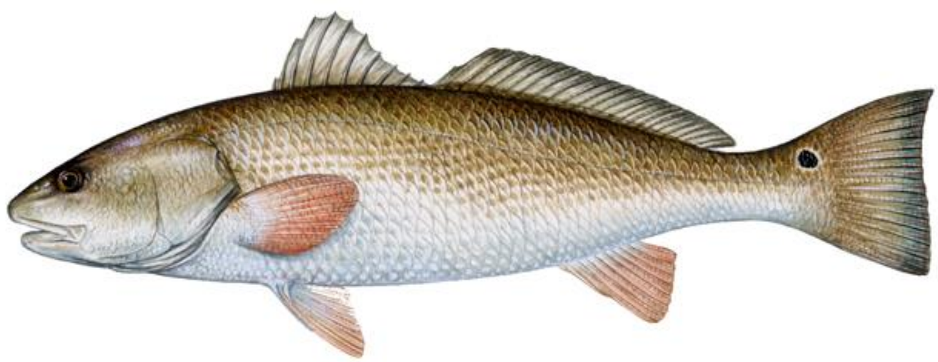
Monterey Bay Aquarium

Seafood Watch®

Red Drum

Sciaenops ocellatus



© Diane Rome Peebles

United States

Ponds

Aquaculture Standard Version A3.1

December 2016

Chris Eardley, Consulting Researcher

Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	8.41	GREEN	
C2 Effluent	9.00	GREEN	NO
C3 Habitat	5.33	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	4.99	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	–3.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**46.73**		
Final score (0–10)	**6.68**		

OVERALL RANKING

Final Score	6.68
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 numerical score for red drum raised in ponds in the U.S. is 6.68 out of 10, and there are no Red-ranked criteria. The final ranking is Green and a recommendation of “Best Choice.”

Executive Summary

Red drum *(Sciaenops ocellatus)*, which is native to much of the U.S. East and Gulf coasts, has long been a popular sport and food fish in this region. Production of this species began in the 1970s to supplement declining wild stocks and has since grown into a global aquaculture industry, with the U.S. producing only a small fraction (Table 1) of the total global volume, from farms in Texas (USDA 2015).

Currently, Texas produces all red drum intended for the food market, with most product being marketed by one company that also manages at least 200 acres of farm. As a food fish, red drum is sold as fresh and frozen fillets and steaks, as well as whole and gutted. The largest marketer reports that all their fish is sold fresh (Ekstrom Enterprises 2016a) (Ekstrom Enterprises 2016b). The species is categorized as a “High” price fish by Sumaila et al. (2007), with U.S.-farmed fish fetching about $6.61/kg (Treece 2016), up from $4.19–4.63/kg in 2005 (FAO 2016c). The industry has grown steadily after rapid growth in the early 2000s and, with improving technology and many of the challenges related to its culture understood and overcome, this trend is expected to continue at the global level. The species has “not yet reached its market potential” (Texas A&M 2016), but in the U.S. it is contending with competition from cheaper imported products, possibly from increasing wild stocks and accompanying commercial catch of the same species on the Atlantic coast (where commercial harvest is permitted), and from recreational fishers along the Gulf Coast. Costs associated with feed, problems with toxic algal blooms, and the regulatory environment are also current challenges for this industry (Treece 2016).

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

Overall, data quality and availability related to red drum farming in the United States scores as moderate-high to high. Informational resources are rich for some areas, such as industry statistics and practices, habitat, management, source of stock, and introduced species. Other areas, such as effluent, are lacking in one dimension (provision of extensive monitoring data) but extremely strong in others (permitting, management, compliance, and enforcement information). Information related to feed includes a large volume of research publication, but details on how research findings are applied in commercial feeds are scarce. A few categories (chemical use, predators and wildlife, and disease) would be strengthened with the provision of more scientific or regulatory publication, and less reliance on self-reporting, personal communications, or dated literature—though additional industry-provided information was helpful for this assessment. Thus, Criterion 1—Data quality and availability—scores 8.4 out of 10.

The red drum industry has a low discharge rate and makes use of settling basins and artificial wetlands for settling of solids before discharge. The Texas Commission of Environmental Quality has effective oversight of the industry, enforcing rigid policies regarding the use of chemicals, treatment of water, disposal of sludge, water quality monitoring, and reporting. Regulations are clearly outlined and agencies provide thorough detail on permitting and results of compliance and enforcement activities, as well as parameters that are monitored. Because the entire red drum industry is in compliance with regulations and there is evidence of enforcement, Criterion 2 scores 9 out of 10.

Red drum farming represents a loss of ecosystem functionality from a pre-altered habitat state, because it occurs largely on land that was originally classified as wetlands and estuarine habitat. But land conversion from these original habitat types to conditions more suitable for agriculture and ranching, as well as for shrimp farming, occurred historically—pre-dating red drum farming. A significant portion of red drum farm acreage is also converted former shrimp ponds. Thus, the use of historical wetland habitat by red drum farming is considered to be a secondary habitat conversion. Current habitat management policy is robust, with particular interest in the protection of existing wetlands and of water quality, but includes a variety of measures. Enforcement of management measures is considered comprehensive, with a large body of detailed information related to enforcement activities available and easily acquired for this assessment. The red drum industry is currently in compliance with all permitting requirements. Criterion 3—Habitat scores 5.33 out of 10.

Numerous sources have indicated that no antibiotics are used by the red drum industry. There is some limited use of FDA- and EPA-approved chemicals to control algae blooms and ectoparasites. The low susceptibility of red drum to bacterial infections and low parasite loads—coupled with alternative treatments available—obviates the need for much chemical input. Further, red drum is raised in ponds with low discharge requirements, lowering the risk to non-target organisms. Published data on the current use of chemicals is scarce, but regulators have clearly stated restrictions on the use of chemicals and are active in enforcing policies. The few chemicals used by this industry are considered to be of low environmental risk if used properly, and the Texas red drum industry appears to be in compliance with regulations regarding chemicals. Therefore, low concern classification is warranted and the score for Criterion 4 – Chemical Use is 8 out of 10.

U.S. farmed red drum relies on fishmeal and fish oil inputs, supported primarily by wild-caught Gulf menhaden. The use of wild fish in red drum feed receives a score of –2 out of –10 for sustainability of the source fishery for Gulf menhaden. There is a strong motivation to lessen reliance of red drum feeds on fishmeal inputs, so red drum feed makes use of crop and land animal ingredients. The most recent, specific data available for this assessment were publications from 2006 and 2009. Because of the high protein requirements of red drum, the ongoing (but decreasing) use of fishmeal, the relatively low edible yield of harvested drum, and the use of at least some of the non-edible parts of the fish, farmed red drum scores 2 out of 10 for net protein loss. Farmed red drum scores a 6 out of 10 in feed footprint for a high ratio of crop to land animal ingredients and a moderate inclusion level of fishmeal.

Factors 5.1, 5.2 and 5.3 combine to give a final Criterion 5 – Feed numerical score of 4.99 out of 10.

Red drum is a native species being farmed within its native range. Multiple safeguards are in place to prevent escapes; the low frequency of water exchange and low volumes of discharge limit the opportunities for escape, though this criterion would benefit from additional details regarding escape prevention mechanisms. Some genetic differentiation in hatchery-produced red drum has been demonstrated, but farmed red drum are likely genetically similar to those used in a massive red drum wild stock enhancement program due to broodstock mandates aimed at promoting genetic diversity. Farmed red drum has both a low risk of escape and of invasiveness and scores 8 out of 10 for Criterion 6—Escapes.

The red drum industry is apparently not often impacted by major disease concerns. The species appears to have a low parasite load and a resilience against bacterial and other issues common to other farmed species. Primary pest concerns include toxic algal blooms and the occasional parasite infestation. The stocking density of fish in ponds and occasional water discharges do pose some risk of amplification and spread of pathogens. One large producer provided details on its fish health and disease management protocols, which include tenets identified by Seafood Watch as robust. Data on reported fish disease issues appear to be absent due to the lack of disease issues for farmed red drum. This industry is viewed as low to low-moderate risk, with infrequent occurrences of disease issues at the typical farm level and infrequent but occasional water discharge. This criterion would benefit from additional disease management protocol information from the rest of the industry. The final score for Criterion 7—Disease is 7 out of 10.

A limited number of red drum are removed from the wild to promote genetic diversity in hatchery-bred red drum. This removal is not viewed as a threat to wild population sustainability because Gulf of Mexico stocks are not considered overfished and stocks in Texas waters are supporting a near-record red drum population size and catch rates. Criterion 8X – Source of Stock scores 0 out of –10, meaning no deductions have been taken.

Wildlife mortalities occur through interaction with the U.S. farmed red drum industry beyond exceptional cases, but permitted take of predatory birds is limited to species of least conservation concern and with no demonstrable impacts to population size. There is evidence of best-management resources and of enforcement occurring, and only two red drum producers (accounting for over 50% of total production) have take permits for wildlife (although illegal take by one former producer has been documented in one instance). Wildlife mortalities related to red drum farming are considered low-moderate. The score for Criterion 9X – Wildlife Mortalities is –3 out of –10.

Because there is no reliance on import of fingerlings from out of state, there is no international or trans-waterbody shipment of live animals associated with this industry; thus, there is no risk of the introduction of non-native species. The final numerical score for Criterion 10X – Escape of Unintentionally Introduced Species is –0 out of 10.

Overall, the final numerical score for red drum raised in ponds in the U.S. is 6.68 out of 10, and there are no Red-ranked criteria. The final ranking is Green and a recommendation of “Best Choice.”

Table of Contents

Introduction

Scope of the analysis and ensuing recommendation

Species
Red drum *(Sciaenops ocellatus)*

Geographic Coverage
United States

Production Method(s)
Ponds

Species Overview

Brief overview of the species
Red drum is a predatory marine finfish native to the east coast of North America from Massachusetts in the United States and along the Gulf coast to Veracruz in central Mexico. The species is euryhaline (tolerant of a wide range of salinities) and is common to estuarine and nearshore environments. Red drum is named for the “drumming” sound produced by males during courtship and spawning (SARC 1990), as well as its characteristic reddish-orange color. The fish also typically has one or more large black “eye spots” on its tail (Miller 1995) (CABI 2007). Red drum is fast-growing, fairly long-lived, highly fecund, and adapts well to captivity—lending the species well to aquaculture settings (CABI 2007) (Treece 2016).

After population declines of this species, commercial harvest of red drum was effectively prohibited by 1990 and remains so in federal waters of the Gulf of Mexico (GFMC 2016). It is largely prohibited in all Gulf state waters (Alabama allows some limited commercial harvest), with only tightly regulated recreational harvest allowed (ADCNR 2015) (MDMR 2015) (TPWD 2015b) (FFWCC 2016) (LDWF 2016). Hatchery production of this species began in the 1970s to supplement declining wild stocks and has since grown into a global aquaculture industry, with the U.S. producing only a small fraction (Table 1) of the total global volume, from farms in Texas (USDA 2016a). Currently, Texas produces all red drum intended for the food market, with most product being marketed by one company that also manages at least 200 acres of farm (Treece 2016) (USDA 2016a). The Texas Parks and Wildlife Department also maintains hatcheries and nurseries used to enhance wild stock and support a multibillion-dollar recreational fishing industry (CABI 2007).

Production system
Red drum are produced in a multistage production cycle from fry to market size. Red drum fry are produced in hatcheries and held in nurseries through the fingerling stage. Many red drum producers feature their own integrated hatcheries, and all fingerlings used for growout in Texas are produced in-state. Red drum are later grown out in enclosed (by levees), aerated earthen

ponds, which are typically about 5 acres in size, and at a density of about 4,000 fish/acre. Farms include nursery ponds and growout ponds, with about 15% of space allocated to nursery ponds—typically about 1–2 acres in size. Though red drum has in the past been raised using other methods, such as in cages at offshore oil platforms, all U.S. red drum is currently produced using intensive pond culture methods (as defined by Edwards and Demaine 1997). The fish are fed at all stages of production—rotifers in the hatchery stage, cultivated zooplankton in the nursery stage, and primarily pellet feed in the grow-out portion. Because the fish are vulnerable to cold temperatures, growers provide thermal refuge in a smaller section of a pond that is pumped with warmer water from groundwater sources. At harvest, pond water levels are lowered and the fish are seined from ponds (Treece 2016).

Some cultivation occurs in ponds located near the Gulf of Mexico shoreline, while other farms are farther inland.

About 30% of existing red drum pond acreage is from converted former shrimp ponds, a transition that currently represents the best avenue for industry growth in Texas because of regulatory constraints (Treece 2016) (pers. comm., J. Ekstrom, Ekstrom Enterprises 2016).

Production Statistics

The U.S. red drum industry is located entirely in the state of Texas. Total capacity in Texas ranges from about 800–1100 acres across five active farms (Treece 2016) (pers. comm., J. Ekstrom 2016), though not all acreage is active in a given year and some space is allocated to fingerling production. Treece (2016) estimates that about 70% of acreage is active for growout annually. It appears that one producer dominates production, with at least approximately 52% of production in 2010, and through whose brand most U.S. red drum is marketed. Three producers account for 75% of total production (pers. comm., J. Ekstrom 2016).

The U.S. red drum industry is small, especially in the context of global production of this species (Table 1). In Texas, typical production volumes averaged about 6,000 lbs. (2,722 kg)/acre/production cycle from 2007–2009, increasing to 10,000 lbs. (4,536 kg)/acre/year in recent years. One growout production cycle takes 18 to 24 months to reach a market size of about 1.5 to 3 lbs. (USDA 2014) (Treece 2016).

Table 1. Red drum production 2010–2014 (Data from FAO).

	2010	2011	2012	2013	2014	Growth 2010–2014
United States production						
Volume (MT)	1,134	1,474	1,474	1,502	1,500	32.2%
Value (USD, millions)	6.95	9.01	9.01	9.18	9.17	31.7%
% of global production (volume)	2.08	2.19	2.17	2.41	2.05	–1.4%
% of global production (value)	9.23	9.84	9.77	10.44	9.13	–1.1%
Global production						
Volume (MT)	54,509	67,299	68,017	62,197	72,819	33.6%
Value (USD, millions)	75.26	91.54	92.19	87.97	100.41	33.4%

The USDA also has some information on U.S. red drum production available, although it is aggregated at the national level. Treece (2016) estimates 2015 production at 907 metric tons (MT) (2 million lbs.) and $6.9 million. Decreased production for 2015 was attributed to high mortalities associated with cold weather in the winter of 2014.

The species is categorized as a “High”-priced fish by Sumaila et al. (2007), with U.S.-farmed fish fetching about $6.61/kg (Treece 2016), up from $4.19–4.63/kg in 2005 (FAO 2016c). The industry has grown steadily after rapid growth in the early 2000s and, with improving technology and many of the challenges related to its culture understood and overcome, this trend is expected to continue at the global level. The species has “not yet reached its market potential” (Texas A&M 2016), but in the U.S. is contending with competition from increasing wild stocks, from the accompanying commercial catch of the same species on the Atlantic coast (where commercial harvest is permitted), from robust recreational catch on the Gulf Coast, and from cheaper imports of red drum farmed in Taiwan and elsewhere. Costs associated with feed, problems with toxic algal and harmful phytoplankton blooms, and the regulatory environment are also current challenges for this industry, and the market was temporarily negatively affected by the BP oil spill in 2010 (Treece 2016) (pers. comm., G. Treece, Texas SeaGrant 2016).

Import and Export Sources and Statistics

The United States is the principal market for red drum produced domestically, with some minor export to Canada (Treece 2016) (pers. comm., J. Ekstrom 2016) (pers. comm., T. Sink 2016). The United States also imports farmed red drum from Taiwan and China (U.S. FDA 2016b). Red drum import statistics are difficult to parse from “drum” and “redfish” data available via the FAO; imported red drum products may be becoming more common (pers. comm., G. Treece 2016). Imported red drum products from China and Taiwan have at times faced import restrictions from the U.S. Food and Drug Administration (U.S. FDA 2016b).

Common and Market Names

Scientific Name	Red drum, redfish, channel bass, spot tail bass
Common Name	*Sciaenops ocellatus*

Product forms

As a food fish, red drum is sold as fresh and frozen fillets and steaks, as well as whole and gutted. The fish most commonly appears on North American menus as red drum or redfish, and the largest marketer of U.S. product, Copper Shoals, reports that all their fish is sold fresh (Ekstrom Enterprises 2016a) (Ekstrom Enterprises 2016b). Some retailers are also having success selling red drum heads and racks as food items (pers. comm., Carol Huntsberger, Quality Seafood Market, 2016) (pers. comm., J. Ekstrom 2016), and waste product is used in crab bait and fertilizer (pers. comm., J. Ekstrom 2016) (pers. comm., D. Gatlin 2016).

Analysis

Scoring guide

- With the exception of the exceptional criteria (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rating. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the three exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Standard that the following scores relate to are available on the Seafood Watch website. http://www.seafoodwatch.org/-/m/sfw/pdf/standard%20revision%20reference/mba_seafoodwatch_aquaculture%20criteria_finaldraft_tomsg.pdf?la=en

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 publically available.

Criterion 1 Summary

Data Category	Data Quality	Score (0–10)
Industry or production statistics	10	10
Management	10	10
Effluent	7.5	7.5
Habitat	7.5	7.5
Chemical use	7.5	7.5
Feed	7.5	7.5
Escapes	10	10
Disease	5	5
Source of stock	10	10
Predators and wildlife	7.5	7.5
Introduced species	10	10
Other – (e.g. GHG emissions)	Not Applicable	n/a
Total		**92.5**

C1 Data Final Score (0-10)	**8.4**	**GREEN**

Brief Summary

Overall, data quality and availability related to red drum farming in the United States scores as moderate-high to high. Informational resources are rich for some areas, such as industry statistics and practices, habitat, management, source of stock, and introduced species. Other areas, such as effluent, are lacking in one dimension (provision of extensive monitoring data), but extremely strong in others (permitting, management, compliance, and enforcement information). Information related to feed includes a large volume of research publication, but details on how research findings are applied in commercial feeds are scarce. A few categories (chemical use, predators and wildlife, and disease) would be strengthened with the provision of more scientific or regulatory publication, and less reliance on self-reporting, personal communications, or dated literature—though additional industry-provided information was helpful for this assessment. Thus, Criterion 1 – Data quality and availability scores 8.4 out of 10.

Justification of Rating

The U.S. red drum farming industry is small, but the cultivation of red drum also supports significant recreational fisheries for the species throughout its native range in the United States. Red drum is also farmed in several other countries and the industry combined is worth $100.4 million in 2014 (FAO 2016a). Current challenges to the U.S. industry are also well identified. These factors have combined to motivate a considerable amount of research on red drum and the cultivation of this species, with research facilities and enhancement programs in Texas, Georgia, Florida, and South Carolina (Hauville 2014). The scientific literature on the biology and ecology of this species is ample. Data and information on production practices and statistics are readily available and up to date. For example, in its annual censuses, the USDA provides data on the number of farms, production, and sales at the national level, as well as some useful data at the state level (though production data are not reported at the state level (USDA 2014)). The Food and Agriculture Organization of the United Nations (FAO) provides details on a number of topics related to red drum aquaculture—from production statistics to disease, production practices, feed, and industry trends. Texas SeaGrant has reported on locations, farm sizes, and production statistics; however, these are self-reported, and Treece (2016) acknowledges some imprecision. Overall, confidence is high that the scale of the industry is well understood; regarding industry and production information, the Data score is 10 out of 10.

Information on management of the aquaculture industry in Texas is generally transparent and available: agencies are identifiable and contactable, and regulatory documents are available on websites at the county, state, and federal levels. The Texas Commission of Environmental Quality (TCEQ) maintains a large amount of detail on permitting, enforcement, and compliance, and additional information is available via a public records request. As outlined below, relevant information is available online or through a records request with the Texas Department of Agriculture (TDA), the U.S. Fish and Wildlife Service (USFWS), the Southern Regional Aquaculture Center (SRAC), and the U.S. Environmental Protection Agency (U.S. EPA). Additionally, Texas SeaGrant has published a number of documents related to management of the aquaculture industry in Texas. The Management data score is 10 out of 10.

Regarding effluent, TCEQ makes regulatory information available on its agency websites. Permit information is searchable through the TCEQ website, as are highly specific compliance/enforcement details and limited monitoring data (also provided by industry for this assessment). The TCEQ also provided compliance history reports for every red drum farm in Texas for this assessment, which was useful for both Criterion 2 (Effluent) and Criterion 3 (Habitat). Additional relevant enforcement information is accessible on the websites for the U.S. EPA, the TCEQ, and others. These agencies have also been helpful in providing additional information for this assessment. Recent publications from Texas SeaGrant also offer some insight into relevant production practices and gaps were filled through interviews with various stakeholders—including industry. Complete, specific monitoring data were not provided for this assessment (though some sample data were) and the scientific literature has not thoroughly addressed impacts related specifically to red drum aquaculture effluent. But Texas regulation is clear and considered stricter than at the federal level, and detailed results of regular compliance work are readily available. Understanding of effluent related to red drum farming is sufficient for an assessment, and the Data score is 7.5 out of 10.

The TDA provides publicly accessible information on farm ownership and locations, and both TDA and the TCEQ make regulatory information available on their agency websites. Additional relevant enforcement information is accessible on the websites of the U.S. Environmental Protection Agency, the Texas Department of Environmental Quality, and others. These agencies have also been helpful in providing additional information for this assessment. The SRAC and Texas A&M SeaGrant have published extensive documents on the red drum industry (including documents related to habitat), and the latter organization provided several recent documents that included specific content that was useful in the conducting of this assessment.

Spatial information related to habitat—such as historical land use and habitat classification—is readily available via online U.S. Geological Survey (USGS) repositories and from web mapping services from the USFWS and Lumb et al. (2015). Industry also provided useful information related to U.S. red drum and habitat, and Tremblay and Calnan (2010, on behalf of the Texas General Land Office [TGLO]) provide a detailed history of wetlands classification and land use trends specific to the Matagorda Bay system, which is the geographical focus of Texas red drum farming. The TGLO has also produced documents outlining coastal zone management planning for the state of Texas—with specific relevance to cumulative effects concerns. Information on some potential habitat impacts, such as those related to pond impacts on soils, is lacking for this industry, but information pertaining to habitat is moderate-high. The Data score is 7.5 out of 10.

A large volume exists of publications outlining chemicals used (either historically or experimented with), though most date to the 1990s and early 2000s. The FAO lists common chemical treatments for an extensive list of known red drum parasites and pathogens, although many are more applicable to production systems and regions outside the focus of this assessment. Recent publications by Texas SeaGrant offer some information on treatment of some current challenges, such as toxic algae blooms. Recent published scientific information on the use of chemicals in U.S. red drum culture is somewhat limited, but much attention is given to alternative techniques for controlling water quality and pathogen threats. Regulations that clearly outline policies regarding the use of chemicals are available from TCEQ, the EPA, and the FDA. Suggested dosage information for some chemicals used is available from the Southern Regional Aquaculture Center (SRAC). Additional information on chemical use was acquired through interviews with researchers, extension agents, agency, and industry. The relative lack of recent information on chemical use possibly stems from the apparent low need for chemicals in this industry—as suggested by industry and academia. The largest producer of red drum provided data on total chemical usage for 2015. This score would benefit from additional details on dosage and application frequency as well as chemical use information from more producers, but overall, the quality and quantity of information on chemicals used by the red drum industry is moderate-high. The Data score is 7.5 out of 10.

A significant amount of research has gone into the nutrition of red drum and on performance of aquaculture feeds with this species, especially in recent years; however, as is typical of the feed industry, specifics on commercial feed ingredients are proprietary and cryptic (pers. comm., D. Gatlin, Texas A&M University 2016) (pers. comm., J. Bowzer, Cargill Animal Nutrition 2016). Details in the multitude of publications on research into experimental feeds provided a basis for some calculations used in the Feed criterion of this assessment, and some useful information is available on feed company websites and from the FAO. Some specifics remain difficult to corner—precise inclusion values are limited to older publications—and were estimated using a variety of sources. Source fisheries for fishmeal are well evaluated, with information available via FishSource, the International Fishmeal and Fish Oil Organization (IFFO), the Marine Stewardship Council (MSC), and others. Some gaps in information were addressed through expert interviews, including feed researchers, feed companies, and industry, though gaps in specific details remain and in these instances, older data or the uncertainty-based options built into the Seafood Watch Aquaculture Standard must be relied upon. Although specific feed values were somewhat challenging to track down, there is a large number of sources from which to mine information—even if it is imprecise on some details. Overall, data availability and quality on feeds is moderate-high for red drum farming, and is scored 7.5 out of 10.

Because Texas (and other Gulf coast states) maintain a robust red drum stock enhancement program, red drum population dynamics, genetics, and life-history are well researched. The consequences of potential hypothetical escapes are fairly well understood, and information on the potential invasiveness of red drum escapes is plentiful in the scientific literature. Protocols for minimizing genetic risk of captive breeding to wild populations are in place, the details of which are readily accessible. Some information on prevention measures for escapement risk (which is considered extremely low) was provided by industry and agency, though more specifics would benefit this category. Information related to invasiveness is ample and there appears to be a strong understanding of the status of wild stocks. Data for Escapes is considered high and scores 10 out of 10.

Disease and parasite issues associated with red drum are well documented, although much of what is available applies more to production systems used outside of the U.S. or is dated. Recent publications from Texas SeaGrant offer details on issues currently affecting the industry; this seems to concern primarily toxic algae/dinoflagellate blooms, which appear to be the primary parasite/pathogen issues faced by the U.S. industry. This is supported by the fact that much of the recent literature on pathogen threats to U.S. farmed red drum focuses on these issues. The SRAC and other broader sources offer resources on best-management practices for fish health. Texas SeaGrant and expert interviews (academia and industry) were helpful in making an assessment on disease and parasite issues for this assessment, which included information on specific fish health management and disease response protocols. This category would benefit from clearer regulation or uniform industry standards on fish health and disease risk management, and information on risk management protocols from additional producers. The Data score is moderate and scores 5 out of 10.

Details on the vertical integration of the red drum industry are available via industry documents and Texas SeaGrant publications. The SRAC also offers publications on hatchery practices. Texas maintains a robust red drum stock enhancement program, and red drum population dynamics, genetics, and life-history are well researched. Information on the status of wild red drum stocks, from which a limited number are removed for broodstock, is available from federal and state management agencies. Information related to Criterion 8X – Source of Stock is ample and there appears to be a strong understanding of the status of wild stocks. Data for Source of Stock is considered high and scores 10 out of 10.

Regarding wildlife interactions, immediately available information includes some enforcement reports from the U.S. Fish and Wildlife Service, regulatory details, permit information, and information provided by industry. The SRAC offers several fact sheet resources on identifying and controlling predators interacting with aquaculture. Further details are available through a Freedom of Information Act request from the U.S. Fish and Wildlife Service (USFWS), which was provided by the Texas USFWS office. Information provided by the USFWS includes specifics on permits issued to individual farms, including total permitted take and self-reported take of permitted species. Overall, the availability and quality of information on predator and wildlife interactions is moderate-high, and is scored 7.5 out of 10.

Information on the movement of live animals and the red drum production system is sufficient and was provided via the scientific literature, Texas SeaGrant publications, and expert interviews. The Data score is 10 out of 10.

Conclusions and Final Score

Data quality and availability on U.S. red drum aquaculture scores as moderate-high to high. Some areas pertaining to U.S. red drum aquaculture are informed by a thorough library of publications and allow for a more solid understanding of practices and performance. In areas with gaps in publication or understanding, communication with expert stakeholders provided extensive helpful information. Some areas are well researched (such as Feeds), but specific information useful to this assessment remains unavailable. The scores for other areas (such as Chemicals and Disease) would be improved by the provision of additional information. In general, the body of information on red drum aquaculture is reliable and adequate for a confident assessment.

The final numerical score for Criterion 1 – Data is 8.4 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

C2 Effluent Final Score (0–10)	9	GREEN

Brief Summary

The red drum industry has a low discharge rate and makes use of settling basins and artificial wetlands for settling of solids before discharge. The Texas Commission of Environmental Quality has effective oversight of the industry, enforcing rigid policies regarding the use of chemicals, treatment of water, disposal of sludge, water quality monitoring, and reporting. Regulations are clearly outlined and agencies provide thorough detail on permitting and the results of compliance and enforcement activities, as well as parameters that are monitored. Because the entire red drum industry is in compliance with regulations and there is evidence of enforcement, Criterion 2 - Effluent scores 9 out of 10.

Justification of Rating

Evidence-based assessment:

Data and information on effluent water treatment, management, monitoring, and compliance are ample. Because effluent data quality and availability is good (i.e., Criterion 1 score of 7.5 out of 10 for the effluent category), the evidence-based assessment was utilized.

Red drum is raised in enclosed earthen ponds; water discharge is variable and depends on the stage of development, time of year, acute pond conditions, and facility location. The Texas CEQ (2015) lists release of total suspended solids and associated potential turbidity problems as the primary concern with this industry. But large discharge events are uncommon—generally only for final harvest (Cason and Anderson 2015) (pers. comm., J. Ekstrom 2016) or for rare occasions when conditions warrant due to poor water quality (such as low dissolved oxygen levels or algae/dinoflagellate blooms (Treece 2016) (pers. comm., Todd Sink, Texas A&M University 2016)). In extreme and rare cases, it may be necessary to exchange water in ponds up to 20% of volume per day, and at times, up to 25% has been discharged and replaced with fresher (low-salinity) water to control algae blooms (pers. comm., Paul Zimba, Texas A&M University 2016). Water quality is generally maintained through aeration, salinity manipulation, addition of freshwater to counter evaporation, and periodic drying and disking of ponds (pers. comm., M. Baez 2016) (pers. comm., T. Sink 2016) (pers. comm., J. Ekstrom 2016). The TCEQ reports that red drum operations discharge at a frequency of about 30 to 120 days per year and at rates of 150,000 to 2 million gallons per day of discharge (though at least one facility produces additional species); one facility discharges at 23.4 million gallons per day over 80 days of discharge and is subject to stricter monitoring (pers. comm., M. Baez 2016). Permits noting higher frequency and volume of discharge are related to hatchery operations, multispecies production, or periodic discharge related to reshaping of ponds (occurring every 8 to 10 years), rather than regular growout procedures. Mass discharge is also unnecessary due to significant ongoing evaporation of pond water (pers. comm., T. Sink 2016). For the largest red drum producer, the most significant discharge occurs at time of harvest, with a total estimated discharge of 4% of total farm water (or 21 acre-feet) per month (pers. comm., J. Ekstrom 2016); Davis (1990) estimates a typical discharge rate of about 1% of total volume per day.

The Texas Department of Agriculture holds authority for the overall regulation of aquaculture (Treece 2005). Permitting and enforcement organizations include the Environmental Protection Agency (EPA), Texas Commission on Environmental Quality (TCEQ), Texas Parks and Wildlife Department (TPWD), U.S. Fish and Wildlife Service, and U.S. Army Corps of Engineers (Treece 2005). Texas discharge permitting and oversight is managed by the Texas Commission on Environmental Quality (TCEQ), which requires a Texas Pollutant Discharge Elimination System (TPDES) permit (Treece 2005). Discharge limits in place are designed to protect aquatic life and human uses of the aquatic/marine environment and include monitoring for, reporting of, and limits on:

- Total suspended solids
- Inorganic suspended solids
- Total residual chlorine
- pH
- Dissolved oxygen
- Carbonaceous biochemical oxygen demand
- Ammonia nitrogen

Cumulative impacts are addressed as a control point in Section 309 of the Texas Coastal Management Plan (CMP) along with secondary impacts of development (TGLO 2015), consistent with the federal Coastal Zone Management Act (CZMA) (NOAA 1972). Regular evaluation of cumulative impacts of aquaculture (as well as other human uses) to the coastal zone is occurring through programmatic updates, and regulations are considered strong and with a need for streamlining extensive permitting (TGLO 2015).

The TCEQ requires that ponds be constructed and maintained in ways that prevent pond overflow or contamination of groundwater, and outlines a series of best-management practices that include efficient use of feeds, sludge management procedures, and other procedures to be used in de-watering of ponds to minimize discharge of bottom sediments and solids (TCEQ

2016a). The agency also has recordkeeping requirements, including those of discharge events (TCEQ 2016b).

State regulations stipulate that wastewater must be treated before being released into state waters (or not released). Facilities that are issued General Aquaculture permits (80% of red drum farms) have lower effluent concerns, as demonstrated through monitoring, and make use of settling basins and constructed wetlands before water is discharged to the environment. One farm is issued an industrial wastewater permit, which is accompanied by stricter limitations, as well as monitoring and reporting requirements—but such permits likely relate to hatchery operations or multi-species production rather than growout of red drum. Monitoring results are reported on the TCEQ website (TCEQ 2016a) (TCEQ 2016b) (TCEQ 2016c) (pers. comm., R. Adami 2016) (pers. comm., M. Baez, TCEQ 2016).

Penalties for infractions of the Texas Agriculture Code and the TCEQ's general permit to discharge waters are clearly identified in Section 134.023 and range from misdemeanor to felony charges (Texas Agriculture Code 2007). The EPA publishes online its enforcement cases with the name of the respondent, description of alleged violation, and the penalty amount, as well as a host of other details (U.S. EPA 2016). The Texas Commission on Environmental Quality supplies monthly and annual enforcement reports (TCEQ 2016b) and reported conducting over 100,000 routine and complaint investigations (across Texas, for all wastewater permittees—not just red drum farms or aquaculture) in 2015.

The TCEQ also provides highly detailed information on wastewater permitting, complaints, investigations, correspondence, and results of compliance inspections and enforcement actions. For example, one large red drum farm was issued at least seven citations (all classified as "moderate") from 2011–2015, with all being declared "resolved" by the TCEQ; another large farm received four minor to moderate citations all related to not keeping specific enough records in 2013. Red drum farms submit monthly Discharge Monitoring Reports (DMRs) and violations of permit requirements can trigger enforcement actions, with Texas Parks and Wildlife Department and TCEQ both having roles; TCEQ additionally responds to complaints (pers. comm., M. Luxemburg 2016). Evidence of compliance investigations is available on the TCEQ website, and several permittees have been fined for various violations related to water quality sampling, recordkeeping, and discharge violations—importantly, with evidence of compliance following enforcement actions. The TCEQ reports that all red drum facilities are currently in compliance with permit requirements (pers. comm., M. Baez, TCEQ 2016), and a review of compliance histories for the industry available on the TCEQ website reveals that red drum producers have received the highest possible rating for compliance by TCEQ (TCEQ 2016d). TCEQ also provides monitoring results via Freedom of Information Act requests with data additionally available on the EPA's ECHO website (U.S. EPA 2016). The U.S. red drum industry is reported as tightly regulated, and illegal discharge or dumping is not believed to be a problem with this industry (pers. comm., G. Treece, pers. comm. 2016).

Additionally, the Southern Regional Aquaculture Center (SRAC) provides a series of resources aimed at helping growers maintain water quality and abide by regulations.

Finally, there are no data or other evidence to suggest that red drum effluent has caused, or contributed to, cumulative impacts to the receiving or surrounding ecosystems.

Conclusions and Final Score

The red drum industry, which is a small industry, is being overseen by effective management. Best-management practices and regulatory requirements for water quality, treatment, and monitoring are in place, with a very low rate of discharge overall. It is evident that compliance monitoring and enforcement is occurring, with data and details available from a number of agencies. The TCEQ reports overall industry compliance with regulations governing effluent water quality. Thus, the red drum industry is considered a low effluent concern. Criterion 2 – Effluent scores 9 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		4
F3.2a Content of habitat regulations	4	
F3.2b Enforcement of habitat regulations	5	
F3.2 Regulatory or management effectiveness score		8
C3 Habitat Final Score (0-10)		**5.33**
Critical?	NO	**YELLOW**

Brief Summary

Red drum farming represents a loss of ecosystem functionality from a pre-altered habitat state, because it occurs largely on land that was originally classified as wetlands and estuarine habitat. But land conversion from these original habitat types to conditions more suitable for agriculture and ranching, as well as for shrimp farming, occurred historically—pre-dating red drum farming. A significant portion of red drum farm acreage is also converted former shrimp ponds. Thus, the use of historical wetland habitat by red drum farming is considered to be a secondary habitat conversion. Current habitat management policy is robust, with particular interest in the protection of existing wetlands and of water quality, but includes a variety of measures. Enforcement of management measures is considered comprehensive, with a large body of detailed information related to enforcement activities available and easily acquired for this assessment. The red drum industry is currently in compliance with all permitting requirements. Criterion 3—Habitat scores 5.33 out of 10.

Justification of Rating

Factor 3.1. Habitat conversion and function

In the U.S. (Texas), red drum is raised in a multistage production system (Figure 1), with the bulk of the production cycle taking place in a intensive system of enclosed earthen ponds, after the hatchery and nursery stages. Ponds are typically about 5 acres (2.02 hectares) in size and are located near the coast (within 50–100 m of bays) behind earthen levees or farther inland, usually close to a creek (Davis 1990) (Treece 2016) (USGS 2016). Farms are typically located at elevations of 5–15 feet above sea level, with some limited acreage located within 100-year flood plains (USGS 2016).

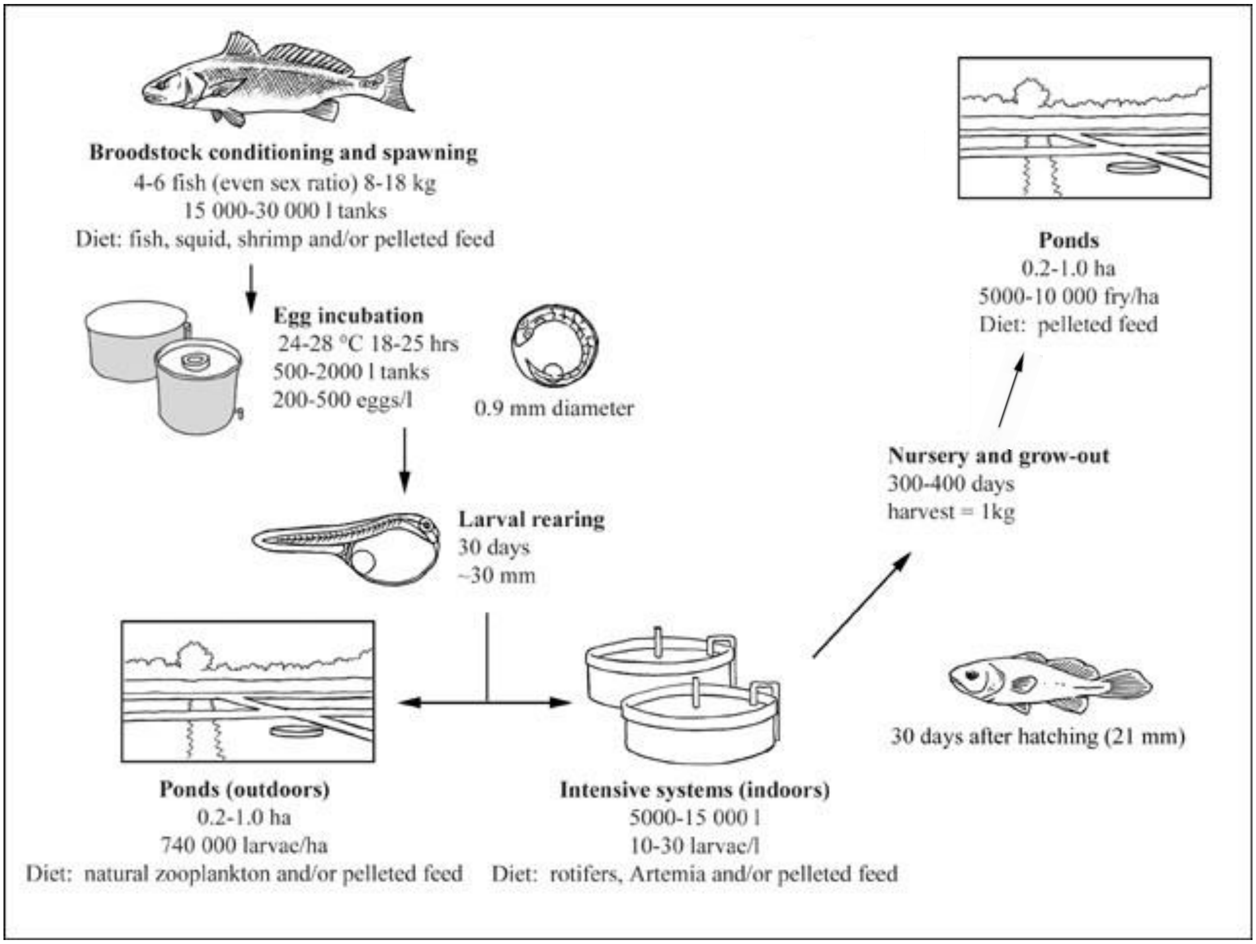


Figure 1. Typical red drum production cycle from spawning to pond growout. Image (slightly adapted) courtesy of FAO 2016a. *Larval rearing in Texas production typically lasts about 10 days, with total length of 30–35 mm achieved after 30 days (pers. comm., R. Vega 2016).

Texas currently has about 710 to 1,100 acres (287 to 445 hectares) developed for pond culture, with about 500–700 acres (202–283 hectares) used for fish growout and the remainder used for fingerling production. Not all pond acreage is active in a given year. The largest three farms are well over 200 acres (81 hectares) in size, with two smaller farms composing the remaining acreage; six farms are currently active in Texas after one farm ceased red drum operations in 2015–2016. About 30% of existing red drum pond acreage is from converted former shrimp ponds (converted in about 2006–2008 in response to changing economics of shrimp farming; Figure 2). The shrimp farms were developed from land previously used for agriculture or ranching dating to at least the 1980s and 1990s (Table 2). A 200+ acre farm was built on the coast in 2004 and at least one existing farm expanded in 2008–2009. Another newer farm is located upland (several kilometers from the coast), developed since 2009 on previously undeveloped and/or agricultural land, and is continuing to expand (Treece 2012) (Treece 2016) (USGS 2016) (pers. comm., J. Ekstrom 2016).

Figure 2. A typical red drum farm, located near the Gulf of Mexico shoreline. Similar to approximately 30% of the present industry acreage, this farm began as a shrimp farm in the 1980s and 1990s, converting to red drum in about 2006 with some expansion into land previously used for agriculture in 2009 (Imagery courtesy of USGS and Google Earth).

Table 1. Land use profile for the Texas red drum industry.

Farm	Size of farm, acres	Established/developed	Previous status of land/classified habitat type	Land classified as former wetland?	Within a 100-year flood plain?
Farm "A" (Palacios)	215 acres+ (82.96 hectares)	Oldest red drum farm: mid-1980s	Pasture or agriculture/ freshwater wetland	Yes—215 acres	No
Farm "B" (Port Lavaca)	120 acres+ (48.56 hectares)	Shrimp from 1980s–2007; expansion 2009	Shrimp ponds since 1980s/ freshwater wetland and estuarine marsh	Yes	No
Farm "C" (Palacios)	60 acres+ (24.28 hectares)	2008–2012	Agriculture or undeveloped/ upland grassland salty prairie	Yes—0.13 acres	Yes
Farm "D" (Palacios)	200 acres+ (80.94 hectares)	2004	Undeveloped or agriculture/ estuarine and marsh	Yes—0.13 acres	No
Farm "E" (Palacios)	200+ acres	Shrimp from 1990s–2006	Shrimp ponds since 1990s/ estuarine	Yes—0.74 acres	No
Total & summary	795+ acres	Industry active at least early 2000s–present ≈30% previously shrimp farms; ≈7.5% previously undeveloped; ≈62.5% previously agricultural	Most occurs on land previously converted for shrimp farming or agriculture	At least 27% of acreage is former wetlands; converted >15 years ago by previous land use (agriculture)	Most is occurring outside of flood zones
Sources:	(Treece 2016)	(Treece 2016) (USGS 2016) (pers. comm., J. Ekstrom 2016)	(Lumb et al. 2015) (Treece 2016) (USFWS 2016c) (USGS 2016)	(Lumb et al. 2015) (USFWS 2016c)	(FEMA 2016)

Approximately 30% of red drum farm acreage was originally developed for shrimp aquaculture 17–36 years ago, with conversion of existing ponds to red drum about 10 years ago. The remaining ≈70% of the industry has been developed on land used for agriculture within the last decade (Figure 2). Most U.S. red drum farms are located in former wetland or estuarine habitat, with approximately 7.5% located in former grassland or "salty prairie" (as classified by (Lumb et al. 2015) and (USFWS 2016c)). In nearly all cases, it appears that conversion of wetlands to pasture or agricultural use (or otherwise now classified as “upland” by (Tremblay and Calnan 2010)) occurred well before the development of these areas for red drum farming (Tremblay and Calnan 2010) (pers. comm., G. Treece, Texas SeaGrant 2016) (USGS 2016). Red drum aquaculture largely represents a “secondary conversion” of land (pers. comm., G. Treece, Texas SeaGrant 2016) with some newer development or expansion onto undeveloped or former agricultural land (USGS 2016). Texas does not currently allow any farms on wetland or within estuarine environments (pers. comm., R. Adami, TPWD 2016).

Figure 3. Examples of red drum farms in a range of areas classified by USFWS as wetlands. In nearly all cases, loss of wetlands occurred in conjunction with previous land uses >15 years ago (From USFWS National Wetland Inventory (USFWS 2016)).

Red drum ponds represent a loss of ecosystem functionality in the form of the historical loss of wetlands and estuarine habitats—which are considered high value by Seafood Watch—with a lesser amount representing loss of coastal or “salty” prairie. But U.S. red drum farms are largely located in habitat that was developed for other uses (shrimp farming, agriculture) historically (>15 years ago) and the red drum industry is not directly responsible for this habitat conversion. Current industry guidelines also advise against siting in wetland areas (Davis 1990), and the TGLO manages for no net loss of wetlands (TGLO 2015). Per the Seafood Watch Aquaculture Standard, as high value habitat that lost functionality >15 years ago, the score for Factor 3.1 is 4 out of 10.

Factor 3.2. Farm siting regulation and management

<u>Factor 3.2a: Content of habitat management measures</u>

The management and regulatory frameworks for aquaculture production of red drum are robust, with operations regulated at both the federal and state levels. The Texas Agriculture

Code applies to licensing, siting, planning, and operations, and it contains basic language aimed at long-term conservation of natural resources required by aquaculture (such as water quality), authorizes oversight of aquaculture by state agencies, and outlines punishments for violations of code. The Code also has stipulations aimed at preventing the siting of aquaculture facilities in sensitive habitat areas. Subchapter C of the Code also contains language directing agencies to consider cumulative impacts to waterbodies when issuing new or expanded discharge permits within the coastal zone.

The Texas Coastal Zone Management Plan (CZMP), under the federal CZMA, also applies to aquaculture. For example, CZMP requires the completion of an environmental impact assessment (TGLO 2015), and a "no net loss of wetlands" policy is in place (complete with mitigation requirements; see also (NEPA 1972)). But the same document states that loss of wetlands is still occurring in general (though not necessarily associated with this industry), despite significant gain through mitigation measures.

The U.S. Army Corps of Engineers oversees some elements related to red drum culture, such as water resources and wetlands, and issues permits for intake pipes, discharge pipes, dredge, and fill of material for levees and road fills. The Corps takes into account cumulative impacts to water quality and impacts to other wildlife when considering permit decisions. Pursuant to the Clean Water Act, a National Pollution Discharge Elimination System (NPDES) permit (or equivalent, in this case stricter permitting from TCEQ and its TPDES) is required per the EPA, and a Texas Land Application Permit (TLAP) is required under TCEQ, as outlined in Criterion 2 of this assessment.

Both the EPA and TCEQ seek to avoid degradation of ecological processes, systems, and wildlife (Treece 2005). The TCEQ requires permits for creation of impoundments for aquaculture (Treece 2005) and requires that they be constructed to prevent contamination of groundwater and maintained in a manner to prevent erosion (TCEQ 2016c) (TCEQ 2016d). Criterion 2 (Effluent) outlines further management measures in place to protect water quality.

Additionally, industry guidelines for the development of red drum ponds for culture were developed by the Southern Regional Aquaculture Center and contain many habitat-related provisions, including the avoidance of wetlands, use of common levees for multiple ponds, and avoidance of siting ponds in areas subjected to regular flooding, storm surge, or tidal fluctuations (Davis 1990).

Management content is considered strong, but there are some weaknesses. Although cumulative impacts are addressed by the CMP, overall ecosystem function is not specifically discussed. Further, as noted in Factor 2.2, some challenges remain for effective cumulative impacts management, including gaps in understanding and regulatory inconsistencies. The TGLO reports issues in tracking of wetlands mitigation projects and gaps in management protection of some wetlands due to classification confusions (TGLO 2015). Therefore, the content of habitat management measures is considered robust but not quite comprehensive, warranting a score of 4 out of 5 for Factor 3.2a.

Factor 3.2b: Enforcement of habitat management measures

As detailed in Criterion 2 (Effluent), enforcement agencies are easily contacted and the enforcement and penalties are robust. Penalties for infractions of the Texas Agriculture Code and the TCEQ general permit to discharge waters are clearly identified in Section 134.023. Penalties and charges for infringements range from misdemeanor to felony charges (Texas Agriculture Code 2007). The EPA publishes its enforcement cases online with the name of the respondent, description of alleged violation, and the penalty amount, as well as a detailed monitoring, compliance, and enforcement history (EPA 2016). Through the Texas Commission on Environmental Quality, a range of information precision is available. TCEQ publishes monthly enforcement reports and, though they are aggregated, they demonstrate that enforcement is active. TCEQ also provides contact information in a detailed agency directory (TCEQ 2016e). It also reported the percent of permitted facilities in compliance with permits, enforcement orders, or programs per annum. In 2012, it was reported that 99% of all water facilities inspected were in compliance (TCEQ 2013b).

Further, compliance reports for individual farms are available on the TCEQ website or through request to the agency. Review of compliance reports provided by TCEQ for every farm in the Texas red drum industry clearly demonstrates that enforcement is active and that some habitat-related concerns (as well as effluent-related concerns) are addressed. For example, TCEQ lists instances in which the agency has followed up on complaints about red drum ponds leaking and contaminating soils with salt (found to be unsubstantiated with no citation issued) and has issued citations for failure to maintain levees (TCEQ 2016c). The red drum industry is small, enforcement is clearly active in overseeing the industry, and TCEQ reports that all Texas red drum farms are currently in compliance with permits they oversee (pers. comm., M. Baez 2016). Enforcement of habitat management measures is thus considered comprehensive for the red drum industry.

The score for Factor 3.2b is 5 out of 5. When combined with the Factor 3.2a score of 4 out of 5, the final Factor 3.2 score is 8 out of 10.

Conclusions and Final Score

Red drum farming occurs in high-value habitat that lost functionality historically, predating red drum farming. Current habitat management is considered robust and enforcement of policies comprehensive. Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 5.33 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

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**8**	
Critical?	NO	**GREEN**

Brief Summary

Numerous sources have indicated that no antibiotics are used by the red drum industry. There is some limited use of FDA- and EPA-approved chemicals to control algae blooms and ectoparasites. The low susceptibility of red drum to bacterial infections and low parasite loads, coupled with alternative treatments available, obviates the need for much chemical input. Further, red drum are raised in ponds with low discharge requirements, lowering the risk to non-target organisms. Published data on current use of chemicals are scarce, but regulators have clearly stated restrictions on the use of chemicals and are active in enforcing policies. The few chemicals used by this industry are considered to be of low environmental risk if used properly, and the Texas red drum industry appears to be in compliance with regulations regarding chemicals. Thus, a low concern classification is warranted and the score for Criterion 4 – Chemical Use is 8 out of 10.

Justification of Rating

Disease and parasite issues for farmed red drum are well understood, with at least 30 pathogenic organisms identified to which red drum is susceptible (Davis 1990) (FAO 2016a), but U.S. pond-raised red drum has an apparent low need for the use of chemicals in controlling pests. Some chemicals to control parasites and pathogens have been experimented with (Lewis et al. 1988) (Oestman and Lewis 1996) and used historically (Treece 2012), but alternative methods, such as freshwater dips, manipulation of salinities, and the use of brine shrimp, are effective at controlling many pests, such as parasitic copepods (Landeberg et al. 1991), dinoflagellates and trophonts (Oestman et al. 1995), and algae (Treece 2012) (Treece 2016). Additionally, some chemical treatments experimented with or used for control of algae blooms (e.g., formalin, copper sulfate, potassium permanganate) have restrictions on their use on food fish (FAO 2016a) (pers. comm., P. Zimba 2016).

Harmful algae blooms remain an issue for the industry, and the Texas Commission on Environmental Quality's general permit to discharge wastes (TCEQ 2016a) requires that any chemicals (such as copper sulfate used to control algae), drugs, or antibiotics used be limited to those approved by the EPA and FDA (Table 3), and that they be logged and reported to the TCEQ. There is evidence that TCEQ is active in enforcing its policies (TCEQ 2016c) and regulations are considered "stringent" by some familiar with the industry (pers. comm., T. Sink 2016). The industry is using EPA-approved copper-based compounds to control some pests, which may typically be limited to 10%–15% of total ponds annually (pers. comm., T. Sink 2016). The industry commonly deals with parasite infestations by emptying ponds of fish (harvesting) and leaving ponds to fallow for 30–60 days, which is sufficient to kill parasites that depend on the fish as hosts (pers. comm., T. Sink 2016). Experiments with salinity control as an alternative means to control algae blooms in ponds are also occurring (Treece 2016) (pers. comm., P. Zimba 2016). In some limited instances, chelated copper has been used in the hatchery setting to treat external parasites such as *Amyloodinium* (Peppard et al. 1991) (Davis and Arnold 2004) but it is not economical to use in pond settings, which make up the bulk of the production cycle (pers. comm., D. Gatlin 2016).

Table 3. Chemicals approved for use by the U.S. red drum industry (from USFDA). Total industry estimates were derived by $0.52x = \Sigma$, where x = the total annual volume of a given chemical used as provided by one producer; 0.52 is the percentage of total industry production by that producer; and Σ is the estimated total volume of a chemical used by the industry annually. Volume per production was projected using estimated 2015 production statistics (Treece 2016).

Chemical	Use	Approved dosage (tanks/raceways)	Approved dosage (ponds)	Total 2015 volume used, largest producer
Formalin, aqueous solution	Parasiticide, fungicide	Up to 250 ul/L (for up to 1 hr)	15–25 uL/L (ponds)	2,082 L
Chorionic gonadotropin	Improving broodstock performance	Injection of 50–1816 I.U. per lb body weight	n/a	n/a
Copper sulfate*	Algicide, parasiticide, fungicide		0.4–3.0 mg/L, depending on water alkalinity	907 kg
Potassium permanganate*	Algicide, parasiticide, fungicide	1–10 mg/L for 1 hour	1–10 mg/L for 1 hour	227 kg

*Have been classified as a "Deferred Regulatory Status Drug," pending further study (U.S. FDA 2011) (AFS 2014).

Red drum is not heavily parasitized (Davis 1990) or plagued by disease (pers. comm., T. Sink 2016), and appears to be resilient against bacterial issues that plague other species (pers. comm., D. Gatlin 2016). There is an apparent low need for the use of antibiotics. The limited number of antibiotics approved by the FDA for use in food fish in the U.S. does not include marine finfish such as red drum, and the FDA does not currently list any medicated feeds as approved for red drum aquaculture (U.S. FDA 2016a), but antibiotics may legally be prescribed under certain circumstances (Kelly 2013). The largest marketer of U.S.-farmed red drum reports their products as "free of antibiotics" (Ekstrom Enterprises, 2016a) (pers. comm., J. Ekstrom 2016). Texas SeaGrant has also stated that antibiotics are not typically used in red drum farming (pers. comm., G. Treece 2016) and this was a statement also made by individuals from agency and academia with familiarity with the industry. The TCEQ requires that red drum producers maintain lists on site of the EPA- and FDA-approved chemicals used in their operations, in case of inspection, and the agency was unable to provide this information directly (pers. comm., Kim Laird, TCEQ 2016). One large producer provided a list of chemicals used as well as volumes and appears to be abiding by regulatory restrictions. The chemicals used by this industry (Table 3) are considered to be of low risk environmental risk when used and stored properly, because they degrade quickly and are not known to bioaccumulate or have harmful effects to receiving waters (Boyd and Massaut 1999).

Conclusions and Final Score

Red drum aquaculture has an apparent low need for chemical use, as reported by several sources, and the closed nature of the production system and its infrequent need to discharge water from these confines may lessen concern regarding discharge of chemicals. One large producer provided details on chemical use, and restrictions are in place by several regulatory agencies at the state and federal levels. The few chemicals used by this industry are considered to be of low environmental risk if used properly, and the Texas red drum industry appears to be in compliance with regulations regarding chemicals. Thus, there is a low concern for impact as a result of on-farm chemical use. The final numerical score for Criterion 4 – Chemical Use is 8 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

Feed parameters	Value	Score
F5.1a Fish In: Fish Out ratio (FIFO)	1.40	6.50
F5.1b Source fishery sustainability score	–2.00	
F5.1: Wild fish use score		5.94
F5.2a Protein IN (kg/100kg fish harvested)	72.65	
F5.2b Protein OUT (kg/100kg fish harvested)	21.04	
F5.2: Net Protein Gain or Loss (%)	–71.05	1
F5.3: Feed Footprint (hectares)	11.66	6
C5 Feed Final Score (0-10)		**4.99**
Critical?	NO	**YELLOW**

Brief Summary

U.S. farmed red drum relies on fishmeal and fish oil inputs, supported primarily by wild caught Gulf menhaden. The use of wild fish in red drum feed receives a score of –2 out of –10 for sustainability of the source fishery for Gulf menhaden. There is a strong motivation to lessen reliance of red drum feeds on fishmeal inputs, so red drum feed makes use of crop and land animal ingredients. The most recent specific data available for this assessment were publications from 2006 and 2009. Because of the high protein requirements of red drum, the ongoing (but decreasing) use of fishmeal, the relatively low edible yield of harvested drum, and the use of at least some of the non-edible parts of the fish, farmed red drum scores 2 out of 10 for net protein loss. Farmed red drum scores a 6 out of 10 in feed footprint for a high ratio of crop to land animal ingredients and a moderate inclusion level of fishmeal.

Factors 5.1, 5.2 and 5.3 combine to give a final Criterion 5 – Feed numerical score of 4.99 out of 10.

Justification of Rating

Red drum is a predatory fish with a high dietary protein requirement of about 35%–45% (Gatlin 2002). External feed is provided to red drum and, traditionally, farmed red drum have been fed a fishmeal-based diet (Minjarez-Osorio et al. 2015) (pers. comm., D. Gatlin 2016), but the red drum industry has identified a need for research and development into feeds requiring less fish protein as an important economic consideration for the industry. Feed currently makes up about 42% of the cost of farming red drum in the U.S. and is a major challenge to the viability of the industry (Treece 2016). As a result of, recent research has been directed at the viability of various alternative feed ingredients, such as plant-based proteins. Although recent and earlier studies have demonstrated that red drum can tolerate relatively high levels of plant-based proteins, specific information on the actual composition of commercial feeds is limited, and a lag between experimentation and implementation is typical. The red drum industry still relies on fishmeal in feed, but significant reductions in the percentage of fishmeal in diet have been achieved in recent years.

Factor 5.1. Wild Fish Use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Recent and past research has focused on the replacement of fishmeal-based protein with plant-based feedstuffs: most prominently soy-based, but also using corn, barley, and cottonseed (Gatlin 2002) (Minjarez-Osorio et al. 2015) (Rossi et al. 2015) (pers. comm., D. Gatlin 2016). Successful experimental replacement of up to 75%–90% of fishmeal protein with plant-based feedstuffs has been achieved in recent and previous studies (McGoogan and Gatlin 1997) (Minjarez-Osorio et al. 2015), while up to 50% replacement levels were used in commercial feeds in the 1990s (Davis 1999). Experimental reductions to as low as 7% fishmeal inclusion have recently been achieved (pers. comm., D. Gatlin 2016). The addition of land-based animal proteins, such as poultry meal and other additives (krill hydrolysate) has successfully reduced fishmeal to 5% inclusion in experimental feeds (Davis and Arnold 2004); the most recent specific data suggests 10% inclusion of meat and bonemeal in commercial feeds (CABI 2006).

It is clear that research has responded to the need to reduce dependence on fishmeal for protein in red drum feeds, but specifics from feed companies were unavailable for this assessment. Because of the high cost of fishmeal, there is a strong motivation from industry to make such reductions, and fish growers may have some influence on feed companies regarding ingredients. Feed companies are looking at research for insight into possibilities (pers. comm., J. Bowzer, Cargill Animal Nutrition 2016) (pers. comm., D. Gatlin 2016), so it is likely that fishmeal inclusion has been significantly reduced since the 1990s. For this assessment, 17.5% was chosen as an average of the 15%–20% fishmeal inclusion estimates provided by experts (pers. comm., J. Ekstrom 2016) (pers. comm., D. Gatlin 2016). This estimate is also close to an average for marine fishes reported by the FAO (18% (Tacon et al. 2011)).

Although not specific to the red drum industry, it was estimated that fisheries by-products contribute 26% of total U.S.-produced fishmeal (Tacon et al. 2011); because Gulf menhaden is consistently reported to be the primary source of fishmeal for the red drum industry (CABI

2006) (Minjarez-Osorio et al. 2015) (pers. comm., D. Gatlin 2016) (pers. comm., J. Ekstrom 2016) (pers. comm., G. Treece 2016), the assumption that 26% of the industry's fishmeal is from by-products is applied. This results in a total whole-fish fishmeal percentage of 12.95% for the formula used in Factor 5.1a.

Although the species utilizes dietary oils well (including from fishmeal), supplemental lipids are necessary and can take a variety of forms, but typically include the use of fish oil (pers. comm., D. Gatlin 2016). Experts interviewed for this assessment estimate the fish oil inclusion range as 1%–2% and 5% (pers. comm., D. Gatlin 2016) (pers. comm., J. Ekstrom 2016). Fish oil inclusion levels in control and basal diets used in recent research and within the range estimated by experts extended from 2.55% to 5%. To estimate the fish oil inclusion percentage in red drum feeds, an average was calculated of five recent values provided by experts and used in recent research control diets. No information was available on a percentage of fish oil coming from by-products; it was assumed for this assessment that by-product inclusion in fish oil is zero.

Table 4. Fish oil estimates used to estimate value used in Factor 5.1. *Where a range in values was provided, an average was used to derive a single estimate value.

Fish oil fraction	Source	Reference
1%–2%*	Expert interview	pers. comm., D. Gatlin 2016
5%	Expert interview	pers. comm., J. Ekstrom 2016
2.55%	Control diet	Minjarez-Osorio et al. 2015
3.3%	Control diet	Rossi et al. 2016
5%	Control diet	Velasquez et al. 2015
3.47%	Average of all estimates	(see above)

No information on fishmeal or fish oil yield was available, so average values (22.5% and 5%, respectively) for Seafood Watch assessments were used.

The economic FCR of red drum is 2:1 (Treece 2012) (Treece 2016).

The values and equations used for Factor 5.1a, in summary:

Table 5. Factor 5.1a Feed fish efficiency ratio (FFER) data.

Parameter	Data
Fishmeal inclusion level	17.5%
Percentage of fishmeal from byproducts	26%
Fishmeal yield (from wild fish)	22.50%[1]
Fish oil inclusion level	3.47%
Percentage of fish oil from byproducts	0%

[1] 22.5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fishmeal from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

Fish oil yield	5.00%[2]
Economic Feed Conversion Ratio (eFCR)	2
Calculated Values	
Fish In : Fish Out ratio (fishmeal)	1.15
Fish In : Fish Out ratio (fish oil)	1.39
Seafood Watch FIFO Score (0-10)	**6.53**

The Seafood Watch Aquaculture Standard uses the higher of these two values (FFER Fish oil, 1.39) in its formulation. The resulting score for Factor 5.1a – Feed Fish Efficiency Ratio is 6.53 out of 10.

Factor 5.1b – Sustainability of the Source of Wild Fish

Gulf menhaden, the primary fishmeal source for the red drum industry (CABI 2006) (Minjarez-Osorio et al. 2015) (pers. comm., D. Gatlin 2016) (pers. comm., J. Ekstrom 2016) (pers. comm., G. Treece 2016), scores > 6 for all FishSource scores and has a score of > 8 on stock health (FishSource 2016). Managers of this fishery have concluded that the Gulf menhaden stock is not overfished and that overfishing is not occurring (VanderKooy and Smith 2015).

In cases in which Gulf menhaden-based fishmeal becomes unavailable, fishmeal from Chilean anchoveta or Mexican sardines may be used—although rarely, because of cost (pers. comm., G. Treece 2016).

This scoring results in a Seafood Watch score of –2 out of –10 for the Gulf menhaden fishmeal source fishery.

The score for Factor 5.1b – Sustainability of the Source of Wild Fish is –2 out of –10. When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1 score of 5.97 out of 10.

Factor 5.2. Net Protein Gain or Loss

Some information on the protein inputs from marine feed ingredients is available. Rangen Feeds reports the protein content of their commercial red drum feed as 44% (Rangen Feeds 2016), which is within the range indicated specifically in various academic publications in control diets used in the scientific literature (Faulk 2005) (Gatlin 2002) (Davis and Arnold 2004) (Minjarez-Osorio 2015) (Rossi et al. 2015) (Treece 2016), and as suggested by expert interviews (pers. comm., D. Gatlin 2016). The protein content of menhaden fishmeal is 63%, as reported by Omega Protein, Inc. (the median of their "typical" range (Omega Proteins 2016)), which is within the range reported by red drum feed studies (Moon and Gatlin 1994) (Rossi et al. 2016).

Feed ingredient data specific to red drum were gathered from the FAO, which relied on 2009 data, as well as CABI (2006). The following statistics were used:

[2] 5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fish oil from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

- Soya protein, 85% protein: 10% inclusion (FAO 2016b) = 19.32% of total feed protein
- Soybean meal, 46% protein: 23.4% inclusion (FAO 2016b) = 24.46% of total feed protein
- Wheat gluten, 75.16% protein (USDA 2016): 5% inclusion (FAO 2016b) = 8.55% of total feed protein
- Wheat starch, 13.21% protein (USDA 2016): 19% inclusion (FAO 2016b) = 5.70% of feed total protein
- Meat and bone meal, 42.7% protein (Seafood Watch 2016): 10% inclusion (CABI 2006) = 9.7% of total feed protein

It is assumed for the sake of calculations in Factor 5.2, per the Seafood Watch scoring guidelines, that meat and bone meal are considered non-edible animal ingredients and that the above-listed crop ingredients are all considered edible crop ingredients.

Harvest of red drum typically results in a 40% yield, a value chosen as a point of overlap in estimates from expert interviews (pers. comm., D. Gatlin 2016) (pers. comm., J. Ekstrom 2016) and a range of values reported following feed experiments in recent and past literature (Moon and Gatlin 1994) (Rossi et al. 2016). The protein content of whole harvested red drum is 17.5% (pers. comm., D. Gatlin 2016) (pers. comm., J. Ekstrom 2016) (Rossi et al. 2016).

The overall fate of the non-edible by-products from harvested fish is unclear. Fish are typically sold whole to processors (wholesalers and retailers) who process the fish as desired (Treece 2016) (pers. comm., J. Ekstrom 2016). One processor reports that they are selling “a lot” of fish heads and that this may increase the total percentage of a fish that is sold for food to 43%–61%, an increase of 3%–21% over the typical edible yield of 40%—“when fish heads are selling” (pers. comm., C. Huntsberger 2016). This processor reports that they buy what amounts to only about 2.5% of annual industry production volume, so it is difficult to apply these estimates broadly. Others familiar with the industry were confident that much of the non-fillet portions of the fish are being utilized—“a significant volume” of heads and racks for soup stock and also for crab bait, and rendered into organic fertilizer and possibly pet food (pers. comm., J. Ekstrom 2016) (pers. comm., G. Treece 2016). Additionally, fishmeal analogues derived from red drum parts have performed well experimentally and research continues into such use in products (Moon and Gatlin 1994) (pers. comm., D. Gatlin 2016). Industry experts suggest that a significant portion of red drum waste is being used directly or indirectly for food. Absent precise estimates, per the Seafood Watch Aquaculture Standard this assessment assumes that 50% of the non-edible portion of red drum is utilized.

Table 6. Factor 5.2b Net protein gain or loss equation data.

Parameter	Data
Protein content of feed	44%
Percentage of total protein from non-edible sources (byproducts, etc.)	17.44%
Percentage of protein from edible sources	82.56%
Economic Feed Conversion Ratio	2.0
Edible Protein INPUT per ton of farmed red drum	72.65 kg
Protein content of whole harvested red drum	17.5%
Edible yield of harvested red drum	40%
Percentage of farmed red drum byproducts utilized	50%
Utilized Protein OUTPUT per ton of farmed red drum	21.04 kg
Net protein loss	–71.05%
Seafood Watch Score (0-10)	**2**

Adjusted protein output value (kg protein per 100 kg harvested farmed fish) = 21.04.

Protein in feeds used for farmed U.S. red drum is sourced from 82.56% edible ingredients and 17.44% inedible ingredients, with an edible protein input of 72.65 kg/100 kg of harvested farmed fish to a utilized protein output of 21.04 kg/100 kg of harvested farmed fish. The result is a net loss of 71.05% of edible protein, leading to a Factor 5.2 score of 2 out of 10.

Factor 5.3. Feed Footprint

Soybean meal is currently the most prevalent crop ingredient used in red drum feed (Tacon et al. 2011). Rendered animal by-products, such as poultry by-product meal and meat and bone meal, have also been found effective in red drum feeds (Kureshy et al. 2000) (Davis and Arnold 2004), and one feed producer reports the inclusion of animal-based proteins (Rangen Feeds 2016). The most recent, specific data available are from 2009 via the FAO (FAO 2016b) and from CABI 2006. Using these data (see Factor 5.2), the total inclusion level of crop ingredients is 57.4% and of land animal ingredients is 10%. For the calculations in Factor 5.3, total crop ingredient conclusion was adjusted to 65.03% to account for the composition of an unknown 11.6% (5% of which is listed as “other” by FAO 2016b) and meet the 95% minimum ingredient total required by the formula used in Factor 5.3.

Table 7. Factor 5.3 Feed footprint equation data.

Parameter	Data
Marine ingredients inclusion	20.97%
Crop ingredients inclusion	65.03%
Land animal ingredients inclusion	10%
Ocean area (hectares) used per ton of farmed red drum	10.91
Land area (hectares) used per ton of farmed red drum	0.71
Total area (hectares)	11.62
Seafood Watch Score (0-10)	**6**

The area necessary for production of marine ingredients required for 1 ton of farmed red drum is 10.91 ha/ton of farmed fish. The area necessary for production of terrestrial (crop and land animal) ingredients required for 1 ton of farmed red drum is 0.71 ha/ton. The combination of these two values results in an overall feed footprint of 11.62 ha/ton of farmed fish. This results in a final Factor 5.3 score of 6 out of 10.

Conclusions and Final Score

U.S. farmed red drum relies on fishmeal and fish oil inputs, supported primarily by wild caught Gulf menhaden. The use of wild fish in red drum feed receives a score of –2 out of –10 for good sustainability and scores a 5.97 for Factor 5.1 Wild Fish Use.

There is a strong motivation to lessen reliance of red drum feeds on fishmeal inputs, so red drum feed makes use of crop and land animal ingredients. The most recent, specific data available for this assessment were publications from 2006 and 2009. Because of high protein requirements of red drum, the ongoing (but decreasing) use of fishmeal, the relatively low edible yield of harvested drum, but the apparent use of some non-edible parts of the fish, farmed red drum scores 2 out of 10 for net protein loss. Farmed red drum scores a 6 out of 10 in feed footprint for a high ratio of crop to land animal ingredients and a moderate inclusion level of fishmeal.

Factors 5.1, 5.2 and 5.3 combine to give a final Criterion 5 – Feed numerical score of 4.99 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

Escape parameters	Value	Score
F6.1 System escape risk	8	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		8
F6.2 Invasiveness		8
C6 Escape Final Score (0-10)		**8**
Critical?	NO	**GREEN**

Brief Summary

Red drum is a native species being farmed within its native range. Multiple safeguards are in place to prevent escapes, and the low frequency of water exchange and low volumes of discharge limit opportunities for escape, though this criterion would benefit from additional details regarding escape prevention mechanisms. Some genetic differentiation in hatchery-produced red drum has been demonstrated, but farmed red drum are likely genetically similar to those used in a massive red drum wild stock enhancement program, because of broodstock mandates aimed at promoting genetic diversity. Farmed red drum has both low risk of escape and of invasiveness and scores 8 out of 10 for Criterion 6—Escapes.

Justification of Rating

Factor 6.1. Escape risk

There is little mechanism for escape of red drum from farms, and multiple safeguards are in place. Red drum are grown in enclosed ponds fortified with earthen levees. Opportunities for escape are rare, because water is not exchanged between ponds and infrequently with surrounding waters. Discharge occurs mainly during harvest, and more rarely when conditions warrant due to water quality (Treece 2016) (pers. comm., R. Adami, TPWD 2016)—possibly limited to about 1% of total volume per day (Davis 1990). Under extreme and rare conditions, it may be necessary to exchange water in ponds at a rate of up to 20%–25% of total volume per day to control harmful algae blooms (pers. comm., P. Zimba 2016) and improve water quality (TCEQ 2016), though this is rare, if not unlikely, because its effectiveness in treating algae blooms is questionable (pers. comm., J. Ekstrom 2016). Additional safeguards, such as 1” x 2” square grates and smaller mesh barriers at outlets, reportedly further limit opportunity for escapes (pers. comm., R. Adami 2016) (pers. comm., T. Sink 2016) (pers. comm., G. Treece 2016), and not all ponds have outlets, with little overall connectivity between ponds and the surrounding environment (pers. comm., R. Adami 2016) (pers. comm., T. Sink 2016). Further, hypothetical escape of fish from one pond to another would be of concern to farmers because of the cannibalistic nature of red drum—they are typically sorted by size to prevent this (Chamberlain 1990) (Treece 2016) (pers. comm., T. Sink 2016). Farmed red drum are harvested at 18–24 months of age, which is before fish typically reach maturity (30 months–4 years), rendering the risk of escapement of eggs or larvae from incidental spawning in ponds also unlikely.

Although water exchange is infrequent and corresponding risk of escapement is low, some red drum farms are located close to the shoreline (50–100 m) and/or within floodplains, and may be at risk of storm damage. The Texas coastline is vulnerable to and experiencing sea-level rise (TGLO 2015). Erosion of pond banks and some minor damage to equipment has occurred, but to date no catastrophic damage has taken place from hurricanes or other storms (pers. comm. J. Ekstrom 2016) (pers. comm., G. Treece 2016) and TCEQ enforces requirements to maintain levees (TCEQ 2016c) and prevent overflow (TCEQ 2016b). The Southern Regional Aquaculture Center (Davis 1990) advises that site selection avoid areas subjected to regular flooding, storm surge, and tidal fluctuations. Part of one older farm is located in a 100-year flood zone, but most are located outside of flood zones or in areas of less than 1% annual risk of flood (Table 2 (USDHS 2016)). Annual flood risk for red drum farms in Texas is typically less than 1%, and is thus considered low risk.

No data (or reporting requirements) exist in regard to escapes from farms, apparently because no escapes have ever been documented (pers. comm., J. Ekstrom 2016). The Texas Parks and Wildlife Department has low risk concerns regarding red drum escapes because the species is native, stocks are supported by a hatchery program, and protocols to promote genetic diversity are in place (pers. comm., R. Adami 2016) (see Factor 6.2).

A slight risk exists of hypothetical escapes associated with some pond water exchange and with some farms either being within 100-year floodplains or close to a vulnerable coastline. Because of the use of enclosed ponds, with quite low daily water exchange, and additional safeguards in the form of physical barriers and limited connectivity to other ponds or the surrounding environment—in addition to multiple sources stating that escapes have never been documented as an issue for this industry – the risk of escapement of farmed red drum is considered to be low. Per the Seafood Watch Aquaculture Standard for enclosed ponds with low daily water exchange, multiple fail-safe prevention methods, and data in the form of statements from credible sources, the score for Factor 6.1 is 8 out of 10.

Factor 6.2. Invasiveness

Red drum is native to the geographic focus of this assessment. Thus, there is no risk of the introduction of a non-native species.

Because red drum are produced in hatcheries, with broodstock used for production of several generations, escapees have the potential for genetic consequences on nearby wild populations, such as through introgression. But hatchery-bred red drum have been found to be more vulnerable to predation than their wild-caught counterparts (Rooker et al. 1998) (Stunz and Minello 2001), which may reduce the risk of hypothetical escapees.

The U.S. red drum industry is required to follow protocols intended to promote genetic diversity in hatchery breeding. For example, fingerlings must be produced with at least 25% of the broodstock being wild-sourced fish (Stickney et al. 2011) (Carson et al. 2014) caught in proximity to each hatchery (Carson et al. 2014), with broodstock collection permit and reporting requirements under the Texas Parks and Wildlife Department (pers. comm., R. Adami 2016). Thus, some wild capture of broodstock occurs in concert with broodstock management aimed at enhancing genetic diversity of hatchery-produced fish (Treece 2016), and some hatcheries are using 100% wild broodstock (pers. comm., J. Ekstrom 2016). Despite these efforts, genetic differences in hatchery-bred versus wild drum have been demonstrated. Verified genetic differences in hatchery-bred versus wild red drum include lower genetic effective size (N_e), lower allelic richness, and lower haplotype diversity (as reviewed by (Araki and Schmid 2010) (Stickney et al. 2011) (Carson et al. 2014)). Population-level genetic effects have not explicitly been demonstrated, but the enhancement program has been a boon to the size of the wild stock, which has increased to near-record numbers since the stock enhancement program began (coupled with a significant reduction in harvest mortality) (Stickney et al. 2011) (Vega et al. 2013) (Treece 2016). But as Turner et al. (2002) point out, even populations with a high number of individuals can be at risk to decline via genetic factors.

Because red drum is a native species with some potential genetic differentiation between hatchery-bred and wild fish but with low risk of potential impacts to wild populations due to ongoing enhancement using identical fish, and because of management practices aimed at promoting genetic diversity and the demonstrated lower survival of hatchery-bred fish, this assessment considers invasiveness of potential escapees to be low risk. The score for Factor 6.2 is 8 out of 10.

Conclusions and Final Score

Red drum is a native species farmed with a low risk of escape and low risk of invasiveness.

Factors 6.1 and 6.2 combine to give a final numerical score of 8 out of 10 for Criterion 7 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body
- Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.
- Principle: preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Criterion 7 Summary

Disease Evidence-based assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	6	
Critical?	NO	YELLOW

Brief Summary

The red drum industry is apparently not often affected by major disease concerns. The species appears to have a low parasite load and a resilience to bacterial and other issues common to other farmed species. Primary pest concerns include toxic algal blooms and the occasional parasite infestation. The stocking density of fish in ponds and occasional water discharges do pose some risk of amplification and spread of pathogens. One large producer provided details on its fish health and disease management protocols, which are considered to be robust. Data on reported fish disease issues appear to be absent due to the lack of disease issues for farmed red drum. This industry is viewed as low to low-moderate risk with infrequent occurrences of disease issues at the typical farm level, and infrequent but occasional water discharge. This criterion would benefit from additional disease management protocol information from the rest of the industry. The final score for Criterion 7—Disease is 6 out of 10.

Justification of Rating

Because disease data quality and availability is moderate (i.e., Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment was utilized.

In red drum aquaculture, the potential for disease outbreaks exists. The FAO Cultured Species Fact Sheet on red drum (Faulk 2005) list the following as diseases that have occurred in red drum under culture, with suggested treatments listed in brackets:

- Viral nervous necrosis (disinfection of culture water – UV, ozone, etc.; culling of affected fish)
- Enteromyxosis (disinfection of culture water – UV, ozone, etc.; culling of affected fish)

- Lymphocystis (minimize stocking density; quarantine fish; disinfection of culture water – UV, ozone, etc.)
- Crustacean ectoparasites (freshwater dip; formalin dip)
- Vibriosis (antibiotics; culling of affected fish; disinfection of culture water; reduce stress; nutritional supplements (Li et al. 2007))
- Streptococcosis (antibiotics; culling of affected fish; disinfection of culture water; reduce stress)
- Amyloodiniosis (freshwater dip; water filtration; copper sulfate (not approved for food fish); suggested as an issue for the U.S. industry (Lewis et al. 1988) (pers. comm., G. Treece 2016)).
- Cryptocaryonosis (reduced salinity; lower temperature; copper sulfate/formalin dip (neither approved for food fish))

Davis (1990) states that at least 30 organisms have been found on or in red drum. It can play host to a number of parasitic worms, though these are not often a serious concern to fish health. Fungal infections and protozoans can also be problematic (Johnson 1990). For example, amyloodiniosis is suggested as a particular issue for the industry and can be financially devastating to farming of red drum (Francis-Floyd and Floyd 2011) (pers. comm., G. Treece 2016).

Farming of red drum does present some risk of amplification or spread of disease due to the density of fish in ponds. The release of water during control efforts has the potential to input pests to the environment, as does the low discharge that occurs on a more regular but infrequent basis. Birds and other wildlife visiting ponds also have the potential to spread pathogens, such as *Amyloodinium* (Francis-Floyd and Floyd 2011), thus presenting another disease-spread risk associated with pond culture of red drum.

Although the list of potential diseases and pathogens in the farm culture of red drum is lengthy, producers in the United States report no occurrences of major disease issues, and many of these issues are more relevant to other production systems or locations. Existing controls include physical barriers (levees) and limited or no connectivity between ponds, to control spread of the gill parasites (pers. comm., G. Treece 2016); dietary supplementation—for example, nucleotide mixtures increase red drum juveniles' ability to overcome bacterial infection from *Vibrio harveyi* (Li, Gatlin, and Neill, 2007); preservation of water quality to promote fish health via husbandry practices, and addition of some EPA- and FDA-approved (non-antibiotic) chemicals in low doses; dehydration and disinfection of ponds between harvest cycles; manipulation of salinity to control pests; and robust disease management protocols. For recirculating tanks, such as those in the hatchery setting, UV or ozone treatment of water are effective options. Biosecurity protocols and quarantine measures can be used to prevent the spread of pathogens between ponds, with prevention of introduction important to successful farming operations, and the Southern Regional Aquaculture Center has developed resources to aid aquaculturists in this regard (Francis-Floyd and Floyd 2011).

The Texas Animal Health Commission (TAHC) requires that animals brought into the state from outside be certified as “disease free” by qualified laboratories or veterinarians (though TPWD reports that the agency has no knowledge of fish being brought in from out of state (pers. comm., R. Adami 2016))—further reducing the risk of introducing new diseases (Treece 2005), although all fingerlings used in Texas red drum farming are produced in-state. Because many operations have their own hatcheries, movement of live fish between facilities is likely minimal. Though few specific biosecurity requirements are in place at the regulatory level (pers. comm., T. Sink 2016), growers do have strict biosecurity protocols in place to protect their farms. For example, one large producer outlined their disease monitoring and biosecurity protocols as including:

- around-the-clock observation of ponds for detection of issues;
- immediate reporting of any unusual fish behavior, any distressed fish, or any dead fish;
- immediate testing of water and necropsy of fish if mortalities are observed;
- immediate response measures if problems are discovered;
- sanitary measures for equipment and personnel potentially in contact with other farms or potential disease instances within-farm (other ponds)
- use of approved treatment chemicals within prescribed limits when necessary.

The most recent reports on the red drum industry in Texas (the only state with commercial production in the United States) stated that major on-farm mortalities were due to algal blooms, not diseases or parasites (Treece 2012) (Treece 2016), although parasites can occasionally be an issue for individual ponds (pers. comm., J. Ekstrom 2016). Red drum is not heavily parasitized (Davis 1990), with farmed red drum having particularly few parasites (Porter et al. 2002), and the species appears to be resilient against bacterial issues that plague other species (pers. comm., D. Gatlin 2016). Further, the main commercial operation in the U.S. reports that they do not utilize chemicals in production (Ekstrom Enterprises 2016b), which suggests that disease is not a major issue. Industry representatives have further stated that they are unaware of major disease issues for farmed red drum (pers. comm., J. Ekstrom 2016), but attempts to gain independent verification, data, or detailed biosecurity details were unsuccessful for this assessment.

Conclusions and Final Score

Disease does not appear to be a significant issue for red drum farmers, and the production system has a relatively low rate of discharge (but does discharge on multiple occasions during a production cycle). Risk management protocols are in place at the farm level, and a lack of regulatory-level measures apparently stems from the lack of perceived risk posed by this industry. Red drum farming is viewed as a low to low-moderate disease risk.

The final numerical score for Criterion 7 – Disease is 6 out of 10.

Criterion 8X: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

Source of stock parameters	Score	
C8 Independence from unsustainable wild fisheries (0-10)	0	
Critical?	NO	GREEN

Brief Summary

A limited number of red drum is removed from the wild to promote genetic diversity in hatchery-bred red drum. This removal is not viewed as a threat to wild population sustainability, because Gulf of Mexico stocks are not considered overfished and stocks in Texas waters are supporting a near-record red drum population size and catch rates. Criterion 8X – Source of Stock scores 0 out of –10, meaning no deductions have been taken.

Justification of Rating

U.S. red drum farming relies on domestic hatchery-produced fingerlings, with facilities in several Gulf and Atlantic coast states. Many Texas farms have integrated hatcheries, and Texas also operates a robust stock-enhancement program that relies on hatchery-produced fingerlings. Hatcheries in Texas supply both the farm and stock-enhancement sectors, and Texas has developed standards intended to maximize the genetic diversity of hatchery-produced fish. These standards include the incorporation of at least some (25%) annually replaced, wild-sourced broodstock (100% use of wild-sourced broodstock is common (pers. comm., J. Ekstrom 2016) (pers. comm., R. Vega 2016)), which results in a small number of wild fish being removed for breeding to promote genetic diversity. The Texas Parks and Wildlife Department issues broodstock collection permits, which include an application, reporting requirements, and collection by individuals licensed by the state (TPWD 2015a) (pers. comm., R. Adami 2016).

Gulf of Mexico stocks are not considered overfished, though it is unknown if overfishing is occurring within this management unit (beyond state waters (NMFS 2016)) and stocks appear to be data-limited for federal and some state jurisdictions (Hightower 2013) (MDMS 2015). Within Texas waters, the state is supporting a near-record red drum population size and catch rates (Vega et al. 2013), with indications of stable to increasing stocks in other Gulf states (Chagaris et al 2015). The number of fish removed from the wild is small, wild populations are supplemented by a robust stock-enhancement program, and wild populations are considered stable and increasing in recent years (Vega et al. 2013), so no reduction is taken for Criterion 8X – Source of Stock.

The final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of –10.

Conclusions and Final Score

Because of a requirement for at least 25% of farmed stock to be from wild-sourced broodstock, the removal of some fish from the wild occurs; however, wild populations are demonstrably robust and small numbers are removed overall. Additionally, permitting and oversight of broodstock collection exists at the regulatory level. The final numerical 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: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with farm sites.

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

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	-3	
Critical?	NO	GREEN

Brief Summary

Wildlife mortalities occur through interaction with the U.S. farmed red drum industry beyond exceptional cases, but permitted take of predatory birds is limited to species of least conservation concern and with no demonstrable impacts to population size. There is evidence of best-management resources and of enforcement occurring, and only two red drum producers (accounting for over 50% of total production) have take permits for wildlife (though illegal take by one former producer has been documented in one instance). Wildlife mortalities related to red drum farming are considered low-moderate. The score for Criterion 9X – Wildlife Mortalities is –3 out of –10.

Justification of Rating

Separated from the marine environment, red drum aquaculture is most likely to interact with avian and terrestrial mammalian predators, which may be attracted by the concentration of easy prey and feeds. Ponds are not covered, so they are vulnerable to exploitation by predators. Brown pelicans, great blue herons, black-crowned night herons, great egrets, osprey, cormorants, anhingas, white pelicans, and a variety of gulls are a few of the birds that have been encountered on red drum and other southern U.S. fish farms (Barras 2007) (U.S. DOJ 2011) (pers. comm., J. Ekstrom 2016).

At the federal level, some species that might be encountered at a red drum farm site are protected by the Endangered Species Act, which prohibits the unpermitted take of protected species (USFWS 2003). The Migratory Bird Treaty Act (MBTA) offers additional protections to many species of birds, such as many of those possibly encountered on red drum farms. Although exceptions may be granted, the Migratory Bird Treaty Act prohibits the killing of migratory bird species (16 U.S.C. 703 et seq., available at http://www.cornell.edu/uscode/text/16/703).

Bird predation, competition for feeds, and even spreading of pathogens can have significant economic impact on aquaculture operations, and the Southern Regional Aquaculture Center offers extension services for implementing non-lethal deterrents, such as scaring devices and physical barriers (Littauer et al. 1997) (Barras 2007). Some non-lethal methods of deterrence are used, such as air cannons and exploding shells (pers. comm., G. Treece 2016), but some lethal methods may be used on occasion. For example, some farm operators report some nuisance occurrences of potential predator birds, but have permits from USFWS to take lethal action to remove specific predators in specific, exceptional cases (pers. comm., J. Ekstrom 2016) (USFWS 2016a). For example, according to the USFWS:

"A depredation permit is intended to provide short-term relief for bird damage until long-term nonlethal measures can be implemented to eliminate or significantly reduce the problem. A depredation permit authorizes "take" of birds protected under MBTA. Take includes killing birds, trapping birds, egg addling (oiling), and destruction of active nests. Capture or killing of birds cannot be the primary methods used to address depredation and will ONLY be authorized in conjunction with ongoing nonlethal measures (USFWS 2016a)."

On the other hand, Barras (2007) notes an expanded ability to use lethal control against double-crested cormorants as of 2003 in concert with the USDA Wildlife Services, although this species is of no conservation concern.

The USFWS restricts the numbers and species of birds taken, requires that records of all lethal control activities be documented and reported annually, and mandates that inspections be authorized as a condition of permit. Additional restrictions on take of Birds of Conservation Concern may apply (USFWS 2016a). Records were received from the USFWS via a FOIA request (pers. comm., USFWS 2016), and indicated that two Texas red drum producers have depredation permits. These two producers account for over half of total industry production. The USFWS permits take of a limited number of laughing gulls *(Leucophaeus atricilla)*, double-crested cormorants *(Phalacrocorax auritus)*, great blue heron *(Ardea herodias)*, black-crowned night heron *(Nycticorax nycticorax)*, American white pelican *(Pelecanus erythrorhynchos)*, great egrets *(Ardea alba)*, and brown pelicans *(Pelecanus occidentalis)*. Table 8 outlines self-reported data from 2012-2015:

Table 8. Permitted and self-reported take totals for the two red drum farms with USFWS depredation permits for 2012–2014.

Species	Permitted take 2012–2014*	Reported take 2012–2014*
Laughing gull	1,000	712
Double-crested cormorant	225+**	55
Black-crowned night heron	35	21
American white pelican	55	0
Great egret	75	15
Brown pelican	0#	0#

* Data is for both permit holders (companies) combined for the period 2012–2014.
** One permit holder is allowed 75 annually, the other up to 5 per day seasonally.
# Take of brown pelicans added to permits beginning 2015.

None of the species legally taken under depredation permits is of state, federal, or international conservation concern, according to Texas Parks and Wildlife (TPWD 2016), USFWS (USFWS 2016b, and the International Union for Conservation of Nature (IUCN) (IUCN 2016). The IUCN additionally lists species such as laughing gull, great blue heron, double-crested cormorant, and brown pelican as having increasing population trends, and great egret and black-crowned night heron as showing increasing population trends in North America.

There is evidence of enforcement of protection measures by the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department against illegal actions, including against one former red drum farm operator who was found guilty of killing over 100 birds in 2011 (U.S. DOJ 2011) (pers. comm., G. Treece 2016). There is also evidence of adaptive management, because USFWS is reportedly not currently issuing take permits (pers. comm., G. Treece 2016). The Texas Department of Parks and Wildlife additionally reports on enforcement actions on its website (TPWD 2016).

Conclusions and Final Score

Wildlife mortalities occur through interaction with the U.S. farmed red drum industry beyond exceptional cases, but permitted take of predatory birds is limited to species of least conservation concern, with no demonstrable impacts to population size, and on two of six total farms (accounting for half of total production). There is evidence of best-management resources and of enforcement occurring. Wildlife mortalities related to red drum farming are considered low to low-moderate. The final numerical score for Criterion 9X – Wildlife Mortalities is –3 out of –10.

Criterion 10X: Escape of unintentionally introduced species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	0	
F10Xb Biosecurity of source/destination	N/A	
C10X Escape of unintentionally introduced species Final Score	**-0.00**	**GREEN**

Brief Summary
Because there is no reliance on import of fingerlings from out of state, there is no international or trans-waterbody shipment of live animals associated with this industry. Thus, there is no risk of the introduction of non-native species. The final numerical score for Criterion 10X – Escape of unintentionally introduced species is –0 out of –10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments
The U.S. (Texas) red drum industry relies exclusively on in-state hatcheries, many of which are part of vertically integrated farms. No fingerlings from out of state are used in the farmed red drum industry (Treece 2012) (Vega, Neill, and Abrego 2010) (pers. comm., G. Treece, Texas SeaGrant 2016).

Because 0% of production is reliant on international/trans-waterbody animal movements, the score for Factor 10Xa is 10 out of 10. Factor 10Xb is not applicable.

Conclusions and Final Score
Because there is no reliance on import of fingerlings from out of state, there is no international or trans-waterbody shipment of live animals associated with this industry. Thus, there is no risk of the introduction of non-native species. The final numerical score for Criterion 10X – Escape of unintentionally introduced species is –0 out of –10.

Overall Recommendation

The overall recommendation is as follows:

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

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

Criterion	Score	Rank	Critical?
C1 Data	7.73	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	5.33	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	4.99	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	–3.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**46.73**		
Final score (0-10)	**6.68**		

OVERALL RANKING

Final Score	6.68
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

Acknowledgements

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

Seafood Watch would like to thank the following for their time and effort in the process of developing this assessment:

Mr. Robert Adami, Texas Parks and Wildlife Department
Ms. Monica Baez, Texas Commission on Environmental Quality
Mr. Jim Ekstrom, Ekstrom Enterprises
Dr. Delbert Gatlin, Texas A&M University
Ms. Melinda Luxemburg, Texas Commission on Environmental Quality
Dr. Todd Sink, Texas A&M University
Mr. Granvil Treece, Texas SeaGrant
Dr. Robert Vega, Texas Department of Parks and Wildlife
Dr. Paul Zimba, Texas A&M University

References

Alabama Department of Conservation and Natural Resources (ADCNR). 2015. Fishing regulations and enforcement. Accessed 03 March 2016. URL: http://www.outdooralabama.com/regulations-and-enforcement.

American Fisheries Society (AFS). 2014. Guide to using drugs, biologics, and other chemicals in aquaculture. URL: https://www.fws.gov/fisheries/aadap/PDF/GUIDE_June_2014b.pdf. Accessed 01 August. 2016.

Araki, H. and Schmid, C. 2010. Is hatchery stocking a help or harm? Evidence, limitations, and future directions in ecological and genetic surveys. Aquaculture, 308: S2-S11.

Barras, S.C. 2007. Avian predators at aquaculture facilities in the southern United States. Southern Regional Aquaculture Center (SRAC) publication: 400.

Boyd, C.E. and Massaut, L. 1999. Risks associated with the use of chemicals in pond aquaculture. Aquacultural Engineering, 20: 113-132.

CABI, 2006. Sciaenops ocellatus [original text by Granvil D. Treece and Robert Adami,]. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

CABI. 2007. *Sciaenops ocellatus* (red drum) [Original text by Treece, G. and Adami, R.]. In: Invasive species compendium. Wallingford, UK: CAB International. Accessed 02 March 2016. URL: http://www.cabi.org/isc/datasheet/64720.

Carson, E.W., Bumguardner, B.W., Fisher, M., Saillant, E. and Gold, J.R. 2014. Spatial and temporal variation in recovery of hatchery-released red drum (*Sciaenops ocellatus*) in stock-enhancement of Texas bays and estuaries. Fisheries Research, 151:191-198.

Cason, P.D. and Anderson, J.D. 2015. A Multivariate Assessment of Factors Influencing Survival of Red Drum in Earthen Outdoor Rearing Ponds, North American Journal of Aquaculture, 2015, 77, 2, 141.

Chagaris, D., Mahmoudi, B., and Murphy, M. 2015. The 2015 stock assessment of red drum, *Sciaenops ocellatus*, in Florida. Florida Fish and Wildlife Conservation Commission publication IHR2015-003. URL: http://myfwc.com/media/3368388/RedDrum-2015.pdf. Accessed 30 October 2016.

Chamberlain, G.W., R.J. Miget, and M.G. Haby, eds. 1990. Red Drum Aquaculture, Texas A &M University Sea Grant College Program, TAMU-SG-90-603,1990, 236 pp.

Davis, J.T. 1990. Red drum biology and life history fact sheet. Southern regional Aquaculture Center Publication No. 320, 2 pp.

Davis, D.A., Lazo, J.P. and Arnold, C.R. 1999. Response of juvenile red drum (*Sciaenops ocellatus*) to practical diets supplemented with medium chain triglycerides. *Fish Physiology and Biochemistry*, *21*(3): 235-248.

Davis, D.A. and Arnold, C.R. 2004. Red drum, *Sciaenops ocellatus*, production diets: replacement of fish meal with soybean Meal. *Journal of Applied Aquaculture*, *15*(3-4): 173-181.
Edwards, P. and Demaine, H. 1997. Rural aquaculture: overview and framework for country reviews. *RAP Publication (FAO)*.

Ekstrom Enterprises. 2016a. Company website. Accessed 03 March 2016. URL: http://www.eksent.com/.

Ekstrom Enterprises. 2016b. Copper Shoals brand website. Accessed 03 March 2016. URL: http://www.coppershoals.com/

Faulk, C.K. 2005. In: Cultured Aquatic Species Information Programme. *Sciaenops ocellatus*. FAO Fisheries and Aquaculture Department [online]. Rome. URL: http://www.fao.org/fishery/culturedspecies/Sciaenops_ocellatus/en

Fishsource. 2016. Sustainable Fisheries Partnership. FishSource Profile for Gulf menhaden - Gulf of Mexico. http://www.fishsource.com/site/goto_profile_by_uuid/9c1cbdd0-3225-11dd-87d8-daf105bfb8c2. Accessed April 20, 2016.

Florida Fish and Wildlife Conservation Commission (FFWCC). 2016. Saltwater fishing regulations: red drum. Accessed 03 March 2016. URL: http://myfwc.com/fishing/saltwater/recreational/red-drum/.

Food and Agriculture Organization of the United Nations (FAO). 2016a. Cultured Aquatic Species Information Programme. Accessed 01 March 2016. URL: http://www.fao.org/fishery/culturedspecies/Sciaenops_ocellatus/en. http://www.fao.org/fishery/culturedspecies/Sciaenops_ocellatus/en. Accessed 20 February 2016.

Food and Agriculture Organization of the United Nations (FAO). 2016b. Aquaculture feed and feed analysis: red drum (*Sciaenops ocellatus*). URL: www.fao.org/fishery/affris/feed-resources-database/aquaculture-feeds-and-feed-analysis/en. Accessed 29 April 2016.

Food and Agriculture Organization of the United Nations (FAO). 2016c. FIGIS FishStat Database. Accessed 20 Feb 2016. URL: http://data.fao.org/ref/babf3346-ff2d-4e6c-9a40-ef6a50fcd422.html?version=1.0.

Francis-Floyd, R. and Floyd, M.R., 2011. *Amyloodinium ocellatum,* an important parasite of cultured marine fish. Southern Regional Aquaculture Center.

Gatlin, D.M. 2002. Red Drum, *Sciaenops ocellatus*. In: Nutrient requirements and feeding of finfish for aquaculture. Chapter 11: 147-158. (Eds. Webster, C.D. and Lim, C.E.). CABI Publishing. Wallingford, UK.

Gulf Fishery Management Council (GFMC). 2016. Commercial fishing regulations for Gulf of Mexico federal waters. Accessed 03 March 2016. URL: http://gulfcouncil.org/fishing_regulations/CommercialRegulations.pdf.

Hauville, M.S. 2014. Larviculture and nutrition of three of Florida's high value food and stock enhancement finfish, common snook (*Centropomus undecimalis*), Florida pompano (*Trachinotus carolinus*) and red drum (*Sciaenops ocellatus*). Doctor of Philosophy thesis--University of Stirling.

Hightower, C.L. 2013. Evaluating the current status of red drum (*Sciaenops ocellatus*) in offshore waters of the north central Gulf of Mexico: age and growth, abundance, and mercury concentration. Master's thesis, University of South Alabama. URL: http://sedarweb.org/docs/wsupp/S49_RD_02_LouAllenHightowerThesis.pdf. Accessed 21 October 2016.

International Union for the Conservation of Nature (IUCN). 2016. The IUCN redlist of threatened species database. Accessed 21 July 2016. URL: http://www.iucnredlist.org/search

Johnson, S. K. 1990. Recognition and control of diseases common to grow-out aquaculture of red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University Sea Grant College Program, College Station, Texas, 113-130.

Kelly, A.M. 2013. Medicated feed for food fish. Southern Regional Aquaculture Center (SARC) publication. Publication number 413, revised March 2013.

Kureshy, N., Davis, D.A., Arnold, C.D. 2000. Partial replacement of fish meal with meat-and-bone meal, flash-dried poultry byproduct meal, enzyme digested poultry byproduct meal in practical diets for juvenile red drum. North American Journal of Aquaculture, 62: 266-272.

Lewis, D. H., Wenxing, W., Ayers, A., & Arnold, C. R. 1988. Preliminary studies on the use of chloroquine as a systemic chemotherapeutic agent for Amyloodinosis in red drum, Sciaenops ocellatus. *Contrib. Mar. Sci.(Suppl.)*, *30:* 183-189.

Li, P., Gatlin, D.M. and Neill, W.H. 2007. Dietary supplementation of a purified nucleotide mixture transiently enhanced growth and feed utilization of juvenile red drum, *Sciaenops ocellatus*. *Journal of the World Aquaculture Society*, *38*(2): 281-286.

Littauer, G.A., Glahn, J.F., Reinhold, D.S. and Brunson, M.W. 1997. Control of bird predation at aquaculture facilities: Strategies and cost estimates. *Southern Regional Aquaculture Center Publication*, *402*.

Louisiana Department of Wildlife and Fisheries (LDWF). 2016. Louisiana fishing regulations. Accessed 03 March 2016. URL: http://www.wlf.louisiana.gov/fishing/regulations.

Lumb, L., Gibeaut, J., Smith, L., Chavez-Ramirez, F. 2015. Comprehensive habitat type dataset for the Central Texas Coast. URL:

https://www.sciencebase.gov/catalog/item/54ef63dee4b02d776a684b77. Accessed 07 April 2016.

McGoogan, B.B. and Gatlin, D.M., III. 1997. Effects of replacing fish meal with soybean meal in diets for red drum *Sciaenops ocellatus* and potential for palatability enhancement. Journal of the Aquaculture Society, 28: 374-385.

Moon, H.Y. and Gatlin, D.M., III. 1994. Effects of dietary animal proteins on growth and body composition of the red drum (*Sciaenops ocellatus*). Aquaculture, 120: 327-340.

Miller, W.W. 1995. Red drum aquaculture curriculum guide. Iowa State University. 85 pp.

Minjarez-Osorio, C., Castillo-Alvarado, S., Gatlin, D.M., Gonzalex-Feliz, M.L., Perez-Velazquez, M., and Rossi, W. 2015. Plant protein sources in the diets of the sciaenids red drum (*Sciaenops ocellatus*) and shortfin corvina (*Cynoscion parvipinnis*): A comparative study. Aquaculture 453: 122-129.

Mississippi Department of Marine Resources (MDMR). 2015. Application for exempted fishing permit for the Exclusive Economic Zone in the Gulf of Mexico. Gulf of Mexico Fisheries Management Council website. URL: http://gulfcouncil.org/council_meetings/BriefingMaterials/BB-03-2015/S-1(b)%20Red%20Drum%20EFP%20Application%20Justification%20(MS).pdf. Accessed 21 October 2016.

Mississippi Department of Marine Resources (MDMR). 2016 Commercial fishing regulations. Accessed 03 March 2016. URL: http://www.dmr.ms.gov/index.php/commercial-fishing/regulations

National Marine Fisheries Service (NMFS). 2016. Summary of stock status for non-FSSI stocks; 3rd quarter update. URL: http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2016/third/q3-2016-stock-status-tables.pdf. Accessed 11 November 2016.s

National Oceanic and Atmospheric Administration (NOAA). 1972. Coastal Zone Management Act. URL: https://coast.noaa.gov/czm/media/CZMA_10_11_06.pdf. Accessed 13 March 2016.

Oestmann, D.J., Lewis, D.H. and Zettler, B.A. 1995. Communications: Clearance of *Amyloodinium ocellatum* Dinospores by Artemia salina. *Journal of Aquatic Animal Health*, *7*(3): 257-261.

Omega Protein, Inc. 2016. Products page. URL: omeganutrient.com/products. Accessed: 29 March 2016.

Peppard, E.M., Wolters, W.R., Avault, J.W. and Guthrie Perry, W. 1991. Toxicity of Chelated Copper to Juvenile Red Drum *Sciaenops ocellatus*. *Journal of the World Aquaculture Society*, *22*(2): 101-108.

Rooker, J.R., Holt, G.J., and Holt, S.A. 1998. Vulnerability of newly settled red drum (*Sciaenops ocellatus*) to predatory fish: is early-life survival enhanced by seagrass meadows? Marine Biology, 131: 145-151.

Rossi, W., Newcomb, M., and Gatlin, D.M. III. 2016. Assessing the nutritional value of an enzymatically processed soybean meal in early juvenile red drum, *Sciaenops ocellatus*. Aquaculture.

Rossi, W., Tomasso, J.R. and Gatlin, D.M. 2015. Production performance and non-specific immunity of cage-raised red drum, *Sciaenops ocellatus*, fed soybean-based diets. *Aquaculture*, *443*: .84-89.

Seafood Watch. 2016. Standard for Aquaculture. Vsersion A3.1. Monterey Bay Aquarium. URL: https://www.seafoodwatch.org/-/m/sfw/pdf/criteria/mba_seafood%20watch_aquaculture%20standard_version%20a3.1.pdf?la=en. Accessed 01 November 2016.

Southern Regional Aquaculture Center (SRAC). 1990. Red Drum Production Fact Sheets. 320-339; 3200-3399. Accessed 01 March 2016. URL: https://srac.tamu.edu/viewCategory/13.

Stickney, R., R. Iwamoto, and M. Rust (editors). 2011. Interactions of Fisheries and Fishing Communities Related to Aquaculture: Proceedings of the Thirty-eighth U.S.-Japan Aquaculture Panel Symposium, Corpus Christi, Texas, October 26–27, 2009. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-113, 97 pp.

Stunz, G.W. and Minello, T.J. 2001. Habitat-related predation on juvenile wild-caught and hatchery-reared red drum *Sciaenops ocellatus* (Linnaeus). Journal of Experimental Marine Biology and Ecology, 260: 13-25.

Sumaila, U.R., Khan, A., Watson, R., Munroa, G., Zeller, D., Baron, N. et al. (2007). Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, B.C., Canada. The World Trade Organization and global fisheries sustainability. Fisheries Research 88:14.

Tacon, A., Hasan, M., Metian, M. 2011. Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects. FAO Fisheries and Aquaculture Technical Paper No. 564. FAO. 87 pp.

Texas A& M University (Texas A&M). 2016. AgriLife Extension Aquaculture, Fisheries, and Pond Management. URL: http://fisheries.tamu.edu/aquaculture/red-drum-production.

Texas Commission on Environmental Quality (TCEQ). 2016a. General Permit to dispose of wastewater. URL: https://www.tceq.texas.gov/assets/public/permitting/wastewater/general/TXG130000.docx. Accessed 21 April 2016.

Texas Commission on Environmental Quality (TCEQ). 2016b. Enforcement Reports. URL: https://www.tceq.texas.gov/enforcement/reports/. Accessed 18 April 2016.

Texas Commission on Environmental Quality (TCEQ). 2016c. Permitting Central Registry. URL: http://www15.tceq.texas.gov/crpub/. Accessed 18 April 2016.

Texas Commission on Environmental Quality (TCEQ). 2016d. Registry of Compliance History. http://www2.tceq.texas.gov/oce/ch/index.cfm.

Texas Commission on Environmental Quality (TCEQ). 2016e. Agency directory. URL: https://www.tceq.texas.gov/about/directory. Accessed 01 November 2016,

Texas General Land Office (TGLO). 2015. Texas coastal management program: Section 309 assessment strategies. Report 2011-2015. URL: https://coast.noaa.gov/czm/enhancement/media/tx3092011.pdf. Accessed 14 March 2016.

Texas Parks and Wildlife Department (TPWD). 2015a. Broodstock collection permit. URL: https://tpwd.texas.gov/publications/pwdforms/media/pwd_1020_t3200_broodfish_collection_permit_app.pdf. Accessed 17 August 2016.

Texas Parks and Wildlife (TPWD). 2015b. Texas saltwater fishing regulations. Accessed 02 March 2016. URL: http://tpwd.texas.gov/regulations/outdoor-annual/fishing/saltwater-fishing/.

Texas Parks and Wildlife Department (TPWD). 2016. Law Enforcement Offices game warden field notes. URL: http://tpwd.texas.gov/newsmedia/releases/?req=gwfn. Accessed 15 April 2016.

Treece, G. 2005. Updated governmental permitting and regulatory requirements affecting Texas coastal aquaculture operations. Texas A&M University. Sea Grant College Program. URL: Texas A&M University. Sea Grant College Program. Accessed 15 March 2016.

Treece, G. 2012. The Texas Aquaculture Industry 2012. Parts 1 and 2. Texas A&M University. Sea Grant College Program. URL: http://fisheries.tamu.edu/files/2011/10/Texas-Aquaculture-2012-Part-1.pdf. Accessed 01 June 2016.

Treece, G. 2016. The Texas Aquaculture Industry 2016. Part 1. Texas A&M University. Sea Grant College Program. URL: http://www.texasaquaculture.org/PDF/2016%20PDF%20Documents/Tex.%20aqua.%202016%20part%201,%202-19-16.pdf. Accessed 01 June 2016.

Tremblay, T.A. and Calnan, T.R. 2010. Status and trends of inland wetland and aquatic habitats, Matagorda Bay area. Final Report prepared for the Texas General Land Office and the National Oceanic and Atmospheric Administration. 85 pp.

Turner, T.F., Wares, J.P. and Gold, J.R. 2002. Genetic effective size is three orders of magnitude smaller than adult census size in abundant, estuarine-dependent marine fish (*Sciaenops ocellatus*). Genetics, 162: 1329-1339.

United States Department of Agriculture (USDA). 2014. 2012 Census of Agriculture. Volume 3, Special Studies Part II.

United States Department of Agriculture (USDA) National Agricultural Statistics Service. 2016a. Quick Stats Database. Accessed 02 March 2016. URL: http://quickstats.nass.usda.gov.

United States Department of Agriculture (USDA) National Agricultural Statistics Service. 2016b. National nutrient database. URL: www.ndb.nal.usda.gov. Accessed 29 April 2016.

United States Department of Homeland Security (USDHS) Federal Emergency Management Agency (FEMA) Flood Map Service Center. URL: 2016. https://msc.fema.gov/portal/search. Accessed 04 June 2016.

United States Environmental Protection Agency (U.S. EPA). 2016. Enforcement and Compliance History Online (ECHO). URL: https://echo.epa.gov/. Accessed 14 April 2016.

United States Department of Justice (U.S. DOJ). 2011. Seaside Aquaculture and owner convicted for killing protected species. Public affairs release. August 12, 2011. URL: https://www.fws.gov/home/feature/2011/pdf/110812Seaside.pdf. Accessed 02 April 2016.

United State Fish and Wildlife Service (USFWS). 2003. Endangered Species Act of 1973. As amended by the 108th Congress. Accessed 15 March 2016. URL: https://www.fws.gov/endangered/esa-library/pdf/ESAall.pdf.

United State Fish and Wildlife Service (USFWS). 2016a. Migratory Birds and Habitat Program Depredation Permit. URL: http://www.fws.gov/forms/3-200-13.pdf. Accessed 21 April 2016.

United State Fish and Wildlife Service (USFWS). 2016b. Environmental Conservation Online System (ECOS) species profiles. Accessed 21 July 2016. URL: https://www.fws.gov/endangered/.

United States Fish and Wildlife Service (USFWS). 2016c. National Wetlands Inventory Wetlands Mapper. Accessed 13 March 2016. URL: https://www.fws.gov/wetlands/data/mapper.html.

United States Food and Drug Administration (U.S. FDA). 2011. Enforcement priorities for drug use in aquaculture. URL: http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/PoliciesProceduresManual/UCM046931.pdf. Accessed 01 August 2016.

United States Food and Drug Administration (U.S. FDA). 2016a. Approved aquaculture drugs webpage. URL: http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.htm. Accessed 03 August 2016.

United States Food and Drug Administration (U.S. FDA). 2016b. Imports Program. URL: Accessed 12 August 2016. http://www.accessdata.fda.gov/cms_ia/importalert_49.html

United States Geological Survey (USGS). 2016. EarthExplorer historical imagery database. URL: http://earthexplorer.usgs.gov/. Accessed 15 April 2016.

VanderKooy, S.J. and Smith, JW. (Eds). 2015. The menhaden fishery or the Gulf of Mexico, United States, Regional Management Plan. Gulf States Marnie Fisheries Commission: 240.

Vega, R.R., Neill, W.H. and Abrego, D. 2013. September. Review of Red Drum Stock Enhancement In Texas. In *143rd Annual Meeting of the American Fisheries Society*. Afs. September 5-14, 2013.

About Seafood Watch®

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

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

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

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

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[3] 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 practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

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

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.

Appendix 1 - Data points and all scoring calculations

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	10
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	7.5
Feed	7.5
Escapes	10
Disease	5
Source of stock	10
Predators and wildlife	7.5
Unintentional introduction	10
Other – (e.g. GHG emissions)	n/a
Total	**92.5**

C1 Data Final Score (0-10)	**8.41**	**GREEN**

Criterion 2: Effluents

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**9**	**GREEN**
Critical?	NO	

Criterion 3: Habitat

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	4

Factor 3.2 – Management of farm-level and cumulative habitat impacts

3.2a Content of habitat management measure	4
3.2b Enforcement of habitat management measures	5
3.2 Habitat management effectiveness	**8**

C3 Habitat Final Score (0-10)	**5.33**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**8**	
C4 Chemical Use Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	17.5
Fishmeal from by-products (%)	26
% FM	12.95
Fish oil inclusion level (%)	3.47
Fish oil from by-products (%)	0
% FO	3.47
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	2
FIFO fishmeal	1.151111111
FIFO fish oil	1.388
FIFO Score (0-10)	**6.53**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-2
Calculated sustainability adjustment	-0.5552
Critical?	NO

F5.1 Wild Fish Use Score (0-10)	**5.97**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	44
eFCR	2
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	82.5604134
Feed protein from NON-EDIBLE sources (%)	17.4395866
Protein OUTPUTS	
Protein content of whole harvested fish (%)	17.5
Edible yield of harvested fish (%)	40
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	88
Edible protein IN kg/100kg fish	72.65316379
Utilized protein OUT kg/100kg fish	21.0365624
Net protein gain or loss (%)	- 71.04522184
Critical?	NO
F5.2 Net protein Score (0-10)	**2**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood		
Inclusion level of aquatic feed ingredients (%)		20.97
eFCR		2
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)		10.90752985
5.3b Land area appropriated per ton of seafood		
Inclusion level of crop feed ingredients (%)		65.03
Inclusion level of land animal products (%)		10
Conversion ratio of crop ingredients to land animal products		*2.88*
eFCR		2

Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.710833333
Total area (Ocean + Land Area) (ha)	11.61836318
F5.3 Feed Footprint Score (0-10)	6

Feed Final Score

C5 Feed Final Score (0-10)	**4.9874**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	6	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape Risk Score (0-10)	**6**	
6.2. Invasiveness score (0-10)	**8**	
C6 Escapes Final Score (0-10)	**8**	**GREEN**
Critical?	**NO**	

Criterion 7: Diseases

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	6	
C7 Disease Final Score (0-10)	**6**	**YELLOW**
Critical?	NO	

Criterion 8X: Source of Stock

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

C9X Wildlife and Predator Score (0-10)	**-3**	
C9X Wildlife and Predator Final Score (0-10)	**-3**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

F10Xa live animal shipments score (0-10)	0	
F10Xb Biosecurity of source/destination score (0-10)	8	
C10X Escape of unintentionally introduced species Final Score (0-10)	**0**	**GREEN**
Critical?	n/a	