily via aquaculture or shipping. For example, *Laminaria japonica* is a species endemic to Japan but has been cultivated in China since the 1950s (Tseng 2001). There is no evidence of *Laminaria japonica* becoming invasive in China; however, introduced species could colonize the new area and alter the habitat. Introduced invasive seaweed species can change the architecture of the existing habitat and impact other organisms that use that space. For example, mat-forming macroalgae may change water flow and sediment deposition, impacting how invertebrates are able to interact with the substrate (Wallentinus and Nyberg 2007).

Undaria pinnatifida, marketed as wakame, is listed as one of the world's 100 worst invasive species (Lowe et al. 2004). It was introduced to the Mediterranean Sea, specifically the coast of France in the 1970s, most likely via oysters that were imported from Japan. It has since spread to many other areas of Europe and elsewhere (i.e., USA, Mexico, Argentina, Australia and New Zealand) likely through escapes from seaweed farms, introduction through oyster aquaculture and shipping (Naylor 2006). *Undaria pinnatifida* is a tolerant seaweed that is highly invasive and grows quickly. It may overgrow native species, affect native herbivorous species, and present fouling problems on other aquaculture farms (FAO 2014).

Seaweeds have been introduced, including via aquaculture, to non-native areas around the world. The most commonly cultivated seaweeds have been particularly successful as a cultured species and also as an introduced species because of their tolerance to varying environmental conditions. While there are a limited number of publications on the effects of introduced seaweeds, those that have been studied tend to show negative environmental effects (Williams and Smith 2007).

Introduced seaweeds may compete with native species for habitat and may alter habitat to the detriment of other species. There may be other impacts as well, such as potential changes to physical processes in the affected area and altered competitive interactions between species. It is not apparent that introduced seaweeds present additional predation pressures or affect the breeding patterns of other individuals. The final score for Factor 6.1b is 6 out of 10.

Factors 6.1a and 6.1b combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

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	8.00	
C7 Disease; pathogen and parasite Final Score	**8.00**	**GREEN**
Critical?	**NO**	

Brief Summary

Although diseases have been known to affect seaweed farms, most can be avoided or treated by simply controlling environmental conditions (i.e., depth, temperature, etc.). There is little evidence of diseases spreading to or affecting natural seaweed populations. For these reasons, the criterion score for disease, pathogen and parasite interactions is 8 out of 10.

Justification of Ranking

Diseases have been known to affect seaweed farms. The diseases can be infectious or non-infectious, caused by pathogens (bacteria, fungi, etc.) or by physical factors (i.e., temperature, salinity, light intensity, etc.). Most diseases in macroalgae are not threatening to natural populations (Largo 2002), however, there are some examples of pathogenic diseases that have affected natural algae populations (i.e., coralline lethal orange disease in coralline algae). Therefore, it is possible for pathogenic diseases to affect both cultivated and natural populations and potentially pass between the two populations (Largo 2002).

Porphyra spp. (nori) farms can be affected by approximately 10 different diseases caused by bacteria, viruses or fungi. Most of these diseases can be managed by adjusting the depth of culture nets so that the seaweed can survive but the pathogen cannot (FAO 2005, The Seaweed Site 2014). *Laminaria* spp. farms may be affected sporadically by some pathogenic diseases, however, there are no serious concerns or disastrous events that have been noted (FAO 2004).

Likely, the most common "disease" for seaweed farms would be epiphytic growth on the species being grown for harvesting (John Forster, personal communication; Vairappan et al. 2009). Epiphytes are other algae or animal species that grow on the seaweed. Again, epiphytic growth can often be prevented by controlling growing and farm conditions (Vairappan et al. 2009).

As there is little evidence for a risk to natural populations from diseases on seaweed farms, Criterion 7 – Disease receives a score of 8 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, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	100	
C8 Source of stock Final Score	**10.00**	**GREEN**

Brief Summary

Seed stock for seaweed farms almost always comes from on-land "hatcheries." If seed is sourced from natural populations, passive settlement techniques are used and there is no impact on the wild population. For these reasons, the score for the source of stock criterion is 10 out of 10.

Justification of Ranking

Source of seed for seaweed farming typically comes from on-land seed "hatcheries." Broodstock may be selected from wild populations or breeding programs, but most often from breeding programs (FAO 2004, FAO 2005). In general, farming of non-clonal (cannot reproduce from fragmentation) species requires more steps in the production cycle than for clonal species (Santelices 2001). Most seaweeds discussed under this report are non-clonal. Figure 6 below illustrates the production cycle of *Porphyra* (nori) and the extensive, indoor hatchery phase where all seed stock comes from breeding programs.

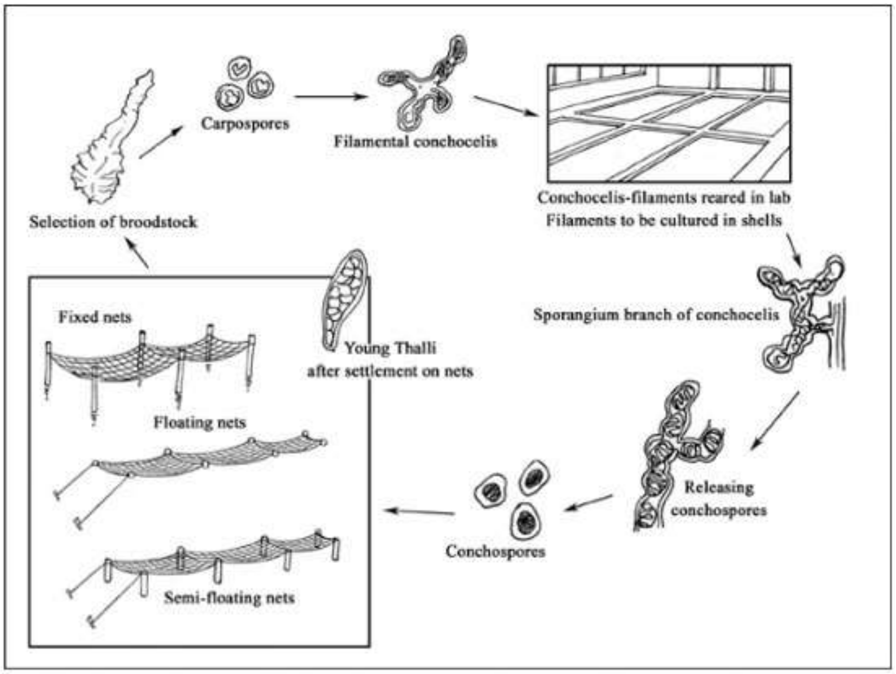

Figure 7. *Porphrya* production cycle (retrieved from www.fao.org)

The final score for Criterion 8 – Source of Stock is 10 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	
9X Wildlife and predator mortality Final Score	**0.00**	**GREEN**
Critical?	NO	

Brief Summary

There are no concerns related to wildlife and predator mortality for seaweed farming. Therefore, the score for wildlife and predator mortality is (a deduction of) zero.

However, it should be noted that a concern has been raised in the past about marine mammal entanglement related to offshore aquaculture (Troell et al. 2009; John Forster, personal communication). Therefore, if seaweed aquaculture systems were to move into the offshore area in the future, there is a possibility for wildlife and predator mortality.

Justification of Ranking

No evidence was found to suggest that seaweed farming causes wildlife or predator mortality. Therefore, this criterion receives a deduction score of zero out of -10.

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. A score of zero means there is no impact.

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
10Xa International or trans-waterbody live animal shipments (%)	10.00	
10Xb Biosecurity of source/destination	10.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

There are no concerns related to the escape of unintentionally introduced species for seaweed farming. Therefore, the score for this criterion is 0.

Justification of Ranking

Criterion 10Xa International or trans-waterbody live animal shipments

No animal shipments occur for seaweed farming.

Criterion 10Xb Biosecurity of source/destination

The biosecurity of the source/destination is irrelevant because there are no animal shipments for seaweed farming.

For the above reasons, the score for unintentionally introduced species is 0.

Overall Recommendation

The overall recommendation is as follows:

The overall final score is the average of the individual criterion scores (after the two exceptional scores have been deducted from the total). The overall ranking is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

– **Best Choice** = Final score ≥6.6 AND no individual criteria are Red (i.e., <3.3).
– **Good Alternative** = Final score ≥3.3 AND <6.6, OR Final score ≥ 6.6 and there is one individual "Red" criterion.
– **Red** = Final score <3.3, OR there is more than one individual Red criterion, OR there is one or more Critical score.

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.25	YELLOW	
C2 Effluent	9.00	GREEN	NO
C3 Habitat	6.18	YELLOW	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8 Source	10.00	GREEN	
9X Wildlife mortalities	0.00	GREEN	NO
10X Introduced species escape	0.00	GREEN	
Total	**63.43**		
Final score	**7.93**		

OVERALL RANKING

Final Score	7.93
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

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About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States 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. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides 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 conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out 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 regularly 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.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. 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.

Disclaimer
Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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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.
- 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

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

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.

Appendix 1 - 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*	2.5	2.5
Effluent	Yes	5	5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	No	10	n/a
Escapes, animal movements	Yes	5	5
Disease	Yes	7.5	7.5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**50**

C1 Data Final Score	6.25	YELLOW

Criterion 2: Effluents

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

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?	Moderately	0.5
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?	Moderately	0.5
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
		2.5

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?	Moderately	0.5
5 - Is there evidence of robust penalties for infringements?	Moderately	0.5
		2.5

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

C2 Effluent Final Score	**9.00**	**GREEN**
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**9**

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

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?	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)	Partly	0.25
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	No	0
		0.75

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?	Yes	1
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
		1.75

F3.2 Score (2.2a*2.2b/2.5)	**0.53**

C3 Habitat Final Score	**6.18**	**YELLOW**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**10.00**	
C4 Chemical Use Final Score	**10.00**	**GREEN**
Critical?	NO	

Criterion 5: Feed

C5 Feed Final Score	**10.00**	**GREEN**
	Critical?	**NO**

Criterion 6: Escapes

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**

6.1b. Invasiveness

Part A – Native species

Score	0

Part B – Non-Native species

Score	**2.5**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	To some extent
Do escapees have some other impact on other native species or habitats?	To some extent
	3.5

F 6.1b Score	**6.0**

Final C6 Score	**4.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	8.00	
C7 Disease; pathogen and parasite Final Score	**8.00**	**GREEN**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	100	
C8 Source of stock Final Score	**10**	**GREEN**

Exceptional Factor 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and Predator Final Score	**0.00**	**GREEN**
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 (%)	10.00	
F6.2Xb Biosecurity of source/destination	0.00	
F6.2X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**