Monterey Bay Aquarium

Seafood Watch®

Sturgeon

White sturgeon (*Acipenser transmontanus*)

United States

Raceways, partial recirculating systems, zero discharge systems

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Seafood Watch Consulting Researcher

Disclaimer

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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 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

Sturgeon, California and Idaho

Criterion	Score	Rank	Critical?
C1 Data	7.05	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	9.33	GREEN	NO
C4 Chemicals	7.00	GREEN	NO
C5 Feed	4.06	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Secondary species escape	0.00	GREEN	
Total	**52.44**		
Final score (0-10)	**7.49**		

OVERALL RANKING

Final Score	7.49
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

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 score for sturgeon produced in California and Idaho is 7.49 out of 10. With no red or Critical criteria, the result is a green Best Choice recommendation.

Executive Summary

Sturgeon aquaculture is currently practiced to varying extents in 35 countries globally. Six species of sturgeon are raised commercially in the US, and approximately 95% of production is white sturgeon (*Acipenser transmontanus*) raised in tanks and raceways in California and to a lesser extent in Idaho. The farms rearing other species of sturgeon typically use recirculating aquaculture systems (RAS) and are located in Florida and North Carolina. Due to the dominance of white sturgeon in the US marketplace, and the majority of other US sturgeon species being produced in RAS (covered in a separate Seafood Watch[2] Report) this assessment defaults to production details for white sturgeon only, unless specifically noted.

This Seafood Watch assessment involves ten 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.

Data

The majority of the data and information for this assessment come from personal communication with industry members and industry representatives. Literature describing ecological impacts of sturgeon farming is largely out of date. With regard to management, applicable permits and regulations are available from the respective agency websites. Although some industry-provided information was difficult to verify and therefore used with some caution, overall, the information provided a moderate-high level of confidence that data used in this assessment accurately describe typical sturgeon production in California and Idaho. The Criterion 1 – Data score is 6.82 out of 10.

Effluent

Of the seven main sturgeon sites in California, only one is required to have a discharge permit, as it discharges effluents into a neighboring conservation wetland as the main source of water under a longstanding agreement with the state. Overflow from this wetland drains into an agricultural discharge system, and eventually into a municipal discharge system. All other sites discharge effluents into agricultural irrigation systems that are not connected to natural waterways. While there are violations associated with the single effluent discharge permit, it was updated to reflect that the ongoing issues were actually related to the quality of influent water, not caused by production practices as the farm. Given these circumstances the data are considered to show no evidence that effluent discharges cause or contribute to effluent impacts at the waterbody scale.

In Idaho flow-through production systems are used, with discharges entering natural waterbodies after being retained in settling ponds. Aquaculture effluent discharges in Idaho are covered by a general aquaculture permit that applies pollutant limits to individual farm sites

[2] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/g/mba_seafoodwatch_global_ras_report.pdf

based on the status of the waterway they discharge to. There are two main producers of sturgeon in Idaho; one has no history of violations, while the other has had one noncompliance with phosphorus limits, as well as 36 counts of missing Discharge Monitoring Report measurements, consisting of a total of 16 missing Phosphorus measurements, 16 missing TSS measurements, 2 missing total Hardness measurements, and 2 total recoverable copper measurements. Personal communication with industry representatives has indicated that these nonconformances are due to an error in the reporting system for the farm site. It was also noted that while this site is permitted to produce sturgeon and other species, it has never been used for sturgeon. Therefore, while one site has non-compliances, they can be attributed to errors in the reporting system, and a species other than sturgeon. At the broader scale, monitoring of Total Phosphorus and Total Suspended Solids in the Middle Snake River according to Total Maximum Daily Loads shows that aquaculture is discharging below its allocated wasteload, and is not contributing to overall cumulative impacts. The Criterion 2- Effluent score for California and Idaho is 8 out of 10.

Habitat

Sturgeon farming in the US is mainly in agricultural areas that were formerly grasslands. The area footprint of these farms is relatively small, as is the scale of the industry. Habitat impacts from construction of farms in these locations are considered to be minor, and Factor 3.1 scores 9 out of 10. Management of habitat impacts associated with sturgeon farming includes several federal and state regulations that effectively manage cumulative impacts from existing farms and other industries, as well as any future expansion. The Factor 3.2 score is 10 out of 10, and the final Criterion 3 – Habitat score is 9.33 out of 10 in both California and Idaho.

Chemical use

Chemical use in US sturgeon farming consists mainly of disinfectants used for cleaning equipment and footbaths. There is, however, some use of Chloramine-T and hydrogen peroxide as therapeutants for parasites, though the quantity used in either case is unknown. The majority of sturgeon production is not connected to natural waterbodies (discharges into agricultural irrigation systems and/or municipal drainage systems), however sites in Idaho are flow-through raceways with settling ponds that discharge into natural waterbodies. Research shows that the discharge of Chloramine-T and hydrogen peroxide from flow-through production systems is highly unlikely to have negative impacts on natural waterbodies. The final chemical criterion score is 7 out of 10.

Feed

Sturgeon production in the US relies on feeds formulated for salmon as well as feeds formulated specifically for sturgeon. Fishmeal and fish oil are partially sourced from byproducts, resulting in a FFER value of 1.59 and Factor 5.1a score of 6.03 out of 10. One feed company commits to having all of its salmon feeds consistent with the FAO Code of Conduct for Responsible Fisheries, while sources of marine ingredients from the other feed company have FishSource scores all ≥6, with the exception of two individual scores. This results in a Factor 5.1b score of -6 out of -10, and a final Factor 5.1 score of 4.13 out of 10. With a net protein loss of 66.86% the Factor 5.2 score is 3 out of 10. To produce the marine and crop ingredients necessary to produce one ton of farmed fish, 13.5 hectares are required. This results in a Factor 5.3 score of 5 out of 10. The scores from these three factors combine for a final Criterion 5 – Feed score of 4.06 out of 10.

Escapes

The majority of US sturgeon production occurs in California, where raceways and partial recirculation systems have no direct connection to natural waterbodies. Effluent from these facilities is either used for crop irrigation or passes through constructed wetlands and later a series of holding levees and pumping stations, thus reducing the possibility that an escapee could survive. Aside from preventative measures enacted, there have been no escapes at these facilities. The score for Factor 6.1 is 10 out of 10 for California

Production in Idaho uses raceways that are connected to natural waterways, however multiple screens between raceways and settling ponds are used at discharge points as a means of escape prevention. All farms in Idaho use settling ponds, and regulations require that any fish that enter settling ponds be quickly removed. One of the two farms producing sturgeon in Idaho had an escape event during a flood in 2015. The score for Factor 6.1 is 6 out of 10 for Idaho.

In California and Idaho, native white sturgeon are the only sturgeon species grown. In California sturgeon have been domesticated for multiple generations, leading to an assumption that sturgeon grown for farm stock are genetically different from those spawned for restocking wild populations. In Idaho an ongoing cooperation between the industry, the College of Southern Idaho, Idaho Power Company, and the Idaho Department of Fish and Game has sturgeon broodstock collected from the wild, spawned, and subsequently returned to the wild, with 50% of the juveniles used for conservation efforts, and the rest used for commercial production. Given this, there is no genetic differentiation between wild and farmed stocks. The Factor 6.2 score is 5 out of 10 for California, and 8 out of 10 for Idaho. Factors 6.1 and 6.2 combine to give a final numerical score of 10 out of 10 for California, and 10 out of 10 for Idaho.

Disease, pathogen and parasite interactions

Although several virulent diseases are known to occur among cultured sturgeon, and the majority of sturgeon production in the U.S. is not connected to natural waterbodies. Production in California does not discharge to natural waterbodies, which reduces the risk of pathogen transfer. Production in Idaho is more open to discharge of pathogens into natural waterbodies. There are multiple viruses that are present on both wild and farmed populations. However, the characteristics of these viruses make it unlikely that horizontal transmission from farm to wild would occur, and it is assumed that the industry does not increase the likelihood of pathogen amplification beyond natural populations. The score for Criterion 7 – Disease is 7 out of 10 for California and Idaho.

Source of stock

US sturgeon production has sourced wild broodstock during the development of the industry (1970s-1980s), however the industry is now completely reliant on hatchery raised broodstock and growout stock. The life cycle for sturgeon in California and Idaho has been closed since 1994 and 2000, respectively. Given that there is 0% reliance on wild populations, the score for Criterion 8X – Source of stock is a deduction of 0 out of -10.

Predator and wildlife mortalities
Preventative measures are taken in order to keep wildlife from interacting with farmed sturgeon. Eventually sturgeon become large enough that predation is no longer a concern, and preventive measures are no longer used. No interactions have been reported for this assessment. As such the score for Criterion 9X – Wildlife interactions is 0 out of -10.

Escape of secondary species
While there are a handful of companies producing sturgeon in California, two of these companies produce approximately 65% of US sturgeon. One of these companies supplies both with juveniles. Juveniles are transported from the hatchery to farm sites all within the same watershed. In Idaho, companies maintain their own broodstock and there are no trans-waterbody movements. It is therefore assumed that the remaining production in the US (smaller companies in California) is similarly not reliant on trans-waterbody movements. This results in a Factor 10Xa score of 10 out of 10, which renders Factor 10Xb is non-applicable. This results in a final Criterion 10X score of 0 out of -10.

The final score for sturgeon produced in California and Idaho is 7.49 out of 10, and results in a green Best Choice recommendation.

Introduction

Scope of the analysis and ensuing recommendation

Species
White sturgeon *(Acipenser transmontanus)*

Geographic Coverage
United States-California and Idaho

Production Method(s)
Outdoor flow-through raceways, partial recirculation systems

Species Overview

Brief overview of the species
Sturgeons are characterized by their distinctive long, narrow body shape, and dermal scutes (NASPS, 2013). They are typically long-lived, and while all species of sturgeon can grow quite large in the wild, White sturgeon can reach lengths of 12-14 feet (NOAA, 2019; USFWS, 2019a). In the wild sturgeons can live for decades, with some species reaching 100 years (Catarci, 2004).

Global catches of wild sturgeon have suffered declines, and beginning in 1998 all species became regulated by CITES due to concerns about unsustainable harvesting of wild sturgeon (CITES, 2019). In the United States the Atlantic sturgeon (*Acipenser sturio*) is listed as 'Critically Endangered' by the IUCN (IUCN, 2010), while the White sturgeon (*Acipenser transmontanus*) is listed as a species of least concern (IUCN, 2004).

White sturgeon are generally a long-lived species, with sexual maturation in the wild occurring at 11-22 years for males, and 11-34 years for females (FAO, 2019). Subsequent spawning events occur every 4-11 years as the individual ages (ibid.). Sturgeon grown on farms using water sources with consistent year-round temperatures, such as groundwater, may halve that maturation time due to the lack of cold water slow-downs (i.e: no winter) (R. Lovell, pers. comm., 2019).

Production system
Partially recirculating tanks are most commonly used in California. These systems include an element of water reuse, while also discharging a percentage of the daily flow.

Flow-through raceway and tank systems are land-based systems that allow farmers to divert water from a stream, well or groundwater (as is the case in Idaho), so it flows continuously through channels containing fish. These structures can be indoor or outdoor and are usually above ground in a terraced configuration. These systems are most commonly used in Idaho, where outdoor raceways using groundwater are the most common production system for sturgeon farming.

Personal communications indicate that the majority of white sturgeon production in the United States includes an element of recirculation, although systems vary, and are generally not fully closed. Communication with industry representatives indicates that systems used in California and Idaho, where the majority of the United States sturgeon industry is based, are often partially recirculating systems (G. Fornshell, pers. comm., 2019). It is unclear exactly what percentage of the industry is represented by these types of systems, as total volumes are unknown, however it is assumed that the majority of the United States industry for white sturgeon uses these types of systems, as the majority of sturgeon production in the United States is in California and Idaho.

Production Statistics

Globally, the sturgeon farming industry consists of 2,329 farms which produced 102,327 tons (92,829.5 mt) in 2017 (Bronzi et al., 2019). Of this production, 79,638 tons (72,246 mt) was produced in China, 6,800 tons (6,169 mt) in Russia, and 6,000 tons (5,443 mt) in Armenia (see Figure 1). The United States Department of Agriculture's 2018 Aquaculture Census shows 18 sturgeon farms in operation in the United States, with 16 of these facilities producing food-size fish, 2 producing stockers, and 1 producing broodfish (USDA, 2018).

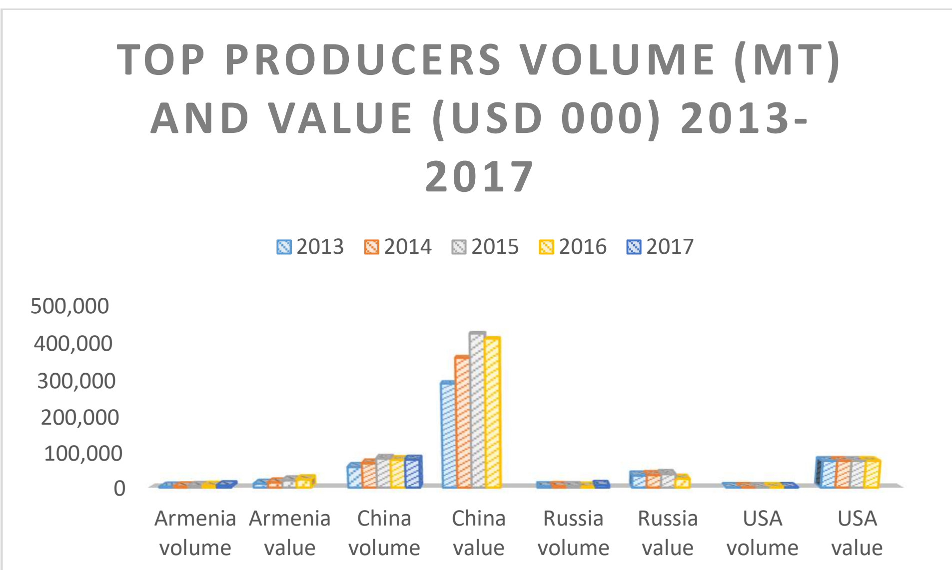

Figure 1: Volume and Value of top sturgeon producers 2013-2017
Sources: (Bronzi et al., 2019; FIGIS, 2019)

Sturgeon species produced in the United States include White (*Acipenser transmontanus*), Siberian *(Acipenser baerii)*, Russian *(Acipenser gueldenstaedti)*, Beluga *(Huso huso)*, Sterlet *(Acipenser ruthenus)* and Sevruga (*Acipenser stellatus*). From 2013-2017, FAO statistics show that the United States produced 947 mt of sturgeon annually (FIGIS, 2019), while Bronzi et al. (2019) report 855 tons (776 mt) in 2017. Figure 1 includes volumes and values from FAO for 2013 – 2016, and volumes from Bronzi et al. (2019) for 2017, while Figure 2 includes only volumes and values from FAO. In 2018 1,166 mt (live weight) was produced (USDA, 2018), and 21 mt of caviar (J. Michaels, pers. comm., 2019). These data do not differentiate between species or state within the United States. California and Idaho produce only White sturgeon (K. Beer, pers. comm., 2019; G. Fornshell, pers. comm., 2019; J. Michaels, pers. comm., 2019), with the other species being commercially grown in smaller volumes in Florida, Idaho and North Carolina.

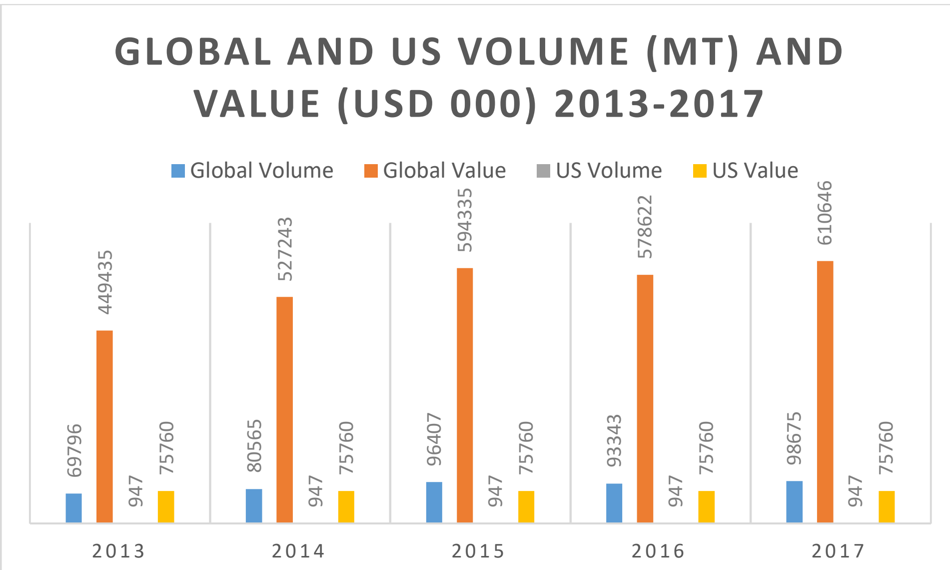

Figure 2: Global and US Volume and Value for sturgeon 2013-2017
Sources: (FIGIS, 2019)

Using the figures provided by individual farms in California it is determined that in 2018 approximately 748.6 mt of white sturgeon were produced in the state. An industry expert in Idaho was able to collect and aggregate production volumes from 2015 – 2018, and stated that the average annual production of white sturgeon in Idaho is 102 mt.

Given that the total volume of sturgeon (all species) produced in the US in 2017 was 947 mt, and given the 2018 volumes reported for California (748.6 mt) and Idaho (102 mt), it can logically be concluded that the majority of US sturgeon production is White sturgeon (850.6 mt total) in California despite a lack of precision in total production volumes and differentiation between species in the dataset.

Import and Export Sources and Statistics
All personal communication with sturgeon companies in the United States indicated that while the majority of sturgeon meat and caviar produced is sold domestically, a portion of caviar production from California is exported (K. Beer, pers. comm., 2019; F. Chapman, pers. comm., 2019; D. Keane, pers. comm., 2019; M. Passmore, pers. comm., 2019; E. Phillips, pers. comm.,

2019; L. Ray, pers. comm., 2019; J. van Eenannaam, pers. comm., 2019; L. Won, pers. comm., 2019). The National Marine Fisheries Service (NMFS) shows export of 119 mt of caviar, and 391 mt of frozen sturgeon roe in 2018, and does not differentiate between species for either commodity (NMFS, 2019).

Common and Market Names

Scientific Name	Common Name	Market Name
Acipenser transmontanus	White Sturgeon	Sturgeon

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 (J. Michaels, pers. comm., 2019).

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 available for analysis.

Criterion 1 Summary: California and Idaho

Data Category	Data Quality	Score (0-10)
Industry or production statistics	5	5
Management	10	10
Effluent	10	10
Habitat	10	10
Chemical use	5	5
Feed	5	5
Escapes	5	5
Disease	5	5
Source of stock	7.5	7.5
Predators and wildlife	7.5	7.5
Introduced species	7.5	7.5
Other – (e.g. GHG emissions)	Not Applicable	n/a
Total		**77.5**

C1 Data Final Score (0-10)	**7.05**	**GREEN**

Brief Summary

The majority of the data and information for this assessment come from personal communication with industry members and industry representatives. Literature describing ecological impacts of sturgeon farming in the US is largely out of date. With regard to management, applicable permits and regulations are available from the respective agency websites. Although some industry-provided information was difficult to verify and therefore used with some caution, overall, the information provided a moderate-high level of confidence that data used in this assessment accurately describe typical sturgeon production in California and Idaho. The Criterion 1 – Data score is 7.05 out of 10.

Justification of Rating

Production

Data and information describing production volumes for sturgeon in the United States are non-aggregated, and inconsistent. The majority of information regarding production volumes, production systems, industry size, and species grown was obtained through personal communication with industry experts and farm representatives. Literature and online resources are largely out of date, and are unlikely to represent current production. While some industry members and representatives were able to provide requested information, it cannot be assumed to be representative of all farms, and therefore gaps in understanding of production volumes remain. The Data score for Production is 5 out of 10.

Management

Information regarding management of the US sturgeon industry is readily available. Applicable national and state regulations are available and up to date through the websites of the associated agencies, and management measures at the farm scale were also made available. Up to date evidence of enforcement mechanisms is available through both state and federal agencies. The Data score for Management is 10 out of 10.

Effluent

Data describing effluent impacts from the US sturgeon industry are readily available. Personal communications with industry members and experts informed the management aspects of the criterion. Information from these communications was confirmed through information available online from the Environmental Protection Agency. For the farms that are required to maintain discharge permits, all associated permits, along with monitoring results, any violations, and enforcement actions are publicly available online. The general aquaculture permits required in Idaho are available online, as are records of noncompliance, and associated enforcement actions. Information regarding the status of associated Total Maximum Daily Loads for rivers the Idaho sturgeon industry discharges into are also available online. The Data score for Effluent is 10 out of 10.

Habitat

Data and information regarding the location of farms are available at the regional level, and in some cases to the farm site level. Google Earth was used to view farm sites where locations were available. Industry representatives provided the history of land conversion, which is consistent with data available from California State University, Chico showing land use changes over time. As the industry is relatively small scale and does not have ongoing impacts, habitat impacts are not monitored. Information describing regulations in place to manage habitat impacts from construction is available from applicable agency websites. The Data score for Habitat is 10 out of 10.

Chemical use

Data regarding the types of chemicals used in production of sturgeon in the US were made available through personal communication with industry members and representatives from producers representing 65% of US sturgeon production, however frequency and volume of use is unknown. The one farm site that is required to maintain a National Pollutant Discharge

Elimination System (NPDES) permit is required to monitor and report any use of chemical therapeutants. The US Food and Drug Administration (FDA) regulates which chemicals may be used in aquaculture, and provides assessments of their risk of ecological impacts. These reports are all available on the FDA's website. Additional information describing ecological impacts is available in peer reviewed articles. The Data score for Chemical use is 5 out of 10.

Feed

Data regarding the wild fish use in feeds for US farmed sturgeon was provided by websites of multiple feed companies, and by sturgeon industry members and representatives. These data and information describe the FCR, inclusion rates of fishmeal and fish oil in feeds, use of byproducts in fishmeal and fish oil. Information regarding the sustainability of sources of fishmeal and fish oil was obtained through personal communication as well as a publicly available company sustainability report, and the Ocean Disclosure Project database. Information regarding the inclusion levels of protein-providing ingredients was more difficult to obtain, and while ingredients were shared by industry in the form of feed labels, percentages of these ingredients were not shared by feed companies or industry experts. The Data score for Feed is 5 out of 10.

Escapes

California farms are not directly connected to natural waterways, therefore impact monitoring is not available. In Idaho regulations requiring screens and stating that no fish can enter settling ponds are available online, and information regarding one escape event was provided through personal communication. Information about the closed life cycle of sturgeon is available online and in personal communications, and information about the number of generations separating hatchery-raised sturgeon and wild sturgeon in California and Idaho was made available in personal communications. The Data score for Escapes is 5 out of 10.

Disease

Information regarding disease in US farmed sturgeon was largely sourced from out of date literature, the United States Fish and Wildlife Service's National Wild Fish Health Survey, and personal communication with industry and academic experts. There is very little recent literature describing diseases affecting farmed sturgeon, however some more recent literature describes the likelihood of disease transfer. Personal communications with industry members yielded information about the types of disease that the industry is faced with, but did not specify frequency of outbreaks beyond a general statement of "rare". Personal communication with academic experts indicated the presence of diseases in wild populations. It is unclear whether there are any monitoring requirements for farms that discharge to natural waterbodies. The Data score for Disease is 5 out of 10.

Source of stock

Information regarding the sources of stock, as well as the process and timeline for closing the life cycle for US sturgeon aquaculture was provided in personal communication with industry members and representatives, as well as from a website operated by an industry group. This information describes the sources of stock as well as the lack of reliance on wild stocks. The Data score for Source of stock is 10 out of 10.

Wildlife interactions
Information regarding wildlife interactions with US sturgeon aquaculture was provided through personal communication with industry members and representatives. There are no reports of interactions or mortalities from any industry members, and no aggregated database to house such reports, should they exist. The Data score for Wildlife interactions is 7.5 out of 10.

Introduced species
Information regarding the percent of the US sturgeon industry reliant on animal movements for broodstock and growout stock was made available through personal communication with industry members and representatives. Typical practices were provided for two farms in California, which comprise 65% of the US industry, with the assumption that the rest of US production (including Idaho) follows these same practices. The Data score for Introduced species is 7.5 out of 10.

Conclusions and Final Score
The majority of data and information for this assessment come from personal communication with industry members and industry representatives. Literature describing ecological impacts of sturgeon farming is largely out of date. With regard to management, applicable permits and regulations are available from the respective agency websites. Overall information provided a moderate-high level of confidence that data used in this assessment accurately describe typical sturgeon production in the US. The Criterion 1 – Data score is 7.05 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 Evidence-Based Assessment: California and Idaho

C2 Effluent Final Score (0-10)	**8**	**GREEN**

Brief Summary

Of the seven main sturgeon sites in California, only one is required to have a discharge permit, as it discharges effluents into a neighboring conservation wetland as the main source of water under a longstanding agreement with the state. Overflow from this wetland drains into an agricultural discharge system, and eventually into a municipal discharge system. All other sites discharge effluents into agricultural irrigation systems that are not connected to natural waterways. While there are violations associated with the single effluent discharge permit, it was updated to reflect that the ongoing issues were actually related to the quality of influent water, not caused by production practices as the farm. Given these circumstances the data are considered to show no evidence that effluent discharges cause or contribute to effluent impacts at the waterbody scale.

In Idaho flow-through production systems are used, with discharges entering natural waterbodies after being retained in settling ponds. Aquaculture effluent discharges in Idaho are covered by a general aquaculture permit that applies pollutant limits to individual farm sites based on the status of the waterway they discharge to. There are two main producers of sturgeon in Idaho; one has no history of violations, while the other has had multiple noncompliances, many of which are due to an error in the reporting system for the farm site. While this site is permitted to produce sturgeon and other species, it has never been used for sturgeon, so these non-compliances cannot be attributed to sturgeon production. At the broader scale, monitoring of Total Phosphorus and Total Suspended Solids in the Middle Snake River according to Total Maximum Daily Loads shows that aquaculture is discharging below its allocated wasteload, and is not contributing to overall cumulative impacts. The Criterion 2-Effluent score for California and Idaho is 8 out of 10.

Justification of Rating

Evidence-Based Assessment:
As effluent data quality and availability is good (i.e. Criterion 1 score of 7.5 or 10 of 10 for the effluent category), the Evidence-based assessment was utilized.

California

The two largest producers in the US are located in the Sacramento area of California, utilizing a mix of zero discharge, partial recirculation and flow-through systems. One producer operates three sites, all of which are zero-discharge facilities, cycling groundwater through a series of ponds used to grow sturgeon as well as other species of fish. These sites only discharge water upon request to either the company's crop irrigation systems, or the neighboring farms for irrigation (K. Beer, pers. comm., 2019). Monitoring and discharge permits are not required for these facilities, as effluents do not go beyond agricultural irrigation systems. This was stated in personal communication with the farm's owner, and is corroborated by a search of the California Integrated Water Quality System Project's (CIWQSP) database, which shows permits for construction at the farm sites, but does not include a National Pollutant Discharge Elimination System (NPDES) permit (CIWQS, 2019a).

The other producer in California operates four sites, one of which is partial recirculation, and the others flow-through. The partial recirculation site is authorized to discharge effluent into the Natomas Basin Conservancy habitat. This habitat includes a wetland for which the site is the primary source of water (E. Phillips, pers. comm., 2019). This discharge is permitted by a NPDES permit, which includes monitoring requirements (CRWQCB, 2016). Overflow from this wetland drains into an agricultural discharge system, and eventually into a municipal discharge system. The remaining three sites (flow-through) discharge effluents into agricultural irrigation systems, and do not require discharge permits or monitoring (E. Phillips, pers. comm., 2019). This is also corroborated using the CIWQSP database, which shows an NPDES permit for one site, with construction permitted at another, but no ongoing NPDES permitting for any other sites (CIWQS, 2019b). The site subject to NPDES permitting has had 31 violations in the past 5 years. These are shown in Table 2 below:

Table 2 Permit violations for individual CA site

Violation type	Details	Number of violations
Category 1 pollutant	Manganese levels greater than permitted limits	17
	Magnesium levels greater than permitted limits*	1
Category 2 pollutant	Arsenic levels greater than permitted limits	7
Deficient monitoring	1. No pH or temperature data provided	3

	2. BOD sample not tested by lab on time 3. Lack of inflow monitoring due to order amendment and not having meters installed until amended	
Order conditions	Effluent flow meter not inspected within required time	1
Late Report	Submitted 17 days late	1
Deficient reporting	Did not report weekly DO, pH and temperature	1

Source: (CIWQS, 2019b)

*Magnesium is not listed as a required parameter for monitoring, and the single violation for 'high magnesium' levels could in fact be attributed to a typographical error, given that the requirements listed on this permit match those for manganese.

In 2015 a Cease and Desist order (from discharging contrary to requirements prescribed – not from operations overall) was instated, however in 2016 the NPDES permit was updated, and monitoring for presence of manganese and arsenic was removed from the requirements, as it was determined that the intake water to the facility was contributing to these levels, rather than operation of the facility (CRWQCB, 2016). The remaining violations include seemingly one-off incidents of late or incomplete reporting, lab errors, and in one case a flow meter that had not been calibrated in over 1 year (CIWQS, 2019b). Many of the violations have associated Notices of Violation, and mitigation measures included where appropriate (ibid.). In the past, the facility paid a $9,000 fine for noncompliance with manganese and arsenic levels.

A search of 'Impaired' water bodies in the area (as designated by the US EPA) shows that the Natomas East Main Drainage Canal meets this designation due to high levels of mercury, diazinon, and polychlorinated biphenyls (PCBs) (US EPA, 2019b) however based on the lack of monitoring or reporting requirements for any of these substances from the single sturgeon farm requiring an NPDES permit, it can logically be assumed that this impairment is not due to sturgeon farming in the area, and these activities do not contribute to the 'Impaired' status of the water body.

Idaho

In Idaho sturgeon facilities operate as flow through systems that use settling ponds for sedimentation, removal of solids and associated nutrients prior to discharge into natural waterbodies (G. Fornshell, pers. comm., 2019). Effluent from aquaculture in Idaho is regulated by a general NPDES permit applicable to "Aquaculture Facilities in Idaho, subject to Wasteload Allocations under Selected Total Maximum Daily Loads (TMDL)" (US EPA, 2007). This permit prescribes pollutant limits for individual farms according to the waterway they discharge into, and the TMDL of that waterway. Sturgeon facilities are all located in the Middle Snake River, which has TMDLs set for Total Phosphorous (TP) and Total Suspended Solids (TSS) and remains listed by the EPA as 'Impaired' (US EPA, 2019a). Reduction targets for TP and TSS were set to achieve instream water quality goals (which were linked to the attainment of state water quality standards for support of cold-water biota such as native trout) by year 10. The preliminary WLA for the aquaculture industry required a 40% reduction from measured 1991 TP loadings (IDEQ, 1998). Data were collected and reviewed over 3 years, and overall WLAs were subsequently modified to include aquaculture WLAs, set to the 40% reduction, in 2004–2005 (IDEQ, 2016). The required 5-year review, conducted in 2010, revealed that the aquaculture industry reduced TP loadings by 62% relative to 1991 levels, exceeding their required reduction levels. Furthermore, the discharge levels of TP for the industry fell under the limits allowed by NPDES permits (IDEQ, 2010). The review also highlighted improvement in overall water quality in every segment of the Middle Snake River in regard to both TP and TSS relative to pre-2000 levels (IDEQ 2010). Data show that >99% of the Middle Snake River has met the 10-year TSS target of < 52.0 mg/L, while 29.2% of the Middle Snake River is currently meeting the 10-year TP target of 0.075 mg/L (IDEQ 2010). These data show that aquaculture in Idaho is consistently outperforming the required effluent limitations. There is no evidence that sturgeon aquaculture effluent discharges cause or contribute to cumulative impacts, particularly beyond the acceptable impacts occurring in the Snake River.

There are two main companies producing sturgeon in this region, both producing approximately the same volume annually (G. Fornshell, pers. comm., 2019). There is an ongoing non-conformance noted by the EPA for consistent lack of reporting of Discharge Monitoring Reports (US EPA, 2019c), however personal communication with a representative from the farm indicates that this is due to a change in the reporting system used, and was previously unknown to the company (L. Ray, pers. comm., 2019). This can be corroborated by the lack of any enforcement action by the EPA (US EPA, 2019c) beyond one informal Notice of Violation by the EPA in 2016 (US EPA, 2019c). This company operates multiple sites, with multiple species permitted for production (L. Ray, pers. comm., 2019). All of their sites are permitted to produce sturgeon, however at the site in question, sturgeon have never been produced (G. Fornshell, pers. comm., 2019; L. Ray, pers. comm., 2019).

The vast majority of sturgeon farming in the US occurs in California and Idaho. In California, only one farm site is required to hold an effluent discharge permit. In a longstanding agreement, this farm discharges effluents into a neighboring conservation wetland which drains into an agricultural discharge system, and eventually into a municipal discharge system. All other farms in California are either zero-discharge sites that cycle water through a series of ponds used to grow multiple species of fish, or discharge effluents into agricultural irrigation systems. The single site requiring an NPDES permit has had violations of pollutant limits on the past, however the permit has been updated to account for the pollutant's presence in influent water, prior to reaching the aquaculture operation. TMDLs are in effect for the receiving water body, however none of the listed impairments are related to sturgeon aquaculture, and it does not contribute to the 'Impaired' status. Given these circumstances, the data are considered to show no evidence that effluent discharges cause or contribute to effluent impacts at the waterbody scale.

In Idaho, sturgeon farms use flow-through production systems, and effluents are regulated by a general NPDES permit for aquaculture that prescribes pollutant limits for individual farm sites based on the waterbodies they discharge to. Of the two companies producing sturgeon, one has had no violations, while the other had a violation in 2012 that resulted in a fine and updated work practices, as well as unachieved and unreported monitoring and status updates due to a faulty reporting system, and no enforcement action by the EPA. Overall monitoring of TP and TSS in the Middle Snake River shows that aquaculture is discharging below its allocated wasteload for TP and TSS, and is not contributing to overall cumulative impacts.

Conclusions and Final Score

Sturgeon production in California includes two main production companies, one of which operates three zero discharge sites and is not required to have any discharge permits. The other operates four sites; one partial recirculation system that discharges into a neighboring conservation wetland as its sole source of water, and three flow-through sites that discharge effluents into neighboring agricultural irrigation systems with no connection to natural waterbodies. The system discharging into a wetland is required to have an NPDES permit, and has a history of violations, however it was found that violations were caused by quality of influent water, rather than practices at the farm, and the permit was updated to reflect these circumstances.

Effluent from sturgeon production in Idaho is regulated under a general NPDES permit for aquaculture. Production systems are flow-through systems with settling ponds for sedimentation, removal of solids and associated nutrients prior to discharge into natural waterbodies. The general permit includes pollutant discharge limits specific to each individual farm site based on the status of the receiving waterbody. There are two main sturgeon farms in Idaho; while one site has non-compliances for lack of reporting, overall monitoring of TP and TSS in the Middle Snake River according to TMDLs shows that aquaculture is discharging below its allocated wasteload, and is not contributing to overall cumulative impacts. The Criterion 2 – Effluent score for California and Idaho is 8 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary: California and Idaho

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		9
F3.2a Content of habitat regulations	5	
F3.2b Enforcement of habitat regulations	5	
F3.2 Regulatory or management effectiveness score		10
C3 Habitat Final Score (0-10)		**9.33**
Critical?	NO	**GREEN**

Brief Summary

Sturgeon farming in the US is mainly in agricultural areas that were formerly grasslands. The area footprint of these farms is relatively small, as is the scale of the industry. Habitat impacts from construction of farms in these locations are considered to be minor, and Factor 3.1 scores 9 out of 10. Management of habitat impacts associated with sturgeon farming includes several federal and state regulations that effectively manage cumulative impacts from existing farms and other industries, as well as any future expansion. The Factor 3.2 score is 10 out of 10, and the final Criterion 3 – Habitat score is 9.33 out of 10 for both California and Idaho.

Justification of Rating

Factor 3.1. Habitat conversion and function

The habitat conversion that occurs for sturgeon production results from the construction of the rearing units themselves (tanks and raceways) and any associated building structures (e.g., feed and equipment storage, offices). Two farms in California make up the vast majority of sturgeon production in the United States, and both are located in Sacramento County. This area was grassland prior to conversion for agriculture in the early 1900s (CSU, Chico, 2003). Small parcels of the agricultural land were further converted for the two sturgeon aquaculture companies in the 1980s. As the majority of sturgeon farming in the United States takes place on land previously converted for other agricultural purposes, further conversion to accommodate an aquaculture facility is unlikely to further impact the surrounding environment, which is considered to have maintained its functionality with minimal impacts.

Figure 1 Sturgeon production site in California
Source: Google Earth

Personal communications indicate that water for sturgeon farms in Idaho is not diverted from streams or surface waterbodies, instead farms are spring fed, or in some cases fed from seep tunnels built by the Civilian Conservation Corps in the 1930s and 1940s (G. Fornshell, pers. comm., 2019). No further habitat conversion is required for either of these sources, as springs are naturally occurring and farms are located downstream.

Figure 2 Sturgeon production site in Idaho

Source: Google Earth

Impacts to habitat are minimal, with overall habitat functionality maintained due to the nature of the habitat utilized, the small land area conversion required by an individual sturgeon farming operation, and the overall relatively small land area used by the sturgeon farming industry in both states. In some cases (all sturgeon production in Idaho) farm sites have been converted from trout production to sturgeon, and do not require further construction. Given this, it is assumed that production of sturgeon has not resulted in further impacts on the surrounding ecosystem.

This results in a Habitat conversion and function (Factor 3.1) score of 9 out of 10 for California and Idaho.

Factor 3.2a: Content of habitat management measures

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. As California and Idaho represent the majority of sturgeon production in the US, this assessment focuses on management in these two states. In California, the lead agency is the Department of Fish and Wildlife (CDFW), and in Idaho it is the Department of Environmental Quality (DEQ).

At the federal level, construction of aquaculture facilities must comply with water quality regulations in the Clean Water Act (CWA). CWA section 404 requires a permit for any dredge and fill activities that discharge into Navigable Waters to ensure that these activities do not violate applicable state water quality standards during construction. The permitting authority for section 404 is the US Army Corps of Engineers (Army Corps) (CAAquaculture.gov, 2018). However, given that sturgeon farming in California and Idaho is largely spring fed, and does not rely of diversion of surface water, dredging is not necessary, and therefore Section 404 permits are not needed. The Army Corps also administer permits for Section 10 of the Rivers and Harbors Act of 1899, which regulates work or structures in, over or under navigable waters of the United States (ibid.). The Army Corps are also the permitting authority for Nationwide Permit #7, which requires that outfall and intake structures must comply with the National Pollutant Discharge Elimination System (NPDES) program, which is held by the Environmental Protection Agency (EPA). The NPDES program regulates water pollution from point sources and is further discussed in Criterion 2 of this report.

The National Environmental Policy Act (NEPA) is a procedural act which often requires the development of an Environmental Impact Assessment (EIA) to determine whether a proposed activity will have a significant impact (NEPA, 2019a). A finding of significant impact in and of itself does not preclude a proposed activity from occurring, however the NEPA process is public and can provide information that can be used for further action. Authority to implement this process can be granted to states, which is the case in California via the California Environmental Quality Act (CEQA) (NEPA, 2019b). Idaho does not have jurisdiction to implement NEPA policies at the state level (ibid.).

California

At the state level, the California Fish and Game Code (FGC) specifies that the Department of Fish and Wildlife (DFW) has the authority to prohibit an aquaculture operation if it is determined that it is detrimental to adjacent native wildlife (CAFGC, 1982). The California Code of Regulations (CCR) states that all aquaculture facilities must have the written approval of the DFW prior to operation on a natural water course or lake, unless the aquaculture facility is constructed below a spring rising on private property (CCR, 1985). The majority of sturgeon production in California uses groundwater, and thus are exempt from the requirement to have written approval from the DFW (K.Beer, pers. comm., 2019). Any proposed expansion, modification, or alteration of existing sites is required to undergo an initial study under CEQA in order to determine whether there may be any significant impacts from the proposed project (at the site level, or cumulatively) (CEQA, 2019). An Initial Study indicates whether there is potential for significant impact will occur at the site level or cumulatively, and is used to determine whether an Environmental Impact Report, a Negative Declaration, or a Mitigated Negative Declaration is appropriate for the proposed project (ibid.).

Idaho

At the state level, the Idaho Statutes include measures regulating commercial fish facilities specifically to ensure wild fish passage through waterbodies is not hindered. Title 22, Chapter 46, Section 22-4602 of the Idaho Statutes specifies that construction cannot cross any waterbodies with wild fish, any dam or diversion of water must not restrict the passage of fish (or a facility must provide a passageway for fish to use), and all water inlets must be properly screened to prevent fish from entering (Idaho Statutes, n.d.-b). Idaho also requires farms to obtain a Stream Channel Alteration Permit (SCAP) in the event that construction will alter natural channels (Idaho Statutes, n.d.-a). However, given that sturgeon farming in Idaho utilizes spring water, and does not necessitate any alteration to stream channels, the SCAP is not required.

Any expansion or modification to the waste system of an existing site must be approved by DEQ, and must meet the requirements of the Idaho Waste Management Guidelines for Aquaculture Operations (IDEQ, 1997). It must also be ensured that any expansion or modification to an existing farm is within TMDL limits set by the EPA for the Middle Snake River (see Criterion 2) (IDEQ, 1998; US EPA, 2007). Between these two management measures, the scale of the aquaculture industry in Idaho is effectively capped at existing levels, and is highly unlikely to expand. As TMDLs are set based on inputs from all industry in an area (IDEQ, 1998), any expansion would require changes in the wastewater outputs of other industries in order to maintain compliance with TMDLs.

In summary, federal regulations manage habitat impacts from construction of aquaculture facilities, and both California and Idaho have further state regulations that protect adjacent habitats. Management measures require farm construction to take ecological factors into account during both construction and operation, and any future construction of farms. Cumulative impacts are directly managed through the CEQA process in California, while in Idaho cumulative impacts from the industry are indirectly managed through the use of waste management planning and TMDLs. These two management measures, while not directly addressing cumulative impacts to habitat, effectively cap the size and number of aquaculture sites as they currently are, and ensure that any (highly unlikely) future expansion would be incompliance with management measures that are based on cumulative, multi-industry management measures. The Factor 3.2a score is 5 out of 5.

Factor 3.2b: Enforcement of habitat management measures

Enforcement of the laws described in Factor 3.2a is strict; operators who construct and operate an aquaculture facility without the proper permits are subject to significant fines and penalties, including possible imprisonment (US EPA, 2013). For the most part, penalties for noncompliance are rare because noncompliance is rare. If an operator is found to be out of compliance, the EPA will generally issue a civil administrative action (notice of violation or order to come into compliance) before taking judicial action (lawsuits), with criminal actions being sought for only the most egregious violations (US EPA, 2013).

There are no records of action taken against sturgeon farms for violating site construction permits in either Idaho or California (likely because all farms are compliant), but there is evidence of consistent formal action from the EPA for NPDES violations in California, and minimal informal enforcement action by the EPA in Idaho. These are discussed in Criterion 2 – Effluent. This demonstrates both the level of enforcement and the strong performance of the sturgeon industry. Because of the strict, transparent permitting or licensing process and some evidence of penalties for infringement, Factor 3.2b “Enforcement of habitat management measures” is scored 5 out of 5.

The score for Factor 3.2b is 5 out of 5. When combined with the Factor 3.2a score of 5 out of 5, the final Factor 3.2 score is 10 out of 10.

Conclusions and Final Score

The sturgeon aquaculture industry in the US is mainly located in agricultural areas that were historically converted from grasslands. Due to this, along with the small footprint of sturgeon farms, habitat functionality is minimally impacted, and the score for Factor 3.1 is 9 out of 10. Management of habitat impacts associated with sturgeon farming includes several federal and state regulations that effectively manage cumulative impacts from existing farms and other industries, as well as any future expansion. The Factor 3.2a score is 5 out of 5, and factor 3.2b scores 5 out of 5, resulting in a Factor 3.2 score of 10 out of 10. Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 9.33 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: California and Idaho

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**7**	
Critical?	NO	**GREEN**

Brief Summary

Chemical use in US sturgeon farming consists mainly of disinfectants used for cleaning equipment and footbaths. There is, however, some use of Chloramine-T and hydrogen peroxide as therapeutants for parasites, though the quantity used in either case is unknown. The majority of sturgeon production is not connected to natural waterbodies (discharges into agricultural irrigation systems and/or municipal drainage systems), however sites in Idaho are flow-through raceways with settling ponds that discharge into natural waterbodies. Research shows that the discharge of Chloramine-T and hydrogen peroxide from flow-through production systems is highly unlikely to have negative impacts on natural waterbodies. The final chemical criterion score is 7 out of 10.

Justification of Rating

Chemicals regulated and used in sturgeon aquaculture in the US include disinfectants, antibiotics and parasiticides. Data provided by farms show that the majority of chemicals used (by volume) are for disinfecting equipment and footbaths to maintain biosecurity. Two chemicals used as therapeutants to control external parasites were reported for production in California: Chloramine-T and hydrogen peroxide (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019). Both are used as a bath treatment as needed, and neither requires a veterinary prescription. It is unclear how often these chemicals are used. One producer has previously reported occasional use of Oxytetracycline to treat bacterial infections in young sturgeon, (Anon, 2014), but no recent reports of antibiotic use were noted from the available data or from personal communications with industry representatives. (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019; G. Fornshell, pers. comm., 2019).

Drug use in US aquaculture is generally well regulated. The United States Food and Drug Administration (FDA) maintains a list of antibiotics, disinfectants and pesticides approved for use in aquaculture (FDA, 2019a). For a drug to be approved by the FDA, an environmental assessment (EA) is often conducted to describe "how much drug is expected to get into the environment; the drug's potential toxicity to aquatic life, and potential effects the drug's use will have on the environment" (FDA, 2019b). If the assessment shows significant environmental impact potential, the FDA will write an environmental impact statement; otherwise, a summary of the findings of the EA is written, called a Finding of No Significant Impact (FONSI) (ibid.). To date, none of the drugs reported as being used in sturgeon aquaculture in the United States has had an environmental impact statement written for their use. All of the summary and FONSI reports are available online (FDA, 2019a).

While permitees are required to record and report the use of chemicals, there is no national, state or industry-wide reporting requirement for chemical or therapeutant use. No records or reports were made available for this assessment, so it is not possible to wholly triangulate these claims. As noted in Criterion 2- Effluent, only one farm site is required to have an NPDES effluent discharge permit. This permit includes requirements for monitoring and reporting of any use of Chloramine-T and hydrogen peroxide , although it does not include limits (CRWQCB, 2016). No violations have been reported (CIWQS, 2019b).

As discussed in Criterion 2 – Effluent, production systems used in sturgeon production include partial recirculation, zero discharge, and flow-through. In California systems discharge into agricultural irrigation systems or a constructed conservation wetland that drains to an agricultural discharge system, and eventually into a municipal discharge system, and is not directly connected to natural waterbodies. In Idaho flow-through systems discharge directly to natural waterbodies.

While it is possible for these chemicals to enter natural waterbodies if used in flow-through systems, Chloramine-T degrades quickly and is unlikely to have acute or chronic impacts on most species (L. Schmidt et al., 2007). When diluted and degraded, as it is in receiving water, a study on freshwater flow-through raceways considered it highly unlikely that it will have any impact on natural ecosystems (ibid.). Under controlled laboratory conditions, exposure to Chloramine-T in crayfish can have temporary impacts if exposure is at a high enough concentration for an extended time period (24 hours in this study), but these impacts are not likely to result in any mortality (Kuklina et al., 2014) and the concentrations used in this study are likely much higher than those that would be contained in effluent from sturgeon farms.

Similarly to Chloramine-T, hydrogen peroxide, is unlikely to have any negative impact on natural freshwater ecosystems (Schmidt et al., 2006). There is some evidence that sea lice in marine systems can develop resistance to hydrogen peroxide, however this has only been demonstrated in marine systems where very high volumes of hydrogen peroxide are being used (Aaen et al., 2015; Hjeltnes et al., 2015). In freshwater environments Schmidt et al. (2006) recommend that monitoring of concentrations in effluent discharge need only be required when the receiving water body has minimal flow, or has minimal oxidizable material. While this description can fit wetland receiving waters, as noted previously the one farm that discharges into a wetland is required to monitor for hydrogen peroxide, and has reported no violations. It is highly unlikely that flow-through systems discharging hydrogen peroxide into natural waterbodies would have a negative impact on the natural ecosystem (Schmidt et al., 2006).

Chloramine-T and hydrogen peroxide are used in white sturgeon production in unknown quantities. The majority of sturgeon production discharges effluents to agricultural irrigation systems that do not connect to natural waterbodies (California), however some production discharges into natural waterbodies (Idaho). One site discharges effluent to a human-made wetland, and is required to monitor for hydrogen peroxide. There are no reported violations, and any drainage from the wetland is discharged into an agricultural system and finally into a municipal waste system. Research shows that it is unlikely that Chloramine-T or hydrogen peroxide from flow-through sites that discharge into natural waterbodies would negatively impact natural ecosystems.

Conclusions and Final Score

Chemical use in US white sturgeon farming consists mainly of disinfectants used for cleaning equipment and footbaths. The use of Chloramine-T and hydrogen peroxide as therapeutants is reported by farm representatives, but the quantity or frequency of use is not known. The majority of sturgeon production is not connected to natural waterbodies (discharges into agricultural irrigation systems), although one site discharges effluents into a wetland, and sites in Idaho are flow-through raceways with settling ponds that discharge into natural waterbodies. The site that discharges into a wetland is required to monitor and report any use of hydrogen peroxide and Chloramine-T, and has no reported violations. Research shows that the discharge of Chloramine-T and hydrogen peroxide from flow-through production systems is highly unlikely to have negative impacts on natural waterbodies. The final chemical criterion score is 7 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: California and Idaho

Feed parameters	Value	Score
F5.1a Feed Fish Efficiency Ratio (FFER)	1.59	6.03
F5.1b Source fishery sustainability score	-6.00	
F5.1: Wild fish use score		4.13
F5.2a Protein IN (kg/100kg fish harvested)	70.90	
F5.2b Protein OUT (kg/100kg fish harvested)	23.50	
F5.2: Net Protein Gain or Loss (%)	-66.86	3
F5.3: Feed Footprint (hectares)	13.50	5
C5 Feed Final Score (0-10)		**4.06**
Critical?	NO	**YELLOW**

Brief Summary

Sturgeon production in the US relies on feeds formulated for salmon as well as feeds formulated specifically for sturgeon. Fishmeal and fish oil are partially sourced from byproducts, resulting in a FFER value of 1.59 and Factor 5.1a score of 6.03 out of 10. One feed company commits to having all of its salmon feeds consistent with the FAO Code of Conduct for Responsible Fisheries, while sources of marine ingredients from the other feed company have FishSource scores all $\geq$6, with the exception of two individual scores. This results in a Factor 5.1b score of -6 out of -10, and a final Factor 5.1 score of 4.13 out of 10. With a net protein loss of 66.86% the Factor 5.2 score is 3 out of 10. To produce the marine and crop ingredients necessary to produce one ton of farmed fish, 13.5 hectares are required. This results in a Factor 5.3 score of 5 out of 10. The scores from these three factors combine for a final Criterion 5 – Feed score of 4.06 out of 10.

Justification of Rating

Factor 5.1. Wild Fish Use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Dietary requirements for sturgeon vary depending on life stage. The values included in this assessment are based on feeds used for the grow out stage, which is the vast majority of the life cycle for sturgeon. As sturgeon are not a commonly cultured fish species in the US, feeds formulated for other species such as salmon are often used (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019). This is the case for sturgeon production in California, while feeds used in Idaho are mainly specific for sturgeon, as a local feed manufacturer supplies them.

US sturgeon producers source feed mainly from two commercial manufacturers; EWOS (Cargill), and Rangen (Van Eenennaam pers. comm. 2014; J. Michaels, pers. comm., 2019). Current Feed Conversion Ratio (FCR) values were provided by members of the industry as well as an industry expert, and averaged 1.74.

Table 3: The parameters used and their calculated values to determine the use of wild fish in feeding farmed white sturgeon in the US

Parameter	Data
Fishmeal inclusion level	24%
Percentage of fishmeal from byproducts	16%
Fishmeal yield (from wild fish)	22.5%
Fish oil inclusion level	4.8%
Percentage of fish oil from byproducts	5%
Fish oil yield (from wild fish)	5%
Feed Conversion Ratio (FCR)	1.74
Calculated Values	
Feed Fish Efficiency Ratio (FFER) (fishmeal)	1.56
Feed Fish Efficiency Ratio (FFER) (fish oil)	1.59
Seafood Watch FFER Score (0-10)	**6.03**

Percentages of fishmeal and fish oil in feeds were collected and provided by an industry expert who maintains contacts with both feed companies providing feeds for the US sturgeon industry in California and Idaho (G. Fornshell, pers. comm., 2019) and were supported by another industry expert (J. Michaels, pers. comm., 2019). Average values are as follows: Fishmeal inclusion level 24%, of the total fishmeal, 16% is sourced from marine byproducts. The fish oil inclusion level is 4.8%, with 5% of the total fish oil sourced from byproducts. These values result in a FFER value of 1.59, and a Factor 5.1a of 6.03 out of 10.

Factor 5.1b – Sustainability of the Source of Wild Fish

The second factor considered in the wild fish use score is the Sustainability of the Source of Wild Fish (SSWF). Publicly available information regarding the sourcing policies for Cargill was used to inform this factor, along with information submitted by an industry expert who maintains contacts with both feed companies.

Cargill is a member of the Ocean Disclosure Project, and states that it requires that "marine raw materials (fish meal and fish oil) are sourced from non-IUU fisheries, that fish species and country of fishing area is [sic] registered, and that the fish species is not listed in the IUCN Red Data list for the current year" (Ocean Disclosure Project, 2019). As sturgeon are not a common species for production, the feeds used for the species are typically formulated for salmonids, which is the case for the diet fed to sturgeon at the two largest farms in California. As a subsidiary of Cargill, salmonid feeds from EWOS utilize marine raw materials that "come from fisheries adhering to FAO's Code of Conduct for Responsible Fisheries" (Cargill, 2018).

Table 4 Source of marine ingredients used in diets fed to white sturgeon in the US

Origin	**Species**	**Management Score***	**Health Status Score ***	**Seafood Watch Sustainability Score (0 - -10)**
Cargill				
FAO Code of Conduct compliant	unknown	n/a	n/a	-6
Rangen				
Hake				
Silver hake	US Atlantic coast northern	10	8.3	-2
South Pacific hake	Peruvian	<6	≥6	-8
North Pacific hake	NE Pacific	10	10	-2
Sardine				
South American pilchard	Gulf of California	≥6	7.5	-4
South American pilchard	Pacific Baja California	<6	≥6	-8
South American pilchard	North-east Pacific	≥6	≥6	-4
Jack mackerel				
Chilean Jack mackerel	SE Pacific	≥6	7.5	-4
Alaska pollock				
Alaska pollock	Gulf of Alaska	10	7.3	-4
Alaska pollock	East Bering Sea	10	10	0
Alaska pollock	Aleutian Islands	10	7.6	-4

Menhaden				
Atlantic menhaden	NW Atlantic	≥6	7.2	-4
Gulf menhaden	Gulf of Mexico	≥6	10	-2

* Fish Source scores available at https://www.fishsource.org

Rangen does not provide publicly available information about their sourcing policies, however an industry expert provided information about the sources of marine ingredients in their feeds. These sources include hake, sardine, Jack mackerel, Alaska pollock and menhaden from the US, Peru and Mexico (G. Fornshell, pers. comm., 2019). Personal communication indicates that applicable certifications include IFFO RS, FAO Code of Conduct for Responsible Fisheries and the Marine Stewardship Council (MSC) (G. Fornshell, pers. comm., 2019), however it is unknown what percentage of source fisheries used by Rangen actually hold these certifications, and therefore scoring of this factor does not include them. FishSource scores for these species in these regions, however, are all ≥6, with the exception of two individual scores that are <6 (Table 4). Current stock health scores are all ≥6, with the majority being higher (FishSource, 2019).

EWOS feeds used by sturgeon farms in California are formulated for salmonids, and utilize marine products compliant with the FAO Code of Conduct for Responsible Fisheries. All sources of fishmeal and fish oil in feeds by Rangen have FishSource scores ≥6 with the exception of two individual scores. Therefore, the Factor 5.1b score is -6 out of -10, resulting a deduction of 1.90 from the Factor 5.1a score of 6.03, and a final Factor 5.1 score of 4.13 out of 10.

Factor 5.2. Net Protein Gain or Loss

Two feeds commonly used by several farms, have a protein content of 43% on feed labels that were submitted (E. Phillips, pers. comm., 2019), while an industry expert stated that 44% protein is common (J. Michaels, pers. comm., 2019). Given this information, an average protein content value of 43.3% was used. Of the ingredients listed on the feed labels, poultry meal, wheat, fishmeal, peas, pea protein concentrate, dried beans, corn gluten meal and feather meal are the protein producing ingredients, but their inclusion rates and relative contributions to the total protein in the feed are unknown. Given this, a conservative formula with all non-marine ingredients assumed to be edible crop is used. Using an average protein content of fishmeal of 66.5%, this means that approximately 5.9% of the protein in sturgeon feed comes from non-edible sources (byproduct in fishmeal) and 94.1% feed protein is from edible ingredients (marine and crop).

The protein content of whole harvested white sturgeon is 18.2% (Price, Hung, Conte, & Strange, 1989). Dress-out percentages for sturgeon are 70% and 40% yield for bullet and fillet form respectively (Palma et al., 2010), resulting in an average edible yield of 55%. The percentage of the industry that further uses protein is unknown, therefore the default assumption of 50% is used.

Table 5 The parameters used and their calculated values to determine the protein gain or loss in feeding farmed sturgeon in the US

Parameter	Data
Protein content of feed	43.3%
Percentage of protein from edible sources (whole fish FM, edible crops)	94.1%
Percentage of total protein from non-edible sources (byproducts, etc.)	5.9%
Feed Conversion Ratio	1.74
Edible protein INPUT per 100kg of farmed fish	70.9 kg
Protein content of whole harvested fish	18.2%
Edible yield of harvested fish	55%
Percentage of farmed fish byproducts utilized	50%
Utilized protein OUTPUT per 100kg of farmed fish	23.50 kg
Net protein gain or loss	-66.86%
Seafood Watch Factor 5.2 Score (0-10)	**3**

The total protein input is therefore 75.34 kg of protein for every 100 kg of harvested farmed fish, of which 70.90 kg per 100 kg are considered edible for human consumption (marine ingredients, crop ingredients). Utilized protein outputs (edible yield of harvested, farmed fish, byproducts used for further consumption) are 23.50 kg of protein per 100 kg of harvested farmed fish. This results in a net protein loss of 66.86%. This is equivalent to a Factor 5.2 score of 3 out of 10.

Factor 5.3. Feed Footprint

As stated above, details about inclusion levels of crop ingredients and land animal ingredients are not known and it is therefore assumed that all non-marine ingredients are from crops. Therefore, inclusion levels of approximately 71.2% crop ingredients and 28.8% marine ingredients are utilized for calculating the feed footprint.

Table 6 The parameters used and their calculated values to determine the ocean and land area appropriated in the production of farmed sturgeon

Parameter	Data
Marine ingredients inclusion	28.8%
Crop ingredients inclusion	71.2%
Land animal ingredients inclusion	0%
Ocean area (hectares) used per ton of farmed fish	13.03 ha
Land area (hectares) used per ton of farmed fish	0.47 ha
Total area (hectares)	13.5 ha
Seafood Watch Factor 5.3 Score (0-10)	**5**

The resulting feed footprint is 13.5 hectares per ton of production (13.03 ha of ocean area, and 0.47 ha of land area for crops). This results in a Factor 5.3 score of 5 out of 10.

Conclusions and Final Score

Sturgeon production in the US relies on feeds formulated for salmon as well as feeds formulated specifically for sturgeon. Fishmeal and fish oil are partially sourced from byproducts, resulting in a FFER value of 1.59 and Factor 5.1a score of 6.03 out of 10. One feed company commits to having all of its salmon feeds consistent with the FAO Code of Conduct for Responsible Fisheries, while sources of marine ingredients from the other feed company have FishSource scores all $\geq$6, with the exception of two individual scores. This results in a Factor 5.1b score of -6 out of -10, and a final Factor 5.1 score of 4.13 out of 10.

While ingredients in feeds used for sturgeon are known, their inclusion levels are not. This leads to a default assumption that protein in feeds is derived from marine ingredients (fishmeal and fishmeal from byproducts), and crop ingredients that are edible for human consumption. There is a net protein loss of 66.86% which results in a Factor 5.2 score of 3 out of 10.

Based on the percentage of marine ingredients in feeds (28.8%) the total ocean area necessary to produce the ingredients required for one ton of harvested, farmed sturgeon is calculated to be 13.03 ha per ton of farmed fish. The inclusion level of crop ingredients is 71.3%, which requires 0.47 ha of land area per ton of farmed fish. In total, 13.50 ha (ocean and land) are required to produce the feed ingredients necessary to produce one ton of farmed fish. This results in a Factor 5.3 score of 5 out of 10.

The combination of scores for Factors 5.1, 5.2 and 5.3 result in a final Criterion 5 – Feed score of 4.06 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: California

Escape parameters	Value	Score
F6.1 System escape risk	10	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		10
F6.2 Competitive and genetic interactions		6
C6 Escape Final Score (0-10)		**10**
Critical?	NO	**GREEN**

Criterion 6 Summary: Idaho

Escape parameters	Value	Score
F6.1 System escape risk	6	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		6
F6.2 Competitive and genetic interactions		10
C6 Escape Final Score (0-10)		**10**
Critical?	NO	**GREEN**

Brief Summary

The majority of US sturgeon production occurs in California, where raceways and partial recirculation systems have no direct connection to natural waterbodies. Effluent from these facilities is either used for crop irrigation or passes through constructed wetlands and later a series of holding levees and pumping stations, thus reducing the possibility that an escapee could survive. Aside from preventative measures enacted, there have been no escapes at these facilities. The score for Factor 6.1 is 10 out of 10 for California

Production in Idaho uses raceways that are connected to natural waterways, however multiple screens between raceways and settling ponds are used at discharge points as a means of escape prevention. All farms in Idaho use settling ponds, and regulations require that any fish that enter settling ponds be quickly removed. One of the two farms producing sturgeon in Idaho had an escape event during a flood in 2015. The score for Factor 6.1 is 6 out of 10 for Idaho.

In California and Idaho, native white sturgeon are the only sturgeon species grown. In California sturgeon have been domesticated for multiple generations, leading to an assumption that sturgeon grown for farm stock are genetically different from those spawned for restocking wild populations. In Idaho an ongoing cooperation between the industry, the College of Southern Idaho, Idaho Power Company, and the Idaho Department of Fish and Game has sturgeon broodstock collected from the wild, spawned, and subsequently returned to the wild, with 50% of the juveniles used for conservation efforts, and the rest used for commercial production. Given this, there is no genetic differentiation between wild and farmed stocks. The Factor 6.2 score is 6 out of 10 for California, and 10 out of 10 for Idaho. Factors 6.1 and 6.2 combine to give a final numerical score of 10 out of 10 for California, and 10 out of 10 for Idaho.

Justification of Rating

Factor 6.1. Escape risk

California

In California, where the majority of US sturgeon are raised, farms are land-based and either operating as partial recirculation, or flow-through systems with no direct connections to natural waterways (K. Beer, pers. comm.,2019; E. Phillips, pers. comm., 2019; (CRWQCB, 2016). The reuse of effluent discharge to irrigate agricultural land further reduces the possibility of escapees entering natural waterways; waste water is either discharged into agricultural irrigation systems or filtered through constructed wetlands. Any water that is not retained by the wetland is used for agricultural irrigation by the Natomas Mutual Water Company (CRWQCB, 2016). In the event that water is not used for irrigation (during certain months of the year there is less need), water is directed through a series of drainage canals, into a confining levee that isolates the river basin, and finally through any of seven pumping stations that pump water into the Sacramento River, the Natomas Cross Canal or the Natomas East Main Drain Canal. (Ibid.). Due to the extensive distance, and the presence of a confining levee and pumping stations, it is assumed that 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 (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019).

The Factor 6.1 Escape risk score for California is 10 out of 10.

Idaho

In Idaho white sturgeon are grown in raceways that have are connected to natural waterbodies via settling ponds. Previous personal communication indicates that as of 2014 there were no escapes (Doroshov pers. comm. 2014; Struffenegger pers. comm. 2014; Van Eenennaam pers. comm. 2014), however 2019 efforts to contact industry representatives to obtain data that would update these claims proved unsuccessful. Idaho Statutes (Title 22, chapter 46) require facilities to install screens for intake water, and state that “effluent control facilities” must be approved by the designated agencies. It is assumed that this refers to effluent control measures at the farm level. In Idaho aquaculture, effluents are regulated by a general NPDES permit which is issued by the EPA. This permit requires that any fish that enter a settling basin be removed as quickly as possible (US EPA, 2007). All sturgeon farms in Idaho use settling basins (G. Fornshell, pers. comm., 2019). Given this permit requirement, multiple screens are used to ensure that fish do not leave the raceway and enter the settling basin, and in the event that a fish did make it to the settling basin, it would be quickly removed, while also being blocked from entry to the natural waterway by screens on the settling basin (G. Fornshell, pers. comm., 2019). Violations of this permit are discussed in Criterion 2 – Effluent, all unrelated to escapes.

Sturgeon production in Idaho uses raceways that are connected to natural waterways, however screens are constructed to keep sturgeon from escaping into settling ponds, which are a buffer between raceways and natural waterways. Personal communications indicate that of the two companies producing in Idaho, one has never had any escape events, while the other had one event during a flood that occurred in 2015 (L. Lemmon, pers. comm, 2019; L. Ray, pers. comm., 2019). Factor 6.1 – Escape Risk scores 6 out of 10 for Idaho.

Factor 6.2. Competitive and genetic interactions

White sturgeon are the only sturgeon species grown in California and Idaho, and they are native to both states.

In California a 1980s cooperation between the industry and University of California collected and spawned wild sturgeon from the Sacramento River and then released them (NASPS, 2013b). In 1994 the progeny of this original spawning event were sexually mature and were spawned, thus closing the life cycle (E. Phillips, pers. comm., 2019). No wild sturgeon have been collected since 1994, and the industry now maintains its own broodstock. Personal communication indicated that a formal assessment of the genetic diversity of the broodstock population was completed at the facility in California that provides juveniles for its own production as well as the production at the largest producer in the state. This assessment determined that broodstock are "very diverse" (E. Phillips, pers. comm., 2019). There have been 2-3 generations of sturgeon spawned since the industry closed the lifecycle in 1994. As farmed sturgeon are more than one generation domesticated, it is assumed that farmed sturgeon have minor genetic differences from wild populations in California.

In Idaho sexually mature adults were collected for broodstock in 1988 in a joint effort by the Idaho Department of Fish and Game (IDFG), the College of Southern Idaho, and the aquaculture industry. In this cooperation juveniles were spawned and IDFG took what was necessary for restocking and recreation. The remainder were left to the aquaculture industry (G. Fornshell, pers. comm., 2019). In 2000 the life cycle was closed when fish from the 1988 spawning matured. Between 2000 and 2012 the industry maintained its own broodstock populations, however in 2012 IDFG reinstated the Cooperative program to support its conservation efforts (L. Ray, pers. comm., 2019). Aside from two specific reaches of the middle Snake River, there are no viable sturgeon populations (IDFG, 2008), the rest are supplemented by hatchery-raised fish, some of which are supplied by commercial sturgeon producing companies (L. Lemmon, pers. comm., 2019; L. Ray, pers. comm., 2019). IDFG now maintains the right to 50% of surviving sturgeon annually that are bred by the industry (L. Lemmon, pers. comm., 2019; L. Ray, pers. comm., 2019). Due to this program, it can be assumed that sturgeon in Idaho do not differ genetically between commercially produced stocks and wild stocks.

Given that farmed sturgeon in California have a closed life cycle with multiple generations being hatchery raised, it is assumed that there are some minor differences between sturgeon raised for farm stock and those in the wild. In Idaho sturgeon are spawned from wild broodstock, and fish are used for both commercial and conservation purposes. The Factor 6.2 score is 6 out of 10 for California, and 10 out of 10 for Idaho.

Conclusions and Final Score

The majority of US sturgeon production occurs in California, where raceways and partial recirculation systems have no connection to natural waterbodies. Production in Idaho uses raceways that are connected to natural waterways, however screens are used at discharge points between the raceways and settling basins as a means of escape prevention. The Escape Risk score for Factor 6.1 is 10 out of 10 for California, and 6 out of 10 for Idaho. In California and Idaho white sturgeon are the only species grown, and they are native to the region. In California sturgeon have been domesticated for multiple generations, leading to an assumption that sturgeon grown for farm stock are genetically different from those spawned for restocking wild populations. In Idaho an ongoing cooperation between the industry, the College of Southern Idaho, Idaho Power Company, and the Idaho Department of Fish and Game has sturgeon broodstock collected from the wild, spawned, and subsequently returned to the wild, with 50% of the juveniles used for conservation efforts, and the rest used for commercial production. Given this, there is no genetic differentiation between wild and farmed stocks. The Factor 6.2 score is 6 out of 10 for California, and 10 out of 10 for Idaho. Factors 6.1 and 6.2 combine to give a final numerical score of 10 out of 10 for California, and 10 out of 10 for Idaho.

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: California and Idaho

California and Idaho: Risk-Based Assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	7	
Critical?	NO	GREEN

Brief Summary

Although several virulent diseases are known to occur among cultured sturgeon, and the majority of sturgeon production in the U.S. is not connected to natural waterbodies. Production in California does not discharge to natural waterbodies, which reduces the risk of pathogen transfer. Production in Idaho is more open to discharge of pathogens into natural waterbodies. There are multiple viruses that are present on both wild and farmed populations. However the characteristics of these viruses make it unlikely that horizontal transmission from farm to wild would occur, and it is assumed that the industry does not increase the likelihood of pathogen amplification beyond natural populations. The score for Criterion 7 – Disease is 7 out of 10 for California and Idaho.

Justification of Rating

Data and information for this criterion are mainly from literature, as very little data were made available directly from industry. As such the data quality and availability is considered moderate/low (i.e. Criterion 1 score is 2.5 for the Disease category), the Seafood Watch Risk-Based Assessment was utilized.

White sturgeon in aquaculture production are vulnerable to a number of viral and bacterial infections. The most common infections are bacterial gill disease (BGD) in hatcheries, two herpes viruses (Acipenserid herpesvirus -1 [AciHV-1] and Acipenserid herpesvirus -2 [AciHV-2]; both previously referred to as white sturgeon herpesvirus [WSHV]), white sturgeon reovirus (K. Beer, pers. comm., 2019) and white sturgeon iridovirus (WSIV) (Doroshov, pers. comm., 2014; Struffenegger pers. comm. 2014). WSIV is likely to only impact sturgeon species, as are AciHV -1 and -2 (Hanson et al., 2016; Hick et al., 2016). As BGD occurs in the hatchery stage before the majority of the life cycle (K. Beer, pers. comm., 2019), it is not considered in this assessment.

The National Wild Fish Health Survey includes WSIV and White Sturgeon Herpes Virus (WSHV) (i.e. AciHV-1 and AciHV-2) in their list of Pathogens of Regional Concern (USFWS, n.d.). Hanson et al. (2016) note that AciHV -1 has been identified in farmed sturgeon in California, and AciHV - 2 has been found in wild and farmed sturgeon in California. Both viruses are present in wild sturgeon populations in the United States (Goodwin, 2012; LaPatra et al., 1999). The presence of both viruses in the wild is also confirmed via personal communication with aquatic animal health experts (Dr. E. Soto Martinez, pers. comm., 2019; Dr. K. Kwak, pers. comm. 2019).

Sturgeon are most susceptible to viral infections in early stages of life, when they can result in high mortality among juveniles (K. Beer, pers. comm., 2019; Hanson et al., 2011; Kwak et al., 2006; Plumb & Hanson, 2011; Watson et al., 1995). Many broodstock are survivors of WSIV and there is evidence that both iridovirus and herpesvirus are transmitted to progeny during spawning (vertical transmission) (Kwak et al., 2006). With WSIV, water-borne transmission and infection via fish-to-fish contact is less frequent, but can occur (Georgiadis et al., 2001). While WSIV can be lethal to juveniles, older sturgeon have a much higher capacity for survival, and survivors of the disease may become resistant (K. Beer, pers. comm., 2019; Hick et al., 2016).

One company in California provided the information that sturgeon on their farm have experienced WSIV, as well as AciHV-1 and AciHV-2, however the frequency of these diseases is unknown (pers. comm., 2019). Other farms (in both California and Idaho) were unable to share information on disease events beyond stating that incidence and prevalence of pathogens are rare and isolated (pers. comm., 2019).

Conclusions and Final Score

Although several virulent diseases are known to occur and persist among cultured sturgeon, production in California is not connected to natural waterbodies. Sturgeon production in Idaho, while using biosecurity protocols, is still open to the introduction and discharge of pathogens, however it is unlikely given the scarcity of horizontal transmission of WSIV, AciHV-1 and -2 that there would be transmission from farms to the wild. The final numerical score for Criterion 7 – Disease is 7 out of 10 for California and Idaho.

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: California and Idaho

Source of stock parameters	Score	
C8X Independence from unsustainable wild fisheries (0-10)	0	
Critical?	NO	GREEN

Brief Summary

US sturgeon production has sourced wild broodstock during the development of the industry (1970s-1980s), however the industry is now completely reliant on hatchery raised broodstock and growout stock. The life cycle for sturgeon in California and Idaho has been closed since 1994 and 2000, respectively. Given that there is 0% reliance on wild populations, the score for Criterion 8X – Source of stock is a deduction of 0 out of -10.

Justification of Rating

In California, individual wild sturgeon were selected from the Sacramento River in 1979 when the Department of Fish and Wildlife gave a grant to researchers at the University of California, Davis to develop spawning for white sturgeon (NASPS, 2013b). In 1994 progeny from the original spawning event were sexually mature and spawned, thus closing the life cycle. No wild sturgeon have been collected since 1994 (E. Phillips, pers. comm., 2019).

Similarly, in Idaho, in 1988 a cooperation between the University of Southern Idaho, IDFG and the aquaculture industry began with collection of wild individuals from the Middle Snake River. These individuals were spawned in captivity, the IDFG took what was necessary for restocking efforts, and the rest were left to the industry. In 2000 individuals from the original spawning event were selected and spawned, thus closing the life cycle (G. Fornshell, pers. comm., 2019).

As such, white sturgeon aquaculture in the US is based on sourcing from broodstock populations maintained by the industry. In California current farmed stock are 3-4 generations hatchery raised (E. Phillips, pers. comm., 2019), while Idaho farmed stock are 4-5 generations hatchery raised (G. Fornshell, pers. comm., 2019). Broodstock are selected from hatchery raised individuals, and there is no longer any reliance on wild populations for broodstock or growout stock (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019; G. Fornshell, pers. comm., 2019). The Criterion 8X score is 0 out of -10.

Conclusions and Final Score

Because 0% of farmed stock is dependent on wild fisheries the final score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

Criterion 9X: Wildlife and predator 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: preventing population-level impacts to predators or other species of wildlife attracted to 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: California and Idaho

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0- -10)	0	
Critical?	NO	GREEN

Brief Summary
Preventative measures are taken in order to keep wildlife from interacting with farmed sturgeon. Eventually sturgeon become large enough that predation is no longer a concern, and preventive measures are no longer used. No interactions have been reported for this assessment. As such the score for Criterion 9X – Wildlife interactions is 0 out of -10.

Justification of Rating
Sturgeon grown in the California and Idaho begin their life cycle in indoor tanks where wildlife and predators are not a threat (K. Beer, pers. comm., 2019; E. Phillips, pers. comm., 2019). Of the two main companies producing sturgeon, one keeps the majority of its biomass indoors for the full life cycle (E. Phillips, pers. comm., 2019). At other sites within this company fish are moved outside when they are approximately 9 months old and 1.5-2.5 lbs. They are covered with shade netting which acts as a barrier to wildlife interactions (ibid.). When fish are approximately 4 lbs they are moved to a larger tank that is 75% covered with shade netting, and is raised a minimum of 3 feet (ibid.). Another site holds fish that are 10-25 lbs in partially covered tanks, while a final site holds fish that are $\geq$30 lbs in uncovered tanks (ibid.). Another company holds fish indoors until they are 6-9 months, at which point they are moved outdoors into tanks covered with bird netting for approximately 1 year. When these fish reach ~2 lbs they are moved to larger tanks that are also netted to exclude birds (K. Beer, pers. comm., 2019).

Communication with farm representatives indicates that one farm maintains a bird depredation permit, however losses are associated with farmed species other than sturgeon production due to the preventative measures noted above (K. Beer, pers. comm., 2019). There are no other permit requirements managing the “take” of any animals due to the lack of interaction with farmed sturgeon, and no interactions with wildlife have occurred (E. Phillips, pers. comm., 2019). Given this, the score for Criterion 9X is a deduction of 0 out of -10.

Conclusions and Final Score

Preventative measures are taken in order to keep wildlife from interacting with farmed sturgeon, including keeping sturgeon indoors until they have reached a size that birds would not target. While one farm maintains a bird depredation permit, it is not associated with sturgeon production at their facility. No interactions have been reported. As such the score for Criterion 9X – Wildlife interactions is 0 out of -10.

Criterion 10X: Escape 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
- Principle: avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals.

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: California and Idaho

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments (%)		10	
F10Xb Biosecurity of source/destination		n/a	
C10X Escape of secondary species Final Score		**0**	**GREEN**

Brief Summary

While there are a handful of companies producing sturgeon in California, two of these companies produce approximately 65% of US sturgeon. One of these companies supplies both with juveniles. Juveniles are transported from the hatchery to farm sites all within the same watershed. In Idaho, companies maintain their own broodstock and there are no trans-waterbody movements. It is therefore assumed that the remaining production in the US (smaller companies in California) is similarly not reliant on trans-waterbody movements. This results in a Factor 10Xa score of 10 out of 10, which renders Factor 10Xb is non-applicable. This results in a final Criterion 10X score of 0 out of -10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

Some US sturgeon facilities maintain their own broodstock, while others source from other companies supplying juveniles.

In California, broodstock are maintained by one of the two largest companies (by volume) and offspring of these broodstock are used to supply juveniles for both companies. This company transports juveniles from the hatchery site to its growout sites, as well as transporting two-day old larvae to the other company, which is approximately 3 miles away within the same watershed (E. Phillips, pers. comm., 2019; K. Beer, pers. comm., 2019). It is unknown whether other producers in California rely on trans-waterbody movements of animals for stocking, however the two farms represented above make up the vast majority of sturgeon production in California (and approximately 65% of total US production).

In Idaho, each company maintains its own broodstock (G. Fornshell, pers. comm., 2019). There are no movements of animals between waterbodies.

The largest two companies producing sturgeon in California, along with the entirety of the industry in Idaho do not rely on trans-waterbody or international movements. It is assumed that the remaining portion of the industry (small California farms) also has no reliance on trans-waterbody movements or international movements of animals. The score for 10Xa is therefore 10 out of 10.

Factor 10Xb Biosecurity of source and destination
As international or trans-waterbody movements of fish do not occur (Factor 10Xa is scored 10 out of 10), Factor 10Xb is not assessed.

Conclusions and Final Score
While there are a handful of companies producing sturgeon in California, two of these companies produce approximately 65% of US sturgeon. One of these companies supplies both with juveniles. Juveniles are transported from the hatchery to farm sites all within the same watershed. In Idaho companies maintain their own broodstock, and there are no trans-waterbody movements. It is therefore assumed that the remaining sturgeon production in the US (smaller companies in California) is not reliant on trans-waterbody movements or international movements. This results in a Factor 10Xa score of 10 out of 10, and a final Criterion 10X score of 0 out of -10.

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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 quality and availability

California and Idaho

Data Category	Data Quality (0-10)
Industry or production statistics	5
Management	10
Effluent	10
Habitats	10
Chemical use	5
Feed	5
Escapes	5
Disease	5
Source of stock	7.5
Predators and wildlife	7.5
Secondary species	7.5
Other – (e.g. GHG emissions)	n/a
Total	**77.5**

C1 Data Final Score (0-10)	**7.05**	**GREEN**

Criterion 2: Effluents

California and Idaho

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Criterion 3: Habitat

California and Idaho

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	9

3.2a Content of habitat management measures	5
3.2b Enforcement of habitat management measures	5
3.2 Habitat management effectiveness	**10**

C3 Habitat Final Score (0-10)	**9.33**	**GREEN**

Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

California and Idaho

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	7	
C4 Chemical Use Final Score (0-10)	**7**	**GREEN**
Critical?	NO	

Criterion 5: Feed

California and Idaho

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	24
Fishmeal from by-products (%)	16
% FM	20.16
Fish oil inclusion level (%)	4.8
Fish oil from by-products (%)	5
% FO	4.56
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.74
FIFO fishmeal	1.56
FIFO fish oil	1.59
FIFO Score (0-10)	**6.03**
Critical?	NO
5.1b Susutainability of Source fisheries	
Sustainability score	-6
Calculated sustainability ajustment	-1.90
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**4.13**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	43.3
eFCR	1.74
Feed protein from fishmeal (%)	36.86
Feed protein from EDIBLE sources (%)	94.10
Feed protein from NON-EDIBLE sources (%)	5.90

Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.2
Edible yield of harvested fish (%)	55
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	75.342
Edible protein IN kg/100kg fish	70.90
Utilized protein OUT kg/100kg fish	23.50
Net protein gain or loss (%)	-66.86
Critical?	NO
F5.2 Net protein Score (0-10)	**3**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood		
Inclusion level of aquatic feed ingredients (%)		28.8
eFCR		1.74
Carbon required for aquatic feed ingredients (ton C/ton fish)		*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)		*2.68*
Ocean area appropriated (ha/ton fish)		13.03
5.3b Land area appropriated per ton of seafood		
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		1.74
Average yield of major feed ingredient crops (t/ha)		*2.64*
Land area appropriated (ha per ton of fish)		0.47
Total area (Ocean + Land Area) (ha)		13.50
F5.3 Feed Footprint Score (0-10)		5

Feed Final Score

C5 Feed Final Score (0-10)	**4.06**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

California

6.1a System escape Risk (0-10)	10
6.1a Adjustment for recpatures (0-10)	0
6.1a Escape Risk Score (0-10)	**10**
6.2. Competitive and genetic interactions score (0-10)	**6**

C6 Escapes Final Score (0-10)	**10**	**GREEN**
CriticaL?	**NO**	

Criterion 6: Escapes

Idaho

6.1a System escape Risk (0-10)	6	
6.1a Adjustment for recpatures (0-10)	0	
6.1a Escape Risk Score (0-10)	**6**	
6.2. Competitive and genetic interactions score (0-10)	**10**	
C6 Escapes Final Score (0-10)	**10**	**GREEN**
CriticaL?	**NO**	

Criterion 7: Diseases

California and Idaho

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	7	
C7 Disease Final Score (0-10)	**7**	**GREEN**
Critical?	NO	

Criterion 8X: Source of Stock

California and Idaho

C8X Source of stock score (0-10)	0	
C8 Source of stock Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Criterion 9X: Wildlife and predator mortalities

California and Idaho

C9X Wildlife and Predator Score (0-10)	**0**	
C9X Wildlife and Predator Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of secondary species

California and Idaho

F10Xa live animal shipments score (0-10)	10.00
F10Xb Biosecurity of source/destination score (0-10)	0.00

C10X Escape of secondary species Final Score (0-10)	**0.00**	**GREEN**
Critical?	n/a	