Monterey Bay Aquarium Seafood Watch®

Farmed Scallops

Argopecten spp., *Chlamys* spp., *Patinopecten* spp.,
Placopecten spp., *Lyropecten* spp., *Pecten* spp., *Aequipecten* spp.

Worldwide

Bottom and Off-bottom culture

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Seafood Watch Consulting Researchers

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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.

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 Watch Assessment. Each assessment 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." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, 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 assessments 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 Watch assessments in any way they find useful.

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 farms must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture farms and collective industries, by design, management and/or regulation, address the impacts of individual farms and the cumulative impacts of multiple farms at the local or regional scale by:

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

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

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

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

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

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

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

Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	6.59	Yellow	n/a
C2 Effluent	10.00	Green	No
C3 Habitat	7.20	Green	No
C4 Chemicals	9.00	Green	No
C5 Feed	10.00	Green	No
C6 Escapes	4.00	Yellow	No
C7 Disease	4.00	Yellow	No
C8X Source	0.00	Green	No
C9X Wildlife	-2.00	Green	No
C10X Introduction of secondary species	-1.8	Green	n/a
Total	46.99		
Final score (0-10)	6.71		

OVERALL RANKING

Final Score	6.71
Initial rank	Green
Red criteria	0
Interim rank	Green
Critical Criteria?	0

Final Rank
Green

Scoring note – scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects a very significant impact. Two or more Red criteria result in a Red final result.

Summary

The final numerical score for scallops produced globally is 6.71 out of 10. With a numerically Green-rated score and no Red criteria, the final rating is Green and a recommendation of “Best Choice”.

Executive Summary

This Seafood Watch assessment involves a number of different criteria covering impacts associated with: effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.

The species under consideration are scallop species, produced globally, which are available to consumers in the United States. Approximately 2,121,638 metric tons (mt) of scallops were produced globally in 2018 (FIGIS 2020). The US imported approximately 16,012 mt of scallops in 2019 (NMFS 2020). Scallop farming methods are similar worldwide and most scallops available in the US are either fished domestically or imported from China. The scored often focused on scallop production in China and Japan, the two countries that dominate scallop aquaculture globally.

Data
With almost all scallop farming occurring in Asian countries, namely China and Japan, this report focuses on production in these countries. Most information is available in reports and databases produced by international organizations such as the FAO, certification standard holders and regional governments. Information was available and data quality and availability are considered robust. The final score for Criterion 1 – Data is 6.6 out of 10.

Effluent
As effluent data quality and availability are good (i.e. Criterion 1 score of 7.5 out of 10 for the effluent category), the Evidence-Based Assessment methodology was utilized. Farmed scallops are not provided external feed or nutrient fertilization for the majority of their lifecycle. Filter-feeding shellfish are often cited as improving water quality and/or nutrient cycling near farms. Scallop farming is considered highly unlikely to result in negative nutrient-related impacts, particularly beyond the immediate vicinity of the farm. The score for Criterion 2 – Effluent is 10 out of 10.

Habitat
Aquaculture of scallops generally takes place in coastal, near-shore areas, with sufficient depth for the suspended or bottom culture that is taking place. These areas are typically considered high-value environments. The impacts of scallop farming are considered to be minimal, with the main concerns coming from harvesting techniques used for bottom culture (dredging) as opposed to suspended culture. The lack of demonstrated impacts coupled with management and enforcement measures in high production volume areas results in a score of 7 out of 10 for Criterion 3 – Habitat.

Chemical Use

It appears that most scallop farming relies on non-chemical methods of removal of predatory or fouling organisms, but data – particularly for the highest-producing regions – are not plentiful. Given the global scope of this report, there may be some circumstances in which chemicals are used for fouling, disease, or predation control. The final numerical score for Criterion 4 – Chemical Use is 9 out of 10.

Feed
External feed is not provided to farmed scallops. Therefore, the final score for Criterion 5 – Feed is 10 out of 10.

Escapes
Scallops are often cultured within their native ranges, but culture of non-native species occurs in many areas as well, with bay scallops in China being the most commonly grown species currently. The direct escape of farmed scallop individuals is highly unlikely. However, there is a high risk of spawning-related escapes during the production cycle, as most species reach sexual maturity before they reach harvest size and literature indicates spawning does indeed occur. The risk of impact, though, is mitigated by the culture of native species that are genetically identical to wild populations (e.g. farmed stock is actually comprised of wild-spawned spat that settle on farm infrastructure) or non-native species that have not established wild populations during the multiple decades of open production. Factors 6.1 (0 out of 10) and 6.2 (8 out of 10) combine to result in a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

Disease
Without a robust understanding of how on-farm disease impacts wild organisms (i.e. Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment methodology was utilized. Scallop culture occurs in open production systems with varied levels of biosecurity. There are many diseases known to affect cultured populations of scallops, however the vast majority of reports are from more than 20 years ago, not all pathogen infections resulted in mortality, and it was suggested that many mortality events seen in scallop culture were driven by environmental – not pathogenic - factors. It is unclear whether disease events have affected wild populations of scallops or other organisms. Ultimately, farms are likely to experience disease challenges and are fully open to the introduction and discharge of pathogens. The final numerical score for Criterion 7 – Disease is 4 out of 10.

Source of Stock
In areas where cultured scallop species are native (e.g. Japanese scallop production in Japan, Chinese scallop production in China), production relies on the collection of wild seed using natural settlement technologies. Areas where cultured scallop production is of non-native species (e.g. Japanese scallop and bay scallop in China), production relies on hatcheries. It is unclear what percentages of the global scallop industry rely on collection of truly wild seed, especially given the collection of "wild" seed from cultured populations in the Chinese scallop industry in China. Collection of wild seed for the Japanese scallop industry in Japan and Chinese scallop industry in China uses collection devices for natural settlement. Ultimately, all scallop seed for farm production comes either from domesticated broodstock or from passive

settlement in open water; as such, there is no unsustainable dependence on wild scallops for farm production. The final score for Criterion 8X – Source of Stock is 0 out of -10.

Wildlife Mortalities

Without a robust understanding of how the presence and operation of scallop farms may result in mortality of wild organisms (a Criterion 1 score of 5 out of 10 for the wildlife mortalities category), the Risk-Based Assessment methodology was utilized. Scallop aquaculture utilizes passive exclusionary devices to avoid predation on cultured stocks. The use of these devices has no evidence of direct or accidental mortality of predators or wildlife. In areas where on-bottom culture methods are used there may be some mortality of resident individuals during clearing, however the cleared area is not thought to affect the impacted species' population status, as many are opportunistic species, and recover rapidly. The final score for Criterion 9X – Wildlife Mortalities is -2 out of -10.

Introduction of Secondary Species

There is evidence of movements of both hatchery raised and wild caught scallop seed. Percentages of the global industry reliant on movements are assumed to be around 20%, as the majority of movements of scallop seed produced in China remain in-country, resulting in a Factor 10Xa score of 7 out of 10. Hatcheries employ best management practices to minimize the risk of disease introduction, and the percentage of the industry reliant on hatchery production is approximately 80%, resulting in a Factor 10Xb score of 4 out of 10. The final numerical score for Criterion 10X –Introduction of Secondary Species is -1.8 out of -10.

Summary and Final Score

The final score for scallops produced globally is 6.71 out of 10. With a numerically Green rated score, and no Red criteria, the final rating is Green with a recommendation of "Best Choice".

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Introduction

Scope of the analysis and ensuing recommendation

Species
Farmed scallops (*Argopecten* spp., *Chlamys* spp., *Patinopecten* spp., *Placopecten* spp., *Lyropecten* spp., *Pecten* spp., *Aequipecten* spp.) available on the U.S. market.

Geographic Coverage
Global

Production Method(s)
Bottom and Off-bottom (suspended or floating systems, longlines, racks/bags) culture

Species Overview

Brief overview of the species
The life cycle of scallops is similar for all species. In some species are hermaphrodites (having both male and female reproductive organs), while others are dioecious (definite sex). Adult scallops release eggs and sperm by broadcast spawning. Once the egg is fertilized it develops and remains in a planktonic stage before settling to the ocean floor and attaching to a surface with a byssus. In most species, the byssus is eventually lost once the scallop becomes larger and the scallop is then a “free-swimming” adult. The scallop can clap its shells together to “swim” short distances.

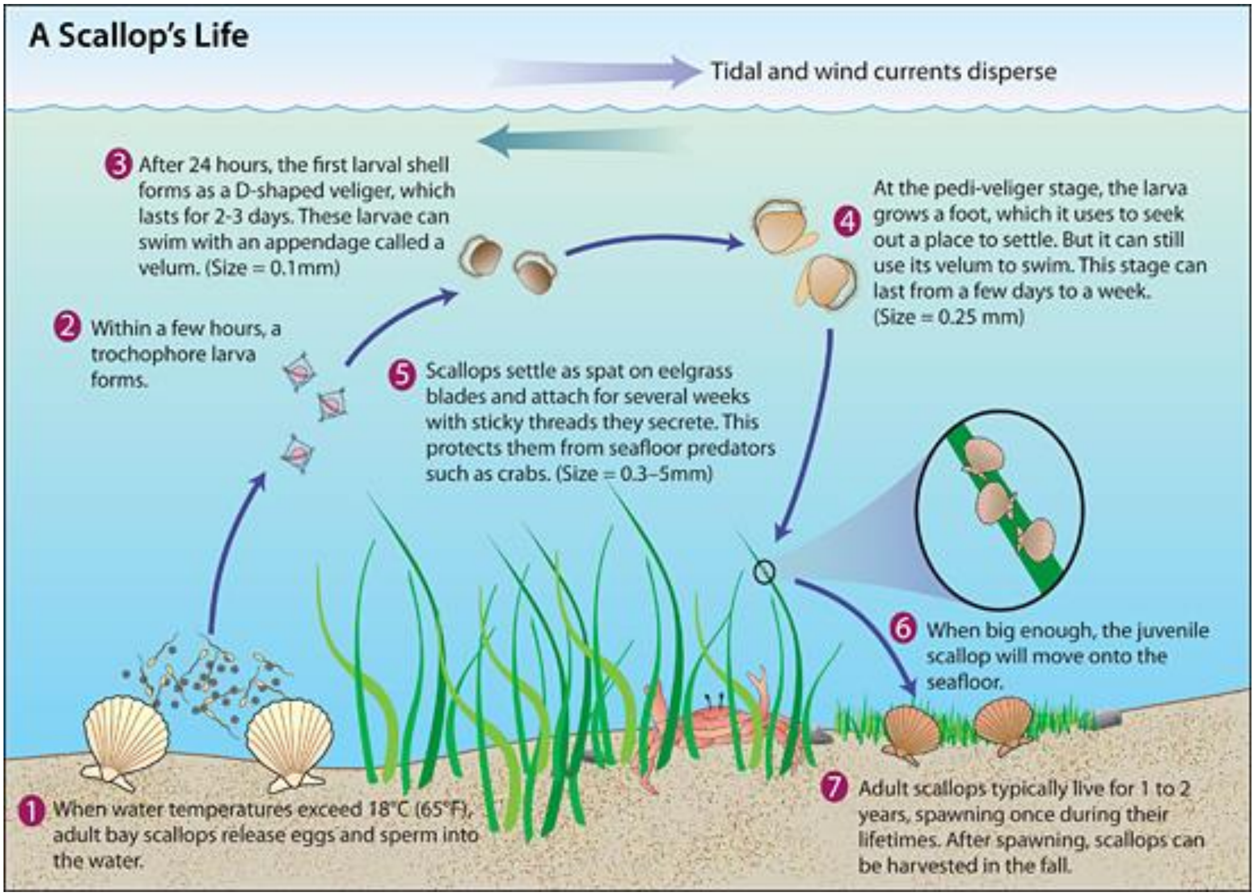

Figure 1. Bay scallop life cycle (http://www.whoi.edu/page.do?pid=80696&i=6627).

Production system

Scallop aquaculture consists of three main phases. The first is obtaining spat through either natural collection or hatcheries, the second is a nursery phase and the third is the grow-out phase.

Where spat are collected in the wild, surfaces (usually mesh bags) are suspended in the water column (i.e. longline). The surface contains suitable cultch onto which the larvae will settle. Larvae metamorphose into post-larvae spat and are collected for on-growing in the natural environment (Gavrilova and Kim 2016). Alternatively, like in other aquaculture industries, spat may come from hatcheries when natural spat collection is poor, to obtain greater or more reliable supply, or when a non-native species is used.

A nursery phase may be used to transition from hatchery to the grow-out phase. The nursery phase allows for extra growth and shell hardening before grow-out. Nursery methods may vary according to country or environmental conditions. In China, scallop spat collectors may be transferred to shrimp ponds or nursery areas where they are suspended in the water column (Guo et al. 1999).

The final grow-out phase may consist of off-bottom (also called hanging or suspended) or bottom culture. Off-bottom culture consists of using either raft or longline systems which are suspended from the sea surface. A variety of systems are used, including pearl nets, lantern nets (multi-tiered accordion style net), trays, cages, ear hanging (a hole is drilled in the "ear" of the shell and hung on ropes), rope culture (cementing scallops to rope), pocket nets, and hog rigging. Bottom culture involves scallops being sowed on the bottom, by releasing them from a moving vessel over a selected area with suitable conditions (wild ranching), or using plastic trays set on the bottom. In the case of global Japanese scallop (*Patinopecten yessoensis*) culture, bottom culture may be used when there is excess seed produced from wild settlement or the nurseries for off-bottom culture (FAO 2006; Gavrilova and Kim 2016). Bottom culture methods often require 2-3 more years for scallops to reach harvest size (CAIA 2017). Scallops farmed using both off-bottom culture and bottom cage culture are harvested by boats, usually equipped with winches, and bottom culture (sea-ranching) harvesting may be done by dredging, or divers (FAO 2006, Shumway and Parsons 2006).

This report will focus on the grow-out phase of scallop production.

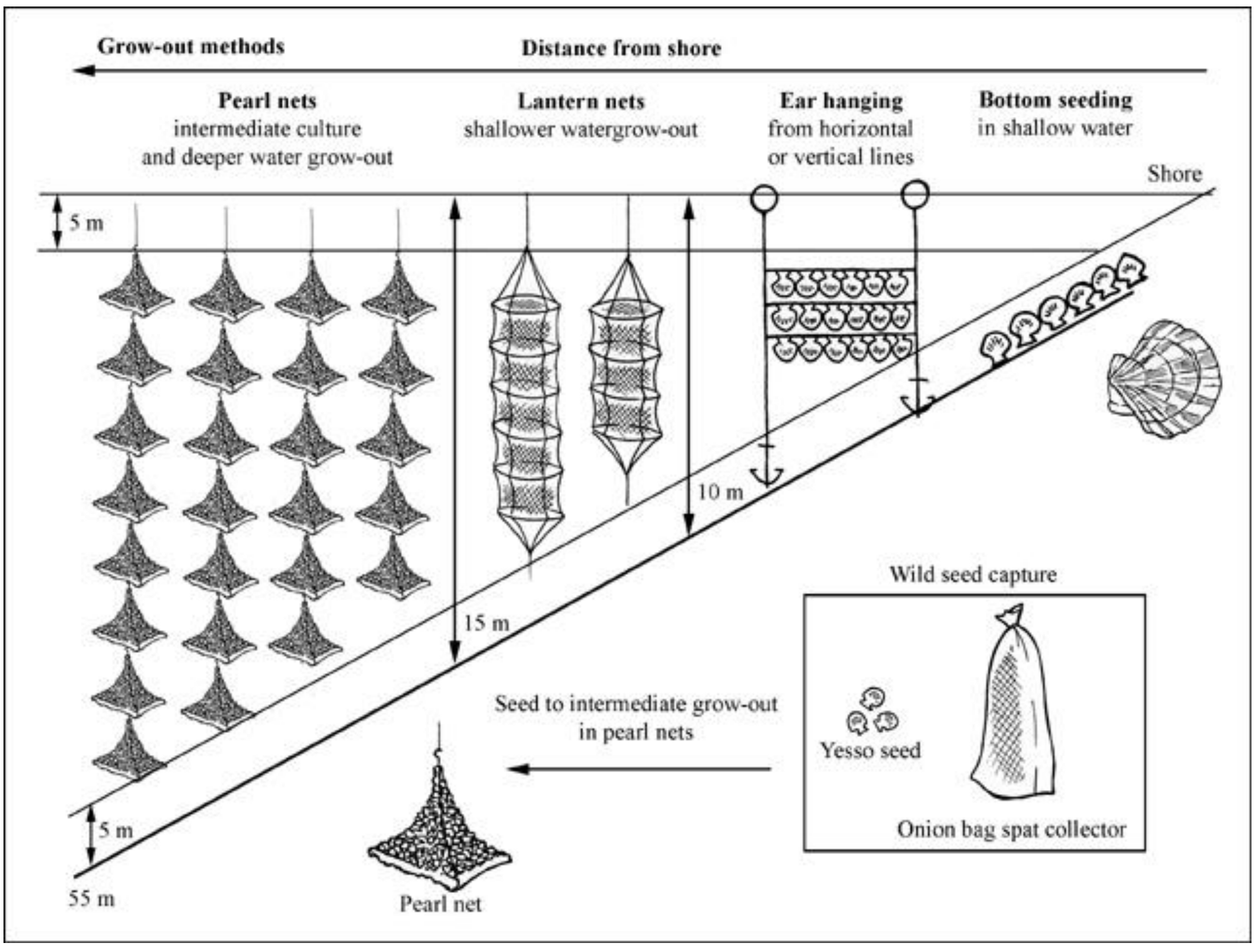

Figure 2. Grow-out methods for Japanese scallop (*Patinopecten yessoensis*) (FAO 2006).

Production Statistics
Global aquaculture production of scallop species in 2018 was 2,121,638 mt (excluding *Atrina* spp.) (FIGIS, 2020). Of this production, 90.4% is categorized by the FAO as "Scallops nei", which does not identify individual species, but consists of species within the family *Pectinidae* (FIGIS, 2020). China produces 99.99% of this volume. Production of the (specifically-identified) Japanese/Yesso scallop *P. yessoensis* represents 8.7% of the remaining global production, with 94.8% of the volume produced in Japan (ibid.). Therefore, approximately 98.6% of total global scallop production is represented by *Pectinidae* and *P. yessoensis* from China and Japan respectively.

Historically, most production in China was of Chinese/Zhikong scallop (*Chlamys farreri*), with production being near 1,000,000 mt (Ocean University of China 2013, Zhang 2012) in the early 2000s, although, due to increasing summer mortalities in this species, production of bay scallop (*Argopecten irradians*) and Japanese/Yesso scallop (*Patinopecten yessoensis*) is increasing in China (Seafish 2015; Guo and Luo 2016). It appears that the bay scallop is now the most produced scallop species in China (58% of production), followed by the Chinese scallop (20% of production), Japanese scallop (19% of production), and the noble scallop (3% of production) (Guo and Luo 2016). *Lyropecten* spp., *Pecten* spp., *Aequipecten* spp., and *Chlamys* spp. all appear to have very low production (under 100 mt for the past 10 years); although it should be noted that Chinese scallop is known to be extensively cultured in China, but apparently not reported at the species level to FAO and likely reported under the category of "Scallops nei".

Canada, the leading source of scallops imported to the US (see the following section), is a minor contributor to global scallop aquaculture production. Production occurs in both western (British Columbia) and eastern (Nova Scotia, New Brunswick, and Quebec) Canada. In British Columbia, which – according to 2013 statistics – accounted for 85% of national production, a Japanese-weathervane hybrid scallop (*Patinopectin caurinus* x *vessoensis*) is produced, known locally as the Pacific or Qualicum scallop. In eastern provinces, production is dominated by the giant/sea scallop (*Placopectin magellanicus*) and the northern bay scallop (*A. irradians*) (CAIA, 2018). Imports to the US are not species-specific, and are categorized as "Scallops nei" (FIGIS, 2020). Volumes fluctuated between 2008 – 2018, with the largest volume produced in 2010 (697 mt), and the lowest in 2015 (31 mt). In 2018, 94 mt were produced (ibid.). Production in 2018 represented .00004% of global production.

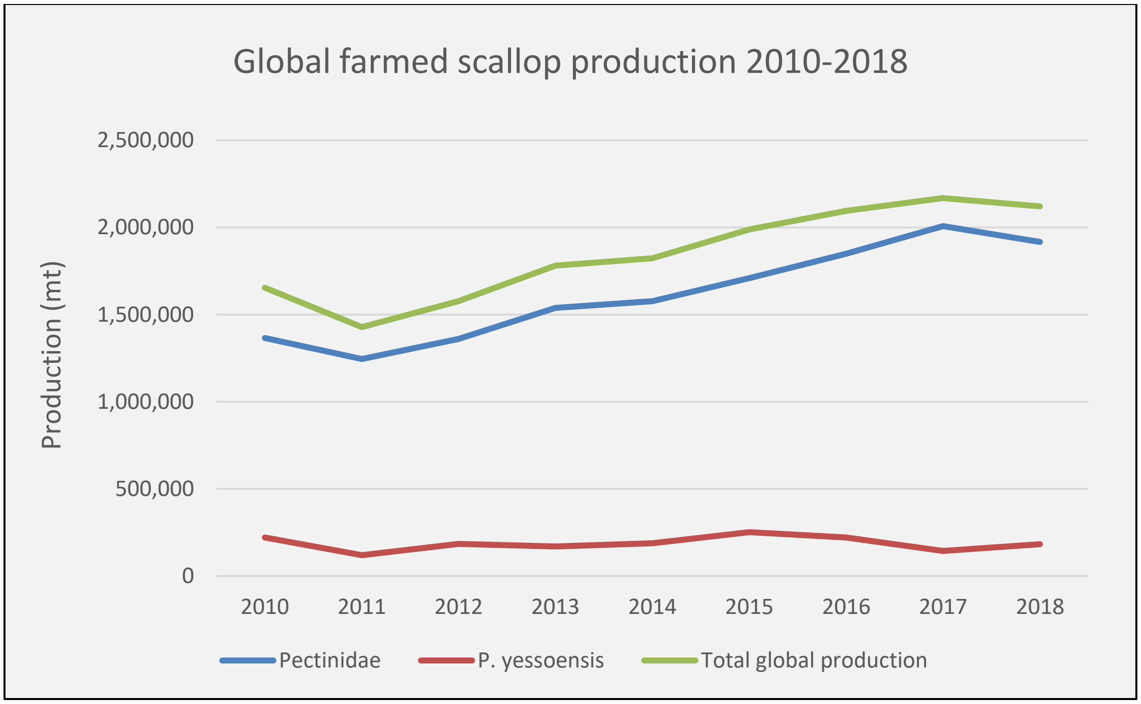

Figure 3. Global farmed scallop production.

<u>Percent of industry represented by each production system</u>
In China, lantern nets suspended on longlines have been the main form of culture for scallops, although on-bottom methods for bay and Japanese scallop production are becoming more popular (Guo et al. 1999; Guo and Luo 2016). Approximately 90% of scallop production in China is done using lantern nets (Pers. comm., X. Guo, 2020).

In Japan, it is unclear what percentages of the industry use off-bottom and bottom culture. Approximately 80% of off-bottom culture uses ear-hanging methods, with the remaining 20% using pearl, lantern or pocket nets (MSC 2013). Bottom culture is known to be used in Hokkaido, where 80% of Japan's scallop production occurs. While it is known to occur along the northwest coast of Hokkaido in the Sea of Okhotsk and the Nemuro Straits (MSC 2019), it is unclear what percentage of prefectural production it represents.

Import and Export Sources and Statistics
Scallop import and export statistics for the US are not broken down by species; they are referred to collectively as "scallops". The US imported approximately 16,012 mt of scallop products in 2019, with 65.3% coming from Canada, China and Japan (NMFS, 2020). In the same year 5,874 mt were exported (ibid.). It is unclear how much of the export volume was farm-grown or wild-caught in the United States (the US has a robust scallop capture fishery), and how much was re-exported. Given the production statistics discussed in the Production Statistics section, it can be seen that most scallops imported from Canada are wild caught, while scallops imported from China and Japan are farmed. While scallops are farmed in the

United States, the industry is focused on research and product development rather than commercial production (MAIC, 2020). As such, the US is not a major producer of cultured scallops, with 0 mt of commercial scallop aquaculture production from the US reported over the past 10 years (FIGIS, 2020). Therefore, it is likely that all exports are from fishery production. Table 1 shows US imports by country for 2019, Table 2 shows US exports by country for 2019, and Table 3 shows total US imports and exports between 2010 – 2019.

Table 1. US imports of scallops (of >300 mt) in 2019

Country	Metric Tons	% of total US import volume (16,012 mt)
Argentina	1,319	8
Canada	3,735	23
China	3,498	22
France	317	2
Japan	3,006	19
Mexico	1,312	8
Peru	2,099	13
Philippines	403	3
Total	**15,689**	**98**

Source: (NMFS, 2020)

Table 2. US exports of scallops (of >300 mt) in 2019

Country	Metric Tons	% of total US export volume (5,875 mt)
Belgium	416	7
Canada	1,877	32
France	722	12
Netherlands	1,028	17
United Kingdom	370	6
Total	**4413**	**74**

Source: (NMFS, 2020)

Table 3. US imports and exports of scallops between 2010 and 2017.

Year	US Imports (mt)	US Exports (mt)
2019	16,012	5,875
2018	21,080	6,429
2017	18,752	7,456
2016	23,152	8,271
2015	22,356	7,631
2014	27,512	9,101

2013	27,614	9,619
2012	15,632	13,044
2011	25,766	14,577
2010	23,526	11,165

Source: (NMFS, 2020)

Common and Market Names

Scientific Name	*Argopecten* spp., *Chlamys* spp., *Patinopecten* spp., *Placopecten* spp., *Lyropecten* spp., *Pecten* spp., *Aequipecten* spp.
Common Name	Scallops

Product forms

The US imports and exports the following scallop products:

- Frozen/dried/salted/brine
- Live/fresh
- Prepared/preserved
- Prepared dinners

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: having robust and up-to-date information on production practices and their impacts publicly available.

Criterion 1 Summary

C1 Data Category	Data Quality
Production	7.5
Management	5.0
Effluent	7.5
Habitat	7.5
Chemical Use	7.5
Feed	10.0
Escapes	7.5
Disease	5.0
Source of stock	7.5
Wildlife mortalities	5.0
Escape of secondary species	2.5
C1 Data Final Score (0-10)	**6.59**
	Yellow

Brief Summary

With almost all scallop farming occurring in Asian countries, namely China and Japan, this report focuses on production in these countries. Most information is available in reports and databases produced by international organizations such as the FAO, certification standard holders and regional governments. Information was available and data quality and availability are considered robust. The final score for Criterion 1 – Data is 6.59 out of 10.

Justification of Rating

<u>Production</u>

Industry or production statistics on worldwide scallop farming are readily available to the public, primarily through international organizations, such as the Food and Agriculture Organization (FAO) of the United Nations. There are also reports from international fisheries and aquaculture certification standard holders, including, the Marine Stewardship Council

(MSC) and Aquaculture Stewardship Council (ASC) on scallop farming, as well as books and peer reviewed journal articles. Some information on production statistics may be uncertain or out of date, particularly for producer countries in Asia. Industry or production statistics for worldwide scallop farming scored 7.5 out of 10.

Management

Management measures in countries producing the largest volumes of scallops globally are available in literature, as well as databases from the FAO. There are international, national and regional management measures described, however gaps still exist in the scope of implementation and enforcement of management measures in major producing countries. The management data quality and availability scores 5 out of 10.

Effluent

Data quality for the effluent category is robust. Information describing the ecological effects of scallop farming is available mainly as well as peer reviewed articles, and books, with some data available from third party certification audits as well. Information describing effluent management and enforcement measures is available through the FAO. The data score for effluent is 7.5 out of 10.

Habitat

The majority of information about habitat impacts from scallop farming is available from peer reviewed articles and books, with some data available from third party certification audits as well. Information describing habitat management and enforcement measures is available through the FAO. The data score for habitat is 7.5 out of 10.

Chemicals

The data quality and availability for chemical use in scallop farming scores 7.5 out of 10. There is literature describing the historic use of chemicals in scallop aquaculture, and peer reviewed articles and books describing their current minimal use, however it is unclear how well these articles and books describe the global industry.

Feed

Scallops are not provided external feed, and there are ample resources (not cited) available supporting this. The data score for the Feed criterion scores 10 out of 10.

Escapes

The data quality and availability score for escapes is 7.5 out of 10. Ample peer reviewed literature describes the nature of scallops as broadcast spawners and the likelihood that spawning occurs during the production cycle. Additional peer reviewed articles and books provide information about the risk of competitive and genetic interactions with wild, natural populations.

Disease

Disease, pathogen and parasite interactions scores 5 out of 10 for data availability and quality. There are peer-reviewed articles that outline many diseases which scallops are susceptible to. However, high-level information regarding biosecurity measures and a paucity of information on disease transmission between farm and wild populations limits understanding.

Source of Stock
The source of stock criterion scores 7.5 out of 10. Peer reviewed literature provides information on the use of wild collection and hatchery practices for different scallop industries globally, however it is difficult to determine what percentage of the industry relies on hatchery produced stock versus natural spat collection.

Wildlife Mortalities
The data availability and quality score for wildlife and predator mortalities is 5 out of 10. The methods for preventing predation of scallops and for harvesting are well-defined in the literature, although there are no databases available describing actual numbers of mortalities, or their impact, if any, to natural ecosystems.

Escape of Secondary Species
The criterion for escape of unintentionally introduced species scores 2.5 out of 10 for data quality and availability. Peer reviewed literature describes the collection and movements of scallop seed, and provides information about the biosecurity measures taken at the source and destination of these movements. It remains unclear what percentage of the global industry relies on animal movements.

Conclusions and Final Score
There is an abundance of high quality and readily available data on scallop aquaculture around the world, with very few information gaps. The industry, like most other shellfish aquaculture, is generally considered sustainable and responsible. There are academic publications and documents from international organizations and various levels of government that all contribute to confidence in scoring the criteria in this report. The final numerical score for Criterion 1 – Data is 6.36 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- Impact: aquaculture species, production systems and management methods vary in the amount of waste produced 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: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Effluent Risk-Based Assessment

C2 Effluent Final Score (0-10)	**10**	Green

Brief Summary

As effluent data quality and availability are good (i.e. Criterion 1 score of 7.5 out of 10 for the effluent category), the Evidence-Based Assessment methodology was utilized. Farmed scallops are not provided external feed or nutrient fertilization for the majority of their lifecycle. Filter-feeding shellfish are often cited as improving water quality and/or nutrient cycling near farms. Scallop farming is considered highly unlikely to result in negative nutrient-related impacts, particularly beyond the immediate vicinity of the grow out site. The score for Criterion 2 – Effluent is 10 out of 10.

Justification of Rating

As effluent data quality and availability are good (i.e. Criterion 1 score of 7.5 or 10 of 10 for the effluent category), the Evidence-Based Assessment methodology was utilized. The Effluent criterion considers the impact of soluble and particulate effluent within and beyond the immediate boundary of the farm; farm construction and presence impacts (i.e. their occupancy of benthic and water column space) are considered in Criterion 3 – Habitat. Farmed scallops are not provided external feed or nutrient fertilization (Yuan et al. 2010), limiting the concern for nutrient-related impacts often observed in fed aquaculture.

Effluent impacts to the water column

As filter-feeding organisms, scallops remove phytoplankton and organic detritus from the water column through filtration. There is potential for intensive scallop aquaculture to reduce the amount of these materials available to other organisms, thus stimulating trophic cascades, in both the near and far-field surrounding areas, however scallop farms may provide a key ecosystem service by reducing primary causes of eutrophication (Liang et al., 2020; Burkholder and Shumway 2011). In addition, a study on the interactions between the microbial food web and Chinese scallops, concluded that scallop culture strengthens the microbial food web Lu et al. (2015). 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. In addition, Peruvian scallops (*Agropecten purpuratus*) and Japanese scallops (*Patinopecten yessoensis*), grown on various farms located in Peru (four farms), Chile (two farms) and China (one farm), are currently certified to the Aquaculture Stewardship Council (ASC) Bivalve Standard, and reports show no pelagic effects (ASC 2020).

The potential positive effects of scallop farming, observed in a eutrophic bay in northern China by Zhou et al. (2006), include decreased seston and chlorophyll-a concentrations in the water column, enhanced deposition of total suspended particulate material, suppressed accumulation of particulate organic matter in the water column, and increase the flux of C, N, and P to the benthos (enhancing pelagic –benthic coupling), mitigating eutrophication in coastal ecosystems that are subject to anthropogenic N and P loadings. Calculations predict that the daily removal of suspended matter from the water column by scallops in the Sishili Bay ecosystem can be as high as 45% of the total suspended matter; and the daily production of biodeposits by the scallops in early summer in farming zone may amount to 7.78 g m^{-2}, with daily C, N and P biodeposition rates of 3.06×10^{-1}, 3.86×10^{-2} and 9.80×10^{-3} g m^{-2}, respectively (Zhou et al 2006). Gallardi (2014) also recognizes the potential for shellfish farming to mitigate eutrophication in coastal areas.

Effluent impacts to benthic environments

As scallops do consume food items, they produce feces and pseudofeces – called biodeposits – which settle on the benthos. Biodeposition of fecal matter from suspended scallop culture can be a concern, most commonly in the near-field areas directly beneath, or immediately surrounding the farm (Yuan et al., 2010). Caution is advised for areas where there is a high density of bivalve culture due to the potential for environmental impact from biodeposition (ibid.). However, it is generally recognized that effects of scallop culture are largely insignificant relative to other forms of culture because artificial feeds and additives are not used (Giles et al. 2009, Weise et al. 2009, Ferreira et al. 2011). Where the accumulation of biodeposits can result in increased nitrogen and reduced oxygen concentrations in other farmed shellfish species (see Seafood Watch, 2018, 2020), the general belief is that if the carrying capacity is not exceeded with scallop aquaculture, the environmental benefits of scallop culture outweigh the minimal costs (SAGB 2008, Shumway et al. 2003). Peruvian scallops (*Agropecten purpuratus*) and Japanese scallop (*Patinopecten yessoensis*), grown on various farms located in Peru (four farms), Chile (two farms) and China (one farm) have been certified to the ASC, and have demonstrated that there are no major benthic effects under suspended and off-bottom culture sites (farms are in areas with depositional sediments and have acceptable levels of total free sulfides (<1500 um) in surficial (0-2 cm from surface) compared to control sites. While it has been surmised that overcrowding in scallop aquaculture farms in China may have contributed to mass summer mortality of cultured scallops in the 1990s, this was considered to be just one of many contributing factors (Guo and Luo 2016), and is not considered typical of the industry.

Conversely, a study in Laizhou Bay, China determined that scallop biodeposits are directly consumed by meiobenthos under the farms, improving their nutritional quality as food items for predators (Huang et al., 2018).

Conclusions and Final Score

As a result of feeding, scallops produce both soluble and particulate effluent. However, because scallops are extractive and not supplied external feed or nutrient fertilization, the nutrient wastes are not considered to have any negative impact on water quality. Therefore, the final score is 10 out of 10 for Criterion 2 – Effluent.

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: being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats.

Criterion 3 Summary

C3 Habitat parameters	Value	Score
F3.1 Habitat conversion and function (0-10)		9
F3.2a Content of habitat regulations (0-5)	3	
F3.2b Enforcement of habitat regulations (0-5)	3	
F3.2 Regulatory or management effectiveness score (0-10)		3.600
C3 Habitat Final Score (0-10)		**7.20**
Critical?	No	Green

Brief Summary

Aquaculture of scallops generally takes place in coastal, near-shore areas, with sufficient depth for the suspended or bottom culture that is taking place. These areas are typically considered high-value environments. The impacts of scallop farming are considered to be minimal, with the main concerns coming from harvesting techniques used for bottom culture (dredging). The lack of demonstrated impacts coupled with management and enforcement measures in high production volume areas results in a score of 7 out of 10 for Criterion 3 – Habitat.

Justification of Rating

Factor 3.1. Habitat conversion and function

Habitat conversion is measured by the effect of that the construction and presence of aquaculture operations has on habitat functionality and services within the farm boundary or allowable zone of effect. While it is acknowledged that scallop farming, and shellfish farming more broadly, may have both positive and negative effects on the surrounding environment, the valuable ecosystem services provided by shellfish are often considered to outweigh the potential negative effects (McKindsey et al., 2006; Yuan et al., 2010; Ferreira et al. 2011; Gallardi 2014; Liang et al. 2020). Further, some effects may be considered positive in some regards and negative in others (Table 4) (Gallardi 2014).

Table 4. Main effects of bivalve aquaculture on the environment. Adapted from Gallardi (2014).

	Effect	Outcome

Water column and nutrients	Phytoplankton modification	Bloom modification
	Reduced turbidity	Increased light penetration
	Increased NH4+	Increased primary production
	Metals concentration	
Sediment and benthic habitat	Increased deposition	Anaerobic sediment
		Increased bacteria and meiofauna
		Decreased suspension-feeders
		Increased deposit feeders
	Modification of topography and hydrogeny	Habitat creation/modification
	Removal of calcium carbonate	Increased acidification
		Decreased positive feedback
Other marine species	Nutrient and habitat modification	Increased crustaceans and some fish
		Seagrass displacement
		Disturbance for mammals and birds
		Creation of new habitat for birds
	Food competition	Decreased zooplankton and larval fish
Introduction	Introduction of nonnative species	Diseases introduction
		Pest introduction

Farm site construction and presence

As depicted in Figure 2, there are multiple systems used for scallop production. Off-bottom suspended culture generally includes ropes strung in depths of 10-60 meters with the chosen production method (ear-suspension, lantern nets, pearl nets, etc.) hung from them. These ropes are kept afloat using surface buoys, and are held in place by anchors on the sea floor (Kosaka, 2016).

On-bottom culture is practiced at different depths (12- 80 meters in the Okhotsk Sea, 10-30 meters in Mutsu Bay, etc.) (Kosaka, 2016). Prior to sowing scallop seeds, the area will be cleared using a dredge to remove potential predators. In Japan this is done using scallop and mop dredges to remove sea urchins and seastars (ibid.). When this stage is complete, scallops will be placed often directly onto the seabed (ibid.). Few effects are reported based on the presence of bottom culture, as most are associated with dredging activities for clearing and harvest. 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, bottom culture may increase species richness and diversity. The MSC (2013) report for scallop aquaculture in Japan indicated that there was little effect on the distribution of benthic animals in Funka Bay.

While information specific to scallop culture is not available, data from studies of mussel culture show altered hydrodynamics from off-bottom suspension systems very similar to those used for scallops. Mussel culture around Goqui Island, China has been shown to impede horizontal currents, and created downwelling (Lin et al., 2016). These shifts in hydrology are noted as having the potential to reduce the carrying capacity of the area (Lin et al., 2016; O'Donncha et al., 2013).

Harvest

Scallops cultured using off-bottom techniques are generally harvested from boats or rafts. 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). Because harvest techniques for suspended scallop culture do not require contact with the benthos, they are believed to have no significant impacts on habitat.

Bottom-cultured scallops are harvested either by hand (by SCUBA divers) or dredge (Mercaldo-Allen and Goldberg 2011, Stokesbury et al. 2011, FAO 2006-2013, MSC 2013). Hand-harvesting is highly selective and is not expected to disturb or otherwise negatively impact the habitat. Regarding dredge harvest techniques, it should be noted that 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 4.3 m 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 and/or the destruction of the habitats they use. 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 affected area and less mortality of non-target organisms. Species in seafloor areas used for scallop culture tend to be opportunists that tolerate highly turbid conditions and are capable of rapidly recolonizing disturbed benthic 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).

While negative effects of scallop farming are possible, following the cessation of scallop mariculture, ecosystems typically recovered from the impacts described above in five to ten years (Shumway and Parsons 2006). Additionally, Gallardi (2014) indicated that all effects of shellfish farming can ultimately be mitigated through effective ecosystem-based management, which include preventative measures like using ecological carrying capacity models and use of environmental risk assessment best management practices and codes of conduct.

Habitats in which scallops are farmed may be improved through filtration and maintain full functionality if suspended culture methods are used or bottom-cultured scallops are harvested by hand. Habitats in which scallops are farmed and then harvested by dredge are subject to increased turbidity, shifts in hydrological patterns, 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 for all grow-out methods used and the score for Factor 3.1 is 9 out of 10.

Factor 3.2. Farm siting regulation and management

Factor 3.2a: Content of habitat management measures

As is noted in the Introduction section of this document, the majority of farmed scallops available in the United States have been imported from China and Japan. The US imports the highest volume of scallops from Canada, however it is thought that the majority of this volume is wild caught.

Canada: In Canada, aquaculture regulation varies by province. In British Columbia, the province issues the lease and the Department of Fisheries and Oceans (federal agency) issues the license. In Prince Edward Island, there is a management board which issues leases and licenses, and in all other provinces, the provincial government issues leases and licenses.

The federal government sets out guidelines for siting and regulation based on environmental protection, and provides information and resources to the public. Canada's regulations include language protecting critical ecosystem elements (such as squid, forage fish, sponges, eelgrass, and other habitats). The primary pieces of legislation for the regulation of aquaculture 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 Activities Regulations within the Fisheries Act give conditions under which operators can treat their fish for disease and parasites, deposit organic matter, and manage facilities, as well as reports on environmental monitoring and sampling requirements (DFO 2016). 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 (Dewey et al. 2011).

China: In China, the Fisheries Law (2004) and the Regulation for the Implementation of the Fisheries Law (1987) provides the legal framework for the fisheries and aquaculture. There are many additional laws, regulations, international treaties, administrative acts, and local regulations and management in place to regulate fisheries and aquaculture (Zou and Huang 2015). Some of the laws that govern aquaculture practices include, but are not limited to the Sea Area Use Management Law (2002), the Environmental Protection Law (1989), the Marine Environment Protection Law (1982), The Law on the Prevention and Control of Water Pollution (1984), and the Environmental Impact Assessment Law (2002).

It is clear that there is a legal framework in place for the regulation of fisheries and aquaculture activities; however, it is also recognized that site selection for aquaculture has no specific legislation (Chen et al. 2011, Zhu and Dong 2013). Nonetheless, use of state-owned land and water areas must meet the local functional zoning scheme set by the Land Administration Law, including conservation areas, industry, aquaculture, etc. (Chen et al. 2011, FAO 2004). The focus of current policy development for aquaculture is on “green growth” and improving licensing, environmental protection, and aquaculture product quality (Zou and Huang 2015).

Most farms are use leases managed by local communities (personal communication with X. Guo, November 29, 2012). An Environmental Impact Assessment (EIA) is required in different environmental laws, and while there is no specific referral to aquaculture, EIAs are required for new construction projects that include aquaculture or that involve sensitive environments such as mangroves (People’s Republic of China Environmental Impact Assessment Law, 2016). EIAs must address pollution from aquaculture sites, the impact that pollution may have on the environment, and ways to mitigate effects; however, there is no standardized process for assessing risk at a farm site before it is licensed. The Environmental Impact Assessment Law (2016) 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 2004). The Environmental Protection Law (1989) indicates that EIAs are the responsibility of appropriate departments of the Environmental Protection Administration of the Peoples’ Government, at or above the county level (NALO 2012), leading to variability from one county to another.

Japan: In Japan, suspended scallop aquaculture and sea-ranching operations are based on fishing rights specified in the Fisheries Act. Fishing licenses based on a certain area and fishery type are issued by prefectures. External committees are designated to review fishing licenses and determine eligibility of the license.

For scallop aquaculture activities, the Japan Fisheries Cooperative is the licensee, and this serves to maintain the involvement of fishing villages and prevent domination of the industry by individuals. Individuals are granted licenses based on their past merit and compliance with fisheries and other legislation. Therefore, the scallop aquaculture industry in Japan is managed under the supervision of the prefectural office (and its research and development institutes) and it is subject to external review to encourage sustainable development and compliance.

Additionally, Japan’s Law to Ensure Sustainable Aquaculture Production (1999) works to prevent environmental deterioration around aquaculture operations. Fisheries Cooperative Associations develop and implement “Aquaculture Ground Improvement Programs”, and suspended scallop aquaculture is subject to these programs. Cooperatives and harvesters work together to make sure that the industry is maintaining sustainability (MSC 2013).

Globally, regulations governing scallop aquaculture are comprehensive and, in some cases, are integrated with other industries based on maintaining the overall functionality of habitats. Regulations are appropriate to the industry and are largely effective. In China, aquaculture regulations are slightly less clear leading to a minor reduction in score. The score for Factor 3.2a is 3 out of 5.

Factor 3.2b: Enforcement of habitat management measures

In Canada, the federal Department of Fisheries and Oceans works to enforce the laws governing aquaculture activities and with relation to marine habitat. Federal fisheries officers ensure that aquaculture operations are compliant with national and regional regulations under the Fisheries Act. Fisheries and Oceans work very closely with other federal and provincial bodies to enforce all aquaculture regulations. Additionally, other federal departments, such as the Canadian Food Inspection Agency, Health Canada, and Transport Canada implement their own regulations and may become involved if needed with enforcement of aquaculture regulations (DFO, 2015).

China: In China, fisheries and aquaculture operate under a hierarchy, involving fisheries administration departments at the national, provincial, regional and municipal levels. In provinces and autonomous regions, counties and cities may also play a role. Fisheries administrative bodies in local regions are responsible for monitoring and enforcing national fisheries regulations and establishing local regulations. The national Bureau of Fisheries leads the Fisheries Law Enforcement Command of China, which coordinates fisheries law enforcement. Regional Fisheries Management Bureaus enforce regional laws (Zou and Huang 2015). Water quality is monitored on lease grounds to ensure that it is suitable and remains suitable for aquaculture; however, monitoring may not be strictly enforced (personal communication with X. Guo, November 2012, Fishfirst nd). Overall, enforcement of aquaculture regulations has been deemed weak in the past as aquaculture is favored by the government as an important economic activity, there are limited numbers of enforcement officers, there is insufficient financial support, and an ineffective management hierarchy (Chen et al. 2011, Fishfirst nd, Yan and Huang 2009). There is no center for information on punitive measures or any documented action against farms that do not comply. Enforcement agencies appear regionally fragmented, and there is little public evidence of monitoring or compliance data. Often, economic development takes precedence over compliance with environmental regulation (Zhu and Dong 2013). However, this is perhaps changing with the focus for policy development shifting to enhance environmental protection and sustainable growth of aquaculture (Zou and Huang 2015).

Japan: In Japan, fishery activities fall under the Fisheries Law (1949, revised 1962). The Law is administered by the Ministry of Agriculture, Forestry and Fisheries, with many tasks being delegated to Prefecture governments. The Fisheries Agency is responsible for preserving and managing marine biological resources and fishery activities. Fisheries Cooperative Associations establish their own strict regulations within their respective geographical areas to best manage fishery resources (MSC 2013).

The score for Factor 3.2b is 3 out of 5, as enforcement organizations are identifiable, appropriate, active, and provide information on activities; however, China represents a large portion of the industry and it is sometimes difficult to confirm strict enforcement of regulations. When combined with the Factor 3.2a score of 3 out of 5, the final Factor 3.2 score is 3.6 out of 10.

Conclusions and Final Score

The impact of farmed scallop operations on habitat is considered to be minimal, with the main concerns stemming from harvest. Lack of impact coupled with reasonable regulation and enforcement regarding licensing and site selection result in an overall high score. Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 7.2 out of 10.

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: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary

C4 Chemical Use parameters		Score
C4 Chemical Use Score (0-10)		**9.00**
Critical?	No	Green

Brief Summary

It appears that most scallop farming relies on non-chemical methods of removal of predatory or fouling organisms, but data – particularly for the highest-producing regions – are not plentiful. Given the global scope of this report, there may be some circumstances in which chemicals are used for fouling, disease, or predation control. The final numerical score for Criterion 4 – Chemical Use is 9 out of 10.

Justification of Rating

The purpose of chemical treatment in scallop farming is broadly to prevent predation, fouling, and infection by disease-causing organisms. The use of chemical substances (e.g. copper sulfate, calcium oxide, sand coated with trichloroethylene, and insecticides) to control predators of mollusks 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 shellfish farms. Furthermore, a (now dated) 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 both off-bottom and on-bottom scallop culture that use netting to exclude predators. Netting is prone to fouling and subsequent clogging that restricts water flow (and hence, both oxygen and food sources) through the nets. Constant cleaning is required to remove fouling organisms. There have been many historical 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, Shumway et al. 1988; Brooks 1993); however, chemicals to control fouling may release potentially toxic constituents into the marine environment which pose a threat to both the species being cultured and to other non-target organisms. 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, antifoulants currently available do not adhere to the plastics from which shellfish gear is made (Bishop 2004). In general, air drying, brine or freshwater dips, power washing, and manual control are not only more successful, but also more environmentally friendly (Creswell and McNevin 2008, Watson et al. 2009).

In China, the Environmental Protection Law, the Law on the Prevention and Control of Water Pollution, and the Marine Environment Protection Law include provisions to prevent pollutant impacts, including impacts from chemicals used in aquaculture (FAO, 2004). The use of drugs in aquaculture is governed by a variety of regulations, but these state that the administration of drugs and drug residue tests are controlled at or above the county level for aquaculture (FAO 2004).

In Japan, the Agricultural Chemicals Regulation Law regulates agricultural chemicals, and the Pharmaceutical Affairs Law governs (among other things) under what circumstances veterinary drugs are to be prescribed (FAO, 2004a). Guidance has been issued by the Fisheries Agency to members of the aquaculture industry that includes information about the use of drugs in aquaculture, which species they can be used for, and quantity (ibid.).

Conclusions and Final Score

It appears that most scallop farming relies on non-chemical methods of removal of predatory or fouling organisms, but data – particularly for the highest-producing regions – are not plentiful. Given the global scope of this report, there may be some circumstances in which chemicals are used for fouling, disease, or predation control. The final numerical score for Criterion 4 – Chemical Use is 9 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: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

C5 Feed Final Score (0-10)		**10.00**
Critical?	**No**	Green

Brief Summary

External feed is not provided to farmed scallops. Therefore, the final score for Criterion 5 – Feed is 10 out of 10.

Justification of Rating

External feed is not provided to farmed scallops as they are filter feeders and consume plankton and other particles that naturally occur in the water column (Yuan et al. 2010). As such, there is zero reliance on marine or terrestrial resources that are typical in the culture of fed species.

Conclusions and Final Score

The final score for Criterion 5 – Feed 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: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

C6 Escape parameters		Value	Score
F6.1 System escape risk (0-10)		0	
F6.1 Recapture adjustment (0-10)		0	
F6.1 Final escape risk score (0-10)			0
F6.2 Competitive and Genetic Interactions score (0-10)			8
C6 Escape Final Score (0-10)			**4.00**
	Critical?	No	Yellow

Brief Summary

Scallops are often cultured within their native ranges, but culture of non-native species occurs in many areas as well, with bay and Japanese scallops in China being the most commonly grown species currently. The direct escape of farmed scallop individuals is highly unlikely. However, there is a high risk of spawning-related escapes during the production cycle, as most species reach sexual maturity before they reach harvest size and literature indicates spawning does indeed occur. The risk of impact, though, is mitigated by the culture of native species that are genetically identical to wild populations (e.g. farmed stock is actually comprised of wild-spawned spat that settle on farm infrastructure) or non-native species that have not established wild populations during the multiple decades of open production. Factors 6.1 (0 out of 10) and 6.2 (8 out of 10) combine to result in a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

Justification of Rating

Factor 6.1. Escape risk

The risk of escape from an aquaculture production system is directly related to the degree of connection to the natural ecosystem. Typical production systems for farmed scallops include a spat collection or hatchery phase, intermediate nursery phase, and a grow-out phase. The nursery and grow-out phases represent the majority of the lifecycle, and typically occur in open systems (e.g., nearshore subtidal pelagic and benthic habitats in coastal areas).

Though scallops are capable of moving/swimming short distances (Stokesbury, 2009),their generally-stationary nature reduces the possibility of movement-induced escape events, particularly from systems which physically confine them (i.e. not sea ranching systems). Because scallop aquaculture systems are in coastal environments, they can be subject to weather-related damage, as is seen in other coastal farming systems like net pens used for finfish culture. In addition, marine organisms that prey on scallops such as fish, echinoderms, crabs, and snails (Guo and Luo 2016), whose efforts to consume them could damage the nets or other farming infrastructure. In these cases, it is possible that scallops do not remain confined to the system. However, literature searches have not yielded instances of adult scallop escape events, so they appear to be uncommon.

There is a risk that farmed scallops spawn before they are harvested, releasing large amounts of eggs to the receiving environment. For example, Chinese scallops can reach maturity in their first year while not attaining market size until 1.5–2 years (Guo and Luo 2016). There is evidence that spawned seed escaping from some cultured populations of Chinese scallops in China provides sufficient volume to support the industry, and hatcheries are not – or are rarely – used for this species (Guo and Luo 2016). In addition, Japanese scallops reach sexual maturity at approximately 2–3 years of age but are not harvested until approximately three years of age (This Fish 2013; Guo and Luo 2016; Silina 2016), and Guo and Luo (2016) report that both Japanese and bay scallops cultured in China spawn and produce larvae every year. While some bivalve aquaculture industries utilize polyploidy to mitigate spawning events during growout, the use of sterility techniques is not apparent in the scallop aquaculture industry.

While the direct escape of scallop individuals from farms may be infrequent, both the off-bottom and bottom culture systems used are open to the surrounding environment and spawning events during the growing cycle is common, if not a certainty. As such, the score for Factor 6.1 – Escape Risk is 0 out of 10.

Factor 6.2. Competitive and Genetic Interactions

Scallops are cultured both within and outside their native regions. Where farmed stock is within its native range, farm seed is generally wild-caught (as opposed to spawned by specific, managed broodstock families within hatcheries).

Culture of the Japanese scallop in Japan, and the Chinese scallop in China are both reliant on wild seed, using spat collector devices to gather and aggregate wild seed for grow-out (Guo and Luo 2016). Therefore, these cultured populations do not differ from wild populations genetically, and do not increase the potential for ecological impact from competition for resources or habitat, as the volume of seed in the wild is not amplified by hatchery production.

Production of bay scallops in Asia, and Japanese scallops in China is almost entirely reliant on hatchery production of seed (Guo and Luo 2016). These species are non-native in these regions (Padilla et al. 2011; Guo and Luo 2016). Japanese scallops were introduced to China for aquaculture and are mainly grown in the northern province of Liaoning and the Shandong peninsula where waters are cold enough (Guo and Luo 2016). The bay scallop, native to North and South America, was introduced to China from the United States for aquaculture, with the first successful introduction occurring in 1982 (Guo and Luo 2016).

Bay scallop seed in China is produced exclusively in hatcheries, with no natural seed available (Guo and Luo 2016). Japanese scallop seeds in China are mainly produced in hatcheries, however some natural seed collection (spawned by aquaculture stocks in the grow-out stage) is occurring (Guo and Luo 2016). Liu et al. (2010) found that genetic structures of cultured and wild Japanese scallop populations in Japan and China were similar, (although cultured populations showed lower genetic diversity), while native Japanese scallop populations in Russia were genetically distinct. Liu et al. (2010) cautioned that the release of Japanese scallops into natural areas could potentially result in disturbances to wild genetic structures, however both species have been produced in large volumes for multiple decades in China, and there is no evidence of established wild populations (Guo and Luo 2016). It is speculated that this is due to predation or a lack of habitat that is conducive to establishment (ibid.).

The Japanese scallop has been introduced in France and Western Canada from Japan, but production quantity is relatively low (Beaumont 2000; Parsons et al., 2016),. The species is non-native in both areas, and is raised in hatcheries (ibid). On the Atlantic coast of North America, scallop aquaculture is insignificant compared to wild captured landings, making up approximately 0.011% of total scallop production. The majority of production of bay scallops is intended for restoration efforts for native, wild stocks, and is not sold commercially (Robinson et al., 2016).

Scallops cultured in their native regions are reliant on collection of wild spat and are therefore genetically the same as their wild counterparts, and do not compete with wild populations for resources or habitat. Non-native scallop species have been grown in Asia for decades, and there is no reporting of the establishment of wild populations; as such, they are considered highly unlikely to establish viable populations. The score for Factor 6.2 is 8 out of 10.

Conclusions and Final Score

The direct escape of farmed scallop individuals is highly unlikely. However, there is a high risk of spawning-related escapes during the production cycle, as most species reach sexual maturity before they reach harvest size and literature indicates spawning does indeed occur. The risk of impact, though, is mitigated by the culture of native species that are genetically identical to wild populations (e.g. farmed stock is actually comprised of wild-spawned spat that settle on farm infrastructure) or non-native species that have not established wild populations during the multiple decades of open production. Factors 6.1 (0 out of 10) and 6.2 (8 out of 10) combine to result in 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: preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Criterion 7 Summary

Risk-Based Assessment

C7 Disease parameters		Score
Evidence or risk-based assessment	Risk	
C7 Disease Final Score (0-10)		**4.00**
Critical	No	Yellow

Brief Summary

Without a robust understanding of how on-farm disease impacts wild organisms (i.e. Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment methodology was utilized. Scallop culture occurs in open production systems with varied levels of biosecurity. There are many diseases known to affect cultured populations of scallops, however the vast majority of reports are from more than 20 years ago, not all pathogen infections resulted in mortality, and it was suggested that many mortality events seen in scallop culture were driven by environmental – not pathogenic - factors. It is unclear whether disease events have affected wild populations of scallops or other organisms. Ultimately, farms are likely to experience disease challenges and are fully open to the introduction and discharge of pathogens. The final numerical score for Criterion 7 – Disease is 4 out of 10.

Justification of Rating

As disease-related data quality and availability are moderate (i.e. Criterion 1 score of 5 out of 10 for the disease category), the Risk-Based Assessment methodology was utilized.

Infectious diseases have the potential to occur in all aquaculture systems, including hatcheries, nurseries, and growout systems, and may be associated with the transfer of broodstock, larval and seedstock. Large-scale culture of molluscs at high densities is prone to outbreaks of disease (Guo and Ford, 2016). There are several viral, bacterial, and parasitic diseases that have impacted scallop aquaculture over the last 4 decades, some with severe consequences for farmed populations. Many of the events that have resulted in mortality have been associated with other abiotic factors and are not directly attributed to pathogenic diseases. For example, Xiao et al. (2005) suggested that although some opportunistic invaders and pathogens were observed during mass annual summer mortalities of cultured Chinese scallop in China, they were likely not the cause of the observed mortalities. It was shown later that mass mortalities of Chinese scallops were caused by a herpesvirus, exacerbated by a combination of many factors including an increase in water temperature, high stocking densities, and low genetic diversity (Guo and Ford, 2016). No specific pathogens have been identified as associated with mass mortalities of Japanese scallops cultured in China (Guo and Luo 2016).

Getchell et al. (2016) list a number of diseases reported in cultured scallops (many of these are not definitively linked to mortalities). In Chinese, Japanese, and bay scallops, many of the reported diseases occurred in hatcheries, not grow-out stages. For purposes of this document, only diseases reported in grow-out are included. These reports are found in Table 5 below. Of note, there is only one report within the last 20 years.

Table 5. Reported disease events in adult Chinese, Japanese and bay scallops. Source: Getchell et al. (2006) unless otherwise noted in the table.

Scallop species	Parasite or disease	Geographic area/timeframe	Additional information
Bay scallop (*A .irradians*)	*Vibrio natriegens*	China 1996	Adult scallops in a hatchery in Shandong province
	"Chlamydia-like organism"	Canada pre 1982	Discovered in a quarantine facility after movement of late juvenile and adult scallops (Morrison and Shum 1982)
	"Chlamydia-like organism"	Japan pre 1998	Directly attributed to mass mortalities
	"Rickettsial-like organism"	Canada pre 1983	Discovered in a quarantine facility after movement of late juvenile and adult scallops (Morrison and Shum 1983)
	"Rickettsial-like organism"		Specimens collected over 12-year period in eastern US. "Light to moderate rickettsial infections of the gill were occasionally found in wild, captive, and cultured adult bay and sea scallops." No significant mortality detected (Liebovitz et al. 1984)
	Coccidia		In cultured settings mortality rates exceeded 80%. Infections later found in wild scallops, but it is unclear whether this was related to cultured populations. (Liebovitz et al. 1984)
	Balanosporida	Yellow Sea, China	Infections minor, but post-spawning mortality was high. No direct causation between infection and mortality.
Chinese scallop (*C. farreri*)	Ostreid Herpesvirus - 1 variant (OsHV-1 var) or acute viral necrosis virus	China beginning 1998, continuing annually with variation	Associated with annual mass summer mortalities, but not directly attributed. Other factors including increased water temperature, high stocking density, and low genetic diversity are also attributed to these mortality events. Bay scallops in the same area at the same time were not affected (Guo and Luo 2016)
	Trichodina jadranica (Xu et al. 1995)	Qingdao, China, October 1993	Unknown whether this resulted in mortality

***Chlamys* sp.**	*Trichodina polanidae*	Japan pre 1974	Unknown whether this resulted in mortality
Japanese scallop (*P. yessoensis*)	*Vibrio splendidus*	China 2009-2011	
	Perkinsus sp.	Russia (from scallops imported from Japan) pre 1986	
	Perkinsus qugwadi	BC, Canada 1988-1995	Native to BC. Between 1988 – 1995 resulted in 60% mortality rate in adult scallops. Disease not easily horizontally transmitted. Progeny of surviving infected scallops display resistance.
	Haplosporidium nelsoni	Yellow Sea, China	Monthly infection rate varied between 10%-40% in the summer, peaking in August. Only found on scallops in raised suspension, not bottom culture
	Trichodinid (possibly *T. polanidae*)	Pre 1986	

While there have historically been recorded incidents of disease in cultured scallops, there is very little information discussing the occurrence or potential for amplification and/or transmission of disease from farmed scallop populations to wild populations of scallops or other potentially affected organisms.

In all areas where scallops are cultured, biosecurity measures are implemented that aim to minimize the risk of impact to farmed populations from disease, and subsequently the risk of transmission between farms is minimized as well. China implements the Entry and Exit of Animal and Plant Quarantine Law, which states that all animals being transported internationally (import or export) are subject to quarantine inspection, and quarantine certificates from the country of export are required for all animals (NALO, 2004). The Law on Animal Diseases provides procedures for the control and management of animal diseases. China has an Aquatic Animal Epidemic Prevention System which works to study, detect, monitor, and report upon aquatic diseases, as well as develop prevention plans and work plans (Feng 2013). There are 13 provincial aquatic animal disease control centers, and 628 county aquatic animal disease prevention stations which work to carry out technical work for the program. Although China is working to strengthen aquatic animal health management through programs such as this one, disease prevention and control is still lacking (Feng 2013). Recent research has developed the ability to detect pathogens in scallops (Xiang, 2015), however it is unclear how widely spread access to this technology is, and how the industry reacts when a pathogen is detected.

Japan implements Measures to be Taken against Invasive Alien Species, which includes movements within the country. The Law to Partially Amend the Law on the Protection of Fishery Resources includes measures to prevent the spread of disease, and requires permits for the shipment of fish (FAO 2004). At the prefecture level, Hokkaido Prefecture has contingency plans in place for disease management (Standard Operating Procedure for Disease Response and Strange Death Manual, Parts 1 and 2), with appropriate response measures (MSC 2013).

In Canada, the National Aquatic Animal Health Program (NAAHP) aims to protect wild and cultured animals against infectious diseases and uses spatial management to limit the introduction and spread of diseases (DFO 2016d). It includes requirements for listed diseases of concern. Diseases included in Table 5 above that are present on Canada's list of reportable diseases include any disease caused by *H. nelsoni*, *Perkinsus marinus*, or *Perkinsus olseni*.

Unfortunately, despite information regarding the diseases farmed scallops are susceptible to and a basic understanding that biosecurity measures are implemented, the understanding of how on-farm diseases have (or have not) impacted wild shellfish populations is poor.

Conclusions and Final Score

Scallop culture occurs in open production systems with varied levels of biosecurity. Historically there have been reports of diseases affecting cultured populations of scallops, however the vast majority of reports are from more than 20 years ago, and not all resulted in mortality. It is unclear whether disease events have affected wild populations of scallops or other organisms. While biosecurity measures may be in place and implemented, current knowledge gaps regarding disease transmission and risk factors may prevent biosecurity measures from removing all risk of spreading disease. Without robust understanding of how on-farm diseases impact wild populations, the Risk-Based Assessment methodology is used; ultimately, farms experience disease-related mortalities and are fully open to both the introduction and discharge of pathogens. The final numerical score for Criterion 7 – Disease is 4 out of 10.

Criterion 8X: 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: using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture.

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 8X Summary

C8X Source of Stock – Independence from wild fish stocks	Value	Score
Percent of production dependent on wild sources (%)	0.0	0
Use of ETP or SFW "Red" fishery sources	No	
Lowest score if multiple species farmed (0-10)		n/a
C8X Source of stock Final Score (0-10)		**0.00**
Critical?	No	Green

Brief Summary

In areas where cultured scallop species are native (e.g. Japanese scallop production in Japan, Chinese scallop production in China), production relies on the collection of wild seed using natural settlement technologies. Areas where cultured scallop production is of non-native species (e.g. Japanese scallop and bay scallop in China), production relies on hatcheries. It is unclear what percentages of the global scallop industry rely on collection of truly wild seed, especially given the collection of "wild" seed from cultured populations in the Chinese scallop industry in China. Collection of wild seed for the Japanese scallop industry in Japan and Chinese scallop industry in China uses collection devices for natural settlement. Ultimately, all scallop seed for farm production comes either from domesticated broodstock or from passive settlement in open water; as such, there is no unsustainable dependence on wild scallops for farm production. The final score for Criterion 8X – Source of Stock is 0 out of -10.

Justification of Rating

The FAO Cultured Aquatic Species Information Program (FAO 2006) for Japanese scallop states that the species can be hatchery raised but spat is almost exclusively collected from the wild for scallop culture. Kosaka (2016) states that the Japanese scallop industry in Japan is now based entirely on wild spat collection using technologies for natural settlement. The same is true for the Chinese scallop industry in China, which collects wild spat spawned from cultured populations (Guo and Luo 2016). Spawning times are estimated, and larval monitoring determines where spawning events will occur. Spat collection devices are set in areas where larvae are common, and left to collect spat, until they are retrieved and brought to nursery sites.

In industries where hatcheries are used for seed stock (e.g. Japanese scallops cultured in China, bay scallops cultured in China and Japan), scallops for broodstock may be selected from cultured or wild stocks and kept as hatchery broodstock (Kosaka 2016; Guo and Luo 2016; Robinson et al. 2016). Generally, scallop species being cultured in areas where they are non-native are typically produced in hatcheries and are not reliant on wild populations for grow-out stock.

Conclusions and Final Score

In areas where cultured scallop species are native, industries rely on the collection of wild spat using natural settlement technology. Areas that culture non-native scallop species are reliant on domesticated hatchery production of spat. As such, there is no unsustainable dependence on wild populations. The final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

Criterion 9X: Wildlife Mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with farm sites.

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

Risk-Based Assessment

C9X Wildlife Mortality parameters		**Score**
Single species wildlife mortality score		-2
System score if multiple species assessed together		n/a
C9X Wildlife Mortality Final Score		**-2.00**
Critical?	No	Green

Brief Summary

Without a robust understanding of how the presence and operation of scallop farms may result in mortality of wild organisms (a Criterion 1 score of 5 out of 10 for the wildlife mortalities category), the Risk-Based Assessment methodology was utilized. Scallop aquaculture utilizes passive exclusionary devices to avoid predation on cultured stocks. The use of these devices has no evidence of direct or accidental mortality of predators or wildlife. In areas where on-bottom culture methods are used there may be some mortality of resident individuals during clearing, however the cleared area is not thought to affect the impacted species' population status, as many are opportunistic species, and recover rapidly. The final score for Criterion 9X – Wildlife Mortalities is -2 out of -10.

Justification of Rating

Without a robust understanding of how the presence and operation of scallop farms may result in mortality of wild organisms (a Criterion 1 score of 5 out of 10 for the wildlife mortalities category), the Risk-Based Assessment methodology was utilized.

A variety of shellfish predators exist on scallop farms, including echinoderms, gastropods, crustaceans, fishes, and seabirds. Infrastructure for shellfish farming, along with the shellfish themselves in some cases can act as both an attractant for wild species, as well as a deterrent

(Callier et al., 2018). Structures can serve as artificial reefs, providing additional habitat area for predatory and non-predatory species (ibid.) This can result in an increase in species diversity and/or abundance, however it is also noted that there is a possibility that large marine species such as pinnipeds, and turtles to avoid suspension-culture areas due to difficulty navigating the infrastructure (ibid.). Best Management Practices for predator control may include system design and methods of prevention, including sowing at times when predation is least likely to occur, hand removal of predatory species, and relocation of predators (pers. comm., Fenjie Chen May 2017). Netting and other passive 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).

Suspended culture methods generally use design technologies to minimize the threat of predators entering the production system (Kosaka 2016; Guo and Luo 2016). These exclusion methods are passive, and are not known to result in direct or accidental mortality to wildlife or predators.

On-bottom culture of scallops requires the clearing of culture area, which can result in the mortality of organisms living on and in the benthos. Harvest practices may also result in mortalities if dredging practices are used. Generally, these mortalities result in an initial decline in abundance and biomass for all species in the immediate area (i.e., predators, target species and other benthic organisms), but the decline is often followed by rapid benthic recovery (Mercaldo-Allen and Goldberg 2011).

It is unclear what percentages of the global scallop industry rely on suspended or on-bottom culture methods. In China, approximately 50% of Japanese scallop production uses on-bottom culture methods, however Japanese scallop production in China represents <20% of the industry (Pers. comm., X. Guo, 2020). It is estimated that >90% of the scallop industry in China uses suspended culture methods (ibid.). Suspended and on-bottom culture methods are also used in Japan (Kosaka 2016) and eastern North America (Robinson et al. 2016), but, it is unclear what percentages of these industries rely on which methods.

Conclusions and Final Score

The global scallop industry relies on both suspended and on-bottom production methods. Suspended culture is not associated with predator or wildlife mortalities beyond removal of fouling species and predators from cages or netting. On-bottom production methods are associated with mortalities of resident individuals from the clearing and harvest stages of production. While these mortalities can reduce the abundance of species immediately following clearing or harvest, recovery is rapid, and these methods are not associated with any impacts to species population status. The final numerical score for Criterion 9X – Wildlife Mortalities is -2 out of -10.

Criterion 10X: Introduction of secondary species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- Impact: aquaculture operations by design, management or regulation avoid reliance on the movement of live animals, therefore reducing the risk of introduction of unintended species.

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

Criterion 10X Summary

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on transwaterbody movements (%)	20.0	7
Biosecurity score of the source of animal movements (0-10)		4
Biosecurity score of the farm destination of animal movements (0-10)		0
Species-specific score 10X Score		-1.80
Multi-species assessment score if applicable		n/a
C10X Introduction of Secondary Species Final Score		**-1.80**
Critical?	No	Green

Brief Summary

There is evidence of movements of both hatchery raised and wild caught scallop seed. Percentages of the global industry reliant on movements are assumed to be around 20%, as the majority of movements of scallop seed produced in China remain in-country , resulting in a Factor 10Xa score of 7 out of 10. Hatcheries employ best management practices to minimize the risk of disease introduction, and the percentage of the industry reliant on hatchery production is approximately 80%, resulting in a Factor 10Xb score of 4 out of 10. The final numerical score for Criterion 10X –Introduction of Secondary Species is -1.8 out of -10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

Production of farmed scallops relies on both locally collected seed and trans-waterbody movements of seed (both hatchery-raised and collected from the wild). The bay scallop is the most commonly produced scallop species in China (Guo and Luo 2016) and is also produced in Japan at commercial volumes (Kosaka 2016). Its production in both China and Japan is entirely hatchery-based. It is not clear whether a percentage of hatchery produced bay scallop seed is transported between waterbodies in China and Japan, although the majority of bay scallop seed are produced in Shandong, and sold to farmers in Shandong, Liaoning and Hebei provinces within China (Pers. comm., X. Guo, 2020).

Production of Japanese scallops occurs in the largest volumes in China and Japan. In China, Japanese scallop seed production occurs in hatcheries, and with the majority transported to Liaoning Province in the same waterbody. In Japan, culture of Japanese scallops relies on spat collected from the wild. While some spat are collected and cultured locally, some is transported to different growout locations around the island of Hokkaido as needed to supplement lower spat collection in certain areas due to natural fluctuations (Kosaka 2016). Japanese scallop juveniles are also transported from the island of Hokkaido to Miyagi and Iwate prefectures on the island of Honshu. The Hokkaido Prefecture introduced movement regulations in 2002 that prohibited the introduction of scallops, oysters, and clams to the island from other areas of Japan or outside of Japan, however scallops are still transported within the island to other Japanese prefectures. Movement of all juvenile scallops is documented by Cooperatives and monitored by the Hokkaido Prefecture (MSC 2013). It is unclear how often these types of transportation occur, and what percentage of the industry they represent.

Culture of Chinese scallops occurs mainly in China, where spat are collected from the wild (Kosaka 2016). The majority of Chinese scallop production occurs in Shandong and Liaoning provinces, as does the majority of seed collection. It is therefore assumed that there is no international or trans-waterbody movement of Chinese scallop seed.

While it is clear that trans-waterbody movements of scallop seed are occurring in the countries with the highest production volumes, it appears that the majority of movements in China and Japan are not international or trans-waterbody. While exact percentages are not known, it is assumed that 20% of global scallop production is reliant on international/trans-waterbody animal movements the score for Factor 10Xa is 7 out of 10.

Factor 10Xb Biosecurity of source/destination

Where scallop seed is grown in hatcheries, generally there are biosecurity measures in place to reduce the risk of introduction of disease. In China, there are approximately 2,000 hatcheries, many of which produce multiple species of mollusks and invertebrates, with Japanese and bay scallops being the focus (Guo and Luo 2016). Large concrete tanks are often used, with influent seawater being treated using a settlement tank and sand filters (ibid.). Scallop seed produced in hatcheries generally go through an intermediate nursery stage between larval rearing and grow-out. This often takes place in large shrimp ponds or selected areas in the ocean, where they grow large enough to be deployed in open grow-out systems (ibid.). While information describing hatcheries in Japan is not available, it is assumed that biosecurity measures are similar to those in China.

In addition to hatchery seed production of bay scallops in Japan, Japanese scallop seed is also collected in the wild in Japan and is transported to various locations within the country, making the source of these seeds an open system. While transportation of wild collected seed does occur, it is not considered to be typical of global scallop industry.

The destinations for all transported scallop seed (hatchery raised or wild collected) are all open systems. While these open systems generally use biosecurity measures to minimize the risk of introduction of disease at that stage (e.g. site selection, water quality, etc.), it is unclear how effective they are in controlling the transmission of any pathogen or other secondary organism to wild populations.

The global scallop industry relies on both hatchery production of seed and wild collection. Some of this seed is grown out locally, while some is transported. These percentages are not known. Hatchery production is generally tank-based for the larval rearing stage, and the nursery portion occurs in large ponds. Biosecurity measures are taken to minimize the risk of introducing disease to hatchery stocks. Wild collection of scallop seed does not include biosecurity measures.

It is estimated that 80% of global scallop production relies on hatchery production (larval rearing tank and nursery ponds) (Pers. comm., X. Guo, 2020), which would result in a Factor 10Xb score 4 out of 10. The remaining 20% is assumed to rely on wild collection, which would result in a Factor 10Xb score of 0 out of 10. It is further assumed that movement of wild collected spat is not typical of the global industry. This results in an score of 4 out of 10 for the stock source for Factor 10Xb.

The destination of movements – the on-bottom or off-bottom growout sites – are likely to have some biosecurity protocols in place but are ultimately open to the environment. The score for the stock destination for Factor 10Xb is 0 out of 10.

The score for Factor 10Xb is 4 out of 10 (the higher of the two Factor 10Xb scores).

Conclusions and Final Score

There is evidence of movements of both hatchery raised and wild caught scallop seed. Percentages of the global industry reliant on these movements are unknown, and are therefore assumed to be 50%, resulting in a Factor 10Xa score of 7 out of 10. While hatcheries employ best management practices to minimize the risk of disease introduction, the percentage of the industry reliant on hatchery production is also unknown, resulting in a Factor 10Xb score of 4 out of 10. The final numerical score for Criterion 10X –Introduction of Secondary Species is -1.8 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 rating is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

- Best Choice = Final Score ≥6.661 **and** ≤10, and no Red Criteria, **and** no Critical scores
- Good Alternative = Final score ≥3.331 and ≤6.66, **and** no more than one Red Criterion, **and** no Critical scores.
- Red = Final Score ≥0 and ≤3.33, **or** two or more Red Criteria, **or** one or more Critical scores.

Criterion	Score	Rank	Critical?
C1 Data	6.59	Yellow	n/a
C2 Effluent	10.00	Green	No
C3 Habitat	7.20	Green	No
C4 Chemicals	9.00	Green	No
C5 Feed	10.00	Green	No
C6 Escapes	4.00	Yellow	No
C7 Disease	4.00	Yellow	No
C8X Source	0.00	Green	No
C9X Wildlife	-2.00	Green	No
C10X Introduction of secondary species	-1.80	Yellow	n/a
Total	46.99		
Final score (0-10)	6.71		

OVERALL RANKING

Final Score	6.71
Initial rank	Green
Red criteria	0
Interim rank	Green
Critical Criteria?	0

Final Rank
Green

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

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Appendix 1 - Data points and all scoring calculations

Criterion 1: Data	
Data Category	**Data Quality**
Production	7.5
Management	5.0
Effluent	7.5
Habitat	7.5
Chemical Use	7.5
Feed	10.0
Escapes	7.5
Disease	5.0
Source of stock	7.5
Wildlife mortalities	5.0
Escape of secondary species	2.5
C1 Data Final Score (0-10)	**6.591**
	Yellow

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**10**
Critical?	NO

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0-10)	9
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	3
3.2b Enforcement of habitat management measures	3
3.2 Habitat management effectiveness	3.600
C3 Habitat Final Score (0-10)	**7.200**
Critical?	No

Criterion 4: Chemical Use	
Single species assessment	Data and Scores
Chemical use initial score (0-10)	9.0
Trend adjustment	0.0
C4 Chemical Use Final Score (0-10)	**9.0**

Critical?	No

C5 Final Feed Criterion Score	**10.0**
Critical?	**No**

Criterion 6: Escapes	**Data and Scores**
F6.1 System escape risk	0
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	0.000
F6.2 Invasiveness score	8
C6 Escape Final Score (0-10)	**4.0**
Critical?	No

Criterion 7: Disease	**Data and Scores**
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0-10)	**4**
Critical?	No

Criterion 8X Source of Stock	**Data and Scores**
Percent of production dependent on wild sources (%)	0.0
Initial Source of Stock score (0-10)	0.0
Use of ETP or SFW "Red" fishery sources	No
Lowest score if multiple species farmed (0-10)	n/a
C8X Source of stock Final Score (0-10)	**0**
Critical?	No

Criterion 9X Wildlife Mortality parameters	**Data and Scores**
Single species wildlife mortality score	-2
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-2**
Critical?	No

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on transwaterbody movements (%)	20
Factor 10Xa score	7
Biosecurity of the source of movements (0-10)	4
Biosecurity of the farm destination of movements (0-10)	0
Species-specific score 10X score	-1.800
Multi-species assessment score if applicable	n/a

C10X Introduction of Secondary Species Final Score	**-1.800**
Critical?	n/a