Red swamp crayfish

Procambarus clarkii

United States

Ponds

July 5, 2022

Report ID 696

Disclaimer

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About Seafood Watch

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

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

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

Guiding Principles

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

The following guiding principles illustrate the qualities that aquaculture farms must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture farms and collective industries, by design, management and/or regulation, address the impacts of individual farms and the cumulative impacts of multiple farms at the local or regional scale by:

1. **Having robust and up-to-date information on production practices and their impacts available for analysis;**
   Poor data quality or availability limits the ability to understand and assess the environmental impacts of aquaculture production and subsequently for seafood purchasers to make informed choices. Robust and up-to-date information on production practices and their impacts should be available for analysis.
2. **Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level;**
   Aquaculture farms minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges.
3. **Being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats;**
   The siting of aquaculture farms does not result in the loss of critical ecosystem services at the local, regional, or ecosystem level.
4. **Limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms;**
   Aquaculture farms avoid the discharge of chemicals toxic to aquatic life or limit the type, frequency or total volume of use to ensure a low risk of impact to non-target organisms.
5. **Sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains;**
   Producing feeds and their constituent ingredients has complex global ecological impacts, and the efficiency of conversion can result in net food gains or dramatic net losses of nutrients. Aquaculture operations source only sustainable feed ingredients or those of low value for human consumption (e.g. by-products of other food production), and convert them efficiently and responsibly.
6. **Preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes;**
   Aquaculture farms, by limiting escapes or the nature of escapees, prevent competition, reductions in genetic fitness, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems that may result from the escape of native, non-native and/or genetically distinct farmed species.

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

7. **Preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites;**
   Aquaculture farms pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites, or the increased virulence of naturally occurring pathogens.
8. **Using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture;**
   Aquaculture farms use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture, or where farm-raised broodstocks are not yet available, ensure that the harvest of wild broodstock does not have population-level impacts on affected species. Wild-caught juveniles may be used from passive inflow, or natural settlement.
9. **Preventing population-level impacts to predators or other species of wildlife attracted to farm sites;**
   Aquaculture operations use non-lethal exclusion devices or deterrents, prevent accidental mortality of wildlife, and use lethal control only as a last resort, thereby ensuring any mortalities do not have population-level impacts on affected species.
10. **Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals;**
    Aquaculture farms avoid the international or trans-waterbody movements of live animals, or ensure that either the source or destination of movements is biosecure in order to avoid the introduction of unintended pathogens, parasites and invasive species to the natural environment.

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

Best Choices/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

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

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Criterion	Score	Rating	Critical?
C1 Data	6.14	YELLOW	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	8.80	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	8.85	GREEN	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	-1.00	GREEN	NO
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Introduction of secondary species	0.00	GREEN	
Total	**51.79**		
Final score (0-10)	**7.40**		

OVERALL RATING

Final Score	7.40
Initial rating	GREEN
Red criteria	0
Interim rating	GREEN
Critical Criteria?	NO

FINAL RATING
GREEN

Scoring note – scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects a very significant impact. Two or more Red criteria result in a Red final result.

Summary

The final numerical score for crayfish produced in pond systems in the United States is 7.40 out of 10 which is in the Green range. There are no Red criteria. The final recommendation is a Green "Best Choice".

Executive Summary

This Seafood Watch assessment describes the production of crayfish (*Procambarus clarkii*) in ponds in the United States (U.S.). There are 481 crayfish farms in the U.S., producing approximately 72,000 metric tons (mt) annually (72,299 mt in 2019). The large majority of farms (93%) are located in Louisiana with other significant states being Texas (12 farms), South Carolina (5), and North Carolina (5). There are multiple production strategies in place, which include various monoculture and crop-crayfish systems. The U.S. is a minor global producer of crayfish (China produced 96.7% of the global total of 2,161,903 mt in 2019) and U.S. production remains in domestic markets.

This Seafood Watch assessment involves a number of different criteria covering impacts associated with: effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability. With over 90% of farms, this assessment of U.S. production focuses on Louisiana, but also uses information from other states where possible.

Data and information for this assessment are largely from the Louisiana State University Agricultural Center's Crawfish Production manual (LSUAC manual) which has been confirmed as still relevant to the industry through recent expert personal communications. Additional information is available from online databases such as the IUCN and FishStatJ, with and from national and state agencies such as the EPA, and LDFW. As such, the accuracy of available data and information is considered to be relatively high, and provide a reliable description of any potential impacts from crayfish farming practices. The final score for Criterion 1 – Data is 6.14 out of 10.

Crayfish grown in ponds in the U.S. are not provided any external feeds; however formulated and whole-fish baits are used for harvesting crayfish crops. Fertilizer is used to boost production of a commercial or forage crop, which supports invertebrate communities that crayfish feed on. Nitrogen is taken up by crops, and is harvested in the form of protein in crayfish. Ponds have an average annual daily water exchange rate of <3%, and use practices that allow sediments to settle prior to draining, as well as proper sludge removal. As such, approximately 14 kg of nitrogen per mt of crayfish production leaves the pond as waste. The score for Factor 2.1 is 9 out of 10.

Nonpoint sources of pollution are managed by the Louisiana Department of Environmental Quality, however, while procedural requirements of these management systems are met, the percent of individual waterbody segments (and total area) that support the propagation of indigenous fish and wildlife has decreased in rivers and streams, and estuary and coast from 32% to 25% (32% to 28% of area), and 75 to 60% (65 to 36% of area), respectively between 2014 - 2020 with seemingly no consequence. It is unclear what, if any, role crayfish aquaculture has in this decrease, but the score for Factor 2.2 is 3.6 out of 10 on a precautionary basis. The Final Criterion 2 – Effluent score is 7 out of 10.

Culture of crayfish occurs in habitats previously modified for agriculture. Conversion of former crop fields to produce crayfish (or crayfish and crops) involves minimal construction or disruption of ongoing practices, allowing these previously modified habitats to maintain their functionality. As the inherent requirements of crayfish aquaculture limit production to existing agricultural areas, it is considered that any expansion of the crayfish industry would not result in any loss of habitat functionality. Factor 3.1 scores 10 out of 10. There are no specific regulatory systems that manage the siting of crayfish aquaculture, and zoning codes are established at the municipality scale, with crayfish production occurring exclusively in agricultural areas due to its inherent characteristics, and the likelihood that zoning codes would not permit crayfish aquaculture in zones not designated as agricultural. Both Factors 3.2a and b score 4 out of 5, and Factor 3.2 scores 6.4 out of 10. Overall, crayfish ponds in former agricultural land do not cause loss of habitat functionality, and siting, while not explicitly required to only operate in previously modified agricultural areas, is effectively limited to such areas. The final Criterion 3 – Habitat score is 8.8 out of 10.

Chemicals are not used in the production of crayfish. Occasionally pesticides are applied to rice in crop-crayfish systems, however this is done in a way that avoids any exposure to crayfish, as they are highly susceptible, and is not considered part of crayfish production. The main pathogen affecting crayfish production is WSSV, which is managed through avoidance strategies rather than post-infection chemical treatments. The final numerical score for Criterion 4 – Chemical Use is 10 out of 10.

Crayfish are not fed any external feed during production, but chopped fish and formulated pellets are used as bait in crayfish traps at harvest. As significant amounts of bait may be used during a production cycle (approximately 0.3 lb per trap, often with hundreds of traps deployed consistently for ~8 months of the year), it was determined that the sustainability of bait should be assessed as feed.

The eFCR (i.e., the ratio of the amount of bait use to the amount of crayfish harvested) is calculated as 0.44. As the two types of bait are used in relatively equal amounts throughout a production cycle, each has an individual FCR value of 0.22. The formulated bait does not include any aquatic ingredients, but for chopped fish, the FFER (i.e., the ratio of wild fish used to the amount of crayfish harvested), is effectively the same as the eFCR of 0.22. Both of the most common fish species used for bait are demonstrably sustainable, and the final score for Factor 5.1 – Wild Fish Use is 8.2 out of 10.

The protein input in the form of bait is 68 kg/mt of crayfish harvested, and the protein output in harvested crayfish is 152 kg/mt. There is an overall net protein gain, resulting in a Factor 5.2 score of 10 out of 10. While Global Warming Potential (GWP) values are unavailable for chopped fish, general values are available for the ingredients in the formulated bait, which result in a small GWP value of 2.16 kg CO_2 equivalent per kg crayfish protein. This results in a

Factor 5.3 score 9 out of 10. Overall, with the only "feed" inputs being bait at harvest, the three factors combine to result in a final score for Criterion 5 – Feed (bait) of 8.85 out of 10.

Multiple strategies are used to reduce the risk of escape of crayfish from ponds in the U.S., particularly with regard to their location and construction to minimize burrowing or flood losses. Due to low average daily exchange rates (and the use of screens), the risk of crayfish escaping during water drainage is also low. Crayfish are native in Louisiana (and in other states where they are farmed) and those stocked in each type of production system are collected from the wild, as well as from other ponds. There is no selective breeding and they are unlikely to be genetically distinct from wild populations; therefore, they do not pose a genetic threat to wild populations in the event of an escape. As farmed population densities are similar to those in the wild, even a substantial escape event would not result in additional pressure on wild populations. As the risk of escape is low, and the likelihood of impact to wild populations from any escaped, farmed crayfish is minimal, the final score for Criterion 6 – Escapes is 10 out of 10.

Historically disease outbreaks have not been a significant concern for crayfish producers. In 2007 WSSV was first identified in the region, and while it is present in both wild and farmed crayfish populations, and results in annual infections, it has not resulted in any notable losses for the industry (for example, a 2009 study showed 111 infected sites, with only 13 (11.7%) showing clinical signs of disease). WSSV has several wild and cultured hosts in the U.S., and the possibility of transferring the virus from crayfish farms to important wild stocks such as Penaeid shrimp in the Gulf of Mexico is acknowledged. Management of WSSV occurs at the farm scale, mainly consisting of preventative measures, and infection is not considered to be characteristic of "typical" crayfish production. Reinfection in the same ponds over consecutive production cycles is rare in the crayfish industry. Farmed population densities are within the range of densities found in the wild, and cultured environments mimic natural ecosystems. Therefore, production practices are considered to have a low risk of amplification WSSV (or any other pathogens or parasites) compared to natural populations. As management measures result in low, temporary, and relatively infrequent occurrences of infection and mortality at the typical farm level, the final score for Criterion 7 – Disease is 6 out of 10.

The percentage of total crayfish production that is reliant on annual restocking of crayfish from the wild is estimated to be ≤15% annually, mainly consisting of ongoing restocking of rice-crayfish-soy/fallow culture systems. The wild crayfish population is considered to have a low vulnerability to fishing activities and is not considered to be overfished or depleted; similarly, the IUCN considers the species to be of "Least Concern" and to be increasing. As such, the sustainability of wild crayfish populations is considered to be of low concern, and their removal from the ecosystem for stocking of new ponds and rice-crayfish-soy/fallow culture systems is considered to have a minimal impact on wild populations. The score for Criterion 8X is a deduction of -1 out of -10.

Many types of wildlife can interact with crayfish ponds, with the most common including fish, amphibians, "fur-bearing" mammals, and birds. As the area covered by ponds is often expansive, netting and fencing is not an economically viable option for farmers, excluding the possibility of accidental mortalities due to entanglements. Of the species commonly attracted to crayfish ponds, birds are considered to have the largest impact to crayfish stock volumes, while mammals can cause damage to pond structures and equipment. In Louisiana fur-bearing mammals can be shot or trapped without a license if they are consuming crayfish or damaging property. The number of mortalities is unknown, however the effort to shoot or trap predators is generally considered to not be worth the losses they cause, and lethal measures are rarely used. Most bird species that interact with crayfish farms are federally protected and cannot be killed, however permits can be obtained for the "take" of double-crested cormorants in the event that non-lethal deterrents are unsuccessful, and an assessment by a representative from the USDA determines that damage is being done to the farm. All double-crested cormorant mortalities must be reported, and the total number of mortalities is capped by geographic sub-regions in Louisiana based on the findings of a PTL model included in an Environmental Impact Assessment completed in 2020. The final numerical score for Criterion 9X – Wildlife Mortalities is -4 out of -10.

Production of crayfish does not rely on international or trans-waterbody movements. Monoculture and rice-crayfish double crop models are self-sustaining, and do not rely on restocking at the start of each cycle. rice-crayfish-soy/fallow culture is reliant on restocking at the start of each cycle, however crayfish stocked are either from local ponds, or collected from ecosystems adjacent to the ponds. As such, Criterion 10X – Escape of Unintentionally Introduced Species has a deduction of 0 out of -10.

The final numerical score for crayfish produced in pond systems in the United States is 7.40 out of 10 which is in the Green range. There are no Red criteria. The final recommendation is a Green "Best Choice".

Introduction

Scope of the analysis and ensuing recommendation

Species
Red swamp crayfish (*Procambarus clarkii*)

Geographic Coverage
United States

Production Method(s)
Ponds

Species Overview

Brief overview of the species
The red swamp crayfish (*Procambarus clarkii*) is native to northern Mexico and the southern, eastern and central United states (McClain and Romaire, 2007). It has been introduced in other areas of the United States, as well as many areas in South America, Europe, Asia and Africa (ibid). It inhabits freshwater environments such as rivers, lakes, streams and ponds, where it feeds on insects, larvae, and detritus and will burrow into sediments during periods of drought and cold. Spawning can occur in open water; however, burrows are often used to protect eggs and early juvenile stages (Ibid.). It has an elongated body shape, with a rough outer shell in adults, and multiple strong spines. Adults are a dark red color, sometimes with shades of brown and a black stripe on the abdomen. Juveniles are grey, sometimes with wavy dark lines (Ibid.).

Production system
Robust information that details contemporary production systems for crayfish in the United States is not readily available, but older literature (e.g., the Louisiana Crawfish Production Manual; LSUAC, 2007) has been supported by recent personal communication with an industry expert (Pers. comm., Lutz, 2021), to show there continues to be multiple strategies for the culture of crayfish in the United States. The three primary production systems are described below, and include monoculture (crayfish production only) and two types of combined crop-crayfish systems (rice-crayfish double crop, and rice-crayfish-soy/fallow). Throughout the assessment, the term “crop-crayfish” refers to both rice-crayfish double crop and rice-crayfish-soy/fallow as applicable (e.g., Criterion 4 – Chemical use).

<u>Monoculture crayfish</u>: These are the most commonly used systems in the United States, with 83% of farmers using at least some ponds solely dedicated to crayfish production (Gillespie, Guidry and Boucher, 2012). Ponds range from large (>300 acres) extensive impounded wetland ponds to smaller (<15 acres) intensively managed ponds (LSUAC, 2007). A forage crop such as rice may be planted in monoculture crayfish pond systems, however it is not harvested for commercial purposes; only provided as a source of feed and shelter for crayfish (ibid.). In some

cases, forage crops are not planted, and natural vegetation provides feed and shelter for crayfish. While the largest percentage of farmers use at least some monoculture ponds (83%), they only cover approximately 38% of the total crayfish production area, as monoculture practices tend to be relatively intensively managed in a smaller area (Gillespie, Guidry and Boucher, 2012). Monoculture systems develop self-sustaining crayfish populations, and do not rely on restocking after the pond is initially stocked after construction.

Crop-crayfish systems (rice-crayfish double crop; rice-crayfish-soy/fallow)

There are multiple strategies for the co-culture of crayfish and agricultural crops in the U.S. While stocking density and management intensity can vary, a general rule of these systems is that they are managed for commercial harvests of both crayfish and crops (most often rice). Two such systems are included here: rice-crayfish double crop, and rice-crayfish-soy/fallow.

- Rice--crayfish double crop systems
  In this system, there is a continuous production (adjusted seasonally) of crayfish and rice. 28% of farmers use rice-crayfish double crop systems, and they represent 26% of the total U.S. crayfish production area (Gillespie, Guidry and Boucher, 2012). These systems develop self-sustaining crayfish populations, and do not rely on restocking after the pond is initially stocked after construction.
- Rice-crayfish-soy/fallow systems
  This production strategy includes rice-crayfish-fallow, and rice-crayfish-soybean systems, in which farmers rotate the use of fields in order to produce 3 yields in a 2-year period. Rice-crayfish-fallow systems account for approximately 27% of farmers, and cover 26% of crayfish farming area, while rice-crayfish-soybean culture systems are used by 7% of farmers, and cover 10% of crayfish farming area (Gillespie, Guidry and Boucher, 2012). These systems rotate the physical location of crayfish production with each cycle, therefore farmed populations are unable to become self-sustaining, and must be restocked each cycle.

In each of these systems, existing rice fields are converted to accommodate crayfish co-culture, often requiring the addition of levees around the pond border that are wide enough to avoid seepage caused by crayfish burrows (9 feet wide at the base), and tall enough to avoid the entry of flood waters (minimum of 3 feet tall) (LSUAC, 2007; Pers. comm., Lutz, 2021). Smaller levees are constructed within the paddy area to assist with guiding water through the system to manage aeration of the water, and canals can be constructed around the perimeter to recirculate water and minimize discharge (ibid.). It is unclear how common recirculation techniques are used, or what the recirculation rate is.

In all systems, harvest of crayfish is done using traps holding formulated bait and/or chopped whole fish. Harvest season is ongoing between November and April-June with regular collection and redeployment of traps during this period. Approximately 67% of a cycle’s crayfish are harvested between March-June, however earlier in the harvesting season is when mature, adult crayfish from the previous cycle are harvested.

Crayfish yields per acre can vary widely according to stocking densities and the rates of growth and reproduction in the ponds. In monoculture pond systems, crayfish densities range from <1 – 20 crayfish per square meter (Pers. comm., Lutz, 2021), and large extensive ponds yield approximately 0.09 mt/acre, while smaller and more intensive ponds can yield 0.54 – 1.13 mt/acre (LSUAC, 2007).

Yields in crop-crayfish systems vary based on the management focus (rice or crayfish). A rice-crayfish double crop system that is managed for crayfish can produce similar yields to those from intensively managed crayfish monoculture, but doing so will produce less rice (LSUAC, 2007). This balance is often decided based on the expected market price for each product, as well as the expected recruitment rate of crayfish in the pond. Yields from rice-crayfish-soy/fallow systems are usually lower than those from monoculture systems but can produce >0.41mt/acre (ibid.).

Production Statistics

In 2018 there were 481 farms producing crayfish in the U.S.; of these farms, 449 (93%) we in Louisiana. Other states with 5 or more farms include Texas (12), South Carolina (5), and North Carolina (5) (USDA, 2019). There do not appear to be any publicly available national crayfish production statistics published in the U.S., but in 2019, the FAO (FishStatJ, 2021) reported a total U.S. harvest of 72,299 mt crayfish. Based on the number of farms it can be estimated that 67,238 mt of this total were produced in Louisiana (i.e., 93% of the total). As such a large portion of crayfish produced in the U.S. are from Louisiana, this assessment focuses heavily on production from this state. Annual U.S. production figures from 2000 to 2019 (for farmed and wild crayfish) are shown in Figure 1

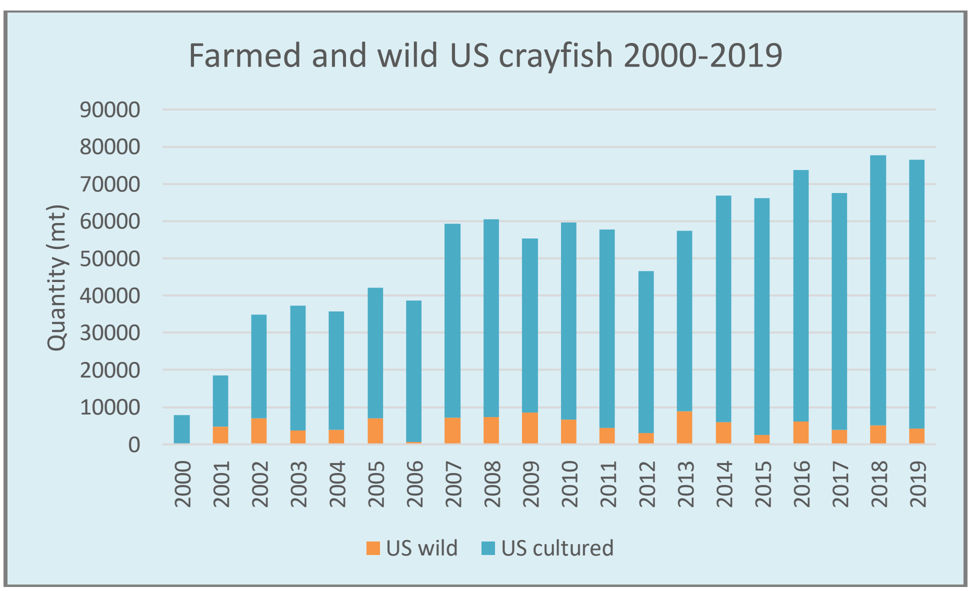

Figure 1. Farmed and wild U.S. crayfish 2000-2019

Source: FishStatJ, 2021; NOAA Fisheries, 2021

Globally, China is the dominant producer of *P. clarkii*; in 2019 a global total of 2,161,903 mt was produced, of which 2,089,604 mt (96.7%) was produced in China (FishStatJ, 2021). Chinese production expanded rapidly in the late 2000's, dwarfing U.S. production, and has continued to grow rapidly (Figure 2).

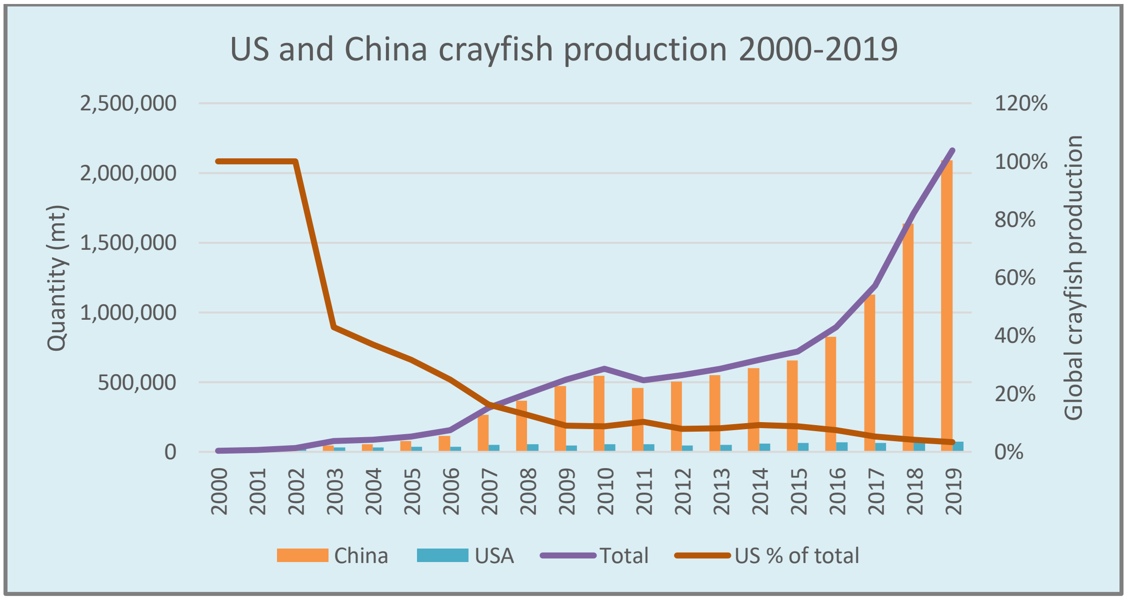

Figure 2. U.S. and China crayfish production 2000-2019
Source: FishStatJ, 2021

Import and Export Sources and Statistics
The majority of crayfish produced in the United States (both wild captured and farmed) is consumed domestically. Since 2000 the U.S. has only exported >30% of its production on two occasions (57% in 2002, and 51% in 2017), as shown in Figure 3 (NOAA Fisheries, 2021). Data were not available to specify what portion of this export was cultured or wild captured, although as shown in Figure 1, the majority of crayfish production in the U.S. is cultured.

The two most consistent export markets for U.S. crayfish are Mexico and China, which have imported totals of 737.1 mt and 374.5 mt respectively between 2000-2020. During this same timeframe, Chile and Sweden imported totals of 254.9 mt and 213 mt, respectively, however there were only two years in which imports from the U.S. occurred to these countries (2018-2019 for Chile, 2002-2003 for Sweden), with no other imports. While other countries imported U.S. crayfish, none imported >70 mt total over the course of 20 years (NOAA Fisheries, 2021).

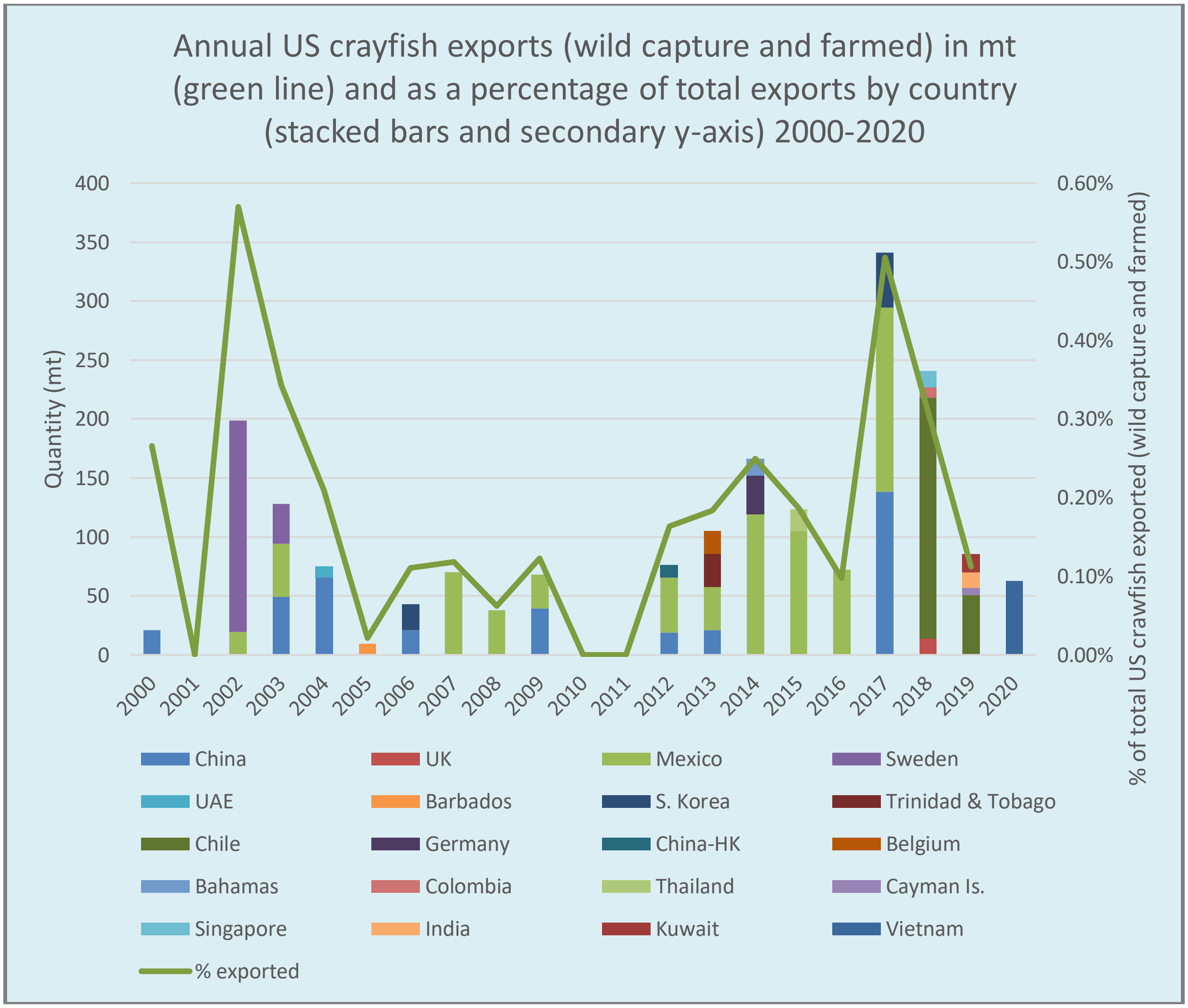

Figure 3. Annual U.S. crayfish exports (wild capture and farmed) in mt (green line) and as a percentage of total exports by country (stacked bars and secondary y-axis) 2000-2020
Source: NOAA Fisheries, 2021

The U.S. also imports crayfish from several countries. The most consistent source of imports is China, totaling 61,434 mt between 2010-2020, followed by Spain which exported 8,342 mt to the U.S. during the same time period (NOAA Fisheries, 2021). It is unclear which species are included in these statistics, and it is unknown whether they were farmed or wild captured (although it can be assumed that crayfish imported from China are farmed *P. clarkii*). Additionally, the U.S. has imported smaller quantities from Japan consistently between 2010 - 2020 (total 1037 mt), with smaller, less consistent imports from Canada, Turkey, Egypt and Argentina during this time period as well (ibid.). While other countries have exported crayfish to the U.S., those that exported totals <20 mt between 2010 – 2020 are not included in these statistics.

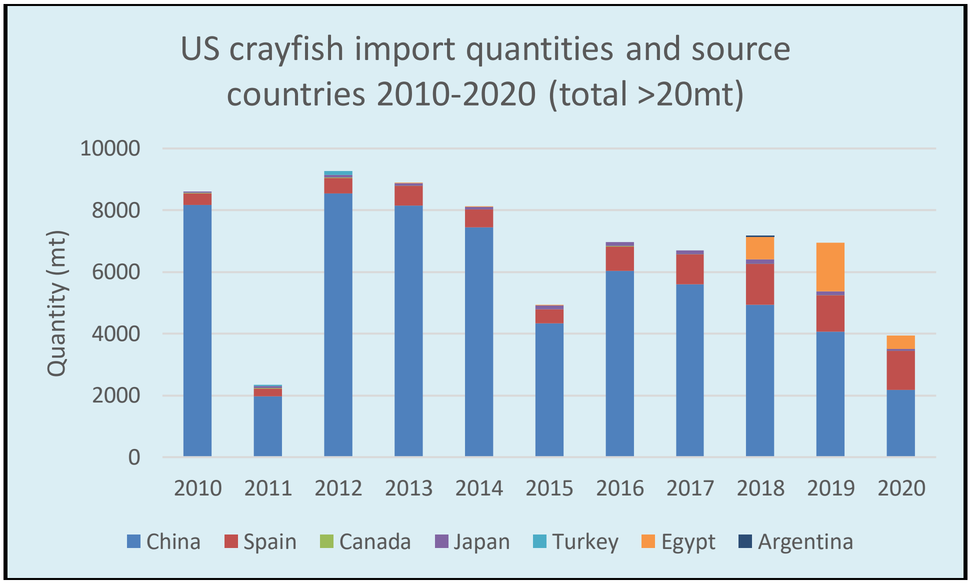

Figure 4. U.S. crayfish import quantities and source countries 2010-2020 (total >20 mt)
Source: NOAA Fisheries, 2021

Common and Market Names

Scientific Name	*Procambarus clarkii*
Common Name	Red swamp crawfish, Red swamp crayfish, crawfish, crawdad, mudbug.

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 or enable businesses to be held accountable for their impacts.
- *Unit of sustainability*: The ability to make a robust sustainability assessment.
- *Principle*: Having robust and up-to-date information on production practices and their impacts available for analysis.

Criterion 1 Summary

C1 Data Category	Data Quality (0-10)
Production	5.0
Management	5.0
Effluent	5.0
Habitat	7.5
Chemical Use	7.5
Feed	5.0
Escapes	7.5
Disease	2.5
Source of stock	7.5
Wildlife mortalities	5.0
Introduction of secondary species	10.0
C1 Data Final Score (0-10)	**6.14**

Brief Summary

Data and information for this assessment are largely from the Louisiana State University Agricultural Center's Crawfish Production manual (LSUAC manual) which has been confirmed as still relevant to the industry through recent expert personal communications. Additional information is available from online databases such as the IUCN and FishStatJ, with and from national and state agencies such as the EPA, and LDFW. As such, the accuracy of available data and information is considered to be relatively high, and provide a reliable description of any potential impacts from crayfish farming practices. The final score for Criterion 1 – Data is 6.14 out of 10.

Justification of Rating

As described below, there is little readily accessible and up-to-date published information on the U.S. crayfish industry. As such, older information has been used where available, and checked for current relevance with expert personal communication. An example is the relatively comprehensive information available in the Louisiana Crawfish Production Manual from the Louisiana State University Agriculture Center (LSUAC, 2007); this was published in 2007, but has been confirmed as largely representative of ongoing practices by a current academic industry expert at the LSUAC (Pers. comm., Lutz, 2021). Other academic and grey literature sources, government agency databases, and personal communications have provided additional data and information to triangulate and further confirm information in the 2007 LSUAC manual, and fill in gaps as needed.

Industry or production statistics
Information describing the size of the industry, aggregated production volumes, species and production methods is readily available through literature and FAO statistics on aquaculture production. These sources do not specify volumes of crayfish produced using different production systems, however estimates of the percent of farmers and the percent of acreage used for each are available. While the literature describing these percentages is old (2007), personal communication confirms the values are still similar. While some aggregation has taken place, data give a reliable representation of the industry. The Data score for Production is 5 out of 10.

Management and regulations
Understanding the regulatory system for aquaculture within the U.S. is challenging. With regard to siting, the industry is relatively self-governing, and is limited by the environmental requirements of crayfish; as such there is no readily available data on any siting requirements for crayfish farms within existing agricultural landscapes. Water quality management measures are available from the U.S. Environmental Protection Agency (EPA), and evidence of enforcement monitoring is available through the How's My Waterway database[2]. A list of authorized chemicals is available from U.S. Food and Drug Administration. This information is further confirmed in published literature as well as personal communications. With regard to management measures for wildlife interactions, the regulations in place to describe allowable "take" of fur-bearers and certain bird species are available from the U.S. Fish and Wildlife Service, the U.S. Department of the Interior, the Louisiana Revised Statutes, and the Louisiana Department of Fish and Wildlife. Mortality records for any species are not available, although information on the population status of most relevant species can typically be found (e.g., from IUCN). Without an accessible and comprehensive understanding of the management measures and their enforcement, the Data score for Management is 5 out of 10.

Effluent
Crayfish farms are managed as non-point sources, and as such do not have farm-specific effluent discharge limits. Instead, waterways in surrounding areas are allocated Total Maximum Daily Loads of pollutants by the EPA based on their designated use. These TMDLs are monitored, and long-term plans for improvement are available on the EPA's How's My Waterway database. While the status and health of surrounding waterway segments is publicly available, these segments are not necessarily developed or assessed at a cumulative scale, nor

[2] https://mywaterway.epa.gov/

do they specify whether crayfish farming contributes to their impaired status. As such, the Data score for the Effluent criterion is 5 out of 10.

Habitat

Information about the habitat type, general locations of farms (at the state or watershed level), and history of habitat conversion is available in peer-reviewed literature as well as grey literature (e.g., USDA, 2019). Specific locations of some individual farm sites are available through the website of the Louisiana Crawfish Promotion and Research Board[3], and can be located using Google Maps. As farms are sited in agricultural zones which were historically modified for non-aquaculture purposes, habitat monitoring is not carried out. Additionally, regulatory measures are not in place that designate siting requirements. Crayfish aquaculture is relatively self-regulating in that its requirements essentially limit it to agricultural areas, and data availability on any habitat impacts is inherently limited. As such, the limited available information is considered to give a reliable description and understanding of the fundamental habitats and ecosystems in which the crayfish industry operates, as well as maintenance of previously modified habitat function. The Data score for the Habitat criterion is 7.5 out of 10.

Chemical Use

Older information about typical (lack of) chemical use in rice-crayfish double crop and rice-crayfish-soy/fallow systems is available in grey literature such as production manuals for crayfish farming in both Louisiana and Alabama (from 2007 and 2012), as well as a study outlining financial requirements of these systems. Perhaps the most relevant information is the lack of any approved chemicals for use in crayfish farming by the U.S. FDA. Additional information about the use of chemicals applied to crops in rice-crayfish double crop and rice-crayfish-soy/fallow systems was provided through personal communication with Greg Lutz, an industry expert with the LSUAC. Given the apparent lack of chemical use in crayfish farming, the lack of current data on their use is not surprising, and the available data and information provide a reliable representation of the use of chemicals in rice-crayfish double crop and rice-crayfish-soy/fallow systems. The Data score for the Chemical use criterion is 7.5 out of 10.

Feed

While crayfish are not provided external feed, chopped fish and formulated pellets are used as bait in traps at harvest, and assessed here as "feed". Feed Conversion Ratio (FCR) values are calculated using information from the Southern Regional Aquaculture Center (in Gillespie, Guidry and Boucher, 2012). This information is old; however, it is considered still descriptive of current practices (Pers. comm., Lutz, 2021). The basic ingredients of formulated bait pellets are available from the primary supplier (Purina). Purina confirmed by email that fishmeal and fish oil are not ingredients. Information describing the population status of the most common bait species is available from up-to-date sources including the Sustainable Fisheries Partnership FishSource database, the IUCN, and Louisiana list of threatened and endangered species. The available data and information leave some uncertainties in key figures about ingredients included in bait. As such, the Data score for the Feed (Bait use) criterion is 5 out of 10.

[3] https://crawfish.org/

Escapes

Information describing measures used to minimize the risk of escapes is readily available in the Louisiana Crawfish Production Manual (LSUAC, 2007). As noted above, while this information is old, it has been confirmed that it still represents current practices (Pers. comm., Lutz, 2021). Numbers of escaped crayfish, and escape events are not recorded. The native status of *P. clarkii* in Louisiana and other states is available from McClain and Romaire, (2007). Population densities in ponds, as well as information describing stocking strategies was available from LSUAC (2007). Personal communication with an academic expert at LSUAC provided information about the densities of wild populations of crayfish. Available information provides a reliable representation of the potential impact of escaped, farmed crayfish on wild populations. As such, the Data score for the Escapes criterion is 7.5 out of 10.

Disease

Historically disease has not been a large concern for the crayfish industry in the U.S., however the history and prevalence of WSSV in both wild and farmed crayfish populations is described in peer reviewed journal articles, as well as the LSUAC crayfish manual. While some articles are relatively dated, personal communication with an industry expert at the LSUAC has provided more up to date information on the prevalence of WSSV, and management strategies used by the industry. Population densities in both ponds and the wild (and subsequent likelihood of disease amplification and retransmission), were provided by the LSUAC manual and personal communication, respectively. Available information is currently not sufficient to give confidence that the potential impacts of the industry are well understood. As such, the Data score for the Disease criterion is 2.5 out of 10.

Source of Stock

Information describing the sources and typical stocking practices of crayfish are available in the Louisiana Crawfish Production Manual (LSUAC, 2007), and a confirmation of current practices (including an estimate of the percentage of production reliant on stocking from wild sources) was obtained from the same industry expert ((Pers. comm., Lutz, 2021). Information describing the status of wild populations is available from a Seafood Watch fishery assessment of *P. clarkii* (Wadsworth, 2020), as well as a listing by the IUCN (Crandall, 2010). This information gives a generally reliable representation of the stocking practices and the sustainability of wild sources of stock, and the data score for the Source of Stock criterion is 7.5 out of 10.

Wildlife Mortalities

Information describing the common types of interactions between wildlife and crayfish farming operations is available in the LSUAC manual, as well as the species most often involved. Regulatory requirements and management strategies are described in national and state legislation, as well as guidance for best management on farms. Records of interactions with mammals are not maintained, however records specific to interaction with double-crested cormorants are kept, but are not publicly available. Up-to-date information (≤6 years old) describing the population status of all potentially impacted wildlife species is available through the IUCN and the Louisiana Department of Fish and Wildlife, among others. While not all interactions are recorded, up-to-date information about population status of potentially impacted species provides a reliable representation of the potential impact of crayfish farming. This provides useful information, but uncertainty remains as to whether data fully represent farming operations. As such, the data score for the Wildlife interactions criterion is 5 out of 10.

Introduction of Secondary Species

Both personal communication and grey literature provide information describing movements of crayfish to support the industry. As no trans-waterbody or international movements occur, no information describing biosecurity protocols at the source and destination were assessed. Data provide a high level of confidence that the operation and potential impacts are understood. As such, the data score for Introduction of secondary species criterion is 10 out of 10.

Conclusions and Final Score

There is very little readily available recent data and information on crayfish production in the U.S.; however, older literature (for example the 2007 Louisiana Crawfish Production Manual from the Louisiana State University Agriculture Center) has been used in consultation with an industry expert from the university to confirm its relevance to current practices. As such, production practices are considered to be relatively well understood. Additional information is available from national and state agencies such as the EPA, and LDFW, in addition to online databases such as the IUCN and FishStatJ, but robust monitoring data of relevance to many criteria assessed here remain very limited. As such, the reliability of available data and information is considered to be moderate, providing a somewhat limited description of potential impacts from crayfish farming practices. The final score for Criterion 1 – Data is 6.14 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 per unit of production. The combined discharge of farms, groups of farms or industries contribute to local and regional nutrient loads.
- *Unit of sustainability*: The carrying or assimilative capacity of the local and regional receiving waters.
- *Principle*: Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Effluent Risk-Based Assessment

Effluent parameters		Value	Score
F2.1a Waste (nitrogen) production per of fish (kg N ton-1)		195.56	
F2.1b Waste discharged from farm (%)		14	

F2 .1 Waste discharge score (0-10)		9
F2.2a Content of regulations (0-5)	3	
F2.2b Enforcement of regulations (0-5)	3	
F2.2 Regulatory or management effectiveness score (0-10)		3.6
C2 Effluent Final Score (0-10)		7.00
Critical?	NO	**GREEN**

Brief Summary

Crayfish grown in ponds in the U.S. are not provided any external feeds; however formulated and whole-fish baits are used for harvesting crayfish crops. Fertilizer is used to boost production of a commercial or forage crop, which supports invertebrate communities that crayfish feed on. Nitrogen is taken up by crops, and is harvested in the form of protein in crayfish. Ponds have an average annual daily water exchange rate of <3%, and use practices that allow sediments to settle prior to draining, as well as proper sludge removal. As such, approximately 14 kg of nitrogen per mt of crayfish production leaves the pond as waste. The score for Factor 2.1 is 9 out of 10.

Nonpoint sources of pollution are managed by the Louisiana Department of Environmental Quality, however, while procedural requirements of these management systems are met, the percent of individual waterbody segments (and total area) that support the propagation of indigenous fish and wildlife has decreased in rivers and streams, and estuary and coast from 32% to 25% (32% to 28% of area), and 75 to 60% (65 to 36% of area), respectively between 2014 - 2020 with seemingly no consequence. It is unclear what, if any, role crayfish aquaculture has in this decrease, but the score for Factor 2.2 is 3.6 out of 10 on a precautionary basis. The Final Criterion 2 – Effluent score is 7 out of 10.

Justification of Rating

While data describing the pollutant status of watersheds in Louisiana are available through the EPA's How's My Waterway database[4], the exact locations and discharge strategies of farms are largely unavailable. Therefore, while it is possible to assess the health of waterbodies in Louisiana, it is unclear which of these may potentially be affected by discharge from crayfish production, or to what extent. As such, the risk-based assessment option is used.

Factor 2.1 Waste discharged per ton of fish production

Factor 2.1a – Biological waste production per ton of fish

With regard to nutrient inputs to the farming system, crayfish grown in ponds in the U.S. are not provided any external feed; however fertilizer may be applied (in crayfish monoculture to encourage growth of a forage crop, and in rice-crayfish or rice-crayfish-soy/fallow culture to support the growth of rice or other crops), and the frequent (often daily) harvesting includes the use of bait (in the form of formulated pellets and/or whole fish).

[4] See footnote 2

Rice-crayfish double crop, and rice-crayfish-soy/fallow systems

Based on values available in Gillespie, Guidry and Boucher, (2012), nitrogen in fertilizer is applied to rice-crayfish double crop and rice-crayfish-soy/fallow systems at a rate of approximately 56.7 kg per acre (140.05 kg/ha), and approximately 0.27 mt of crayfish are produced per acre (0.67 mt/ha) (ibid.); therefore, fertilizer nitrogen is applied at a rate of 209.03 kg/mt of crayfish production. It is estimated that 0.12 mt of bait is used to harvest 0.27 mt of crayfish per acre (0.30 mt bait/0.67 crayfish/ha) (see Criterion 5 – Feed for more details on the values used here for bait). The protein content of the formulated bait is approximately 14.5%, while the average protein content of whole fish used for bait is considered to be 16.6%. With an approximately 50:50 use of each bait type, the average bait protein content is 15.6% (see Criterion 5 – Feed for more details). Protein is comprised of 16% nitrogen, which means 10.9 kg N/mt is applied to the system as bait. By combining the nitrogen inputs in fertilizer and bait, there is a total nitrogen input of 219.92 kg/mt of crayfish production.

Nitrogen is directly removed from the system in harvested crayfish, and by the rice crops, which can be estimated as follows. Crayfish whole-body protein content is 15.2% (Zaglol and Eltadawy, 2009), which represents 24.3 kg N/mt of crayfish if protein contains 16% nitrogen.

Rice crops take up nitrogen at a rate of 100.56 kg/ha (Liu *et al.*, 2019), and therefore approximately at a rate of 150.1 kg N/mt of crayfish produced (it takes approximately 1.49 ha to produce 1mt of crayfish).

With a total nitrogen input of 219.92 kg/mt and removal of 24.32 kg/mt and 150.1 kg/mt in crayfish and rice respectively, this leaves 45.5 kg N/mt in a crayfish pond.

Monoculture systems

In monoculture systems urea (45% nitrogen) is applied at a rate of 15.3 kg N/acre (37.8 kg N/ha), while crayfish are harvested at a rate of 0.27 mt/acre (0.67 mt/ha). Therefore, nitrogen from urea is applied at a rate of 56.32 kg/mt of crayfish production. Harvesting strategies are the same as those in rice-crayfish double crop and rice-crayfish-soy/fallow systems. By combining the nitrogen inputs in urea and bait, there is a total nitrogen input of 67.2 kg/mt of crayfish production.

In monoculture systems rice is not harvested, therefore the only removal of nitrogen from the system is in the form of protein in crayfish, at 24.3 kg N/mt of crayfish. This leaves 42.9 kg N/mt crayfish produced in the pond. As the values for nitrogen remaining in ponds after harvest are similar, (45.5 kg/mt and 42.9 kg/mt for crop-crayfish and monoculture, respectively) the higher of the two values is used for scoring.

<u>Factor 2.1b – Production system discharge</u>

Ponds used for crayfish production are managed to mimic the wet and dry seasons in the natural environment; i.e., they are flooded in the fall, and drained in the spring (LSUAC, 2007;

Pers. comm., Lutz, 2021). Ponds will often be partially drained and re-flooded a few times during the early stage of the cycle when temperatures are still warm in order to manage water quality. For purposes of calculating exchange rates, it is assumed ponds are filled to 7 inches and drained to 4 inches 3 times early in the cycle. When temperatures become cooler, water levels will be increased to approximately 12 inches, and maintained for the winter months. In the spring, ponds will be drained slowly over the course of a few weeks to encourage crayfish to burrow (Pers. comm., Lutz, 2021). While rates will vary, based on the timeline outlined above, average annual daily water exchange rates are low at approximately 0.5%. A low exchange rate (in this case well within the <3% daily exchange rate in the Seafood Watch Aquaculture Standard) allows further breakdown of nutrients in the ponds and it is initially assumed that approximately 42% of waste produced (i.e., 42% of the 45.5 kg N per mt of production in Factor 2.1a) has the potential to leave the farm (per values outlined in the Seafood Watch standard).

The slow draining of ponds in the spring allows sediments to settle rather than be flushed out of pond systems, and additionally, sludge that builds up at the bottom of ponds is often used by farmers to repair levees (Lutz *et al.*, 2011), or as a source of nutrients and burrowing material for rice and crayfish, respectively (Parr, 2002). This results in an additional 28% of waste captured prior to discharge (i.e., 8% for settlement, and 20% for proper sludge removal according to the Seafood Watch standard).

As is noted in Factor 2.1a above, 45.5 kg N/mt of crayfish produced remains in crop-crayfish ponds after harvest, and 42.9 kg N/mt in monoculture systems. Approximately 14% of this is discharged from ponds (42% minus 28%), resulting in a calculated 6.37 and 6.01 kg N (from crop-crayfish and monoculture systems, respectively) leaving farm sites for every mt of crayfish production. Discharged water either enters irrigation canals for further use in agricultural settings, or drainage systems which eventually run to natural water bodies. The characteristics of drainage ditches can significantly impact the distance discharged solids can be carried once they leave the pond setting. Within 268 meters, a deep, vegetated ditch can remove 80% of solids; a shallow, vegetated ditch can remove ~28%, and a dry, unvegetated ditch is unlikely to remove any solids (Parr, 2002). It is unclear what percentage of discharged effluent from crayfish ponds enters each type of drainage system.

Due to the low net discharge of effluent wastes from the ponds, the Factor 2.1a score is 9 out of 10.

Factor 2.2 Management of farm-level and cumulative impacts

<u>Factor 2.2a: Content of effluent management measures</u>

Crayfish ponds are located in agricultural areas; therefore, any wastewater discharge is treated as a non-point source (NPS), and a permit to discharge under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act (CWA) is not required (LDEQ, 2020a).

As 93% of crayfish farms are in Louisiana, it is the focus of this assessment, but it is assumed that similar management and implementation systems are in place in other crayfish-producing states (i.e., it is assumed that although the national Clean Water Act is implemented at the state level, its intended purpose is consistently upheld in all states). In Louisiana, pollution from NPS is managed by the Louisiana Department of Environmental Quality (LDEQ). LDEQ has developed and implemented a NPS Management Plan which includes best management practices for minimizing the impacts of NPS pollution. These include management programs, timetables for implementation of BMPs, and identification of priority watersheds (LDEQ, 2020a).

Development and management of water quality standards in Louisiana is based on ecologically identified ecoregions. These water quality standards serve as the basis for any Total Maximum Daily Loads (TMDL) that are assigned, as well as permitted pollutant limits (LDEQ, 2014). Water quality is assessed for three purposes, and TMDLs are assigned based on whether the water body supports the intended use(s). These uses include Primary Contact Recreation (swimming), Secondary Contact Recreation (Boating), and Fish and Wildlife Propagation [5].

Large amounts of crawfish production occur in the parishes of Vermillion, Acadia, Jeff Davis, St. Landry, Evangeline and Iberia, which are within the Atchafalaya, Gulf Coastal Prairie, and Coastal Chenier Marshes ecoregions. Crayfish production occurs beyond these ecoregions as well, however the majority is within the southwest, south-central, and central areas of the state (Pers. comm., Lutz, 2021). The EPA lists 538 identified waterbody subsegments in Louisiana, of which 334 have one or more TMDL (although some subsegments are listed as impaired, but do not have a TMDL in place) (EPA, 2022). The LDEQ has identified 499 individual TMDLs in place in waterbodies (some subsegments having more than 1 TMDL in place) (LDEQ, 2020; EPA, 2022). In the Atchafalaya, Vermillion-Teche and Mermentau River Basins, where the majority of crayfish production occurs, 12, 44, and 18 subsegments, respectively, are designated for Fish and Wildlife Propagation. Of these, 8 (67%), 9 (20%), and 1 (6%) fully support this intended use, respectively, while the remaining 56do not support fish and wildlife propagation due to impairment (LDEQ, 2020). While some causes of impairment in these subsections are not relevant to crayfish production (e.g., mercury in fish tissue, fecal coliform, etc.), others such as Organic Enrichment/Oxygen Depletion, Total Dissolved Solids, Nutrients, and Turbidity are relevant to the industry. Of the 56 assessed subsegments in these river basins that do not support fish and wildlife propagation, approximately 55 impairments are due to dissolved oxygen, total dissolved solids, nitrate/nitrite, and/or turbidity (among other non-aquaculture related limits). Of these, 29 are suspected to be from natural causes, while 18 are due to unknown causes. Of the remainder, 5 are due to irrigated crop production, 2 are due to non-point sources, and 1 from silviculture harvesting.

[5] Defined by LDEQ as "the use of water for aquatic habitat, food, resting, reproduction, cover, and/or travel corridors for any indigenous wildlife and aquatic life species associated with the aquatic environment. This also includes the maintenance of water quality at a level the prevents damage to indigenous wildlife and aquatic life species associated with the aquatic environment…"

While this cannot be attributed to crayfish aquaculture, the industry operates within this system, which allows long-term timelines for improvement of polluted conditions that impact the propagation of indigenous fish and wildlife. Between 2014 and 2020 there was actually a decrease in the percentage of subsegments and area designated for Fish and Wildlife Propagation that supports this intended use (i.e., water quality in general decreased). This occurred in rivers and streams; as well as estuary and coast, while lakes and wetlands remained relatively constant (see Figures 5-8).

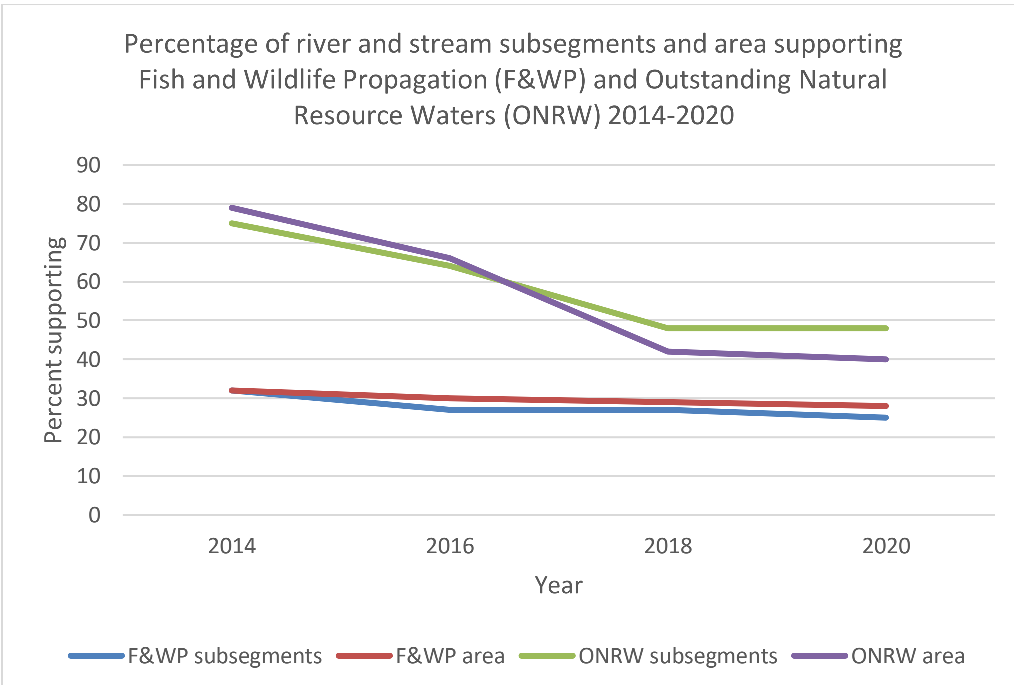

Figure 5: Percentage of river and stream subsegments and area supporting Fish and Wildlife Propagation (F&WP) and Outstanding Natural Resource Waters (ONRW) 2014-2020

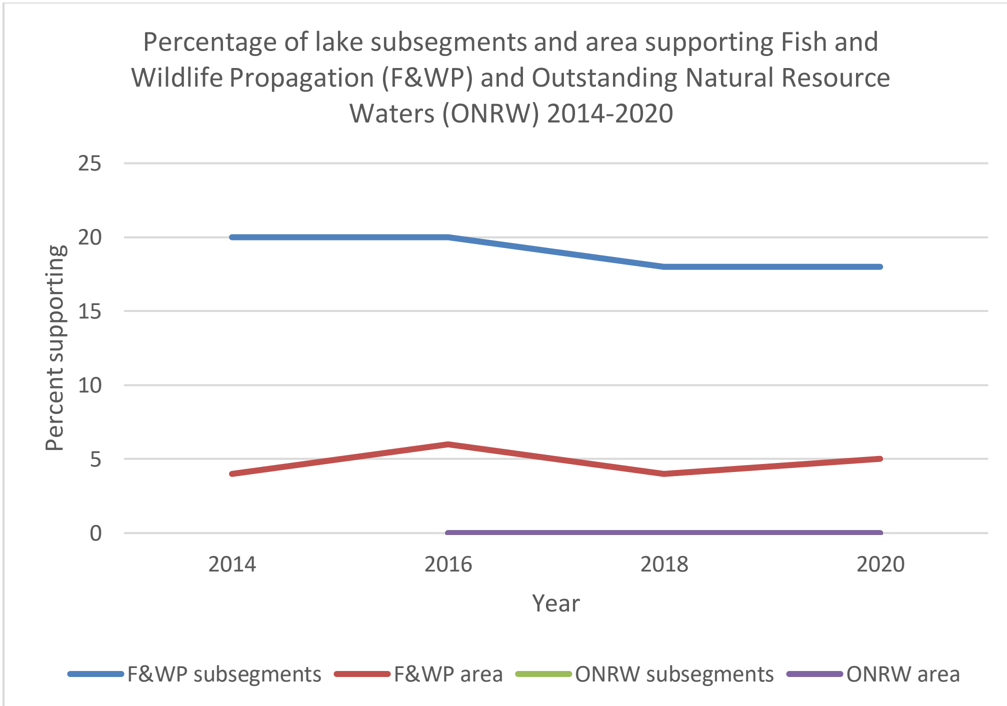

Figure 6: Percentage of lake subsegments and area supporting Fish and Wildlife Propagation (F&WP) and Outstanding Natural Resource Waters (ONRW) 2014-2020

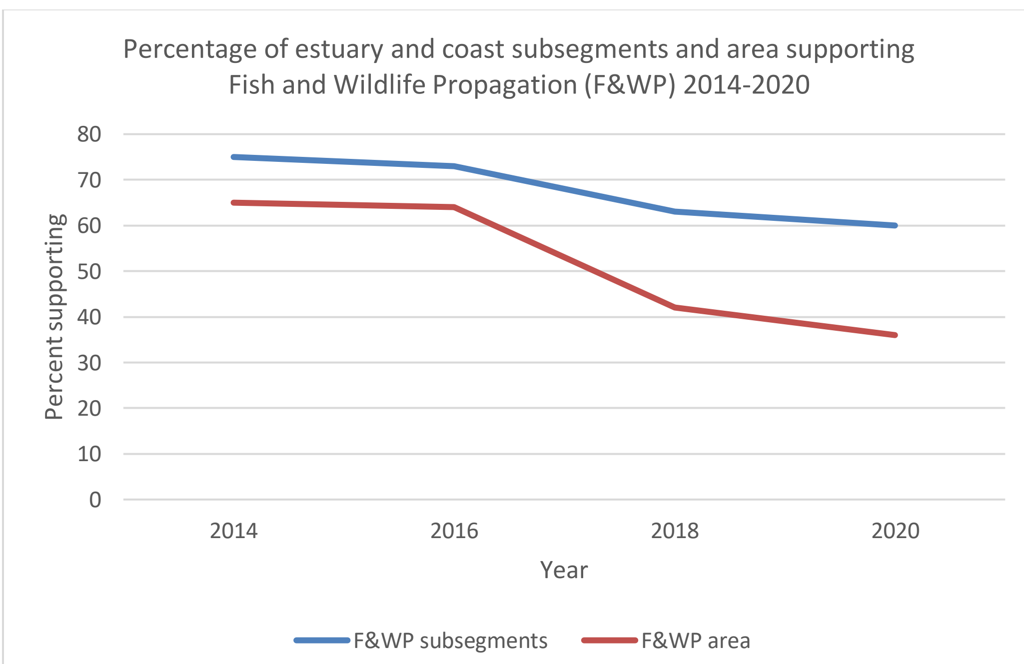

Figure 7: Percentage of estuary and coast subsegments and area supporting Fish and Wildlife Propagation (F&WP) 2014-2020

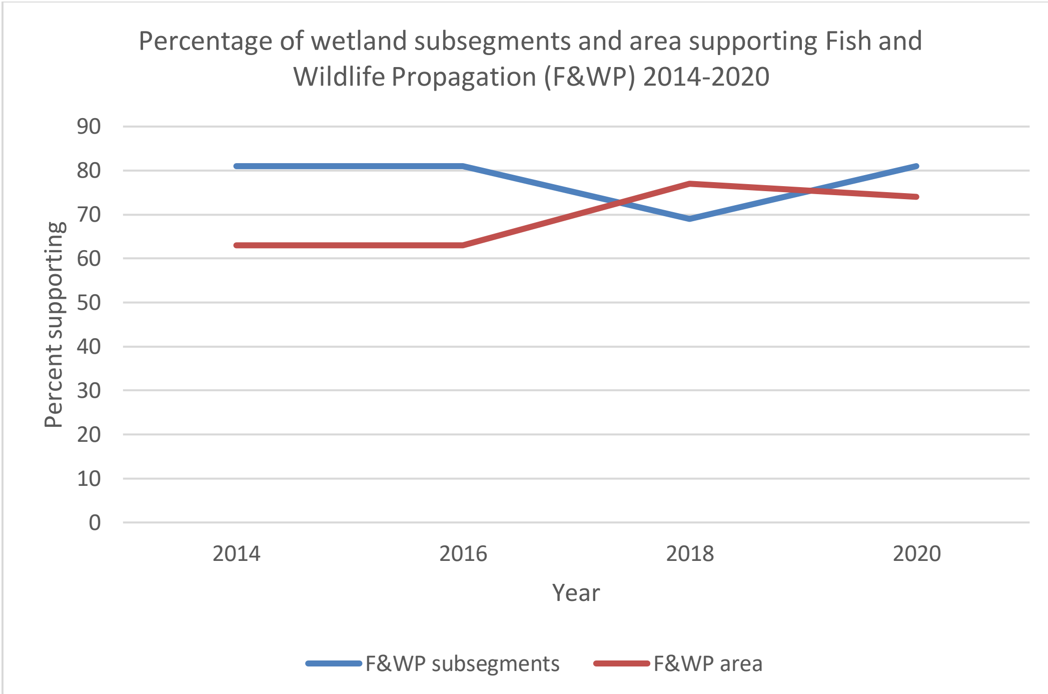

Figure 8: Percentage of wetland subsegments and area supporting Fish and Wildlife Propagation (F&WP) 2014-2020

Neither the CWA nor the Environmental Protection Agency (EPA), which implements NPDES programs at the national scale, has defined or limited the scale of a TMDL (US EPA, 2015b). As such, states' interpretations of "waterbody" can differ (e.g., some states use a watershed approach, while others identify specific segments of larger bodies of water for TMDL allocation). In Louisiana, TMDLs are often applied to very specific segments of a larger body of water (e.g., Vermilion River-From headwaters to LA-3073 bridge). While this approach can be positive in that it can provide pollutant limits and solutions unique to a specific area, it can also result in a lack of coordinated effort at the full waterbody scale. These TMDLs are often implemented in phases, with potentially long timelines for improving water quality for the identified use. However, without information about which specific waterbody subsegments are potentially impacted by crayfish production, the potential contribution of crayfish production to impairment is not possible to identify.

The NPDES program and TMDL system in Louisiana is implemented at the subsegment scale. As such, effluent limits may not account for cumulative impacts to an entire waterbody, and the score for Factor 2.2a is 3 out of 5.

<u>Factor 2.2b: Enforcement of effluent management measures</u>

As mentioned in Factor 2.2a, individual permits are not required for effluent waste discharge from crayfish farming, as agricultural zones in which they are located are considered non-point source areas. Therefore, enforcement of individual permit limits is not applicable. The NPS Management Plan is compliant with procedural requirements of the LDEQ non-point source pollution program (which is compliant with the national Clean Water Act). However, while it is a long-term goal of the NPS Management Plan to improve impaired waters to meet Water Quality Standards, this is done through projects that aim to implement Best Practices for water pollution management issues at the subsegment scale in order to improve water quality in a watershed (LDEQ, 2012). It is therefore assumed that enforcement of these improvement projects will vary, as circumstances and mitigation measures will likely differ from one subsegment to the next. With 499 individual TMDLs in Louisiana, this strategy for implementation of improvement activities is indeed, a long-term one.

As is discussed in Factor 2.2a, the percentages of both area and individual subsegments that are impaired has increased with time. Therefore, a conclusion can be drawn that even if effective enforcement of individual improvement projects is implemented, the system as it currently operates is inadequate for maintaining, let alone improving, water quality in Louisiana. As such, it is considered that enforcement measures are limited, resulting in a Factor 2.2b score 3 out of 5.

Effluent discharge from crayfish operations is managed as a non-point source, and therefore farms are not subjected to discharge permits. Effluents are managed through the TMDL system, which identifies segments of waterbodies, identifies their intended uses, and assigns pollutant levels accordingly. Between 2014-2020 water quality in general decreased, with 56 of 74 segments in major crayfish production parishes not supporting fish and wildlife propagation by 2020. While this cannot be directly attributed to crayfish aquaculture, the industry operates within a system in which implementation and enforcement of water quality management measures is clearly lacking. The Factor 2.2a and 2.2b scores are both 3 out of 5, resulting in a Factor 2.2 score of 3.6 out of 10 for effluent management.

Conclusions and Final Score

Crayfish grown in ponds in the U.S. are not provided any external feeds, however formulated and whole-fish baits are used for harvesting. Fertilizer is used to boost production of a commercial or forage crop, which supports invertebrate communities that crayfish feed on. Nitrogen is taken up by crops, and is harvested in the form of protein in crayfish, but some excess remains. Ponds have an average annual daily water exchange rate of <3%, and use practices that allow sediments to settle prior to draining, as well as proper sludge removal. As such, it is calculated here that 6.37 kg of nitrogen leaves the pond as effluent waste per mt of crayfish production. The score for Factor 2.1 is 9 out of 10. Nonpoint sources of pollution are managed by the Louisiana Department of Environmental Quality, however, while procedural requirements of these management systems are met, the percent of individual waterbody segments (and total area) that support the propagation of indigenous fish and wildlife has decreased. In rivers and streams they have decreased from 32 to 25% (32 to 28% of area) between 2014 – 2020, and in estuary and coast areas from 75 to 60% (65 to 36% of area), seemingly with no consequence. It is unclear what, if any, role crayfish aquaculture has in this decrease, but the score for Factor 2.2 is 3.6 out of 10 on a precautionary basis. The Final Criterion 2 – Effluent score is 7 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact*: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats as well as to the critical "ecosystem services" they provide.
- *Unit of sustainability*: 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		10
F3.2a Content of habitat regulations	4	
F3.2b Enforcement of habitat regulations	4	
F3.2 Regulatory or management effectiveness score		6.40
C3 Habitat Final Score (0-10)		**8.80**
Critical?	NO	**GREEN**

Brief Summary

Culture of crayfish occurs in habitats previously modified for agriculture. Conversion of former crop fields to produce crayfish (or crayfish and crops) involves minimal construction or disruption of ongoing practices, allowing these previously modified habitats to maintain their functionality. As the inherent requirements of crayfish aquaculture limit production to existing agricultural areas, it is considered that any expansion of the crayfish industry would not result in any loss of habitat functionality. Factor 3.1 scores 10 out of 10. There are no specific regulatory systems that manage the siting of crayfish aquaculture, and zoning codes are established at the municipal scale, with crayfish production occurring exclusively in agricultural areas due to its inherent characteristics, and the likelihood that zoning codes would not permit crayfish aquaculture in zones not designated as agricultural. Both Factors 3.2a and b score 4 out of 5, and Factor 3.2 scores 6.4 out of 10. Overall, crayfish ponds in former agricultural land do not cause loss of habitat functionality, and siting, while not explicitly required to only operate in previously modified agricultural areas, is effectively limited to such areas. The final Criterion 3 – Habitat score is 8.8 out of 10.

Justification of Rating

Factor 3.1. Habitat conversion and function

Crayfish production occurs on lands that have been previously modified for agricultural purposes. As shown in Figure 9, crayfish ponds are located within vast areas of agricultural landscape. Crayfish production generally occurs in fields previously dedicated exclusively to rice farming (LSUAC, 2007). Conversion for the inclusion of crayfish often necessitates an increase in the size of external and interior levees to accommodate the burrowing nature of crayfish, as well as increased water depths. These systems often rely on preexisting irrigation and drainage systems in place for irrigation of crops (ibid.).

Crayfish monoculture ponds are similarly constructed, replacing former agricultural land (rice, or other crops). Interior and exterior levees are constructed to withstand the burrowing activity from crayfish, while ensuring minimal seepage, and adequate flow for aeration. Irrigation and drainage systems may or may not be present prior to conversion for crayfish production.

Both crop-crayfish and monoculture crayfish systems rely on vegetation to form the basis of the food web, with plant matter supporting invertebrates, which crayfish consume. In crop-crayfish systems this plant matter is most often rice, which is managed for a commercial harvest. In monoculture vegetation may be rice, which is managed for stem and leaf production rather than grain, or natural vegetation (LSUAC, 2007). As such, crayfish pond systems do not displace vegetation, or result in any loss of function to the previously modified habitat[6].

As crayfish production occurs in areas previously modified for agriculture and results in no loss of habitat functionality, Factor 3.1 scores 10 out of 10.

Figure 9. Crayfish ponds located in Vermilion Parish, Louisiana, showing their location in a historically altered agricultural landscape. Image copied from Google Earth.

[6] There is a body of research available describing the potential benefits to migratory bird species, as well as other wildlife provided by crayfish ponds. As the score for Factor 3.1 is 10 out of 10 based on the maintained functionality of a previously modified habitat, this is not included in the justification of scoring, as it is not an explicit part of the Seafood Watch Aquaculture Standard.

Figure 9.1. Interior of red circled section of Figure 9 above showing baffle levees within crayfish ponds. Source: https://www.google.com/maps

Factor 3.2. Farm siting regulation and management

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

Crayfish culture takes place in previously modified habitat and requires minimal conversion of preexisting exclusive crop fields to accommodate it. Therefore, there is little regulation applicable to the construction or siting of crayfish production systems. While a Section 404 permit from the U.S. Army Corps of Engineers may have been required to regulate dredge and fill operations during the initial conversion of the land into agricultural habitat, one is not required for conversion from exclusive crop land to crayfish culture, as there is an exemption in place for ongoing operations (Tarr, Brown and Rumley, 2013; US EPA, 2015a).

In Louisiana, zoning and land use planning are carried out at the municipal scale, with local municipalities holding the authority to designate zones according to maintenance of the "general welfare of the area" (as opposed to being focused mainly on guiding the economic development of the parish) (Tarr, Brown and Rumley, 2013). The characteristics of crayfish aquaculture (i.e., requiring raising and lowering of water levels with seasonal changes; requiring maintained sources of feed based on management of vegetation, etc.) effectively limit it to operation within agricultural areas, and it is unlikely that crayfish aquaculture would be allowed in areas not zoned for agriculture due to other land uses. Therefore, it is considered that any expansion of crayfish culture will occur only in areas zoned for agriculture. Aside from best management practice recommendations for ensuring proper siting of farms for successful crayfish yields, there are no applicable management requirements for site-selection within previously modified agricultural habitats. A license is required to operate a crayfish farm within an agricultural zone, however licensing is not contingent on any siting requirements (Louisiana Revised Statutes, 2004), as there is minimal new construction or land conversion occurring due to placement in preexisting agricultural areas.

While regulatory management measures do not explicitly require crayfish farms to be sited only in agricultural areas, the nature of crayfish culture systems, and the likelihood that crayfish aquaculture would not be allowed in non-agricultural zoned areas effectively restricts the industry to previously modified agricultural habitats where they would not contribute to any additional cumulative habitat impacts.

While specific regulatory measure with regard to habitat impacts are challenging to determine, the broader management measures with regard to zoning combined with the nature of crayfish culture systems, are effective in limiting crayfish production to previously modified agricultural habitats. As such, the score for Factor 3.2a is 4 out of 5.

Factor 3.2b: Enforcement of habitat management measures

While regulatory measures are not in place that explicitly limit crayfish farming to agricultural areas, it is assumed that the industry would not be allowed to operate in areas zoned for other purposes, effectively limiting the industry to agricultural zones. Zoning codes are enforced at the municipal scale through legal code enforcement mechanisms utilized by the city or parish, therefore if crayfish aquaculture were to be conducted in an area not zoned for agriculture it would likely be recognized by a municipality and addressed on a case-by-case basis. Generally if a violation has occurred, notice of violation will be served, followed by an investigation, and subsequent administrative or judicial action (Louisiana Revised Statutes, 2011). This, combined with the nature of crayfish culture systems, effectively forces crayfish production to remain in previously modified agricultural habitats where it will not contribute to any additional cumulative habitat impacts, despite a lack of explicit regulatory siting requirements.

Enforcement of zoning codes occurs at the municipality scale, and is assumed to be effective, however is unlikely to account for cumulative impacts. As such, the score for Factor 3.2b is 4 out of 5. The final Factor 3.2 score is 6.40 out of 10

Conclusions and Final Score

Culture of crayfish occurs in habitats previously modified for agriculture. Conversion of former crop fields to produce crayfish (or crayfish and crops) involves minimal construction or disruption of ongoing practices, allowing these previously modified habitats to maintain their functionality. As the inherent requirements of crayfish aquaculture limit production to existing agricultural areas, it is considered that any expansion of the crayfish industry would not result in any loss of habitat functionality. Factor 3.1 scores 10 out of 10. There are no specific regulatory systems that manage the siting of crayfish aquaculture, and zoning codes are established at the municipality scale, with crayfish production occurring exclusively in agricultural areas due to its inherent characteristics, and the likelihood that zoning codes would not permit crayfish aquaculture in zones not designated as agricultural. Both Factors 3.2a and b score 4 out of 5, and Factor 3.2 scores 6.4 out of 10. Overall, crayfish ponds in former agricultural land do not cause loss of habitat functionality, and siting, while not explicitly required to only operate in previously modified agricultural areas, is effectively limited to such areas. The final Criterion 3 – Habitat score is 8.8 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact*: The use of chemical treatments can impact non-target organisms and lead to ecological and human health concerns due to the acute or chronic toxicity of chemicals and the development of chemical-resistant organisms.
- *Unit of sustainability*: Non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to treatments.
- *Principle*: Limit 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)	**10**	
Critical?	NO	**GREEN**

Brief Summary

Chemicals are not used in the production of crayfish. Occasionally pesticides are applied to rice in crop-crayfish systems, however this is done in a way that avoids any exposure to crayfish, as they are highly susceptible, and is not considered part of crayfish production. The main pathogen affecting crayfish production is WSSV, which is managed through avoidance strategies rather than post-infection chemical treatments. The final numerical score for Criterion 4 – Chemical Use is 10 out of 10.

Justification of Rating

Production of crayfish in the U.S. does not necessitate the use of chemicals, and there are no drugs currently approved for veterinary use in crayfish aquaculture (FDA, 2022). Efforts to ensure cultured crayfish are not exposed to pesticides include (but are not limited to) siting to avoid exposure from aerial application in neighboring agricultural fields, as well as avoiding runoff from agricultural practices that might discharge pesticides into influent water (LSUAC, 2007; Pers. comm., Lutz, 2021). While pesticides may occasionally be used to treat crops in crop--crayfish systems (Gillespie, Guidry and Boucher, 2012), crayfish are highly susceptible to them, and any applications will be done when crayfish are in their burrows, and with enough time before they reemerge to ensure they are not exposed to residue (LSUAC, 2007; Pers. comm., Lutz, 2021). Pesticides are not used in monoculture systems, as crops are solely for forage, and are not commercial (Gillespie, Guidry and Boucher, 2012; Boucher and Gillespie, 2014). A 2014 assessment of production costs and returns for crayfish farming notes includes the use of herbicides, fungicides, and insecticides in crop-crayfish systems, however each of the listed chemicals is distinctly for use in crop culture, while some specifically warn against applying to fields used for crayfish aquaculture (see Table 1 below).

Table 1: Chemicals used for crop cultivation in crop-crayfish systems (from Boucher and Gillespie, 2014).

	Product name	Active ingredient	Use	Notes	Reference
Herbicide	Stam 4E	propanil	For postemergence weed control for rice grown in Arkansas, Florida, Kansas, Louisiana, Mississippi, Missouri, South Carolina, Texas	Toxic to fish and aquatic invertebrates. Specifies not to use in fields where catfish farming is practiced, but does not specify crayfish.	https://www3.epa.gov/pesticides/chem_search/ppls/071085-00036-20171011.pdf
	Facet 75DF	quinclorac	Weed control in dry-seeded, wet-seeded and clearfield rice production	Specifically notes "DO NOT use treated rice fields for the aquaculture of edible fish and crustaceans (crayfish)."	https://www3.epa.gov/pesticides/chem_search/ppls/007969-00113-20080714.pdf
	Londax 60DF	Bensulfuron methyl	Pre-emergent and post-emergent weed control in rice. Inhibits the growth of broadleaf weeds and sedges	Specifically notes "do not harvest crayfish prior to harvesting rice" treated with Londax	https://www3.epa.gov/pesticides/chem_search/ppls/070506-00372-20201216.pdf
	2, 4-D Amine 4	Dimethylamine salt of 2, 4-Dichloro-phenoxyacetic acid	Weed control	Pesticide is toxic to fish and aquatic invertebrates.	https://www3.epa.gov/pesticides/chem_search/ppls/034704-00120-20151106.pdf
Fungicide	Quadris	azoxystrobin; difenoconazole	Targets fungal diseases in rice crops	EPA specific use restrictions include "Do not treat fields used for aquaculture of fish or crustacean."	https://www3.epa.gov/pesticides/chem_search/ppls/000100-01313-20170719.pdf
Insecticide	Karate Zeon	lambda-cyhalothrin	Insect control on crops	Restricted use pesticide due to toxicity to fish and aquatic organisms	https://www3.epa.gov/pesticides/chem_search/ppls/000100-01097-20071019.pdf

Source: Boucher and Gillespie, 2014

With regard to the potential use of chemical treatments in response to pathogens or disease, White Spot Syndrome Virus has become a significant challenge for crayfish production un the U.S. (see Criterion 7 – Disease), however best management practices focus on avoidance strategies (e.g. stocking density, biosecurity measures) rather than post-infection treatment with chemicals (Lutz, Shirley and Romaire, 2007). This information is similarly confirmed through recent personal communication with an industry expert in academia (Pers. comm., Lutz, 2021).

Conclusions and Final Score

There are no drugs currently approved for veterinary use in crayfish aquaculture, and there is no evidence that chemicals are used in crayfish monoculture systems. While some pesticides, herbicides, fungicides, and insecticides may occasionally be applied to the crop-crayfish systems, they are targeted specifically at the crops, and used in ways that avoids exposure to crayfish (that are highly susceptible to them). With regard to pathogen or disease control, the main pathogen affecting crayfish production in the U.S. is White Spot Syndrome Virus, but this is managed through avoidance strategies rather than chemical treatments. Therefore, crayfish are considered to have a demonstrably low need for chemical use, and there is no evidence of recent or ongoing chemical use. The final score for Criterion 4 – Chemical Use is 10 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact*: Feed consumption, feed type, ingredients used, and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients.
- *Unit of sustainability*: 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

C5 Feed parameters	Value	Score
F5.1a Forage Fish Efficiency Ratio	0.22	
F5.1b Source fishery sustainability score (0-10)		8.00
F5.1: Wild fish use score (0-10)		8.20
F5.2a Protein INPUT (kg/100kg fish harvested)	6.81	
F5.2b Protein OUT (kg/100kg fish harvested)	15.20	
F5.2: Net Protein Gain or Loss (%)	124.1	10.00
F5.3: Species-specific kg CO2-eq kg-1 farmed seafood protein	2.16	9.00
C5 Feed Final Score (0-10)		8.85
Critical?	**No**	**GREEN**

Brief Summary
Crayfish are not given any external feed during production, but chopped fish and formulated pellets are used as bait in crayfish traps at harvest. As significant amounts of bait may be used during a production cycle (approximately 0.3 lb per trap, often with hundreds of traps deployed consistently for ~5 months of the year), it was determined that the sustainability of bait should be assessed as feed.

The eFCR (i.e., the ratio of the amount of bait to the amount of crayfish harvested) is calculated as 0.44. As the two types of bait are used in relatively equal amounts throughout a production cycle, each has an individual FCR value of 0.22. The formulated bait does not include any aquatic ingredients, but for chopped fish, the FFER (i.e., the ratio of wild fish used to the amount of crayfish harvested), is effectively the same as the eFCR of 0.22. Both of the most common fish species used for bait are demonstrably sustainable, and the final score for Factor 5.1 – Wild Fish Use is 8.2 out of 10.

The protein input in the form of bait is 68 kg/mt of crayfish harvested, and the protein output in harvested crayfish is 152 kg/mt. There is an overall net protein gain, resulting in a Factor 5.2 score of 10 out of 10. While Global Warming Potential (GWP) values are unavailable for chopped fish, general values are available for the ingredients in the formulated bait, which result in a small GWP value of 2.16 kg CO2 equivalent per kg crayfish protein. This results in a Factor 5.3 score 9 out of 10. Overall, with the only "feed" inputs being bait at harvest, the three factors combine to result in a final score for Criterion 5 – Feed (bait) of 8.85 out of 10.

Justification of Rating
Crayfish produced in the U.S. are not provided with any external feed. In both monoculture and crop-crayfish systems leftover crop "stubble" and/or a ratoon crop (regrowth from a harvested crop) provides the basis of a food web in paddy systems that supports crayfish forage (LSUAC, 2007). Invertebrates feed on decomposing plant matter, and crayfish feed on the invertebrates.

While crayfish are not fed directly, harvesting strategies include the use of bait, which consists of chopped fish and/or formulated pellets. Harvest strategies vary based on density, age and size of crayfish, as well as pond size, temperature, etc., but generally occurs with relative consistency between January and May. As hundreds of traps may be operated at a time, each with approximately 0.3 lb (130 g) of bait (LSUAC, 2007), this can add up to a considerable amount over the course of a production cycle. Using values modeled by Gillespie, Guidry and Boucher, (2012) it is estimated that an average of 0.12 mt of bait is used per acre (0.30 mt/ha) per production cycle. In seasons marked by water temperatures <70°F (November – February) the chopped fish bait is most effective, while formulated bait is more effective in water temperatures >70°F (March-June) (LSUAC, 2007). This near 50/50 temporal split supports additional values by Gillespie, Guidry and Boucher, (2012) approximating 51% of bait is chopped fish, and 49% is formulated bait. The sustainability of these inputs is assessed using Criterion 5.

Factor 5.1 – Wild Fish Use

Factor 5.1 combines an estimate of the amount of wild fish used to produce farmed crayfish with a measure of the sustainability of the source fisheries.

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

The Feed Fish Efficiency Ratio (FFER) for aquaculture systems is driven by the economic feed conversion ratio (eFCR), and the amount of aquatic animals used in feeds. In this case, the FFER indicates the amount of wild fish used as bait to harvest the crayfish, and the eFCR is the ratio of the total bait used to the amount of crayfish harvested.

Values estimated by Gillespie, Guidry and Boucher, (2012) show an average annual harvested biomass of crayfish totaling 0.27 mt/acre (0.67 mt/ha) and an average total bait use of 0.12 mt/acre (0.30 mt/ha) (chopped fish and formulated). As such, the economic feed conversion ratio (eFCR) is 0.44, with individual eFCR values of 0.22 for each bait type, as they are used in equal amounts.

Formulated bait does not include any fishmeal or fish oil (Pers. comm., Purina Mills representative, 2022), therefore the FFER value (i.e., the amount of wild caught fish used to produce one mt of crayfish) is based solely on the chopped fish. As this constitutes 51% of the total bait used, the fish inclusion level is considered to be 51%. When whole (chopped) fish are used as feed or bait, the FFER value is effectively the same as the eFCR, resulting in an FFER value of 0.22.

Factor 5.1b – Source fishery sustainability

The most commonly used species of fish for bait include Gulf menhaden (*Brevoortia patronus*, commonly called pogy), and gizzard shad (*Dorosoma cepedianum*) (LSUAC, 2007). Both are native species that are locally caught. Gulf menhaden score highly on FishSource.org, with Management Quality scores all ≥6 and Stock Health scores both >8 (SFP, 2021). As such, it receives a score of 8 out of 10 in Factor 5.1b. Gizzard shad are unassessed by Seafood Watch, FishSource.org, and are not certified by the MSC, but they are listed as a species of Least Concern by the IUCN (NatureServe and Daniels, 2018). Additionally, the U.S. Fish & Wildlife Service maintains a list of threatened and endangered species by parish in Louisiana. This list does not include gizzard shad (USFWS, 2020). Further, articles published in scientific journals refer to gizzard shad as a "common" species captured during sampling activities (Rutherford, Gelwicks and Kelso, 2001; Kaller *et al.*, 2017). As such, the score for Factor 5.1b is 8 out of 10.

Final score for Wild Fish Use

With an FFER value of 0.22, and a source fishery sustainability score 8 out of 10, the final score for Factor 5.1 – Wild Fish Use is 8.20 out of 10.

Factor 5.2 – Net protein gain or loss

The average protein content of the chopped menhaden and shad used for bait is considered to be 16.3% (menhaden 16.25%[7]; shad 16.43%[8]), while the protein content of formulated bait is 14.5% (Purinamills.com, no date). With approximately 50:50 use of each bait type, the weighted mean bait protein content is 15.4%. Using the eFCR of 0.22 and the average bait protein content of 15.4%, the total bait protein input is 68 kg/mt of harvested crayfish. The protein content of whole, harvested crayfish is 15.2% (i.e., 152 kg/mt of harvested crayfish (El-Sherif and El-Ghafour, 2015). When calculated, this results in a 124.1% net protein gain, and the score for Factor 5.2 is 10 out of 10.

Table 2: The parameters used and their calculated values to determine the protein gain or loss in the production of farmed crayfish

Parameter	Data
Protein content of bait	15.4%
Economic Feed Conversion Ratio	0.22
Total protein INPUT per ton of farmed crayfish	68.0 kg
Protein content of whole harvested crayfish	15.2%
Total protein OUTPUT per ton of farmed crayfish	152.0 kg
Net protein gain	**124.1%**
Seafood Watch Score (0-10)	10

Factor 5.3 – Feed Footprint

The Feed Footprint approximates the embedded global warming potential (kg CO2-eq including land-use change (LUC)) of the feed ingredients required to grow one 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[9] to estimate the GWP of one metric ton of feed (or bait in this case), followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. If an ingredient of unknown or unlisted origin is found in the GFLI database, an average value between the listed global "GLO" value and worst listed value for that ingredient is applied; this approach is intended to incentivize data transparency and provision. Detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

Ingredients in formulated bait include cereal grains, grain byproducts, animal protein products, vitamins and minerals (LSUAC, 2007; Purinamills.com, no date), however without specific ingredient types, GWP values associated with these ingredients are based on categories (e.g. total animal origin; total minerals, additives, vitamins; total cereals) (see Table 3).

Table 3: Estimated embedded global warming potential of one mt of typical bait used for crayfish produced in the U.S.

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[7] Based on an average of values from Dubrow, Hale and Bimbo, (1976)

[8] Based on average values from Liu *et al.*, (2017)

[9] http://globalfeedlca.org/gfli-database/gfli-database-tool/

Bait ingredients	GWP (inc. LUC) Value	Ingredient inclusion %	Kg CO_2 eq/ mt bait
Cereal grains	Total cereals, at farm/RER Economic S	45	567.92
Animal protein products	Total animal origin, at plant/RER Economic S	45	2553.7
Vitamins and minerals	Total minerals, additives, vitamins, at plant/RER Economic S	10	1176.3
	Sum of total	**100**	**4297.92**

There are currently no values associated with the whole fish used as bait in the GFLI database. The total GWP/mt of bait used is 1522.36, which results in 2.16 kg CO2 equivalent/kg farmed crayfish protein. This results in a Factor 5.3 score 9 out of 10.

Conclusions and Final Score

Crayfish are not given any external feed during production, but chopped fish and formulated pellets are used as bait in crayfish traps at harvest. As significant amounts of bait may be used during a production cycle (approximately 0.3 lbs per trap, often with hundreds of traps deployed consistently for ~8 months of the year), it was determined that the sustainability of bait should be assessed as feed.

The eFCR (i.e., the ratio of the amount of bait use to the amount of crayfish harvested) is calculated as 0.44. As the two types of bait are used in relatively equal amounts throughout a production cycle, each has an individual FCR value of 0.22. The formulated bait does not include any aquatic ingredients, but for chopped fish, the FFER (i.e., the ratio of wild fish used to the amount of crayfish harvested), is effectively the same as the eFCR of 0.22. Both of the most common fish species used for bait are demonstrably sustainable, and the final score for Factor 5.1 – Wild Fish Use is 8.2 out of 10.

The protein input in the form of bait is 68 kg/mt of crayfish harvested, and the protein output in harvested crayfish is 152 kg/mt. There is an overall net protein gain, resulting in a Factor 5.2 score of 10 out of 10. While Global Warming Potential (GWP) values are unavailable for chopped fish, general values are available for the ingredients in the formulated bait, which result in a small GWP value of 2.16 kg CO2 equivalent per kg crayfish protein. This results in a Factor 5.3 score 9 out of 10. Overall, with the only "feed" inputs being bait at harvest, the three factors combine to result in a final score for Criterion 5 – Feed (bait) of 8.85 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact*: Competition, altered genetic composition, 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
- *Unit of sustainability*: 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	6	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		6
F6.2 Competitive and genetic interactions		10
C6 Escape Final Score (0-10)		**10**
Critical?	NO	**GREEN**

Brief Summary

Multiple strategies are used to reduce the risk of escape of crayfish from ponds in the U.S., particularly with regard to their location and construction to minimize burrowing or flood losses. Due to low average daily exchange rates (and the use of screens), the risk of crayfish escaping during water drainage is also low. Crayfish are native in Louisiana (and in other states where they are farmed) and those stocked in each type of production system are collected from the wild, as well as from other ponds. There is no selective breeding and they are unlikely to be genetically distinct from wild populations; therefore, they do not pose a genetic threat to wild populations in the event of an escape. As farmed population densities are similar to those in the wild, even a substantial escape event would not result in additional pressure on wild populations. As the risk of escape is low, and the likelihood of impact to wild populations from any escaped, farmed crayfish is minimal, the final score for Criterion 6 – Escapes is 10 out of 10.

Justification of Rating

Factor 6.1. Escape risk

Multiple strategies are used to reduce the risk of escape of crayfish from ponds in the U.S. These include constructing ponds in areas not prone to flooding, and ensuring levees are wide enough that crayfish cannot burrow through them, and tall enough to withstand any flooding events (LSUAC, 2007). Drains are installed to avoid overflow (and subsequent damage to levees, or contamination of pond waters) in the event of heavy rains (Lutz *et al.*, 2011). Guidance available for crayfish producers recommends lowering pond water levels before forecasted hurricane events in order to minimize the risk of flooding in ponds due to excessive rainfall (Lutz and Sink, 2021). It is further noted that the Atlantic hurricane season occurs during months when crayfish are generally in their burrows, and are less likely to escape from a pond due to flooding or levee damage (ibid.). This was recently demonstrated during Hurricane Ida, which caused widespread damage in Louisiana, but approximately 98% of crayfish ponds were unharmed (Pers. comm., Lutz, 2021).

With regard to the potential escape of crayfish during water exchanges, ponds are partially filled or drained on multiple occasions during the production cycle (to mimic conditions in the natural environment, and screens are used to prevent any predatory fish entering the pond but also serve to reduce the risk of crayfish leaving the ponds (LSUAC, 2007). The average daily water exchange is also low (approximately 0.5% of pond volume per day overall - see Criterion 2 – Effluent). If an escape were to occur, there is no evidence that any specific recapture efforts would take place, and there is no recapture adjustment applied here.

Because ponds have a low average daily water exchange rate, are constructed in areas that are not prone to flooding, and use best management practices for design, construction and escape prevention during normal operation and flood events, Factor 6.1 scores 6 out of 10.

Factor 6.2. Competitive and genetic interactions

The red swamp crayfish has proven to be highly invasive outside its native region both in the U.S. and internationally, but crayfish are native to Louisiana (and to the other states in which it is farmed). Ponds are stocked with crayfish collected from the wild as well as from other ponds (see Criterion 8X – Source of Stock for more detail on stocking strategies), and there is minimal (if any) selection for "favorable" traits in stocked crayfish that could potentially genetically differentiate farmed populations from those in the wild. Therefore, crayfish grown in ponds are not considered to be genetically distinct from wild populations.

In the unlikely event of a large-scale escape, even intensively managed monoculture systems with the highest densities (yields of ~1.25 mt/ha/cycle) are such that escaped, farmed crayfish are not expected to have any additional impact on wild populations. Density of crayfish in ponds range from <1 – 20 crayfish per square meter, while densities in the wild vary from 1 crayfish per 50 square meters to ≥20 crayfish per square meter, as they tend to aggregate and disperse based on environmental factors such as water levels, oxygen conditions, temperature, and water flow (Pers. comm., Lutz, 2021). As densities in the wild vary significantly, with pond density ranges similar to natural levels, it is considered that densities in ponds mimic densities in the wild. As such, it is not expected that even a large-scale escape event from a pond with a high density of crayfish would result in increased competition for food or habitat between escaped, farmed crayfish and wild populations. As such, the score for Factor 6.2 is 10 out of 10.

Conclusions and Final Score

Multiple strategies are used to reduce the risk of escape of crayfish from ponds in the U.S., particularly with regard to their location and construction to minimize burrowing or flood losses. Due to low average daily exchange rates (and the use of screens), the risk of crayfish escaping during water drainage is also low. Crayfish are native in Louisiana (and in other states where they are farmed) and those stocked in each type of production system are collected from the wild, as well as from other ponds. There is no selective breeding and they are unlikely to be genetically distinct from wild populations; therefore, they do not pose a genetic threat to wild populations in the event of an escape. As farmed population densities are similar to those in the wild, even a substantial escape event would not result in additional pressure on wild populations. As the risk of escape is low, and the likelihood of impact to wild populations from any escaped, farmed crayfish is minimal, the final score for Criterion 6 – Escapes is 10 out of 10.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact*: Amplification of local pathogens and parasites on fish farms and their transmission or retransmission to local wild species that share the same water body.
- *Unit of sustainability*: 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

Risk-Based Assessment

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

Brief Summary

Historically disease outbreaks have not been a significant concern for crayfish producers. In 2007 WSSV was first identified in the region, and while it is present in both wild and farmed crayfish populations, and results in annual infections, it has not resulted in any notable losses for the industry (for example, a 2009 study showed 111 infected sites, with only 13 (11.7%) showing clinical signs of disease). WSSV has several wild and cultured hosts in the U.S., and the possibility of transferring the virus from crayfish farms to important wild stocks such as Penaeid shrimp in the Gulf of Mexico is acknowledged. Management of WSSV occurs at the farm scale, mainly consisting of preventative measures, and infection is not considered to be characteristic of "typical" crayfish production. Reinfection in the same ponds over consecutive production cycles is rare in the crayfish industry. Farmed population densities are within the range of densities found in the wild, and cultured environments mimic natural ecosystems. Therefore, production practices are considered to have a low risk of amplification WSSV (or any other pathogens or parasites) compared to natural populations. As management measures result in low, temporary, and relatively infrequent occurrences of infection and mortality at the typical farm level, the final score for Criterion 7 – Disease is 6 out of 10.

Justification of Rating

The Criterion 1 – Data score for the Disease criterion is 5 out of 10, and the Risk-based assessment option is used to score this criterion.

Historically crayfish production in Louisiana has not been subject to noteworthy challenges with pathogens or parasites; while occasional small-scale incidents have affected individual crayfish, or single ponds, the industry historically has not been characterized by any epidemics that have impacted production (LSUAC, 2007).

Crayfish introduced in Europe and Asia from the United States are carriers of *Aphanomyces* fungi, which has severely affected wild, native populations of crayfish due to the invasiveness of the introduced species. However, crayfish native to North America are not susceptible to the fungus, and while it is hugely detrimental to European populations, its presence is not a concern in either wild or farmed populations in the U.S.

The most noteworthy pathogen present in the crayfish industry in Louisiana is white spot syndrome virus (WSSV), which was first identified in the area in 2007, when 3 farms in St. Martin, and Vermillion parishes reported >90% mortality in traps in some of their ponds (while neighboring ponds within a farm were unaffected) (Baumgartner *et al.*, 2009). WSSV was first identified in the U.S. in the late 1990s when it was introduced in South Carolina and Texas likely via infected shrimp broodstock imported from Asia (Swinford *et al.*, 2021). Ship ballast water, farm effluent (species unspecified), shrimp packing plant waste, and imported bait and "commodity" shrimp have also been implicated as potential sources of transmission, and introduction of WSSV to Louisiana (Baumgartner *et al.*, 2009). Several wild and farmed crustacean species in the U.S., including crayfish, can be hosts or reservoirs of WSSV (although often at low prevalence) (Swinford et al., 2021), and those authors specifically note that due to outbreaks of WSSV on crayfish farms, it is possible to transfer the virus to native shrimp species – of which wild Penaeid shrimp populations in the Gulf of Mexico are a particular concern.

Management measures are adopted at the farm scale to lower the risk of introduction of WSSV into ponds. Rice-crayfish-soy/fallow systems that rely on stocking of crayfish with each cycle generally source crayfish from other ponds that have not had any WSSV infection (~85% of stocked crayfish are from other ponds, while the remaining 15% are from the wild) (Pers. comm., Lutz, 2021). The use of well water to irrigate ponds has tradeoffs, and the percentage of farms using well water is unknown, however it is another strategy used to decrease the potential for introduction of WSSV (and fish, pesticides, etc.) into pond systems (LSUAC, 2007). Additional preventative measures taken at the farm scale focus on reducing potential stressors to crayfish. These include managing crops to ensure adequate feed supply for crayfish, avoiding overcrowding in ponds, and ensuring appropriate water quality (ibid.).

In the event that a pond is infected with WSSV and clinical signs are present, harvesting activities will be paused (Pers. comm., Lutz, 2021). In some cases, the infection will clear up and harvesting will resume, while in other cases the pond will eventually be drained and managed normally for rice during the summer months. It is rare for ponds to become infected with WSSV for more than one consecutive cycle, and WSSV has not been known to eliminate an entire pond population (ibid.)[10].

A survey by Baumgartner *et al.*, (2009) sampled 184 sites in Louisiana for presence of WSSV (174 ponds and processors; 10 wild sites). Of these sites 111 (60.3%) were positive. However, clinical signs of WSSV were only detected in 10 ponds (5.7% of all ponds and processors sampled), with 6 severely affected (3.4% of all ponds and processors sampled). Of the 10 wild test sites in the Atchafalaya River Basin, 3 tested positive, with dead crayfish present at 1. Since its initial identification in 2007, infections with WSSV have occurred annually in farmed crayfish populations in Louisiana (not all resulting in clinical signs), although none have resulted in notable impacts to the commercial industry (Pace *et al.*, 2016). Generally, between 4-12% of the total crayfish farm acreage in Louisiana is infected annually, however infections are scattered, and tend to result in mortality of adult crayfish, while younger crayfish survive (Pers. comm., Lutz, 2021).

Research conducted by Pace *et al.*, (2016) determined that the strain of WSSV found in the Atchafalaya River Basin is highly virulent (relative to strains of WSSV isolated in other species in other parts of the world), however further research is needed to better understand the factors leading to clinical signs of WSSV in some ponds and wild sites, while others infected with WSSV do not experience clinical infection (Baumgartner *et al.*, 2009; Pace *et al.*, 2016; Schultz, 2020). It is expected that environmental conditions, as well as the innate immune response of crayfish exposed to WSSV will influence their susceptibility to WSSV, however further study is needed.

While this strain of WSSV is noted as highly virulent, and more research is required to understand the variations in clinical infection rates, due to the similar stocking densities and conditions in the ponds and in the wild, it is not considered that crayfish production increases the risk of infection in wild populations. That is, although the potential connection to wild Penaeid shrimp populations in the Gulf of Mexico is recognized (i.e., in Swinford et al., 2021), it is not considered that crayfish ponds amplify WSSV (or any other pathogen or parasite) above the levels expected to be seen in the surrounding natural environment. Therefore, while water is discharged from ponds multiple times per cycle without treatment[11], and wild decapod species are susceptible to infection with WSSV (OIE, 2019; Swinford et al., 2019), this risk of infection is unlikely to be substantially amplified due to the presence of WSSV in crayfish farms.

Conclusions and Final Score

Historically disease outbreaks have not been a significant concern for crayfish producers. In 2007 WSSV was first identified in the region, and while it is present in both wild and farmed crayfish populations, and results in annual infections, it has not resulted in any notable losses for the industry (for example, a 2009 study showed 111 infected sites, with only 13 (11.7%) showing clinical signs of disease). WSSV has several wild and cultured hosts in the U.S., and the

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[10] Note that Baumgartner et al (2009) states >90% mortality in traps, however traps generally hold adult crayfish; not juveniles.

[11] See Criterion 2 – Effluent for further description of water discharge from crayfish production ponds

possibility of transferring the virus from crayfish farms to important wild stocks such as Penaeid shrimp in the Gulf of Mexico is acknowledged. Management of WSSV occurs at the farm scale, mainly consisting of preventative measures, and infection is not considered to be characteristic of “typical” crayfish production. Reinfection in the same ponds over consecutive production cycles is rare in the crayfish industry. Farmed population densities are within the range of densities found in the wild, and cultured environments mimic natural ecosystems. Therefore, production practices are considered to have a low risk of amplification WSSV (or any other pathogens or parasites) compared to natural populations. As management measures result in low, temporary, and relatively infrequent occurrences of infection and mortality at the typical farm level, the final 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.
- *Unit of sustainability*: 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	
C8X Independence from unsustainable wild fisheries (0-10)	-1	
Critical?	NO	GREEN

Brief Summary

The percentage of total crayfish production that is reliant on annual restocking of crayfish from the wild is estimated to be ≤15% annually, mainly consisting of ongoing restocking of rice-crayfish-soy/fallow culture systems. The wild crayfish population is considered to have a low vulnerability to fishing activities and is not considered to be overfished or depleted; similarly, the IUCN considers the species to be of “Least Concern” and to be increasing. As such, the sustainability of wild crayfish populations is considered to be of low concern, and their removal from the ecosystem for stocking of new ponds and rice-crayfish-soy/fallow culture systems is considered to have a minimal impact on wild populations. The score for Criterion 8X is a deduction of -1 out of -10.

Justification of Rating
In monoculture and rice-crayfish double crop systems, broodstock crayfish are generally only stocked once when the pond is newly converted to include crayfish. If extensive work building or maintaining levees is done to an existing pond, restocking may be necessary, however typical monoculture and rice-crayfish double crop production does not rely on restocking after each harvest, as populations of crayfish become self-sustaining (LSUAC, 2007). In the case of rice-crayfish-soy/fallow culture, restocking of juvenile crayfish is required each cycle, because fields are rotated and crayfish populations cannot become self-sustaining (ibid.).

Crayfish are obtained from other ponds or from wild populations (LSUAC, 2007; Pers. comm., Lutz, 2021). Historically it was perceived that crayfish from the wild were more robust, however farmers now prefer to use crayfish from other ponds in order to minimize the risk of introducing WSSV from the wild into their ponds (Pers. comm., Lutz, 2021). It is estimated that ≤15% of crayfish stocked into ponds (mainly individuals stocked into rice-crayfish-soy/fallow systems at the start of each new cycle) come from wild populations (ibid). As the percent of production volume represented by rice-crayfish-soy/fallow systems is unknown, the percent of total crayfish production dependent on wild individuals cannot be extrapolated. For that reason, and on a precautionary basis, it is considered that 15% of total production relies on wild individuals, while accepted that this value is likely higher than the actual percent of total production reliant on wild individuals.

Wild populations of *P. clarkii* in the U.S. are considered by the IUCN to be of Least Concern, and increasing (Crandall, 2010). Outside of their native range, *Procambarus clarkii* are a highly invasive species, and have been introduced throughout the U.S., as well as throughout Africa, Asia, Europe and South America (Huner and Bonham, 2011).

A Seafood Watch assessment of the ecological sustainability of the wild-capture commercial fishery for *P. clarkii* in the Atchafalaya Basin, Louisiana has determined that it has a low vulnerability to fishing activities. While wild populations fluctuate, this is not due to pressure from fishing, but natural, environmental fluctuations (Wadsworth, 2020). Population surveys are not routinely carried out, however wild populations are not thought to be overfished or depleted (ibid.). The Seafood Watch fishery assessment results in a Yellow "Good Alternative" rating for commercial wild-capture of *P. clarkii* in Louisiana, and therefore, whatever the level of use of wild caught broodstock for pond culture, the crayfish farming industry is not considered to rely on vulnerable wild stocks.

Conclusions and Final Score
The percentage of total crayfish production that is reliant on annual restocking of crayfish from the wild is estimated to be ≤15% annually, mainly consisting of ongoing restocking of rice-crayfish-soy/fallow culture systems. The wild crayfish population is considered to have a low vulnerability to fishing activities and is not considered to be overfished or depleted; similarly, the IUCN considers the species to be of "Least Concern" and to be increasing. As such, the sustainability of wild crayfish populations is considered to be of low concern, and their removal from the ecosystem for stocking of new ponds and rice-crayfish-soy/fallow culture systems is

considered to have a minimal impact on wild populations. The score for Criterion 8X is a deduction of -1 out of -10.

Criterion 9X: Wildlife mortalities

Impact, unit of sustainability and principle

- *Impact*: Mortality of predators or other wildlife caused or contributed to by farming operations
- *Unit of sustainability*: Wildlife or predator populations
- *Principle*: Preventing population-level impacts to predators or other species of wildlife attracted to farm sites.

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

Criterion 9X Summary

Wildlife mortality parameters	Score	
C9X Wildlife mortality Final Score (0-10)	**-4**	
Critical?	NO	**YELLOW**

Brief Summary

Many types of wildlife can interact with crayfish ponds, with the most common including fish, amphibians, "fur-bearing" mammals, and birds. As the area covered by ponds is often expansive, netting and fencing is not an economically viable option for farmers, excluding the possibility of accidental mortalities due to entanglements. Of the species commonly attracted to crayfish ponds, birds are considered to have the largest impact to crayfish stock volumes, while mammals can cause damage to pond structures and equipment. In Louisiana fur-bearing mammals can be shot or trapped without a license if they are consuming crayfish or damaging property. The number of mortalities is unknown, however the effort to shoot or trap predators is generally considered to not be worth the losses they cause, and lethal measures are rarely used. Most bird species that interact with crayfish farms are federally protected and cannot be killed, however permits can be obtained for the "take" of double-crested cormorants in the event that non-lethal deterrents are unsuccessful, and an assessment by a representative from the USDA determines that damage is being done to the farm. All double-crested cormorant mortalities must be reported, and the total number of mortalities is capped by geographic sub-regions in Louisiana based on the findings of a PTL model included in an Environmental Impact Assessment completed in 2020. The final numerical score for Criterion 9X – Wildlife Mortalities is -4 out of -10.

Justification of Rating
The Criterion 1 – Data score for the Wildlife mortalities criterion is 5 out of 10, and therefore the Risk-based assessment option is used to score this criterion.

Crayfish ponds are an attractive habitat to a variety of wildlife including amphibians, mammals, fish and birds. Predation of crayfish by wild animals is common, and while it can result in large volumes of farmed crayfish being consumed by predators, the reproductive and growth rates of crayfish are such that these losses are typically not a significant concern to farmers (LSUAC, 2007; Pers. comm., Lutz, 2021). Given the area covered by crayfish ponds, fencing or netting to exclude these types of wildlife is not an economical solution (and therefore wildlife mortalities due to entanglement are not a concern) (LSUAC, 2007).

Birds

Birds are commonly perceived to be the most harmful to crayfish stock volumes, as they may feed on crayfish and/or bait used (LSUAC, 2007). In this case an allowance will be made to the producer for the killing of double-crested cormorants provided that they record all lethal takes, provide logs to the USFWS annually, and report any accidental take of other cormorant species. In addition to specifics about the hours of day, types of ammunition, and handling of deceased cormorants, regulations also state that no lethal control of double-crested cormorants can occur within 1,500 feet of nesting wood stork colonies, 1,000 feet of wood stork roosts, 750 feet of feeding wood storks, and 750 feet of bald eagle nests (ibid.).

A Finding of No Significant Impact (FONSI)[12] was completed in 2017 assessing the potential impact to double-crested cormorant populations from the issuance of depredation permits in the U.S. (including, but not limited to, minimizing their impact at aquaculture facilities). The FONSI outlined two options; a proposed option which would limit cumulative, authorized takes to 74,396 cormorants annually, which is the lower limit identified by a Potential Take Level (PTL) model. A second, more precautionary approach would limit the total allowable take to 51,571 annually based on "reasonably foreseeable effects", and the estimated take of each of the geographic sub-populations of double-crested cormorants. This second approach was designated as the preferred option by the USFWS (USFWS, 2017). Despite this being the preferred option of the USFWS, in the time between the issuance of the FONSI and the completion of an Environmental Impact Assessment (EIA) in 2020 outlining permitting options, the USFWS amended the maximum take limit to the higher of the two options (74,396 total per year based on the lower range of the PTL model). Takes of double-crested cormorants are capped by geographic subregions including those in which crayfish farms are most prevalent (USDOI, 2020).

While logs of recorded takes must be submitted to the USFWS annually by crayfish farmers, the Final EIS was not completed until November of 2020, therefore at the time of writing, annual reports have not been submitted, and it is unclear whether they will be made publicly available. However, despite the adoption of the less conservative of the two options, the maximum take

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[12] https://www.epa.gov/nepa/national-environmental-policy-act-review-process#ea

number (74,396) is still based on the low end of the PTL model findings, and takes are capped by sub-region. It is assumed for purposes of this assessment that the numbers of double-crested cormorants taken by crayfish farmers in Louisiana are consistent with the limits in place for their subregion, and the cormorant population is not negatively impacted. Further, double-crested cormorants are listed as a species of Least Concern, by the IUCN, with an increasing population (BirdLife International, 2018).

Mammals

Mammals such as raccoons and otters can cause damage to traps in their efforts to reach the crayfish inside. Nutria and muskrats can dig holes in levees, while beavers can block drainage systems with dams (LSUAC, 2007). These mammals are all regulated as “fur-bearers” (otter, raccoon, opossum, nutria, muskrat, mink and beaver), and may be trapped or shot in order to minimize disruption to crayfish farms (Louisiana Revised Statutes, 2015; Louisiana Fur Advisory Council, no date). Regulations for the trapping and “take” of fur-bearing mammals can differ slightly by species, however if it is determined that they are damaging crayfish or crayfish ponds, fur-bearers can be trapped or shot during both trapping season and the off-season with no bag limit, and a license is not required. As an alternative to lethal control, permits for the use of live traps can be obtained to trap and relocate fur-bearers by either a landowner or a licensed trapper (ibid.). According to an industry expert (Pers. comm., Lutz, 2021), lethal control is generally only done in extreme cases, as producers generally do not feel that the losses of crayfish justify the effort needed to trap or shoot predators (Pers. comm., Lutz, 2021).

As licenses are not required for lethal control of fur-bearers, records of takes are not maintained, and it is unknown how many fur-bearing mammals are trapped or shot at crayfish farms. However, the population status of each of these species is available, and show that despite the unknown numbers of mortalities, populations remain healthy, that is, none of the additional fur-bearing mammals that regularly interact with crayfish farms are listed as rare, threatened or endangered at the global, federal or state level (LDWF, 2020).

Conclusions and Final Score

Many types of wildlife can interact with crayfish ponds, with the most common including fish, amphibians, “fur-bearing” mammals, and birds. Of the species commonly attracted to crayfish ponds, birds are considered to have the largest impact to crayfish stock volumes, while mammals can cause damage to pond structures and equipment. In Louisiana fur-bearing mammals can be shot or trapped without a license if they are consuming crayfish or damaging property. The number of mortalities is unknown, however the effort to shoot or trap predators is not generally considered to be worth the losses they cause, and lethal measures are rarely used. In addition, as the area covered by ponds is often expansive, netting and fencing to exclude wildlife is not an economically viable option and the risk of accidental mortalities due to entanglements is low. Most bird species that interact with crayfish farms are federally protected and cannot be killed without a multi-agency review, and a subsequently issued permit. The most common strategy used by farmers is non-lethal harassment of birds. Permits can be obtained for the “take” of double-crested cormorants in the event that non-lethal deterrents are unsuccessful and the USDA determines that damage is being done to the farm.

All double-crested cormorant mortalities must be reported, and the total number of mortalities is capped by geographic sub-regions in Louisiana based on the findings of a recent (2020) Environmental Impact Assessment. While records of wildlife mortalities are not maintained, lethal control for any type of wildlife is considered to only be used in exceptional circumstances, and the final score for Criterion 9X – Wildlife Mortalities is -4 out of -10.

Criterion 10X: Introduction of secondary species

Impact, unit of sustainability and principle

- *Impact*: Movement of live animals resulting in introduction of unintended species.
- *Unit of sustainability*: Wild native populations.
- *Principle*: Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals.

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

Criterion 10X Summary

Introduction of secondary species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10	
F10Xb Biosecurity of source/destination	n/a	
C10X Introduction of secondary species Final Score	**0.00**	**GREEN**

Brief Summary

Production of crayfish does not rely on international or trans-waterbody movements. Monoculture and rice-crayfish double crop models are self-sustaining, and do not rely on restocking at the start of each cycle. rice-crayfish-soy/fallow culture is reliant on restocking at the start of each cycle, however crayfish stocked are either from local ponds, or collected from ecosystems adjacent to the ponds. As such, Criterion 10X – Escape of Unintentionally Introduced Species has a deduction of 0 out of -10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

The only movements of live crayfish (for stocking or restocking – see Criterion 8X – Source of Stock) are between local farms, or between local wild populations and farms; therefore, production of crayfish in the U.S. is not considered to rely on any international or trans-waterbody animal movements. The score for Factor 10Xa is 10 out of 10.

Factor 10Xb Biosecurity of source/destination

As there are no international or trans-waterbody animal movements in the culture of crayfish in the U.S., Factor 10Xb is not assessed.

Conclusions and Final Score

The only movements of live crayfish (for stocking or restocking – see Criterion 8X – Source of Stock) are between local farms, or between local wild populations and farms; therefore, production of crayfish in the U.S. is not considered to rely on any international or trans-waterbody animal movements and there is not considered to be a risk of accidentally introducing non-native organisms during any movements. The final score for Criterion 10X is a deduction of 0 out of -10.

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References

Baumgartner, W.A. *et al.* (2009) 'Primary diagnosis and surveillance of white spot syndrome virus in wild and farmed crawfish (Procambarus clarkii, P. zonangulus) in Louisiana, USA', *Diseases of Aqauatic Organisms*, 85, pp. 15–22.

BirdLife International (2018) *Double-crested Cormorant Nannopterum auritus*, *IUCN Red List of Threatened Species*. Available at: https://www.iucnredlist.org/species/22696776/133552919 (Accessed: 15 October 2021).

Boucher, R. and Gillespie, J. (2014) 'Projected Costs and Returns for Crawfish Production in Louisiana 2014.' LSU Agricultural Center. Available at: https://www.lsuagcenter.com/portals/our_offices/departments/ag-economics-agribusiness/extension_outreach/budgets/2014/projected-costs-and-returns-for-crawfish-production-in-louisiana-2014 (Accessed: 15 February 2022).

Cleland, M. (2022). Pers. comm., 'Louisiana crawfish inquiry'.

Crandall, K.A. (2010) *Red Swamp Crayfish: Procambarus clarkii*, *IUCN Red List of Threatened Species*. Available at: https://dx.doi.org/10.2305/IUCN.UK.2010-3.RLTS.T153877A4557336.en (Accessed: 12 October 2021).

Dubrow, D., Hale, M. and Bimbo, A. (1976) 'Seasonal variations in chemical composition and protein quality of menhaden', *Marine Fisheries Review*, 38(9), pp. 12–16.

El-Sherif, S. and El-Ghafour, S. (2015) 'Nutritive value of canned River Nile Crayfish (Procambarus clarkii) products', *The Egyptian Journal of Aquatic Research*, 41. doi:10.1016/j.ejar.2015.06.002.

EPA, U. (2022) *Louisiana by the Numbers*, *How's My Waterway?* Available at: https://mywaterway.epa.gov/state/LA/advanced-search (Accessed: 7 February 2022).

FDA (2022) *Approved Aquaculture Drugs*, *FDA*. FDA. Available at: https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs (Accessed: 14 February 2022).

FishStatJ (2021) *FishStatJ*. Rome: FAO. Available at: http://www.fao.org/fishery/statistics/software/fishstatj/en (Accessed: 25 August 2021).

Gillespie, J., Guidry, K. and Boucher, R. (2012) 'Crawfish Production: Financial Characteristics and Record-Keeping Options'. Southern Regional Aquaculture Center. Available at: https://fisheries.tamu.edu/files/2019/01/SRAC-2405.pdf.

Huner, J. and Bonham, V. (2011) *Procambarus clarkii (red swamp crayfish)*, *CABI Invasive Species Compendium*. Available at: https://www.cabi.org/isc/datasheet/67878 (Accessed: 12 October 2021).

Kaller, M. *et al.* (2017) 'Diel differences in electrofishing catch in the Atchafalaya River basin, Louisiana', *Journal of the Southeastern Association of Fish and Wildlife Agencies*, 4, pp. 39–45.

LDEQ (2012) 'Louisiana's Nonpoint Source Management Plan'. Louisiana Department of Environmental Quality. Available at: https://deq.louisiana.gov/page/water-quality-management.

LDEQ (2014) 'Louisiana Water Quality Standards Ecoregions: For Use in Ecologically-Driven Water Quality Standards'. Louisiana Department of Environmental Quality. Available at: https://www.deq.louisiana.gov/assets/docs/Water/Water_Quality_Standards/Ecoregions/LDEQ2014-Ecoregion_Delineation_FINAL_R1.pdf.

LDEQ (2020) *2020 Water Quality Inventory: Integrated Report (305(b)/303(d)) | Louisiana Department of Environmental Quality*. Available at: https://ldeq.maps.arcgis.com/apps/MapSeries/index.html?appid=8186b44f9a30453483fedd0df4bad9fa (Accessed: 8 November 2021).

LDEQ (2020a) *Nonpoint Source | Louisiana Department of Environmental Quality*. Available at: https://www.deq.louisiana.gov/page/nonpoint-source (Accessed: 8 November 2021).

LDWF (2020) 'Louisiana's Animal Species of Greatest Conservation Need (SGCN) - Rare, Threatened, and Endangered Animals - 2020'. Louisiana Department of Wildlife and Fisheries. Available at: https://www.wlf.louisiana.gov/assets/Conservation/Protecting_Wildlife_Diversity/Files/rare_animals_tracking_list_2020.pdf.

Liu, C. *et al.* (2019) 'Aquaculture Feeds Can Be Outlaws for Eutrophication When Hidden in Rice Fields? A Case Study in Qianjiang, China', *International Journal of Environmental Research and Public Health*, 16(22), p. 4471. doi:10.3390/ijerph16224471.

Liu, Z. *et al.* (2017) 'Effects of different salinities on growth performance, survival, digestive enzyme activity, immune response, and muscle fatty acid composition in juvenile American shad (Alosa sapidissima)', *Fish Physiology and Biochemistry*, 43. Available at: https://www.semanticscholar.org/paper/Effects-of-different-salinities-on-growth-survival%2C-Liu-Gao/0aff4cea35435d6f0178f30c8d2f057a4829037b (Accessed: 22 March 2022).

Louisiana Fur Advisory Council (no date) 'Louisiana Laws and LDWF Commission Regulations that Pertain to Trapping, Furbearers, and Quadrupeds'. Louisiana Fur Advisory Council. Available at: https://www.louisianafur.com/uploads/1/0/4/8/104800207/louisianafurlaws.pdf.

Louisiana Revised Statutes (2004) *Louisiana Aquacultural Development Act*. Available at: http://legis.la.gov/Legis/Law.aspx?d=86769 (Accessed: 17 September 2021).

Louisiana Revised Statutes (2011) *2011 Louisiana Laws :: Revised Statutes :: TITLE 9 — Civil code-ancillaries :: RS 9:5625 — Violation of zoning restriction, building restriction, or subdivision* *regulation*. Available at: https://law.justia.com/codes/louisiana/2011/rs/title9/rs9-5625/ (Accessed: 21 September 2021).

Louisiana Revised Statutes (2015) *Louisiana Laws: Louisiana Revised Statutes: Title 56 Wildlife and Fisheries, Section 116.1 Wild birds and wild quadrupeds: Times and methods of taking; Penalties, Subsections C1 - C2c*. Available at: http://legis.la.gov/legis/Law.aspx?d=104867.

LSUAC (2007) 'Louisiana Crawfish Production Manual'. Louisiana State University Agricultural Center. Available at: https://www.lsuagcenter.com/~/media/system/f/5/0/8/f508bea15f42bd9275fed1291c712184/pub2637crawfishproductionmanuallowres.pdf.

Lutz, C., G., Shirley, M.G. and Romaire, R.P. (2007) *White Spot Syndrome Virus (WSSV) Has Been Confirmed In Louisiana Crawfish*, *LSU AgCenter*. Available at: https://www.lsuagcenter.com/topics/livestock/aquaculture/crawfish/diseases nuisance wildlife/white-spot-syndrome-virus-wssv-has-been-confirmed-in-louisiana-crawfish (Accessed: 23 September 2021).

Lutz, G. *et al.* (2011) 'Crawfish Environmental Best Management Practices'. LSU AgCenter Communications. Available at: https://www.lsuagcenter.com/portals/communications/publications/publications_catalog/environment/best%20management%20practices/crawfish-environmental-best-management-practices.

Lutz, G. and Sink, T. (2021) 'Hurricane Preparation and Recovery in the Southeastern United States: Crawfish Producers Guide'. USDA; USFS. Available at: https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs260g.pdf.

Lutz, G. (2021). Pers. comm., 'Crawfish aquaculture inquiry - Seafood Watch'.
McClain, W.R. and Romaire, R.P. (2007) *FAO Fisheries & Aquaculture - Cultured Aquatic Species Information Programme - Procambarus clarkii (Girard, 1852)*, *Cultured Aquatic Species Information Programme*. Available at: https://www.fao.org/fishery/en/culturedspecies/procambarus_clarkii/en (Accessed: 16 July 2021).

NatureServe and Daniels, A. (2018) *Gizzard Shad: Dorosoma cepedianum*, *IUCN Red List of Threatened Species*. Available at: https://www.iucnredlist.org/en (Accessed: 16 February 2022).

NOAA Fisheries (2021) *Foreign trade*, *US Trade in Fishery Products*. Available at: https://www.fisheries.noaa.gov/foss/f?p=215:2:20757956363711::NO::: (Accessed: 27 August 2021).

OIE (2019) 'Infection with white spot syndrome virus', in *Manual of Diagnostic Tests for Aquatic Animals*. World Organisation for Animal Health. Available at: https://www.oie.int/fileadmin/Home/eng/Health_standards/aahm/current/chapitre_wsd.pdf.

Pace, B. *et al.* (2016) 'Experimental inoculation of Louisiana red swamp crayfish Procambarus clarkii with White spot syndrome virus (WSSV)', *Diseases of Aquatic Organisms*, 120, pp. 143–150. doi:10.3354/dao03018.

Parr, L.D. (2002) *Water discharge models, seasonal effluent mass loading, and best management practices for crawfish ponds*. Louisiana State University. Available at: https://digitalcommons.lsu.edu/cgi/viewcontent.cgi?article=2958&context=gradschool_theses.

Purinamills.com (no date) *Cajun World Crawfish Bait Fish Feed | Purina*, *purinamills.com*. Available at: https://www.purinamills.com/fish-and-aquatics-feed/products/detail/purina-cajun-world-crawfish-bait (Accessed: 16 February 2022).

Rutherford, D.A., Gelwicks, K.R. and Kelso, W.E. (2001) 'Physicochemical Effects of the Flood Pulse on Fishes in the Atchafalaya River Basin, Louisiana', *Transactions of the American Fisheries Society*, 130(2), pp. 276–288. doi:10.1577/1548-8659(2001)130<0276:PEOTFP>2.0.CO;2.

Schultz, B. (2020) *With crawfish season winding down, it's time to restock ponds*, *The News-Star*. Available at: https://www.thenewsstar.com/story/money/2020/05/28/louisiana-crawfish-season-ending-time-restock-ponds/5276521002/ (Accessed: 20 October 2021).

SFP (2021) *Gulf menhaden Gulf of Mexico*, *FishSource.org*. Available at: https://www.fishsource.org/stock_page/887.

Swinford, J.L. *et al.* (2021) 'Diagnostic Molecular Investigation of White Spot Syndrome Virus Finds No Infection in Wild White Shrimp and Brown Shrimp along the Texas Gulf Coast', *Journal of Aquatic Animal Health*, 33(2), pp. 69–76. doi:10.1002/aah.10126.

Tarr, M., Brown, C. and Rumley, R.W. (2013) 'Louisiana Direct Farm Business Guide'. National Agricultural Law Center. Available at: http://nationalaglawcenter.org/wp-content/uploads/assets/articles/LAdirectfarm.pdf.

US EPA (2015a) *Exemptions to Permit Requirements under CWA Section 404*. Available at: https://www.epa.gov/cwa-404/exemptions-permit-requirements-under-cwa-section-404 (Accessed: 17 September 2021).

US EPA (2015b) *Overview of Total Maximum Daily Loads (TMDLs)*. Available at: https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls (Accessed: 2 February 2022).

USDA (2019) *2018 Census of Aquaculture*, *USDA National Agricultural Statistics Service*. Available at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/Aqua.pdf (Accessed: 25 August 2021).

USDOI (2020) 'Final Environmental Impact Statement for the Management of Conflicts Associated with Double-crested Cormorants'. United States Fish and Wildlife Service. Available at: file:///C:/Users/Lisa%20Tucker/Downloads/Cormorant%20Final%20EIS%2011-12-2020%20signed.pdf.

USFWS (2017) 'Finding of No Significant Impact Environmental Assessment: Issuing Depredation Permits fpr Double-Crested Cormorant Management'. United States Fish and Wildlife Service. Available at: https://www.fws.gov/regulations/cormorant/sites/default/files/2020-02/CormorantEAFONSI.pdf.

USFWS (2020) 'Endangered, Threatened, and Candidate species of Louisiana'. USFWS. Available at: https://www.fws.gov/southeast/lafayette/endangered-species-and-recovery/ (Accessed: 16 February 2022).

Wadsworth, T. (2020) 'Red swamp crayfish Procambarus clarkii'. Monterey Bay Aquarium. Available at: https://www.seafoodwatch.org/recommendation/crayfish/yellow-crayfish-red-swamp-crayfish-united-states-louisiana-atchafalaya-basin-traps-unspecified?species=290.

Zaglol, N.F. and Eltadawy, F. (2009) 'Study on chemical Quality and Nutrition Value of Fresh Water Cray Fish (Procambarus clarkii)', *Journal of the Arabian Aquaculture Society*, 4(1). Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1039.2420&rep=rep1&type=pdf.

Appendix 1 - Data points and all scoring calculations

Criterion 1 - Data

C1 Data Category	Data Quality
Production	5.0
Management	5.0
Effluent	5.0
Habitat	7.5
Chemical Use	7.5
Feed	5.0
Escapes	7.5
Disease	2.5
Source of stock	7.5
Wildlife mortalities	5.0
Introduction of secondary species	10.0
C1 Data Final Score (0-10)	**6.136**

Criterion 2 - Effluent

C2 Effluent parameters	Value	Score
F2.1a Waste (nitrogen) production per of fish (kg N ton-1)	195.564	
F2.1b Waste discharged from farm (%)	14.000	
F2.1b Boundary adjustment (0-1)	0.000	
F2 .1 Waste discharge score (0-10)		9
F2.2a Content of regulations (0-5)	3	
F2.2b Enforcement of regulations (0-5)	3	
F2.2 Regulatory or management effectiveness score (0-10)		3.600
C2 Effluent Final Score (0-10)		**7**
Critical?	No	Green

Criterion 3: Habitat

C3 Habitat parameters	Value	Score
F3.1 Habitat conversion and function (0-10)		10
F3.2a Content of habitat regulations (0-5)	4	

F3.2b Enforcement of habitat regulations (0-5)	4	
F3.2 Regulatory or management effectiveness score (0-10)		6.400
C3 Habitat Final Score (0-10)		**8.800**
Critical?	No	Green

Criterion 4: Chemical Use

C4 Chemical Use parameters		**Score**
C4 Chemical Use Score (0-10)		**10.000**
Critical?	No	Green

Criterion 5: Feed

C5 Feed parameters	**Value**	**Score**
F5.1a Forage Fish Efficiency Ratio	**0.224**	
F5.1b Source fishery sustainability score (0-10)		**8**
F5.1: Wild fish use score (0-10)		**8**
F5.2a Protein INPUT (kg/100kg fish harvested)	**6.784**	
F5.2b Protein OUT (kg/100kg fish harvested)	**15.200**	
F5.2: Net Protein Gain or Loss (%)	**124.059**	**10.000**
F5.3: Species-specific kg CO2-eq kg-1 farmed seafood protein	**2.159**	**9.000**
C5 Feed Final Score (0-10)		**8.850**
Critical?	**No**	Green

Criterion 6: Escapes

C6 Escape parameters		**Value**	**Score**
F6.1 System escape risk (0-10)		6	
F6.1 Recapture adjustment (0-10)		0	
F6.1 Final escape risk score (0-10)			6
F6.2 Invasiveness score (0-10)			10
C6 Escape Final Score (0-10)			**10**
	Critical?	No	Green

Criterion 7: Disease

C7 Disease parameters		Score
Evidence or risk-based assessment	Risk	
C7 Disease Final Score (0-10)		**6**
Critical	No	Yellow

Criterion 8X: Source of Stock

C8X Source of Stock – Independence from wild fish stocks	Value	Score
Percent of production dependent on wild sources (%)	15.0	-1
Use of ETP or SFW "Red" fishery sources	No	
Lowest score if multiple species farmed (0-10)		n/a
C8X Source of stock Final Score (0-10)		**-1**
Critical?	No	Green

Criterion 9X: Wildlife Mortalities

C9X Wildlife Mortality parameters		Score
Single species wildlife mortality score		-4
System score if multiple species assessed together		n/a
C9X Wildlife Mortality Final Score		**-4**
Critical?	No	Yellow

Criterion 10X: Introduction of Secondary Species

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on transwaterbody movements (%)	0.0	10
Biosecurity score of the source of animal movements (0-10)		0
Biosecurity score of the farm destination of animal movements (0-10)		0
Species-specific score 10X Score		0.000
Multi-species assessment score if applicable		n/a
C10X Introduction of Secondary Species Final Score		**0.000**
Critical?	No	Green