Monterey Bay Aquarium Seafood Watch®

Red swamp crayfish

Procambarus clarkii

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China

Ponds

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Final Seafood Recommendation

Criterion	Score (0–10)	Rank	Critical?
C1 Data	3.06	RED	
C2 Effluent	3.00	RED	NO
C3 Habitat	7.00	GREEN	NO
C4 Chemicals	6.00	YELLOW	NO
C5 Feed	9.75	GREEN	NO
C6 Escapes	0.00	RED	YES
C7 Disease	3.00	RED	NO
C8 Source	10.00	GREEN	
3.3X Wildlife mortalities	-6.00	YELLOW	NO
6.2X Introduced species escape	0.00	GREEN	
Total	**35.81**		
Final score	**4.48**		

OVERALL RANKING

Final score	4.48
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical criteria?	YES
Final Rank	AVOID

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 Chinese farmed crayfish is 4.48, which is in the yellow range, but with three red criteria for effluent, escapes and disease (the Data criterion is not included in this count). The final recommendation is "Avoid".

Executive Summary

China is the world's largest farmed crayfish producer with approximately 563,281 metric tons produced in 2010 (over 90% of the global supply; FAO 2011). However, this production quantity was drawn from reports submitted by the Chinese government to the Food and Agriculture Organization of the UN, and there has been some question as to whether this quantity may include counts from certain capture fisheries (McClain pers. comm., September 2013).

Procambarus clarkii (common name: red swamp crayfish; Lutz pers. comm.) is the species of crayfish farmed in China since its introduction in 1929. Currently, red swamp crayfish is found in more than twenty provinces and municipalities with wide distribution in the middle and lower regions of the Yangtze River where the majority of production occurs.

Prior to the 1980s, crayfish in China were treated as an invasive species and pest. During the 1980s, a market for crayfish developed and processing plants were established, leading to increased interest in cultivation. Crayfish aquaculture in China grew rapidly with the adoption from the US of a crayfish-crop rotation strategy in regions of China where only one crop of mid-season rice was possible. Single-crop rice fields presented optimal aquaculture sites, and crayfish farming increased the productivity and economic viability of these areas.

After the rice harvest, compost fertilizer is applied to fields to grow the vegetation needed for crayfish culture. Young crayfish are transferred from loop ditches (where adult crayfish are placed after the previous harvest) into the paddy fields. Fertilizer and soybean cake along with wheat and rice byproducts are applied to ponds to directly and indirectly feed the crayfish (indirectly by the establishment of invertebrate communities).

Discharge of effluent from crayfish ponds is infrequent, occurring when rainwater causes overflow, when water is exchanged to improve water quality or manage water temperature, and once a year when ponds are drained after the crayfish harvest. The addition of fertilizer and supplemental feed to crayfish ponds introduces nutrients that may be discharged as nitrogenous effluent. The estimated amount of effluent waste is considered a low to moderate concern, but the overall effluent score reflects the near absence of regulatory and management effectiveness.

Farms are considered to have low impacts on habitat as they are sited on existing agricultural fields. Crayfish in China are grown in rotation with rice during the periods when fields would otherwise be left fallow.

Regulations for the management of effluent as well as licensing and site selection are weak or non-existent; enforcement is minimal. Despite the potential low impact from crayfish aquaculture (a species that can be raised extensively with few inputs), these regulatory shortfalls increase the concern level for both the effluent and habitat criteria.

Although no information is available on chemical treatments for crayfish aquaculture in China, crayfish are highly sensitive to pesticide chemicals. Antibiotics, pesticides and disinfectants are typically not used in crayfish ponds, which eliminates the risk of impact on non-target species in the surrounding ecosystem. While it is possible that certain chemical treatments may be in use, a lack of direct evidence along with the documented disuse in other regions due to species sensitivity results in a moderate to low concern.

The risk of escape is considered to be a moderate to high concern. Crayfish ponds have low water exchange rates, which reduce escape risk, but the species being raised is not native to China. Although crayfish have become established in some regions, this is not true throughout the country. Red swamp crayfish are a demonstrably invasive species, fully capable of overland travel and causing dramatic shifts in native ecosystems. Precautions must be taken when farming the species in new regions.

Transferring parent crayfish to loop ditches or filled ditches in a paddy field after crayfish harvest occurs allows the natural reproduction cycle to continue. At the beginning of each season, pond restocking is performed using the young crayfish from these ditches. There is no reliance on wild populations for broodstock.

Diseases and pathogens are not considered directly problematic to crayfish aquaculture in China. However, red swamp crayfish are carriers of both white spot syndrome virus and crayfish plague. Although no connection has been thoroughly reported, these pathogens have the potential to cause lethal and widespread impacts on native crayfish and farmed shrimp populations. The risk from these pathogens results in a high concern score for disease.

Certain aspects of this assessment are based only on information available in English and may be limited in their ability to explain the full variety of impacts for all production methods currently practiced with red swamp crayfish in China. Scores may be different with the availability of full data for each criterion.

Overall, crayfish farmed in China receive a moderate numerical score of 4.48 out of 10. Lower-density production and farm locations in agricultural regions result in a system with low to moderate impacts on immediate and surrounding habitats, but the lack of regulation and management for effluent and habitat, as well as the risk of escape events, the invasiveness of the species and the potential for pathogen introduction and disease spread increase the impact potential. This results in an overall ranking of "Red", and therefore the recommendation is "Avoid".

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Introduction

Scope of the analysis and ensuing recommendation
Species: Red swamp crayfish (*Procambarus clarkii*)
Geographic coverage*:* Crayfish aquaculture in China originated in Hubei province and has spread through several nearby regions. The majority of production is focused in the middle and lower reaches of the Yangtze River, predominantly in the provinces of Anhui, Hubei, Jiangsu and Jiangxi (Liu & Li 2010).
Production methods*:* Ponds and paddy rice field rotation

Species overview
The crayfish farmed in China are red swamp crayfish (*Procambarus clarkii*), intentionally introduced into China for fishing via Japan in 1929 (Yue *et al.* 2010). Crayfish are raised in rice paddy fields in rotation with rice during the regular fallow period when crayfish are supported with applications of fertilizer and external feed to increase yields. There is little data regarding the use of chemical therapeutants in China, but the sensitivity of crayfish along with a lack of evidence leads to an assumption of low use. Water is added periodically both to improve water quality and to manage water temperature. In 2008, the size of the area growing mid-season rice in rotation with crayfish was more than 160,000 hectares nationwide (Gong *et al.* 2012). Approximately 330,000 hectares of rice paddies are of the mid-season variety and would be suitable for rotation with crayfish should demand increase. Prior to purposeful cultivation, crayfish were considered an invasive pest in China (Gong *et al.* 2012, Liu & Li 2010). *Procambarus clarkii* is a highly invasive species and presents risk to native ecosystems, especially in regions where populations are not already established.

Production cycle and system
Although it is likely that a variety of production methods are used depending on the region and environment, the following methods are most clearly documented for crayfish aquaculture in China. Upon completion of rice growth, paddies are drained and harvested. After paddies have dried, they are irrigated and as many as a million young crayfish are introduced to each hectare of pond area along with fertilizer to stimulate aquatic plant growth. Young crayfish are placed in nylon bags covered with a web of plants to protect them from predators and direct sunlight. At 2–3 weeks of age, the web can be removed and the young crayfish will climb into the paddy field. Aquatic plant growth should cover 40–60% of the pond; crop by-products (e.g., bean dregs and bran) are used to supplement feeding accordingly. Water levels in crayfish ponds are maintained at 0.3–0.6m through daily additions of fresh water. Crayfish harvest begins in mid-April and continues through mid-May using bamboo cages. This ongoing harvest serves to reduce stocking density and improve growth rates over the duration of the season. During July and August, remaining mature crayfish are transferred into loop ditches (1–1.5 m deep and 0.8 m wide) on the inside of the paddies. Loop ditches operate as *in situ* hatcheries where mature crayfish will be stimulated by low water levels to dig holes and reproduce, supplying young crayfish for the next production cycle.

Production statistics
China produced 563,281 metric tons of farmed crayfish in 2010 (FAO 2011). A large portion of production is exported, but the domestic market and demand have been developing.

Import and export sources and statistics
China was the largest importer of crayfish to the US with 8,545 t of trade in 2012 (NMFS 2012). Significant markets for crayfish exist in Sweden and Australia.

Common and market names
In China*, Procambarus clarkii* are known as crayfish or small/little lobster; individuals are sometimes referred to as shrimps (Cheung 2010, Gong et al. 2012, Xiong pers. comm.). In the US market, crayfish are also known as Louisiana crayfish, crayfish, crawdads and mudbugs.

Product forms
Crayfish imports from China are generally frozen processed (peeled tail meat) and whole-boiled product (Romaire *et al.* 2005). Whole crayfish in Chinese restaurants in the US are from China (Huner pers. comm.).

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.*

Summary

Data category	Relevance (Y/N)	Data quality	Score (0–10)
Industry or production statistics	Yes	5	5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	0	0
Feed	Yes	2.5	2.5
Escapes, animal movements	Yes	5	5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Other (e.g., GHG emissions)	No	Not relevant	n/a
Total			**27.5**

C1 Data final score	**3.06**	**RED**

Justification of ranking

Despite China's dominance in the international market for crayfish, the availability and quality of Chinese data and research are poor. As production has grown, more articles have become available in English, mostly regarding the potential impact of escapes and genetic variability within and between populations. Gong *et al.* released an English overview of the crayfish industry in China in 2012 describing many aspects of production and potential for growth and improvement. Unfortunately, there are no other sources of information equal to this. Therefore, data quality and availability are considered low with an overall score of 3.06 out of 10.

There are a number of academic and government programs dedicated to the study of aquaculture, including nutrition, disease, breeding and management. Results of these studies are published in a number of local journals in Chinese with some abstracts available in English. A survey of abstracts indicates relevant research is occurring and higher quality data exists, but a language barrier prevents its use in the Monterey Bay Aquarium assessment. The true absence of certain data, including effluent management, farm location and siting regulations, has been confirmed, making a robust and informed assessment of ecological impacts challenging (Cheung 2010, Gong *et al.* 2012, Liu pers. comm.).

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

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N per ton)	108.7		
F2.1b Waste discharged from farm (%)	34		
F2 .1 Waste discharge score (0–10)		6	
F2.2a Content of regulations (0–5)	1		
F2.2b Enforcement of regulations (0–5)	0.75		
F2.2 Regulatory or management effectiveness score (0–10)		0.3	
C2 Effluent final score		**3.00**	**RED**
Critical?	NO		

Justification of ranking

As effluent data availability is low, the Seafood Watch Full Assessment for effluent was used.

The Seafood Watch assessment criteria use nitrogen as a proxy for evaluating potential impacts from biological waste. The amount discharged is calculated using the protein level in feed and nitrogenous fertilizer minus the protein in the harvested fish. This discharge potential is then weighted by the proportion of effluent released from the system. The nitrogen discharge score is combined with the intent and effectiveness of management and regulations in place to prevent ecological impacts from these wastes.

Crayfish ponds in China are supplied with external feed and fertilizer in the form of aquatic plants and compost fertilizer (Gong *et al.* 2012). Gong *et al.*'s comprehensive overview of crayfish production indicates high levels of both, with 1,500–2,250 kg of aquatic plants and 750–1,500 kg of compost fertilizer applied twice a month per hectare of crayfish pond. No data is available regarding the nitrogen content of the supplemental nutrients, but preliminary calculations indicate the amount of feed and fertilizer may be a mistranslation of units or scale. A recent review of nitrogen application to rice paddies in China indicates that rates of 150–250 kg/hectare are most common (Peng *et al.* 2010). Fertilizer is applied before the rice season and again before crayfish growth to supply sufficient forage for the invertebrate food chain on which the crayfish feed. It is assumed the amount of fertilizer required for the aquatic plant community for crayfish is less than that applied to maximize rice yields and a one time use of the lower end of the nitrogen application range was used during the assessment.

In addition to fertilizer, supplemental feed such as bran, soybean cake and byproducts of wheat and rice are added to ponds (Gong *et al.* 2012, Liu pers. comm.). No country-specific feed conversion ratio (FCR) was available, but research regarding feed growth potential indicates FCR values of 1.21–1.80 for crayfish (McClain & Romaire 2009). Formulated feeds have not been developed for crayfish aquaculture, although nutritional research is being conducted (Gong *et al.* 2012, Lutz pers. comm.).

Evaporation is one of the main reasons water is added to crayfish ponds. Decreasing water levels result in reduced water quality in terms of important variables such as dissolved oxygen, pH, hardness, alkalinity, iron, hydrogen sulfide, ammonia, nitrite, temperature and salinity (LSU 2012). Water depth is typically maintained at 30–40 cm and increased to 40–60 cm when the atmospheric temperature drops. Fresh water is added to ponds about once every 10 days, with full drainage and drying of paddies only occurring after harvest of crayfish and transfer of mature crayfish for broodstock to loop ditches (Gong *et al.* 2012). Due to the infrequent water release outside of draining at harvest, the discharge factor assigned for crayfish ponds is 0.34, indicating that approximately 66% of wastes are broken down in the ponds.

Crayfish aquaculture in China developed as a solution to the agricultural problem in fields where only one crop of mid-season rice was possible (Gong *et al.* 2012). Although local government bodies should regulate and monitor pond discharge, no specific effluent regulations exist for crayfish aquaculture (Liu pers. comm.). The majority of aquacultural production in China comes from many small-scale farms rather than fewer large-scale facilities. The carrying capacity of the environments used for aquaculture and the potential cumulative impacts of the many small-scale farms are being researched, but currently there is a lack of effective monitoring and legislation to deal with the problem of effluent (Chen *et al.* 2011, FAO 2012). The magnitude of crayfish production in China and its growth has the potential to cause large-scale impacts from effluent releases if regulations and management are not appropriately designed and enforced. The current absence of any framework to govern effluent monitoring and management is a cause for high concern.

The effluent waste score is a moderate 6 and not a cause for high concern by itself, but when combined with the weak or absent regulation score of 0.3, the overall effluent score is 3.0 out of 10, which earns a “Red” ranking.

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		7.00	
F3.2a Content of habitat regulations	1.50		
F3.2b Enforcement of habitat regulations	0.75		
F3.2 Regulatory or management effectiveness score		0.45	
C3 Habitat final score		**7.00**	**GREEN**
Critical?	NO		

Justification of ranking

Factor 3.1. Habitat conversion and function

This Seafood Watch criterion measures the impact of aquaculture on habitat through maintenance or loss of ecosystem services. Crayfish aquaculture in China is located predominantly in the middle to lower region of Yangtze River where mid-season rice is grown. Prior to development of rotational crayfish farming in this area, these rice fields were only planted for one season per year. Crayfish aquaculture increases the productivity of this region with little to no need for further habitat conversion since approximately 330,000 hectares of suitable mid-season rice paddies exist (Gong *et al.* 2012). No information exists regarding the potential beneficial properties of crayfish aquaculture in China similar to those in the US where crayfish ponds are considered analogous to constructed wetlands (McClain pers. comm.). Although there is a lack of habitat impact data in China, crayfish aquaculture typically has a low impact on habitat and is unlikely to create any irreversible loss of ecosystem services. It is assumed from the higher intensity of production practices in China that habitat impacts are higher than the well-documented low impacts of more extensive production. However, as crayfish ponds are located in rice paddies, which are previously converted habitats that do not operate as fully functional ecosystems, the score for habitat conversion and function is 7 out of 10.

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

All land in China is state owned and governed according to overall use plans as mandated by the Land Administration Law with the influence of the Water Law (FAO 2012). Aquacultural and agricultural lands are both managed through these state plans, which outline development strategy and use permits. China's Ministry of Agriculture published its most recent Five Year plan in 2011, including the goal of having 100 percent of aquaculture facilities licensed by 2015 (USDA 2011). The rapid increase in China's aquaculture production has mostly been accomplished through a proliferation of small-scale farms (Chen *et al.* 2011). The number of facilities has proven a challenge. Despite the 100 percent licensing directive, it is currently unknown what proportion of producers are unlicensed (Broughton & Walker 2010). Implementation of the nationwide licensing system has been delayed, but work will continue on improving aquaculture regulation and enforcement (USDA 2011). In addition to the difficulties in licensing thousands of small farms, there are currently no specific requirements for environmental impact assessments for aquaculture projects (FAO 2012). Although a number of laws and regulations in China deal with the management and regulation of land and water use, there is a lack of effective enforcement and punitive measures (Chen *et al.* 2011).

Habitat conversion and function scores 7 out of 10 (moderate-high) as there is little or no habitat conversion required for crayfish aquaculture beyond that already undertaken for rice cultivation; only moderate functionality impacts are caused by the crayfish production. Therefore, although the aquaculture regulations are currently poorly developed, it is not appropriate to penalize the crayfish production for habitat impacts that have already (historically) occurred due to the conversion of land to agricultural rice fields.

Therefore, in this unusual case of the crayfish being supplemental to an existing agricultural system and causing moderate additional habitat impacts, the initial habitat impact score of 7 out of 10 will remain as the final score (i.e., it will not be adjusted by the management effectiveness score). The final score for the habitat criterion for this assessment of Chinese crayfish production is therefore 7 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	**-6.00**	**YELLOW**
Critical?	NO	

Justification of ranking

Aquaculture facilities can cause the mortality of predators or wildlife that are drawn to production by the concentration of the farmed species. Crayfish production attracts many species including frogs, snakes and rats. No estimates are available for mortality rates, but the conventional advice is to eliminate threats to production (Gong *et al.* 2012). Given that the nuisance wildlife and predator species' status and impacts are unknown, the Wildlife and Predator Mortality criterion scores a -6 out of -10 on a precautionary basis.

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	**6.00**	
C4 Chemical use final score	**6.00**	**YELLOW**
Critical?	NO	

Justification of ranking

Research indicates that a variety of antibiotics and pesticides are used in aquaculture production in China, including some not permitted in the US (Nyambok 2011). No evidence is available specifically pertaining to chemical use in crayfish aquaculture, with the exception of indicating a need to sterilize ponds prior to stocking with juvenile crayfish and experimental use of vaccines for treatment of white spot syndrome (Gong *et al.* 2012, Jha *et al.* 2006). Red swamp crayfish is a species with a demonstrated low tolerance for chemical use, even when these chemicals are applied to nearby agricultural fields (LSU 2012). No antibiotics, pesticides or disinfectants are typically used in crayfish aquaculture (LSU 2012). There is no data available regarding sterilization practices for ponds, but crayfish intolerance for chemicals suggests that the sterilization of ponds must be performed in a manner that does not use or leave a harmful chemical residue. Improved husbandry is the main treatment method recommended for treating crayfish diseases; this includes strategies to prevent food shortages, overcrowding and poor water quality (FAO 2010). Despite the use of chemicals in many Chinese aquaculture production systems, high crayfish sensitivity suggests that while specific data are not available, there is little risk of chemical use. Consequently, the overall chemical criterion score is 6 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 ingredient, 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

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	0.00	10.00	
F5.1b Source fishery sustainability score		-2.00	
F5.1: Wild fish use		10.00	
F5.2a Protein IN	0.00		
F5.2b Protein OUT	13.50		
F5.2: Net protein gain or loss (%)	>100	10	
F5.3: Feed footprint (hectares)	0.59	9	
C5 Feed final score		**9.75**	**GREEN**
Critical?	NO		

Justification of ranking

Crayfish are omnivores and can be produced without the addition of any supplemental feed, but the higher production density practices in China requires additional application of external feed and fertilizer. The natural diet of crayfish consists of plant matter, small mollusks, other small invertebrates and detritus (LSU 2012). Wild fish use is not a concern in crayfish aquaculture as there are no marine inputs in the external feed provided in Chinese crayfish production. Producers do supply additional nutrition in the form of soybean cakes, rice and wheat byproducts.

Factor 5.1. Wild fish use

Unlike the widespread use of marine ingredients in shrimp farming, crayfish aquaculture does not utilize formulated feeds containing fishmeal and fish oil, relying instead on by-products from rice, wheat and soy fields (Gong *et al.* 2012, Liu pers. comm.). Although there is some indication that surimi, crushed snail/mussel meat and offcuts from butchery may be added if foodstuffs in the ponds fail, their use is not a regular part of crayfish aquaculture (Gong *et al.* 2012). Experimental use of formulated feeds has been reported in Jiangsu province, but their continued use does not appear to be widespread (Lutz pers. comm.). Wild fish use for Chinese crayfish scores 10 out of 10.

Factor 5.2. Net protein gain or loss

Crayfish aquaculture in China results in a positive yield of edible protein. Net protein gain or loss is calculated using the proportion of edible protein in feed and edible proteins in the harvested biomass or used for other purposes. Bean dregs, bran, soybean cake and other byproducts of wheat and rice are added to crayfish ponds at a rate of about 1–2% daily (Gong *et al.* 2012, Liu pers. comm.). Feed conversion ratios observed with supplemental feed are moderate, ranging from 1.21–1.80 with a mean of 1.55 and an average protein content of 23.17% in the feed (McClain & Romaire 2009). Although there is protein in supplemental crayfish feed, it is from non-edible sources. There is no commercial formulated feed industry for crayfish in China, but rather it is supplied through byproducts from local sources (Cheung 2010, Gong *et al.* 2012). Reliance on byproducts offsets the protein use, resulting in a maximum net protein gain or loss factor score of 10 out of 10.

Factor 5.3. Feed footprint

The feed footprint is calculated using all raw ingredients in supplemental aquaculture feed, including non-edible portions. Land animal and marine feed ingredients result in the first and second highest feed footprint respectively. Neither of these is provided to crayfish aquaculture, meaning that 100% of feed ingredients are crop based. The land footprint required to produce supplemental feed is 0.59 hectares per ton of crayfish harvest. The low footprint results in a Feed footprint score of 9 out of 10.

The exclusive use of crop byproducts in Chinese crayfish aquaculture means that the feed does not impact wild fisheries or require high use of edible protein or land area for growth and results in high overall scores for wild fish use (10), protein gain (10) and feed footprint score (9). Overall, the combination of the three feed scores yields in a high final feed score of 9.75 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage, spawning disruption and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations.*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: 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		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		0.5	
C6 Escape final score		**0.00**	**RED**
Critical?	YES		

Justification of ranking

The escape criterion score includes factors examining the likelihood of escape events, the recapture and mortality of escapees and the invasive characteristics of the cultivated species.

Factor 6.1a. Escape risk

The escape risk factor is based solely on pond connection to surrounding ecosystems, as no estimates of escape or recapture are available for crayfish ponds in China. Water is added to ponds to improve water quality and help control temperature during colder months. Although there may be some amount of overflow when precipitation exceeds pond capacity, due to flooding and if water quality needs further improvements, water is only fully drained once at harvest (Gong *et al.* 2012). Individuals may escape or be released from ponds during these water discharges. Crayfish are fully capable of overland travel, increasing the risk of escape and therefore warranting a moderate-high risk and a score of 2 out of 10.

Factor 6.1b. Invasiveness

Red swamp crayfish are demonstrably invasive in regions where they are non-native, including China (Lodge *et al.* 2012). *Procambarus clarkii* is native to northeastern Mexico and the south-central United States, and it was first introduced to China in 1929 from Japan (Cheung 2010, Li *et al.* 2012, Yue *et al.* 2010). After introduction into Jiangsu and Anhui provinces, crayfish spread to north, central and south China (Yan *et al.* 2001). The short life cycle and high fecundity of crayfish allows it to establish vast, wild populations (Gherardi & Panov 2006). Invasion into non-native regions is furthered by a 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). Crayfish mate in the open water, after which mature females burrow into pond banks or levees where those that escape harvest remain to create self-sustaining populations (LSU 2012). While this is good for the aquaculture industry (no hatcheries are required), it has prevented the eradication of invasive crayfish populations.

Procambarus clarkii is on the invasive species list and is already established in some regions of China where production occurs, but there is potential for the range to expand further (ISSG 2011). Invasive populations are established in Europe, Africa, Asia, North America and South America, making red swamp crayfish the most widely introduced crayfish in the world (Lodge *et al.* 2012). Crayfish are tolerant of many environmental conditions including varied salinity and oxygen levels, a wide range of temperatures and pollution, and they can experience two recruitment periods annually (Cruz & Rebelo 2007, Gherardi & Panov 2006, Scalici *et al.* 2010). Although there are few English studies available regarding the impacts of crayfish in China, documented impacts elsewhere include the loss of provisioning, regulatory, supporting and cultural services (Lodge *et al.* 2012). In addition to interfering with conspecifics through reproductive interference or hybridization with native species, crayfish very quickly become a primary contributor to the ecosystem they invade (Lodge *et al.* 2012). Established invasive populations of red swamp crayfish have caused reduced or eradicated populations of native species (e.g., crustaceans, amphibians, mollusks, macroinvertebrates and fish; Gil-Sanchez & Alba-Tercedor 2006, Peeler *et al.* 2011). These dramatic changes observed in native plant and animal communities alter food webs, disturbing native ecosystem dynamics (Geiger *et al.* 2005, Mccarthy *et al.* 2006). Instances of cascading ecosystem alterations have been observed; for example, in Spain, *Procambarus clarkii* introduction reduced macrophyte plant coverage by 99% leading to loss in macroinvertebrate genera (71%), amphibian species (83%), duck species (75%) and other waterfowl (52%; Rodriguez *et al.* 2005). Crayfish activities such as burrowing, foraging and feeding can disrupt water supply and cause other damage to agricultural fields (Holdrich *et al.* 2009, Yue *et al.* 2010). *Procambarus clarkii* has been identified as a vector of introduction for the crayfish plague (*Aphanomyces astaci*) and white spot syndrome virus (*Nimaviridae whispovirus*) in China, the latter of which has immense implications for the shrimp aquaculture industry (ISSG 2006, Liang *et al.* 2011, Peeler *et al.* 2011).

As a non-native species on the invasive species list with well-documented and widespread impacts, the invasiveness factor for crayfish aquaculture in China is 0.5 out of 10.

Low water exchange ponds that drain fully at harvest represent a moderate-high risk of escape, with a score of 2 out of 10. *Procambarus clarkii* are on the invasive species list with many populations established outside of their native range and a demonstrable ability to irreversibly alter ecosystems and ecosystem dynamics. Their invasiveness results in a score of 0.5 out of 10. Overall, crayfish in China result in a low (critical, red) escape score of 0 out of 10.

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

Although crayfish were originally introduced into China via Japan, the current aquaculture industry does not rely on importation of broodstock or other seed stock (Li *et al.* 2012). Crayfish production is generally self-sustaining after initial stocking (generally from nearby ponds or established populations) (Gong *et al.* 2012, Yan *et al.* 2001). Without evidence of international or trans-waterbody live animal shipments, there is little concern for the unintentional introduction of other species. The score for this exceptional criterion is 0.

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	3.00	
C7 Disease, pathogen and parasite final score	**3.00**	**RED**
Critical?	**NO**	

Justification of ranking

As indicated under the chemical criterion, the main approach to dealing with crayfish pathogens and parasites is prevention rather than treatment due to the species' high sensitivity to chemicals. Crayfish pond aquaculture maintains conditions that reduce the likelihood of disease outbreak, mainly via extensive (rather than intensive) culture methods (Gong *et al.* 2012, Stentiford *et al.* 2012). Few studies are available outlining the impact of crayfish disease outbreaks in China. The disease criterion score is informed by known pathogen issues in crayfish aquaculture systems and their connections to surrounding ecosystems.

White spot syndrome virus (WSSV; *Nimaviridae*) has been identified as a pathogen that may cause production loss through mortality (Liang *et al.* 2011). This virus has been highly lethal in the shrimp aquaculture industry, resulting in 100% mortality within seven to ten days of infection (Sanchez-Martinez *et al.* 2007). Crayfish have been identified as a natural host, and while the extent to which WSSV impacts crayfish aquaculture production (or shrimp production via crayfish as a vector) has not been thoroughly reported, WSSV has been commonly observed in natural and farmed populations in Jiangsu province (Baumgartner *et al.* 2009, Liang *et al.* 2011, Longshaw 2011, Lutz pers. comm.). Given the economic losses caused by WSSV in shrimp farming, the potential damage from this pathogen must be recognized.

The other major pathogen associated with *Procambarus clarkii* is crayfish plague, a fungus facilitated by the specialized parasite *Aphanomyces astaci* that affects North American freshwater crayfish populations (Strand *et al.* 2011). *Procambarus clarkii* and other North American crayfish species are mostly asymptomatic when infected, but crayfish plague has been carried to Europe by imported crayfish, resulting in up to a 90% loss of native crayfish populations (Holdrich *et al.* 2009, Lodge *et al.* 2012, Longshaw 2011). There are native species of crayfish in China, located in the Northeast near the Korean peninsula (Fetzner 2005), and although the ranges of crayfish aquaculture in China do not overlap with native species, there is potential for serious disease concern if the aquaculture industry continues to expand. This concern is made greater by the invasiveness of the species. Even if aquaculture production does not expand into the range of native crayfish populations, *Procambarus clarkii* has a proven ability to extend its range and establish new populations.

Other known diseases, pathogens and parasites of *Procambarus clarkii* include bacterial septicemia (*Vibrio mimicus* and *V. cholera*), parasitic cysts (*Southwellinia dimorpha*), porcelain disease (*Thelohania*) and shell diseases (Chitinoclastic; FAO 2010, Longshaw 2011). Although outbreaks are rare and preventable through improved husbandry (e.g., not overcrowding, sufficient food supply, adequate water quality), a range of potential diseases exist that could be amplified and transferred to the surrounding ecosystem (FAO 2010). Despite the fact that crayfish ponds do not require frequent water exchange (only fully draining once per production cycle), the potential impact if a disease (such as the crayfish plague) were to be transmitted to native crayfish in China is of high concern.

Although disease and pathogen incidents do not commonly cause problems in crayfish aquaculture and water exchanges are limited, the potential introduction or spread of crayfish plague (to native crayfish) and WSSV (for crayfish and shrimp aquaculture) increase concern to moderate to high levels. The disease criterion scores 3 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	100	
C8 Source of stock final score	**10.00**	**GREEN**

Justification of ranking

Crayfish aquaculture in China was founded with the cultivation of wild, invasive populations (Gong *et al.* 2012). Once production is established, the natural reproductive cycle of crayfish is maintained in aquaculture operations, eliminating the need for (and cost of) hatcheries (Yan *et al.* 2001). Crayfish mate in open pond water after which mature females burrow into pond banks and levees to incubate their eggs. Enough crayfish generally escape harvest to sustain aquaculture production (LSU 2012). Strategies to promote reproductive cycles include selection of broodstock prior to harvest and of the placement of these individuals in loop and field ditches that are subsequently drained to stimulate burrowing (Gong *et al.* 2012). Restocking may be necessary after long-term fallowing, pond renovations or major disease outbreak, but usually occurs from neighboring crayfish ponds. In addition to being a species that easily and naturally maintains production stock, the cost and legislation required for hatcheries provide further barriers (Honglang 2007, Yan *et al.* 2001). While there have been efforts at artificially breeding crayfish, the technology for large-scale hatchery production does not currently exist (Gong *et al.* 2012). Crayfish aquaculture in China is increasing and may lead to the creation of a hatchery industry, but the current sourcing from either wild or existing aquaculture stocks does not cause ecosystem impacts at this point.

Due to the high reliance on broodstock from existing stock crayfish ponds and the low concern level for sourcing from established non-native populations, the source of stock criterion score is 10 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	3.06	RED	
C2 Effluent	3.00	RED	NO
C3 Habitat	7.00	GREEN	NO
C4 Chemicals	6.00	YELLOW	NO
C5 Feed	9.75	GREEN	NO
C6 Escapes	0.00	RED	YES
C7 Disease	3.00	RED	NO
C8 Source	10.00	GREEN	
3.3X Wildlife mortalities	-6.00	YELLOW	NO
6.2X Introduced species escape	0.00	GREEN	
Total	**35.81**		
Final score	**4.48**		

OVERALL RANKING

Final score	4.48
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical criteria?	YES
Final Rank	AVOID

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

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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*	5	5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	0	0
Feed	Yes	2.5	2.5
Escapes, animal movements	Yes	5	5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**27.5**

C1 Data Final Score	3.056	RED

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	23.17
eFCR	1.55
Fertilizer N input (kg N/ton fish)	75
Protein content of harvested fish (%)	14.85
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	132.4616
N in each ton of fish harvested (kg)	23.76
Waste N produced per ton of fish (kg)	**108.7016**

Factor 2.1b - Production System discharge score

Basic production system score	0.34
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0

Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.34**

34 % of the waste produced by the fish is discharged from the farm

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

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Partly	0.25
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Partly	0.25
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	No	0
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Partly	0.25
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Partly	0.25
		1

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Partly	0.25
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Moderately	0.5
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	No	0
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	No	0
		0.75

F2.2 Score (2.2a*2.2b/2.5)	**0.3**

C2 Effluent Final Score	**3.00**	**RED**
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	7

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?	Partly	0.25
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
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)	Moderately	0.5
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	No	0
		1.5

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?	No	0
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
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?	No	0
		0.75

F3.2 Score (2.2a*2.2b/2.5)	0.45

C3 Habitat Final Score	7.00	GREEN
	Critical?	NO

Exceptional Factor 3.3X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
F3.3X Wildlife and Predator Final Score	**-6.00**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**6.00**	
C4 Chemical Use Final Score	**6.00**	**YELLOW**
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	1.55
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	-2
SSWF Factor	0

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

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	23.17
eFCR	1.55
Feed protein from NON-EDIBLE sources (%)	100
Feed protein from EDIBLE CROP soruces (%)	0
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18
Edible yield of harvested fish (%)	50
Non-edible by-products from harvested fish used for other food production	50
Protein IN	0.00
Protein OUT	13.5
Net protein gain or loss (%)	13500000
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	1.55
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 (%)	100
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	1.55
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.59

Value (Ocean + Land Area)	**0.59**

F5.3 Feed Footprint Score	**9.00**

C5 Feed Final Score	9.75	GREEN
	Critical?	NO

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	2

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

6.1b. Invasiveness

Part 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?	Yes
Do escapees act as additional predation pressure on wild native populations?	Yes
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some extent
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	Yes
Do escapees have some other impact on other native species or habitats?	Yes
	0.5

F 6.1b Score	0.5

Final C6 Score	0.00	RED
	Critical?	YES

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	
F6.2X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	3.00	
C7 Disease; pathogen and parasite Final Score	**3.00**	**RED**
Critical?	NO	

Criterion 8: Source of Stock

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