Farmed Scallops

Argopecten spp., Chlamys spp., Patinopecten spp, Placopecten spp.

Worldwide

Hatchery, Nursery and Grow-out (Subtidal Coastal Areas)

September 4, 2013
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Final Seafood Recommendation

Farmed Scallop
Argopecten spp., *Chlamys* spp., *Patinopecten* spp., *Placopecten* spp.
Cultured worldwide via hatchery, nursery, and grow-out production systems

Criterion	Score (0-10)	Rank	Critical?
C1 Data	7.5	GREEN	
C2 Effluent	9.00	GREEN	NO
C3 Habitat	8.40	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	8.00	GREEN	NO
C8 Source	10.00	GREEN	
3.3X Wildlife mortalities	-2.00	GREEN	NO
6.2X Introduced species escape	0.00	GREEN	
Total	70.9		
Final score	8.86		

OVERALL RANKING

Final Score	8.86
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
Final Rank	BEST CHOICE

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

Farmed scallops cultured around the world have a final numerical score of 8.86 out of 10 and with no red criteria the final ranking is “Best Choice”.

Executive Summary

There are abundant research publications, grey literature, and shellfish growers association documents regarding the biology, production, and potential environmental impacts of farmed bivalve molluscs, with some sources focusing specifically on scallops (especially for those cultured in the United States). A fewer number of publications are available for those scallop species cultured in Asia. The most recent reliable information regarding production statistics is available in reports or databases produced by international organizations such as the FAO. Data quality and availability regarding farmed scallops are considered moderate to high.

Farmed scallops are not provided external feed or nutrient fertilization. Scallop farming may result in the localized deposition of feces and pseudofeces and the resultant waste impacts. Therefore, there is low to no concern regarding resultant effluent.

Farmed scallop spat collection is generally located in areas where densities of wild scallop populations are high. Criteria may include, but are not limited to, spat levels, water temperature, salinity, food availability, water quality, and tidal flow; ideal conditions have been identified as having water depths of about 20 -30 m and 4 m visibility (Hardy 2006, Lin et al. 2007). Grow-out operations are primarily located in coastal, inshore, subtidal environments which are generally considered to be of moderate habitat value. The impact of farmed scallop operations on habitat is considered to be minimal, with the main concerns stemming from biodeposition and mechanical harvest, such as dredging.

Aquaculture operations can attract a variety of predators and result in direct or indirect mortality from trapping, entanglement, drowning, and other elements. Predator exclusion devices used on scallop farms are usually in the form of netting or fences, both forms of passive, non-harmful barriers, which result in no direct or accidental mortality of predators or other wildlife; however, mechanical harvest by dredge of farmed scallops has the potential to impact scallop predators or other wildlife attracted to scallop farms. This impact is mitigated by best management practices and preventative measures and would not result in a population-level effects.

Little to no chemicals are used in the culture of scallops. Best management practices and environmental codes of practice for shellfish farming designate manual labor to prevent and remove predators and fouling from gear. Improved husbandry and cleaning methods rather than use of antibiotics are employed to prevent bacterial infections. No chemicals are used during the grow-out phase of scallop culture. Cleaning solutions (i.e., bleach) used during the hatchery phase are not discharged to the marine environment.

The majority of farmed scallops are cultured within their native ranges. The escape score results from the combination of the escape risk (6.1) and the invasiveness (6.1b) scores. The risk of escape is considered to be low because scallops are only capable of swimming short distances, and cultured within their native ranges with best management practices. The invasiveness score is high as farmed scallops are wild-caught or one generation hatchery-raised with little evidence to support negative effects of escaped scallops on ecosystems or wild populations.

Diseases in farmed scallops have the potential to occur at every stage of production, from the hatchery to grow-out; however, relatively few diseases have been reported in scallops. The fact that farmed scallop grow-out systems are open to the natural environment and there is the possibility of pathogen exchange would normally result in a moderate to high risk of parasite or pathogen infection; however, the low or infrequent occurrence of scallop diseases, coupled with biosecurity measures that have been put in place at the farm, government and international levels, reduces the risk of parasite and pathogen infection to a low level.

The majority of the source of stock for farmed scallops comes from natural or passive settlement. Due to the lack of data on source stocks, the percentage of production from hatchery-raised broodstock or natural (passive) settlement is difficult to quantify; however, the removal of wild scallops for broodstock is not expected to have any negative impacts on the wild stock, and is beneficial in reducing the ecological risks associated with domestication selection across generations. Due to the lack of information available to quantify this score, the source of stock criterion score was based on the available data that show natural (passive) settlement, or that use of wild stock for broodstock is beneficial to the environment.
Overall, farmed scallops available on the U.S. market get a high overall numerical score of 8.81 out of 10. The analysis of farmed scallops has all “green” rankings and the overall ranking is “green”. Therefore, the final recommendation is “**Best Choice**”.

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Introduction

Scope of the analysis and ensuing recommendation
Species: Farmed scallops available on the U.S. market, including *Argopecten* spp., *Chlamys* spp., *Patinopecten* spp., and *Placopecten.*
Geographic coverage: Worldwide (namely China, Canada, United States, Brazil, Ecuador, Norway)
Production Methods: Spat collection and sowing culture; hatchery, nursery and grow-out.

Production statistics
Aquaculture is the fastest growing sector of food production and provides half of the seafood products consumed worldwide (Shumway 2011). Global capture fisheries cannot meet current demand for the scallop due to overfishing and increased market demand; therefore scallop farming has become an increasingly important global aquaculture activity (FAO 1990, Figures 1 - 3). Scallops currently account for the second greatest proportion of molluscan global aquaculture production.

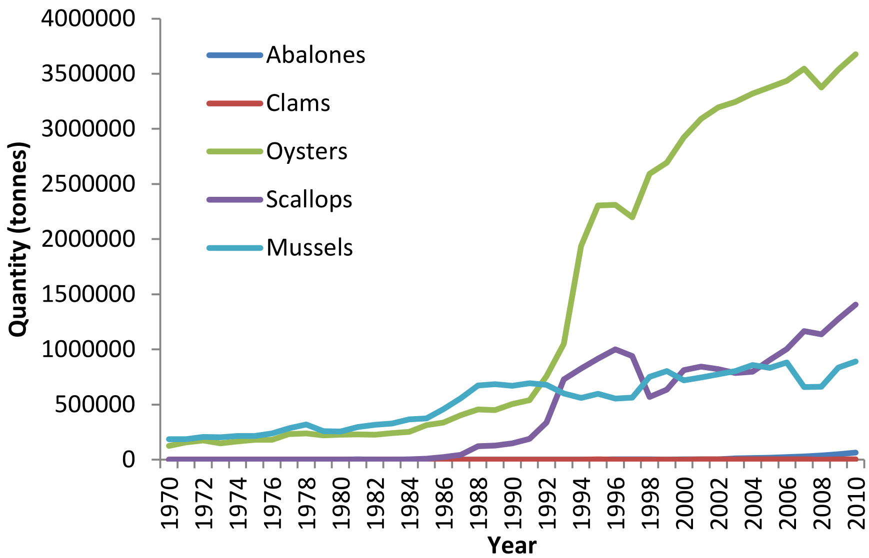

Figure 1. The quantity of global mollusc production (FAO 2013).

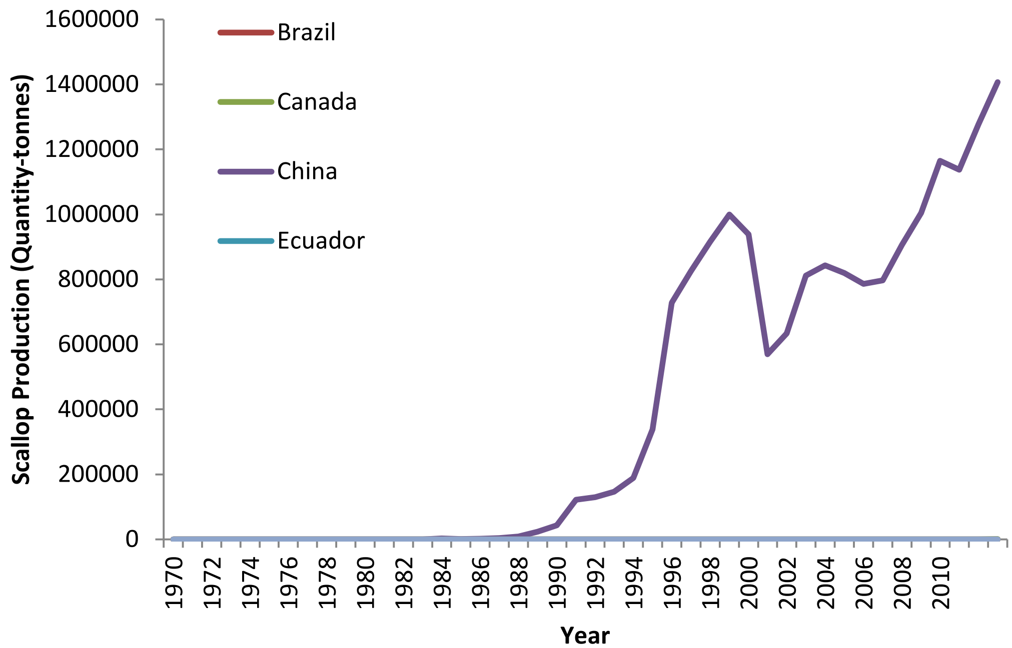

Figure 2. The quantity of global scallop production in tonnes (FAO 2013).

This trend reflects the overwhelming contribution of China to global scallop production. The information presented in Figure 2 is collected by the United Nations Food and Agriculture Organization (FAO) from the reporting country and may not reflect actual production. In addition, reports from China regarding aquaculture may be exaggerated (Haw 2013). Figure 3 depicts the contribution of the other countries that currently culture scallops.

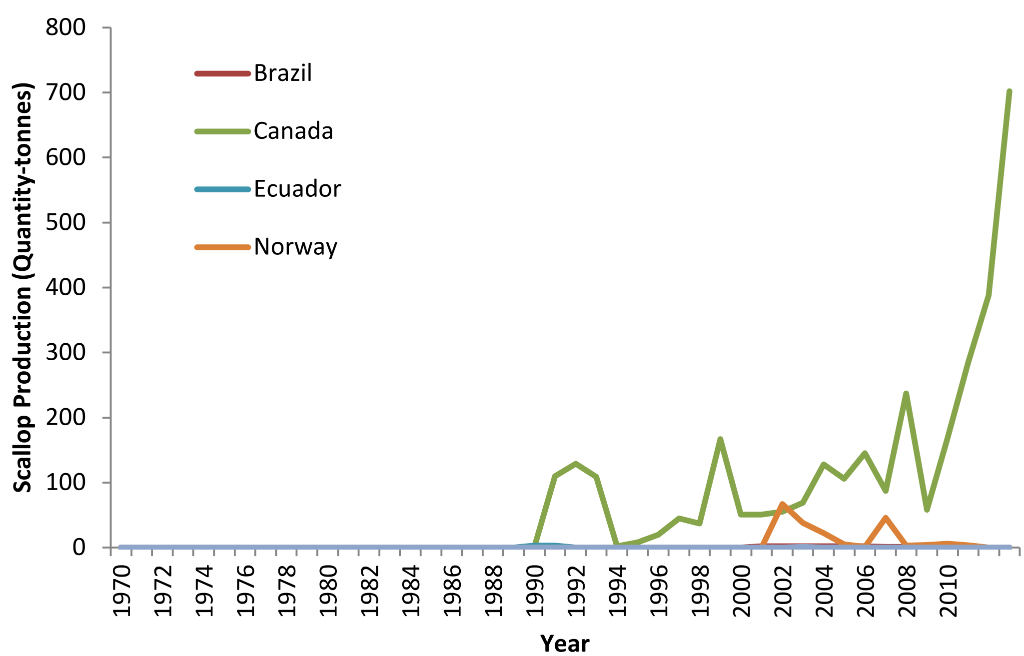

Figure 3. The contribution of global scallop production by country excluding China (FAO 2013).

Scallop farming continues to play an increasing role in the U.S. market, with both increased quantity of imports and exports (Figure 4).

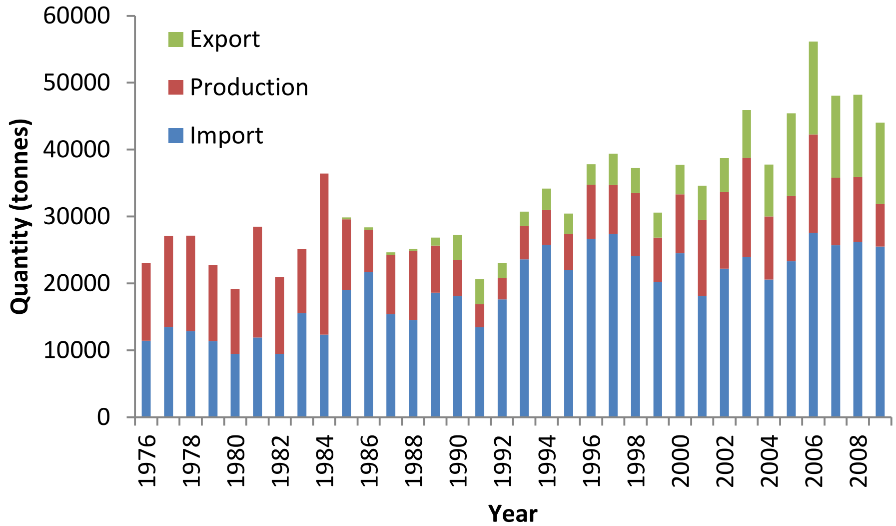

Figure 4. Production and trade of scallops in the United States (FAO 2013).

Product forms

There are relatively few species of scallops currently being produced in culture. Most of the scallop production in China in the late 1990s was from two major species: the native zhikong scallop (*Chlamys farreri*) and the introduced bay scallop (*Argopecten irradians*). The Japanese scallop (*Patinopecten yessoensis*) is also cultured but with less yield (Guo 1999). Scallops are available on the U.S. market in multiple forms, including live or shucked, fresh or chilled, frozen, and prepared or preserved (Figure 4).

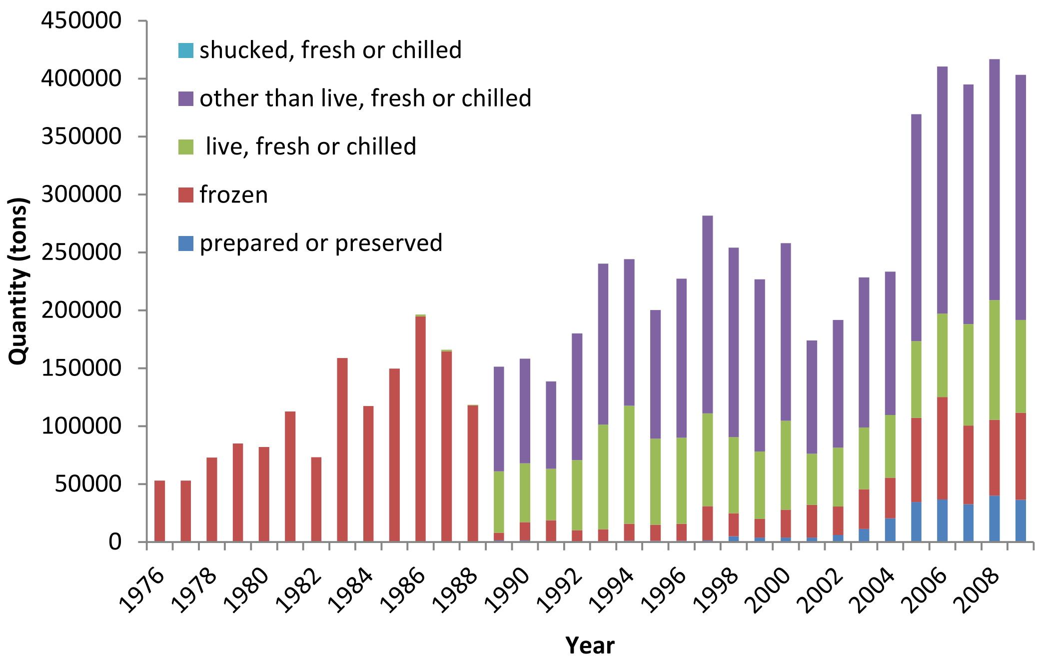

Figure 5. Quantity of product forms of cultured scallops available on the U.S. market.

Common Market Names

Farmed scallops are available on the U.S. market as "scallops", but are commonly referred to as *hotate* or *hotategai* when referencing sushi. Species include:

Argopecten irradians – bay scallop
Argopecten purpurratus – Peruvian scallop
Chlamys farreri. – zhikong scallop
Patinopecten yessoensis – Japanese (Yesso) scallops
Pecten maximus – synonymous with *Pecten vulgaris* and *Chlamys maximus*
Placopecten magellanicus – sea scallop

Other species that fall within the same genera are also cultured in many different countries, but production quantity and market value is relatively low and not commonly reported to the FAO of the United Nations.

Species

Argopecten irradians. The bay scallop, *A. irradians*, is geographically distributed along the Atlantic and Gulf coasts of the United States. The species was introduced for culture in China during the early 1980s and has since become one of the dominant species of scallops cultivated in that country (FAO 2013).

Chlamys farreri. The Zhikong scallop is native to north China, Korea and Japan. Zhikong scallop culture was first developed in these countries sometime between 1973 and 1983 (Guo 1999).

Patinopecten yessoensis. The majority of the production of *P. yessoensis* comes from China and Japan, with the Republic of Korea and the Russian Federation contributing as minor producers. There is also a relatively small production source originating from the Pacific coast of Canada. For the past decade, the total value of annual global production of *P. yessoensis* has exceeded 1.5 billion U.S. dollars (FAO 2006-2013).

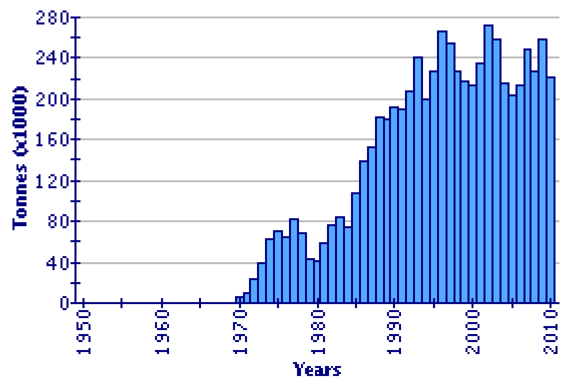

Figure 6. Global aquaculture production of the Yesso scallop (FAO 2006-2013).

Pecten maximus/ Chlamys maximus. *Pecten maximus* is native to the eastern Atlantic ocean, from Norway to Spain, as well as the Azores and the Canaries. The species is considered a delicacy and has been fished in large numbers (FAO 2013).

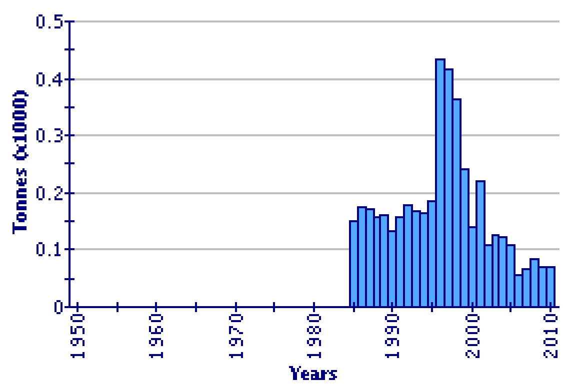

Figure 7. Global aquaculture production of *P. maximus* (FAO 2013).

Placopecten magellanicus. Suspended, on-bottom, and polyculture of sea scallops has been investigated in regions of Canada and New England (Kleinman et al. 1996, Pilditch et al. 2001, Parsons et al. 2002) and has proven successful at fairly small scales.

Production Systems

Spat Collection

Scallop culture has been significantly enhanced since the 1950s due to success in natural spat collection. There are a variety of ways in which spat can be collected, including a series of mesh bags suspended in the water column on a line which is anchored to the seafloor (i.e., long-lining). Mesh bags are filled with a suitable cultch onto which scallop larvae will settle. Larvae undergo metamorphosis into post-larvae spat and can be collected and transferred to a farm site for on-growing. An intermediate culture stage may be employed to allow the development of a harder shell to prevent high mortality of scallop spat associated with early transfer. After this phase, a wide range of techniques are used for grow-out (FAO 1988).

Sowing Culture

In sowing culture, young scallops are released from a moving vessel and spread over a pre-selected area, chosen for its suitable habitat conditions. Growth and successful yield are dependent upon stocking density; overstocking results in reduced growth (FAO 1988).

Hatchery

In countries where natural spatfall is poor, or in the case of introduced scallops, artificial propagation of spat occurs in shellfish hatcheries. Spat are collected from culture vessels (i.e., tanks) onto ropes or nylon nets and screens.

Nursery

The nursery phase interfaces between hatchery production and the grow-out phases, and may occur in land-based or in-water seawater systems. Nursery methods vary according to country and environmental conditions. In China, scallop spat collectors (ropes or nets) are transferred to shrimp ponds or nursery areas that consist of scallop spat collectors suspended in the water column (Guo et al. 1999).

Grow-out

Two methods are recognized for the grow-out phase of scallops: hanging and bottom culture. Hanging culture relies on either a raft or longline system that floats on the sea surface from which the cultured scallops are suspended. Scallops are suspended in pearl, lantern, or pocket nets; hog rigging; ear hanging; rope culture; or plastic trays. In China, lantern nets suspended on longlines is the main form of culture for all scallops (Guo et al. 1999). Bottom culture employs the use of scallop-filled plastic trays or wild ranching. Seed scallop are planted in plots in the intertidal or shallow subtidal zones. Predator-exclusion devices (i.e., fencing) may be used)

Analysis

Scoring guide

- With the exception of the exceptional factors (3.3x and 6.2X), 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 on our website at www.seafoodwatch.org.
- 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.

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	10	10
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	5	5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**60**

C1 Data Final Score	**7.50**	**GREEN**

Justification of Ranking

There are few data shortages regarding scallop farming and relevant important issues related to production systems, management practices and their associated potential environmental impacts. Information on feed is not relevant as scallops feed on phytoplankton and other particulate matter available in the natural environment. There is sufficient information on effluent management, escapes, potential impacts on predator and wildlife mortalities, and disease to make relevant assessments. There is a general lack of detailed information regarding the genetics of farmed scallops (Hedgecock 2011), which makes it difficult to assess the impact of stock sources of farmed scallops on wild stock. The available U.S. data for farm level records, independent monitoring data, and industry data enable informed decision-making and environmental assessments. There is a lack of updated data on the management, regulation, and enforcement of scallop production in Asia; however, the most current available data suggest the appropriate framework exists to enable informed environmental decisions and planning. Overall, data quality and availability are considered moderate to high. The final score for data is 7.5 (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 Synthesis

Effluent Rapid Assessment

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

Farmed scallops are not provided external feed or nutrient fertilization, therefore there is low to no concern regarding resultant effluent or waste impacts (Score = 9).

Rapid assessment – used when good quality data clearly defines an appropriate score

Key relevant information:
During all stages of production, scallops feed exclusively on materials in natural seawater. If the hatchery phase is employed, scallop larvae and early spat either feed on the materials in natural seawater, or they are fed algae in closed culture vessels (FAO 1988).

There has been little discussion regarding effluents from shellfish hatcheries, largely due to the fact that no drugs, pesticides, or herbicides are added to the seawater that flows through and around the shellfish. Shellfish sequester bacteria and phytoplankton from the surrounding water, and essentially cause the hatchery effluent to be cleaner than the water that entered. For this reason, several states within the U.S. do not require discharge permits. Additionally, the National Pollutant Discharge Elimination System has an exemption for hatcheries that produce less than a specified number of pounds of animals. Land-based nurseries pump ambient seawater to the facility and may require a discharge permit solely for this reason (Creswell and McNevin 2008, Flimlin et al. 2010).

Waste discharged hatcheries, land-based nurseries and grow-out areas include feces and pseudofeces. Where the accumulation of biodeposits usually results in increased nitrogen and reduced oxygen concentrations, the general belief is that if the carrying capacity is not exceeded, the benefits of scallop culture far outweigh the minimal costs (SAGB 2008).

Because scallops are extractive and not supplied external feed or nutrient fertilization, the only concern over effluent is the discharge of feces and pseudofeces. Therefore, the effluent score 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.

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		9.00	
F3.2a Content of habitat regulations	4.00		
F3.2b Enforcement of habitat regulations	4.50		
F3.2 Regulatory or management effectiveness score		7.20	
C3 Habitat Final Score		**8.40**	**GREEN**
Critical?	NO		

Justification of Ranking

Factor 3.1. Habitat conversion and function

Habitat conversion is measured by the effect of aquaculture on ecosystem services. Scallop farming, and shellfish farming as a whole, provide valuable ecosystem goods and services, with few negative impacts (Ivin et al. 2006, as reviewed in Coen et al. 2011, Ferreira et al. 2011). The potential negative effects of scallop mariculture on coastal, semi-enclosed bays include:

- a reduction in phytoplankton and organic detritus (i.e., nutrients) due to filter feeding activity of scallops, which in turn reduces the trophic potential of the bays in which the scallop farms are located;
- alteration of the biochemical composition of the adjacent waters due to the production and break-down of feces and pseudofeces;
- increased sedimentation from biodeposition;
- alteration of the structure and dynamics of phtyo- and zooplankton, as well as benthic communities; and
- fouling of structures used in scallop mariculture.

Following the cessation of scallop mariculture, ecosystems typically recovered from the impacts described above in five to ten years.

<u>Pelagic effects</u>

Scallop farms remove phytoplankton and organic detritus from the water column through filtration. Besides reducing the amount of these materials available to other organisms, thus stimulating trophic cascades, scallop farms may provide a key ecosystem service by reducing primary causes of eutrophication (Burkholder and Shumway 2011). Reduction of the causative agents of eutrophication decreases the cycling time of suspended organic matter by removing the opportunity for bacterial remineralization, and therefore the onset of hypoxia and anoxia. Potential recognized benefits include an increase in the amount of underwater light, extension of the euphotic zone and the recovery of submerged aquatic vegetation and macroalgae. Submerged aquatic vegetation provides further ecosystem services, such as a refuge and nursery for juvenile fish, as well as increased sediment stability (Yamamuro et al. 2006).

<u>Benthic effects</u>

Biodeposition of fecal matter from suspended scallop culture is also a habitat concern; however, it is widely recognized that effects of scallop culture are insignificant relative to other forms of culture because artificial feeds are not used (Giles et al. 2009, Weise et al. 2009, Ferreira et al. 2011). Few effects are reported for bottom culture. Potential effects include the accumulation of shells resulting from mortality and the establishment of a living assemblage; both of which provide hard substrate necessary for attachment of epifaunal species that otherwise might not be present in areas of soft sediment (Coen et al. 2011). Thus, on bottom culture may increase species richness and diversity.

<u>Harvest</u>

Bottom-cultured scallops are harvested either by hand (SCUBA divers) or dredge (Mercaldo-Allen and Goldberg 2011, Stokesbury et al. 2011, FAO 2006-2013). Scallops cultured in suspension are harvested by different means. For example, the harvest of *P. yessoensis* from suspension culture employs the use of vessels outfitted with winches to lift longlines and associated nets (FAO 2006-2013). Hand harvest techniques and those associated with suspended scallop culture are believed to have no significant impacts on habitat.

Dredge harvest techniques for wild scallops often involve steel-framed structures with or without a cutting bar on the leading edge that drags above the surface of the substrate, and collects scallops in an attached steel-ring bag (DeAlteris et al. 2000). Dredge size, towing speed, and length of tow vary with water depth and scallop density (Stevenson et al. 2004), and dredge efficiency varies with sediment type (Currie and Parry 1999). Small, light, mechanical dredges designed to remove adult scallops from areas with submerged aquatic vegetation have been used to harvest bay scallops in shallow waters along the east coast of the United States (MacKenzie 2008). The impacts of dredges on seafloor habitat have been compared to “forest clear-cutting”. Dredging has been shown to directly reduce habitat complexity and species diversity, cause shifts in community structure, cause loss of vertical structure, and reduce productivity or biomass (as reviewed by Collie et al. 1997, Dorsey and Pederson 1998, Levy 1998, Auster and Langton 1999, Baulch 1999, Mercaldo-Allen and Goldberg 2011). Dredging can also increase or decrease nutrient cycling, cause hypoxia, increase exposure of organisms to predation, and increase turbidity (Stokesbury et al. 2011).

There is a difference between dredging for wild scallops and dredging for farmed scallops. For instance, New Bedford style dredges are commonly used to harvest sea scallops in the offshore waters of Georges Bank and the Mid-Atlantic. These dredges are large (approximately 4.3m in width), heavy (1 MT), and sometimes fished in pairs (Stevenson et al. 2004, as reviewed in Mercaldo-Allen and Goldberg 2011). Additionally, wild harvest fishermen often sample immense areas because they do not know the exact location and expanse of scallop density. This practice can result in high mortality of non-target organisms. In contrast, scallop farmers know exactly where and when to dredge because they are responsible for seeding the area. Thus, tows for farmed scallops are generally much shorter, resulting in less mortality of non-target organisms. Additionally, most shellfish farming takes place in shallow coastal areas which can recover from major disturbances within short timeframes (Coen 1995). Species in these areas tend to be opportunists that tolerate highly turbid conditions and are capable of rapidly recolonizing disturbed seafloor habitats (Stokesbury et al. 2011). An important issue to consider is that while dredging has been shown to flatten vertical structure and habitat provided by emergent epifauna such as sponges and corals, shellfish lease sites are generally devoid of such species. There also is evidence that the space created by harvesting adult shellfish provides space for new recruits. Furthermore, shellfish farmers often reseed their crops on an annual basis, which can restore vertical structure to the seafloor, enhances habitat for many additional species, and promotes resource sustainability (Mercaldo-Allen and Goldberg 2011, Stokesbury et al. 2011).

Habitats in which scallops are farmed may be improved through filtration and maintain full functionality if harvested by hand. Habitats in which scallops are farmed and then harvested by dredge are subject to increased turbidity, changes to sediment, and reduction in species diversity and biomass; however, these areas have been shown to recover quickly from all impacts. Therefore, effects to habitat function and services from scallop culture are expected to be minimal and the score for this factor is 9 (out of 10).

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

China and Japan account for the majority of global scallop culture; and the majority of cultured scallops imported to the United States. Scallops are consumed in many forms (Figure 5), but are not imported live. Each country regulates aquaculture and enforces aquaculture policies differently, but often with the same goal. In the U.S., the U.S. Army Corps of Engineers issues aquaculture permits before a farm can be established, which often require consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service, as well as individual states to ensure consistency with Coastal Zone Management Programs. Additionally, environmental best management practices (BMP) are also employed to reduce, minimize, or mitigate the effects of farming practices on aquatic (or terrestrial) resources and interactions with other users of marine resources (Dewey et al. 2011, Getchis and Rose 2011).

In Canada, provinces are responsible for aquaculture planning, site leasing, licenses and site approvals, aquaculture training and education, collection of statistics, and the management of the industry’s day to day operations. British Columbia (B.C.) is the province with the largest share of aquaculture industries in Canada, and the primary applicable laws and regulations are the Fisheries Act (1996) and the Fisheries Act Regulations (1976), the Aquaculture Regulation

(2002) and the Environmental Management Act (SCBC 2003 C.53). Aquaculture in B.C. is overseen by three provincial government agencies: the Ministry of Agriculture and Lands, the Ministry of Environment, and the Integrated Land Management Bureau. Under the Service Agreement on Compliance and Enforcement Programs Finfish and Shellfish Aquaculture in 2002, the Ministry of Agriculture and Lands is designated as the lead agency for compliance, including receiving, adjudicating and issuing commercial aquaculture and seafood licenses and permits (FAO 2012). Additionally, the B.C. Shellfish Growers Association employs the Environmental Management System Code of Practice that fosters commitment to working with growers to protect marine resources (British Columbia Shellfish Growers Association 2001; Dewey et al. 2011).

In China, the use of the aquatic and terrestrial environment is regulated by different laws including the Fisheries Law (2004), the Regulation Law for Sea Area Usage (2001), and the Environmental Impact Assessment Law (2002), but site selection for aquaculture has no specific legislation (Chen et al. 2011). Use of state owned land and water areas is required to meet the local zoning scheme set by the Land Administration Law, including conservation areas, industry, and aquaculture (Chen et al. 2011, FAO 2012). Most farms are family operated and shellfish leases are managed by local communities (personal communication with X. Guo, November 29, 2012). Environmental Impact Assessment (EIA) is required in accordance with different environmental laws, and while there is no specific referral to aquaculture, EIAs are required for construction projects that include large-scale aquaculture. Additionally, the Environmental Impact Assessment Law (2002) expands EIA requirements from individual construction projects to government planning for the development of agriculture, aquaculture, animal husbandry, forestry, water conservation and natural resources (FAO 2012). Water quality is monitored on lease grounds to ensure that it is suitable for aquaculture; however, monitoring may not be strictly enforced (personal communication with X. Guo, November 29, 2012). Overall, enforcement of aquaculture regulations is often weak as aquaculture is favored by the government as an important economic activity (Chen et al. 2011).

Regulation and management of farm siting and licensing across all locations resulted in an overall habitat and farm siting management effectiveness score of 7.2 out of 10.

Conclusions

The impact of farmed scallop operations on habitat is considered to be minimal, with the main concerns stemming from biodeposition and harvest. Lack of impact, coupled with reasonable regulation and enforcement regarding licensing and site selection result in an overall high score (8.41).

Factor 3.3X: Wildlife and predator mortalities

This factor is 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” factor 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.

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and predator mortality Final Score	**-2.00**	**GREEN**
Critical?	NO	

F3.3X Wildlife and predator score

Predator control methods

A variety of shellfish predators exist on scallop farms, including echinoderms, gastropods, crustaceans, fishes, and seabirds. Control methods may include benign forms of prevention, including sowing at times when predation is least likely to occur, hand removal, and relocation of predators. Netting and other predator exclusion devices (i.e., fences) also may be used to protect scallops, especially during juvenile stages. In all cases, the lowest impact control methods are generally used first, and higher impact methods are employed only as needed (Flimlin and Beal 1993).

Harvest

Scallop harvest by dredging can result in an immediate and initial decline in abundance and biomass for all species (i.e., predators, target species and other benthic organisms) that occur on and in scallop farms, but the decline is often followed by rapid benthic recovery (Mercaldo-Allen and Goldberg 2011). While dredging may initially damage or reduce certain organisms, scavengers and opportunistic predators may also benefit from the effects of dredging by feeding on exposed prey or by colonizing newly exposed seafloor. For example, predatory fish and crustaceans increase in density in the vicinity of clam dredges (as reviewed by Mercaldo-Allen and Goldberg 2011).

The use of passive non-harmful barriers yields no evidence of direct or accidental mortality of predators or wildlife. In contrast, dredge harvest techniques result in mortality of wildlife beyond exceptional cases, but due to rapid recovery and some potential benefit to predators, there is no significant impact to the affected species' population size. Furthermore, dredging is conducted using best management practices. Therefore, clam farming has a low impact on predators or other wildlife and results in a score of -2.

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

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

Justification

Key relevant information:

The purpose of chemical treatment in scallop farming would be to prevent predators, fouling, and infection by disease-causing bacteria. The use of chemical substances (i.e. copper sulfate, calcium oxide, sand coated with trichloroethylene, and insecticides) to control predators of molluscs was pioneered in the 1930s in the U.S. (Loosanoff 1960, Jory et al. 1984, Shumway et al. 1988). While such chemicals proved effective, the concern for potential environmental and public health risks of copper sulfate, trichloroethylene, and insecticides were perceived to outweigh the benefits and the chemicals are no longer used to control predators at scallop farms. Furthermore, a review of predator controls in bivalve culture conducted by Jory et al. (1984) revealed that the installation of exclusionary devices (i.e. netting) was more successful than chemical treatment for control of bivalve predators. Some shellfish growers associations have even adopted best management practices in which predator control is addressed by exclusionary devices and frequent inspection of sites followed by hand-removal of predators (Creswell and McNevin 2008, Flimlin et al. 2010).

Fouling is a significant problem in suspended and bottom scallop culture that uses netting to exclude predators. Netting is prone to fouling and subsequent clogging that restricts water flow through the nets. Constant cleaning is required to remove fouling organisms. There have been many attempts to prevent fouling in bivalve culture through the use of chemicals such as Victoria Blue B, copper sulfate, quicklime, saturated salt solutions, chlorinated hydrocarbon insecticides, and other pesticides (Loosanoff 1960, MacKenzie 1979, Shumway et al. 1988; Brooks 1993); however, chemicals to control fouling may release potentially toxic constituents into the marine environment which pose a threat not only to the species being cultured, but to other non-target organisms. Even antifoulants commonly used in finfish culture are not applied to shellfish gear, because the antifoulants approved for finfish culture have not been approved for shellfish culture. Additionally, the antifoulants currently available do not adhere to the plastics from which shellfish gear is made (Bishop 2004). Experiments are being conducted in which antifoulant coatings are applied to netting, but they are inconclusive to date and the East Coast Shellfish Growers Association Best Management Practices (Flimlin et al. 2010) caution the use of chemicals to control fouling. Air drying, brine or freshwater dips, power washing, and manual control are not only more successful but also environmentally friendly antifouling methods (Creswell and McNevin 2008, Watson et al. 2009). Additionally, chemical antifoulants are not used in the hatchery because larval tolerance to such chemicals is typically low (Castagna and Manzi 1989).

Antibiotics typically are not used in the grow-out phase of scallop farming (British Columbia Shellfish Growers Association 2012). Bacteria that may cause disease in the larval phase often originates in algal cultures or from incoming water and pipes or other hatchery equipment and can be controlled with antibiotics (Ford et al. 2001); however, hatchery operators are concerned about the development of antibiotic resistance and do not employ the use of antibiotics. Instead, operators rely on improved animal husbandry and regular cleaning of hatchery equipment (Ford et al. 2001, Creswell and McNevin 2008, Flimlin et al. 2010). Dilute hypochlorite (bleach) solutions often are used for disinfection of equipment, but they are disposed of in the municipal sewer system instead of the marine environment (Creswell and McNevin 2008, Flimlin et al. 2010). Furthermore, the use of antibiotics or therapeutics in U.S. aquaculture is overseen by the U.S. Food and Drug Administration (FDA) and regulations are quite stringent regarding use of unapproved chemicals. The U.S. Environmental Protection Agency (EPA) also regulates the use of non-pharmaceutical chemicals used in shellfish culture; laws are strict and shellfish producers typically do not use unapproved chemicals.

The amount of chemicals used in scallop hatcheries would be minute, if at all. Further, the water in which chemicals would be used generally is not released to the marine environment. Thus, there is no threat of chemical contamination to adjacent waters. Additionally, there is no use of chemicals during the grow-out phase of scallop farming. The most effective methods of treatment for predator and fouling control are manual removal, which does not entail discharge of active chemicals. Therefore, the chemical use score is 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.

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

Criterion 5 Synthesis

External feed is not provided to farmed scallops, therefore the feed criterion score is 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.

Escape parameters	Value	Score	
F6.1 Escape Risk		8.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		10	
C6 Escape Final Score		**10.00**	**GREEN**
Critical?	NO		

Criterion 6 Synthesis

Factor 6.1a. Escape risk

The risk of escape is directly related to degree of connection to the natural ecosystem. Typical production systems for farmed scallops include a hatchery phase, intermediate phase, and a grow-out phase. The intermediate and grow-out phases occur in open systems (e.g., nearshore subtidal pelagic and benthic habitats in coastal areas). Most cultured scallops available on the U.S. market are grown domestically or imported from Canada, China, or Japan. Both the U.S. and Canada employ best management practices or environmental codes of practice for shellfish aquaculture (BCGSA 2001, PCGSA 2001, Creswell and McNevin 2008, Flimlin et al. 2010). There is a lack of information on best management practices or environmental codes of practice that may be employed in China or Japan. While scallops undergo a planktonic larval phase that could be transported away from the farm sites, larval mortality would likely be high. Furthermore, adult scallops are only capable of swimming short distances. There is little chance of escape from farm sites since nets or mesh are generally used to secure the scallops. If a juvenile or adult scallop were to escape, it could easily be recaptured by hand. Even though scallops are farmed in open systems, the risk criterion does not directly apply in this case. Given these facts, the risk of escape is considered low, resulting in an escape score of 8 (out of 10). There is a paucity of information available regarding scallop escapes and recapture. Therefore, the recapture and mortality score is 0. The overall escape risk score is 8 (out of 10).

Factor 6.1b. Invasiveness

For scallops cultured in their native regions, farmed stock is generally wild-caught. For example, zhikong scallops are naturally found in China, Korea, and Japan and culture of the zhikong scallops was first developed using hatchery seed; however, large scale culture has led to establishment of breeding populations in certain provinces and scallop culture now relies entirely on wild seed (Guo et al. 1999). In the U.S., scallops for broodstock are usually selected from wild stocks for optimal color and morphological traits, as well as optimal growth rates and high fecundity and survival, regardless of the species being cultured (FAO 2004,). Because farmed stock are wild caught or naturally settled from the same water body, the score for genetic difference from wild populations is 5 (out of 5).

Of the farmed scallop species analyzed in this report, only one is cultured outside of its native range with significant production: the bay scallop *Argopecten irradians* (Padilla et al. 2011). The bay scallop, native to North and South America, was intentionally introduced to Asia for the purpose of aquaculture (Guo et al. 1999). No effects on ecosystems or native species have been reported. Bay scallop seeds in China were produced exclusively in hatcheries, but most production continues from the initial introduction of 26 individuals (Guo et al. 1999). Similarly, *P. yessoensis* has been introduced into France and Western Canada from Japan (Beaumont 2000), but production quantity is relatively low. At this time, there is no evidence of significant hybridization between introduced and wild scallop species; however, Liu et al. (2010) found that intentional or accidental release of selected Japanese scallops into natural marine environments might result in disturbance of local gene pools and loss of genetic variability; and recommended monitoring the genetic variability of selected hatchery populations to enhance conservation of wild scallop populations.

Historic introductions that have been used to establish domesticated stock (i.e., the bay and zhikong scallops) have been excluded from this analysis. The remaining species are farmed in areas that fall within their native ranges. There is little information that suggests the escape of farmed scallops would have a negative effect on wild stocks. Therefore, the ecosystem impact of ongoing escapes is 5 (out of 5). The overall invasiveness score is 10 (out of 10).

Factor 6.2X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species <u>other than the principle farmed species</u> 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.

Escape of unintentionally introduced species parameters	**Score**	
F6.2Xa International or trans-water body live animal shipments (%)	10.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Factor 6.2X Synthesis

Production of farmed scallops available on the U.S. market is self-sufficient in terms of broodstock (either through wild capture or hatchery production of seed), and currently does not involve any international or trans-water body live animal shipments. New U.S. laws are being implemented to reduce the transfer of species, as well as the introduction of species known to be harmful at the proposed site. Because it is not possible to predict which species will be harmful or their associated impacts, risk-averse strategies are employed to ban the transfer of any non-native species. Likewise, European regulatory framework controls the movement of any species that is locally absent for use in all types of aquaculture (Padilla et al. 2011). Scallops imported from Asia are never live. Since there are no live animal movements, the risk of unintentionally introducing non-native species or species moved with farmed scallops is negligible.

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.

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

Justification

Diseases associated with scallops

There is little available data that demonstrate negative impacts on the environment as a result of shellfish aquaculture, except for the historical introduction of disease agents to new areas (Elston and Ford 2011) ; however, relatively few diseases have been reported in scallops, let alone the farmed species analyzed in this report (McGladdery et al. 2006).

Mortensen (2000) reviews the following reported and potentially disease-causing agents of scallops.

- Virus-like particles have been shown to cause lesions in digestive gland tissue of *Pecten* sp.
- Rickettsiae and Chilamydae have been shown to cause necrosis of gill and kidney tissue, with the potential for mass mortality.
- The bacterial infection is a common and widespread problem in the rearing of scallop larvae. Control measures for vibriosis in other bivalve molluscs include improved husbandry techniques and sterilization of water used in algal and batch culture (FAO 2004).
- Fungal species have been shown to occur in adductor muscles and can also result on the mortality of cultivated larvae.
- Various protozoan species (i.e. *Perkinsus* spp.) result in damage to eye, kidney, digestive, and connective tissues, and have been associated with mortalities of both wild and cultured scallops.
- Cestodes, trematodes, and nematodes may be found in the digestive or reproductive tissues with varying degrees of impact on the host scallop.

- Sponges (*Cliona* spp.), hydroids (*Hydractinia* spp.), and polychaetes (*Polydora* spp.) grow on and form holes or deformities in scallop shells. While there is usually little impact on the host, some have been associated with mortalities or early life stages.
- Other crustaceans like copepods and pea crabs may live as commensals attached to gills or in the mantle cavity, which may damage or affect the host.

<u>Disease and the production system</u>
Shellfish hatcheries provide a highly concentrated environment in which opportunistic disease agents have the ability to become established, resulting in significantly reduced production. Opportunistic disease agents like bacteria and viruses may be introduced from ambient seawater, broodstock transfer, or via algal food sources (Elston and Ford 2011). In shellfish nurseries, risk factors for disease are high animal density, poor flushing, and the likely build-up of bacteria (Boettcher et al. 2006). Reduction of animal density, and enhanced water flow and sanitation can be used to reduce the risk of disease (Elston and Ford 2011). Infectious diseases are also recorded in grow-out systems, but the origin may be from hatchery seed or the wild. For example, protozoan infections have been associated with mortalities of wild *Argopecten* sp. (Moyer et al. 1993)), as well as for mortalities of cultured *Argopecten* sp. (Chu et al. 1996).

<u>Biosecurity and Authority for disease control</u>
The U.S. Department of Agriculture requires that shellfish farms applying for Animal and Plant Health Inspection Service certifications for interstate export of live shellfish product comply with the Shellfish High Health Plan. The Plan requires participating shellfish producers to establish and practice a customized animal health management plan for their farms, ultimately reducing the risks associated with infectious disease outbreaks (Elston and Ford 2011). Outside of the U.S., the World Organization for Animal Health adopted the Aquatic Animal Health Code and the Manual of Diagnostic Tests for Aquatic Animals, inclusive of molluscs (OIE 2011, 2012). These documents are used by member country authorities to develop individual country standards for all matters related to aquatic products that carry risk of disease. Generally, there is a moderate to high risk of pathogen and parasite interaction with cultured animals when farm systems are open to the environment; however, implementation of biosecurity measures and Best Management Practices or Environmental Management Codes of Practice, coupled with the fact that data show low, temporary, or infrequent occurrences of scallop disease, reduces this risk to low, and correlates to a pathogen and parasite interaction 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 thereby avoiding the need for wild capture

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

Justification

The impact of farmed scallops on wild fisheries is measured by the farm's independence from active capture of wild scallops for on-growing or broodstock. Currently, there is a lack of data regarding the bivalve genetics, breeding, and genomics for the top seven cultured species, which include *Patinopecten yessoensis* (Hedgecock 2011). There is also a paucity of information available for the remaining farmed scallop species analyzed in this report. It is known, however, that in most countries, scallops for broodstock are usually selected from wild stocks or more commonly, spat is passively collected. Quantifying the amount of spat produced in hatcheries is difficult because of the lack of information on the number of producers that rely on hatchery seed. Despite some dependence on wild stock for broodstock, the removal of the necessary number of scallops from the wild typically does not have negative impacts on wild stocks. Hedgecock (2011) states that no shellfish can be considered domesticated, and suggests that the risk of cumulative effects of domestication selection can be mitigated by continual replacement of hatchery broodstock with wild adults and exclusion of hatchery-bred adults from hatchery broodstock. Thus, the source of stock final score is 10 (out of 10).

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	7.5	GREEN	
C2 Effluent	9.00	GREEN	NO
C3 Habitat	8.40	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	8.00	GREEN	NO
C8 Source	10.00	GREEN	
3.3X Wildlife mortalities	-2.00	GREEN	NO
6.2X Introduced species escape	0.00	GREEN	
Total	70.9		
Final score	8.86		

OVERALL RANKING

Final Score	8.86
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
Final Rank	BEST CHOICE

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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.

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.

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*	7.5	7.5
Effluent	Yes	10	10
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	5	5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**60**

C1 Data Final Score	7.5	GREEN

Criterion 2: Effluents

Effluent Rapid Assessment

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

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?	Mostly	0.75
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Mostly	0.75
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1
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?	Moderately	0.5
		4

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?	Mostly	0.75
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Yes	1
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?	Mostly	0.75
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Yes	1
		4.5

F3.2 Score (2.2a*2.2b/2.5)	**7.20**

C3 Habitat Final Score	**8.40**	**GREEN**
	Critical?	NO

Exceptional Factor 3.3X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and Predator Final Score	**-2.00**	**GREEN**
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	**8**

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	**8**

6.1b. Invasiveness

Part A – Native species

Score	5

Part B – Non-Native species

Score	**0**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	No
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)?	No

Do escapees have some other impact on other native species or habitats?	No
	5

F 6.1b Score	**10**

Final C6 Score	**10.00**	**GREEN**
	Critical?	**NO**

Exceptional Factor 6.2X: 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**

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 or natural (passive) settlement	100	
C8 Source of stock Final Score	**10**	**GREEN**