Monterey Bay Aquarium
Seafood Watch®

Farmed Sturgeon

White sturgeon (Acipenser transmontanus)
Siberian sturgeon (Acipenser baerii)
Russian sturgeon (Acipenser gueldenstaedti)
Atlantic sturgeon (Acipenser oxyrinchus)
Beluga Sturgeon (Huso huso)
Sterlet (Acipenser ruthenus)
Sevruga (Acipenser stellatus)

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United States

Land-based flow-through and recirculating aquaculture systems

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Final Seafood Recommendation

The final numerical score for US farmed sturgeon is 7.53, which is in the green range. All criterion scores are in the green range with the exception of Feed and Chemicals, which are yellow. The final recommendation for aquaculture production of sturgeon in the US is green overall, or "Best Choice".

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.75	GREEN	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	8.93	GREEN	NO
C4 Chemicals	5.00	YELLOW	NO
C5 Feed	3.59	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	9.00	GREEN	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**60.27**		
Final score	**7.53**		

OVERALL RANKING

Final Score	7.53
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
Final Rank	BEST CHOICE

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Executive Summary

- Sturgeon aquaculture is currently practiced to varying extents in 35 countries globally. In the US, 1,350 metric tons of sturgeon meat and 15-20 metric tons of caviar were produced via aquaculture in 2012.
- Six species of sturgeon are raised in the US, but approximately 95% of production is white sturgeon *Acipenser transmontanus* raised in California and to a lesser extent in Idaho. The farms rearing other species are located in Oregon, Florida, Georgia, North Carolina and Hawaii. Due to the dominance of white sturgeon in the US marketplace, the assessment defaults to production details for this species, unless specifically noted.
- The majority of sturgeon produced in the US is raised for caviar, but the meat is also sold as whole (round and bullets), boneless, skinless fillets and varied smoked meat products as well. Smaller live fish (up to 5 kg) are sold to Asian markets in some North American cities.
- Much of the data used for this assessment was from personal communications with producers, researchers and government contacts. Very little recent academic data or information is available on the US sturgeon aquaculture industry due to its relatively small production volume and farm/species specific practices and proprietary nature.
- Sturgeons in aquaculture production are fed with commercial feed pellets. Most development of sturgeon feeds for North American production has occurred within the last two decades as sturgeon aquaculture has grown. Major feed manufacturers supplying US producers include Skretting, EWOS and Rangen.
- Feed formulation were not available from US feed suppliers due to their proprietary information, instead data from BioMar (a major European feed supplier) was used and indicates approximately 30% marine ingredients, with the remainder comprised of crop ingredients. Aquafeeds in North America, including for sturgeon, may contain terrestrial animal ingredients such as poultry by-products, blood and feather meal. The FCR ranges from 1.4-1.5 for younger, harvested males to 2.5 for mature females. This FCR holds true only if both the caviar and meat are being harvested. Since feeding is mostly weighted towards females, an FCR of 2.5 was used and results in an FIFO of 1.97. The high demand on marine resources and loss of edible protein results in a low-moderate score of 3.59 out of 10.
- Sturgeon aquaculture in the US is practiced in tanks, either in flow-through or recirculating systems. Most farms practice filtration and effluent treatment, and even flow-through facilities will sometimes use water multiple times, passing it through hatcheries, tanks, or ponds (Van Eenennaam pers. comm.). Some flow-through systems in California and Idaho use more traditional raceways. The major producers in California re-use effluent for agricultural irrigation or filter through. Nutrient waste in discharged water is taken up by farming operations or wetlands prior to entering natural waterways. Overall, there is a low risk of impact beyond the farm from effluent discharge and the score is 7 out of 10.
- Chemical therapeutants such as antibiotics and parasiticides are not used frequently or prophylactically in sturgeon aquaculture, although some treatment may be required

when fish are young and more vulnerable to disease. Not all production cycles require chemical treatment, and not all fish need to be treated at any one time. External parasites that occur are usually remedied using salt treatments. Although antibiotics are used on a small proportion of fish early in a long (4-8 year) production cycle (and for this would score 8 out of 10), the drug in use (oxytetracycline) is still considered highly important for human health. The chemical criterion results in a moderate score of 5.

- As high value commodities, sturgeon in production facilities are tightly controlled and numerous biosecurity measures are used to prevent any escape of fish. White sturgeon are a native species in California and the long. Discharge water leaving sturgeon farms goes into the local irrigation district and used in agricultural fields prior to reentering natural waterways. No escapes events have been observed and no escapees would survive the water use for irrigation.
- In California, where the most white sturgeon production occurs, broodstock are no longer sourced from the wild and production animals are approximately two-three generations removed from the wild.
- Several sturgeon diseases, particularly viruses, can become problematic in aquaculture production, however with preventative disease management strategies, disease occurrences are limited and the lack of connection between aquaculture production and wild populations greatly reduces the risk of disease transmission. There is no evidence of transfer to wild populations or amplification of naturally occurring pathogens. The disease criterion score is a high 9 out of 10.
- With regard to environmental impacts, aquaculture production of sturgeon in the US has high (green) scores in all criteria with the exception of a moderate chemical use score (5 out of 10) and low score for Feed (3.59 out of 10). Overall, farming sturgeon in the US does not result in significant ecological risks or impacts. With a final score of 7.53 out of 10, sturgeon aquaculture in the US receives a “Best Choice” seafood recommendation.
- **NOTE: The above scoring and recommendation assume the production and sale of both caviar and sturgeon meat. Sturgeon aquaculture with caviar as the sole product would result in a different recommendation that has not yet been assessed.**

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Introduction

Scope of the analysis and ensuing recommendation

Species:
White sturgeon (*Acipenser transmontanus*) are the primary species in aquaculture production, comprising about 95% of sturgeon products on the US marketplace (Michaels pers. comm.). Although it is anecdotally reported that Siberian sturgeon (*A. baerii*) are the secondary species in the US production (Van Eenennaam pers. comm.), the remaining 5% are a combination of Siberian sturgeon (*Acipenser baerii)*, Russian sturgeon (*A. gueldenstaedti*), Atlantic sturgeon (*A. oxyrinchus*), sterlet (*A. ruthenus*) and sevruga (*A. stellatus*). Although there are two farm raising beluga (*Huso huso*), they are not currently selling either meat or caviar.

Geographic coverage:
This assessment focuses on sturgeon production in the US, mainly on California sturgeon aquaculture and smaller operations in Idaho, Oregon, Florida, Georgia and North Carolina.

Production Methods:
Sturgeon are raised using land-based tanks, operating either as flow-through or recirculating aquaculture systems.

Species Overview

Sturgeon aquaculture originated a century ago in Europe and North America as an attempt to supplement wild stocks and to augment sturgeon fisheries. However, global sturgeon catches have been declining rapidlysince the late 1970's, and all twenty-six species of sturgeon (order Acipenseriformes, family Acipenseridae) are now depleted, with several species currently threatened with extinction. Although Siberian sturgeon *A. baerii* seems to dominate sturgeon aquaculture production sturgeon aquaculture of the United States is nearly entirely comprised of white sturgeon (*A. transmontanus*) native to Alaska, California, Idaho, Montana, Oregon, Washington and British Columbia). The commercial sturgeon aquaculture industry arose in the US in the 1980's, when the white sturgeon life cycle was successfully closed in captivity in California (Carter 2011, Doroshov 1985).

Sturgeon biology and life history make it a unique species to culture. The late sexual maturity and longevity of many sturgeon species leads to a much longer production cycle compared to most other cultured fish. Sex differentiation does not occur in white sturgeon until the ages two and four years. Sturgeons do not have well expressed external sex dimorphism and ultrasound is the most common method to determine the sex once differentiation has occurred. When sex is known, gender specific gamete production cycles are followed: annual in males and biennial in females. The selected individuals of each gender are retained as a broodstock, and most males are slaughtered for meat prior to four years of age or sold in the live fish markets while most females are kept for the caviar harvest.

Production statistics:
Sturgeons are currently raised and bred via aquaculture in 35 countries around the world. Global production of all species of sturgeon (meat and all other reported products) in 2010 was estimated to be 40,000 metric tons with 88% coming from China (FAO 2011). The other leading producers are Russia, Italy, Bulgaria, France and Iran. US sturgeon aquaculture yielded 1,350 metric tons of meat and 15-20 metric tons of caviar in 2012 (Michaels 2012).

Import and export sources and statistics:
The main sturgeon and caviar importers to the US are Germany, Israel, Italy, Korea and China with a total of about 19 metric tons imported in 2012 (import statistics do not distinguish between farmed and wild caught product; NMFS 2012). The import and sale of caviar from certain sturgeon species, such as beluga (*Huso huso*) is banned in the US.

Common and market names:
US farmed sturgeon is sold as such, while farmed caviar is typically clearly listed as US farmed but marketed under various names including American Ossetra (or Osetra), Alverta, White Californian, Transmontanus and Siberian. Large producers in the US include Sterling Caviar (a division of Stolt Sea Farm) and Tsar Niccoulai (TNC Holding Company).

Product forms:
The majority of sturgeon produced in the US is raised for caviar, with meat sold as whole (round and bullets), boneless, skinless fillets and varied smoked meat products. Smaller, live fish (up to 5 kilograms) are sold on the Asian markets in some North American cities (Michaels, 2012).

Analysis

Scoring guide

- With the exception of the exceptional factors (3.3x and 6.2X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.seafoodwatch.org/cr/cr_seafoodwatch/content/media/mba_seafoodwatch_aquaculturecriteramethodology.pdf
- The full data values and scoring calculations are available in Annex 1

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	Yes	5	5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other – (e.g. GHG emissions)	Yes	5	5
Total			**67.5**

C1 Data Final Score	**6.75**	**GREEN**

Justification of Ranking

Data quality and availability for sturgeon aquaculture in the US is generally high. Areas with data gaps that affect the assessment include industry and production statistics and information regarding feed formulation and ingredient sourcing. No official sources provide comprehensive production statistics for all species, however individual producers and researchers have been very helpful in this capacity (Michaels pers. comm., Struffenegger pers. comm., Van Eenennaam pers. comm.). Feed formulations are often not made available, even to producers and researchers or may require confidentiality agreements. As such, both data for ingredient proportions and sourcing of raw ingredients were necessarily obtained from data less specific to species and region. The data for many aspects of the assessment is improved by the fact that the industry is relatively small (~20 farms) and production facilities are land-based. Much data in the report is from producers and has not been independently verified; without verification the highest data score possible is 7.5. Overall, US sturgeon aquaculture scores 6.75 out of 10 for the Data criterion.

Criterion 2: Effluents

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary

Effluent Rapid Assessment

C2 Effluent Final Score	**7.00**	**GREEN**

Although the fate of effluent discharge differs from farm to farm, the data from the largest white sturgeon producer in California demonstrates that wastewater is managed by using it for agricultural irrigation or filtered through wetlands. The data quality score is 7.5 so the rapid assessment was used. Data show no evidence of impact on natural waterways and minimal risk of contributing to local or regional impacts and US Sturgeon aquaculture scores a 7 out 10 for the Effluent criterion.

Justification of Ranking

Sturgeon aquaculture in the US is entirely made up of land-based production facilities, operating somewhere along the spectrum of traditional flow-through to complete recirculation (Doroshov pers. comm., Van Eenennaam pers. comm.). Currently there are 22+ sturgeon operations in North America (Michaels 2012), nearly all owned and operated independently of one another. The system characteristics and effluent filtration and treatment are not uniform across all production, but the split between flow-through and recirculating systems is approximately 50:50 (Van Eenennaam pers. comm.). Approximately 95% of US production is white sturgeon (*A. transmontanus*) and as 85% of that comes from California, the water use and filtration characteristics of these farms have been used to inform the system characteristic score (Carter 2011, Michaels pers. comm.).

Traditional flow-through tank operations pump water into production tanks for a single use through the system. California has water restrictions and use guidelines in place that result in flow-through sturgeon facilities that often multi-use water (feeding it first through hatcheries, then on-growing tanks, then ponds; Van Eenennaam pers. comm.). Effluent guidelines may also require solids filtration and some level of water treatment depending on the final destination of effluent discharge.

Sterling Caviar, one of the largest producers in California operates three farms, two functioning as flow-through and one as partial recirculation. Land for one flow-through farm is leased from an irrigation district with effluent released back to the district to resell for use on agricultural land. The second flow-through farm is situated on a large ranch and all effluent water is pumped to irrigate the ranch. Although no filtration or treatment is employed for either of these farms, the nutrients and water are applied directly to agricultural fields rather than being discharged back to natural water bodies. The partial recirculation system releases its effluent to a neighbouring property, a wetland owned by a conservation group intended to enhance habitat for giant garter snakes and Swainson's hawk. When water is eventually discharged from the wetland property, it goes back to the reclamation district and is sold for irrigation (Struffenegger pers. comm.). Research has demonstrated that constructed wetlands remove between 86-98% ammonium nitrogen and 95-98% total inorganic nitrogen is from aquaculture effluents (Lin *et al*. 2002). The effluent from all the Sterling farms has nearly all the particulate and dissolved nutrients removed by wetlands or agricultural use prior to entering natural waterways.

Other sturgeon production systems in the US have endeavoured towards the goal of becoming zero-discharge facilities. Tsar Nicoulai is another white sturgeon producer in California, which operates as near complete recirculation using stripping towers, drum filters, biofilters and aquaponics to remove nutrients from water before it is run through the production tanks again (TNC Holding Company 2011). Mote Marine Laboratory in Florida operates a Sturgeon Commercial Demonstration Program, which produces mainly Siberian sturgeon (*A. baerii)* with the additional purpose of improving production technology and reducing the environmental impact from sturgeon aquaculture. Mote Laboratory operates a recirculating system with 12% water usage per day and uses denitrification processes along with aquaponics (for seedstock/replanting of littoral zones of stormwater retention ponds) to reduce the effluent waste from production. Any remaining water is spread on pastureland, resulting in a zero-discharge facility (Michaels pers. comm.).

The combination of federal regulations and California state regulations result in appropriate oversight and management of effluent in sturgeon aquaculture. Effluent regulations are scientifically robust; specific to aquaculture operations; and site-specific limits to discharges, effluents and biomass are set to cover the entire production cycle. Discharges from aquaculture facilities are permitted and monitored under the National Pollutant Discharge Elimination System (NPDES) as authorized by the Federal Clean Water Act (US EPA 1972). Within this, sturgeon production is governed as Concentrated Aquatic Animal Production, which requires certain management practices and record-keeping activities (US EPA 2006). In California, NPDES permits are issued by the Regional Water Quality Control Board (RWQCB) for the production area and are subject to compliance monitoring as well as periodic review and renewal, currently on a five-year basis. Each permit is tailored for a specific discharge and takes into consideration the type of activity, nature of the discharge, receiving water quality and other discharge sources to that water. The central water governance for the region ensures that cumulative impact of multiple facilities (aquatic and otherwise) is taken into consideration when issuing permits. Observance with NPDES permits is monitored by the RWQCB and limits are enforced with penalties for non-compliance.

A combination of proper effluent treatment through agricultural operations or wetlands prior to release into natural waterways and high regulatory and management effectiveness results in a high overall Effluent score of 7 out of 10. This good (green) result supports the conclusion that as the large majority of farmed US sturgeon comes from sites where wastewater has a low risk of negative environmental impacts.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		10.00	
F3.2a Content of habitat regulations	4.25		
F3.2b Enforcement of habitat regulations	4.00		
F3.2 Regulatory or management effectiveness score		6.80	
C3 Habitat Final Score		**8.93**	**GREEN**
Critical?	NO		

Sturgeon aquaculture is practiced in land-based facilities with a small footprint, generally on former agricultural land. Strong regulations exist in the US to prevent the loss of high value ecosystems or ecological services. The Habitat criterion receives a high score of 8.93.

Justification of Ranking

Factor 3.1. Habitat conversion and function

Land-based sturgeon farming in the US involves intensive production, with large amounts of biomass produced per farm. The life cycle of sturgeon necessitates that any of the facilities producing caviar have been established for at least 8-10 years prior to entering the marketplace (although farms selling younger males for meat may start sale earlier). Many production facilities are located on land previously used for other agricultural purposes. In California (where approximately 80% of US sturgeon production occurs), aquaculture is defined in the Fish and Game Code as a form of agricultural production and facilities are treated as agricultural facilities and land uses in planning (Conte 1996). Although originally the conversion of natural habitats to agricultural land may have resulted in loss of ecosystem service and function, the construction of buildings and tanks for sturgeon has not resulted in further impacts on the surrounding ecosystem.

The lack of farms sited in high-value habitat and no net loss of ecosystem services results in a Habitat conversion and function (Factor 3.1) score of 10 out of 10.

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

As mentioned in the Effluent criterion, aquaculture in the US operates under the governance of several federal and state laws and regulations, which are implemented by a number of federal and state agencies permitting and monitoring different aspects of production. In California, the lead agency is the Department of Fish and Wildlife (CDFW). The inland aquaculture industry in California is currently small enough that cumulative impacts are not considered (by this assessment) to be a concern; consideration will be given to the industries' total size and concentration if growth increases (Lovell pers. comm.). Regulatory control measures prevent the siting of facilities in high-value habitats and the placement of sturgeon facilities on agricultural land may prevent it from being converted to residential or other use. The application and approval process differs depending on the location and species, but is considered suitable to prevent farm siting from reducing ecosystem function (Lovell pers. comm.). In 2005, the Public Resources Code (PRC) Section 30411(e) amended the Department of Fish and Game Code to require the preparation of programmatic environmental impact reports (PEIRs) for both coastal and inland commercial aquaculture projects. While the PEIR for inland aquaculture is currently still under development, its requirements will include systematic assessment of appropriate siting, potential impact on sensitive habitats, the cumulative effects of multiple farms and facility design to minimize impact. Under this, CDFW will be responsible to prevent or stop activities deemed damaging to the environment. The combination of the regulatory content and enforcement means that the regulatory management effectiveness score (Factor 3.2) is 6.8 out of 10.

US sturgeon aquaculture receives high scores for both Habitat conversion and function (10) and Regulatory and management effectiveness (6.8), resulting in a high overall score of 8.93 out of 10 for the habitat Criterion.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use*

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**5.00**	
C4 Chemical Use Final Score	**5.00**	**YELLOW**
Critical?	NO	

Justification of Ranking

Chemical therapeutants such as antibiotics and parasiticides are very infrequently used during the aquaculture production of sturgeon in the US; often a salt treatment is the only remedy required (Doroshov pers. comm., Van Eenennaam pers. comm.). Chemical intervention may be necessary early in the life cycle when fish are most susceptible to disease problems (Michaels pers. comm., Struffenegger pers. comm., Renschler pers. comm.). Only one sturgeon producer interviewed indicated any use of antibiotics; oxytetracycline (Terramycin) is used periodically for treating bacterial infections in young fish. A small proportion of fish are treated (~4-5 out of every 50 tanks), when they are less than a year old. The volume of water with antibiotic in it is = about 100-200 gallons (depending on the tank) and is diluted in the untreated effluent that is passed through the farm at 3-9 Million gallons per day. There are no reports of prophylactic use of antibiotics. Best management practices are implemented to prevent disease occurrence through stress reduction and optimized stocking density. Hormonal injections are used to induce spawning in broodstock, however, these individuals are maintained separately from production animals and with the method used, there is no concern for the release of hormones into the surrounding natural waterways or causing risk to human health (Chebanov & Galich 2013).

Drug use in US aquaculture production is generally well governed. The US Fish and Wildlife Service run the Aquatic Animal Drug Approval Partnership Program (AADAP) in association with the AFS Fish Culture Section, AFS Fish Health Section and FDA Center for Veterinary Medicine (US FWS 2010). The AADAP publishes a list of drugs approved for use by the FDA, as well as recommended dosages and veterinary prescription requirements, and the farm indicating use of antibiotics is a participant in the AADAP (USFDA 2012). Regulatory restrictions governing chemical use are critical; oxytetracycline is an antimicrobial considered highly important to human health and its use should be judicious (WHO 2012).

The Chemical criterion for US sturgeon aquaculture scores 5 out of 10 due to evidence that although therapeutants are used on occasion, it is on average less than once per production cycle (or once out of a 4 or 8 year production cycle). However, the antibiotic used (oxytetracycline) is considered highly important to human health. The final chemical criterion score is a moderate 5 out of 10 and represents a mid-point between the very low chemical usage and the importance the drug being administered.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	1.97	5.07	
F5.1b Source fishery sustainability score		-2.00	
F5.1: Wild Fish Use		4.68	
F5.2a Protein IN	70.05		
F5.2b Protein OUT	14.11		
F5.2: Net Protein Gain or Loss (%)	-79.87	2	
F5.3: Feed Footprint (hectares)	19.40	3	
C5 Feed Final Score		**3.59**	**YELLOW**
Critical?	NO		

As noted in the executive summary, the scoring in this report reflects values calculated assuming the harvest and sale of both meat and caviar from sturgeon production. If a farm were producing solely for the sale of caviar, the feed use criterion would be critical. Sturgeon production in the US relies on the use of formulated feeds of proprietary origin; European sturgeon feed formulations have been used for the purpose of assessment and differences have been identified. The moderate use of marine resources, large loss of edible protein and large feed footprint results in low, but non-critical, feed score of 3.59.

Justification of Ranking

Factor 5.1. Wild Fish Use

Feed formulations are often considered proprietary and it can be very difficult to obtain all data points required to run a full feed assessment. Sturgeon producers have been working along with feed manufacturers to reduce the amount of marine ingredients in commercial feed during the development process (Michaels pers. comm.). Dietary requirements for sturgeon vary depending on life stage with crude protein requirements between 32-48% and lipid content between 8-16% (Michaels pers. comm., Van Eenennaam pers. comm.). There does not appear to be significant differences between the growout diets provided to different species of sturgeon in aquaculture production.

US sturgeon producers source feed from a number of large commercial feed manufacturers, including EWOS, Skretting and Rangen (Van Eenennaam pers. comm.). Although these companies keep feed composition values confidential, BioMar (a large European feed company) disclosed the values of their sturgeon feed. BioMar does not currently have US clients, however for the purposes of this assessment, it will be assumed that fishmeal and fish oil inclusion rates are similar to those used in US feed production. One main difference between aquaculture feed in North America and Europe is that terrestrial animal byproducts are prohibited for use in the European Union countries. North American feeds typically include poultry or porcine byproduct, but without confirmation of details no byproducts can be applied for this assessment.

BioMar sturgeon feed includes 24% fishmeal and 4.8% fish oil (Moutounet pers. comm.). Recent sustainability reports for EWOS and Skretting indicate an average of 26.1% of fishmeal from byproducts or trimming (28.2% and 24% respectively) and 19.5% of fish oil from byproducts or trimmings (15% and 24% respectively; Cermaq 2012, Skretting Norway 2012).

As stated under the Effluent criterion, feed conversion ratio is life stage dependent with the majority of feed going to mature females. The same eFCR value of 2.5 is applied in the Feed criterion to calculate the fish in fish out (FIFO) ratio. After accounting for the inclusion percentages of byproducts and trimmings in fishmeal and fish oil, the FIFO is a moderate 1.97. This means from first principles, 1.97 tonnes of wild fish would need to be caught to produce 1 tonnes of farmed sturgeon. This equates to a score from 0-10 of 5.07 in the Seafood Watch criteria.

The second factor considered in the wild fish use score is the Sustainability of the Source of Wild Fish (SSWF). Again, this can be a difficult data point to obtain accurately, as each batch of feed is usually formulated based on the most available and affordable source of fishmeal and fish oil. Since a large amount of sturgeon feed is sourced from EWOS and Skretting, the summary of their 2012 fisheries was used to inform this factor. Table 1 outlines the species and fishery origin of the major sources for both EWOS and Skretting and the associated percentage used (Cermaq 2012, Skretting Norway 2012). The FishSource management and fish stock scores are also listed, along with averages weighted by proportion of sourced fishmeal and fish oil (excluding the percentage from by-product and trimmings; SFP 2013).

Table 1: Reduction fishery sources and FishSource scores for Skretting and EWOS feed.

Company	Species and fishery origin	Fishmeal %	Fish oil %	FishSource scores				
				1	2	3	4	5
Skretting	Anchoveta - Peruvian northern-central stock	36.2	45.4	6	10	10	8.3	8

	Capelin - Icelandic	9.8	0	6	10	10	6	-
	Capelin - Barents Sea	8.3	10	8	10	10	6	6
	European sprat - North Sea	7.9	11.9	6	5.7	10	6	6
	Boar fish - NE Atlantic	3.1	0	6	-	-	6	6
	Lesser sand-eel - North Sea	1.8	0.8	6	10	6	6	6
	Atlantic herring - Icelandic summer-spawning	1.3	4	6	10	8.6	9.9	8.9
	Atlantic herring - Norwegian spring-spawning	1.1	0	8.4	10	9.9	8.9	7.7
	Blue whiting - Northeast Atlantic	0.9	0	8.9	10	6	10	10
	Norway pout - North Sea	0	0.8	6	10	10	8.5	6
	Gulf menhaden - Gulf of Mexico	0	9	6	6	6	10	10
	(By-product/trimmings)	28.2	15	-	-	-	-	-
	Total & Weighted Average	**98.6**	**96.9**	**6.3**	**9.0**	**9.4**	**7.7**	**7.1**
EWOS	Anchoveta (Peru)	52		6	10	10	8.3	8
	Anchoveta (Chile - III & IV)			6	5.4	10	6.8	9.3
	Anchoveta (Chile - V-X)			6	10	10	6	6
	Anchoveta (Chile - XV-I-II)			6	0.4	6	6	6
	Capelin – Norway, Iceland	9		7	10	10	6	6
	Sand Eel – Denmark, Norway	2		6	10	6	6	6
	Sprat – Denmark	5		6	5.7	10	6	6
	Menhaden – USA	4		6	6	6	10	10
	(By-product/trimmings)	24		-	-	-	-	-
	Total & Weighted Average	**96**		**6.1**	**6.9**	**8.9**	**6.8**	**7.2**

On the scale from 0 to -10 (with 0 being the best performance), both major feed manufacturers receive a high SSWF score of -2 out of -10. The weighted average FishSource scores demonstrate that in general sources of fishmeal and fish oil (and especially the most significant sources) are from more sustainable fisheries. Although there are a few exceptions, nearly all fisheries have FishSource scores of greater than or equal to 6, with at least one score of 8 or higher.

With a fish in fish out score of 5.07 and a SSWF score of -2, sturgeon aquaculture scores a moderate 4.68 out of 10 for the wild fish use factor.

Factor 5.2. Net Protein Gain or Loss

Commercial sturgeon feed has a protein content of 44%, derived primarily from fishmeal, corn protein concentrate, soya bean meal and poultry by-product meal (Michaels pers. comm.).

Ingredients that may be fit for human consumption include (the wild fish providing) the portion of fishmeal and fish oil not from by-products and some amount of protein in crop ingredients (Stoner 2012). Although producers indicate the presence of terrestrial animal meal and crop by-product, due to proprietary formulations it is unknown what percentages US sturgeon feed contain. As such, it is not possible to include these ingredients in the assessment and a conservative formula with all non-marine ingredients assumed to be edible crop. Using an average crude protein content of fishmeal of 65%, this means that approximately 10.8% of the protein in sturgeon feed comes from non-edible sources (from the 26.1% of fishmeal byproduct) and 89.2% feed protein is from edible crop ingredients (Miles & Jacob 2011).

The protein content of whole harvested white sturgeon is 18.2% (Price *et al.* 1989). Dress-out percentages for sturgeon are 70% and 40% yield for bullet and fillet form respectively (Palma *et al.* 2010). Some by-products from harvest are currently being composted, but it is unknown whether this accounts for all wastes and as such 50% of non-edible by-products from farmed fish are assumed as being used (indirectly) in other food production.

Accounting for protein going into the system in the form of feed and protein out in the form of fish, there is a substantial net protein loss for sturgeon aquaculture of 79.9% and results in a low score of 2 out of 10 for this factor.

Factor 5.3. Feed Footprint

As stated above, details about inclusion levels of crop ingredients and land animal ingredients are not available for US sturgeon feed. As the remainder of European sturgeon feed beyond marine ingredients comes from crop, for the purpose of this assessment the same composition is assumed for feeds in the US. For sturgeon feed, this means inclusion levels of approximately 71.2% crop ingredients. The resulting feed footprint is 19.4 hectares per ton of production (18.73 for marine and 0.67 for crop) and receives a score of 3 out of 10.

Sturgeon aquaculture requires high protein and marine inputs, and use of edible protein results in high demand on both marine and terrestrial resources. If the full formulations of US feed were known, the score would likely change due to inclusion of crop and animal byproducts. US farmed sturgeon scores 4.68 for wild fish use, 2 for net protein gain/loss and 3 for feed footprint combining for a low final Feed criterion score of 3.59.

As noted previously, the feed score would be lower and presumably critical if sturgeon were only produced and harvested for caviar rather than both caviar and meat.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		10.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		5	
C6 Escape Final Score		**10.00**	**GREEN**
Critical?	NO		

Justification of Ranking

The Escape criterion is more species dependent than other criteria as certain sturgeon species will have different invasiveness risk profiles. Although some information for other species is included in the description for the escape factors, the final scoring for this assessment is decided by the escape risk and invasiveness as assessed for white sturgeon because it dominates US production.

Factor 6.1a. Escape risk

Biosecurity at sturgeon production facilities is important for a number of reasons. To regulators, escapees can cause a variety of ecosystem impacts including additional competition, predation and possibility of breeding with wild individuals. To the producers, the cost and potential value per fish is very high. Multiple screens sized appropriately for the life stage of fish are on the inlets and outlets of sturgeon tanks to prevent any accidental escapes. White sturgeon farms in California are land-based and either operating as recirculating (some with zero discharge) or flow-through systems with only indirect connections to natural waterways. The reuse of effluent discharge to irrigate agricultural land further reduces the possibility of escapes; waste water is either applied to agricultural fields or filtered through wetlands prior to entering natural waterways. No sturgeon would survive this process should escapes occur. The escape risk score is further informed by the fact that no escape events have occurred (Doroshov pers. comm., Struffenegger pers. comm., Van Eenennaam pers. comm.).

Production in other areas of the country includes white sturgeon in Idaho and Siberian sturgeon (*A. baerii)*, bester sturgeon (beluga x sterlet hybrid) and Russian sturgeon (*A. gueldenstaedtii*) in Florida. Sturgeon aquaculture in Idaho operates using raceway facilities that operate as flow-through systems discharging directly into natural water bodies. However, multiple escape prevention measures are in place on inlets and outlets of tanks and are subject to regular inspection by the Idaho Department of Agriculture. Farms in Florida operate as recirculating systems with "zero" discharge to natural waterways due to the fact that Florida sturgeon culture is based on non-native species and it is a requirement for these operations (FDACS 2005, Hill 2006). To date, no escape events have been reported in Florida (Michaels pers. comm.).

In addition to preventative measures, the lack of direct connection that land-based sturgeon aquaculture facilities have to natural water bodies results in very low concern for escape risk and a score of 10.

Factor 6.1b. Invasiveness

The invasiveness factor is informed by two parts, the first scored for either native species (based on potential genetic differences from wild populations) or non-native species (based on species potential for establishment) and the second scored according to the species potential to cause ecosystem impacts.

White sturgeon (*A. transmontanus*) and Atlantic sturgeon (*A. oxyrinchus*) are the only native sturgeons cultured in the US. Due to the long life cycle of sturgeon neither of these has been domesticated, with three to five generations of hatchery raised fish used for aquaculture stock (Doroshov pers. comm., Struffenegger pers. comm., Van Eenennaam pers. comm.). The white sturgeon being raised in California and Idaho were sourced from nearby populations when breeding programs began and there is very little concern that theoretical escape of individuals from aquaculture facilities would result in loss of genetic fitness if they were to breed with wild populations.

Siberian sturgeon (*A. baerii*), Russian sturgeon (*A. gueldenstaedti*), sterlet (*A. ruthenus*) and sevruga sturgeon (*A. stellatus*) are all non-native species to the US. There is evidence from other areas of the world that a number of these species are capable of survival and even hybridization upon introduction to non-native regions (Arndt *et al.* 2002, CASIP 2005, Farský *et al.* 2013). It is this evidence that has resulted in strict guidelines for the aquaculture of non-native sturgeon species in the US.

Based on the farming of white sturgeon in the US, the invasiveness score is a moderate 5 out of 10, due to the number of generations raised in captivity and theoretical added competition for food, habitat or breeding partners and predation pressure from escapees.

Overall, white sturgeon aquaculture in the US results in a high score of 10, due to the fact that the facilities present very low concern of escape to natural waterways.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	9.00	
C7 Disease; pathogen and parasite Final Score	**9.00**	**GREEN**
Critical?	**NO**	

Justification of Ranking

Two main factors are considered in the scoring of the Disease criterion. First is the diseases that exist in cultured populations (or may be introduced to aquaculture facilities) and secondly, the potential of these infections to be amplified and transmitted to wild fish in the surrounding ecosystem. Many elements within these can affect the disease risk aquaculture production poses to wild populations.

White sturgeon in aquaculture production are vulnerable to a number of viral and bacterial infections. The most common infections in production facilities are bacterial gill disease, two herpes viruses and white sturgeon iridovirus (WSIV) (Doroshov pers. comm., Michaels 2012, Struffenegger pers. comm.).

Typically WSIV and herpes viruses affect sturgeon in early stages of life, and can result in high mortality among juveniles (Hanson *et al.* 2011, Kwak *et al.* 2006, Plumb & Hanson 2011, Watson *et al.* 1995). Both herpes viruses and WSIV are endemic in native populations and are believed to have been brought into aquaculture facilities through wild sourced broodstock (Watson *et al.* 1995). Testing has shown evidence of both iridovirus and herpesvirus in gonadal tissue and it is believed they are transmitted to progeny during spawning; many broodstock fish are survivors of both WSIV and herpes viruses (Kwak *et al.* 2006). Water-borne transmission and infection via fish to fish contact is less frequent, but also has been shown to occur (Georgiadis *et al.* 2001). Management practices are vital to limit the occurrence of viruses that are lethal and currently without treatment (Kwak *et al.* 2006). Early detection and stress reduction, along with ongoing directed breeding programs to decrease susceptibility (despite lack of domestication) are implemented in sturgeon production facilities (Kwak *et al.* 2006, Struffenegger pers. comm.).

As described in the Effluent and Escapes sections of this report, effluent discharge from land-based sturgeon production systems in California is not directly connected to natural bodies of water. There is no concern for escaped farmed fish to come into contact with wild sturgeon (no escapes events have occurred), and effluent is passed through wetlands or into irrigation ditches and over agricultural fields. It must be noted that for any sturgeon production system practicing as flow-through directly into a natural body of water (i.e. those in Idaho) the Disease score would likely be lower due to potential transmission concern. However, there is currently no evidence of the amplification and re-transmission of diseases from aquaculture production to wild populations.

Although several virulent diseases are known to occur and persist among cultured sturgeon populations there is no evidence of their transfer to wild populations and systems operating as flow-through are not directly connected to natural waterways, but are filtered through wetlands or used for irrigation first. The pathogen risk of sturgeon aquaculture is scored as 9 out of 10.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

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

Criterion 8 Summary

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

Justification of Ranking

White sturgeon aquaculture in the US is based on sourcing from hatcheries, with many years since any broodstock were obtained from the wild (Doroshov pers. comm., Van Eenennaam pers. comm., Struffenegger pers. comm.). Non-native sturgeon species are also hatchery sourced (Michaels pers. comm.). Aquaculture production of sturgeon in the US is not dependent on wild populations and does not increase pressure on wild populations. Sturgeon score 10 out of 10 for the Source of Stock criterion.

Criterion 9X: Wildlife and predator mortalities

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

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

Factor 3.3X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**0.00**	**GREEN**
Critical?	NO	

Justification of Ranking

A large proportion of US sturgeon production comes from enclosed, land-based aquaculture facilities that are inherently less prone to problems with wildlife and predators than more open systems such as ponds (Michaels pers. comm.). Any remaining tanks that are outdoors are either for fish that are too large for predatory birds to be problematic, or have shade netting over them to passively prevent problems (Struffenegger pers. comm.). There are no reported interactions or mortalities of wildlife (deliberate or accidental) associated with sturgeon aquaculture. Therefore the score for this exceptional criterion is not scored (i.e. the penalty score is 0 out of -10).

Criterion 10X: Escape of unintentionally introduced species

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

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

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Justification of Ranking

Most US facilities either maintain their own broodstock and hatcheries or source from broodstock programs such as the Domestic White Sturgeon Broodstock Program at University of California, Davis (TNC Holding Company 2011), neither of which require the transfer of live animals from ecologically distinct bodies of water.

It should be noted in this section that other species of sturgeon may be sourced internationally (i.e. fertilized Siberian sturgeon eggs are brought in from Germany for culture in Florida; Michaels pers. comm.), but the zero discharge requirements for facilities raising non-native species prevent unintentional introductions.

Therefore as there are either no animal movements (white sturgeon) or movements occur into biosecure zero-exchange facilities (other species), there is not considered to be any risk of introducing other non-native species as a result of sturgeon farming and the final score is a deduction of 0 out of -10 for this exceptional criterion.

Overall Recommendation

The overall recommendation is as follows:

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

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

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.75	GREEN	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	8.93	GREEN	NO
C4 Chemicals	5.00	YELLOW	NO
C5 Feed	3.59	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	9.00	GREEN	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**60.27**		
Final score	**7.53**		

OVERALL RANKING

Final Score	7.53
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
Final Rank	BEST CHOICE

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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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About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

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

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Guiding Principles

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

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

Seafood Watch will:

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

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

practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

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

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

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

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

Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	7.5	7.5
Chemical use	Yes	7.5	7.5
Feed	Yes	5	5
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other – (e.g. GHG emissions)	Yes	5	5
Total			**67.5**

C1 Data Final Score	6.75	GREEN

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	44
eFCR	2.5
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	18
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	176
N in each ton of fish harvested (kg)	28.8
Waste N produced per ton of fish (kg)	**147.2**

Factor 2.1b - Production System discharge score

Basic production system score	0.6
Adjustment 1 (if applicable)	-0.24
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0

Discharge (Factor 2.1b) score	0.36

3
6 % of the waste produced by the fish is discharged from the farm

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

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Yes	1
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Moderately	0.5
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Yes	1
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc.?	Yes	1
		4.5

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Yes	1
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Yes	1
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Yes	1
4 - Does enforcement demonstrably result in compliance with set limits?	Mostly	0.75
5 - Is there evidence of robust penalties for infringements?	Mostly	0.75
		4.5

F2.2 Score (2.2a*2.2b/2.5)	8.1

C2 Effluent Final Score	7.00	GREEN
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	10

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

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including a EIAs requirement for new sites?	Yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Mostly	0.75
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		4.25

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Yes	1
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Yes	1
		4

F3.2 Score (2.2a*2.2b/2.5)	**6.80**

C3 Habitat Final Score	**8.93**	**GREEN**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**5.00**	
C4 Chemical Use Final Score	**5.00**	**YELLOW**

Critical?	NO

Criterion 5: Feed

5.1. Wild Fish Use

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

Fishmeal inclusion level (%)	24
Fishmeal from by-products (%)	26.1
% FM	17.736
Fish oil inclusion level (%)	4.8
Fish oil from by-products (%)	19.5
% FO	3.864
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	2.5
FIFO fishmeal	1.97
FIFO fish oil	1.93
Greater of the 2 FIFO scores	1.97
FIFO Score	**5.07**

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

SSWF	-2
SSWF Factor	-0.39

F5.1 Wild Fish Use Score	**4.68**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	44
eFCR	2.5
Feed protein from NON-EDIBLE sources (%)	10.80
Feed protein from EDIBLE CROP sources (%)	89.19
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.2
Edible yield of harvested fish (%)	55
Non-edible by-products from harvested fish used for other food production	50
Protein IN	70.05
Protein OUT	14.10
Net protein gain or loss (%)	-79.86

	Critical?	NO
F5.2 Net protein Score	**2.00**	

5.3. Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	28.8
eFCR	2.5
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	18.73

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

Inclusion level of crop feed ingredients (%)	71.2
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	2.5
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.67

Value (Ocean + Land Area)	**19.40**

F5.3 Feed Footprint Score	**3.00**

C5 Feed Final Score	**3.59**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**10**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**10**

6.1b. Invasiveness

Part A – Native species

Score	3

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	Yes
Do escapees act as additional predation pressure on wild native populations?	Yes
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	Yes
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	2

F 6.1b Score	**5**

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

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	9.00	
C7 Disease; pathogen and parasite Final Score	**9.00**	**GREEN**
Critical?	NO	

Criterion 8: Source of Stock

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

Exceptional Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**0.00**	**GREEN**
Critical?	NO	

Exceptional Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10Xb Biosecurity of source/destination	0.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**