Rainbow Trout

Oncorhynchus mykiss

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United States

Net pens

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

About Seafood Watch®

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

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

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

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Guiding Principles

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

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

Seafood Watch will:

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

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

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

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

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

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

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

Final Seafood Recommendation

Rainbow Trout, Steelhead Trout
Oncorhynchus mykiss
United States
Net Pens

Criterion	Score (0-10)	Rank	Critical?
C1 Data	7.78	GREEN	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	8.67	GREEN	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	5.22	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**53.66**		
Final score	**6.71**		

OVERALL RANKING

Final Score	6.71
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

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

Summary

The final numerical score for rainbow trout grown in net pens in the United States is 6.71 and with no red criteria the final ranking is Green.

Executive Summary

Rainbow trout (*Onchorynchus mykiss*) are native to many North American rivers and lakes that drain into the Pacific Ocean. They have also been introduced as a sport fish throughout much of North America. The United States produces over 15,000 mt of rainbow trout making it the 10th largest producer worldwide. These fish are grown primarily in concrete raceways, but approximately 3,600 tonnes are produced in net pens on a single farm in the Columbia River, Washington. The net pen operation assessed in this report therefore represents a small fraction of the United States rainbow trout aquaculture industry.

Data for this report were drawn from primary literature, feed suppliers, government and industry reports, and expert consultation. Moreover, direct communication from farm managers provided additional important data. Therefore, data quality and availability scored 8.33 out of 10.

Rainbow trout in net pens produce a nutrient-rich effluent from excess feed, feces and soluble wastes; however the available monitoring data combined with effective regulations shows that the risk of significant effluent impacts beyond the immediate farm area is low and the Effluent Criterion receives a score of 6 out of 10.

The regulatory, management, and siting requirements placed on rainbow trout net pens severely limit the size of the industry. This strict oversight coupled with monitoring data provided by the farm is shown to effectively limit the habitat impacts of rainbow trout net pens and Criterion 3 – Habitat receives a score of 8.67 out of 10.

Communications with academics and the farm manager have indicated that the use of chemicals is demonstrably low due to effective management and the use of vaccines to optimize fish health and reduce the occurrence of disease. However, due to the small size of the industry, peer-reviewed data on the amount and type of chemicals used in net pen trout aquaculture in the United States is unavailable. Moreover, the nature of net pen systems indicates that any chemicals that are used are discharged untreated into the surrounding environment. Until more data becomes available a precautionary score of 4 out of 10 is applied to Criterion 4 – Chemical Use.

Rainbow trout are a carnivorous species. At the operation under assessment the fish are fed a commercial pelleted diet with 19% fishmeal inclusion and 6% fish oil inclusion. The feed conversion ratio of rainbow trout grown in these systems is 1.6:1 with a fish in: fish out value of 1.63. While a portion of the protein in the feed is from non-edible sources (i.e., processing byproducts), this aquaculture production results in an approximate 59% loss of protein. The land and ocean area required to support this production is approximately 11.1 ha per tonne of trout produced. The overall score for Criterion 5 – Feed is 5.22 out of 10.

While the inherent escape risk from net pen production systems is high, evidence on the specific number of escapes from net pens is unavailable. Although anecdotal evidence suggests that escapes are sporadic but potentially large, the fish are sterile and unable to breed with wild populations. It is important to note that any potential escape numbers from the farm are dwarfed by the number of intentional introductions for sport fishing, and for this reason, escapes of rainbow trout from this farm are not considered a risk and the overall score for escapes is 10 out of 10.

Due to the open nature of net pens, any diseases which occur can be easily transmitted to wild populations. However, anecdotal evidence and input from academic experts indicate that the occurrence of disease in rainbow trout net pen aquaculture is low due to the use of vaccines and effective husbandry and management. While disease impacts are shown to be low, the risk of transmission to wild populations remains; for this reason Criterion 7 - Disease receives a score of 6 out of 10.

Rainbow trout are sourced from fully controlled broodstock independent of wild populations. No wild harvesting is required for the continuity of the industry and as such Criterion 8- Source of Stock scores 10 out of 10.

Interactions with wildlife are primarily a result of bird predators feeding on fish. Anecdotal evidence suggests that these problems are limited in rainbow trout net pens and that mortality is limited to exceptional cases. A score of -4 is therefore applied to the exceptional Criterion 9X.

With dedicated hatcheries throughout the United States, rainbow trout are not transported across different water bodies or internationally. For this reason a score of zero out of -10 is applied for the exceptional Criterion 10X.

Overall, rainbow trout net pen aquaculture in the US receives a score of 6.71 out of 10, and with no red or critical criteria, the final recommendation is a green “Best Choice.”

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Introduction

Scope of the analysis and ensuing recommendation

Species: Rainbow trout, aka steelhead trout (*Oncorhynchus mykiss*)
Geographic coverage: United States of America
Production Methods: Net pens

Species Overview

Rainbow trout (*Oncorhynchus mykiss*) are a salmonid fish native to the streams, rivers, and lakes that drain into the Pacific Ocean; they range from Alaska to Mexico and belong to the genus *Oncorhynchus*, which includes the closely related Pacific salmon and many Pacific trout species. Some rainbow trout, known as steelhead, are anadromous, meaning that they begin their life in freshwater, travel to the ocean for their adult development and return to freshwater to spawn (Behnke 2002). As many as 7 distinct subspecies of rainbow trout have been identified but there is no clear agreement by taxonomists. These include: coastal rainbow trout; several subspecies of redband trout; golden trout; and those native to the Gulf of California (Behnke 2002).

Rainbow trout are fast growing, cold water fish that can attain sizes of more than 25 kg, although typically not more than 1-3 kg, with larger sea-run steelhead often reaching 10 kg (Behnke, 2002). They are speckled with a darker back and silvery sides that have a pink-to-red band. This band is often iridescent, resembling a rainbow, which gives the fish their common name. Their diet is varied and includes many insects, crustaceans, other small fish and eggs. Due to their popularity as a sport and food fish, rainbow trout have been intentionally introduced all over the world and currently inhabit all continents except Antarctica (FAO 2013). In North America, rainbow trout have established breeding populations throughout most of the USA and Canada (NatureServe 2013).

The rearing of rainbow trout principally for stocking purposes began in the United States in the 1800s. This continues to this day, albeit in a more controlled manner to avoid environmental consequences of introduction into new habitats. Rainbow trout aquaculture for the purpose of market production began in earnest in the 1960s. Since then it has grown amid innovations in management and feed that have resulted in more efficient and less impactful production techniques.

Production system

This assessment is focused on the production of rainbow trout in open net-cages. Net pens have two main components: the collar and the net (or cage). Collars are the floating portion which provides structure. Collars can be made out of wood, metal (usually steel), or plastic. They will often support a walkway that provides farm workers access to the enclosure. The nets are typically made of plastic and are woven together to prevent the escape of fish while allowing the free-flow of water and other materials (e.g., feces) into and out of the growing environment. Most net pens will have a third component—an anchoring system—used to prevent movement of the cages and to keep the nets under tension so they do not become deformed.

Production statistics

In 2010, the culture of rainbow trout worldwide reached a total of 728,448 tonnes (FAO 2010). This is up from an annual production of roughly 550,000 tonnes during 2001-2005 (FAO 2010). This production occurs in over 70 countries but is dominated by a few large producers. In 2010, the top three—Chile, Iran and Turkey—produced 220,244, 91,519, and 85,244 tonnes respectively, accounting for approximately 55% of global production. In that same year, the USA produced 15,401 tonnes or just above 2% of global production, making it the 10th largest producer of rainbow trout (FAO 2010).

In 2012, American production of trout (mostly rainbow trout but including other trout species) was approximately 21,600 tonnes for a total value of $79.7 million USD (USDA 2013c). The culture of trout occurs in more than 16 states but about 75% (by weight) occurs in Idaho, concentrated in the Snake River region (Hardy, Fornshell, & Brannon 2000; pers. comm. March 2013; Gary Fornshell, University of Idaho). Other prominent producer states include North Carolina, California and Pennsylvania (USDA 2013c). Approximately 90% of all rainbow trout production in the United States occurs in concrete raceways (Fornshell 2002).

Only two operations growing rainbow trout in net pens have been identified. This includes a very small research operation in New Hampshire that produced under 550 kg in 2012 (pers. comm. Mr. Chambers, April 2013) and a larger commercial operation in the Rufus Woods Lake (a reservoir along the Columbia River in Washington State that is created by the Chief Josef Dam) that now produces over 3,600 tonnes yearly. This facility has been certified for best aquaculture practices (BAP) by the Global Aquaculture Alliance (GAA) and is the first salmonid net pen facility in the USA to have done so (SeafoodSource 2013). This report focuses only on the larger commercial operation.

Import and export sources and statistics

Exports of fresh and frozen rainbow trout in the United States are small as most of the production is sold and consumed domestically. After reaching a value of over $5 million USD in 2003, exports declined to roughly $2 million a year (USDA 2013a). However in 2012, exports spiked to $5.8 million. Overwhelmingly, these exports are bound for Canada, which accounted for $5.66 million of U.S. exports in 2012 (nearly 98%) (USDA 2013b).

Imports of trout are much more significant than exports and have been increasing steadily, reaching a value of over $72 million in 2012 (USDA 2013a), nearly rivaling the value of domestic production. The majority of these imports are from Chile and secondarily from Canada, accounting for $49.9 and $8.6 million USD respectively in 2012 (more than 80% of total combined) (USDA 2013b).

Common and market names

Rainbow trout, steelhead trout, salmon trout, golden trout (Behnke 2002)

Product forms

Rainbow trout is commonly sold whole or as fillets. These can be fresh, frozen, smoked or other value-added products (e.g., breaded, ready-made).

Analysis

Scoring guide

- With the exception of the exceptional Criterion (9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.seafoodwatch.org/cr/cr_seafoodwatch/content/media/mba_seafoodwatch_aquaculturecriteramethodology.pdf. The full data values and scoring calculations are available in Annex 1.

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	10	10
Predators and wildlife	Yes	5	5
Chemical use	Yes	5	5
Feed	Yes	10	10
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	No	n/a	n/a
Total			**70**

C1 Data Final Score	**7.78**	**GREEN**

Brief Summary

The majority of scientific data regarding trout farming focuses on production systems other than net pens. Published data on topics such as feed, source of stock, and habitats were more readily available than information on chemical use, escapes, and disease. Direct communications with academics and farm managers provided valuable data to supplement the primary literature; the final score for Criterion 1 – Data is 7.78.

Justification of Ranking

Rainbow trout aquaculture in the U.S. is a large and historically important industry, and has been the focus of a great deal of research; however, the majority of this research has focused on production systems other than net pens (e.g., raceways, ponds, and recirculating aquaculture systems). Despite the lack of net pen-specific information, several aspects of rainbow trout culture in general are applicable to this assessment. Reports generated by state and federal government departments provided important insight into more general descriptive statistics (e.g., total production, trade data). Information on net pen trout operations was obtained from farm management by email and phone correspondence. Reports directly relevant to these net pens included environmental assessments and effluent reporting data. Information regarding feed formulations was obtained from the feed supplier. Where necessary, experts were consulted for up-to-date analysis of industry and current practices.

Overall, the data availability in the primary literature is moderate due to the small number of operations; specific information regarding production practices was provided by the farm managers and academics but was unable to be verified through published research. Data scores for such topics as production statistics, escapes, and diseases were all 7.5 and were obtained through communications with farm managers. Information on predator and wildlife interactions and chemical use were also obtained in this way, but were unable to be verified and thus scored a 5. Data on feed, source of stock, and locations/habitats are more widely available and these categories are therefore assigned a data score of 10. The effluent category was given a 7.5 for data quality because farm specific discharge monitoring reports for the National Pollutant Discharge Elimination System (NPDES), covering relevant time periods with non-critical time gaps, were provided by farm managers. The final numerical score for Criterion 1 – Data is 7.78 out of 10.

Criterion 2: Effluents

Impact, unit of sustainability and principle

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

Criterion 2 Summary

Effluent Evidence-Based Assessment

C2 Effluent Final Score	**6.0**	**YELLOW**

Brief Summary

While net pen production systems inherently result in the discharge of untreated effluent, in the case of the one net pen trout operation in the United States effluent impacts beyond the immediate farm area are shown to be minor. Proper siting coupled with strict monitoring and regulatory enforcement result in a score of 6 out of 10 for Criterion 2 – Effluent.

Justification of Ranking

Effluent Evidence-Based Assessment

The emission of effluents containing excess nutrients, organic matter and wastes remains one of the most persistent environmental concerns associated with aquaculture of finfish worldwide, especially for salmonid species such as rainbow trout (Bureau & Hua 2010; Tello, Corner, & Telfer 2010). The nutrients ultimately contained in the effluent first enter the water as feed. As they pass through the aquaculture system, they can be divided into three fractions: the first fraction are those nutrients that are digested and retained in the body of the fish (e.g., the rainbow trout body composition contains 15.7% of nitrogen; see Dumas, De Lange, France, & Bureau 2007); the second fraction is passed through the body of the fish and released as solid and dissolved wastes; and the final fraction is in uneaten feed (typically about 5%). It is the last two fractions (wastes and uneaten feed) that flow from net pens into downstream and benthic environments as effluent.

Effluents contribute to environmental problems because they are a source of nutrients that may otherwise be limiting (nitrogen in seawater and phosphorus in freshwater) and lead to eutrophication, biological oxygen demand, and an increase in suspended solids (Tucker, Hargreaves, & Boyd 2008). The ecological consequences of these changes alter the structure and function of affected areas by contributing to increases in phytoplankton growth, hypoxia, changes in species composition, water turbidity, the accumulation of sediments on the benthos, and direct toxic effects (Sindilariu 2007).

In the USA, effluent water quality from aquaculture is regulated at the federal level by the Environmental Protection Agency (EPA) through the National Pollutant Discharge Elimination System (NPDES)—an amendment to the Clean Water Act (CWA) (Jensen & Zajicek 2008). Trout farms that discharge water more than 30 days per year (unless they produce less than 9,090 kg/year of trout and use less than 2,272 kg/month of feed) must have an NPDES permit in order to farm trout. These permits regulate effluent based on water quality standards or technology-based standards (Jensen & Zajicek 2008). On a state level, states may set standards that are more stringent than those of the NPDES (pers. comm. Gary Fornshell, March 2013). If the water quality of a given water body is not meeting permitted standards then they must be designated as 'water quality limited.' In the event that a water body is declared quality limited, specific total maximum daily load (TMDL) limits will be put in place (McCoy 2000). While this is an issue for raceway trout farms operating in the Middle Snake River in Idaho (IDEQ 2013) the same is not the case for net pens on the Columbia River, as water quality consistently meets EPA standards (Rensel 2010).

The effluent regulations in the U.S. are applicable to aquaculture and address cumulative impacts with regard to TMDL (USEPA 2006). They are site-specific and in the instance of the Columbia River, set according to ecological status of receiving water bodies as a result of a thorough environmental assessment conducted in 2011 (USEPA 2011). Compliance to these regulations must occur at all times throughout production, including times of peak biomass (pers. comm. Gary Fornshell, March 2013). Effluent limits have been shown to be highly effective NPDES (pers. comm. Gary Fornshell, March 2013). Trout pens on the Columbia River have never been found to exceed these limits (pers. comm. John Bielka, May 2013). In instances where farms are in violation of the NPDES permit, they are first subject to remediation before any penalties (if any) are put in place (Boyd, Zajicek, Hargreaves, & Jensen 2008).

The only commercial rainbow trout farm currently growing 'fish in' net pens in the U.S. is located in the Rufus Woods Lake Reservoir along the Columbia River in Washington State. Water monitoring in this river has shown that total phosphorus (mg/L) has been declining steadily from as high as 30 µg/L in the mid-1970s to a mean of 5.6 µg/L during 2000-2009 (Richards, Rensel, Siegrist, Brien, & Kiefer 2011). This is attributed to reduced outflow from a phosphorus fertilizer plant located upstream that caused historically high levels of total phosphorus. Additionally, as a result of nutrient trapping from upstream dams and storage reservoirs, phosphorus levels are so low that the reservoir has been considered oligotrophic (i.e., lacking in nutrients available for plant growth) for at least a decade (Rensel 1999, Richards et al. 2011).

Monitoring data undertaken as part of the NPDES requirements show very little impact of farm-site effluent on water quality. Measurements taken at the surface, half the depth of the pens and 3 feet from the bottom, show that turbidity of downstream areas increases by 0%–15% over the baseline and dissolved oxygen shows a minor decrease (the largest difference from 7.5

mg/L to 7.1 mg/L) (unpublished data 2012). These reports indicate no significant impacts caused by effluent, however, they were available for only the month of September 2012 and, to acquire a more robust understanding, data from other monitoring periods would be necessary. In addition to the monitoring reports, underwater video monitoring is employed to observe the habitat underneath the pens. This footage has not found any visible impacts to date (pers. comm. John Bielka, May 2014), and therefore there is a low risk that there are significant benthic impacts beyond the immediate farm area.

Together, the low evidence of effluent impacts (but limited temporal data coverage) combined with the regulations and management in the U.S., result in a moderate final numerical score for Criterion 2 – Effluent of 6 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		9.0	
F3.2a Content of habitat regulations	4.0		
F3.2b Enforcement of habitat regulations	5.0		
F3.2 Regulatory or management effectiveness score		8.0	
C3 Habitat Final Score		**8.67**	**GREEN**
Critical?	NO		

Brief Summary

Net pen rainbow trout aquaculture is shown to maintain habitat functionality with minimal impacts based on several environmental impact assessments, scientific studies, and strong monitoring and recording at the farm level. Strict regulation and enforcement ensures that the continued operation of the farms do not result in unacceptable habitat impacts.

Justification of Ranking

Factor 3.1. Habitat conversion and function

While the floating net pens have little direct habitat impacts, the ecological effects of salmonid farms can be caused by nutrients, pathogens and chemicals that are emitted to receiving water bodies (Tello et al. 2010). In net pens located in freshwater, phosphorus excreted by fish can lead to increased primary productivity within the immediate footprint of the farm, however, this can be mitigated by proper siting and feed management strategies (Belle & Nash 2008).

Several environmental assessments of the Rufus Woods Lake Reservoir along the Columbia River in Washington State have been completed to get a better understanding of local ecology in order to manage stocking and fishing programs more effectively (Rensel 2010, Richards et al. 2011). Additionally, as part of the NPDES permit requirements for an additional net pen at Rufus Woods Lake Reservoir, an environmental assessment was conducted on behalf of the U.S. Environmental Protection Agency (USEPA 2011). These studies have found that the overall impacts of aquaculture historically (the two net pens already operating) is minimal and is expected to remain so in the future (regarding the proposed third net pen which is now operational) (Rensel 2010, USEPA 2011). These findings are corroborated by video recordings of the habitat underneath the cages, which find no visible impacts (pers. comm. John Bielka, May 2014).

In fact, recent research on the food web dynamics of the Rufus Woods Lake suggest that ecosystem function is being maintained and perhaps even enhanced by the addition of nutrients from nearby trout farms (Rensel 2010). This is because many areas along the Columbia River (including Rufus Woods Lake) are nutrient poor due to nutrient trapping and sediment retention caused by dams built for hydropower. The additional nutrients released by the net pen appear to support plants, benthic invertebrates and fish without contributing to nutrient build-up on the benthic environment (Rensel 2010). This is in stark contrast to other open net pen operations growing salmonids (in marine environments), which have been found to contribute to impacts on the benthic environment, creating zones of hypoxia and reducing benthic biodiversity (Brooks & Mahnken 2003; Findlay, Watling, & Mayer 1995; Pelletier & Tyedmers 2007).

For the purposes of this assessment, rainbow trout net pen aquaculture is shown to maintain habitat functionality with minimal impacts. As such, Factor 3.1 scores 9 out of 10.

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

Site selection is important in trout production, both to ensure that appropriate conditions exist for maintaining optimum fish health and to reduce environmental impacts (Belle & Nash 2008). Currently, the net pen industry for rainbow trout is very small, with only one commercial freshwater business in operation as of the writing of this report. Siting for this farm was determined as part of an environmental assessment of the ecological conditions of the Colombia River (USEPA 2011). Currently, there are no requirements for restoration of habitat or ecosystem services affected by trout aquaculture (pers. Comm. Dirk Helder, April 2013).

In the U.S., environmental impact assessments are not required at a federal level, therefore, most states do not require one to be completed prior to licensing for aquaculture, although many of the permits (e.g., NPDES) require much of the same type of information to be collected and submitted (Telfer, Atkin & Corner 2009). However, as mentioned above, an environmental assessment was conducted as part of the planning for the net pen sites on the Columbia River.

The size of the industry is regulated by the cumulative effects that it has (along with other industries) on receiving water bodies based on emissions of solids and phosphorus (pers. Comm. Dirk Helder). If the water body is deemed to be 'water quality limited,' then a total maximum daily load (TMDL) is put in place and restrictions on future effluents are implemented (Fornshell & Hinshaw 2008, USEPA 2006). When this occurs, future development is constrained by the discharge of regulated substances (typically, solids and phosphorus for freshwater). These constraints have limited the growth of rainbow trout aquaculture in the past (Fornshell 2002). As a result of these regulations the rate of expansion of rainbow trout production in the

U.S. (i.e., total trout production in all systems) declined throughout the 2000s with a moderate increase from 2010 to 2012 (FAO 2010, USDA 2013c). Overall, Factor 3.2 Siting and Management Effectiveness is given a score of 8 out of 10.

The overall effect of aquaculture on the Rufus Woods Lake Reservoir and the Columbia River in Washington is minimal with no apparent impacts on the delivery of ecosystem services. When combined with the active adherence to and enforcement of strong effluent regulations, Criterion 3 – Habitat scores 8.67 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: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**4.0**	
C4 Chemical Use Final Score	**4.0**	**YELLOW**
Critical?	NO	

Brief Summary

While chemicals (most notably antibiotics) are known to be utilized in the global trout aquaculture industry, anecdotal evidence suggests that recent U.S. net pen trout production use either little or no chemicals during production. Unfortunately, detailed and specific data on this chemical use is not currently available. Moreover, due to the open nature of the net pen production system, any chemicals that are used are able to be discharged untreated directly into the surrounding environment. Since the actual use is unknown and chemicals are discharged directly into the environment, the score for Criterion 4 – Chemical Use is 4 out of 10.

Justification of Ranking

The primary chemicals used in trout aquaculture in the United States are antibiotics; these are regulated by the FDA and are administered through medicated feeds. In the United States, these chemicals are allowed to be used only with a veterinary prescription (i.e., no unregulated use allowed) (MacMillan, Schnick & Fornshell 2006). In the U.S., there are currently 8 classes of drug permitted for use with aquatic animals for treating pathogens, promoting spawning, and anaesthetizing animals (USFWS 2010). Across all animal husbandry industries, antibiotic use is an area of concern because these chemicals can create resistance in pathogenic bacteria, impact downstream organisms, and accumulate in the tissues of exposed organisms (Benbrook 2002, Rodgers & Furones 2009, Tucker et al. 2008).

In trout production, it is in the best interest of the producer to avoid diseases through management of fish health, as any chemicals required to treat disease outbreaks can be costly from both an economic and environmental perspective (Tucker et al. 2008). While diseases do still occur, producers employ practices that optimize fish health and limit the need for chemicals in the rearing environment (pers. comm. Fornshell, March 2013).

In a global study of rainbow trout across several different production systems, Benbrook (2002) estimates that trout aquaculture in the U.S. used between 17.3 and 28.8 tonnes of antibiotics in the year 2000. This equates to roughly 0.0003 – 0.0006 kg of antibiotic per kg of fish produced. More recently, a global survey of aquaculture professionals found that 37% and 42% of respondents reported frequent use and rare use (respectively) of tetracyclines in trout production (Tuševljak et al. 2012) . Frequent and rare use of other antimicrobials ranged from 3%–25% and 18%–45% respectively, with some respondents claiming the use of quinolones, a banned substance in the US (Tuševljak et al. 2012). While this survey does not record quantitative use of chemicals and includes respondents from many countries, it nonetheless allows the authors to identify some general conclusions; namely, that antimicrobial use appears to be a regular part of many trout production operations and some producers in the U.S. are using substances that are prohibited (Tuševljak et al. 2012). Due to the design of this study, it is not possible to draw any further conclusions; moreover, it is unclear how representative this research is of the small U.S. net pen trout industry, which is distinct from the larger raceway and ponds industry. For this reason, this study is described here for informational purposes only and not used in scoring the industry.

On the farm sites that grow rainbow trout in net pens, anecdotal evidence suggests that the health management of the fish has been relatively effective with low historic use of antibiotics and no antibiotics or pesticides (either legal or prohibited) used during the most recent production cycle (pers. comm. Bielka, May 2013 and September 2013). Based on this information and communications with experts (pers. comm., Fornshell, March 2013; pers. comm. Naylor, March 2013), the evidence suggests that throughout a typical net pen trout production cycle, the use of chemicals is likely low.

Due to the open nature of net pens, any chemicals that are used on-site will be released untreated to the surrounding environment, potentially contributing to ecological effects, including mortality and resistance (Burridge, Weis, Cabello, Pizarro & Bostick 2010). To date, there is no evidence of impacts on non-target species or antibiotic resistance in organisms surrounding net pen trout aquaculture. It is noted that there is no limit to the total use of antibiotics in the U.S. aquaculture regulations (i.e., should a significant disease outbreak occur), however, due to the very limited size of the net pen farmed trout industry, there is not considered to be a significant risk from a large cumulative use.

Overall, although the available information suggests chemical use is low, it is largely anecdotal and covers a limited temporal range. Therefore, while accepting that the risk of impacts are likely to be low based on the small size of the industry, the actual chemical use is considered to be largely unknown and the treatment method would allow the release of chemicals into the environment. A precautionary final score of 4 out of 10 has been applied until more data can provide greater reassurance that the zero use of antibiotics in the most recent production cycle is representative of routine production.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	1.63	5.92	
F5.1b Source fishery sustainability score		-3.00	
F5.1: Wild Fish Use		5.43	
F5.2a Protein IN	28.79		
F5.2b Protein OUT	11.78		
F5.2: Net Protein Gain or Loss (%)	-59.10	4	
F5.3: Feed Footprint (hectares)	11.14	6	
C5 Feed Final Score		**5.22**	**YELLOW**
Critical?	NO		

Brief Summary

Although fishmeal and fish oil inclusion levels are moderately high (19% and 6% respectively), a significant amount comes from fishery byproducts; therefore, the calculated fish in: fish out ratio is 1.63; meaning it takes 1.63 kg of wild fish to produce 1 kg of farmed trout (in net pens). There is 59% net loss of protein, and a moderate feed footprint which, combined, result in a final score of 5.22 for the feed criterion.

Justification of Ranking

Factor 5.1. Wild Fish Use

5.1.a Fish In: Fish Out

The fish in: fish out (FIFO) ratio for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of fish used in feeds, and the source of the marine ingredients (e.g., from processing byproducts or whole fish targeted by wild-capture fisheries). FCR is the ratio of feed given to an animal per amount of weight gained, measured in mass (e.g., FCR of 1.4:1 means that 1.4 kg of feed is required to produce 1 kg of fish). It can be reported as either biological FCR, the straightforward comparison of feed given to weight gained, or economic FCR, which is the amount of feed used per product harvested. The FCR of trout is often difficult to ascertain because most organizations report the biological FCR, which is a measure of biological growth and does not account for mortalities (these losses are considered in the economic FCR). For this reason, it is common to see claims that trout have an FCR of 1:1 or even lower. In reality, trout production in the U.S. has historically seen economic FCRs in the range of 1-1.3 (Tacon & Metian 2008) with only very efficient commercial operations or those using very high fish oil content in the 1:1 range (Cho 1992, Fornshell & Hinshaw 2008). The most representative data available comes from yield studies done by Tuomikoski & Hinshaw (unpublished data in Fornshell & Hinshaw 2008) where the authors found an average FCR of 1.16 in 12 U.S. trout farms from 2004 to 2005. For commercial net pen trout operations in the U.S., the economic FCR is in the range of 1.4-1.6 (pers. comm. Bielka, May 2013), therefore, the higher value of 1.6 is used in this report.

Formulating feeds that optimize fish growth and reduce cost has been a topic of considerable research (Azevedo, Leeson, Cho & Bureau 2004; Bilgüven & Barış 2011; Tacon & Metian 2008). Of particular focus has been the substitution of marine ingredients (fishmeal and oil) with vegetable and livestock meals and oils (Barrows, Gaylord, Stone & Smith 2007). This is important because the availability of fish-derived meals and oils is constrained by the catch of wild fish, which has its own inherent environmental impacts (Tacon & Metian 2008). Moreover, the use of whole fish in feed has been criticized, as this otherwise edible seafood could be used for human consumption (Alder, Campbell, Karpouzi, Kaschner & Pauly 2008).

Recently, there has been a trend by the trout industry to feed high nutrient diets containing 45%–50% total protein (made up of fishmeal from both wild-capture fisheries and byproducts, as well as terrestrial animal and crop proteins) and up to 20%–35% total crude fat (made up of fish oil from both wild-capture fisheries and byproducts, as well as terrestrial crop oils) (Barrows et al. 2007, Sindilariu 2007); these feed formulations have been found to decrease nutrient excretion and increase FCR. Historically, trout feeds in the U.S. have included fishmeal and fish oil at approximately 20%–30% and 4%–10% respectively (Tacon & Metien 2008). The considerable variation in trout feeds is demonstrated by differences in published reports; Pierce et al. (2008) described “traditional” diets with 63.14% fishmeal and 10.10% fish oil; Azevedo et al. (2004) tested 4 trout diets ranging from 23%–34% fishmeal and 14%–22% fish oil; Barrows et al. (2007) tested experimental diets containing 0%–59.24% fishmeal and 7.3%–79% fish oil and a commercial diet with 46% protein (unknown fishmeal content) and 16% fish oil.

For rainbow trout reared in net pens in the U.S., feed containing 19% fishmeal and 6% fish oil is used, with 35% and 15%, respectively, of these ingredients originating from byproducts (pers. comm. Dr. Jason Mann, a representative of the feed manufacturer that supplies the feed for net pen trout on the Columbia River, May 2013). This use of byproducts is similar to claims by the International Fishmeal and Fish Oil Organization (IFFO) that, on average, 25% of fishmeal and fish oil in U.S. aquaculture feeds comes from trimmings and processing byproducts (Chamberlain 2011).

As a result of the FCR, coupled with the wild fishmeal/oil and byproduct inclusion rates, the FIFO score calculated for U.S. net pen trout production is 1.63. From first principles, this means that 1.63 tonnes of wild fish are required to produce 1 tonne of culture rainbow trout. This translates into a score of 5.92 out of 10 for Factor 5.1.a.

5.1b. Sustainability of Wild Fish Source

The specific source of fishmeal and fish oil used in fish feeds is typically variable and subject to change, depending on market price and availability (pers. comm. Dr. Ronald Hardy, April 2013). Globally, the majority of the fishmeal and oil comes from small wild pelagic fish, including herring, menhaden and anchoveta (Pauly & Watson 2009). Fishmeal and oil produced in the U.S. are produced primarily from menhaden (Péron, François Mittaine & Le Gallic 2010), with some reports claiming this species accounts for up to 90% of U.S. fishmeal production (Miles & Jacob, 1997). Much of the remainder of U.S.-produced fishmeal and oil is derived from unused portions (e.g., offal, processing trimmings, bycatch) of other fisheries (e.g., Alaskan pollock, Pacific whiting) (Péron et al. 2010).

Fishmeal and oil used to feed trout grown in net pens in the United States is derived primarily from Gulf menhaden with smaller volumes of Alaskan pollock, Pacific whiting (aka hake), Pacific herring, and anchovetta making up the bulk of the remainder (pers. comm. Dr. Jason Mann, May 2013). The sustainability of these source fisheries was assessed using data from the Marine Stewardship Council (MSC) and FishSource. MSC is an NGO that certifies seafood products from fisheries and aquaculture based on their sustainability (for more info see MSC 2013a). FishSource is a database maintained by the Sustainable Fisheries Partnership that scores capture fisheries from 0-10 (10 = best score) based on management and stock health. FishSource utilizes such information sources as stock assessments, scientific literature, sustainability assessments by environmental NGOs/ aquaria, and online databases (FishSource, 2013). According to FishSource, the U.S. Gulf menhaden fishery scores over 6 in all management categories, with current stock health and future stock health both scoring 10. Recent reports claim that the U.S. menhaden fishery is not considered overfished, and the fishery is of an acceptable size (Atlantic Menhaden Technical Committee 2006), while the Pacific hake fishery is MSC certified (MSC 2013b). The Pacific herring fishery had been assessed by Seafood Watch as a “best choice” alternative, however, due to changes in the fishery, its assessment has been withdrawn (Shore 2011) and there is currently no assessment by SFW, MSC, FishSource or any other certifying body . The anchovetta fishery, on the other hand, has received all FishSource scores over 6 with at least one score over 8 in Peru, but one score below 6 in all Chilean regions (FishSource 2013). The poorly managed Chilean anchovetta fisheries and the unknown status of Pacific herring represent a small fraction of total fish meal and oil used. Together, these fisheries result in an adjustment score of -3 out of -10 for Factor 5.1.b.

When the Factor 5.1b adjustment score is applied, the final numerical score for Factor 5.1 is 5.43 out of 10.

Factor 5.2. Net Protein Gain or Loss

By feeding fish to fish, there is potential for a net protein loss where cultured fish actually produce less protein then they consume (Naylor et al. 2000). This is determined by the amount of protein fed to the fish and the amount of protein harvested in the fish. Total protein contents in trout feeds are typically in the range of 35%–50% (Barrows et al. 2007; McIntosh, Ryder, Dickenson & Fitzsimmons 2004; Sindilariu 2007); this protein consists of fishmeal (from both whole wild fish and processing byproducts) as well as terrestrial animal and crop proteins. For this assessment, a feed total protein content of 45% is used (pers. comm. Dr. Mann, May 2013).

In typical trout feeds used in the raceway and pond operations, roughly half of protein comes from plant sources, with the remainder coming from fish and other animals (pers. comm. Dr. Hardy, April 2013). For trout feeds used in the commercial net pen operation being assessed here, protein is more or less evenly supplied by fishmeal, poultry byproducts, and vegetable sources (33% inclusion of each) (pers. comm. Dr. Mann, May 2013). Since 35% of fishmeal is derived from byproducts (see Factor 5.1), 11% of total feed protein emanates from byproducts (33%*35%=11%). With animal byproducts accounting for an additional 33% of total protein, 44% of total protein is from nonedible sources (33% from terrestrial animal byproducts + 11% from fish processing byproducts). There is no further information on whether or not the vegetable sources utilized for feed protein are fit for human consumption and, thus for the purposes of this assessment, they are assumed to be edible. If the remaining protein from vegetable sources is treated as edible, this means that 56% of total feed protein is derived from edible sources.

The protein content of the fish carcass is estimated to be 15.7% (Dumas et al. 2007), with yield of fillet estimated at 50% (conservative estimate based on a range of 50%–53% from Rasmussen & Ostenfeld 2000). Using these values, protein loss for net pen trout farms is calculated at 59.8% and the score for Factor 5.2 is calculated to be 4.0 out of 10.

Factor 5.3. Feed Footprint

While the exact feed formulation is proprietary, based on inputs from academics, the feed company, and the farm manager, 10.4 ha of ocean area and 0.74 ha of land area are calculated to be required to produce enough feed to grow one tonne of farmed rainbow trout. With a total ocean and land area of 11.14 ha, Factor 5.3 results in a score of 6 out of 10.

Final Criterion 5 – Feed Score

The scores from Factors 5.1, 5.2, and 5.3 combine to give a final numerical score of 5.22 out of 10 for Criterion 5 – Feed.

While not used to calculate the score, it is important to note that considerable research is ongoing in the development of trout feeds, investigating palatability, digestibility, ingredients and more (Azevedo et al., 2004; Brinker & Reiter, 2011; Bureau & Hua, 2010; Okumus &

Mazlum, 2002). Particularly relevant is research investigating the potential of feeds with reduced and/or no fish meal/oil (Gatlin et al. 2007). Recent studies spearheaded by the USDA have found that not only is it possible to use feeds without fish meal that do not negatively impact growth (Barrows et al. 2008) but that there is potential to develop strains of trout that may be better suited to those feeds (Overturf et al. 2013). These feeds use plant-based substitutes and nutritional supplements to provide the dietary requirements of trout. This research has resulted in a variety organizations adopting feed formulations with reduced or even no fish meal (pers. comm., Dr. Rick Barrows, April 2, 2014).

As a practical example, TwoXSea in California[2] produces trout feeds without any fish meal or fish oil (pers. comm. William Foss, March 24, 2014). This is accomplished through the use of corn, soy, and nut meals, as well as oils derived from algae. This reduction in dependence on marine resources is applauded and further utilization of such feeds by the aquaculture industry is encouraged.

[2] www.twoxsea.com

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		2.0	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		10.0	
C6 Escape Final Score		**10.0**	**GREEN**
Critical?	NO		

Brief Summary

While the inherent escape risk from net pen production systems is high, evidence on the specific number of escapes from trout net pens is unavailable. Anecdotal evidence suggests that escapes are sporadic but potentially large, but the fish are sterile and unable to breed with wild populations. It is important to note that any potential escape numbers from the farm are dwarfed by the number of intentional introductions for sport fishing, and for this reason, escapes of rainbow trout from this farm are not considered a risk and the overall score for escapes is 10 out of 10.

Justification of Ranking

When fish escape from aquaculture sites into the environment they can cause a wide variety of ecological impacts negatively affecting wild-conspecifics, reducing local species abundance and biodiversity, and altering habitats (Myrick 2002). In most regions where rainbow trout are cultured, escapees enter environments where they are native or have been purposefully introduced in the past, thus minimizing any impact directly attributable to aquaculture (Fornshell & Hinshaw 2008). This holds true for the Columbia River where rainbow trout are native and large numbers of this species are grown specifically for stocking and purposeful release into the wild.

The rainbow trout raised in net pens are rendered sterile through triploidy, a process that involves temperature- or pressure-treating eggs in the hatchery to result in three sets of chromosomes with subsequent sterility (pers. comm. Mr. Bielka, May 2013). This triploidy prevents successful interbreeding with wild fish.

Factor 6.1a. Escape risk

Net pen production systems are open to the environment and as such the escape risk is greater for these systems than the risk associated with systems that physically separate the growing area from the surrounding environment (e.g., recirculation systems). While no reported escapes have occurred over the most recent production cycle, the net pen operations on the Colombia River have had some instances of escapes of farmed fish in the past. The most recent escape event occurred in 2011. In this instance, water released from a dam located upstream contained high-dissolved gases and resulted in wide-spread mortality in one net pen. The mass of these mortalities being pulled by the current caused a breach in the net pen, which allowed a high number of fish to escape. While this event is unusual, the likelihood of a similar event occurring again is unknown.

The farm covered by this assessment employs best aquaculture practices (BAPs), which include requirements for comprehensive procedures and infrastructure to prevent escapes (Global Aquaculture Alliance 2011). Despite this, studies of other species grown in net pen operations indicate that the open nature of these systems implies an inherent high risk of escape (McGinnity et al. 2003, Morris et al. 2008). Despite large numbers of hatchery-reared rainbow trout being purposefully released into the Colombia River for sport fishing, Factor 6.1a assesses the risk of escape and, based on the net pen production system utilized, the score for Factor 6.1a is 2 out of 10.

Factor 6.1b. Invasiveness

Though they are a highly invasive species, rainbow trout have been purposefully introduced as a sport-fish all over the world (FAO 2013, Okumus 2002), and are now established and/or maintained by stocking throughout much of the US (Fuller, Larson & Fusar 2013). Typically, in instances where these fish enter the wild environment (either through intentional stocking or unintentional escape from farms) they have the potential to cause ecological harm by eating, out-competing conspecifics (both for feed and mates), and breeding with wild native species, especially other salmonids (Cucherousset & Olden 2011,Muhlfeld et al. 2009).

In the event that fish from the aquaculture operations under assessment do manage to escape, concerns of genetic impacts on wild stocks are mitigated because the farmed trout are triploid—genetic modification induced at the hatchery by shocking eggs shortly after fertilization using heat or pressure, and preventing them from attaining the normal diploid condition (Rottmann, Shireman & Chapman 1991). Triploidy results in sterility and therefore any escaped farmed fish are unable to breed with wild populations.

Regarding other impacts of escapees, such as out-competing native trout, the Columbia River is purposefully stocked with large numbers of rainbow trout for sport fishing. Given that there more fish that are intentionally released than the total number of fish at the farm sites, assigning a high concern to the impacts of escapes of farmed fish is not reasonable. For these reasons the invasiveness of rainbow trout in net pens on the Columbia River is negligible and they are assigned a score of 10 for Factor 6.1b. The final numerical score for Criterion 6 – Escapes is 10 out of 10.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	6.0	
C7 Disease; pathogen and parasite Final Score	**6.0**	**YELLOW**
Critical?	**NO**	

Brief Summary

Reports from farm managers and industry professionals suggest that the incidence of disease in the net pen operation on the Columbia River is infrequent. However, due to the open nature of the farm site and its connection with the river, there is potential for disease transmission. The final score for Criterion 7- Disease is 6.00 out of 10.

Justification of Ranking

In general, the occurrence of disease is low on rainbow trout farms (pers. comm. Gary Fornshell, April 2013). Anecdotal evidence suggests that over the most recent production cycle, rainbow trout raised on the Columbia River experienced no significant problems with diseases due to best management practices such as vaccines used to promote fish health (Global Aquaculture Alliance 2011; pers. comm. Mr. Bielka, May 2013). The only disease reported in the past several years was Columnaris (pers. comm. Mr. Bielka, September 2013), a common freshwater disease that occurs naturally in most freshwater environments (Durborow, Thune, Hawke & Camus 1998). A vaccine for this disease is currently being tested (pers. comm. Mr. Bielka, September 2013).

At the time this report was prepared there was no additional data available on the prevalence or outbreak of diseases in net pens on the Columbia River. There is also no indication in the scientific literature or among experts that any diseases that have occurred in these net pens have been transferred to wild species. Nonetheless, the net pen production system implies that there are no barriers between the water where trout are raised and the surrounding environment. This means that there is the possibility that pathogens can be amplified on farms and then transmitted to wild populations (Krkosek et al. 2006). While all the evidence suggests this has not occurred, a precautionary approach is warranted given the inherent connection between net pens and the surrounding environment. The final score for Criterion 7 – Disease is 6 out of 10.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for ongrowing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Criterion 8 Summary

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

Justification of Ranking

The first recorded transport of wild rainbow trout to non-native habitat occurred in 1878-1879 from the McCloud River in California to locations throughout the continental US (Fornshell 2002, Okumus 2002). It is believed that these fish are the primary source from which many of today's stocks originated (Okumus 2002). Regardless of their exact origin, rainbow trout have been cultured successfully for over 100 years and today 100% of the stock is from hatcheries around the U.S. (Fornshell 2002). Trout raised on the Columbia River in net pens are all sourced from Troutlodge hatcheries (pers. comm. Mr. Bielka, May 2013) and therefore there is not considered to be any use of wild populations for either fry or broodstock supply. For these reasons, Criterion 8 – Source of Stock scores 10 out of 10.

Criterion 9X: Wildlife and predator mortalities

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

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

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**-4.00**	**GREEN**
Critical?	NO	

Brief Summary

Trout net pen operations in the United States utilize exclusion devices (bird netting) to deter predation of their stock. Some mortality is expected to occur, but endangered species are not considered to be involved. Although mortalities are likely to be limited to exceptional cases, there are no robust data and therefore the score for Criterion 9X is a moderate deduction of -4 out of -10.

Justification of Ranking

The most common interactions between net pen trout farms and other wildlife occur when birds or aquatic mammals attempt to prey on the fish. During these interactions, the predators can become entangled or trapped leading to injury or death (Hume 2012).

In the past, predation has resulted in substantial economic losses to trout farm operators (Belle & Nash 2008; Glahn, Rasmussen, Tomsa, & Preusser 1999). For this reason, it is in the best interest of trout farmers to install protective devices to deter predation. When properly implemented, these defenses are usually inexpensive and effective, reducing the impact on the fish and other wildlife (Belle & Nash 2008; pers. comm. Steve Naylor, March 2013). In instances where non-lethal methods are insufficient, lethal methods are used and result in wildlife mortalities.

Rainbow trout grown in net pens on the Columbia River employ BAPs that actively favor non-lethal control of predators through means of exclusion (e.g., nets over the tops of the pens) (Global Aquaculture Alliance 2011). When lethal methods are employed, only legal methods (e.g., shooting) can be used and only with approved licenses (Global Aquaculture Alliance 2011). Unfortunately, detailed data of predator and wildlife interactions on this farm were unavailable. Predator species known to exist in the area include coyote, river otter, muskrat, salmon, sockeye and many species of bird such as the American white pelican and the Ferruginus hawk (Quigley, Haynes & Graham 1996). Some of these species, especially predatory birds and waterfowl, are likely to attempt to prey on the trout in the net pens; none of these are considered threatened or endangered (the Ferruginus hawk has been considered endangered in the past but is now listed as “least concern” by the International Union for the Conservation of Nature (IUCN 2013)). By following the best aquaculture practices and employing exclusionary netting, wildlife mortality is possible and may be limited “exceptional cases,” but without robust data to confirm mortality numbers the score for Criterion 9X is a moderate deduction of -4 out of -10.

Criterion 10X: Escape of unintentionally introduced species

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

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

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	0.00	
C10Xb Biosecurity of source/destination	4.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

With dedicated hatcheries located across the country, there is no need to transport live animals internationally or across water bodies. As such, this criterion is not necessary to be scored and an adjustment score of zero out of -10 is applied.

Justification of Ranking

Rainbow trout are reared in hatcheries throughout the U.S. (Needham & Behnke 1962) and have historically been shipped as eyed eggs all over the world (Okumus 2002). Due to its value as a recreational and farmed species, public and private hatcheries for rainbow trout have been established throughout much of the U.S. (Hershberger 1992). Trout are now shipped from dedicated hatcheries via truck to their destination.

Eggs for fish grown in net pens on the Columbia River are sourced from Troutlodge hatcheries at various locations throughout the Pacific Northwest, before being moved to Boxely Springs Hatchery in Washington State where they are grown to sufficient size to be transported to net pens (pers. comm. Mr Bielka, September 2013). As these hatcheries are located in the same region as the net pens where ongrowing occurs, no trans-waterbody or international shipping is said to occur and no adjustment score is applied to this exceptional criterion.

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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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Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	10	10
Predators and wildlife	Yes	5	5
Chemical use	Yes	5	5
Feed	Yes	10	10
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**70**

C1 Data Final Score	7.78	GREEN

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	45
eFCR	1.6
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	15.7
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	115.2
N in each ton of fish harvested (kg)	25.12
Waste N produced per ton of	**90.08**

fish (kg)	

Factor 2.1b - Production System Discharge core

Basic production system score	0.8
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.8**

80 % of the waste produced by the fish is discharged from the farm

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

Factor 2.2a - Regulatory or management effectiveness

Question	**Scoring**	**Score**
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Yes	1
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Yes	1
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Mostly	0.75
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc.?	Yes	1
		4.75

Factor 2.2b - Enforcement level of effluent regulations or management

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

F2.2 Score (2.2a*2.2b/2.5)	**9.5**

C2 Effluent Final Score	6.00	YELLOW
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	9

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

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Yes	1
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	No	0
		4

Factor 3.2b - Siting regulatory or management enforcement

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

F3.2 Score (2.2a*2.2b/2.5)	**8.00**

C3 Habitat Final Score	**8.67**	**GREEN**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	**Score**	
C4 Chemical Use Score	**4.00**	
C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

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

Fishmeal inclusion level (%)	19
Fishmeal from byproducts (%)	35
% FM	12.35
Fish oil inclusion level (%)	6
Fish oil from byproducts (%)	15
% FO	5.1
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.6
FIFO fishmeal	0.88
FIFO fish oil	1.63
Greater of the 2 FIFO scores	1.63
FIFO Score	**5.92**

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

SSWF	-3
SSWF Factor	-0.4896

F5.1 Wild Fish Use Score	**5.43**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	45
eFCR	1.6
Feed protein from NON-EDIBLE sources (%)	44
Feed protein from EDIBLE CROP sources (%)	56
Protein OUTPUTS	
Protein content of whole harvested fish (%)	15.7
Edible yield of harvested fish (%)	50
Non-edible byproducts from harvested fish used for other food production	50
Protein IN	28.79
Protein OUT	11.775
Net protein gain or loss (%)	-59.0982

	Critical?	NO
F5.2 Net protein Score	**4.00**	

5.3. Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	25
eFCR	1.6
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	10.40

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

Inclusion level of crop feed ingredients (%)	50
Inclusion level of land animal products (%)	25
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.6
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.74

Value (Ocean + Land Area)	**11.14**

F5.3 Feed Footprint Score	**6.00**

C5 Feed Final Score	**5.22**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**2**

6.1b. Invasiveness

Part A – Native species

Score	5

Part B – Non-Native species

Score	**0**

Part C – Native and Non-native species

Question	**Score**
Do escapees compete with wild native populations for food or habitat?	No
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	5

F 6.1b Score	**10**

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

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	6.00	
C7 Disease; pathogen and parasite Final Score	**6.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

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

Exceptional Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-4.00**	**GREEN**
Critical?	NO	

Exceptional Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10Xb Biosecurity of source/destination	4.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**