Monterey Bay Aquarium Seafood Watch

Environmental sustainability assessment of farmed Red drum *(Sciaenops ocellatus)* from the United States farmed using ponds

Species: Red drum *(Sciaenops ocellatus)*

Location: United States

Gear: Ponds

Type: Farmed

Author: Seafood Watch

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Assessed using Seafood Watch Aquaculture Standard v3.1

Final Seafood Recommendation

Criterion	Score (0–10)	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
C8 Source	0.00	GREEN	
C9X Wildlife mortalities	–3.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**46.73**		
Final score	**6.68**		

OVERALL RANKING

Final Score	6.68
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
FINAL RANK	**BEST CHOICE**

Scoring note – scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. 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

This assessment was originally published in December 2016 and reviewed for any significant changes in February 2023. No changes were made to the body of the report. See Appendix 2 for details of the review.

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 United States 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 nonnative 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 8.41 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—Effluent 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 nontarget 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 Factor 5.1 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 (Factor 5.2). Farmed red drum scores a 6 out of 10 in feed footprint (Factor 5.3) 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 affected 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 6 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 that 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 nonnative 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."

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Introduction

An update of this assessment was conducted in February 2023. The scope of the analysis and ensuing recommendation were updated with new information. The update can be found in Appendix 2 at the end of this document.

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 of Mexico 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 grow-out 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 grow-out 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—with 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 to 1,100 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 grow-out 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 to 2009, increasing to 10,000 lbs (4,536 kg)/acre/year in recent years. One grow-out 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 available on U.S. red drum production, 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	*Sciaenops ocellatus*
Common Name	Red drum, redfish, channel bass, spot tail bass

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 publicly 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 are extremely strong in others (permitting, management, compliance, and enforcement information). Information related to feed includes a large volume of research publications, 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 census, 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). In addition, 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 that 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 Effluent 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 conducting 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 Habitat 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 Chemical Use 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 are moderate-high for red drum farming, and the score is 7.5 out of 10.

Because Texas (and other Gulf Coast states) maintains 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 are considered high and score 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, particularly 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 Disease 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 are considered high and score 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 the 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 for Introduced Species 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 the 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 grow-out 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 the 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 record-keeping 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 multispecies production rather than grow-out 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 the 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 in 2015 (across Texas, for all wastewater permittees—not just red drum farms or aquaculture).

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 to 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, record-keeping, 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).

In addition, 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

An update of this assessment was conducted in February 2023. This criterion was updated with new information. The update can be found in Appendix 2 at the end of this document.

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 an 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).

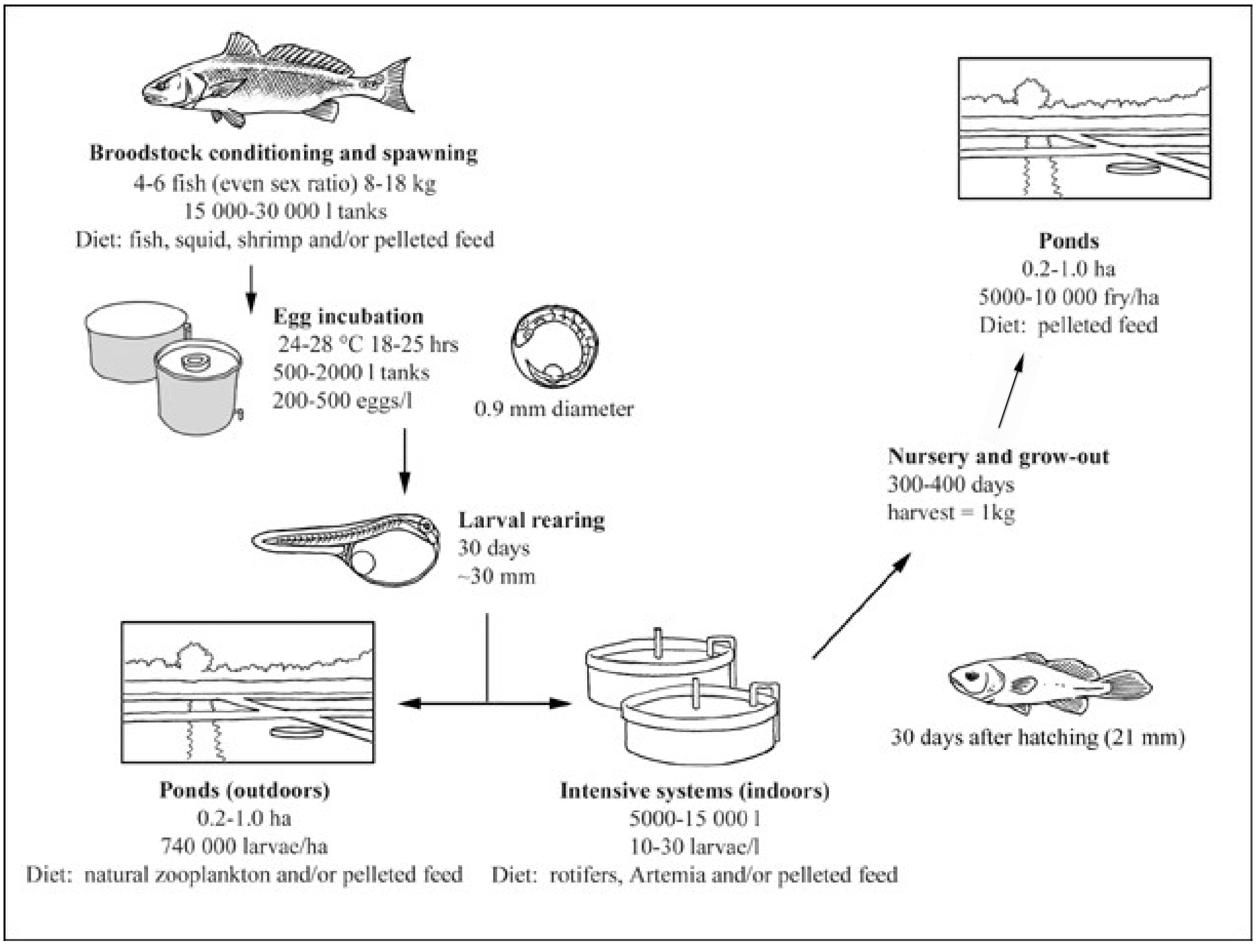

Figure 1. Typical red drum production cycle from spawning to pond grow-out. Image (slightly adapted) courtesy of FAO 2016a. *Larval rearing in Texas production typically lasts about 10 days, with total length of 30–35 mm achieved after 30 days (pers. comm., R. Vega 2016).

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 grow-out 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-plus 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 2. 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-plus acres (82.96 hectares)	Oldest red drum farm: mid-1980s	Pasture or agriculture/ freshwater wetland	Yes—215 acres	No
Farm "B" (Port Lavaca)	120-plus 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-plus acres (24.28 hectares)	2008–2012	Agriculture or undeveloped/ upland grassland salty prairie	Yes—0.13 acres	Yes
Farm "D" (Palacios)	200-plus acres (80.94 hectares)	2004	Undeveloped or agriculture/ estuarine and marsh	Yes—0.13 acres	No
Farm "E" (Palacios)	200-plus acres	Shrimp from 1990s–2006	Shrimp ponds since 1990s/ estuarine	Yes—0.74 acres	No
Total & summary	795-plus 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. 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 (Figure 3) (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

Factor 3.2a: Content of habitat management measures

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 the 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.

In addition, 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.

<u>Factor 3.2b: Enforcement of habitat management measures</u>

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 the 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, pre-dating 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, obviate the need for much chemical input. Further, red drum are raised in ponds with low discharge requirements, lowering the risk to nontarget 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). Also, 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 must 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

* Has 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 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

An update of this assessment was conducted in February 2023. This criterion was updated with new information. The update can be found in Appendix 2 at the end of this document.

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/100 kg fish harvested)	72.65	
F5.2b Protein OUT (kg/100 kg 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 the 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, 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 (e.g., krill hydrolysate) has successfully reduced fishmeal to 5% inclusion in experimental feeds (Davis and Arnold 2004); the most recent specific data suggest 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% (Table 4). 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 are summarized in Table 5.

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

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

[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).

[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).

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:

- 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 nonfillet 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). In addition, 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).

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 (by-products, 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 by-products 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**

The 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 to meet the 95% minimum ingredient total required by the formula used in Factor 5.3 (Table 7).

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 the 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, 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 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 the 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 the 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)). The 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 nonnative 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 the 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 red 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 6—Escapes.

Criterion 7: Disease; Pathogen and Parasite Interactions

An update of this assessment was conducted in February 2023. This criterion was updated with new information. The update can be found in Appendix 2 at the end of this document.

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) lists the following as diseases that have occurred in red drum under culture, with suggested treatments listed in parentheses:

- 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 the 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 for this assessment were unsuccessful.

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 that 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. In addition, 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 pelican, great blue heron, black-crowned night heron, great egret, osprey, cormorant, anhinga, white pelican, 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 nonlethal deterrents, such as scaring devices and physical barriers (Littauer et al. 1997) (Barras 2007). Some nonlethal 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 cormorant 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 gull (*Leucophaeus atricilla*), double-crested cormorant (*Phalacrocorax auritus*), great blue heron (*Ardea herodias*), black-crowned night heron (*Nycticorax nycticorax*), American white pelican (*Pelecanus erythrorhynchos*), great egret (*Ardea alba*), and brown pelican (*Pelecanus occidentalis*). Table 8 outlines self-reported data from 2012 to 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-plus**	55
Black-crowned night heron	35	21
American white pelican	55	0
Great egret	75	15
Brown pelican	0***	0***

* Data are 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 are 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 the 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 nonnative 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 0 out of 10. Factor 10Xb is not applicable.

Conclusions and Final Score

Because there is no reliance on the 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 nonnative 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 (0-10)	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
C8 Source	0.00	GREEN	
C9X Wildlife mortalities	–3.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**46.73**		
Final score	**6.68**		

OVERALL RANKING

Final Score	6.68
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
FINAL RANK	**BEST CHOICE**

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About Seafood Watch®

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

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

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

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

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/100 kg fish	88
Edible protein IN kg/100 kg fish	72.65316379
Utilized protein OUT kg/100 kg 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	

Appendix 2: Update (2023)

An update of this assessment was conducted in February 2023 in the most up-to-date Seafood Watch Aquaculture Standard Version 4.0. Updates focus on an assessment's limiting (i.e., Critical, Red, or lowest scoring) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review updates Criterion—3 Habitat, Criterion—5 Feed, and Criterion—7 Disease, while also updating the Scope section. Results of the update indicate that the Final Score and Rating may be at risk of a downgrade; from Green to Yellow. Therefore, a general review of the other criteria—Effluent, Escapes, Wildlife Mortalities, and Source of Stock—was completed, and no information was found to suggest a change (e.g., reduction) in score. Altogether, no information was found or received that would suggest the final rating is no longer accurate. No substantial changes were made to the text of the report (except an update note in the Executive Summary and all updated criteria). The following text summarizes the findings of the review.

Update Scoring Summary

Results of the update support the findings of the previous assessment, and the Overall Recommendation for red drum (*S. ocellatus*) grown in ponds in the United States remains Best Choice with a Green rating. The recommendation and rating are a result of reviewing and evaluating the limiting criteria: Criterion 3—Habitat, Criterion 5—Feed, and Criterion 7—Disease. The findings indicate there is no risk of a score change for Criterion 7—Disease. But, the score for Criterion 5—Feed has changed from the original assessment score of 4.99 to 3.83, and the Criterion 3—Habitat score has changed from 5.33 to 8.00. These scoring changes put the assessment at risk of a downgrade in rating from Green to Yellow because the original Final Score of the assessment was 6.68, making this assessment especially sensitive to scoring changes; the baseline for Green ratings must be ≥6.66. Therefore, a general review of the other more limiting criteria—Effluent, Escapes, Wildlife Mortalities, and Source of Stock—was completed. The results found no information to suggest a change (e.g., reduction) in score. As a result, the overall rating for red drum grown in ponds remains a Green Best Choice.

Update Criteria Summary

Farmed red drum in the United States is currently produced only in the state of Texas, and the majority of the farms are located in Matagorda Bay. Red drum aquaculture largely represents a "secondary conversion" of land from former shrimp farms or agricultural land, and the small expansion happening on undeveloped areas appears to be taking place in coastal shrubland, otherwise classified as upland with minimal impacts. Because the industry lacks a national growth and management plan, the siting of red drum farms is considered for approval on an individual basis. But, current habitat management is considered robust because local, state, and federal regulations consider potential habitat impacts of farm construction and operate in conjunction with other industries and resource users. In addition, the enforcement of policies is comprehensive and accessible in the public domain. Ultimately, there is a moderate impact at worst for habitat conversion (Factor 3.1) and there are robust regulations regarding siting of aquaculture facilities and enforcement (Factor 3.2). As a result, there does not appear to be any information readily available to suggest that the previous rating for the Habitat criterion is no longer accurate.

Overall, red drum feed in the U.S. uses fishmeal and fish oil made from whole wild fish and by-product sources with an eFCR of 2.0. The fishmeal inclusion level is moderate-high (22.08%); a small fraction (2.04%) is sourced from fishery and/or aquaculture by-products, and the rest from whole-fish reduction processes. The fish oil inclusion level is moderate-high at 5.89%, and 0.74% comes from by-product sources. The resulting score for Factor 5.1a—Feed Fish Efficiency Ratio (FFER) is moderate-high (2.075), meaning that, from first principles, 2.075 mt of wild fish are needed to produce the fishmeal required for 1 mt of farmed red drum. Most of the fishmeal used by U.S. feed suppliers is sourced from a well-managed fishery and results in a score for Factor 5.1b—Source fishery sustainability of 7 out of 10. The moderate-high inclusion levels of these wild fish ingredients in U.S. red drum feeds, combined with the sustainability of raw material, result in a Factor 5.1—Wild Fish Use score of 3.65 out of 10. Factor 5.2—Net Protein Gain or Loss scores 1 out of 10 and is driven by a high net protein loss of –80.56%. Factor 5.3—Feed Footprint scores 7 out of 10 due to a moderate feed footprint of 13.288 kg CO_2-eq. per kg of harvested protein. Altogether, Factor 5.1, 3.65 out of 10; Factor 5.2, 1 out of 10; and Factor 5.3, 7 out of 10, combine for a Criterion 5—Feed final score of 3.83 out of 10, which results in a Yellow rating for Criterion 5—Feed.

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors from escaped individuals, water/sediment discharge, and animals (birds and wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, there are reports of parasites, such as *Amyloodinuym ocellatum*, being a problem on farms. Still, no data about the prevalence or intensity of the infestations on farms are available. Anecdotal evidence suggests that such prevalence is low, as does the absence of antibiotic treatments. Farms employ robust health and biosecurity protocols (e.g., in-state fingerling sourcing, around-the-clock pond surveillance, immediate water testing in case of any mortalities, and sanitary measures for equipment and personnel) and typically have low rates of water discharge. There is some indication that on-farm biosecurity measures also prevent pathogen transmission to wild species, because wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, health and biosecurity measures are robust, and no indicators signal any additional disease impacts or risk since the last assessment. As a result, there does not appear to be any information readily available to suggest that the previous rating for the Disease Criterion is no longer accurate.

Results of the Update

Scope of the Analysis and Ensuing Recommendation
Species: Red drum (*Sciaenops ocellatus*)
Geographic coverage: United States of America
Production Method: Ponds, intensive

Species Overview
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 of Mexico coast to Veracruz in central Mexico. The species is euryhaline (tolerant of a wide range of salinities, 0 to 1.5 times greater than normal seawater) and is common in 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 typically has one or more large black "eye spots" on its tail and have been recorded to reach up to 94 pounds in the wild (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, 2017). But, optimal growth of fingerlings to adults has been recorded at 21 to 28.5 °C and at a pH of ≈8.0 (Miller, 1995). Although red drum has been reared to maturity and used as broodstock in several public and private hatcheries, most broodstock used commercially are captured in the wild (Sink et al., 2018).

After population declines of this species, commercial harvest of wild red drum was effectively prohibited in 1990 and remains so in federal waters (Gulf of Mexico Fishery Management Council, 2021). Hatchery production of this species began in the 1970s to supplement declining wild stocks and has since grown into a global aquaculture industry.

Production System
About half of all red drum farms in the U.S. are vertically integrated, with hatcheries, nurseries, and grow-out ponds (Figure 4). Typical grow-out earthen pond production systems feature attributes such as levee-controlled sluice gates, aeration about 5 acres in size, and a stocking density of about 8,000–10,000 lb/acre (pers. comm. T. Sink, Texas Aquaculture Extension Specialist, April 2022). About 15% of the total farm space is allocated to nursery ponds—typically 1–2 acres in size. Most producers reuse water by pumping it from pond to pond because maintaining salinity is critical in many of the inshore areas. Water releases during a production cycle are minimal but do occur in emergency situations, such as toxic algal blooms, which have plagued the industry in the past[4] (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). The fish are fed at all stages of production—with 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 (lethal temperatures for juveniles start at 8–10 °C), growers provide thermal refuge in a smaller section of a pond that is pumped with warmer water from groundwater sources. At harvest, which is usually achieved around 11

[4] https://tpwd.texas.gov/landwater/water/environconcerns/hab/

months (or when fish reach ≈1 kg), pond water levels are lowered, and the fish are seined from ponds (FAO, accessed in August 2022) (pers. comm. G. Treece, Treece & Associates, 2016). Most cultivation occurs in ponds near the Gulf of Mexico shoreline (see Figure 2 in Criterion 3); a few other farms are farther inland, and one farm produces in the Permian Basin (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). This farm takes advantage of the high salinity groundwater in the Permian Basin, using RAS for part of the year (mainly winter) when they move their production out of ponds into warehouses to protect fish from the cold, and flow-through pond systems for the rest of the year.

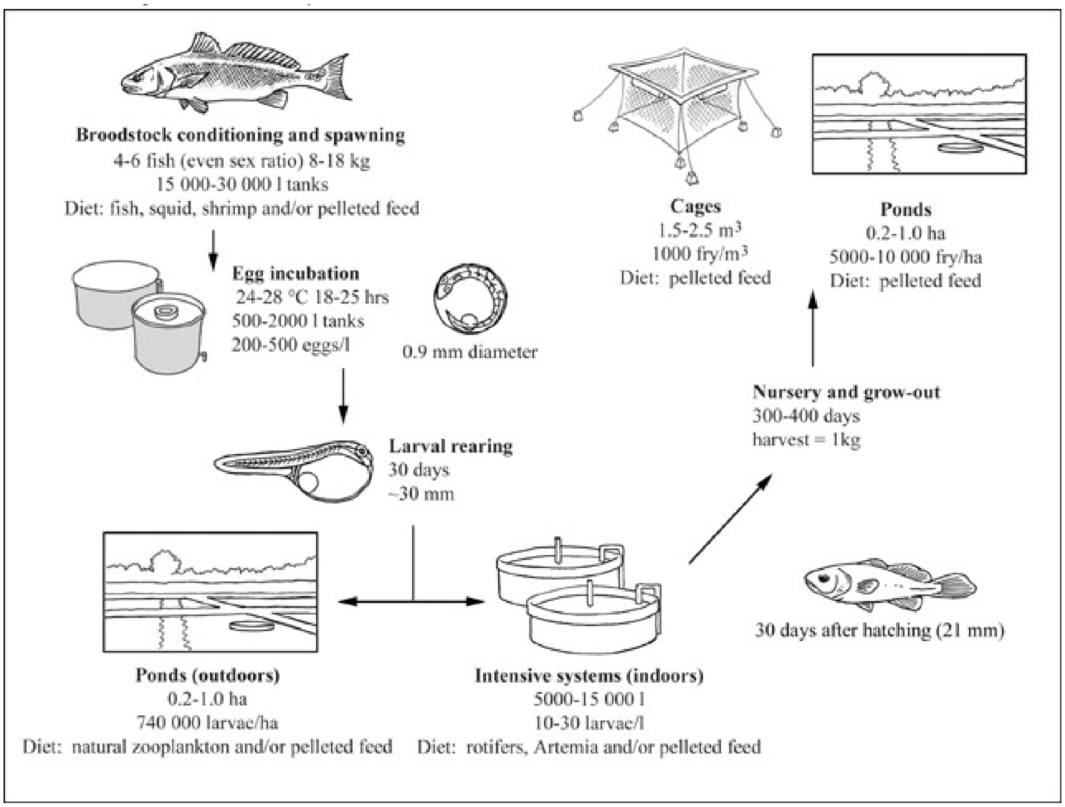

Figure 4. Production cycle of red drum (*Sciaenops ocellatus*). (FAO[5] accessed August 2022).

Production Statistics

The U.S. cultured red drum industry is located entirely in the state of Texas. In 2022 there were nine private farms (four of which have their own hatchery) and two state hatcheries (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). The most recent estimate on area coverage for the production of red drum is 525 hectares and should account for more than 95% of the total area used by the industry (TCMP, 2020) (Kureshy, 2022). Three additional farms have recently joined the industry, and no estimated area coverage is available, but it is likely minimal (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). It is worth noting that not all acreage is active in a given year, and as mentioned before, about 15% of the area is used to produce fingerlings. Treece (2017) estimates that about 70% of the acreage is active for grow-out annually. Currently, one distinctively larger producer (Bowers & Saha Aquaculture,

[5] https://www.fao.org/fishery/en/culturedspecies/Sciaenops_ocellatus/en

LLC) accounts for ≈31% of the total hectares producing red drum in the U.S., after acquiring Ekstrom Enterprises' red drum farm in 2022 (J. Ekstrom, Ekstrom Enterprises, 2022) (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022).

The U.S. produces only a small fraction of the total global volume (2.7% on average from 2003 to 2020) from farms in Texas (Figure 5) (FAO, 2022) (USDA, 2016a). Global red drum production has steadily increased from 40,053 metric tons (mt) to 84,342 mt. China has been the largest producer, accounting for approximately 95% of global volume since 2003 (FAO, 2022). In the U.S., production was steady from 2004 to 2017, at around 1,000 to 1,800 mt annually, with an average market value of approximately USD 8.2 million (FAO, 2022). Production increased in 2018 to 3,245 mt and an average farm-gate value of USD 20.5 million (FAO, 2022).

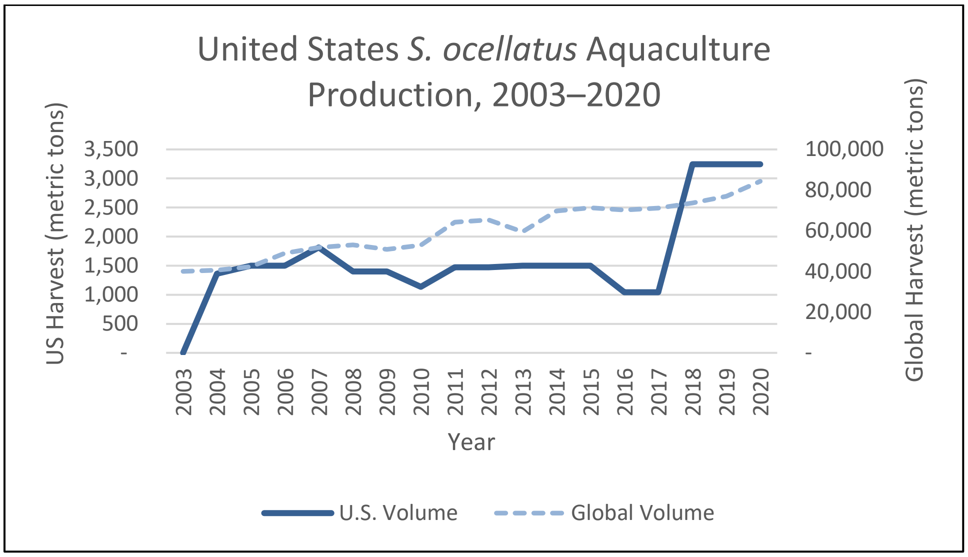

Figure 5. U.S red drum annual production (mt) from Food and Agriculture Organization, Global Aquaculture Production Quantity (August 2022).

In 2020, U.S. red drum production ranked 13th and 14th in terms of volume and value, respectively, compared to all other aquaculture species grown in the United States (FAO, 2022). It was not until 2020 that red drum bettered the Japanese carpet shell (JCS) in value (USD 19.5 million versus 17.5 million, respectively), mainly due to a lower production volume of JCS (FAO, 2022). The species is categorized as a "High"-priced fish by Sumaila et al. (2007), with U.S.-farmed fish fetching about $7.00–8.00/kg live weight at harvest (pers. comm. J. Ekstrom, Ekstrom Enterprises, September 2022) (Sink, 2019), up from $4.19–4.63/kg in 2005 (FAO, 2016[6]). 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 the robust recreational catch on the Gulf Coast, and from cheaper imports of red drum farmed in China and Mauritius (Ag MRC, 2022[7]) (Kureshy, 2022). Costs associated

[6] https://www.fao.org/fishery/en/culturedspecies/Sciaenops_ocellatus/en
[7] https://www.agmrc.org/commodities-products/aquaculture/aquaculture-fin-fish-species/red-drum-or-redfish

with feed, problems with toxic algal and harmful phytoplankton blooms, the regulatory environment, the BP oil spill in 2010, and most recently, the winter storm Uri that killed over 90% of red drum inventory, are some challenges that the industry has faced (Treece, 2017) (Kureshy, 2022). It is worth mentioning that during winter storm Uri (February 13–17, 2021), the farms that did not have their own hatchery had to temporarily shift species to catfish or hybrid striped bass, because red drum fingerlings became unavailable. It took a few months for the privately owned hatcheries to have a surplus of fingerlings, but all producers resumed red drum production once this happened (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022).

Import and Export Sources and Statistics

The United States is the principal market for red drum produced domestically, with some minor exports to Canada (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022) (pers. comm., J. Ekstrom, Ekstrom Enterprises, September 2022) (Treece, 2017).

But, red drum import statistics are difficult to parse. For example, imported red drum products from China and Taiwan have sometimes faced import restrictions from the U.S. Food and Drug Administration, but no specific volumes are available for this trade data (U.S. FDA 2016b). Stakeholders also indicate that red drum produced in Mauritius is the main competitor to U.S. domestic red drum production (Kureshy, 2022). There is no indication that the U.S. imports red drum from anywhere other than these three countries, mainly because the only red drum commercial fishery happens in the U.S. and the rest of the countries producing red drum through aquaculture appear to be targeting only their own domestic markets (FAO, 2016) (FAO, 2022) (Industria Acuicola, 2015[8]). Although the U.S. foreign trade data (from NOAA Fisheries[9]) do not report any imports specifically for red drum, it can be inferred that red drum is included in the "Bass" and "Sea Bass" product categories (see Table 9 for red drum's common market names). Therefore, it is safe to assume that imports from China, Taiwan, and Mauritius reported as Bass and Sea Bass include red drum. Figure 6 shows that Taiwan was the major importer until 2021, when Mauritius took the lead. Although these data are not precise because they might include other species (e.g., *Dicentrarchus* spp.), they are a clear indication that the majority of red drum consumed in the U.S. is produced domestically (see Figures 5 and 6). Still, as shown in Figure 5, the high volumes of red drum produced in Asia pose significant competition to domestic production, requiring U.S. producers to market their fish as a premium product with superior food safety while emphasizing the locally grown and fresh-not-frozen benefits (Ag MRC, 2022).

[8] https://issuu.com/industriaacuicola/docs/edicion10_5_web/6
[9] https://www.fisheries.noaa.gov/foss/f?p=215:2:3675807281657::NO:::

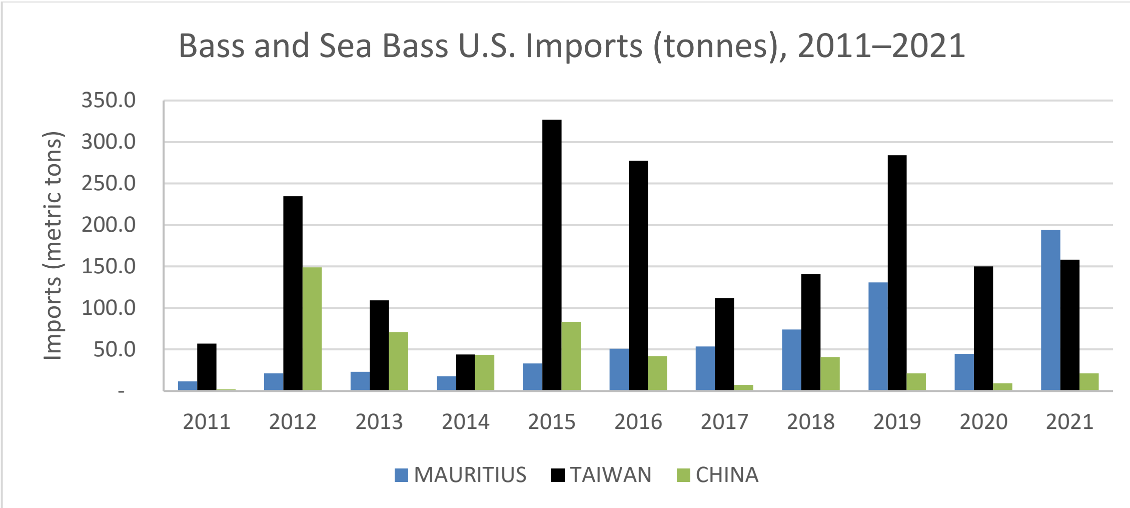

Figure 6. United States red drum imports by country in metric tons (2011 to 2021). Source: (NMFS, 2022).

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 (Table 9). The two largest direct markets of U.S. products until 2022 were Copper Shoals and New Orleans Fish House; both of these distributors sell their fish fresh and directly to restaurants (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). In January 2022, Copper Shoals was acquired by Bowers & Saha Aquaculture, LLC, and changes to the distribution channels may occur or are occurring. Also, some retailers have had success selling red drum heads and racks as food items (pers. comm., Carol Huntsberger, Quality Seafood Market, 2016) (pers. comm., J. Ekstrom, Ekstrom Enterprises, 2016), and waste products have been used in crab bait and fertilizer (pers. comm., J. Ekstrom, Ekstrom Enterprises, 2016) (pers. comm., D. Gatlin 2016).

Table 9. Red drum common and market names

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

Criterion 1: Data Quality and Availability

The availability and quality of data for red drum farmed in the United States in intensive ponds is moderate. Criterion 3—Habitat data were captured from the previous assessment and were complemented with personal communication with stakeholders, who were able to confirm current production area coverage and the rate at which the industry is expanding. Data for Criterion 5—Feed were readily available in the literature, but they were either outdated or applicable to marine finfish species in general. But, the three main red drum feed manufacturers (supplying over 90% of the industry) provided reliable, current, and detailed information for this assessment, including inclusion levels for fishmeal, fish oil, vegetable ingredients, and land animal products. Data for Criterion 7—Disease were obtained from peer-reviewed literature, which described common pathogens, parasites, and treatments, but more details such as prevalence, frequency, mortalities, and the risk of transmission to wild organism at the regional level were missing. Altogether, the availability of information for the updated Criteria (Habitat, Disease, and Feed) is moderate-high, suggesting that the previous rating for Data is still accurate.

Criterion 3: Habitat

Brief Summary

Farmed red drum in the United States is currently only produced in the state of Texas, and the majority of the farms are located in Matagorda Bay. Red drum aquaculture largely represents a "secondary conversion" of land from former shrimp farms or agricultural land, and the small expansion happening on undeveloped areas appears to be taking place in coastal shrubland, otherwise classified as upland with minimal impacts. Therefore, red drum farming is considered to be maintaining habitat functionality with minor to moderate impacts, resulting in a score of 8 out of 10 for Factor 3.1. Because the industry lacks a national growth and management plan, the siting of red drum farms is considered for approval on an individual basis. But, current habitat management is considered robust because local, state, and federal regulations consider the potential habitat impacts of farm construction and operate in conjunction with other industries and resource users. In addition, the enforcement of policies is comprehensive and accessible in the public domain. Ultimately, there is a moderate impact at worst for habitat conversion (Factor 3.1) and there are robust regulations regarding the siting of aquaculture facilities and enforcement (Factor 3.2). This results in a final score of 8 out of 10 for Criterion 3—Habitat.

Justification of Ranking

Factor 3.1: Habitat Conversion and Function

In February 2020, Seafood Watch updated the Seafood Watch Aquaculture Standard, and because of the changes in evaluating, addressing, and scoring the ecological impacts from aquaculture, the C3—Habitat, Factor 3.1 Habitat Conversion and Function is reevaluated. Substantial new information was not readily available, but the context of habitat conversion and function according to the latest standard is addressed, and results in a change in the interpretation of ecological impacts from habitat conversion and function from moderate to minimal impacts.

All grow-out facilities for red drum in the United States are intensive pond systems in Texas. Current stocking densities are around 20,000–25,000 lbs/hectare (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022). For further details about the multiple stages involved in the red drum production cycle, refer to the Production System section above, which includes an illustrated diagram (Figure 4).

In 2022, there were nine private farms (four of which have their own hatchery), and the Texas Parks and Wildlife Department operates three state farms and two state hatcheries (targeting stock enhancement) (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). The most recent estimate of area coverage for the production of red drum is 525 hectares and accounts for more than 95% of the total area used by the industry (TCMP, 2020) (Kureshy, 2022). Three of the nine private farms have recently joined the industry, and no estimated area coverage is available, but it should be minimal (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022). Therefore, it appears that the industry is slowly expanding.

The majority of farms are located in the Texas counties of Matagorda, Calhoun, Jackson, and Wharton, which are clustered around Matagorda Bay (Figures 7, 8, and 9). There are some exceptions, such as the farm located inland in the Permian Basin (Figure 7b) and a couple along the coast of Texas south of Matagorda Bay (Rosenberg, 2021[10]) (Sink, 2019). Figure 7a shows an aerial view of the state of Texas as a way to refer to the farms' locations within the state. Figure 7b provides a closer view of the farm operating in the Permian Basin: Crystal Waters Seafood, Incorporated, which uses the underground brackish water available in that area. Figure 7c shows Matagorda Bay, where most of the red drum production is located (six out of nine farms). The blue circle indicates the location of the only red drum farm at Chocolate Bay, which is connected to Matagorda Bay's larger body of water (R&G Fish; see Figure 8). The yellow circle shows the location of Holub Fish, LLC, and the red circle shows the location of the cluster where five red drum farms operate along Matagorda Bay.

[10] https://thegroundtruthproject.org/texas-redfish-farmers-barely-survived-the-pandemic-then-came-the-february-deep-freeze/

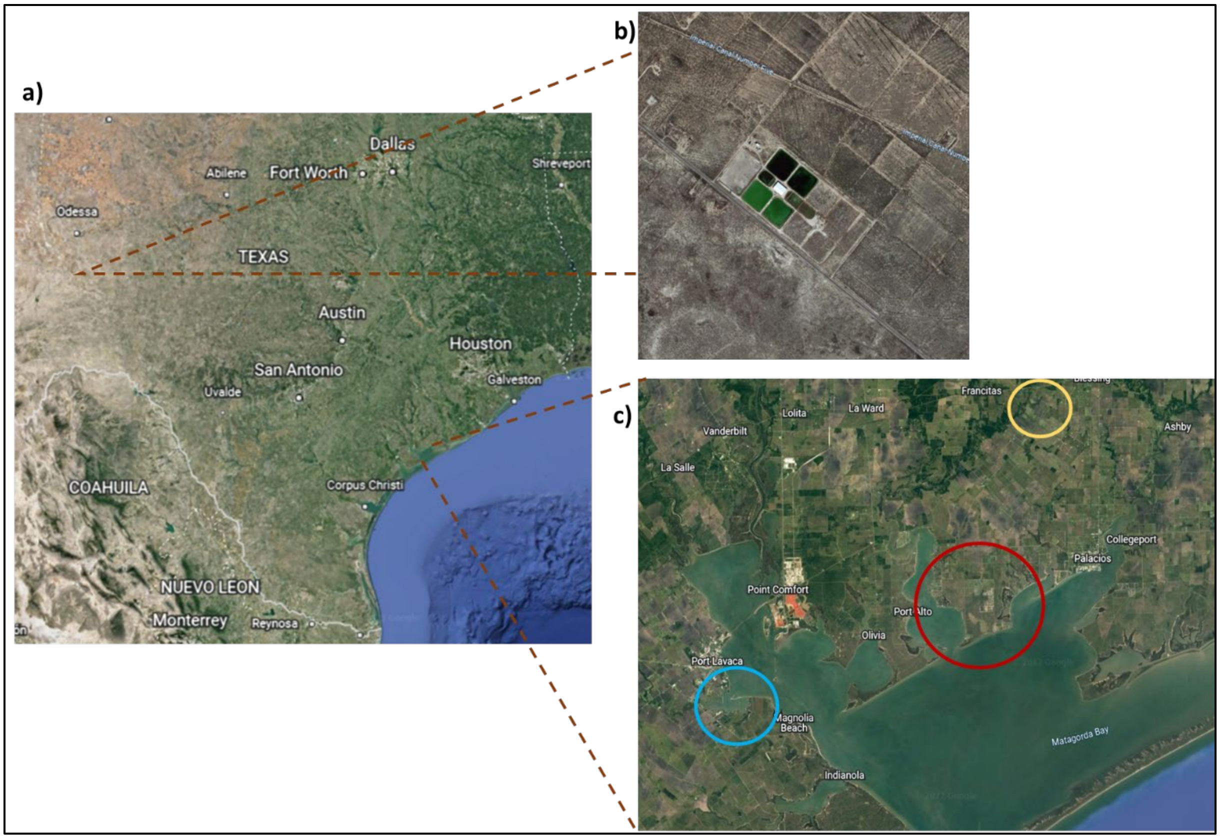

Figure 7. a) Landscape map of central and southeastern Texas. b) An aerial view of red drum ponds from Crystal Waters Seafood Inc. c) An aerial view of the area adjacent to Matagorda Bay, where most red drum farms are located in Texas. The blue and yellow circles indicate the location of R&G Fish farm and Holub Fish farm, respectively. The red circle shows the location of the densest concentration of red drum farms in the U.S. Images copied from Google Earth.

R&G Fish farm is located along the coast of Chocolate Bay (blue circle in Figure 7c) and an aerial view is shown in Figure 8a. Holub Fish farms is located inland (yellow circle in Figure 7c), in Matagorda County, and an aerial view is shown in Figure 8b. Figure 9 shows an aerial view of the area with the densest concentration of red drum farms in the U.S. (red circle in Figure 7c), which includes: (a) Bowers & Saha Aquaculture, LLC; (b) Redfish Unlimited; (c) St. Martin Aquaculture Inc.; (d) Gulf States Aquaculture LLC; and Turtle Creek Aquaculture LLC.

Figure 8. a) Aerial view of R&G Fish farm, located along the coast of Chocolate Bay (blue circle in Figure 7c). b) Aerial view of Holub Fish farm, located inland in Matagorda County (yellow circle in Figure 7c).

Figure 9. Aerial view of the area with the densest concentration of red drum farms in the U.S., along the coast of Matagorda Bay, including: a) Bowers & Saha Aquaculture, LLC; b) Redfish Unlimited; c) St. Martin Aquaculture Inc.; d) Gulf States Aquaculture LLC; and e) Turtle Creek Aquaculture LLC.

Before red drum farming, the land was used for agricultural purposes or shrimp farming. The current proportional land conversion source is as follows (pers. comm., G. Treece, Treece & Associates, 2016) (USGS, 2016) (Lumb et al., 2015) (Treece, 2017) (USFWS, 2016c):

- Thirty percent of current red drum farmland use was converted from old shrimp farms developed in the 1980s.
- Seventy percent of current red drum farmland use was converted directly from agricultural land or from cattle grazing land.

More recent development or expansion onto undeveloped land appears to be happening in coastal shrubland (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022). But, for the purposes of this assessment, the habitat type best applicable for the typical red drum farm is from previously modified habitat: agricultural land. In the Seafood Watch aquaculture standard, this is considered “low” habitat value.

The ecosystem services provided by agricultural land are primarily provisioning services, such as food, fiber, and fuel production, but it can also provide hydrological services and the maintenance of soil structure (Morri and Santolini, 2021) (Spangler et al., 2020). For instance, agriculture land or upland in the Matagorda Bay can be covered by vegetation such as coastal prairie grasses, forbs, and oak trees. This bay and Jackson County also support part of the U.S. Rice Belt, the area with the highest concentration of rice farming in Texas. This coastal habitat can absorb floodwaters, thus reducing property damage (e.g., 1 acre may store up to 1.5 million gallons of flood water), and also function as stormwater runoff filtration systems. The conversion from agricultural land to red drum farms requires the construction of ponds (around 4 feet deep) and levees (typically placed in flat areas 20 inches above the historic high flood level) (Avery, 2010) (Davis, 1990). Furthermore, the water supply and drainage to and from farms require the placement of drain pipes, pumps with supply lines, and in many cases the construction of open canals from the shoreline to an inland site (Avery, 2010) (Davis, 1990). Although these are considerable modifications to the landscape, the land use of red drum pond farms still aligns well with the provisioning service of food production. In addition, the area covered by the red drum industry (525 hectares) accounts for a quite small percentage of the overall land area in the places where the farms are sited. Therefore, red drum farms maintain the functionality of previously modified habitat.

Overall, the red drum industry is located in habitats that have already been converted for other purposes (e.g., plant and/or animal agriculture or aquaculture for other species). According to the Seafood Watch aquaculture standard, modified habitats (agricultural land and shrimp farms) are of low habitat value. Therefore, conversion to red drum farms does not result in a loss of habitat functionality.

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. In 2021, there was a significant change in Texas' aquaculture legislation because the State of Texas and the Texas Department of Agriculture[11] (TDA) stopped requiring aquaculture facilities licensing, as was previously stipulated in the Texas Agriculture Code (TAC). Therefore, the Texas Commission on Environmental Quality (TCEQ) and the Parks and Wildlife Department (TPWD) entered into a new Memorandum of Understanding (MOU) to coordinate the regulation of matters related to aquaculture (Sec. 134.031[12]), resulting in rule §7.103, which was included in the Texas Administrative Code (Title 30, Part 1, Chapter 7). This rule explains the agreements between these two agencies (TCEQ and TPWD), their responsibilities related to the regulation of aquaculture, procedures on applications and permits, and other coordination activities (Texas Administrative Code[13]). Within several sections of the Texas Water Code (TWC) and the Texas Parks and Wildlife Code (§5.102, §5.103, §5.104, §5.105; §12.001 and §12.001), it appears that the TCEQ and the TPWD matter, with the facultative power to cover the duties and responsibilities that fell under the TDA before this legislative change.

Among other functions performed by the TCEQ, this agency requires aquaculture producers to obtain the Aquaculture General Permit (AGP) (TXG130000) by submitting a Notice of Intent and filing a Core Data Form.[14] Though the AGP mainly delineates water and waste discharge requirements, it also indicates that the TCEQ's executive director should "consider any sensitive aquatic habitats in the coastal zone identified in the general guidelines developed by the TPWD.[15]" These guidelines detail the information needed to evaluate proposed projects or actions (e.g., farm expansions) at an area-based level, while considering other industries and land uses at the site. For example, by considering factors such as soil and biogeographic characteristics (e.g., tidal influences, flood activity, and vegetation community coverage), the natural and climate processes affecting the area, and by requiring farmers to identify ecosystem characteristics in general, these guidelines appear to be geared toward maintaining the functionality of the affected habitat. In addition, the TPWD is also required to review the initial draft permit (AGP) and, if needed, provide information and recommendations regarding the construction of aquaculture facilities. If the facility must dig or construct levees along a water body, the farmer would also be required to get the Marl, Sand, Gravel, Shell or Mudshell Permit, which also falls under TPWD's responsibilities.

The Texas Coastal Management Program (TCMP), under the federal Coastal Zone Management Act (CZMA), also applies to aquaculture. Aquaculture farms that operate in Texas' Coastal Zone Management Area (where the majority of red drum farms operate) are required to abide by the

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[11] https://www.texasagriculture.gov/regulatoryprograms/aquaculture.aspx

[12] https://statutes.capitol.texas.gov/Docs/AG/htm/AG.134.htm#:~:text=134.031.,of%20matters%20related%20to%20aquaculture.

[13] https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=7&rl=103

[14] https://www.tceq.texas.gov/permitting/wastewater/general/TXG13_steps.html

[15] https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/habitat_assessment/tools.phtml

Texas General Land Office (TGLO, 2020), which is responsible for the management and use of state-owned public lands, including any cultivation activities that begin in the mean high tide line and extend into bays and estuaries (TGLO 2015). Also, the "Wetland Protection Policy (GM-190.26)" requires the Natural Resource Conservation Service to "avoid, minimize, or mitigate, in that order, damage to wetlands as a condition of providing technical and financial assistance to landowners" (NRCS website,[16] accessed August 2022). But, TGLO 2020 states that loss of wetlands is still occurring in general (though not necessarily associated with the aquaculture industry), despite significant gains through mitigation measures.

Overall, the content of management measures overseeing the siting of red drum farms (including farm expansions) is comprehensive. Although farm siting is regulated on an individual basis, it is tightly managed by coordinating multiple regulatory bodies at the local, state, and federal levels. The permitting process clearly integrates other industries and land use activities, so it appears to pursue the maintenance of ecosystem functionality at an area-based level. Even with one less state agency overseeing the aquaculture industry in Texas (TDA) after 2021, it appears that the mechanisms to protect habitats are covered by the TCEQ, TPWD, and TGLO, as well as by federal agencies when applicable; hence, the score for Factor 3.2a is 5 out of 5.

Factor 3.2b: Enforcement of habitat management measures

Aquaculture facilities are required to be compliant with state and federal legislation (e.g., those listed in Factor 3.1) and must allow facility access to enforcement agencies for assessment of compliance at any point, during normal business hours (Sec. 134.016). Enforcement agencies are easily contacted, and the enforcement and penalties are robust. Penalties and fines for infringements range from misdemeanors to felony charges (Texas Agriculture Code, 1981). But, after reviewing the legislation and the agencies' web pages, it is not clear with what frequency farms are inspected; nonetheless, the agencies are clearly active.

In 2021, the TCEQ performed 175 site visits and conducted over 117,000 investigations to businesses under its jurisdiction (TCEQ, 2021). Furthermore, compliance reports for individual farms are available on the TCEQ website or through a request to the agency. A compliance history review through the TCEQ[17] search engine demonstrates that enforcement is active and that some habitat-related concerns (as well as effluent-related concerns) are addressed. For example, TCEQ lists two active violations for two red drum producers. The first violation involves a producer that failed to meet the limit for one or more permit parameters (ammonia nitrogen and inorganic suspended solids) and did not submit a noncompliance notification to TCEQ. The second one consists of a producer that failed to report its monthly effluent gross average during the first two quarters of 2021. Though these violations are related to effluent discharges, they indicate an active enforcement agency.

It is worth noting that, during the renewal or amendment of the Aquaculture General Permit (which should include the NOI and all other materials submitted by the applicant), the TCEQ

[16] https://www.nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcs144p2_056681
[17] https://www2.tceq.texas.gov/oce/ch/index.cfm?fuseaction=main.home&message=clinofound

must provide an initial draft permit to the TPWD for review and comment before submitting the draft to the EPA for review and approval (Rule §7.103). The TPWD has 45 days to complete its initial assessment of this draft and provide formal written recommendations. More details about this review process are described in the MOU (Rule §7.103). Hence, it appears that the TCEQ and the TPWD are well coordinated and are processing aquaculture applications through a robust reviewing process.

Overall, it is clear that the enforcement organizations are identifiable and contactable, and their resources are appropriate to the scale of the industry. Enforcement is active at the area-based scale, the permitting and licensing processes are transparent, and there is evidence of penalties for regulatory infringements. Thus, the score for Factor 3.2b is 5 out of 5. Combining Factors 3.2a (5 out of 5) and 3.2b (5 out of 10) provide the final Factor 3.2 score of 10 out of 10.

Conclusions and Final Score

Farmed red drum in the United States is currently produced only in the state of Texas, and the majority of the farms are located along Matagorda Bay. Red drum aquaculture largely represents a "secondary conversion" of land from former shrimp farms or agricultural land, and the small expansion happening on undeveloped areas appears to be taking place in coastal shrubland, otherwise classified as upland with minimal impacts. Because the industry lacks a national growth and management plan, the siting of red drum farms is considered for approval on an individual basis. But, current habitat management is considered robust because local, state, and federal regulations consider the potential habitat impacts of farm construction and operate in conjunction with other industries and resource users. In addition, the enforcement of policies is comprehensive and accessible in the public domain. Ultimately, there is a moderate impact at worst for habitat conversion (Factor 3.1) and there are robust regulations regarding siting of aquaculture facilities and enforcement (Factor 3.2). As a result, there does not appear to be any information readily available to suggest that the previous rating for the Habitat Criterion is no longer accurate.

Criterion 5: Feed

Brief Summary

Overall, red drum feeds in the U.S. use fishmeal and fish oil made from whole wild fish and by-product sources with an eFCR of 2.0. The fishmeal inclusion level is moderate-high (22.08%); a small fraction (2.04%) is sourced from fishery and/or aquaculture by-products, and the rest from whole-fish reduction processes. The fish oil inclusion level is moderate-high at 5.89%, and 0.74% comes from by-product sources. The resulting score for Factor 5.1a—Feed Fish Efficiency Ratio (FFER) is moderate-high (2.075), meaning that, from first principles, 2.075 mt of wild fish are needed to produce the fishmeal required for 1 mt of farmed red drum. Most of the fishmeal used by U.S. feed suppliers is sourced from a well-managed fishery and results in a score for Factor 5.1b—Source fishery sustainability of 7 out of 10. The moderate-high inclusion levels of these wild fish ingredients in U.S. red drum feeds, combined with the sustainability of raw material, result in a Factor 5.1—Wild Fish Use score of 3.65 out of 10. Factor 5.2—Net Protein

Gain or Loss scores 1 out of 10 and is driven by a high net protein loss of –80.56%. Factor 5.3—Feed Footprint scores 7 out of 10 due to a moderate feed footprint of 13.288 kg CO_2-eq. per kg of harvested protein. Altogether, Factor 5.1, 3.65 out of 10; Factor 5.2, 1 out of 10; and Factor 5.3, 7 out of 10, combine for a Criterion 5—Feed final score of 3.83 out of 10, which results in a Yellow rating for Criterion 5—Feed.

Justification of Ranking

In the U.S., the majority of farmed red drum are fed commercial pelleted feeds produced by Cargill Inc., Rangen Feeds (Wilbur-Ellis Nutrition LLC), and Zeigler Bros Inc. Information requests were made to each feed supplier, and details regarding the composition of red drum feeds were provided. While one of the suppliers provided specific ingredient composition and source of origin for their red drum diet, two suppliers provided only their feed inclusion levels, leaving out either specific ingredients or their origin. Although feed inclusion rates may vary from batch to batch and often are influenced by the price and availability of ingredients, the data provided are considered to represent the entirety of the red drum feeds used in the U.S. The information provided by feed manufacturers is aggregated and included in this assessment, alongside information from the literature and additional personal communications.

The Seafood Watch Aquaculture Standard assesses three feed-related factors: wild fish use (including the sustainability of the source), net protein gain or loss, and the feed “footprint” or embedded climate change impact of ingredients in feed required to produce 1 kg of farmed red drum protein.

Factor 5.1: Wild Fish Use

Factor 5.1 combines an estimate of the amount of wild fish used to produce farmed red drum with a measure of the sustainability of the source fisheries. Table 10 shows the data used to calculate the Feed Fish Efficiency Ratio (FFER) for fishmeal and fish oil.

<u>Factor 5.1a: Feed Fish Efficiency Ratio (FFER)</u>

The Feed Fish Efficiency Ratio (FFER) for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of fish used in feeds, and the source of the marine ingredients (i.e., does the fishmeal and fish oil come from processing by-products or whole fish targeted by wild capture fisheries). For a summary of all values used to calculate the FFER, see Table 10.

FCR is the ratio of feed given to an animal per weight gained, measured in mass (e.g., FCR of 1.4:1 means that 1.4 kg of feed is required to produce 1 kg of fish). It can be reported as either biological FCR (bFCR), which is the straightforward comparison of feed given to weight gained, or economic FCR (eFCR), which is the amount of feed given per weight harvested (i.e., accounting for mortalities, escapes, and other losses of otherwise-gained harvestable fish). The Seafood Watch Aquaculture Standard utilizes the eFCR. Using a single eFCR value to represent an entire industry is challenging. The difficulty is rooted in the differences in red drum genetics, feed formulations, farm practices, and more. The most representative data available on U.S. red drum production come from personal communication with red drum farmers, and no changes have been reported since the original Seafood Watch red drum assessment (SFW, 2016)

(Treece, 2012 and 2017) (pers. comm. T. Sink, Aquaculture Extension Specialist, April 2022) (pers. comm. Jim Ekstrom, Ekstrom Enterprises, September 2022) (anonymous feed manufacturers, November 2022). Therefore, an eFCR of 2.0 is considered representative of the U.S. red drum industry and it is the value used in this assessment. An eFCR value of 2.0 is also consistent with global marine fish production, which has historically seen eFCRs in the range of 0.9 to 3.0 (Tacon and Metian, 2008), and it is also within the range of more recent global estimates of 1.6 to 2 (Tacon, 2011, 2019 and 2021).

Similarly, the ingredient composition for red drum feed is highly variable, and the information available in the literature and obtained through stakeholders show a wide range of inclusion levels. A single inclusion value was determined by weighing the averages of the ranges for fishmeal (i.e., 24%, 20%, and 17.5%) and fish oil (i.e., 7.75%, 3.5%, and 4.5%) provided by each feed manufacturer based on their market share (Eq. 1) (pers. comm., anonymous feed manufacturers, November 2022) (pers. comm. Jim Ekstrom, Ekstrom Enterprises, September 2022).

(Eq. 1)

$$FM_{inclusion} = \left(24\%_{feed\ manufacturer\ 1} \times 55_{share\ 1}\%\right) + \left(20\%_{feed\ manufacturer\ 2} \times 40_{share\ 2}\%\right) + \left(17.5\%_{feed\ manufacturer\ 2} \times 5_{share\ 3}\%\right)$$

$$FO_{inclusion} = \left(7.75\%_{feed\ manufacturer\ 1} \times 55_{share\ 1}\%\right) + \left(3.5\%_{feed\ manufacturer\ 2} \times 40_{share\ 2}\%\right) + \left(4.5\%_{feed\ manufacturer\ 2} \times 5_{share\ 3}\%\right)$$

Where:

$feed\ manufacturer_n$ = average of lower and upper bound of FM and FO inclusion ranges reported by U.S. red drum feed manufacturer.

$M_{share\ n}$ = estimated market share for each respective feed manufacturer within the U.S. red drum industry.

The resulting calculated fishmeal (FM) and fish oil (FO) inclusions are 22.08% and 5.89%, respectively, and are consistent with the literature. For instance, more than a decade ago, global commercial feeds for marine fishes included 7 to 70% of FM and 1 to 15% of FO (Tacon and Metian 2008), for which the U.S. ranged from 20 to 40% of FM and 5 to 20% of FO (Tacon et al., 2011). More recent literatures demonstrate how advances in feed formulation and new alternatives to replace FM and FO have successfully reduced FM inclusion to 10 to 20% and FO inclusion to 3 to 9.8% across all fed aquaculture species (Wang et al., 2020) (Rossi et al., 2015 and 2016) (Naylor, 2021) (Minjarez-Osorio et al., 2016) (Perez-Velazquez et al., 2018) (FAO, accessed in 2022). Thus, the estimate provided here, 22.08% FM, is greater than the global range, while the estimate of 5.89% FO is within the average inclusion range, but on the higher range.

The use of by-products in red drum feeds can result in even broader inclusion ranges than other ingredients, varying by formulation and feed manufacturer. Therefore, a weighted average, determined by market share, of the data provided by red drum feed manufacturers was also used to determine a single inclusion level for FM and FO by-products (Eq 2).

(Eq. 2)

$$FM_{bp\ inclusion} = \left(0\%_{f.\ manufacturer\ 1} \times 55_{share\ 1}\%\right) + \left(20\%_{f.\ manufacturer\ 2} \times 40_{share\ 2}\%\right) + \left(25\%_{f.\ manufacturer\ 2} \times 5_{share\ 3}\%\right)$$

$$FO_{bp\ inclusion} = \left(0\%_{f.\ manufacturer\ 1} \times 55_{share\ 1}\%\right) + \left(25\%_{f.\ manufacturer\ 2} \times 40_{share\ 2}\%\right) + \left(50\%_{f.\ manufacturer\ 2} \times 5_{share\ 2}\%\right)$$

Where:

$\%_{f.\ manufacturer\ n}$ = by-product inclusion level for FM and FO reported by U.S. feed manufacturer.

$M_{share\ n}$ = estimated market share for each respective feed manufacturer within the U.S. red drum industry.

The results estimate that 9.25% and 12.5% of fishmeal and fish oil inclusions, respectively, come from by-products. Literature of global and North American fishmeal and fish oil by-product inclusion levels indicates that the calculated FM by-product value of 9.25% is below the global industry range of 30–43% and below the North American average of 35.6% (IFFO website[18]) (Naylor et al., 2021). Similarly, the estimated 12.5% of fish oil by-product inclusion is below the global range of 40–50% and below the North American average of 22% (IFFO website) (Naylor et al., 2021) (Jackson and Newton 2016).

Whole fish inclusion levels were determined by calculating the difference between the by-product percentages determined from above and 100% (Eq. 3).

(Eq. 3)

$$FM_{wf\ inclusion} = \left(100\% - FM_{bp\ inclusion}\right)$$

$$FO_{wf\ inclusion} = \left(100\% - FO_{bp\ inclusion}\right)$$

The resulting differences are 90.75% and 87.5% for fishmeal and fish oil whole fish inclusions, respectively.

The following equation (Eq. 4) calculates the fishmeal and fish oil feed fish efficiency ratio ($FFER_{FM}$ and $FFER_{FO}$) and it incorporates the estimated feed composition values calculated so far. The FFER is a measure of the dependency on wild fisheries for feed ingredients, using the ratio of the amount of wild fish used in feeds to the harvested farmed fish. Each variable used in these calculations, as detailed below, is also summarized in Table 10. The whole fish inclusion levels for fishmeal and fish oil are used and can be found in Table 10 as variables a and c, respectively. To capture the ecological cost of production associated with by-products, only 5%

[18] https://www.iffo.com/product

of the estimated FM and FO by-product inclusion levels are considered when calculating the FFER, and are also noted in Table 10 as variables b and d. The eFCR (g) and the fish oil (f) and fishmeal yield (e) values are also identified in Table 10 and used in Equation 4. Note that fishmeal and fish oil yield values were not available, so global averages provided by Tacon and Metian (2008) were utilized.

(Eq. 4)

$$FFER_{FM} = [(a + b) \times g]/e$$

$$FFER_{FO} = [(c + d) \times g]/f$$

The resulting FFER for fishmeal is 1.790, and the FFER for fish oil is 2.075.

Table 10. Parameters used and their calculated values to determine the use of wild fish in feeding U.S. farmed red drum.

Eq. variable	Parameter	Data
	Fishmeal inclusion level (total)	22.08%
a	Fishmeal inclusion level (whole fish)	20.04%
	Fishmeal inclusion level (by-product)	2.04%
b	Assessed fishmeal inclusion level (by-product)[19]	0.10%
e	Fishmeal yield	22.50%
	Fish oil inclusion level (total)	5.89%
c	Fish oil inclusion level (whole fish)	5.15%
	Fish oil inclusion level (by-product)	0.74%
d	Assessed fish oil inclusion level (by-product)	0.04%
f	Fish oil yield	5.00%
g	Economic Feed Conversion Ratio (eFCR)	2.0
Calculated values		
Fish meal feed fish efficiency ratio ($FFER_{fm}$)		1.790
Fish oil feed fish efficiency ratio ($FFER_{fo}$)		2.075
Assessed FFER		2.075

The Feed Criterion considers the FFER from both fishmeal and fish oil and uses the higher of the two to determine the score. As seen in Table 10, the high inclusion level of fish oil from whole

[19] The by-product inclusion level data point utilized in this equation is the reported inclusion level multiplied by 0.05. See the Seafood Watch Aquaculture standard page 38 for more information. https://www.seafoodwatch.org/globalassets/sfw/pdf/standards/aquaculture/seafood-watch-aquaculture-standard-version-a4.pdf

fish drives the high $FFER_{fo}$ for U.S. farmed red drum. Therefore, the score for Factor 5.1a—$FFER_{fo}$ is 2.075; based on first principles, 2.075 tons of wild fish are required to produce 1 ton of farmed US red drum.

Factor 5.1b: Source fishery sustainability

This factor evaluates the sustainability of the fisheries supplying fishmeal and fish oil for U.S. red drum grow-out feed. The majority (more than 60%) of marine raw materials are sourced from Gulf menhaden fished in the Gulf of Mexico. About 35% of marine raw materials are sourced from sardines fished in the Gulf of California, mackerel from Chile, and squid from Chile and Peru. It is worth noting that one of the feed manufacturers provided the range of inclusion levels used from these fisheries in their diet but did not provide the source of their ingredients. Therefore, the precautionary approach is used here, and an unknown source fishery is allocated to the remaining 5% of raw materials (Table 11) (pers. comm., anonymous feed manufacturers, November 2022). Although the final inclusion of these raw materials can vary per batch produced and will depend mainly on market dynamics, such as availability and price, the information presented here is the best readily available data.

The following steps were completed to calculate a final 5.1b score:

1. Determine the sustainability score for each source fishery.
2. Determine the inclusion levels for each marine ingredient.
3. Calculate whole fish and by-product 5.1b Source fishery sustainability scores.
4. Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.
5. Calculate a final Factor 5.1b score by weighting the overall Fishmeal and Fish Oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

A summary of each process and resulting calculations are provided in the descriptions below.

Step 1: Determine the sustainability score for each source fishery

A summary of the following section is provided in Table 11. The following text summarizes the rationale and justification for each species, which is informed by the certification, the FishSource scores, and/or the SFW rating of the fishery. In addition, the SFW Standard for Aquaculture V4.0 assigns a fishery sustainability score of zero when the raw materials are sourced from an unknown fishery.

Table 11: Source fisheries and resulting F5.1b scores.

Common Name (*Genus species*)	Country/fishing region of origin	Gear type	Relevant certifications/ratings	F5.1b Score
Gulf menhaden (*Brevoortia patronus*)	United States: Gulf of Mexico	Purse Seine	MSC & IFFO RS	8
Sardine (*Sardinops sagax*)	Mexico	Purse Seine	MSC	6

Chilean jack mackerel (*Trachurus murphyi*)	Chile	Purse Seine	MSC & IFFO RS	8
Squid (*Dosidicus gigas*) meal	Chile/Peru	Artisanal Fleet	SFW Yellow	6
Unknown	NA	NA	NA	0

The Gulf menhaden (*Brevoortia patronus*) is fished in the Gulf of Mexico using purse seines, and all FishSource scores are ≥6, including stock health scores >9 (FishSource, 2021c). According to the Gulf States Marine Fisheries Commission's assessment in 2020, which is an update to the 2018 benchmark for the Gulf of Mexico (SEDAR 63), the Gulf of Mexico menhaden fishery is not likely overfished, nor is overfishing occurring (Schueller, 2021). Although the Commission develops and maintains regional fishery management plans for the largest fisheries that coastal states share, these fisheries operate under the Inter-Jurisdictional Fisheries Act of 1949. Therefore, the Regional Management Plan for Gulf menhaden asserts that each of the five individual states exercises the most direct management authority for this fish stock (Vanderkooy and Smith 2015). For example, there is no Gulf-wide catch limit for Gulf menhaden, and Texas (a minor producer) adopted its own catch quota, which went into effect in 2009 (FishSource, 2021c). Although fishery managers have raised concerns about the uncertainty regarding the estimated biomass of Gulf menhaden, they have agreed that the stock is likely not undergoing overfishing and is likely not overfished, mainly because of the following factors: the fishery's historical population structure, its accurate and available catch records, a small fleet, only a few landing ports, relatively stable productivity, the fact that almost all fish reach maturity and spawn before fishing season starts, and a relatively consistent relationship between measured effort and catch (suggesting that harvests have been well regulated) (Schueller, 2021) (Vanderkooy and Smith, 2002 and 2015). As a result, Factor 5.1b for Gulf menhaden scores 8 out of 10 for this source fishery (Table 11).

All FishSource scores (e.g., Management Quality: management strategy, managers compliance, and fishers compliance; and Stock Health: current health and future health) for Pacific sardine (*Sardinops sagax*) fished in the Gulf of California are ≥6, including a stock health score of ≥6 (FishSource, 2021d). In addition, the fishery has been certified (with conditions) by the Marine Stewardship Council since 2011. There are currently 36 vessels using purse seine nets to catch this small pelagic, with a total annual production of over 130,000 mt for 2018 and 2019 (Ruiz-Dominguez, 2019) (MSC website,[20] 2022). As in every fishery in Mexico, sardines are regulated by the national Ley General de Pesca y Acuacultura Sustentables (The Fisheries Law) (DOF 2007). The National Fisheries Letter includes general provisions and recommendations, and the Mexican National Standard (Norma Oficial Mexicana 003-PESC-1993) outlines the management measures. The Federal Institute of Fisheries and Aquaculture (INAPESCA) is mandated to provide scientific recommendations to the Federal Commission of Fisheries and Aquaculture (CONAPESCA) enforcement agency. Both organizations are active, identifiable, and can be reached, within reason. As a result, Factor 5.1b for Pacific sardine scores 6 out of 10 for this source fishery (Table 11).

[20] https://fisheries.msc.org/en/fisheries/

Similarly, all FishSource scores for Chilean jack mackerel (*Trachurus murphyi*) fished with purse seines are ≥6, including stock health scores of >9 (FishSource, 2021b). This fishery achieved the MSC certification and the Global Standard for Responsible Supply of Marine Ingredients (IFFO-RS) in 2019 (MSC website 2022) (Daly, 2019). The South Pacific Regional Fisheries Management Organization has been conducting Chilean jack mackerel stock assessments since 2010. In 2013, catch limits were agreed upon for the assessment unit area and for the Convention area (FishSource, 2021b). The spawning stock has been fluctuating around the maximum sustainable yield but is now above this threshold and has continued to show signs of improvement since 2010 (FishSource, 2021b). As a result, Factor 5.1b for Chilean jack mackerel scores 8 out of 10 for this source fishery (Table 11).

The jumbo squid (*Dosidicus gigas*) used for U.S. red drum feeds comes 100% from by-products and is harvested through Chilean and Peruvian artisanal fisheries, primarily using jiggers (pers. comm., anonymous feed manufacturer, April 2022) (SFW, 2018). Both Chilean and Peruvian squid receive a SFW Yellow rating and score of 3.5 (Good Alternative). The stock inside Chilean and Peruvian EEZs is not considered depleted, and fishing effort does not exceed recommended levels (SFW, 2018). A recent stock assessment on Humboldt squid outside these EEZs showed no evidence of overfishing. Refer to the complete SFW assessment for more details on these fisheries. As a result, Factor 5.1b for jumbo squid scores 6 out of 10 for this source fishery (Table 11).

Step 2. Determine the inclusion levels for each marine ingredient.

Some estimates were made to determine the inclusion levels for each marine ingredient. Consider that species-specific inclusion levels were not provided by two of the three feed manufacturers. When the species were known, but no inclusion level for each species was specified by the manufacturer, the inclusion level was divided evenly between the number of species reported. For example, if a feed manufacturer reported that three marine species were used to produce a feed with an inclusion level of 9% of fishmeal from whole fish but did not specify the proportion of each species used, the 9% was distributed evenly between the three species (i.e., 3% allocated for each species). When different feed manufacturers reported the use of the same species in their feeds, the estimated inclusion for each manufacturer's species was added (Table 12). Whole fish and by-products inclusion level values for each species used in FM and FO were provided by feed manufacturers and are shown under the "Feed manufacturer values" columns in Table 12. Lastly, to determine each species' contribution to fishmeal and fish oil whole fish and by-product inclusion levels, Equation 5 is used (Eq. 5). The resulting scores are shown in Table 12 under the "Resulting calculated inclusion levels" columns.

Table 12: Feed manufacturer marine ingredient composition for U.S. red drum feed.

Common Name (*Genus species*)	Feed manufacturer values			Resulting calculated inclusion levels			
	Sp. Inclusion %	Whole fish %	By-product %	FM_{WF}	FM_{BP}	FO_{WF}	FO_{BP}
Gulf menhaden (*Brevoortia patronus*)	61.51	100	0	13.68	0	3.52	0
Sardine (*Sardinops sagax*)	15.41	78	22	2.68	0.61	0.69	0.33
Chilean jack mackerel (*Trachurus murphyi*)	15.41	78	22	2.68	0.61	0.69	0.33
Squid (*Dosidicus gigas*) meal	2.18	0	100	0	0.61	0	0
Unknown	5.58	80	20	1.00	0.23	0.25	0.08

The following calculations show how the approximated inclusion level for each species used in U.S. red drum feeds was determined:

(Eq. 5)

$$Sp.FM_{WF}\ Inclusion\ \% = Sp_{inclusion}\% \times WF\% \times FM_{inclusion}$$

$$Sp.FM_{BP}\ Inclusion\ \% = Sp._{inclusion}\ \% \times BP\% \times FM_{inclusion}$$

$$Sp.FO_{WF}\ Inclusion\ \% = Sp._{inclusion}\ \% \times WF\% \times FO_{inclusion}$$

$$Sp.FO_{BP}\ Inclusion\ \% = Sp._{inclusion}\ \% \times BP\% \times FO_{inclusion}$$

Where:

For each species:

$Sp.FM_{WF}\ Inclusion\ \% = Inclusion\ rate\ of\ fishmeal\ from\ whole\ fish$

$Sp.FM_{BP}\ Inclusion\ \% = Inclusion\ rate\ of\ fishmeal\ from\ by\text{–}product$

$Sp.FO_{WF}\ Inclusion\ \% = Inclusion\ rate\ of\ fish\ oil\ from\ whole\ fish$

$Sp.FO_{BP}\ Inclusion\ \% = Inclusion\ rate\ of\ fish\ oil\ from\ by\text{–}product$

$Sp._{inclusion}\ \%$ = $the\ given\ percentage\ of\ each\ species\ used\ as\ raw\ materials\ in\ the\ FM\ and\ FO\ of\ U.S.red\ drum\ feed$

$FM_{inclusion} = 22.08\%\ FM\ inclusion\ rate$

$FO_{inclusion} = 5.89\%\ FO\ inclusion\ rate$

The resulting inclusion levels per species are included in Table 12.

Step 3. Calculate whole fish and by-product 5.1b Source fishery sustainability scores.

After determining each species' sustainability score and its individual inclusion levels through the procedures shown in Step 1 and 2, a single Factor 5.1b Source fishery sustainability score for each marine ingredient was determined and included in Table 13.

Table 13: Marine ingredients inclusion levels and sustainability scores.

Marine Ingredient	Inclusion (%)	Sustainability Score
Fishmeal from whole fish	**20.03**	
Gulf menhaden (*Brevoortia patronus*)	13.68	8
Sardine (*Sardinops sagax*)	2.68	6
Chilean jack mackerel (*Trachurus murphyi*)	2.68	8
Unknown	1	0
Sustainability score for fishmeal whole fish		7.33
Fishmeal from by-product	**2.04**	
Sardine (*Sardinops sagax*)	0.61	6
Chilean jack mackerel (*Trachurus murphyi*)	0.61	8
Peruvian and Chilean squid meal (*Dosidicus gigas*)	0.61	6
Unknown	0.22	0
Sustainability score for fishmeal by-products		6.22
Fish oil from whole fish	**5.15**	
Gulf menhaden (*Brevoortia patronus*)	3.52	8
Sardine (*Sardinops sagax*)	0.69	6
Chilean jack mackerel (*Trachurus murphyi*)	0.69	8
Unknown	0.25	0
Sustainability score for fish oil whole fish		7.34
Fish oil from by-products	**0.74**	
Sardine (*Sardinops sagax*)	0.33	6
Chilean jack mackerel (*Trachurus murphyi*)	0.33	8
Unknown	0.08	0
Sustainability score for fish oil by-products		6.22

The following equations are used to determine a single Factor 5.1b Source fishery sustainability score for fishmeal and fish oil sourced from whole fish and by-products (Eq. 6).

(Eq. 6)

$$S.Score_{FM-WF} = \Sigma(\mathrm{K}_n/\alpha_n) \times \mathrm{F}_n$$

$$S.Score_{FM-BP} = \Sigma(\mathrm{K}_n/\alpha_n) \times \mathrm{F}_n$$

$$S.Score_{FO-WF} = \Sigma(\mathrm{K}_n/\alpha_n) \times \mathrm{F}_n$$

$$S.Score_{FO-BP} = \Sigma(\mathrm{K}_n/\alpha_n) \times \mathrm{F}_n$$

Where:

K_n = Inclusion (%) of each type of marine ingredient

α_n = Total fishmeal or fish oil inclusion from whole fish or by-product for each feed type

F_n = SFW 5.1b sustainability score for each type of marine ingredient

The results of the calculations of Step 3 are included in Table 13, under each marine ingredient type (e.g., Sustainability score for fishmeal whole fish).

Step 4: Determine the total sustainability scores by combining the whole fish and by-product sustainability scores for fishmeal and fish oil.

The results of the calculations described below are summarized in Table 14.

Table 14. Ingredient inclusion levels and total sustainability scores.

Marine Ingredient	Inclusion (%)	Sustainability Score
Weighted fishmeal sustainability score (including 5% by-products)	22.08	7.278
Weighted fish oil sustainability score (including 5% by-products)	5.89	7.282
Factor 5.1b score		7.280

Using the fishmeal and fish oil sustainability score values for whole fish and by-products calculated in Step 3, the following equation is then used to calculate the weighted overall sustainability scores for total fishmeal and fish oil (Eq. 7):

(Eq. 7)

$$S.Score_{FMtotal} = (S.Score_{FM-WF} \times 0.95) + (S.Score_{FM-BP} \times 0.05)$$

$$S.Score_{FOtotal} = (S.Score_{FO-WF} \times 0.95) + (S.Score_{FO-BP} \times 0.05)$$

Where:

$S.Score_{FM-WF}$ = weighted whole fish sustainability score for fishmeal
$S.Score_{FM-BP}$ = weighted by-product sustainability score for fishmeal, considering only 5%
$S.Score_{FO-WF}$ = weighted whole fish sustainability score for fish oil
$S.Score_{FO-BP}$ = weighted by-product sustainability score for fish oil, considering only 5%

Step 5: Calculate a final Factor 5.1b score by weighting the total Fishmeal and Fish Oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

The last step is to modify the weighted overall sustainability scores for fishmeal (7.278) and fish oil (7.282) by their respective FFER calculated in F5.1a ($FFER_{FM}$ = 1.790; $FFER_{FO}$ = 2.075). This is done to accurately attribute the sustainability of source fishery scores with the biomass utilized for red drum feed, and the following equation is used (Equation 8):

(Eq. 8)

$$\text{Final 5.1b score} = \frac{(FFER_{FM} \times S.Score_{FMtotal}) + (FFER_{FO} \times S.Score_{FOtotal})}{(FFER_{FM} \times FFER_{FO})}$$

As a result, the Final 5.1b Source fishery sustainability score is 7.280 out of 10. Most of the fishmeal used by U.S. feed suppliers is sourced from MSC-certified or IFFO-RS-certified fisheries and receives FishSource scores greater than 6, while the squid meal is produced 100% from by-products that originate from artisanal fisheries that are rated Yellow (Good Alternative) by SFW. Most of the marine source ingredients results in SFW sustainability scores of 6 or 8, except for the raw materials for which the source was unknown, and received a score of 0. Once each ingredient's inclusion levels are accounted for, then combined with the sustainability score and eventually contextualized with the FFER, the resulting fishmeal and fish oil in U.S. red drum feeds combine for a final score for Factor 5.1b SFW fishery sustainability of 7.280 (Table 14), which is rounded to 7 out of 10.

The FFER Factor 5.1a score of 2.075 is combined with the Factor 5.1b Source fishery sustainability score of 7 out of 10 for a Factor 5.1—Wild Fish Use score of 3.65 out of 10.

Factor 5.2: Net Protein Gain or Loss

Factor 5.2 measures the net protein efficiency of the fish farming process based on the feed protein inputs and the harvested fish protein outputs. The two U.S. red drum feed manufacturers that provided data for this assessment report that their red drum diets use 45% total protein (pers. comm., anonymous feed manufacturers, November 2022). The net protein gain or loss is calculated according to the following equation and the results are included in Table 15:

(Eq. 9)

$$\text{Net Protein} = \frac{[\text{Harvested fish protein content \%} - (\text{feed protein content \%} \times \text{eFCR})]}{(\text{feed protein content \%} \times \text{eFCR}) \times 100}$$

Where:

- Harvested fish protein content, the percent of whole harvested fish, is 17.5%
- Feed protein content was reported at 45%
- eFCR was reported at 2.0

Table 15. The parameters used and their calculated values to determine the protein gain or loss in the production of farmed U.S. red drum.

Parameter	Data
Protein content of feed	45%
Economic Feed Conversion Ratio	2.0
Total protein INPUT per ton of farmed red drum	900 kg
Protein content of whole harvested red drum	17.5%
Total protein OUTPUT per ton of farmed red drum	175.0 kg
Net protein loss	–80.56%
Seafood Watch Score (0–10)	1

Considering the eFCR of 2.0 (see Factor 5.1a for details), alongside a whole-red drum protein content of 17.5% (Rossi et al. 2016) (Seafood Source, 2014[21]), the net protein loss is –80.56%. This results in a score of 1 out of 10 for Factor 5.2—Net Protein Gain or Loss.

Factor 5.3: Feed Footprint

Factor 5.3—Feed Footprint is an approximation of the embedded Climate Change Impact value (CCI) (kg CO_2-eq, including land-use change [LUC]) of the feed ingredients required to grow 1 kilogram of farmed seafood protein. This calculation is performed by mapping the ingredient composition of a typical feed used against the Global Feed Lifecycle Institute (GFLI) database[22] to estimate the CCI of 1 metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. The detailed calculation methodology can be found in Appendix 4 of the Seafood Watch Aquaculture Standard.

As noted previously, information requests were made to primary feed suppliers operating in the U.S. (Rangen Feeds–Wilbur-Ellis Nutrition LLC, Zeigler Bros Inc., Skretting, and Cargill Inc.). Although some of the acquired information was limited, enough detail was provided to map most ingredients and assign each a CCI value. Table 16 contains the inclusion levels for each ingredient and the economic allocation value for CCI, including land-use change as it appears in the GFLI database.

Typical ingredients in U.S. feeds for red drum include fishmeal and fish oil (see Factor 5.1), alongside soybean meal, wheat products, rice products, corn gluten meal, poultry blood and by-product meal, and feather, bone, and pork meal (pers. comm., anonymous feed manufacturers, November 2022). Most of these plant, marine, and land animal ingredients are produced domestically in the U.S. (pers. comm., anonymous feed manufacturers, November 2022).

Because of the high level of transparency and detail, it was possible to map most of the ingredients against an applicable CCI estimate of the GFLI database.[23] For instance, if the specific ingredient and the source of origin were known, the CCI value was pulled from the best-matching product listed in the GFLI database. For example, for the 17.21% inclusion of Gulf menhaden, the value applicable to the product "Fishmeal, from Gulf menhaden, at plant/US Economic S" was considered in the calculations to estimate the total embedded CCI value. But, if the ingredients and their origin source were unknown, the average between the best-matching global or universal value and the worst CCI value found under the same product category was considered in the calculations to estimate the total embedded CCI value. For example, the global estimate classified as "Fishmeal from fishmeal and fish oil production, at plant/GLO Economic S" was averaged with the worst value under the fishmeal products in the GFLI database, "Fishmeal, from blue whiting, at plant/DE Economic S," and was used to represent the 1.0% of fishmeal from unknown origin (Table 16). The same process was carried out to assign CCI values to crop ingredients. Lastly, land animal ingredients were mapped

[21] https://www.seafoodsource.com/seafood-handbook/finfish/drum
[22] https://globalfeedlca.org/gfli-database/lcia-download/
[23] See the SFW Aquaculture Standard page 42 and 43 for guidance on GFLI decision rules.

against species-specific but not country-specific CCI estimates, because the GFLI database only has global values for these product categories.

Table 16. Estimated embedded climate change impact of 1 mt of typical U.S. red drum.

Feed ingredients	Species or Ingredient	Climate Change Impact (incl. LUC) item	Ingredient inclusion %	kg CO_2-eq/mt feed
Fishmeal from whole fish	Gulf menhaden (*Brevoortia patronus*)	Fishmeal, from Gulf menhaden, at plant/US Economic S	13.68	196.97
	Mexican sardine (*Sardinops sagax*)	Fishmeal, from fishmeal and fish oil production, at plant/GLO Economic S	2.68	
	Chilean jack mackerel (*Trachurus murphyi*)	Fishmeal, from fishmeal and oil production, at plant/CL Economic S	2.68	
	Unknown	Fishmeal, from fishmeal and fish oil production, at plant/GLO Economic S and Fishmeal, from blue whiting, at plant/DE Economic S	1.00	
Fishmeal from by-products	Sardine (*Sardinops sagax*)	Fishmeal, from fishmeal and fish oil production, at plant/GLO Economic S	0.61	24.83
	Chilean jack mackerel (*Trachurus murphyi*)	Fishmeal, from fishmeal and oil production, at plant/CL Economic S	0.61	
	Squid (*Dosidicus gigas*) meal	Fishmeal, from fishmeal and oil production, at plant/CL Economic S and Fishmeal, from fishmeal and oil production, at plant/PE Economic S	0.61	
	Unknown	Fishmeal, from fishmeal and fish oil production, at plant/GLO Economic S and Fishmeal, from blue whiting, at plant/DE Economic S	0.23	
Fish oil from whole fish	Gulf menhaden (*Brevoortia patronus*)	Fish oil, from Gulf menhaden, at plant/US Economic S	3.52	34.77
	Mexican sardine (*Sardinops sagax*)	Fish oil, from fishmeal and fish oil production, at plant/GLO Economic S	0.69	
	Chilean jack mackerel (*Trachurus murphyi*)	Fish oil, from fishmeal and oil production, at plant/CL Economic S	0.69	
	Unknown	Fish oil, from fishmeal and fish oil production, at plant/GLO Economic S and	0.25	

		Fish oil, from blue whiting, at plant/DE Economic S		
Fish oil from by-products	Mexican sardine (*Sardinops sagax*)	Fish oil, from fishmeal and fish oil production, at plant/GLO Economic S	0.33	5.80
	Chilean jack mackerel (*Trachurus murphyi*)	Fish oil, from fishmeal and oil production, at plant/CL Economic S	0.33	
	Unknown	Fish oil, from fishmeal and fish oil production, at plant/GLO Economic S and Fish oil, from blue whiting, at plant/DE Economic S	0.08	
Total vegetable meals	Wheat products	Wheat middlings and feed, from dry milling, at plant/GLO Economic S	23	609.50
	Soybean meal	Soybean meal, from crushing (solvent), at plant/GLO Economic S	15	
	Corn gluten meal	Maize gluten meal, from wet milling (gluten drying), at plant/GLO Economic S	4	
	Rice bran	Total vegetable meals, at plant/RER Economic S	3	
Land animal meals	Porcine meat meal	Animal meal, pig, from dry rendering, at plant/RER Economic S	7	236.82
	Poultry by-product meal	Animal meal, poultry, from dry rendering, at plant/RER Economic S	15.4	
Sum of total			**95.36%**	**1,108.69**

Based on the available information, the estimated embedded CCI of 1 mt of a typical U.S. red drum feed is 1,108.69 kg CO_2-eq. Considering a whole harvest red drum protein content of 17.5%, an eFCR of 2.0, and the total inclusion of all ingredients, the estimated kg CO_2-eq per kg of farmed seafood protein is 13.29 and is calculated using Equation 9:

(Eq. 9)

$$Est.\,kg\;CO2 - \frac{eq}{kg}\,of\;farmed\;seafood\;protein = \frac{eFCR}{whole\;harvested\;fish\;protein\;content} \times \left(\frac{Total\;CCI}{mt\;of\;Feed} \times \frac{10}{Total\;ingredient\;inclusion}\right)$$

As a result, the feed footprint of U.S. farmed red drum is considered low to moderate, and results in a score of 7 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

Overall, red drum feeds in the U.S. use fishmeal and fish oil made from whole wild fish and by-product sources with an eFCR of 2.0. The fishmeal inclusion level is moderate-high (22.08%); a small fraction (2.04%) is sourced from fishery and/or aquaculture by-products, and the rest from whole-fish reduction processes. The fish oil inclusion level is moderate-high at 5.89%, and 0.74% comes from by-product sources. The resulting score for Factor 5.1a—Feed Fish Efficiency Ratio (FFER) is moderate-high (2.075), meaning that, from first principles, 2.075 mt of wild fish are needed to produce the fishmeal required for 1 mt of farmed red drum. Most of the fishmeal used by U.S. feed suppliers is sourced from a well-managed fishery and results in a score for Factor 5.1b—Source fishery sustainability of 7 out of 10. The moderate-high inclusion levels of these wild fish ingredients in U.S. red drum feeds, combined with the sustainability of raw material, result in a Factor 5.1—Wild fish use score of 3.65 out of 10. Factor 5.2—Net Protein Gain or Loss scores 1 out of 10 and is driven by a high net protein loss of –80.56%. Factor 5.3—Feed Footprint scores 7 out of 10 due to a moderate feed footprint of 13.29 kg CO_2-eq. per kg of harvested protein. Altogether, Factor 5.1, 3.65 out of 10; Factor 5.2, 1 out of 10; and Factor 5.3, 7 out of 10, combine for a Criterion 5—Feed final score of 3.83 out of 10, which results in a Yellow rating for Criterion 5—Feed.

Criterion 7: Disease; Pathogen and Parasite Interactions

Brief Summary

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors from escaped individuals, water/sediment discharge, and animals (birds and wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, there are reports of parasites, such as *Amyloodinuym ocellatum*, being a problem on farms. Still, no data are available about the prevalence or intensity of the infestations on farms. Anecdotal evidence suggests that such prevalence is low, as does the absence of antibiotic treatments. Farms employ robust health and biosecurity protocols (e.g., in-state fingerling sourcing, around-the-clock pond surveillance, immediate water testing in case of any mortalities, and sanitary measures for equipment and personnel) and typically have low rates of water discharge. There is some indication that on-farm biosecurity measures also prevent pathogen transmission to wild species, because wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for, and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, and health and biosecurity measures are robust. As a result, there does not appear to be any information readily available to suggest that the previous rating for the Disease Criterion is no longer accurate.

<u>Disease prevalence and primary disease concerns</u>

Limited data were available in the literature and from farms to further add or support what was described in the 2016 version of the SFW red drum report for Criterion 7—Disease. U.S. industry stakeholders do not consider viral diseases to be a problem for red drum, and there has been no reported mortality from viral pathogens (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022) (pers. comm., J. Ekstrom, Ekstrom Enterprises, September 2022) (Kureshy, 2021). The Texas Aquaculture Extension Officer, Todd Sink, who also performs as Director of the Aquatic Diagnostic Laboratory in Texas (the only one in the state) that services most red drum producers in the U.S., explains that the only two disease-related issues affecting red drum are parasites, such as *Amyloodinium ocellatum,* and toxic algal blooms. Although *Amyloodinium* is considered the primary disease present in red drum, followed by other gill parasites, the major on-farm mortalities were due to harmful algal blooms (HABs)—

mainly *Karenia* (Dinoflagellate)—not diseases or parasites (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022) (Kureshy, 2022) (Treece, 2017). HABs can result in 100% fish loss when not diagnosed and treated on time. In addition, winter storm Uri caused mass red drum die-offs in February 2021, when producers lost more than 90% of their fish, including fingerlings, market-size fish, and broodstock, accounting for about $195 billion in damages (Rosenber, 2021) (Kureshy, 2021). Although important, both mortality events—HABs and the recent cold spell in Texas—are out of scope for this criterion.

But, there are significant disease issues with red drum in other parts of the world that do cause significant mortalities. For example, there were massive mortalities of cultured red drum (more than 70%) in 2011 in Eastern China due to the pathogen *Streptococcus iniae* (Mmanda et al., 2014). *S. iniae* has been found to infect wild fish species, marine mammals, and humans (Irion et al., 2021). Although *S. iniae* can infect humans (Lau et al., 2003), Shoemaker (2000) explains that it does not present a serious public health threat, but rather it represents a limited risk for older or immunocompromised people that handled and prepared fish with open or puncture wounds. In addition, no outbreaks of this disease for red drum have been reported in the U.S. in the last decades (Agnew and Barnes, 2007) (Shoemaker et al., 2000) (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022) (pers. comm. Jim Ekstrom, Ekstrom Enterprises, September 2022). Although the lack of disease outbreaks suggests that the biosecurity, farm practices (e.g., water exchange only happens in extreme cases), and regulations are effective in minimizing disease issues on farms, it can also be attributed to red drum's intrinsic resistant to disease. For instance, red drum appears to be resilient against bacterial issues that plague other species (pers. comm., D. Gatlin 2016). Tarnecki et al. (2018) suggest that red drum exhibited higher survival rates when challenged with *Amyloodinium* because of the good hematocrit volume and much higher lysozyme concentrations (285–1,399 U/ml) compared to other fish species. Also, the presence of the A1AT enzyme in red drum blood may protect against exposure to foreign enzymes, such as certain bacteria. Members of the genera *Bacillus*, *Acinetobacter*, and *Corynebacterium* found in the red drum bloodstream have the potential to aid in disease defense (Tarnecki et al., 2018).

Nonetheless, red drum farming still presents some risk of amplification or spread of disease due to the density of fish in ponds. The release of water during control efforts (one of the measures used to control *A. ocellatum*) has the potential to input pests into the environment (FAO, 2022). *A. ocellatum* can also potentially spread through birds and other wildlife visiting ponds (Francis-Floyd and Floyd 2011), thus presenting another disease-spread risk associated with pond culture of red drum. Although *A. ocellatum* does not appear to negatively affect wild fish by causing mortalities, it does affect marine teleost and elasmobranchs (Frasca et al., 2018), and it has been a contributing factor to mortalities of young hatched fish in already deplorable environments (high salinity and temperature), such as in the Salton Sea in the U.S. (Kuperman and Mattey, 1999).

Treatment and management

For certain bacterial diseases, there are approved medicated (antibiotic) feeds: for example, streptoccocosis (*S. iniae*) can be treated with AQUAFLOR®, containing 50% florfenicol (FDA,[24] 2022). The only treatments available to treat the sporadic occurrence of *A. ocellatum* and other gill parasites are copper sulfate, potassium permanganate, and formalin (Kureshy, 2021). Copper sulfate and potassium permanganate are not FDA approved but are legally available for limited use in food fish falling under the special category "Products found not to be low regulatory priority but regulatory action deferred pending further study" (Center for Veterinary Medicine,[25] 2002) (Yanong et al., 2021). Formalin is FDA approved for its use in finfish and penaeid (saltwater) shrimp, and no water change is required after administration (Yanong et al., 2021). Farmers also use copper sulfate and potassium permanganate to mitigate HABs (WAS, 2022). Refer to Criterion 4—Chemical Use for further information about approved chemicals for aquaculture use. Additional biosecurity protocols were described in the original red drum evaluation (Criterion 7—Disease, SFW 2016), and there was no indication by stakeholders that these protocols have considerably changed in the last 5 years (pers. comm., T. Sink, Aquaculture Extension Specialist, 2022) (pers. comm. Jim Ekstrom, Ekstrom Enterprises, September 2022).

Disease reporting and monitoring

Except for reportable diseases (e.g., those included in the U.S. National List of Reportable Animal Diseases, 2022), there are no requirements to notify or keep records of disease, and no monitoring data for any disease incidence or on-farm prevalence are publicly available. The U.S. Fish and Wildlife Service does conduct pathogen monitoring on wild fish in waterbodies throughout the country under its National Wild Fish Health Survey, and searches of the database return results suggest that on-farm diseases at red drum farms cannot be tied to those pathogens present in the wild. For example, a search of monitoring results for the pathogens noted to occur on farms that have also been sampled for in the wild (*A. salmonicida*, *E. tarda*, *F. columnaris*, and IPNV) show that there have been zero detections from 1997 to 2016 across the state of Texas.

Conclusions and Final Score

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors from escaped individuals, water/sediment discharge, and animals (birds and wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, there are reports of parasites, such as *Amyloodinuym ocellatum*, being a problem on farms. Still, no data are available about the prevalence or intensity of the infestations on farms. Anecdotal evidence suggests that such prevalence is low, as does the absence of antibiotic treatments. Farms employ robust health and biosecurity protocols (e.g., in-state fingerling sourcing, around-the-clock pond surveillance, immediate water testing in case of any mortalities, and sanitary measures for equipment and personnel) and typically have low rates of water discharge. There is some indication that on-farm

[24] https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs
[25] https://www.fda.gov/media/70193/download

biosecurity measures also prevent pathogen transmission to wild species, because wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for, and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, health and biosecurity measures are robust, and no indicators signal any additional disease impacts or risk since the last assessment. As a result, there does not appear to be any information readily available to suggest that the previous rating for the Disease Criterion is no longer accurate.

Results of the General Review

Criterion 2: Effluent

Recent communications with the red drum industry confirm that farms still have a low discharge rate (i.e., discharge occurs only in exceptional cases, such as toxic algal blooms) and make use of settling basins and artificial wetlands for settling of solids before discharge into the natural watershed (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022). There is no evidence to suggest that the effluent discharge from red drum farms is affecting the surrounding watershed (TCEQ, 2022) (ECHO, 2023). All farms continue to be managed within a robust cumulative regulatory framework. In addition, the Texas Commission of Environmental Quality continues effective oversight of the industry, enforcing rigid policies regarding the use of chemicals, treatment of water, disposal of sludge, water quality monitoring, and reporting. After reviewing the compliance history of red drum farms through the TCEQ[26] and the ECHO[27] search engines, it appears that enforcement remains active and vigilant. Only one producer received a formal enforcement action over the last 5 years (in October 2021) (ECHO accessed in January 2023). St. Martin Aquaculture Seafood was fined $47,821 due to failing to submit a noncompliance notification for ammonia nitrogen and inorganic suspended solids. But, this producer resolved this violation, its overall compliance under TCEQ is classified as "High," and it has not had any active violations since. Gulf States Aquaculture received 18 NPDES nonreceipt violations due to not reporting its monthly effluent gross average during the first two quarters of 2021. These violations did not result in penalties because the producer submitted the required information 8 days after the due date. Therefore, there does not appear to be any information readily available to suggest that the previous rating for the Effluent Criterion is no longer accurate.

Criterion 6: Escapes

Accidental releases of red drum are a minor concern. The combination of multiple escape-preventing mechanisms with the low frequency of water exchange and low volumes of discharge limit the opportunities for red drum to escape from farms. In addition, no red drum escape events have been reported to TPWD or TDA in the last 5 years, even after the direct hit from Hurricane Harvey in 2017 (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022). Red drum is also native to the region, and the hatchery program sources wild individuals through a permitted program for use as broodstock, indicating high genetic similarity to wild conspecifics. Therefore, there does not appear to be any information readily available to suggest that the previous rating for the Escapes Criterion is no longer accurate.

Criterion 8x: Source of Stock—Independence from Wild Fisheries

The source of broodstock in the red drum farming industry still appears to be marginally reliant on wild stocks, through the use of a limited number of mature wild individuals to promote genetic diversity in hatchery-bred red drum. But, commercial farms have only collected about

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[26] https://www2.tceq.texas.gov/oce/ch/

[27] https://echo.epa.gov/

15 broodstock in the last 5 years (pers. comm. R. Adami, Natural Resource Specialist V, February 1, 2023). As the original assessment states, wild red drum are sourced from the Gulf of Mexico in Texas state waters; these stocks are not considered overfished and are supplemented by a robust stock-enhancement program, while commercial harvests are prohibited (Vega et al. 2013). Any removal of fish for broodstock requires permitting, which includes licensing and reporting requirements (Vega et al. 2013). Therefore, the limited number of fish removed each year is of minimal concern, especially in comparison to the volume of legal recreational take (≈225,000 individuals annually in Texas[28]). There does not appear to be any information readily available to suggest that the previous rating for the Source of Stock criterion is no longer accurate.

Criterion 9X: Wildlife and Predator Mortalities

Wildlife mortalities caused by the red drum farming industry are limited to exceptional cases and are considered highly unlikely to affect the health of wild populations. During this update, it was confirmed that the permitted take of predatory birds is limited to species of least conservation concern.[29] In addition, this activity is heavily regulated by U.S. Fish and Wildlife Service procedures, with strong enforcement and respective quotas (pers. comm., T. Sink, Aquaculture Extension Specialist, April 2022) (pers. comm., G. Treece, Treece & Associates, January 25, 2023). Therefore, there does not appear to be any information readily available to suggest that the previous rating for the Wildlife Mortalities Criterion is no longer accurate.

[28] https://tpwd.texas.gov/fishboat/fish/didyouknow/coastal/reddrum.phtml
[29] https://eol.org/

Overall Recommendation

The overall updated 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 (0–10)	Rank	Critical?
	C1 Data	8.41	GREEN	
Reviewed	C2 Effluent	9.00	GREEN	NO
Updated	C3 Habitat	8.00	GREEN	NO
Reviewed	C4 Chemicals	8.00	GREEN	NO
Updated	C5 Feed	3.83	YELLOW	NO
Reviewed	C6 Escapes	8.00	GREEN	NO
Updated	C7 Disease	6.00	YELLOW	NO
Reviewed	C8 Source	0.00	GREEN	
Reviewed	C9X Wildlife mortalities	–3.00	GREEN	NO
	C10X Introduced species escape	0.00	GREEN	
	Total	**48.23**		
	Final score	**6.89**		

OVERALL RANKING

Final Score	6.89
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO
FINAL RANK	**BEST CHOICE**

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