Red swamp crayfish

Procambarus clarkii

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United States

Ponds

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Final Seafood Recommendation

Criterion	Score (0–10)	Rank	Critical?
C1 Data	6.56	YELLOW	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	7.64	GREEN	NO
C4 Chemicals	9.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8 Source	9.00	GREEN	
3.3X Wildlife mortalities	-5.00	YELLOW	NO
6.2X Introduced species escape	0.00	GREEN	
Total	**60.20**		
Final score	**7.53**		

OVERALL RANKING

Final score	7.53
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical criteria?	NO
Final Rank	BEST CHOICE

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

Summary

The final numerical score for US farmed crayfish is 7.53, which is in the green range. As there are no red or critical criteria, the final overall recommendation remains “Best Choice”.

Executive Summary

Approximately 53,000 metric tons of crayfish were produced via aquaculture in the US in 2010 (FAO 2011). Over 95% of US crayfish production occurs in Louisiana, with a few farms located in Alabama, Arkansas, New York, North Carolina, South Carolina, Texas and Virginia (USDA 2005; NY and VA produce a different species than other states, Lutz pers. comm. September 2013). Due to the dominance of Louisiana, this assessment is based on production in that state of *Procambarus clarkii* whose accepted common name in the scientific and technical literature is red swamp crayfish (Lutz pers. comm. September 2013). The majority of crayfish produced in Louisiana are sold in live markets.

No supplemental feed is provided in crayfish aquaculture. Cultivated or volunteer vegetation supports a natural aquatic food web including invertebrates, which are the main source of nutrition for crayfish. As omnivores, crayfish also consume plant matter, seeds, algae and detritus found in ponds.

Farms are considered to have low impact on habitat as most are sited on existing agricultural fields or those unsuitable for other crops. Crayfish aquaculture mimics the natural wetland cycle and is valuable wetland habitat for waterfowl and furbearers.

Three basic production strategies are used in crayfish aquaculture:

- Crayfish monoculture — often occupies marginal lands unsuitable for traditional row crops and can be more intensively managed to maximize production; risks overcrowding after several cycles and can result in stunted growth. Despite monoculture being more intensive than other production strategies, the species requires low stocking densities and has low input requirements (i.e., no feed, no chemicals, low or no fertilizer).
- Rice-crayfish-rice — situated on existing rice fields, crayfish growth follows rice harvest with residual growth (and regrowth) supporting invertebrate communities. This strategy does not maximize either rice or crayfish crops but is often the most economical alternative for family farms.
- Rice-crayfish-fallow (or rice-crayfish-soybean) — a rotational strategy where rice is not grown in the same field in consecutive years. Rice is grown and harvested, followed by crayfish growth and harvest, which is followed either by fallowing or growth of another crop (soybean, hay, pasture or grain sorghum). Some drawbacks to this strategy include greater land requirements and routinely low population densities.

Effluent or “tailwater” discharge from crayfish ponds is infrequent, occurring when rainwater causes overflow, when water is exchanged to improve water quality, and annually when ponds are drained post crayfish harvest. The annual draining of ponds allows breeding stock to complete their natural life cycle in burrows while vegetation is grown to provide the basis of the food web for the following season. Very little (if any) fertilizer is used during the crop growth phase in all production strategies. Annual draining results in a peak release of particulate matter and nutrients; as such, it is considered an occasional release without evidence of impacts beyond the vicinity of the farm. Consequently, nitrogenous effluent is of moderate concern for crayfish aquaculture.

Crayfish are highly sensitive to chemicals. No antibiotics, pesticides or disinfectants are used on crayfish ponds, which eliminates the risk of impact on non-target species in the surrounding ecosystem.

The risk of escapes from these systems is a low to moderate concern, but red swamp crayfish are native to Louisiana and pose little risk to surrounding populations in the event of escapes in this region. The potential for impact from escapes increases in areas where the species is non-native and not established. Potential impacts include competition with wild native populations and detrimental habitat modification. However, as over 95% of production occurs in Louisiana, the final escape score is based on risk for this region.

Crayfish populations naturally reproduce under farm conditions after initial stocking. Restocking may be required after fallowing or any pond or levee reconstruction. Broodstock are sourced from farmed and wild populations. No significant difference has been found in genetic variation between cultivated and wild crayfish.

Disease and pathogen occurrence is rare in crayfish aquaculture. Preventative practices include maintaining high water quality, avoiding food shortages, and reducing stress and overcrowding.

Overall, crayfish farmed in the US receive a moderate to high score of 7.53 out of 10. The semi-extensive (monoculture) or extensive (crop rotation strategy), low-density, low-input methods used in crayfish aquaculture result in systems with little impact on immediate and surrounding habitats. This results in an overall ranking of “Green”, and therefore the recommendation is “Best Choice”.

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Introduction

Scope of the analysis and ensuing recommendation
Species: Red swamp crayfish (*Procambarus clarkii*)
Geographic coverage: Although a small amount of crayfish production occurs in several other states, 95% of farms are located in Louisiana; the assessment is based on production in this state.
Production methods: Ponds

Species overview
The main species of crayfish farmed in the United States is red swamp crayfish (*Procambarus clarkii*). Although red swamp crayfish are the target production species and represent 70–80% of production, some amount of eastern white river crayfish (*Procambarus acutus acutus)* and gulf white river crayfish (*Procambarus zonangulus)* are inadvertently raised (20–30%; LSU 2007). Red swamp crayfish are native in parts of Alabama, Arkansas, Florida, Illinois, Oklahoma, Kentucky, Louisiana, Mississippi, Missouri Tennessee and Texas. Crayfish are raised in ponds, either in rotation with crops (usually rice) or with forage plants. Crayfish aquaculture is considered extensive production as there are no inputs such as supplemental feed or chemical therapeutants. Water is periodically added to ponds to improve water quality and oxygen levels. Water quality maintenance is aided by the crayfish feeding upon plant matter and detritus as well as the invertebrate community the forage supports. Approximately 190,000 acres in Louisiana were dedicated to farming crayfish in 2011, performing functions similar to constructed wetlands (LSU 2011).

Production cycle and system
The crayfish life cycle is closely associated with the natural flooding and drying common to their native range. Mating takes place in the open water of the ponds, followed by burrowing activity in the late spring/early summer when the ponds begin to drain and dry. Eggs begin developing prior to burrowing and upon completion (in burrows) the eggs attach to the underside of the females' tails. All individuals of a sufficient size (including males and females of all ages) engage in burrowing to survive the dry period. Hatching takes three weeks and is temperature dependent. Crayfish undergo two stages of molt before females and hatchlings emerge from burrows when flooding occurs in the fall. Crayfish growth is affected by a number of variables including food availability, water temperature, population density and oxygen levels. Typically, harvest size is reached after 3 to 5 months.

The methods involved in crayfish aquaculture in the US differ depending on which strategy is being employed and are outlined in Table 1.

Months	Crawfish Monoculture	Crop Rotational Systems	
		Rice-Crawfish-Rice	Rice-Crawfish-Fallow or (Rice-Crawfish-Soybean)
Jul - Aug	Forage crop planted or natural vegetation allowed to grow	Rice crop harvested in August and stubble managed for regrowth	Rice crop harvested and stubble managed for regrowth
Sep - Oct	Pond flooded and water quality monitored and managed	Pond flooded in October and water quality monitored and managed	Pond flooded in October and water quality monitored and managed
Nov - Dec	Harvest when catch can be economically justified	Harvest when catch can be economically justified	Water quality monitored and managed
Jan - Feb	Crawfish harvested 2-4 days per week according to catch and markets	Crawfish harvested 2-4 days per week according to catch and markets	Crawfish harvested 2-4 days per week according to catch and markets
Mar - Apr	Crawfish harvested 3-5 days per week according to catch and markets	Crawfish harvested 3-5 days per week until late April, then pond drained and readied for planting	Crawfish harvested 3-5 days per week according to catch and markets
May - Jun	Crawfish harvested until catch is no longer justified; then pond drained	Rice planted in May and rice crop managed for grain production	Pond drained and soybeans planted or harvest proceeds as long as catch is feasible; pond then drained and left fallow
July - . . .	Repeat cycle	Repeat cycle	Harvest soybeans in October, plant rice in March/April, stock crawfish in May, repeat cycle

Table 1. Summary of crayfish production strategies (from LSU 2007).

Production statistics
The United States produced 52,942 metric ton of crayfish in 2010 (FAO 2011). This figure includes both red swamp and white river crayfish, as they are not separated for market. Out of the 447 crayfish farms in the US in 2005, 433 were located in Louisiana and accounted for 95% of production in 2010 (LSU 2010, USDA 2005).

Import and export sources and statistics
The majority of US raised crayfish are consumed domestically, with only 76 t exported in 2012. Some crayfish is imported from Spain, Turkey, Japan and Canada (a total of 718 t), but the largest importer to the US market is China at 8,545 t in 2012 (NMFS 2012).

Common and market names
Red swamp crayfish are also known as Louisiana crawfish, crawdads and mudbugs.

Product forms
Most crayfish farmed in the US are sold in live markets, with between 10–25% packaged as frozen, cooked and peeled tail meat depending on the amount of crayfish tail meat imported from China (Romaire *et al.* 2005, Romaire pers. comm. August 2013). Inexpensive imports from China have taken over the frozen processed and whole-boiled product market, and whole crayfish served in Chinese restaurants in the US are also imported from China (Huner pers. comm. March 2013).

Analysis

Scoring guide

- With the exception of the exceptional factors (3.3X and 6.2X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available on our website at www.seafoodwatch.org.
- The full data values and scoring calculations are available in Annex 1

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data category	Relevance (Y/N)	Data quality	Score (0–10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	7.5	7.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other (e.g., GHG emissions)	No	Not relevant	n/a
Total			**52.5**

C1 Data final score	**6.56**	**YELLOW**

Justification of ranking

Data availability for crayfish production in the US is generally good with some gaps in relevant criteria. Extensive research has been conducted to improve production efficiency and practices. Congress established the Southern Regional Aquaculture Center (SRAC - srac.tamu.edu) in the mid-1980s to encourage cooperative and collaborative research. Many documents are available from here and the prominent Louisiana State University Agricultural Center (www.lsuagcenter.com/en/crops_livestock/aquaculture/crawfish/). LSU publishes production manuals, statistics, research, best management practices and newsletters, maintaining the most up to date information available.

Data quality is generally high but varies between the assessment criteria. Those areas considered of low concern are often not as thoroughly reported on. As an extensive production system farming a native species, effluent, habitat and escapes have a demonstrated low impact. Consequently, no extensive data sets have been compiled. Despite the fact that wildlife and predator interactions often occur, little to no data is available on the frequency of problems. Supplemental feed is not used in crayfish aquaculture and is therefore considered not relevant for the sake of this assessment. Overall, the data criterion scores 6.56 out of 10.

Criterion 2: Effluents

Impact, unit of sustainability and principle

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

Summary

C2 Effluent final score	**6.00**	**YELLOW**

Note: as there is sufficient scientific and industry data available, the rapid assessment was used.

Justification of ranking

Crayfish aquaculture employs extensive production methods using naturally available foodstuffs and cultivated forage rather than supplemental feed. As no supplemental feed is added and sufficient data exists on the effluent impacts of crayfish aquaculture, the rapid assessment was used.

Crayfish are omnivorous with a diet consisting of a combination of vegetative matter, small mollusks, insects, other small invertebrates and detritus. Louisiana crayfish culture uses forage-based production, which relies on communities of invertebrates for crayfish to feed on (McClain & Romaire 2004). A continuous supply of plant matter is required to sustain sufficient invertebrate populations and provides energy to the food web that supports crayfish. Three basic production strategies are used to ensure this supply: crayfish monoculture, rice-crayfish-rice rotation and rice-crayfish-fallow (or rice-crayfish-soybean; LSU 2007). Fertilizer is applied during the rice-growing (or other forage crop growing) phase of production and the plants absorb most of the nutrients. In a crayfish farm survey, approximately 62% of of the land uses a rotational strategy with some amount of fertilizer applied, but the quantity is often far less than the recommended amount given that fertilizer costs are increasing and rice yields are generally not maximized when grown in rotation with crayfish (Gillespie *et al.* 2012, LSU 2007, McClain pers. comm.). Water is added routinely in crayfish aquaculture to replenish evaporated water and occasionally to increase dissolved oxygen, with full pond discharge occurring once at the end of the production season (summer drawdown; McClain pers. comm.). In addition to water exchange and discharge, unintentional releases occur when rainfall exceeds pond storage capacity. The total amount of intentional and unintentional effluent release (Figure 1) is estimated at 23.4 inches per acre of surface water (Romaire 2012).

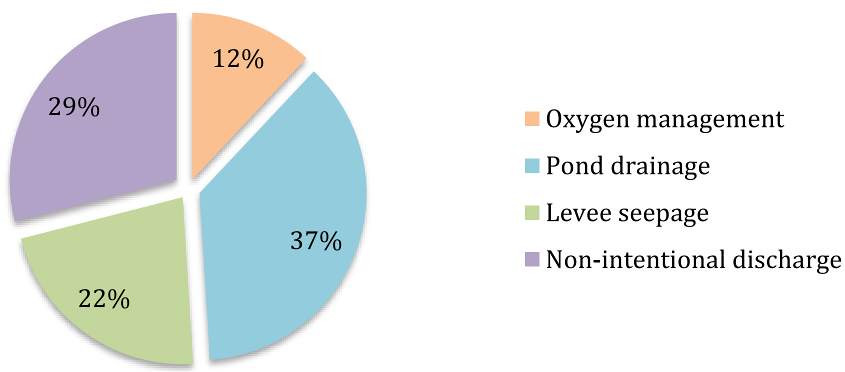

Figure 1. Intentional and unintentional effluent discharge in crayfish aquaculture production by source (from experimental rice/crayfish ponds in southwestern Louisiana (Romaire 2012)).

Nutrient loading estimates from single crop crayfish production indicates that total nitrogen is 10.6 lbs/acre and total suspended solids are 848 lbs/acre (Romaire 2012). Large proportions (70% and 89%, respectively) of these nutrients are released from crayfish ponds in the last 20% of summer drawdown. Heavily vegetated drainage ditches mitigate nutrient releases and have been demonstrated to significantly reduce both suspended solids and total nitrogen over a distance of 800 feet (Romaire 2012).

Crayfish effluent water (or "tailwater") is discharged infrequently and, although turbidity and suspended solids can be high at certain times of the year, the effluent is usually low in nutrients and oxygen demand (Yuan *et al.* 2007). Producers are beginning to adopt voluntary best management practices (BMPs), which have been demonstrated as an effective and practical means for conserving water and reducing effluent (LDEQ 2006, LSU 2007, Nyaupane *et al.* 2012). The BMPs recommended for crayfish production include: capture and storage of rainfall to reduce effluent volume, installation of drain outlets to draw overflow from pond surface (avoiding poor quality water in lower layers), creating vegetated drainage ditches or natural/constructed wetlands to reduce tailwater solids/nutrients, retaining water prior to summer drawdown to reduce nutrient loads, reuse pond water in adjacent ponds (or into reservoirs for reuse), use tailwater for irrigation, practice erosion control in drained ponds and to minimize environmental impacts during pond construction/renovation (from LSU 2007).

Crayfish raised in aquaculture systems are not provided with external feed, fertilizer use is generally low and limited to the forage growth period, effluent discharges are infrequent and best management practices are encouraged to improve ecological performance. Occasional discharges of effluent with high turbidity and particulate matter can be mitigated with the implementation of recommended best management practices and are not considered a significant source of irreversible impacts beyond the farm. Overall, crayfish score a moderate 6 out of 10 for the effluent criterion.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		10.00	
F3.2a Content of habitat regulations	3.25		
F3.2b Enforcement of habitat regulations	2.25		
F3.2 Regulatory or management effectiveness score		2.93	
C3 Habitat final score		**7.64**	**GREEN**
Critical?	NO		

Justification of ranking

Factor 3.1. Habitat conversion and function

Crayfish ponds in Louisiana are typically sited on land that is too marginal for traditional row crops or integrated with agricultural lands of low ecological sensitivity (LSU 2007, McClain pers. comm.). The pre-existence of farms or fields typically determines the location of ponds when crayfish are to be raised in rotation with crops (McClain 2012). Water supply, contamination probability, access, flood probability, soil type and topography are also important siting considerations regardless of production strategy.

Crayfish aquaculture uses extensive production methods, converting lower value habitat to more favorable wetland. Production strategies mimic the natural annual flood and drainage cycle in Louisiana and provide wetland vegetation and habitat. Nearly 190,000 acres were dedicated to crayfish production in Louisiana in 2010; these lands are considered working wetland landscape, similar to constructed wetlands (LSU 2011, McClain pers. comm.). The wetland in Southwest Louisiana (including crayfish ponds) is designated as Audubon Important Bird Area because it is critical to waterfowl conservation (National Audubon Society 2012, Huner *et al.* 2002).

Overall, crayfish aquaculture does not necessitate the conversion of high value habitat and, in fact, can increase the habitat value of agricultural lands by providing habitat for wading and water birds. For these reasons, crayfish aquaculture scores 10 out of 10 with habitat that maintains the full functionality of ecosystem services.

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

Although there is also crayfish production in Mississippi, Alabama, Texas, S. Carolina and Arkansas, the vast majority is in Louisiana (>95% according to the Louisiana Summary (LSU 2010)). Thus, Factor 3.2 mostly reflects Louisiana regulation and management. No license is required to farm crayfish on agricultural lands in Louisiana, although this indicates that the lands have already undergone a license and/or permit process for agricultural use (Louisiana Sea Grant 2012). The Louisiana Aquacultural Development Act was approved in 2004 with the goal of providing "a regulatory framework for the orderly development and maintenance of a modern aquacultural segment of Louisiana's agriculture industry and for the promotion of aquaculture and aquacultural products" (LRS 2004). The licensing and enforcement processes are not fully transparent, but attention is being given to the potential cumulative impacts of the aquaculture industry by the Louisiana Department of Agriculture and Forestry. Additionally, recommended voluntary best management practices help to ensure that aquaculture producers are reducing their environmental impact.

Largely due to the improved habitat functionality expected from crayfish aquaculture and the preference for siting on existing agricultural lands, regulations governing farm location and licensing are moderately effective and enforced. The regulations relating to habitat management for crayfish aquaculture in Louisiana score a 3.25 out of 5 while their enforcement scores 2.25, producing a management effectiveness score of 2.925 out of 10. Overall, the fully functioning ecosystem services supplied by US crayfish aquaculture fields under established habitat regulations result in a high overall habitat score of 7.64 out of 10.

Factor 3.3X: Wildlife and predator mortalities

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

This is an "exceptional" factor 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.

Summary

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and predator mortality final score	**-5.00**	**YELLOW**
Critical?	NO	

Justification of ranking

Wildlife can cause varying degrees of damage and disturbance to crayfish aquaculture ponds. Wildlife interactions include raccoons, otters, muskrats, nutria (copyu), beavers, coyotes, armadillos, skunks, opossums, Norway rats and birds (herons, egrets, ibis, sea gulls, pelicans, double-crested cormorants, etc.; LSU 2007). The recommended approach for dealing with each circumstance depends on the species, situation and time of year. During trapping season, licensed trappers are required to deal with fur bearing animals (raccoons, otters, muskrats, nutria, mink, etc.), while at other times of the year producers are allowed to trap or shoot these nuisance animals (some regions require producers to have a license).

Outside of trapping season, no permits are necessary to trap or shoot nutria, beavers, coyotes, armadillos, skunks and opossums if they are causing problems during daylight hours. Norway rats are dealt with through weather resistant poison bait boxes (hidden to avoid non-target organisms). Other than when dealing with double-crested cormorants (which can be shot with approval from the USDA Wildlife Service and compliance with other stipulations), pyrotechnics and other scare tactics are the only approved means to drive away birds (LSU 2007).

Although there are no estimates available regarding wildlife/predator mortality numbers, the restrictions in place (including license requirements for certain species) indicate that regulatory oversight is preventing mortality among low population (including endangered or threatened) species. The exceptional wildlife and predator mortality factor score is -5 out of -10 as mortality rates may be significant and may have some impact on local numbers but do not otherwise have a significant negative impact on the affected species' population size or status.

Criterion 4: Evidence or risk of chemical use

Impact, unit of sustainability and principle

- *Impact: improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments.*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Summary

Chemical use parameters	Score	
C4 Chemical use score	**9.00**	
C4 Chemical use final score	**9.00**	**GREEN**
Critical?	NO	

Justification of ranking

Crayfish are extremely sensitive to chemical use (especially pesticides) and exposure is not recommended. Careful siting of crayfish farms should avoid agricultural or industrial areas with chemical effluent (LSU 2007). No antibiotics or disinfectants are used in crayfish production and no other chemical treatments are used with the exception of an occasional herbicide during establishment of forage crops (McClain pers. comm.). There is little risk of chemicals entering the surrounding ecosystem from crayfish ponds. Disease problems are not commonly seen in crayfish aquaculture and thus practices to prevent stress are the primary disease management activity (LSU 2007). Improved husbandry strategies include ensuring adequate feed sources, preventing overcrowding and maintaining water quality (FAO 2010). Data show that chemical treatments are not used over multiple production cycles (pesticides, antibiotics, disinfectants) and are used less than once per production cycle when applied (herbicides). Overall, the chemical use criterion score is 9 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 the efficiency of conversion can result in net food gains or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Summary

C5 Feed final score		**10.00**	**GREEN**
Critical?	NO		

Justification of ranking

No external feed is supplied during crayfish aquaculture production in the US (Gillespie *et al.* 2012, LSU 2007, McClain 2007), and therefore the feed criterion score is 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Summary

Escape parameters	Value	Score	
F6.1 Escape risk		6.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		10.00	
C6 Escape final score		**10.00**	**GREEN**
Critical?	NO		

Justification of ranking

Given the overwhelming proportion of production that occurs in Louisiana, the escape criterion will be scored for the potential impact in this state. It should be noted that the score for other states would differ and likely be of higher concern.

Factor 6.1a. Escape risk

No estimates of escape or recapture are available for production in Louisiana, thus the escape risk factor is based solely on pond connection to surrounding ecosystems. Water may be released from ponds as overflow when rain exceeds pond capacity or when ponds are flushed to improve water quality; full flushing occurs only once per production cycle (LSU 2007). The risk of escape from ponds with low water exchange is determined to be of low-moderate concern with a score of 6 out of 10.

Factor 6.1b. Invasiveness

Invasiveness is of low concern in Louisiana where *Procambarus clarkii* is native. Ponds are stocked after major levee renovation or if a field has been left dry or fallowed for an extended period. Crayfish aquaculture production cycles mimic natural ones and reproduction of unharvested crayfish provides stock for the following cycle (LSU 2007). Broodstock for the initial stocking are sourced from a variety of places including monoculture ponds, rotational ponds and the wild crayfish fishery (LSU 2007). Due to the lack of breeding programs and hatcheries, no significant differences have been found between wild and farmed crayfish (Busack 1988, Lutz pers. comm. September 2013). Crayfish escaping from aquaculture production facilities have not been found to reduce genetic fitness in wild populations.

There is very little possibility of ecosystem impacts from escaping crayfish. Population density in the wild is determined by carrying capacity. With virtually no genetic differences between wild and farmed crayfish, escapees do not act as additional competition for food, habitat or predation (Lutz pers. comm. September 2013). Escapees do breed with wild individuals, where females mate with numerous males, resulting in multiple paternity contributions within a clutch (3–5 or more; Lutz pers. comm. September 2013). Wild genetic fitness can be enhanced by contributions from farmed individuals.

Overall, there is a moderate likelihood of escape events due to the possibility of ponds flooding and annual drainage, but escaped crayfish do not create large ecosystem impacts or reduce the genetic fitness of wild populations. Factor 6.1b receives a score of 10 out of 10.

When Factors 6.1a and 6.1b are combined, the final score for the escape criterion is 10 out of 10.

Note: It is important to mention that the above score is based on Louisiana where red swamp crayfish are native and more than 95% of production occurs. The species is also native in Arkansas, Texas and Alabama, where some amount of production occurs. Invasive populations have been introduced into a number of states, including North Carolina, South Carolina and Virginia, where aquaculture production was the vector.

The potential for high impact escapes increases for production occurring where red swamp crayfish are non-native in the US (Klose & Cooper 2012, Moody & Taylor 2012). Red swamp crayfish are demonstrably invasive in regions where they are non-native (ISSG 2011). *Procambarus clarkii* has established populations in Europe, Africa, Asia, North America and South America, making it the most widely introduced crayfish in the world (Lodge *et al.* 2012). The invasiveness of red swamp crayfish is enabled by their tolerance of many environmental conditions including varied salinity and oxygen levels and a wide range of temperatures (Cruz & Rebelo 2007, Scalici *et al.* 2010). Invasion into non-native regions is furthered by long-range dispersal potential (up to 3 km on land daily) and high fecundity (two reproductive cycles per year have been observed; Gherardi & Vadim 2006). Introduction of *Procambarus clarkii* has resulted in dramatic changes in ecosystems and eradication of native crayfishes in some regions (Gil-Sanchez & Alba-Tercedor 2006, Rodriguez *et al.* 2005). These impacts must be considered when *P. clarkii* are farmed in regions where they are not native.

Although it is a very small proportion of total US production, crayfish aquaculture originating in any state where red swamp crayfish are not native has high invasiveness potential and would score “Red” for escapes.

Factor 6.2X: Escape of unintentionally introduced species

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

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

Summary

Escape of unintentionally introduced species parameters	Score	
F6.2Xa International or trans-waterbody live animal shipments (%)	10.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Justification of ranking

As described in Factor 6.1b, crayfish broodstock are sourced initially from nearby ponds or wild crayfish fisheries and are subsequently restocked through natural reproduction (LSU 2007). There is no evidence of international or trans-waterbody live animal shipments or concern for the unintentional introduction of other species and the score for this exceptional criterion is a deduction of zero.

Criterion 7: Disease, pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	7.00	
C7 Disease, pathogen and parasite final score	**7.00**	**GREEN**
Critical?	**NO**	

Justification of ranking

The extensive practices associated with crayfish aquaculture have prevented the occurrence of serious pathogen and disease problems; the main recommended health strategies are stress reduction through maintenance of water quality, adequate food and low population densities (FAO 2010). Outbreaks of bacterial septicemia (*Vibrio mimicus* and *V. cholera*) have been reported in crayfish aquaculture, but these occurred predominantly in high-density holding systems (11 cases versus 4 in ponds) (LSU 2007). Red swamp crayfish are a resistant carrier of the crayfish plague caused by the specialized parasite *Aphanomyces astaci* and are a suspected vector to non-native regions (Longshaw 2011, Stentiford *et al.* 2012). Although high mortalities to native European crayfish populations have occurred due to importation of North American crayfish, *Procambarus clarkii* (and other native North American crayfish) are mostly asymptomatic with crayfish plague and do not experience high disease-related mortality (Lodge *et al.* 2012).

White spot syndrome virus (WSSV) is a pathogen typically associated with shrimp aquaculture and was documented in both wild and farmed populations of *P. clarkii* in 2009 (Baumgartner *et al.* 2009); of the 184 study sites sampled, 60% tested positive (including 3 out of 10 wild stock locations). The 2009 study was the first documented occurrence of WSSV in Louisiana crayfish population, but no major mortalities were reported in the commercial crayfish industry.

Despite these disease and pathogen incidents, outbreaks are considered rare and unlikely to increase pathogens loads compared to wild populations. The disease concern level is between low and low-moderate and scores a 7 out of 10.

Criterion 8: Source of stock – independence from wild fisheries

Impact, unit of sustainability and principle

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

Summary

Source of stock parameters	Score	
C8 Percent of production from hatchery-raised broodstock or natural (passive) settlement	90	
C8 Source of stock final score	**9.00**	**GREEN**

Justification of ranking

Broodstock for crayfish aquaculture are sourced from both pond and wild sources, but populations in ponds tend to be self-sustaining after initial stocking (LSU 2007). Mating occurs in open pond water after which mature females burrow into pond banks or levees to spawn. Generally, a sufficient number of individuals escape harvest to maintain natural reproduction levels capable of continuing aquaculture production. Restocking can be required after pond or levee renovation or in long-fallowed ponds (LSU 2007). There are no estimates available regarding the amount of production dependent on wild-sourced stock, but the percentage is not likely to be large due to natural settlement and other broodstock sourcing options. The small amount of sourcing that occurs from healthy, wild populations of red swamp crayfish has shown no evidence of having any negative effect (LSU 2007, Taylor *et al.* 2011). A nominal 10% of US production has been allocated to this use of wild broodstock (i.e., 90% of production is independent of wild fisheries).

Due to the high reliance on natural reproduction in crayfish aquaculture ponds and a low concern level for sourcing from wild populations, the source of stock criterion score is 9 out of 10.

Overall Recommendation

The overall recommendation is as follows:

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

– **Best Choice** = Final score ≥6.6 AND no individual criteria are Red (i.e. <3.3)
– **Good Alternative** = Final score ≥3.3 AND <6.6, OR Final score ≥ 6.6 and there is one individual "Red" criterion.
– **Red** = Final score <3.3, OR there is more than one individual Red criterion, OR there is one or more Critical score.

Criterion	Score (0–10)	Rank	Critical?
C1 Data	6.56	YELLOW	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	7.64	GREEN	NO
C4 Chemicals	9.00	GREEN	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8 Source	9.00	GREEN	
3.3X Wildlife mortalities	-5.00	YELLOW	NO
6.2X Introduced species escape	0.00	GREEN	
Total	**60.20**		
Final score	**7.53**		

OVERALL RANKING

Final score	7.53
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical criteria?	NO
Final Rank	BEST CHOICE

Acknowledgements

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

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About Seafood Watch®

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

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

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

Guiding Principles

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

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

Seafood Watch will:

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

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

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

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

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

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

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

Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	7.5	7.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	7.5	7.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**52.5**

C1 Data Final Score	6.56	YELLOW

Criterion 2: Effluents

Effluent Rapid Assessment

C2 Effluent Final Score	**6.00**	**YELLOW**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**10**

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

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Mostly	0.75
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Mostly	0.75
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Mostly	0.75
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		3.25

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Partly	0.25
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	No	0
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Moderately	0.5
		2.25

F3.2 Score (2.2a*2.2b/2.5)	**2.93**

C3 Habitat Final Score	**7.64**	**GREEN**
	Critical?	NO

Exceptional Factor 3.3X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and Predator Final Score	**-5.00**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	9.00	
C4 Chemical Use Final Score	**9.00**	**GREEN**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

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

Fishmeal inclusion level (%)	0
Fishmeal from by-products (%)	0
% FM	0
Fish oil inclusion level (%)	0
Fish oil from by-products (%)	0
% FO	0
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	0
FIFO fishmeal	0.00
FIFO fish oil	0.00
Greater of the 2 FIFO scores	0.00
FIFO Score	**10.00**

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

SSWF	0
SSWF Factor	0

F5.1 Wild Fish Use Score	**10.00**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	0
eFCR	0
Feed protein from NON-EDIBLE sources (%)	0
Feed protein from EDIBLE CROP soruces (%)	0
Protein OUTPUTS	
Protein content of whole harvested fish (%)	0

Edible yield of harvested fish (%)	0
Non-edible by-products from harvested fish used for other food production	0
Protein IN	0.00
Protein OUT	0
Net protein gain or loss (%)	0

	Critical?	NO
F5.2 Net protein Score	**10.00**	

5.3. Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	0
eFCR	0
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	0.00

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

Inclusion level of crop feed ingredients (%)	40
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	0
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.00

Value (Ocean + Land Area)	**0.00**

F5.3 Feed Footprint Score	**10.00**

C5 Feed Final Score	**10.00**	**GREEN**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**6**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**6**

6.1b. Invasiveness

Part A – Native species

Score	5

Part B – Non-Native species

Score	**0**

Part C – Native and Non-native species

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

F 6.1b Score	**10**

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

Exceptional Factor 6.2X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F6.2Xa International or trans-waterbody live animal shipments (%)	10.00	
F6.2Xb Biosecurity of source/destination	0.00	
F6.2X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	7.00	
C7 Disease; pathogen and parasite Final Score	**7.00**	**GREEN**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	90	
C8 Source of stock Final Score	**9**	**GREEN**