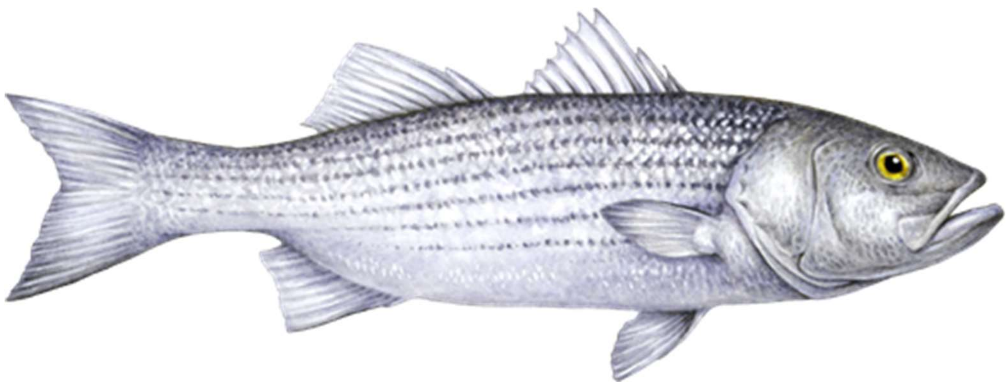
Monterey Bay Aquarium
Seafood Watch®

Hybrid Striped Bass

Morone chrysops x Morone saxatilis



United States

Ponds

Tanks

January 13, 2020

Seafood Watch Consulting Researcher

Disclaimer

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Final Seafood Recommendation

Ponds

Criterion	Score	Rank	Critical?
C1 Data	7.73	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.00	GREEN	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	4.47	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-2.00	GREEN	NO
C10X Secondary species escape	-0.90	GREEN	
Total	**48.30**		
Final score (0-10)	**6.90**		

OVERALL RANKING

Final Score	6.90
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

Summary

The final numerical score for hybrid striped bass produced in pond production systems in the United States is 6.90 out of 10 which is in the green range, and with no red or critical criteria, the final recommendation is green “Best Choice.”

Tanks

Criterion	Score	Rank	Critical?
C1 Data	7.73	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.00	GREEN	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	5.39	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Secondary species escape	-0.90	GREEN	
Total	**50.22**		
Final score (0-10)	**7.17**		

OVERALL RANKING

Final Score	7.17
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

Summary

The final numerical score for hybrid striped bass produced in tank production systems in the United States is 7.17 out of 10 which is in the green range, and with no red or critical criteria, the final recommendation is a green “Best Choice.”

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

Executive Summary

Introduction

This report evaluates the production of hybrid striped bass (HSB) reared in ponds and tanks in the United States (US). HSB for food production (often called "sunshine bass") is an artificial hybrid of a female white bass (*Morone chrysops*) and a male striped bass (*Morone saxatilis*). Current annual production varies but has ranged from 3,600 to 5,600 metric tons (MT). In terms of value, HSB are the fourth most important aquaculture species in the US. Most fish are sold whole, on ice, to the US and Canadian markets, and though volumes of imports to the US market are not listed in statistical records, imported frozen HSB is known to be sold in the US.

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

Data

The data available to assess or estimate the ecological impacts of HSB production in the US were moderately good. A body of peer reviewed literature exists, but the studies typically focus on improving production and are not often at an industry scale. Personal communication with industry experts and producers was integral to understanding impacts, and regulatory information available in the public domain supported anecdotal and/or literature-derived information. There is a notable lack of publicly available information on chemical use and escapes. Overall, confidence in the information to determine the impacts was good for both production systems under assessment, and the final score for ponds and tanks is 7.73 out of 10 for Criterion 1 – Data.

Effluent

Data quality for effluent was good, and although there is a lack of information in the public domain relating to specific farm discharges, the general data examining quality and quantity of effluent were detailed and relatively recent. This allowed the use of the Evidence-Based Assessment. Research has shown HSB effluent to have marginally elevated suspended solids, total nitrogen (including ammonia), and BOD compared to supply water, but the report states that "current pond production methods practiced for warm-water species in the southern region do not have widespread negative effects on the environment." Pond and tank discharge, averaged throughout a production cycle, is typically low, but indeed variable (once per production cycle, zero over multiple production cycles, regularly throughout the production cycle, or recycled and treated). Regulations governing aquaculture effluent do so in conjunction with other industries and with allowable discharge characteristics to maintain (or improve) the water quality of receiving waterbodies. Given this strong management, evidence that farms are in compliance with regulations, and no evidence for ecological impacts as a result of effluent discharge, it can be concluded that the data show no evidence that effluent discharges from HSB farms cause or contribute to cumulative impacts at the waterbody or regional scale. As such, the final score for both pond and tank production is 8 out of 10 for Criterion 2 – Effluent.

Habitat

The southeastern states have the largest number of HSB farms and account for the highest volume of production. Farms are typically sited in former agricultural land or, in some cases, moderate value semi-riparian habitat. However, the industry is demonstrably disparate and limited in scale, resulting in minor–moderate habitat impacts. As such, the score is 7 out of 10 for Factor 3.1 for both ponds and tanks. As the industry lacks a national growth and management plan, the siting of HSB farms is considered for approval on an individual basis. However, in all locations where HSB are farmed, local, state, and federal regulations consider the potential habitat impacts of farm construction and operation in conjunction with other industries and resource users. Ultimately, a moderate habitat conversion (Factor 3.1) and robust regulations regarding permitting of aquaculture facilities (Factor 3.2) results in a final score of 8 out of 10 for ponds and tanks for Criterion 3 – Habitat.

Chemical Use

Best Management Practices (BMPs) in HSB farming require the use of certain chemicals to ensure that good husbandry and fish health and welfare standards are maintained. Of highest concern are the antibiotic treatments available for HSB. Unfortunately, there are no federal or state requirements to publish use information; as such, there are no data in the public domain or otherwise available to indicate the true frequency of antibiotic use across the industry. However, the reported need for antibiotics across the industry is low (tanks) to none (ponds). Chemical use is highly restricted and strongly regulated in US aquaculture. Regulation is based on thorough risk analysis, including data on residues, fate, and toxicity to target and non-target species, which limits the risk of ecological impact should any chemicals used on a farm be discharged to the environment. Ultimately, low discharge, strong regulation, and indications that chemicals of concern are used less than once per production cycle results in a final score of 8 out of 10 for both pond and tank production for Criterion 4 – Chemical Use.

Feed

This criterion combines the scores for the feed fish efficiency ratio (FFER) and sustainability of wild fish source, the net protein gained or lost, and the ecosystem area (terrestrial and marine) appropriated for food production. Marine ingredient inclusion in HSB feeds is estimated to be 16% for fishmeal and 7% for fish oil, with 0% of those coming from byproduct sources. Values for eFCR are high compared to many other farmed finfish species, at 2.1 for pond systems and 1.75 for tank systems, and result in FFER values of 5.92 and 6.60 for pond and tank systems respectively. The wild fish source was determined to be Atlantic and Gulf menhaden, with overall good sustainability which, when combined with the FFER score, results in overall scores of 4.94 out of 10 for ponds and 5.78 for tanks for Factor 5.1. A single feed composition across the entire industry is challenging, but a representative HSB feed was estimated from formulated diets published in scientific literature. These were comprised of 23% marine ingredients, 26% land animal ingredients, and 47% terrestrial crop ingredients. Net protein loss was estimated to be 62.5% and 57.4% for ponds and tanks respectively, resulting in respective Factor 5.2 scores of 3 and 4 out of 10. The feed footprint (Factor 5.3) was estimated at 13.54 and 11.28 hectares (ha) per ton of production, resulting in scores of 5 out of 10 for ponds and 6 out of 10 for tanks. Overall, the final score for Criterion 5 – Feed was 4.47 out of 10 for ponds and 5.39 out of 10 for tanks.

Escapes

There are no apparent data on escape events in the HSB industry; however, reporting of escapes is required since it is illegal to “release” fish into public waters without a permit; this indicates that escapes from HSB facilities have not occurred. The risk of escape can be estimated by the exchange of water through rearing units and vulnerability to flooding. Though ponds are typically outside the 100-year flood plain, water exchange appears variable. On average, however, there are indications that farms discharge ponds during harvest but have a low average exchange rate throughout the production cycle (<0.5% per day). Water exchange for tank production is also variable, since some farms (an unknown proportion) are reported to use single-pass flow-through and some employ recirculation rates up to 85%. All producers, however, use Best Management Practices for escape mitigation. As such, the Escape Risk score for both ponds and tanks is 8 out of 10. Because HSB are artificially propagated, they do not occur naturally in any waterbody, but widespread historic and ongoing intentional stocking for biological control of forage fish or recreational fisheries means that ecological impact by aquaculture escapees is unlikely. As a result, the score for Competitive and Genetic Interactions is 9 out of 10. For both pond-raised and tank-raised HSB, Factors 6.1 and 6.2 combine to result in a final score of 8 out of 10 for Criterion 6 – Escapes.

Disease

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors including escaped individuals, discharged water/sediment, and animals (birds, snails, wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, several diseases are reported to have occurred on farms with no data available that allow for an estimation of typical disease prevalence or intensity on farms. Anecdotal evidence suggests such prevalence is low, as does the absence of antibiotic treatments. In order to export product to Canada, farms must be certified as disease-free by USDA-APHIS; this requires all disease events to be documented and reported and requires sworn affidavits to affirm the reports. Farms employ robust health and biosecurity protocols (e.g., disease-free fingerling sourcing, quarantine, not allowing equipment to be used on multiple sites, disinfection of hauling trucks, etc.) and typically have low rates of water discharge. There is some indication that on-farm biosecurity measures also prevent pathogen transmission to wild species, since wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, and health and biosecurity measures are robust. The final score for ponds and tanks is 7 out of 10 for Criterion 7 – Disease.

Source of Stock
HSB fry and fingerlings are all hatchery raised. Broodstock fish are both domesticated and sourced from the wild, and efforts are being made to develop improved genetic lines. Overall reliance on wild broodfish is low, and there is good evidence to suggest that the numbers of fish taken for broodstock do not have a detrimental effect on wild stocks. For these reasons, the final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

Wildlife Mortalities
Birds (cormorants, pelicans, and great blue herons) are the most likely nuisance species on HSB farms. All can prey on fish, and herons are part of the life cycle of the yellow grub, a parasite that lowers the marketability of fish. However, permits for lethal control of nuisance species are tightly regulated and the main methods of control are non-lethal. There is no evidence to suggest non-compliance on the part of the producers. Pond production occurs entirely outdoors, but some tank production occurs indoors, which limits the potential for wildlife interaction and the necessity to use lethal control. The final score for Criterion 9X – Predator and Wildlife Mortalities is -2 out of -10 for ponds and -1 out of -10 for tanks.

Escape of Secondary Species
Trans-waterbody movement of fish from hatcheries to growout sites is likely high; however, the biosecurity measures at the source (i.e., hatcheries) is also high and results in a low risk of introducing secondary species during transport. Of note, the widespread stocking of HSB into reservoirs and lakes in almost every state means that the potential contribution of aquaculture to unintentional spread of secondary species is small by comparison to the wild stocking program. Therefore, despite high trans-waterbody movements, the final deductive score for Criterion 10X – Escape of Secondary Species is -0.9 out of -10 for pond and tank systems.

Overall Recommendation
The final numerical score for hybrid striped bass produced in pond production systems in the United States is 6.90 out of 10 which is in the green range, and with no red or critical criteria, the final recommendation is a green "Best Choice."

The final numerical score for hybrid striped bass produced in tank production systems in the United States is 7.17 out of 10, which is in the green range; with no red or critical criteria, the final recommendation is a green "Best Choice."

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Species Overview

Brief overview of the species
Hybrid striped bass (HSB) are a cross between two species belonging to the family Moronidae, order Perciformes. They are intermediate in appearance between their parent species, the striped bass *Morone saxatilis* and the white bass *M. chrysops*; body size is medium to large and body depth is more than one-third its length. Hybrid striped bass are more tolerant to warm and shallow waterbodies and have growth and disease resistance characteristics that are favorable for intensive production. Both cross variations (i.e., male *M. chrysops* and female *M. saxatilis*, and vice versa) are commercially produced; the original cross (female *M. saxatilis* x male *M. chrysops*), known as Palmetto bass, is generally produced for stocking reservoirs and rivers as a sport fish, while the reciprocal cross (female *M. chrysops* x male *M. saxatilis*), known as sunshine bass, is predominantly or wholly produced as a cultured food fish. The parent species habitats are freshwater (white bass) and anadromous (striped bass) and geographically isolated from one another in nature. However, widespread stocking of different *Morone* species and their hybrids has resulted in almost all states in the US (all but Alaska and Idaho) having some form of *Morone* in their natural waterbodies, and the extent of outcrossing and backcrossing is unknown.

Production system
In the United States, HSB are produced in ponds and in tanks. These systems are detailed below. This report encompasses the growout phases (i.e., excludes the hatchery phase) of HSB production in the United States.

<u>Pond Production</u>
HSB fingerlings are produced in ponds that are ideally 1.2 to 2 hectares (ha) in area, 1 to 2 meters (m) deep (“Phase I”). Natural plankton productivity is controlled and enhanced with organic and sometimes inorganic fertilizers to allow natural succession of the zooplankton species on which the fry feed. Fry are stocked at 5 days post-hatch, weaned onto exogenous feed after they are 26 days old (Ludwig 2004) (Ohs et al. 2008), and re-stocked into Phase II ponds at 30 to 45 days or ~1 gram (g). In Phase II, feed-trained fingerlings are stocked at a density of 30,000 to 45,000 fish

per ha (12,000 to 18,000 per acre), which, when attaining weights of 125 to 225 g, are transferred into Phase III rearing units. In Phase III, fish are stocked at 7,500 to 11,000 fish per ha (3,000 to 4,400 per acre). Market-sized fish of 0.6 to 1.1 kg are reached after a total of 19 months (all three phases).

In some cases, fry are grown in Phase I rearing units until they reach a larger fingerling size (3 g), from which point they are directly stocked into on-growing ponds at a density of 9,250 to 9,880 per ha (3,750 to 4,000 per acre). This allows a shorter time to market of 12 to 14 months.

North Carolina pond production involves draining once per production cycle or frequently throughout the production cycle, while in Texas, water is drained once, or retained over multiple production cycles (Sydorovych and Daniels 2011) (H. Daniels, pers. comm. February 2017) (J. Ekstrom, pers. comm. July 2017). All pond systems use aerators to maintain water quality. HSB grow best in low salinity (< 5 parts per thousand (ppt)) but also tolerate freshwater (J. Ekstrom, pers. comm. July 2017).

Tank Production

These open/closed/semi-closed systems generally afford more control over physical and chemical parameters and result in a shorter time to harvest, since ideal conditions for growth, particularly temperature, can be maintained. Typically, production reaches 40 to 59 kg m^{-3} (re-calculated from (Ohs et al. 2008) and after 5 to 7 months of grow-out, fish reach marketable size of 0.7 to 0.9 kg. Obtaining data on tank production systems that are currently in operation is difficult. One company, Colorado Catch, currently has an annual production capacity of 550,000 lb (250 metric tons [MT]), grown in a variety of outdoor tanks supplied with water from a geothermal well at an approximate recirculation rate of 85%. Fish are stocked as fingerlings and growout density is approximately 72 kg m^{-3} (T. Faucette, pers. comm. September 2017). One North Carolina producer uses 24' indoor (fully enclosed) tanks supplied with artesian well water, at an estimated replacement (i.e., not recirculation/re-use) rate of 25 to 30% per day. The producer states that this could be optimized but this is not a current priority, since there is a plentiful water supply. Hatchery supplied fish are stocked at 3 to 4" (7.5 to 10 cm) and it takes approximately 12 months for fish to reach a market size of 1.5 lb. (0.68 kg).

HSB are carnivorous and fed a pelleted commercial diet containing approximately 40% protein from the fry/fingerling transition onwards.

Production Statistics

Production of HSB as food fish is almost entirely of the sunshine bass (female *M. chrysops* x male *M. saxatilis*). Production was steady for the years 2010 to 2015, at around 3,500 to 3,800 MT annually and with a market value of approximately USD 29 million (FAO 2018) (Kelly 2016), having decreased from its peak in 2005 of 5,448 MT. Production increased again in 2016 to a total of 4,682 MT and a farm-gate value of USD 37.7 million, which is considerably higher than the 2005 value of ~USD 30 million (FAO 2016/2017) (USDA 2014), indicating a recent price increase.

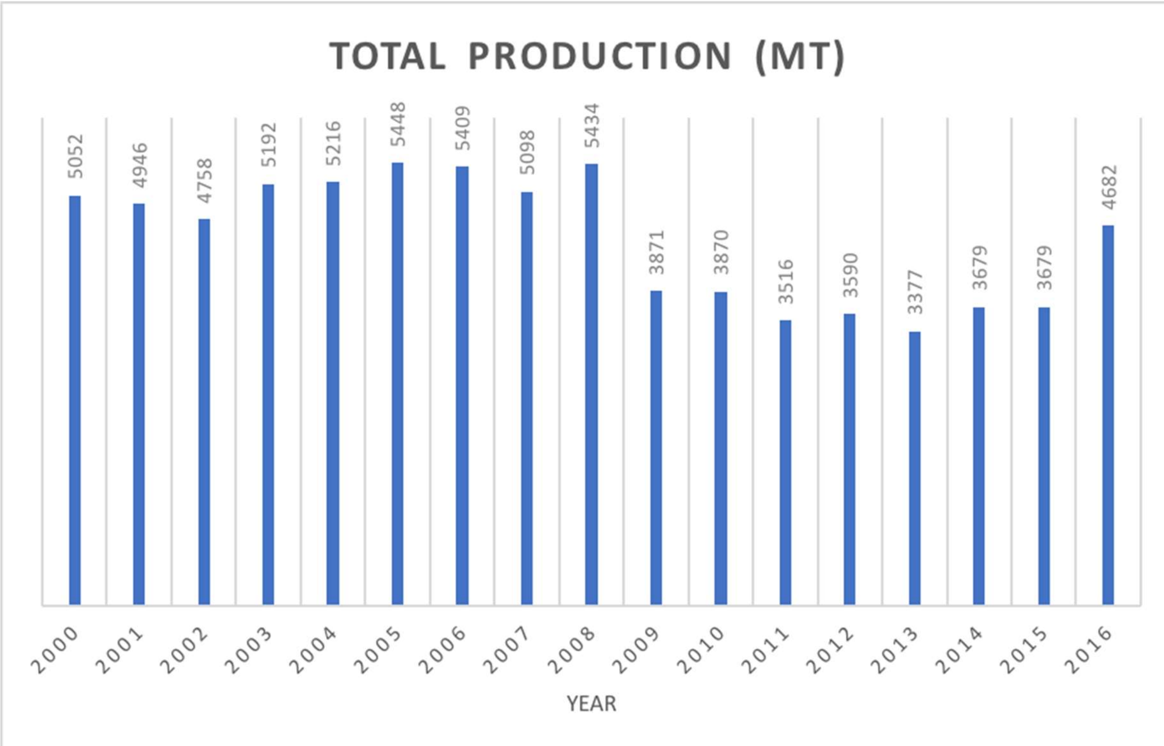

Figure 1. HSB production statistics between 2000 and 2016 (Source: FAO fish stat).

HSB is the fourth-largest aquaculture industry in terms of value in the US, behind catfish, salmon, and trout, and the fifth-largest in terms of volume (Quagrainie 2015). Currently, according to the USDA (2014) there are a total of 68 farms producing sunshine bass, comprised of 52 producers of market size fish (on-growers), 10 producers of stockers, and 9 producers of fingerlings or fry, although fingerling/fry production is heavily dominated by one farm in Arkansas. The farms are distributed across 20 states, with the largest number of farms in North Carolina (14 farms, 21%) and Texas (10 farms, 15%), though the largest farm area (i.e., number of water hectares) is in Texas. The remaining two-thirds of farms are scattered across 18 states, predominantly in the southeast and few in the southwest (Arizona, Colorado, California) (USDA 2014). However, according to a recent industry survey, only 40 farms returned data (Kelly 2016). Although not all producers participated in the survey, it is the opinion of Kelly that the greater majority did so.

Both the FAO (2016) and Kelly (2016) estimate that over the last ten years, production in ponds has accounted for 70 to 90% of total production. They give figures for 2014/15 production as 81% in ponds, 17% in closed or semi-closed tank systems, and 2% in cages. The decline in production seen between 2006 and 2009 was largely due to decreasing tank production while pond and cage production remained approximately constant. It is the opinion of Dr. Anita Kelly that current production quantities and production systems are likely to remain approximately as they are for the foreseeable future (A. Kelly, pers. comm. October 2016).

Import and Export Sources and Statistics

The majority of market-sized fish remain in the United States. North Carolina-grown fish are predominantly sold to markets in the United States, with "some" going to markets in Canada

(Anon. 2013); however, data on the Canadian market share do not seem to be available publicly. The FAO (2016) also states that currently there is “limited” export of market-sized fish, but does not give export quantities or destinations. Dr. Anita Kelly is unaware of any market for food-sized fish outside of the US or Canada.

The US exports fry and some fingerlings to growers in Europe and Asia, predominantly Israel, and in both 2014 and 2015 the quantities of fry exported (between approximately 36 and 45 million pieces) were slightly higher than those for the domestic market (approximately 28 to 42 million pieces). Fingerlings represent a very small share of exports at about 1 million pieces in 2014 and zero in 2015 (Kelly 2016).

Production in Europe and Asia is predicted to increase as broodstock begin to be maintained locally by producers, and reliance on seed from the United States lessens. Nonetheless, the FAO (2016) also reports that there are strong pricing growth expectations as export to Europe and Asia increases. Currently, fish produced outside of the United States are reported to be consumed locally in regard to their production areas (e.g., Italy and Israel) (FAO 2016).

Common and Market Names

Scientific Name	*Morone chrysops* x *Morone saxatilis*
Common Name	Hybrid striped bass; sunshine bass

Product forms

Fish are predominantly sold on ice (~93%), with some sold live (~7%) (Kelly 2016), and although quick flash freezing is reported as becoming more common (FAO 2016), it is not yet significant in terms of volume compared to the aforementioned methods.

Analysis

Scoring guide

- With the exception of the exceptional criteria (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rating. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the three exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Standard that the following scores relate to are available on the Seafood Watch website: https://www.seafoodwatch.org/seafood-recommendations/our-standards

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Ponds and Tanks

Data Category	Data Quality	Score (0-10)
Industry or production statistics	10	10
Management	10	10
Effluent	7.5	7.5
Habitat	7.5	7.5
Chemical use	7.5	7.5
Feed	7.5	7.5
Escapes	7.5	7.5
Disease	5	5
Source of stock	7.5	7.5
Predators and wildlife	7.5	7.5
Introduced species	7.5	7.5
Other – (e.g., GHG emissions)	Not Applicable	n/a
Total		**85**

C1 Data Final Score (0-10)	**7.73**	**GREEN**

Brief Summary

The data available to assess or estimate the ecological impacts of HSB production in the US were moderately good. A body of peer reviewed literature exists, but the studies typically focus on improving production and are not often at an industry-scale. Personal communication with industry experts and producers was integral to understanding impacts, and regulatory information available in the public domain supported anecdotal and/or literature-derived information. There is a notable lack of publicly available information on chemical use and escapes. Overall, confidence in the information to determine the impacts was good for both production systems under assessment, and the final score for ponds and tanks is 7.73 out of 10 for Criterion 1 – Data.

Justification of Rating

Industry/Production Statistics

Industry and production statistics were freely available from industry researchers (World Aquaculture Society presentations), from the FAO online querying system, and the US Department of Agriculture (USDA 2014). Additionally, many states where HSB are an important cultured species have specific information on production volumes and values. The quality of the data was good and much of it was current, as confirmed by personal communication with academic researchers. The data score is 10 out of 10.

Management

Data pertaining to management of the HSB industry was freely available online via the various federal and state agencies involved in regulation of the aquaculture industry. The US Fish and Wildlife Service (FWS), US Food and Drug Administration (FDA) and US Environmental Protection Agency (EPA), and all their state derivatives, produced abundant information regarding the regulatory environment, permits, and management practices that are enforced or encouraged. Compliance and enforcement data are available online through the EPA, and some states also produce their own searchable enforcement history data (e.g., Texas, TCEQ). Academic institutions such as the Regional Aquaculture Centers (SRAC, NCRAC, etc.) and various universities also provide summaries of management protocols. The data score is 10 out of 10.

Effluent

Scoring for effluent production and discharge was evidence based; although there are no specific data for individual farms' effluent characteristics available in the public domain, contact with several producers provided a level of detail and quality assurance that allowed the evidence-based assessment to be used. Published data existed in the form of peer-reviewed research or technical papers that gave figures for effluent characteristics over various farms, seasons, and years. Though some of the literature was dated, it was corroborated by more recent analyses. The quality of the data used to undertake the assessment was high. Evidence for management content of, and compliance with, effluent discharge limits was also high. The National Pollutant Discharge Elimination Scheme is a highly developed regulatory tool under the jurisdiction of the EPA. Compliance data for facilities with discharge permits are all stored online in an interactive database (Enforcement and Compliance Online). The data score is 7.5 out of 10.

Habitat

Data used to assess the habitat criterion were moderate, but where they existed they were detailed and very up to date. These state-specific data were bolstered with information from individual producers; however, although in various locations, those contacted only represent a small percentage of all HSB producers. State regulations for North Carolina and Texas (the states with the biggest number of farms/volume of production) regarding aquaculture facility siting, permitting and licensing were available through the relevant state department websites (e.g., TCEQ, NCDEQ). Additionally, information about federal level requirements is available online through the EPA/FWS websites. There are a great number of regulatory requirements relevant to aquaculture and these are found across a number of different online sources. For this reason, a report published in 2005 that summarizes the regulatory environment for aquaculture in Texas was relied on as a guide. Although this is both state specific and somewhat dated, information was checked against appropriate current websites. The use of satellite imagery (i.e., Google Earth) was useful in understanding the location, scale, and surrounding habitat of HSB farms. The data were good quality but there were no example permits available to demonstrate the EIA-like functionality of site permitting regulations. The data score is 7.5 out of 10.

Chemical Use

Data detailing chemical use on individual farms are not available; however, through the EPA and FDA websites there is an abundance of more general information regarding regulated and unregulated chemicals, their allowed use, and discharge limits where appropriate. Additionally, other online sources (RACs and the American Fisheries Society) provided summary information regarding appropriate use of antibiotics, drugs, and other biologics. Communication with industry suggested that chemical use was not of primary concern in HSB production, but ultimately, there is an absence of data to demonstrate this. The data score is 7.5 out of 10.

Feed

Feed data quality was variable. Many academic research papers cover specific aspects of HSB feed formulation and feeding strategy; however, data related to actual commercial formulations were limited. Nonetheless, because many of the research efforts use commercially applicable feed formulations, a confident “best-guess” could be made for many of the details required. Furthermore, the number of papers available meant that figures could be averaged from the literature with some degree of confidence, and these figures were adjusted where appropriate, in accordance with information from producers. The source of wild fish used in fishmeal and fish oil could not be confirmed, although again, a confident approximation could be made. Information regarding the status of the wild fish fisheries was good quality and up to date (Seafood Watch and Fish Source). Some data did not exist, such as the percentage of fishmeal and fish oil produced from by-products, and the percentage of HSB by-products utilized. In these cases, approximate or default values were used. The data score is 7.5 out of 10.

Escapes

Although industry practices aimed at mitigating escape risk are well detailed in BMPs and biosecurity protocols, and escapes are required to be reported, data regarding actual escape numbers were not available. Communication with industry professionals indicated that likelihood of escape was very low under normal circumstances. Due to evidence of minimal ecological impact when compared to the potential impact of fishery stocking programs in the wild, it was possible to assess the potential impact with decent confidence; nonetheless, because of the lack of industry statistics, the data score is 7.5 out of 10.

Disease

Robust disease statistics for HSB farms were not publicly available. HSB are not affected by any listed diseases and are considered resilient when maintained in good water quality and with appropriate feed and stocking densities. This was confirmed by the producers contacted who recounted very few problems with disease and minimal need for chemical or drug treatments, including antibiotics. For certain producers this was verified by disease-free certificates. The lack of broader-scope industry data, together with variable effluent discharge rates somewhat compromised the ability to assess likelihood of ecological impact. These factors were considered alongside the known high level of on-farm biosecurity, as well as farm access to good quality information and help. Wild fish health monitoring data were available, but not all pathogens affecting farms are tested for, and there is some uncertainty regarding the proximity of sampling locations to farm sites. Overall, disease-related data are moderate with a particular lack of understanding of how on-farm pathogens might interact with the environment. The data score is 5 out of 10.

Source of Stock

The source of stock for HSB production is well established in online industry information (SRAC/NRAC) and on university pages where breeding programs are carried out. Furthermore, the wild stock from which broodstock could be sourced were reliably assessed by Seafood Watch and the IUCN. However, due to uncertainty in the quantity of wild versus domesticated broodstock used, and also in the origin of some of the wild broodstock, the data score is 7.5 out of 10.

Predator and Wildlife Mortalities

Information regarding wildlife interactions was not specific to HSB production, but rather to US aquaculture in general (and the southeast in particular); nonetheless, there were data detailing problematic species and methods of control, alongside the regulatory environment that allows (or prohibits) the lethal removal of certain species (EPA, FWS and state authorities, RACs). Though generic, data provided information regarding which species were relevant to which region, and were up to date, and these data were corroborated by individual producers and were thought to be a good representation of the industry. However, due to the lack of specific figures regarding lethal take of predator populations, the data score is 7.5 out of 10.

Secondary Species Introductions

Information regarding generic biosecurity protocols for pond and tank aquaculture is widely available through the RACs and this was supplemented by information from individual producers who provided overviews of their protocols. However, specific data regarding the movement of fish across and between different waterbodies were not apparent. As such, the data score is 7.5 out of 10.

Conclusions and Final Score

In general, the data available were rather non-specific, meaning assumptions have been made that the described situation does in fact reflect the reality. After making assessments using the data available, an effort was made to contact HSB producers and academics to review the evaluation and assure its appropriateness. Other data, notably data for the feed and habitat criteria, had abundant and specific data that were highly reliable but not generally representative of the entire industry conditions. In these cases, careful assessment and aggregation where appropriate was undertaken. The final numerical score for ponds and tanks for Criterion 1 – Data is 7.73 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.
- Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.
- Principle: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Evidence-Based Assessment

Ponds and Tanks

C2 Effluent Final Score (0-10)	8	GREEN

As effluent data quality and availability is good (i.e., Criterion 1 score of 7.5 out of 10 for the effluent category), the Evidence-Based Assessment was used.

Brief Summary

Data quality for effluent was good, and although there is a lack of information in the public domain relating to specific farm discharges, the general data-examining quality and quantity of effluent were detailed and relatively recent. This allowed the use of the Evidence-Based Assessment. Research has shown HSB effluent to have marginally-elevated suspended solids, total nitrogen (including ammonia), and BOD compared to supply water, but the report states that "current pond production methods practiced for warm-water species in the southern region do not have widespread negative effects on the environment." Pond and tank discharge, averaged throughout a production cycle, is typically low, but indeed variable (once per production cycle, zero over multiple production cycles, regularly throughout the production cycle, or recycled and treated). Regulations governing aquaculture effluent do so in conjunction with other industries and with allowable discharge characteristics to maintain (or improve) the water quality of receiving waterbodies. Through strong management, with evidence that farms are in compliance with regulations, and no evidence for ecological impacts as a result of effluent discharge, it can be concluded that the data show no evidence that effluent discharges from HSB farms cause or contribute to cumulative impacts at the waterbody or regional scale. As such, the final score for both pond and tank production is 8 out of 10 for Criterion 2 – Effluent.

Justification of Rating

In US HSB aquaculture, discharge from earthen ponds is variable and depends on location, fish health, pond conditions, season, and production stage (i.e., fry/fingerling/grow-out). In the cases where effluent is released, the volume of effluent from HSB discharge events is generally considered to be more problematic than the nutrient concentration it contains (Sydorovych and Daniels 2011). Water release tends to occur over summer months, i.e., April to October (Daniels et al. 2016) and April to August (Romaire 2012); Romaire (ibid.) counted 24 major, intentional (non-overflow) discharge events over the course of two years on one North Carolina farm, which equated to an annual release of 48 inches (120 cm) per water surface area. Wui and Engel (2004) presented figures for average water discharged for 28% of HSB farms, representing 56% of water acres, and showed that small farms tend to discharge a higher volume per surface area (21,736,000 L/ha) compared to medium and large sized farms (17,400,000 L/ha). If a typical pond is 1.5 m deep, this is equivalent to complete discharge once a year, plus a further 45% (small farms) or 16% (medium and large farms) of the pond capacity discharged over the course of the year, presumably during flushing events. Given that the production cycle is 12 to 19 months with the growout phase (i.e., Phase III) accounting for 10 to 12 months, this overall percentage of pond discharge per ~300-day production cycle is less than 0.5% per day (0.48% and 0.39% for small and large farms respectively).

Under normal circumstances, effluent discharge mainly occurs at harvest where ponds are drained after each crop to make sure all fish are removed. Since HSB are predators, fingerlings cannot be stocked into ponds with any remnant adult fish without suffering poor survival. Furthermore, draining ponds between crops helps control snail populations and eliminates any holdover unintentional resident fish (i.e., those mentioned by Ekstrom [J. Ekstrom, pers. comm. July 2017] to be potentially introduced by birds, etc.). Industry practice in North Carolina is to release effluent directly out of ponds into drainage ditches that flow into natural streams (Sydorovych and Daniels 2011), many of which are very low flow. In Texas and Mississippi, it has been stated that a focus on water resource management means that ponds are zero-exchange ponds over the course of a production cycle (H. Daniels, pers. comm. February 2017). However, discharge in these states does tend to be into flowing waterbodies (ibid.). In addition to draining, "flushing" with fresh water is sometimes carried out to mitigate against poor water quality, particularly high concentrations of un-ionized ammonia. This is neither thought to be effective, nor responsible use of water (D'Abramo and Frinsko 2008) (Romaire 2012); however, on certain farms, the practice still continues, resulting in an estimated annual exchange of 5% of total pond water volume (Sydorovych and Daniels 2011). One major producer (Ekstrom Aquaculture LLC Farm) is reported to flush ponds with well water as a last resort when ammonia levels get too high, normal control methods have failed, and fish are in imminent danger of dying. These are rare events, usually happening in the warmer months of spring and early summer before bacterial and algae blooms have become fully active and stable. For each affected pond, pumping rates of up to 3,000 gallons per minute (11,356 liters per minute) are maintained for 1 to 3 days, depending on circumstances (J. Ekstrom, pers. comm. July 2017).

Also, unintentional discharge may result from natural events, since some farms are situated on floodplains or subject to hurricane damage. Ekstrom Aquaculture LLC Farm has approximately 1,000 water-acres located on the Tres Palacios River, and just outside the modelled 100-year floodplain (Harris 2010) (J. Ekstrom, pers. comm. July 2017). Flooding events of the area are not uncommon and significant floods occurred in 1998 and 2002; however, the farm facilities were unaffected, even following a rainfall event of 22" in 24 hours within the watershed. The levee tops and standpipes are above any conceivable flood event—ponds are designed with 24 inches of freeboard above the design water level, and water levels are normally kept 3 to 6 inches below the top of the standpipe in order to capture most rainfall and limit groundwater requirements. Excess rainfall is slowly released as overflow through the standpipes, but no other unintentional discharge events have occurred in the history of the farm (J. Ekstrom, pers. comm. July 2017). Similarly, North Carolina is susceptible to hurricanes, but wash-out of the ponds is "not regular" (H. Daniels, pers. comm. February 2017).

Water quality is maintained by natural biological and chemical processes in the pond and aided by careful management of feed input, addition of freshwater to counteract evaporation, and maintenance of dissolved oxygen (DO) above 4 ppm (D'Abramo and Frinsko 2008) by monitoring and use of mechanical aerators when indicated. However, there are inevitable changes in composition throughout the production cycle. Tucker (1998) measured water quality parameters in 20 HSB ponds in South Carolina and found great variation from pond to pond, but in general, suspended solids, total nitrogen (including ammonia nitrogen), and biological oxygen demand (BOD) were all significantly higher as compared to water supply. This is consistent with more recent findings which showed measured effluent contained a very small amount of settleable solids; 95% of total solids and 65% of total suspended solids were < 5µm, and 80% of BOD, total phosphorus, and total nitrogen was associated with such particles (Romaire 2012). Where ponds are drained into ditches (e.g., North Carolina), some nitrogen is removed from the effluent by uptake therein. Calculated from figures given in Culbreth (2016), total oxidized nitrogen (NO_2-N + NO_3-N) was reduced by 60%, and un-ionized nitrogen was reduced by 17%, but there were small increases in total suspended solids (5%) and in chlorophyll-a (4%).

A review of treatment options for effluent from ponds (Wui and Engle 2004) identified best management practice to be retention of water over multiple production cycles. No significant effect on production statistics were observed in the short term, although feed consumption and mean weight were lower in the undrained ponds, and the report acknowledges that the effects on production over multiple production cycles needs to be quantified. Similarly, Romaire (2012) reported that following three consecutive years of zero exchange production, the only difference in water quality was a higher concentration of total suspended solids in the undrained ponds. However, some producers are reluctant to forego draining and drying ponds due to that strategy's aforementioned efficacy at removal of nuisance snail and grub populations.

The Wui and Engle (2004) review identifies that constructed wetlands are effective in treating effluent but too expensive to be implemented by farms. More recent research has indicated that integrated aquaculture-agriculture in the form of woody biomass crops and HSB is effective for boosting production of the tree crop, as well as improving effluent quality. Chlorophyll a, total organic carbon, total suspended solids, and nitrogen in groundwater of HSB effluent irrigated poplar plantations were all maintained below regulatory limits (Shifflet et al. 2016); chlorophyll a was reduced by 84% and suspended solids by 47%. Furthermore, application of effluent for irrigation effectively turns a point source of pollution into a non-point source, with an attendant reduction in compliance criteria and therefore a possible appeal to producers as well. However, to date this approach has not been commercially adopted (H. Daniels, pers. comm. February 2017).

Romaire (2012) recommends the use of BMPs to further reduce the volume and improve the quality of effluent. BMPs developed as part of this project are reproduced here (Table 1). They include: measures to address effluent volume; minimization of suspended solids through erosion control; methods for improvement of pond and effluent water quality; best practice regarding therapeutants and chemicals, and; best practice regarding construction of new ponds. Although there is no obligation to use these practices, they both facilitate compliance with measures that are legally required (e.g., BOD) and they also promote an environment conducive to maximizing production. It is therefore in the interest of HSB producers to put the suggested measures in place.

Table 1. Best Management Practices for Effluent Discharge.

	Best Practice Recommendation
Effluent volume	• Create new watershed ponds with a watershed area to pond area ratio of ≤ 10:1. • Maintain good vegetative cover on all parts of the pond watershed. • Harvest fish by seining, without draining ponds. • Maintain at least 8 inches of storage capacity in finfish ponds during summer/fall. • Do not flush well or stream water through finfish ponds.
Erosion control (Minimizing suspended solids)	• Use vegetative cover and terraces to control watershed/dam/ embankment erosion. • Exclude livestock from watersheds. • Eliminate steep slopes on farm roads, cover roads with gravel. • Avoid empty ponds in winter or spring, close drains in empty ponds. • If possible, discharge effluent from ponds into natural wetlands.
Water quality	• Make careful feed selection. • Careful feed application. • If feed accumulates in ponds, remove it manually. • Careful and monitored fertilization. • Careful storage of feed and fertilizers.
Chemicals	• Careful storage to avoid spillage. • Use of good husbandry to avoid fish stress and minimize disease incidence. • Follow label instructions for use of therapeutic agents. • Follow recommended application rates for copper sulfate, sodium chloride, lime, limestone, and gypsum. • Avoid release of copper sulfate treated water for 72 hours. • Obtain definite diagnoses and treatment recommendations for diseases prior to treatment with therapeutic agents.
Pond construction	• New pond construction according to the USDA-NRCS standards. Riparian vegetation should be preserved or established to provide a vegetative buffer zone along streams. • Do not locate new ponds in watersheds that are already affected by subdivisions, industrial activities, or row-crops.

For tank production systems, the volume and composition of effluent varies with the specific type of system used; single-pass flow-through systems release large amounts of dilute effluent, while recirculating systems can re-use upwards of 95% of the original water volume. Ohs et al. (2008) state that Florida producers use flow-through systems, although “some” use this water for irrigation of terrestrial crops or to cultivate other fish species, and some recirculate a proportion of the water by passing it through settlement ponds and wetlands before return to the HSB ponds. The two tank producers (North Carolina and Colorado) that were successfully contacted for this assessment both have hybrid flow-through/recirculation systems, although at very different recirculation rates (~30% compared to ~85%). HSB effluent is comprised of a high proportion of fine solids (Romaire 2012); both producers use drum filters to partially remove larger particles and have various subsequent systems in place to further reduce the fine solids load. Colorado Catch circulate the effluent through tilapia tanks, tilapia acting as biofilters, and then use either settling tanks (November to March) prior to diluting and discharging wastewater, or directly apply the wastewater onto land used for growing small grains and alfalfa (April to November) (T. Faucette, pers. comm. September 2017). The North Carolina producer uses a biobead filter in conjunction with the drum filter, following which the effluent flows into a 0.1 ha (0.25 acre) holding pond for settling of solids. After this, effluent passes into natural wetland before being released into a creek (Anonymous, pers. comm. September 2017). Both producers directly apply settled solids onto land that is also under their own management; for production of grains and alfalfa (Colorado Catch) or hogs (North Carolina). Both producers are upgrading their systems to include further drum filters and possibly swirl separators (Colorado) and sand filters for polishing of effluent (North Carolina). It is therefore anticipated that the effluent quality will further improve in the near future.

Management of farm-level and cumulative impacts

The US EPA (Environmental Protection Agency) is the federal agency responsible for setting standards for, and maintaining, water quality. This is incorporated in legislation under the Clean Water Act (1972) and administered using the National Pollutant Discharge Elimination System (NPDES). This is specific to point sources of effluent, for production quantities of over 100,000 lb (45.4 MT) of freshwater fish per annum, and may be transposed to state law as is, or with additional criteria (EPA 2013). A production facility must obtain a permit before discharging effluent. Permits contain: “technology-based effluent limitations (based on the amount of pollutant reduction that can be achieved by applying pollution control technologies or practices), water quality-based effluent limitations (based on the water quality standards for and the condition of the receiving waterbody), or both. They might also contain additional Best Management Practices (BMPs), as needed (see Table 1) (EPA, 2006). In general, limits to water quality parameters of Biological Oxygen Demand (BOD), chlorophyll-a, and total suspended solids are set. North Carolina Division of Water Quality, for example, enforces limits of 5 mg L^{-1}, 40 µg L^{-1} and 30 mg L^{-1}, respectively (Sydorovych and Daniels 2011). The Texas Pollution Discharge Elimination System (TPDES) effluent limitations vary according to the scale of the facility and also the character of the receiving waters; in this case, a differentiation is made based on whether receiving streams have a head flow of greater or less than 2.5 cu ft per second. According to these criteria, parameters for dissolved oxygen (DO: 5 mg L^{-1} or 6 mg L^{-1}), carbonaceous biological oxygen demand (BOD: 250 lb day^{-1} or 64 lb day^{-1}) and ammonia nitrogen (2 mg L^{-1}) are set, along with required frequency of monitoring. Additionally, independent of receiving waterbody type, flow, total suspended solids (90 mg L^{-1}), inorganic suspended solids, residual chlorine, and pH must all be monitored and reported.

In Texas, most HSB effluent is discharged into flowing streams; however, in North Carolina some farms drain into slow-moving (or even zero-flow) waters (e.g., the Pamlico Sound, which is designated as nutrient sensitive and has been classified as having impaired nutrient status since 1991 (NC DEQ 2018)). This designation requires implementation of a strategy for recovery of water quality and includes a total maximum daily load (TMDL) for the pollutant(s) implicated in the loss of good water quality status in the first place, in this case nitrogen and phosphorus. Regarding point source contributions to nutrient loading, 98% come from wastewater treatment facilities in the Pamlico Sound and these are regulated under a collective nutrient cap. Although the contribution made by aquaculture is not specified, it is indeed small by comparison (i.e., a percentage of the remaining 2%). Identification and quantification of HSB effluents with potential impacts to surface waters is a target action in the Tar-Pamlico River Basin action plan, with the possibility of incorporating their contributions to the overall nutrient budgeting (NC DEQ 2010). Management in this case is ecosystem based (i.e., watershed) and takes into account the cumulative impact of all factors contributing to decreased water quality.

The EPA requires monthly completion and submission of Discharge Monitoring Reports (DMRs) to the relevant state bodies (e.g., TCEQ and NCDEQ). These submissions are necessary in order to maintain an aquaculture license; they detail both quantity and quality of effluent discharged and refer to general effluent characteristics (suspended solids, BOD, etc.) as well as those specific to individual farms, for example, relating to drugs or chemicals not monitored across the board. In Texas, the Compliance History Database (http://www2.tceq.texas.gov/oce/ch/) allows a search for an entity's rating and classification (regarding effluent discharge) using a specific Regulated Entity Number and/or Customer Number. More specific information on the violations documented at a site can be found online by searching the TCEQ's Central Registry database, along with the possibility of generating Compliance History Reports for specific Customer (CN) and Regulated Entity (RN) combinations (M. Staedtler, TCEQ, pers. comm. April 2017). A search of all current Texas HSB facilities (as listed in Treece 2017) revealed that all were rated with the highest (best) classification and none were in violation of their permits.

Compliance monitoring is carried out by qualified EPA inspectors, and all facilities covered by the Clean Water Act have their current and historical compliance/non-compliance information held online in a searchable database, Enforcement and Compliance History Online (ECHO). Violations are preferentially dealt with administratively via a “notice of violation” and if this does not result in compliance, a legal process is initiated. There is a searchable database that demonstrates that violations are acted upon, and that penalties do result in a return to compliance (https://echo.epa.gov/facilities/facility-search). A search on the ECHO site using the search criteria shown in Figure 2, below, returned results only for trout farms (Figure 3). From this it can be concluded that there are no North Carolina farms that exceed the criteria requiring an NPDES discharge license (100,000 lb/year or discharge more than 30 days/year). Looking at the results for the trout farms it can indeed be confirmed that where licenses are granted, compliance is monitored and enforced and the data are publicly available. Regarding North Carolina HSB farms however, their relatively small size necessitates regulation by other means; see the paragraph referring to Tar-Pamlico river basin management above.

Figure 2: ECHO database search criteria used to identify North Carolina aquaculture compliance.

Facility Name	NPDES ID	Mapped	Reports	Street Address	City	State	FRS ID	Significant Noncompliance (SNC) Status	Quarters in Noncompliance (3 yrs)	Effluent Violations (3 yrs)	On-Site Inspections (5 yrs)	Formal Enf Actions (5 yrs)
BURKHART TROUT FARM	NCG530081		C E L	6298 BLUE RIDGE RD	LAKE TOXAWAY	NC	110018596223	--	0	--	1	0
CAMP COVE TROUT FARM	NCG530069		C E L	PO BOX 132A	LAKE TOXAWAY	NC	110018508319	--	0	--	1	0
CAROLINA FISHERIES, INC.	NCG530164		C E L	NCSR 1912	AURORA	NC	110022564063	--	0	--	1	0
CHEROKEE TRIBAL TROUT FARM	NC0052451		C I E L	QUALLA BOUNDARY	CHEROKEE	NC	110016693773	--	4	20	--	1
CHEROKEE TROUT FARM	NC0054992		C I E L	10285 BIG COVE ROAD	CHEROKEE	NC	110009720123	--	2	18	--	1
CRAIG'S TROUT FARM	NCG530068		C E L	4670 OWL CREEK RD	MURPHY	NC	110018531347	--	0	--	1	0
GRANDFATHER TROUT PONDS	NCG530047		C E L	HWY 105	BANNER ELK	NC	110018750118	--	0	--	1	0
HIGH VALLEY TROUT FARM	NCG530064		C E L	615 CATHEYS CREEK RD	BREVARD	NC	110018574292	--	0	--	1	0
MORGAN MILL TROUT FARM	NCG530074		C E L	RT 2 BOX 397	BREVARD	NC	110018529877	--	0	--	1	0
PARKER CREEK TROUT FARM	NCG530080		C E L	RT 1 BOX 89	LAKE TOXAWAY	NC	110018574540	--	0	--	1	0
				2697								

Figure 3: North Carolina aquaculture non-compliance history (as shown on ECHO database).

It can be seen that there is variation between different states regarding availability of monitoring and compliance information. However, the EPA ECHO system acts as a "catch-all" and provides access to this information even where individual states do not. So that although, for example, North Carolina DEQ does not have the same searchable facility as Texas, the relevant information is still available and compliance and enforcement in this case are considered to be highly effective, since enforcement organizations are identifiable and contactable, and resources are appropriate to the scale of the industry. Enforcement is active at the area-based scale and covers the entire production cycle and peak events. Evidence of monitoring and compliance, and evidence of penalties for infringements are available.

Conclusions and Final Score

Data quality for effluent was good, and although there is a lack of information in the public domain relating to *specific* farm discharges, the general data examining quality and quantity of effluent were detailed and relatively recent. This allowed the use of the Evidence-Based Assessment. The recent SRAC report (Romaire 2012) states that "current pond production methods practiced for warm-water species in the southern region do not have widespread negative effects on the environment, nor do they waste resources." Discharge averaged throughout a production cycle is typically low, but indeed variable (once per production cycle, zero over multiple production cycles, regularly throughout the production cycle or recycled and treated). Combined with strong management and enforcement of regulations, with evidence that farms are in compliance with regulations, and no evidence for ecological effects as a result of effluent discharge, it can be concluded that the data show no evidence that effluent discharges from HSB farms cause or contribute to cumulative impacts—particularly beyond those regulated to be protective of ecosystems and their services—at the waterbody or regional scale. As such, the final score for both pond and tank production is 8 out of 10 for Criterion 2 – Effluent.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Ponds and Tanks

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		7
F3.2a Content of habitat regulations	5	
F3.2b Enforcement of habitat regulations	5	
F3.2 Regulatory or management effectiveness score		10
C3 Habitat Final Score (0-10)		**8**
Critical?	NO	**GREEN**

Brief Summary

The southeastern states have the largest number of HSB farms and account for the highest volume of production. Farms are typically sited in former agricultural land or, in some cases, moderate value semi-riparian habitat. However, the industry is demonstrably disparate and limited in scale resulting in minor to moderate habitat impacts. As such, the score is 7 out of 10 for Factor 3.1 for both ponds and tanks. As the industry lacks a national growth and management plan, the siting of HSB farms is considered for approval on an individual basis. However, in all locations where HSB are farmed, local, state, and federal regulations consider the potential habitat impacts of farm construction and operation in conjunction with other industries and resource users. Ultimately, a moderate habitat conversion (Factor 3.1) and robust regulations regarding permitting of aquaculture facilities (Factor 3.2) results in a final score of 8 out of 10 for ponds and tanks for Criterion 3 – Habitat.

Justification of Rating

Factor 3.1. Habitat conversion and function

The Habitat criterion assesses the potential ecological impacts within the boundary of the farm and therefore consider initial siting and size of the farm, land-use conversion, water source, dredging and filling, and the overall impact to the functionality of the ecosystem in which the farms are sited.

The majority of HSB pond farms are situated in the southeastern states, and as North Carolina and Texas have the largest number of farms and the largest production volume respectively, the assessment of their habitat-related impacts drives the score.

North Carolina has 21% of HSB farms in the US (14 farms), and there are data relating to land use/habitat types in which NC aquaculture farms are situated. Culbreth (2016) studied land use surrounding 36 NC farms (of which at least 10 were HSB farms) and calculated the following land cover in the 1 km zone surrounding the farms:

Table 1: Habitat type around NC HSB farms, denoting percentage cover and habitat "value" according to SFW criteria.

Habitat Type	***% cover***	***Habitat value (SFW category)***	***Total %***
a) *Open water*	3	High	3
b) *Woody or emerging herbaceous wetlands* ***c)*** *Deciduous and mixed forest*	25.5 4	Moderate	29.5
d) *Herbaceous* ***e)*** *Shrub/scrub* ***f)*** *Evergreen forest*	4 13 11.5	Low	28.5
g) *Cultivated crops & hay pasture* ***h)*** *Developed space or barren land*	35 5	Unaffected	40

North Carolina HSB farm sizes range from 3 to 100 water-acres (1.2 to 40.5 water-ha), 18 water-acres (7.3 water-ha) being the median (Dasgupta and Thompson 2013). In Texas, there are currently 11 HSB farms, with a total of 1,900 water-acres (768.9 water-ha) under production, of which Ekstrom Aquaculture LLC farms are approximately 1,000 water-acres (404.7 water-ha) (Treece 2017). Prior to establishment of the farms, the land was used for pasturing cattle, and before that it was used to farm rice (J. Ekstrom, pers. comm. July 2017). Data specifying the location of farms using tank production was not generally available; however, they are more intensive systems that by their nature take up less land area. Confirming this, Colorado Catch has a small total areal footprint of 0.81 ha (2 acres) with an annual production capacity of 550,000 lb (~250 metric tons) (T. Faucette, pers. comm. September 2017). The site has been an aquaculture site since 1972 and producing HSB since 1992. Prior to 1972, it was agricultural land; therefore, the conversion is, for the purposes of this assessment, deemed historical.

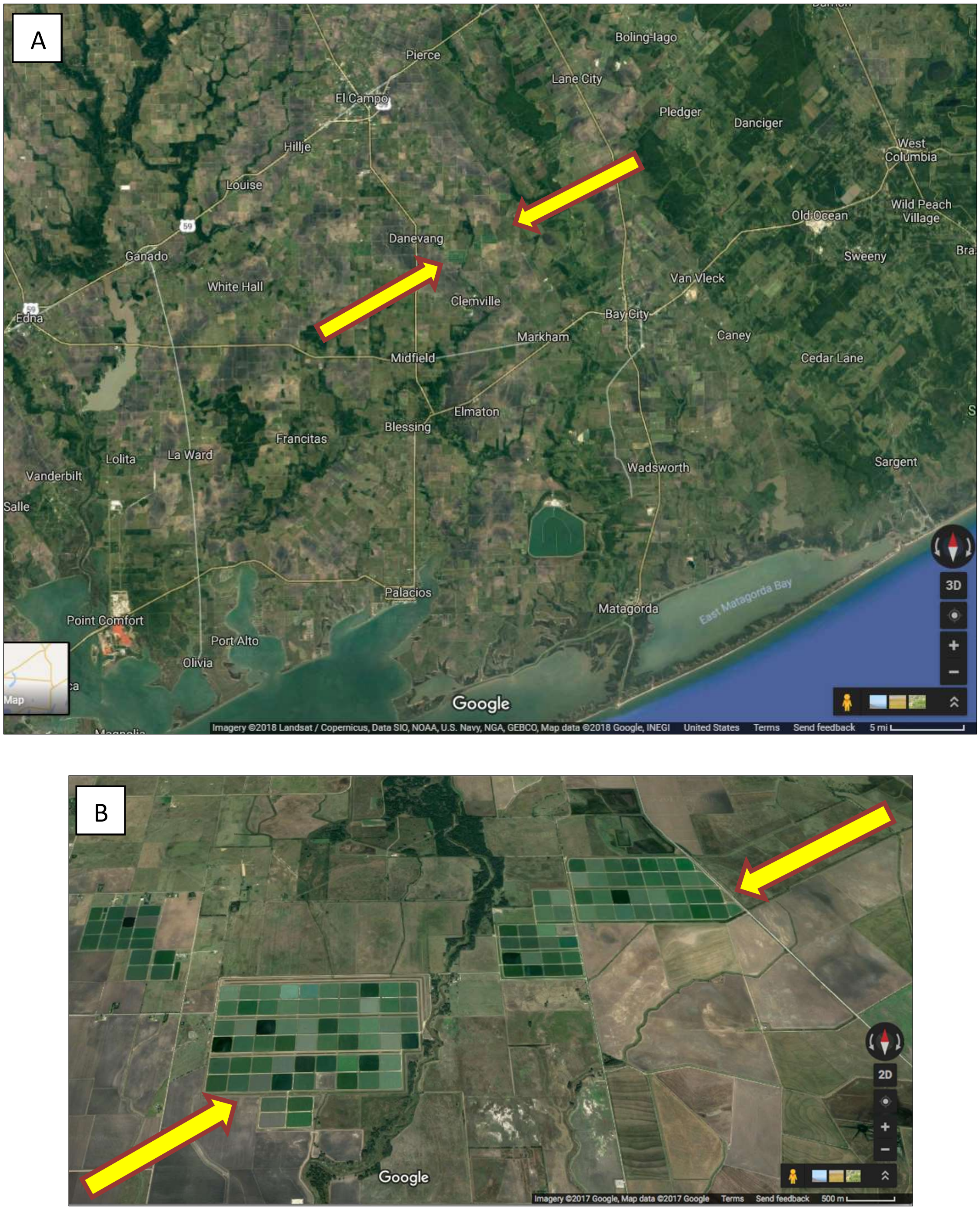

Figure 1. An aerial view of the largest HSB producer in the US, Ekstrom Aquaculture LLC, Danevang, TX. The yellow arrows in *A* indicate the location and size of the two primary pond clusters as similarly indicated in *B*.

Figure 2: An aerial view of Vanguard Farms and surrounding habitat in North Carolina. The yellow arrow in A indicates the location and size of the pond cluster as similarly indicated in B.

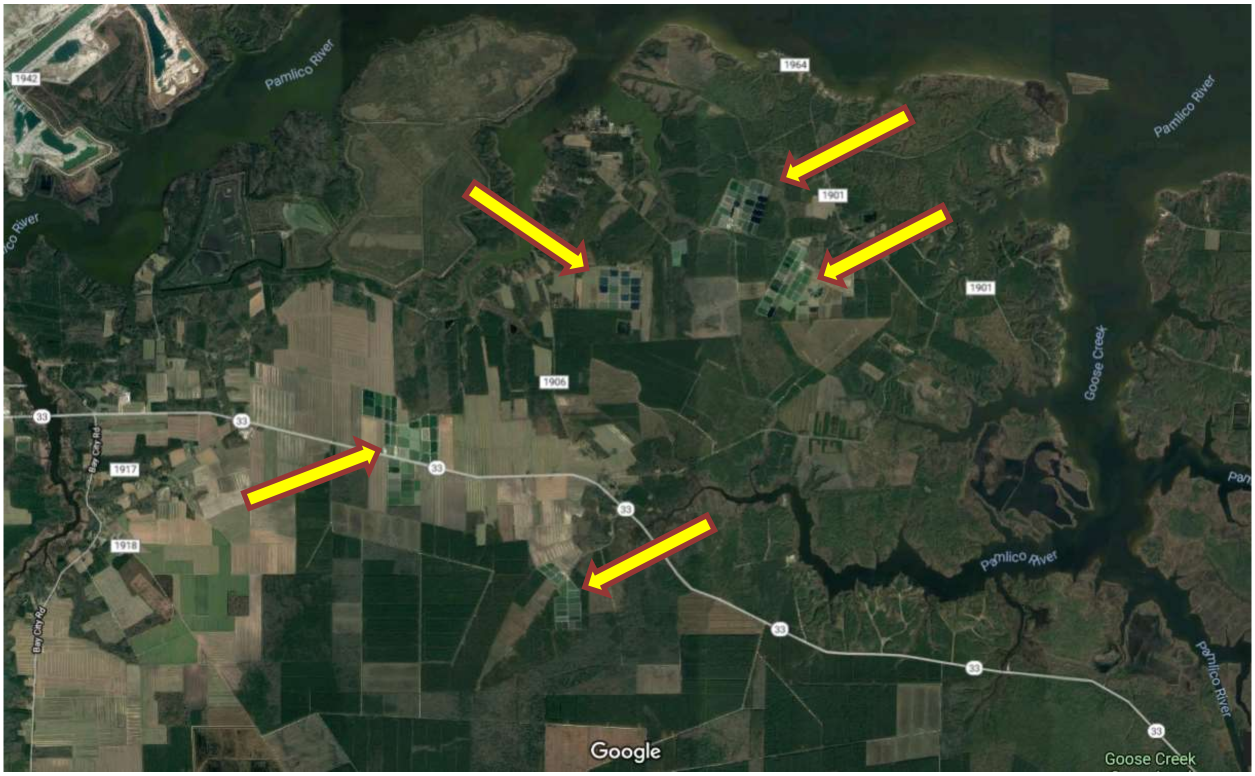

Figure 3: An aerial view of HSB ponds, as indicated by yellow arrows, adjacent to the Pamlico River in eastern North Carolina. This is likely an example of the densest concentration of HSB farms in the US.

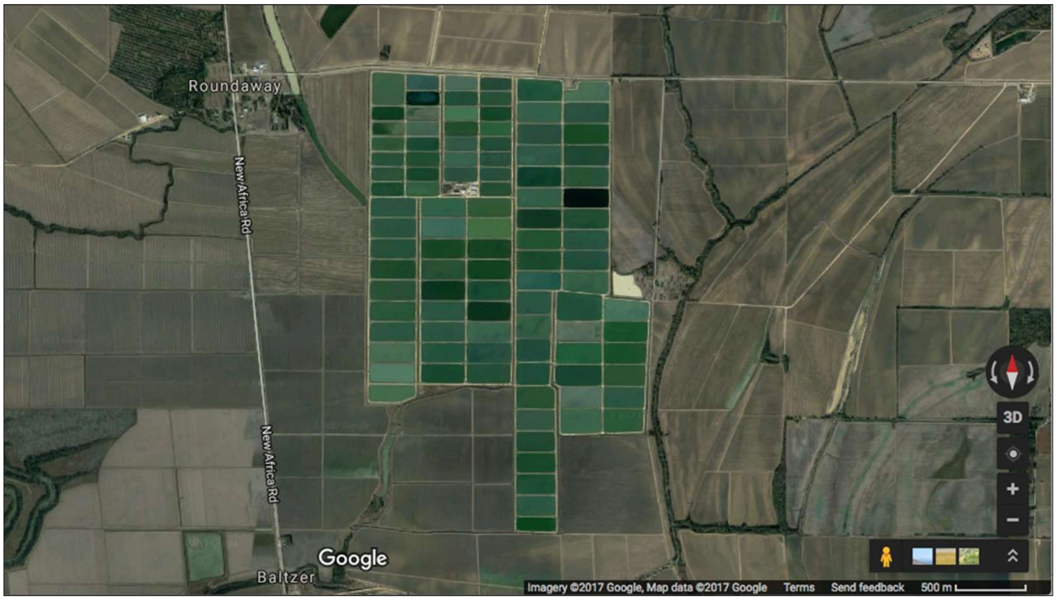

Figure 4. An aerial view of pond producer Nature's Catch, Mississippi.

Figure 5. An aerial view of tank-based producer Colorado Catch, Colorado.

Most HSB farms have been in operation for many years: in North Carolina, production began in 1987 (Sydorovych and Daniels 2011), in Texas, Ekstrom Aquaculture LLC began farming in the mid-1980s, and Colorado Catch began farming HSB in 1992. Therefore, the conversion of land is considered "historic" for the purposes of this assessment (i.e., >15 years ago), and there are indications that many farms were built on previously converted land (i.e., for terrestrial agriculture, etc.). For any farms that may have been built on virgin land, satellite imagery (namely Google Earth) in conjunction with the information in Culbreth (2016) indicate the habitats that may have been converted for HSB farms in the US are that of terrestrial agriculture or woody or scrubby forest land.

Importantly, the HSB industry, with only a few dozen farms, is scattered. Aerial imagery, as seen in Figures 1–5, demonstrates that farms are isolated from one another and account for a very small percentage of the overall land area in the places where they are sited. The largest farm in the country, accounting for 1,000 of the 1,900 total water-acres in Texas (Treece 2017), can be seen in Figure 1B to be representative of the scale of pond acreage compared to that in use for agriculture. Similarly, even in an area where "most" of the North Carolina producers operate (Angione 2008), it can be seen how little pond coverage contributes to the broader habitat (Figure 3).

Overall, most of the HSB industry is located in habitats that had already been converted for other purposes (e.g., plant and/or animal agriculture). Additionally, the industry is sparsely distributed with farms typically in isolation from one another. In some locations, farms are sited in habitats that are of moderate value (e.g., the semi-riparian lands lining the Pamlico River), but overall, it can be concluded that HSB farms—while having a moderate impact to the land directly within the farm footprint—do not result in a loss of broader ecosystem functionality. As such, the score for Factor 3.1 is 7 out of 10.

Factor 3.2. Farm siting regulation and management

<u>Factor 3.2a: Content of habitat management measures</u>
Although Environmental Impact Assessments (EIAs) are not specifically required for initial site licensing by federal law, some states do require them (e.g., California), and where they are not required, much of the information that would be included in an EIA is required in order for an aquaculture facility license to be granted (Telfer et al. 2009). For example, many of the aspects that form the basis of EIAs must be considered prior to issuance of a permit, including: species to be cultured; protection of ecosystems from detrimental species; protection of critical habitat; protection of water resources; protection of plant and wildlife genetic integrity; disease potential and protection of plant and wildlife health; protection of natural resources from illegal harvesting and commercialization; protection of natural resources from nuisance species; security and welfare of the aquaculture industry of the state (Telfer et al. 2009).

The responsibility for this protection falls to a number of federal and state agencies. Engaging in aquaculture requires an aquaculture license from the relevant state Department of Agriculture, and licenses are issued together with additional permit requirements and stipulations for record-keeping. Where necessary, an effluent discharge license must be submitted alongside this application—to the EPA (for discharge under the NPDES) or the equivalent state authority (e.g., the TCEQ in Texas [for discharge under the TPDES]). Initial siting and construction of a facility usually requires a Section 404 permit under the Clean Water Act (CWA) and is administered by the Army Corps of Engineers (ACE). The CWA relates to maintenance and protection of the nation's water sources and a permit is required for construction of intake structures, laying pipelines, dredging and spoiling and levee creation, among other activities. Applications for permits are reviewed by the ACE in coordination with other relevant agencies. For example, in Texas, comment and review of the permit application is (or may be) required by the EPA, FWS, TCEQ, TPWD, and the TDA who are collectively responsible for the regulation of aquaculture activities. Additionally, the TCEQ approves/regulates diversion of surface freshwater, discharge of effluent to public waters, and use of effluent for land irrigation. Where state regulations are stricter than their federal equivalent, they take precedent. Activities must also be compliant with all local and regional authorities' regulations regarding water supply, solid and waste disposal, land use zoning, and construction (summarized from Treece et al. 2005). In HSB production, most ponds and tanks are filled using groundwater, which is also used to replace that lost to evaporation throughout the year; all producers contacted for the purposes of this report (both tank and pond systems) used groundwater sources for their operations. Groundwater withdrawal permits are acquired from the affected water district.

In North Carolina, state code specifies suitable watersheds for aquaculture of certain species. For example, the NC General Statutes Ch. 106 Article 63) states, regarding fish passage and residual stream flow:

> (a) Natural watercourses as designated by law or regulation shall not be blocked with a stand, dam, weir, hedge, or other water diversion structure to supply an aquaculture facility that in any way prevents or fails to maintain the free passage of anadromous or indigenous fish.
> (b) Residual flow in a natural watercourse below the point of water withdrawal supplying an aquaculture operation shall be sufficient to prevent destruction or serious diminution of downstream fishery habitat and shall be consistent with rules adopted by the Environmental Management Commission.

The Texas Agriculture Code broadly applies to licensing, siting, planning, and operations; Section 201.001 (Findings, Purpose and Policy) contains basic language aimed at long-term conservation of water and soil resources (both required by aquaculture) and which broadly take into account food and water resources, provision of habitat, and cover for wildlife. It also refers specifically to the breaking of natural grass, plant, and forest cover interfering with natural processes that maintain ecosystem functions. This language authorizes oversight of aquaculture by state agencies and outlines punishments for violations of code. The Code also has stipulations aimed at preventing discharge of effluent into sensitive habitat in the coastal zone, effectively preventing the siting of aquaculture facilities in sensitive coastal areas.

Overall, the siting of HSB farms is regulated on an individual basis and the presence of an industry-wide development plan, complete with restrictions on cumulative habitat impacts, is not apparent. However, farm siting is indeed tightly managed by the coordination of multiple regulatory bodies at the local, state, and federal level, whose functions include assessing development and habitat use for multiple industries and resource users—inclusive of aquaculture—together. The score for Factor 3.2a is 5 out of 5.

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

Aquaculture facilities are required to be compliant with state and federal legislation and must allow access to facilities for assessment of compliance. For example, as relates to South Carolina: The Department of Natural Resources may amend, suspend, or revoke a permit if it determines some aspect of the permitted aquaculture activity adversely impacts the natural resources of the State or the security or welfare of the aquaculture industry of this State. Access to the facility must be granted to department agents and it is unlawful to fail to comply with the requests of a department agent. Facilities operating without permits are unlawful by default and therefore subject to legal penalty (Aquaculture Enabling Act (50-18-2)—South Carolina Legislative Services Agency).

More specifically, evidence of enforcement and compliance is demonstrated as detailed in Criterion 2: Effluent, the EPA has an online, searchable database—Enforcement and Compliance History Online (ECHO)—detailing violations of environmental laws and regulations. This provides information about the facility in violation, the action being taken to bring the facility into compliance (either administrative or formal), the penalty imposed, and the progress of the action. Texas Commission on Environmental Quality (TCEQ) also has a similar searchable database, the Texas Compliance History Database, detailing the same information as ECHO. North Carolina Department of Environmental Quality (NCDEQ) provides information on its enforcement actions according to each division in the DEQ. Links on the website provide relatively up-to-date (division-dependent) information on infringements, and in some cases on the penalties imposed. This is neither searchable, nor as comprehensive as the information available through ECHO or TCEQ but does demonstrate that enforcement is active.

Overall, it is clear that the enforcement organizations are identifiable and contactable, and their resources are appropriate to the scale of the industry. Enforcement is active at the area-based scale, the permitting and licensing process is transparent, and there is evidence of penalties for regulatory infringements. As such, the score for Factor 3.2b is 5 out of 5.

When combining Factors 3.2a (5 out of 5) and 3.2b (5 out of 10), the final Factor 3.2 score is 10 out of 10.

Conclusions and Final Score

The southeastern states have the largest number of HSB farms and account for the highest volume of production. Farms are typically sited in former agricultural land or, in some cases, moderate value semi-riparian habitat. However, the industry is demonstrably disparate and limited in scale resulting in minor to moderate habitat impacts. As such, the score is 7 out of 10 for Factor 3.1 for both ponds and tanks. Since the industry lacks a national growth and management plan, the siting of HSB farms is considered for approval on an individual basis. However, in all locations where HSB are farmed, local, state, and federal regulations consider the potential habitat impacts of farm construction and operation in conjunction with other industries and resource users. Ultimately, a moderate habitat conversion (Factor 3.1) and robust regulations regarding permitting of aquaculture facilities (Factor 3.2) results in a final score of 8 out of 10 for ponds and tanks for Criterion 3 – Habitat.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.
- Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments
- Principle: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary

Ponds and Tanks

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

Brief Summary

Best Management Practices (BMPs) in HSB farming require the use of certain chemicals to ensure good husbandry and that fish health and welfare standards are maintained. Of highest concern are the antibiotic treatments available for HSB. Unfortunately, there are no federal or state requirements to publish use information; as such, there are no data in the public domain or otherwise available to indicate the true frequency of antibiotic use across the industry. However, the reported need for antibiotics across the industry is low (tanks) to none (ponds). Chemical use is highly restricted and strongly regulated in US aquaculture. Regulation is based on thorough risk analysis, including data on residues, fate, and toxicity to target and non-target species, which limits the risk of ecological impact should any chemicals used on farm be discharged to the environment. Ultimately, low discharge, strong regulation, and indications that chemicals of concern are used less than once per production cycle results in a final score of 8 out of 10 for both pond and tank production for Criterion 4 – Chemical Use.

Justification of Rating

Chemicals are used in HSB farming for control of pest species, medication/treatment during disease outbreaks, and routine handling and cleaning procedures. Some chemicals are required in order to comply with Best Management Practices (e.g., disinfectant use for effective biosecurity, tricaine methanesulfonate (MS-222) for sedation prior to handling), and others (e.g., therapeutants), may be legally required if animal health and/or welfare becomes compromised. In general, it is in the interest of the aquaculturist to be judicious in the use of chemicals in order to maintain cost effective production, and furthermore, HSB production does not require extensive use of chemical treatments. Table 2 provides a summary of chemicals approved or available for use in HSB production (adapted from USFWS 2015) (Boyd and McNevin 2015). These product listings are not exhaustive; chemical use varies as choices of chemical will depend on current market availability and price.

Table 2. Chemicals approved/available for use in HSB production.

Category	Products	Uses	Restrictions/Comments
Pesticides	Rotenone	Insecticide; piscicide; pesticide.	EPA approved. Must be used by certified pesticide applicator.
Herbicides	Various: see http://www.weedscience.ncsu.edu/aquaticweeds/pesticide.pdf for a thorough appraisal (Richardson & Getsinger 2016)	Indications for use depending on the species/type of weed (filamentous / planktonic / macrophyte etc.) to be controlled and the environment to which the herbicide should be applied.	Algal or weed die-off can result in decreased oxygen and therefore water quality problems.
Antibiotics	50% Florfenicol (AQUAFLOR)	Approved for streptococcal septicaemia (*Streptococcus iniae*) and columnaris disease (*Flavobacterium columnare*)	Veterinary Feed Directive Drug (VFD) requires prescription from a licensed veterinarian. 28-day withdrawal period.
	Oxytetracycline dihydrate (TERRAMYCIN® 200 for Fish)		Extra-label use for HSB under direction of licensed veterinarian only.
	Sulfadimethoxine + Ormetoprim (ROMET® 30, ROMET® TC)		Extra-label use for HSB under direction of licensed veterinarian only.
Chemical Therapeutants	Emamectin benzoate (SLICE®)	Control of external copepod parasites.	7 days consecutive infeed treatment. 60-day withdrawal period.
	Potassium permanganate (CAIROX®)	Control of protozoan and metazoan parasites, bacterial and fungal infections in warmwater fish.	Static bath, 1-10mg/L for 1 hour. No withdrawal for fish that are not susceptible to legal harvest for 7 days post-treatment.
	Formalin (PARASITE-S, FORMALIN-F, FORMACIDE-B)	Control of external protozoa and monogenetic trematodes.	Earthen ponds: 15-25 uL/L Do not treat ponds containing striped bass
	100% chloramine t* (e.g. Halamid-Aqua®)	Approved for external columnaris disease in warmwater freshwater finfish.	20md/L for 60 min, once daily on consecutive or alternate days for 3 treatments. Bypass biofilter in recirculating systems. 0-day withdrawal.
	Hydrogen peroxide* (35% PEROX-AID®)	Control of mortality caused by ectoparasites including *Ichthyophthirius, Ichthyobodo, Trichodina.*	100-200 mg/L for 30 minutes once daily on 3 consecutive or alternate days. No withdrawal period.
Anaesthetics	Tricaine methane sulfonate – (MS-222)	Temporary immobilization	15–330 mg/L. 21-day withdrawal time. Water temp. should not exceed 10°C.
	Eugenol (AQUI-S® 20E 10% Eugenol)	Temporary immobilization	USFWS INAD Exemption. 3-day withdrawal time.
	CO_2 gas	Temporary immobilization, but not all fish respond well.	Low regulatory priority
Disinfectants (various)	NA+ hypochlorite/NA+ hydroxide Ethyl Alcohol/Isopropyl Alcohol Hydrogen peroxide 3-5% Chlorine, Phenols, Iodine	Cleaning and disinfecting equipment and surfaces to mitigate potential pathogen transfer and control spread of disease.	

On-Farm Chemical Use

As discussed in greater detail below, all chemicals licensed for use are regulated by federal legislation which is transposed either directly to state law or with additional specifications. The frequency and volume of actual on-farm use is specific to the treatment and the local farm conditions; unfortunately, there is no federal requirement for reporting of chemical or antibiotic use in the US. It is, therefore, difficult to comprehensively understand exactly what constitutes chemical usage across the HSB industry.

One major producer (Ekstrom Aquaculture, LLC) uses copper sulfate and/or Diuron (phenylurea) to control blue green algae, Polaris (glyphosate) for emergent vegetation, and Sonar (fluridone) for submerged vegetation. The frequency of use for submerged and emergent vegetation is minimal due to their use of biological control (triploid grass carp). Similarly, while the farm reports having used rotenone or chlorine to eliminate any remaining fish following pond draining, usage is minimal because of the design of ponds for complete draining and the lack of secondary (i.e., not stocked) fish or invertebrate species due to the use of well water (Ekstrom, pers. comm. 2019). Tank producers contacted listed Virkon, Chloramine-t, sodium chloride, formalin (Parasite S), copper sulfate, and potassium permanganate as necessary for prevention and control of fungal infections, parasites, and for general disinfection, with occasional use of bleach and its neutralizer sodium thiosulfate when absolutely necessary—but this is not the preferred option.

In the case of antibiotics, the major concern for impact of use is the potential for development of antimicrobial resistance. Antimicrobial resistance is one of the greatest current global health concerns, and its presence and/or emergence in association with aquaculture has been demonstrated in shrimp ponds, trout farms, *Pangasius* farms, and around Chilean and Scottish salmon farms (Boyd and McNevin, 2015) (Tomova et al. 2015) (Price et al. 2016). The predominant antibiotic available for use in HSB production is florfenicol, for *Streptococcus iniae* infection (e.g., Kelly 2013), a chemical considered highly important for human medicine by the World Health Organization (WHO) (WHO 2017), though it is used only in veterinary medicine, and critically important to veterinary medicine by the World Organisation for Animal Health (OIE) (OIE, 2014). These designations, in combination with data from some aquaculture industries showing the potential for overuse to facilitate antimicrobial resistance (Henriquez-Nunez et al. 2012) (Tomova et al. 2015), demonstrate the imperativeness of judicious florfenicol use.

As with most antibiotics used in aquaculture, florfenicol is administered via medicated feed, and of this, it has been estimated that 70 to 80% of antibiotic from feed can enter the receiving environment either via excretion or as a result of uneaten feed (Rico et al. 2012) (Romero et al. 2012) (Boyd & McNevin 2015). For the case of Aquaflor® (50% florfenicol), which is licensed for use in treatment of several freshwater finfish diseases, a Finding of No Significant Impact (FONSI) was issued which details the toxicity studies carried out (FDA, 2017). In this case, some toxic effects on algae, duckweed, and cyanobacteria were noted. These were deemed to be transient, as a result of characteristics of the affected species of high population density and quick turnover time, and in the case of pond culture, effects were expected to be confined to the pond itself due to infrequent water discharge. One major producer, Ekstrom Aquaculture LLC, has reported to have never used antibiotics at all and is not aware of any antibiotic use at pond production facilities nationwide (J. Ekstrom, pers. comm. July 2019). The Fish Connection, a HSB producers' cooperative in North Carolina (www.thefishconnection.net accessed September 2019), reports on its website that its members (both pond and tank producers) do not use antibiotics. In the specific case of tank production, one producer (Colorado) contacted reported to have no need for antibiotics, while another (North Carolina) "occasionally required" the use of Romet (active ingredients sulfadimethoxine and ormetoprim) or oxytetracycline; sulfadimethoxine and oxytetracycline are both listed as highly important for human medicine by the WHO. These products are approved for use in aquaculture by the FDA; however, since they are not listed for use in HSB, they are administered as "extra-label" and only under the direction of a veterinarian. (FDA 2018).

Research into vaccination for *S. iniae* has been carried out (Buchanan et al. 2005) (Locke et al. 2010) (Cotter et al. 2012) and has demonstrated both a high level of protection and no impact/limited impact of the vaccine on production statistics. This may, in the future, result in reduced use of antibiotics for treatment of streptococcal infections; however, this may not prove to be necessary if antibiotic use is already low to non-existent; for example, one major producer (J. Ekstrom, pers. comm. July 2017) has investigated the use of vaccines, and would not be opposed to using them, but reports to currently have no need for them. Colorado Catch are currently looking into the possibility of vaccine development for *Aeromonas* spp. infections. These are often the cause of mortality of fingerlings following initial stocking into tanks as a result of stress from long-distance transport coupled with a significant change in water hardness (300 ppm in the hatchery, 80 ppm in Colorado) which compromises their immunity. This would reduce the occasional need for antibiotics that the farm currently reports.

Ultimately, however, the true extent of antibiotics use within the HSB industry is unknown, since there are no records available in the public domain or for the purposes of this assessment.

Potential Impacts

The fate and impact of chemicals entering the environment depends on the concentration and frequency of dose, degradation pathways, potential for bioaccumulation, and the presence of sensitive organisms within the receiving environment. All chemicals licensed for use are regulated by federal legislation, which is transposed either directly to state law or with additional specifications. The US FDA CVM (Center for Veterinary Medicine) has responsibility for regulation of drugs (pesticides, herbicides, antibiotics, anesthetics) which are classified as "approved and conditionally approved; low regulatory priority, or; INAD (Investigation New Animal Drug) temporary exemption." In order for the FDA to approve a drug for use, its likely impact to the environment must be assessed. This assessment includes the drug's pharmacokinetics, its fate in the environment under typical and worst-case scenarios, toxicity to aquatic life, and likely concentrations and persistence. The assessment either results in "Findings of No Significant Impact" (FONSI), or a more detailed Environmental Impact Assessment. Acceptable dose rates are all specified in Guide to Using Drugs, Biologics and Other Chemicals in Aquaculture (American Fisheries Society, 2014 revision). Frequency of dosing will be specific to the treatment and the local farm conditions; however, because there is no federal requirement for reporting of chemical or antibiotic use in the US, it is difficult to understand the exact impact of any on-farm chemical usage on HSB farms.

Given the aforementioned potential for antibiotics to go either unconsumed or excreted post-ingestion, the variable water exchange strategies in pond and tank production, and the uncertainty in water treatment post-pond discharge, it is expected that at least some of applied antibiotics will enter the receiving waterbody unless they bind with sediments/organic solids and are removed. Although the environmental assessments conducted for all three drugs available or reported to be used (florfenicol, oxytetracycline, and sulfdimethoxine/ormetoprim) concluded there was no significant risk of impact to the ecosystems that receive them, the assessments' experimental designs did not account for continuous discharge or cumulative impacts, which are possible with multiple farms with staggered simultaneous production cycles discharging into the same waterbody.

The environmental fate and persistence of oxytetracycline and florfenicol are both well documented and understood (USFDA 2007) (Schmidt et al. 2007).

Oxytetracycline (OTC) is known to sorb to dissolved organic matter and biosolids, such as suspended aquaculture solids (i.e., uneaten fish feed and excrement), and become largely biologically unavailable (Schmidt et al. 2007). Given the variable water exchange rates and post-pond water management (e.g., direct discharge to waterbodies, use of settling ponds, use as terrestrial crop irrigation, etc.) across the industry, it is expected that some, though likely not all, of applied OTC is captured and properly disposed of (applied as fertilizer, composted, or buried in compliance with state law) prior to discharge into the receiving waterbody (Schmidt et al. 2007). OTC that is discharged, both in solution and bound to sediments, is subject to dilution as well as biotic and abiotic degradation in the receiving waterbody, further mitigating its impact (Schmidt et al. 2007). There is some evidence of OTC desorbing from sediments into a bioavailable form, though this is negligible at the assessed dosage and application rate (Schmidt et al. 2007). It is worth noting that the environmental assessment of OTC was based on a total release of 19 kg OTC over 8 years, and there are currently no industry data available to indicate or estimate what volumes of bioavailable OTC enter the environment. It is unlikely, though perhaps possible, for concentrations of bioavailable OTC in the receiving waterbody to exceed those aforementioned.

Florfenicol, on the other hand, is much more likely to persist in the water column, with roughly 20% to 30% of aqueous florfenicol partitioning to solids and/or sediment (USFDA 2007). Thus, a larger percentage of florfenicol is likely to be discharged, relative to oxytetracycline. The compound is bioavailable in the water column and, though dilution and degradation mitigate environmental risk, "short-term inhibitory effects on sensitive algae and bacteria downstream of a very small percentage (< 5%) of locations where [florfenicol] is used" are possible (USFDA 2007).

The environmental impacts of sulfadimethoxine/ormetoprim are much less clear; the 1984 environmental assessment that approved this drug states, "there appears to be no information available for predicting the effects [of Romet-30] on sediment (or soil) bacteria, protozoans, fungi, benthic crustaceans, worms, clams, snails or rooted aquatic macrophytic plants" (USFDA 1984). Still today, there is little information available for reliably predicting the effects of Romet-30® on bacterial and algal communities, though the literature is in congruence that the majority of Romet-30 discharged is mobile and bioavailable (Bakal 2001) (Sanders 2007). The original assessment concludes that any impacts to benthic fauna and microbial communities are likely to be short term and intermittent (USFDA 1984).

Short-term inhibitory effects will result in the repopulation of unaffected bacteria and algae, possibly including those that carry resistant/resistance genes. The occurrence of antibiotic resistance to all three of these drugs in water and sediments nearby to aquaculture farms/industries has been well documented in various locations globally, and evidence of resistance is becoming more robust for freshwater systems (Cabello et al. 2013) (Gildemeister 2012) (Miranda 2012) (Sanders 2007) (Schmidt et al. 2000) (Stamm 1989). Importantly, however, there is no evidence that the discharge of antibiotics or their residues from HSB farms in the US has resulted in the development of antibiotic-resistant bacteria or mobile resistant genes.

Regulation and Monitoring

The use of drugs and chemicals in a manner not specifically detailed is illegal and therefore prosecutable by law. The US EPA has responsibility for regulation of pesticides and ensuring their safety in both the environment and in foods for human consumption. It also has control over disinfectants and herbicides used in aquaculture. Apart from the regulatory procedure for drugs detailed above, license of general products (disinfectants/herbicides/pesticides, etc.) requires that an assessment of their safety must also be made. This includes consideration of their potential for bioaccumulation, acute toxicity, and safety for human use. Provision for the registration, monitoring, and enforcement of pesticides is set out in the Code of Federal Regulations (40 CFR Part 158) and administered under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Individual states have enforcement responsibility for chemicals registered under FIFRA, although they can request the EPA to act on a violation (EPA OECA 2015).

According to Jim Ekstrom, in Texas, producers are not required to report chemical use, but applicators for Restricted Use Pesticides (RUPs) are required to be licensed, and strict record keeping of each application are part of the license requirements and BMPs. These records are subject to inspection by EPA, FDA, Texas Department of Agriculture or Texas Commission on Environmental Quality (J. Ekstrom, pers. comm. July 2017). In North Carolina and Texas, the Department of Agriculture (NCDA, TDA) has jurisdiction over pesticide licensing. Private Pesticide Applicators (including fish farmers or their employees) who use RUPs are required to pass an exam following which they become certified as Private Pesticide Applicators. The Pesticide Section of NCDA has the responsibility to carry out, on a statewide basis, the inspection of pesticide programs. Unlawful use of pesticides, or sale to unlicensed applicators, can result in a fine of up to $2,000 (ncagr.gov/SPCAP/pesticides/enforcementtrends.htm#License).

Furthermore, certain products (including certain drugs) may also fall under the jurisdiction of the EPA via the Clean Water Act, and therefore be subject to control under the National Pollutant Discharge Elimination Scheme (NPDES). Compounds (marked with * in Table 2) require consultation with the relevant NPDES authority prior to first use, during which it is established if they require a permit for discharge. In these cases, the EPA has set a benchmark for discharge limits; for example, chloramine t has an acute benchmark of 0.13 mg L^{-1}, which “should be protective of aquatic life where the pH is <= 6.5.” Similarly, the acute benchmark for hydrogen peroxide is 0.7 mg L^{-1} on a short-term basis. The discharge stipulations in this case state that “monitoring of effluent concentrations should only be required for those facilities that discharge to receiving water with either minimal flow relative to the hatchery discharge or that have minimal oxidizable material in the receiving water.”

Finally, BMPs list protocols and guidelines for dealing with chemical storage and spills, and good husbandry practices; see Table 1 in the Effluent criterion.

There do not appear to be any published studies relating to chemical contamination of the environment or coincident damage to wildlife or habitats as a result of HSB farming. This does not equate to evidence of no environmental impact however, and although the requirement for chemicals in HSB production appears to be low, there are no data available to indicate the frequency or volume of actual on-farm use and there is variable water exchange of ponds/tanks and the environment. Perhaps the ecological impacts of on-farm chemical use are of low concern, but the lack of data and resultant uncertainty negatively impacts the score.

Conclusions and Final Score

There are indications of a generally low need for chemicals in HSB farming in the US (on average, less than once per production cycle), and these are predominantly approved algicides. In regard to antibiotics, pond producers self-report zero use of antibiotics, while one tank producer reported occasional use of antibiotics; however, tank production accounts for a small proportion of total HJSB production. Although there are no data in the public domain describing chemical usage, low water exchange rates together with the FONSIs for approved chemicals provide an indication of negligible off-farm impact. The approval and use regulations for aquaculture chemicals are strong in the US, and in combination with the above factors and low release of water outside the farm boundary receives a score of 8 out of 10 for Criterion 4 – Chemical Use.

Criterion 5: Feed

Impact, unit of sustainability and principle

- Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.
- Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.
- Principle: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

Ponds

Feed parameters	Value	Score
F5.1a Fish In: Fish Out ratio (FIFO)	1.63	5.92
F5.1b Source fishery sustainability score	-3.00	
F5.1: Wild fish use score		4.94
F5.2a Protein IN (kg/100kg fish harvested)	51.34	
F5.2b Protein OUT (kg/100kg fish harvested)	19.22	
F5.2: Net Protein Gain or Loss (%)	-62.56	3
F5.3: Feed Footprint (hectares)	13.54	5
C5 Feed Final Score (0-10)		**4.47**
Critical?	NO	**YELLOW**

Tanks

Feed parameters	Value	Score
F5.1a Fish In: Fish Out ratio (FIFO)	1.36	6.60
F5.1b Source fishery sustainability score	-3.00	
F5.1: Wild fish use score		5.78
F5.2a Protein IN (kg/100kg fish harvested)	42.79	
F5.2b Protein OUT (kg/100kg fish harvested)	18.24	
F5.2: Net Protein Gain or Loss (%)	-57.37	4
F5.3: Feed Footprint (hectares)	11.28	6
C5 Feed Final Score (0-10)		**5.39**
Critical?	NO	**YELLOW**

Brief Summary

This criterion combines the scores for the feed fish efficiency ratio (FFER) and sustainability of wild fish source, the net protein gained or lost, and the ecosystem area (terrestrial and marine) appropriated for food production. Marine ingredient inclusion in HSB feeds is estimated to be 16% for fishmeal and 7% for fish oil, with 0% of those coming from byproduct sources. Values for eFCR are high compared to many other farmed finfish species, at 2.1 for pond systems and 1.75 for tank systems, and result in FFER values of 5.92 and 6.60 for pond and tank systems respectively. The wild fish source was determined to be Atlantic and Gulf menhaden, with overall good sustainability, which when combined with the FFER score, results in overall scores of 4.94 out of 10 for ponds and 5.78 for tanks for Factor 5.1. A single feed composition across the entire industry is challenging, but a representative HSB feed was estimated from formulated diets published in scientific literature. These were comprised of 23% marine ingredients and 26% land animal ingredients, 47% terrestrial crop ingredients. Net protein loss was estimated to be 62.5% and 57.4% for ponds and tanks respectively, resulting in respective Factor 5.2 scores of 3 and 4 out of 10. The feed footprint (Factor 5.3) was estimated at 13.54 and 11.28 ha per ton of production, resulting in scores of 5 out of 10 for ponds and 6 out of 10 for tanks. Overall, the final score for Criterion 5 – Feed was 4.47 out of 10 for ponds and 5.39 out of 10 for tanks.

Justification of Rating

Factor 5.1. Wild fish use

Factor 5.1a – Feed fish efficiency ratio (FFER)

The Feed Fish Efficiency Ratio (FFER) ratio for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of marine ingredients used in feeds, and the source of the marine ingredients (i.e., does the fishmeal and fish oil come from processing by-products or whole fish targeted by wild capture fisheries?). FCR is the ratio of feed given to an animal per weight gained, measured in mass (e.g., FCR of 1.4:1 means that 1.4 kg of feed is required to produce 1 kg of fish). It can be reported as either biological FCR (bFCR), which is the straightforward comparison of feed given to weight gained, or economic FCR (eFCR), which is the amount of feed given per weight harvested (i.e., accounting for mortalities, escapes, and other losses of otherwise-gained harvestable fish).

Economic Feed Conversion Ratio (eFCR)

Most reports of FCR are given for individual fish in the course of feed (or other research) trials and therefore do not take into account mortality over the course of the production cycle, and given the nature of small, highly efficient trials, tend to have better FCRs than under commercial conditions. For hybrid striped bass farmed in the US, averaging published figures for individual FCRs gives a composite value of 1.99, calculated from (D'Abramo and Frinsko 2008) (McEntire et al. 2015) (Wui and Engle 2004) (Rawles et al. 2009) (Sydorovych and Daniels 2011) (Turano et al. 2008). However, Rawles et al. (2011) give an eFCR of between 2.07 ± 0.02 and 2.27 ± 0.21. Communication with Ekstrom Aquaculture LLC owner Jim Ekstrom (J. Ekstrom, pers. comm. July 2017) suggested that the FCR "can be better or can be worse—depending on the quality of feed a producer uses, the size the fish are raised to, the type of system they are in, survival, and any number of other factors." He states pond production at Ekstrom Aquaculture LLC has had FCRs as low as 1.5 but suggests a good industry average to be 2.0 to 2.25. Finally, recent research by Rawles et al. (2018) noted that their achieved FCRs of 1.34 to 1.37 were the result of "several efficiencies not necessarily feasible in a commercial setting" and that past research efforts into pond management has resulted in "improved FCRs [of] <2.5." Based on these data, an estimated eFCR of 2.1 is considered representative of HSB pond production.

Figures in the scientific literature for FCRs of striped bass grown in tank systems are scarce, and subject to the same limitations as mentioned above for pond systems. In general, more controlled environments, the FCRs of tank systems, particularly full or partial recirculation systems, tend to be lower than in open pond systems. Supporting this are data from Rawles et al. (2006), who achieved FCRs with generic and experimental diets for fish cultivated in tank systems between 1.58 and 1.72, but again this is not eFCR data. Figures for eFCR received from tank system producers were 1.25 (North Carolina farm, pers. comm. September 2017), to 1.75–1.8 (T. Faucette, pers. comm. September 2017). Taking these data together, a value of 1.75 (i.e., the upper end of the range) has been used to generate the score for tank systems to take into account the generally improved FCR using these methods of production.

Fishmeal and Fish Oil Inclusion

Fishmeal inclusion rates in published literature vary, and most of the information in this report comes from feed research trials which generally use a control diet that reflects a standard commercial diet against which to compare the trial diets. Rawles et al. (2009) described a "general" diet that includes 25% fishmeal and stated greater than 20% menhaden fishmeal (MFM) to be typical of commercial formulations. Hill et al. (2015) used a control diet that included 30% MFM, whereas Bowzer et al. (2016) included only 19.6%. The most recent published research (Rawles et al. 2018) at the time of writing (October 2019), investigating dietary protein content's influence on fish performance and water quality in growout ponds, used fishmeal contents of 14.6%, 16.2%, and 17.8%. These data, in combination with anecdotal information indicating commercially used fishmeal contents of 10 to 15% (J. Ekstrom, pers. comm. March 2019) and 15 to 20% (J. Trushenski, pers. comm. June 2017), lend an estimated average fishmeal inclusion of 16% for HSB growout feeds.

Fish oil inclusion is similarly variable with "typical" inclusion rates varying between 3% (Rawles et al. 2011) and 9.8% (Bowzer et al. 2016). Taking an average of fish oil inclusion rates reported in past literature gives 6.68%, which is close to the 6.94% that Rawles et al. (2009) consider typical of commercial formulations, and the 6.89%, 6.77%, and 6.65% used in recent research by Rawles et al. (2018). Again, these are in combination with anecdotal estimations of commercially used fish oil contents of less than 7% (J. Ekstrom, pers. comm. March 2019) and 5 to 10% (J. Trushenski, pers. comm. June 2017). Given these values, a fish oil inclusion of 7% can be assumed to be representative of HSB growout feeds.

Research is demonstrating the possibility of fish oil and fishmeal sparing for HSB diets with a variety of animal and plant alternatives, e.g., Asian carp meal (Bowzer and Trushenski 2015);

soybean meal (Rawles et al. 2011); beef tallow (Bowzer and Trushenski 2016); canola oil (Hill et al. 2015); therefore, it can be anticipated that fish meal and oil inclusion rates will drop in the future. However, for the purposes of this assessment, 7% has been used as the estimated fish oil inclusion rate and 16% as the estimated fishmeal inclusion rate, using averages of the values reported in the literature. Consultation with experts has confirmed that these are representative of the industry as it stands currently (J. Trushenski, pers. comm. May 2017).

As is the case for the US catfish industry (Seafood Watch 2017), the use of by-products in HSB feeds is difficult to estimate because availability is highly variable and data collection is poor. According to the International Fishmeal and Fish Oil Organization (IFFO), 25% of fish meal and oil currently produced in the US comes from trimmings and by-products (Jackson and Shepherd 2012) (Chamberlain 2011). However, although it is not possible to determine the precise inclusions of domestic fishmeals and fish oils used in domestic HSB feeds because most feed producers' formulations are proprietary, sources indicate that both fishmeal and fish oil used in HSB feeds are from menhaden, and that none of this is derived from byproduct. The fishmeal and fish oil yields for menhaden have been estimated from six year averages as reported by Omega Protein who harvest and process Atlantic Menhaden (http://www.annualreports.com/Company/omega-protein-corp; Bibus 2015).

	2011	2012	2013	2014	2015	2016	TOTAL[1] AVG	ANNUAL[2] AVG
FM YIELD	25.76	26.24	25.48	26.24	25.86	26.73	**26.03**	**26.05**
FO YIELD	7.83	6.32	12.78	8.66	7.82	11.05	**8.92**	**9.08**

1 Total average yield was calculated as the average of the six-year total; i.e., the six-year total meal and oil production were each divided by the six-year total catch
2 Annual average yield was calculated as the average of each year's yield

Table 3: Wild fish products in HSB feeds.

Parameter	Ponds	Tanks
Fishmeal inclusion level	16%	16%
Percentage of fishmeal from byproducts	0%	0%
Fishmeal yield (from wild fish)	26%	26%
Fish oil inclusion level	7%	7%
Percentage of fish oil from byproducts	0%	0%
Fish oil yield	9.0%	9.0%
Economic Feed Conversion Ratio (eFCR)	2.1	1.75
Calculated Values		
Feed Fish Efficiency Ratio (FFER) (fishmeal)	1.29	1.08
Feed Fish Efficiency Ratio (FFER) (fish oil)	1.63	1.36
Seafood Watch FFER Score (0-10)	**5.92**	**6.60**

The Seafood Watch Aquaculture Standard uses the higher of these two values (FFER Fish oil, 1.63/1.36) in its formulation. The resulting score for Factor 5.1a – Feed Fish Efficiency Ratio is 5.92 out of 10 for ponds and 6.60 out of 10 for tanks.

Factor 5.1b – Sustainability of the source of wild fish

Fishmeal and fish oil sources for feed ingredients are not commonly available, being considered proprietary information, but all research diet formulations—which are stated to be commercially relevant (Blaufuss and Trushenski 2012) (Burr et al. 2010) (Cheng et al. 2012) (Rawles et al. 2009, 2011, 2018) (Rombenso et al. 2013) (Savolainen and Gatlin 2010) (Trushenski and Gause 2013)—use menhaden species (*Brevoortia patronus, B. tyrannus*) as the source of fishmeal (with Rawles et al. (2018) specifying the use of Special Select® fishmeal[1]) and fish oil. There are two menhaden fisheries: the northwest Atlantic (for Atlantic menhaden, *B.tyrannus*) and the Gulf of Mexico (for Gulf menhaden, *B. patronus*). For both, all FishSource scores were ≥6, and while the Gulf menhaden attains a Stock Health score of ≥8 (10), the Atlantic menhaden Stock Health score is <8 (7.2, although the future health score is 9.4). Both fisheries have attained MSC certification. As such, the most appropriate score for Factor 5.1b Sustainability of the Source of Wild Fish (SSWF) -3 out of -10. This adjusts the initial FFER score of 5.92 out of 10 by -0.98 for ponds, and the initial FFER score of 6.60 out of 10 by -0.82 for tanks.

When combined, the Factor 5.1a (5.92/6.60 out of 10) and Factor 5.1b (-0.98/-0.82) scores result in a final Factor 5.1 score of 4.94 out of 10 for ponds and 5.78 out of 10 for tanks.

Factor 5.2. Net protein gain or loss

The score for this factor is based on the protein content of feed that is derived from edible (from a human perspective) ingredients. There are two possible options for this calculation, the choice of which is based on the availability of data regarding specific ingredients. The first option is used where the inclusion levels of crop and land animal ingredients are known, and the second where they are unknown. The second makes the "worst case" assumption that all non-marine ingredients (i.e., fishmeal) are derived from edible crops. While there are some non-edible ingredients used in research HSB feed formulations, and these are likely to be representative of commercial formulations, there is a lack of evidence detailing what is currently being used commercially, and in what proportions. However, the calculation has been based on the diet formulation used in commercially focused research by Rawles et al. (2009, 2018), the assumption being that this will be closer to the actual situation than assuming the worst-case scenario. The authors state that the protein is supplied by "typical" sources and the MFM and poultry by-product meal quantities are considered typical of commercial formulations. The diets have the following compositions but have been adjusted slightly to account for a lower value of 16% MFM used in this report.

Ingredient	*Rawles et al. 2009 (%)*	*Rawles et al. 2018[1] (%)*	*Adjusted (%)*	*Protein content (%)*	*Contribution to total feed protein (%)*	*Edible?*
Menhaden fishmeal	25	16.2	16	64	24.98[2]	Y
Poultry by-product meal	7.73	18.06	15	58.7	21.48[2]	N

[1] https://omeganutrient.com/products/fish-meal/special-select/

Soybean meal	25.9	21.79	23.84	45	26.17[2]	Y
Blood meal		3.73	3.73	79.8	7.26[2]	N
Feather meal		3.25	4	89.4	8.28[2]	N
Wheat middlings	17.35		7	16.4	2.80[2]	Y
Wheat / wht. flour	8	15.8	11.9	14.4	4.18[3]	Y
Cottonseed meal	4.8		2.4	47.3	2.77[3]	N
Rice bran	3.8		1.9	14.2	0.66[3]	Y
Menhaden fish oil	6.94	6.77	7	0	-	-
Poultry fat		6.94	3.47	0	-	-
Vitamins + other additives		7	3.5	0	-	-
Total	99.52	99.92	99.74		98.57	

1 Given as the mean of the three diets' inclusion of each ingredient.

2 Calculated using ingredient protein content as given in Seafood Watch Aquaculture Standard (adjusted in the case of fishmeal to reflect a menhaden protein content of 64% (Omega Protein) rather than the Seafood Watch default value of 66.5%).

3 Calculated using protein content as given in Heuzé et al. (2015, 2016).

Protein content has been estimated using figures for commercially relevant "practical" diets formulated for research purposes and published in peer-reviewed literature, publically available values for commercial diets, and reviews of literature (e.g., as published by the SRAC). Feed protein generally decreases as the fish grow, from 45 to 48% (Lochman 2015) (Skretting[2] 2016) at the fry-fingerling transition to 38 to 40% during the final months (Lochman 2015). Forty percent is commonly used in the research literature as being representative of commercial formulations, e.g., 35 to 40% (D'Abramo and Frinsko 2008); 40% (Rawles et al. 2010) (Rawles et al. 2012) (Bowzer and Trushenki 2015); 41% (Bowzer et al. 2016); 45% (Rawles et al. 2009) (McEntire et al. 2015) (Trushenki and Aardsma 2015). The most recent relevant research reported digestible protein contents of 35%, 38%, and 41% for the three feeds tested in the final 171 days of pond growout, though the analyzed crude protein for these feeds was 46.4%, 49.5%, and 52.1% respectively (Rawles et al. 2018). The beginning of the trial utilized a "commercial hybrid striped bass diet" with a 48% crude protein content (Rawles et al. 2018). The recommended diet for HSB from Skretting (Nova LE) even at the largest pellet sizes (late stage growout feeds, lowest protein content) contains 42 to 43% protein. Choice of feed protein content will vary according to factors such as season (temperature), fish health status, and water quality, so there is not a single definitive value of feed protein content. However, given that most commercially relevant formulations reported in the literature included ~40% protein but that an actual commercial formula (Skretting, Nova LE) uses 42%, 41% was chosen to represent feed protein content.

The protein content of whole HSB has been reported as 16% (Rawles et al. 2018) and 18.4% (Green et al. 2016) and the edible yield of the harvested whole fish estimated at 45% (Ohs 2008).

[2] https://nutreco.showpad.com/share/MTdeeV0FWXhthiPHxLwp

As HSB tend to be sold whole on ice (Ekstrom, pers. comm. July 2017) (Trushenski, pers. comm. June 2017) the percentage of harvesting byproducts that are currently further utilized is unknown. For the purposes of this report, a default estimated value of 50% has been used.

Table 4: Net protein transformation calculations (after adjustment from 98.57% protein accounted for to 100%).

Parameter	Ponds	Tanks
Protein content of feed	41%	41%
Percentage of total protein from non-edible sources (i.e., byproducts)	40.37%	40.37%
Percentage of protein from edible sources (i.e., edible marine and crop)	59.63%	59.63%
Feed Conversion Ratio	2.1	1.75
Protein INPUT per 100 kg of farmed HSB	86.1 kg	71.75 kg
Protein content of whole harvested HSB	18.4%	18.4%
Edible yield of harvested HSB	45%	45%
Percentage of farmed HSB byproducts utilized	50%	50%
Utilized protein OUTPUT per ton of farmed HSB	192.2 kg	182.4 kg
Net protein gain	-62.56%	-57.37%
Seafood Watch Score (0-10)	**3**	**4**

Protein in feeds used for HSB in the US is estimated to be sourced from 23% marine ingredients, 33.8% edible crop ingredients, 2.77% non-edible crop ingredients and 37.02% non-edible land animal ingredients with a total of nearly 40% from non-edible sources and almost 60% from edible sources. There is an overall net edible protein loss of 62.56% for ponds and 57.37% for tanks, leading to Factor 5.2 scores of 3 out of 10 for ponds and 4 out of 10 for tanks.

Factor 5.3. Feed footprint: This factor describes the areas required (marine area and terrestrial area) to produce the feed ingredients necessary for production of one ton of farmed HSB product. It is an approximate measure of the global resources used to produce aquaculture feeds, based on the global ocean and land area used to produce the feed ingredients necessary to grow one ton of farmed fish.

Table 5: Ocean and land area of primary productivity appropriated by feed ingredients per ton of farmed seafood.

Parameter	Ponds	Tanks
Marine ingredients inclusion	23%	23%
Crop ingredients inclusion	47.04%	47.04%
Land animal ingredients inclusion	26.20%	26.20%
Ocean area (hectares) used per ton of farmed HSB	12.56	10.47
Land area (hectares) used per ton of farmed HSB	0.97	0.81
Total area (hectares)	13.54	11.28
Seafood Watch Score (0-10)	**5**	**6**

The area necessary for production of marine ingredients required for one ton of HSB is 13.54 and 11.28 ha/ton of farmed fish for ponds and tanks respectively. The area necessary for production of terrestrial (crop and land animal) ingredients required for one ton of HSB is 0.97 and 0.81 ha/ton, for ponds and tanks respectively. The combination of these two values results in overall feed footprints of 13.54 ha/ton of farmed HSB for ponds, and 11.28 ha/ton of farmed HSB for tanks, resulting in a Factor 5.3 score of 5 out of 10 for ponds and 6 out of 10 for tanks.

Conclusions and Final Score

HSB are a carnivorous species and their health presently relies on a supply of wild fish forming a proportion of their diet. This reliance on wild fish, good sustainability of the stock, and somewhat-high eFCR values (compared to most globally dominant farmed species), has resulted in a moderate score for both pond and tank production systems. The estimated fishmeal and fish oil contents in HSB diets are 16% and 7% respectively, and the eFCR tends to be better in tank production (1.75) than in pond production (2.1). Research is currently underway and it is expected that improvements in feed formulation will improve the eFCR further, and simultaneously decrease the reliance on wild fish through inclusion of alternative protein and oil sources. Gulf and Atlantic menhaden are the source fisheries used, and both have relatively high sustainability. However, both systems represent a significant loss in total protein, at 57 to 62%. The score for wild fish use (Factor 5.1) was 4.94 out of 10 for ponds and 5.78 out of 10 for tanks, while net protein loss (Factor 5.2) was 3 out of 10 for ponds and 4 out of 10 for tanks. The score for total ecosystem area appropriated for feed production (Factor 5.3) was 5 out of 10 for ponds and 6 for tanks. Factors 5.1, 5.2, and 5.3 combine to result in a final Criterion 5 – Feed numerical score of 4.47 out of 10 for ponds and 5.39 out of 10 for tanks.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations
- Sustainability unit: affected ecosystems and/or associated wild populations.
- Principle: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

Ponds and Tanks

Escape parameters	Value	Score
F6.1 System escape risk	8	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		8
F6.2 Competitive and genetic interactions		9
C6 Escape Final Score (0-10)		**8**
Critical?	NO	**GREEN**

Brief Summary

There are no apparent data on escape events in the HSB industry, but, reporting of escapes is required since it is illegal to “release” fish into public waters without a permit; this indicates that escapes from HSB facilities have not occurred. The risk of escape can be estimated by the exchange of water through rearing units and vulnerability to flooding. Although ponds are typically outside the 100-year flood plain, water exchange appears variable. On average, however, there are indications that farms discharge ponds during harvest but have a low average exchange rate throughout the production cycle (<0.5% per day). Water exchange for tank production is also variable, since some farms (an unknown proportion) are reported to use single-pass flow-through and some employ recirculation rates up to 85%. All producers, however, use best management practices for escape mitigation. As such, the Escape Risk score for both ponds and tanks is 8 out of 10. Because HSB are artificially propagated, they do not occur naturally in any waterbody, but widespread historic and ongoing intentional stocking for biological control of forage fish or recreational fisheries means that ecological impact by aquaculture escapees is unlikely. As a result, the score for Competitive and Genetic Interactions is 9 out of 10. For both pond-raised and tank-raised HSB, Factors 6.1 and 6.2 combine to result in a final score of 8 out of 10 for Criterion 6 – Escapes.

Justification of Rating

Factor 6.1. Escape risk

Data detailing numbers of HSB escape events, or even farm flooding events, are not available. According to one major producer, HSB escapes are required to be reported but the data are not in the public domain. Furthermore, it is illegal in Texas to release fish into public waters without authorization (J. Ekstrom, pers. comm. July 2017). There is an inherent risk of escape of cultured fish from the levee-type ponds in which HSB are raised, either from flooding events or via discharged water from the farm. Water exchange is variable; some ponds are zero-exchange over multiple production cycles, some are completely drained at harvest, and some may undergo frequent discharge events for water quality or water level control. This, therefore, means that the potential for escape would also appear to be variable. On average, however, past farm surveys (e.g., Wui and Engel 2004) have indicated that pondwater exchange throughout the production cycle, including draining for harvest, is less than 0.5% per day.

Provision of farm-based best management practices such as mesh-covered outflow/overflow pipes, farm siting outside 100-year floodplains, and levees with sufficient freeboard are designed to minimize risk of such events occurring. In certain states, legislation relating to escape prevention also exists. For example, the Aquaculture Development Act; Article 63 – North Carolina State aquaculture facility registration and licensing: "Hybrid striped bass. - Production, propagation, and holding facilities in the Neuse, Roanoke, or Tar/Pamlico River basins for the hybrid striped bass shall comply with additional escapement prevention measures prescribed by the Wildlife Resources Commission." Attempts to contact the Wildlife Resources Commission for further detail on these escapement prevention measures have been unsuccessful.

One major producer (Ekstrom Aquaculture LLC) has the following mitigative measures in place to prevent routine and/or exceptional escapes: the facility is located out of the 100-year floodplain; the levee tops and standpipes are above any conceivable flood event; internal drain structures are screened with galvanized expanded steel, and two feet of freeboard is maintained to prevent overtopping of levees (J. Ekstrom, pers. comm. July 2017). These measures have been successful in ensuring that, to the best of their knowledge, neither under normal circumstances nor during flooding events has any stock been lost to escape from the ponds (ibid.).

Based on the information presented regarding the exchange of water—sometimes only at harvest, sometimes very occasionally during the production cycle, and sometimes frequently during the production cycle, but likely averaging <0.5% per day—and the existence of BMPs and demonstration of implementation of BMPs together with suggestion of their effectiveness (zero reported escapes in the farm history), the most appropriate Escape Risk score for ponds is 8 out of 10.

Tank production systems tend to be contained by their nature and have a number of biosecurity measures in place as required under their initial permitting conditions, and by default of their design. For example, the only possibility for escape from Colorado Catch tanks is via overflow, and in this case the fish fall onto concrete; there is no way for them to access a natural water body (T. Faucette, pers. comm. September 2017). Biosecurity measures are state and/or facility specific and may vary, but Best Management Plans (usually required for permits to be granted) must detail protocols for regular monitoring of the structural integrity of production and wastewater treatment facilities, and necessitate repair of any damage. Ultimately, it appears that water exchange strategies for tank producers are similarly variable as seen in pond production; there are reports of single-pass, flow-through production as well as recirculation of up to 85%. As such, the Escape Risk score for HSB tank production is 8 out of 10.

The score for Factor 6.1 is 8 out of 10 for both pond and tank production.

Factor 6.2. Competitive and genetic interactions

This factor is designed to give a measure of the extent of ecological impact escaped fish might have on local ecosystems, particularly regarding competitive and genetic interactions. Both white bass and striped bass are native to many, but not all, of the places in which they are farmed, but as HSB are artificially propagated; there are no native HSB anywhere. Furthermore, hybrid vigor has been demonstrated in HSB and exploited to produce the typical characteristics of fast growth, broad-temperature tolerance, and disease resistance (Harrell 1997), all qualities that increase their potential for invasiveness. More recently however, HSB (sunshine) were shown to be more susceptible to *Flavobacterium columnare* (columnaris disease) than the parent white bass strain, while striped bass susceptibility was untested (Fuller et al. 2014).

There has been a widespread and regular stocking of *Morone* spp. (endemic or transplanted species, or congeneric hybrids) across the US; in fact, only two states (Idaho and Alaska) have no history of stocking (Harrell 2013) and in 2013, according to the USDA census of aquaculture, almost 19 million HSB were stocked into national waters (USDA 2014). Stocking takes place to boost sport fisheries, to restructure panfish communities, to control invasive species, and as part of management strategies for biological control of over-abundant populations of forage fish—particularly the gizzard shad (*Dorosoma cepedianum*) (Harrell 2013) (Schultz et al. 2013) (Michaletz et al. 2014), although the effects on forage fish populations have been variable (Gilliland 1982). In general, it is the sunshine bass that has primarily been used for food fish production through aquaculture, and the palmetto bass that has been stocked into natural waterbodies, although there is also a history of some states stocking the sunshine bass (Schultz et al. 2013). For example, in Texas between 2010 and 2016, a total of over 42.5 million HSB were stocked into state waters and of these, 9.5 million (22%) were sunshine bass (TPWD 2017). The following paragraphs discuss examples of ecological and genetic impacts of *Morone* complex species in general, since the available data (detailed below) do not indicate the impact of escaped farm-origin sunshine bass would be materially different than that of their intentionally-stocked sunshine counterparts or their reciprocal cross, palmetto bass.

It has been demonstrated that straying of stocked *Morone* from their original stocking area, including HSB, from their stocking location does occur (Jahn et al. 1987) (Kilpatrick 2003) but at rates that are unknown (Jahn et al. 1987) and emigration has been considered limited by some authors (Kilpatrick 2003). Because repeated stocking is generally necessary for maintenance of sizeable populations, it has sometimes been assumed that viability of strayed, stocked fish in the wild is low. Despite this, re-stocking is not necessary in all cases and viable naturalized populations exist. One example is in the Cape Fear River estuary in North Carolina (Patrick and Moser 2001), where a two-fold decrease in native striped bass was concomitant with a two-fold increase in established HSB populations.

Evidence for direct competitive interactions is inconclusive. High dietary overlap has been recorded between white bass, yellow bass, and HSB (Fose 2013), striped bass and HSB-palmetto (Patrick and Moser 2001), walleye (*Sander vitreus*), white bass, and HSB-sunshine (Olsen et al. 2007), striped bass and HSB-sunshine (Rash 2003), and largemouth bass (*Micropterus salmoides*) and HSB-palmetto (Gilliland 1982) in various waterbodies. Similarly, in the Barren River, Kentucky, native white bass were found to share spawning grounds with introduced yellow bass (*M. mississippiensis*) and HSB-sunshine, and although the timing of spawning was slightly staggered, there was overlap. In this case, yellow bass were postulated to be interfering with the white bass reproductive success via predation, but there was no evidence that HSB were doing the same (Fose 2013). In general, the information points toward potential for competition being mitigated by resource abundance (Gilliland 1982) (Jahn et al. 1987) (Patrick and Moser 2001) (Rash 2003) or by resource partitioning (Fose 2013) (Olsen et al. 2007). At least two studies that demonstrate negative interactions of introduced *Morone* on native stocks also make the point that while the introduced species is likely having some impact, the low abundance of the native stock is probably at least partly attributable to other factors such as declining environmental conditions (Fose 2013) (Patrick and Moser 2001).

There is also some debate about the potential for genetic effects and indeed about the extent to which introgression and/or hybrid swarms might be occurring—in general because backcrosses and F_2's have not been looked for, and due to phenotypic similarity to “pure” parent strains, these may easily be missed by routine stock sampling. For example, meristic traits were not always sufficient to distinguish between HSB and striped bass in Claytor Lake, Virginia and in some cases, genetic analysis was necessary for differentiation (Rash 2003). Because of this uncertainty, Harrel (2013) makes the case that the apparent lack of hybridization/introgression does not equate to evidence of no effect, and that there is an ethical case for using the precautionary principal until the risk is fully understood. One recent study of hybridization between white bass, yellow bass, and striped bass in the Toledo Bend Reservoir (Louisiana-Texas border) used morphological and genetic techniques (examination of microsatellites) to examine genetic impingement of striped bass on the native (white bass and yellow bass) populations. The authors found 5% of fish sampled were hybrids (4 out of 75 fish, three white bass x striped bass, one yellow bass x striped bass) and state “Although more extensive collections and larger sample sizes may produce different numbers, our results suggest that, given the small number of hybrids present, introgression-related impacts on native species’ genomes appear to be minimal” (Taylor et al. 2013). Matlock (2014) considers the historical and future case of stocking striped bass in Texas and, similarly to Harrel (2013), argues that use of the precautionary principle in regard to further stocking might be well advised until the effects are better understood.

There are indeed potential negative genetic and ecological effects of escaped farmed HSB; authors have noted there is much scientific uncertainty and make a strong case for further research. Additionally, the industry would benefit from a more transparent system for reporting escape events, although this is appreciably difficult. However, the impacts of aquaculture escapes must be measured against the widespread and deliberate stocking of millions of HSB that has occurred since the 1970s and continues today. Although the true number of farm escapees is unknown, it cannot be reasonably assumed to be a significant contributor to the total number of HSB being deliberately stocked in waterbodies nationwide, and research has not indicated that farm fish (i.e., sunshine bass) would have materially different ecological impacts than stocked fish (i.e., palmetto bass). As such, the receiving environment characteristics are such that escapees would not cause additional ecological impacts, and the score for Factor 6.2 is 9 out of 10 for both pond and tank systems.

As a final note, some farms use grass carp (*Ctenopharyngodon idella*) for the control of submerged vegetation. Grass carp are non-native, having been introduced in the 1960s to control aquatic weeds. Currently, it is a prohibited invasive species (USDA 2018), which means import, possession, transport, and introduction into the wild is prohibited. Any fish stocked for aquatic weed control purposes must be certified as triploid. At Ekstrom Aquaculture LLC farm, triploid grass carp are stocked at 15 per surface acre. They are sourced from the same hatchery that provides the fingerling bass and are certified by USFWS as 100% triploid. The possession and transportation of these exotics is strictly controlled by Texas Parks & Wildlife. Due to the certified triploidy, any escape of these fish will not result in establishment and the effects of their escape would be limited to the ecological impact of the escapees themselves, in this case likely to be increased herbivory of aquatic vegetation. Considering the relatively small numbers stocked and the small chances of escape due to on-farm escape mitigation measures, any potential impact is considered very small.

Conclusions and Final Score

Although HSB are artificial hybrids, and by definition are non-native, there is only a low/moderate risk of escape. Though water exchange is indeed variable within each production system, the discharge rate of both ponds and tanks tends to be low, and both production systems use multiple escape prevention measures (screens, water treatment, and secondary capture devices). On-farm data on fish counting and escape records indicate escapes do not occur. Any remaining escape risk is mitigated by a low risk for further ecological impact than might have already occurred from a very widespread and continuing stocking program. For both pond and tank production, Factors 6.1 (6 out of 10) and 6.2 (9 out of 10) combine to give a final numerical score of 8 out of 10 for Criterion 6 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Ponds and Tanks

Disease Risk-Based Assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	7	
Critical?	NO	GREEN

Brief Summary

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors being escaped individuals, discharged water/sediment, and animals (birds, snails, wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, several diseases are reported to have occurred on farms with no data available that allow for an estimation of typical disease prevalence or intensity on farms. Anecdotal evidence suggests such prevalence is low, as does the absence of antibiotic treatments. In order to export product to Canada, farms must be certified as disease-free by USDA-APHIS; this requires all disease events to be documented and reported and requires sworn affidavits to affirm the reports. Farms employ robust health and biosecurity protocols (e.g., disease-free fingerling sourcing, quarantine, not allowing equipment to be used on multiple sites, disinfection of hauling trucks, etc.) and typically have low rates of water discharge. There is some indication that on-farm biosecurity measures also prevent pathogen transmission to wild species, since wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, and health and biosecurity measures are robust. The final score for ponds and tanks is 7 out of 10 for Criterion 7 – Disease.

Justification of Rating

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

Disease prevalence and primary disease concerns

Viral diseases are not thought to be a problem for HSB and there has been no reported mortality from viral pathogens. However, they may increase susceptibility of the fish to other infectious agents. Bacterial pathogens tend to be ubiquitous in the water, but infections tend to be opportunistic and do not produce clinical disease unless predisposing factors are present. Nevertheless, they are the most serious pathogens affecting cultivated HSB. *Streptoccocus iniae* has been reported to be problematic for HSB cultivation; for example, Cotter et al. (2012) estimated annual losses of $1,000,000 as a result of *S. iniae* infection, and Shoemaker et al. (2001) found prevalence of infected fish to vary by farm between 0% and 21.6%. A *Francisella*-like bacterium has also been found to cause mortality in HSB in a recirculating system in California (Ostland et al. 2006). Fungal infections are usually the result of stress, poor nutritional status, or injury, and can be managed by good husbandry. There are many types of parasites, including flagellated, cilliated, metazoan monogenetic trematodes, metazoan digenetic trematodes, metazoan worms, and crustaceans. Of these, the protozoan flagellate ichthyobodo and the ciliated parasites *Ichthyophthirius multifiliis* (white spot disease), *Trichodina* spp., *Chilodonella* spp. and *Epistylis* spp. are relatively common. Additionally, the yellow grub, *Clinostomum marginatum* (a trematode) can cause problems for the HSB industry. This does not affect fish health but is unsightly and makes the fish unsaleable (FAO 2016-2017).

A list of pathogens/diseases found in HSB is given in Table 6. Though the list is quite extensive, in practice, few diseases seem to be problematic. Information in the table summarized from: (Smith 2010) (Plumb and Hansen 2011) (FAO 2016–2017).

Table 6: Diseases of HSB.

Category	Species	Comments
Bacterial	*Aeromonas* spp. / *Pseudomonas* spp.	Motile aeromonad septicemia. Frequently detected pathogen but little overt infection.
	Mycobacterium spp. / *Nocardia* spp.	Chronic granulomatous diseases—difficult to tell apart. Mycobacteriosis occurs in wild striped bass. Some species of mycobacterium are pathogenic to other poikilotherms. Has been problematic in RAS but not reported from pond cultures.
	Pasteurella piscicida	Photobacteriosis. Seen in wild and cultivated HSB. Mainly occurring in marine fish. High mortality in brackish water ponds in Alabama in the '80s. Can be serious in wild striped bass populations where it can cause high mortality.
	Vibrio spp. *(V. anguillarum)*	Problematic in cage-reared striped bass and wild populations. Infections are usually related to stress and bad husbandry.
	Flavobacterium spp. *(F. columnaris)*	Columnaris disease, bacterial gill disease. Appears in cultured and wild striped bass but is more severe in cultivated populations.
	Enterococcosis faecium	Enterococcosis. Occasionally observed in intensive freshwater systems.
	Edwardsiella tarda	Edwardsiella septicemia. Occasional infection in cultured striped bass.
	Streptoccocus iniae	Streptococcosis. Endemic in brackish water ponds. Known in wild fish but more prevalent in cultivated populations. Handling and moving stress predispose fish to Strep infection. Especially abrasions and environmental

	Corynebacterium aquaticum *Francisella* spp.	stressors. Corynebacteriosis. Normal waterborne organism—may also be infections in other homeothermic animals. Caused massive mortality in HSB in semi-closed RAS.
Viral	Lymphocystivirus Infectious Pancreatic Necrosis Virus (IPNV) Striped Bass Aqueovirus	Does not cause mortality—tends to heal without intervention. Quarantine fish to prevent spread. On the US National List of Reportable Animal Diseases (2016). Does not cause mortality and clinical signs are limited to darkened pigmentation but there is a risk of transmission to other susceptible species. No reported mortality.
Parasitic	Ichthyophthirius multifiliis Trichodina sp. / Chilodonella sp. / Epistylis sp. Ichthyobodo sp.	Ciliated protozoan causing white spot disease. Relatively common. Avoid passively stocked fish in ponds. Ciliated protozoans. Flagellated parasite. From water supply or carrier fish.
Fungal	Aphanomyces sp. / Saprolegnia sp. Achlya sp. Branchiomyces sp.	Tend to occur when fish are weakened, often in association with bacterial or parasitic infections. Gill rot. Usually occurring in fingerlings under stress of high-water temperatures or high organic matter content. Causing osmoregulatory deficiency and impaired O2 exchange.
Environmental	Water quality; Improper nutrition; Gas supersaturation; Soft water; Temperature; Overcrowding; Overhandling	With exception of water temperature in ponds, all these factors can be managed with good husbandry practices.

Treatment and management

HSB are generally robust and relatively resistant to disease (Smith, 2010) unless susceptibility is increased as a result of poor conditions (over-stocking, poor water quality, stress). According to one producer (J. Ekstrom, pers. comm. July 2017), secondary bacterial infections are the most problematic diseases in HSB; in fact, he states: “The only disease events we have experienced have been secondary bacterial infections induced by water quality stressors. These have been extremely rare: the last time we lost any fish [to bacterial infections] was approximately 10 years ago, and in those cases, we had a few ponds with 10–15% mortality.” Management is therefore mainly a case of maintaining fish in good health, maintaining the proper environment for the fish, and preventing the introduction and/or transmission of disease. Of paramount importance for hybrid striped bass is high water quality and gentle handling. BMPs specific to this point include: provision of high-quality feed; supplemental aeration in ponds; correct flow of water through RAS; ensuring correct stocking densities; prophylactic use of salt (0.5 to 3%) and/or potassium permanganate (2 to 5 mg/L) during handling to reduce parasite load.

In tank systems, the producers successfully contacted for this assessment reported very little problem with diseases. For Colorado Catch, overall survival rate during the grow-out phase is 85 to 86%, and the greatest risk of mortality is during the first six weeks post transfer from the hatchery. Fingerlings are quarantined on arrival and treated with saline water (20 ppt) to mitigate freshwater bacterial infections that may result from the stress of transportation and change in environmental parameters between farms. Occasionally fungal infections need to be managed with Chloramine-t (North Carolina producer) or more severe bacterial infections are managed with antibiotics (Colorado Catch; see details following). Once the initial settling period is over, both producers said that disease problems were rare.

As outlined in Criterion 4 – Chemical Use, for certain bacterial diseases, there are approved medicated (antibiotic) feeds: for example, streptoccocosis (*S. iniae*), and columnaris disease (*F. columnaris*) can both be treated with AQUAFLOR®, containing 50% florfenicol (USFWS 2015).

External parasites and fungal infections are generally prevented by good husbandry but may be treated with copper sulfate, formalin, potassium permanganate, acetic acid, and salt. At Ekstrom Aquaculture LLC, occasional outbreaks of the yellow grub (*Clinostomum* spp.) occur, but the incidence is reported as "very low" and not of concern. The life cycle is dependent on intermediate snail and bird hosts, and management involves control of these populations. Ponds are drained and dried between crops, which limits snail populations, and additionally bird populations—particularly the blue heron—are controlled as much as possible.

General biosecurity measures and use of additional BMPs further limit the incidence of on-farm outbreaks of disease. These include health certification of fish brought onto the farm, pathogen screening upon arrival, quarantining new stock, disinfection protocols (equipment and people), management of predators and domestic animals that may be vectors, routine health and disease screening, obtaining fast diagnosis and treatment of moribund fish; regular removal and proper disposal of mortalities (Dvorak 2009) (Barras and Godwin 2005) (Sadler and Goodwin 2007) (Yanong and Erlacher-Reid 2012) (Yanong 2013). Although the practices of each farm are unknown, since it is in the farmers' interest not to lose stock to disease, and the availability of information and access to help is high, it is likely that there is good uptake of these measures. The largest producer company in the industry, Ekstrom Aquaculture LLC, employs the following protocols to prevent the introduction of pathogens and to limit stressors as far as is practicable: use of groundwater rather than surface water so the water source is pathogen-free and free of wild fish; fingerlings come from a hatchery that is certified disease free for diseases of concern, although each shipment does not require certification; hauling trucks are sanitized before loading; equipment from other farms is not allowed on the farm; vectors such as birds and snails are controlled to the degree practical; water quality is controlled to the degree possible (J. Ekstrom, pers. comm. July 2017).

<u>Disease reporting and monitoring</u>

Excepting reportable diseases (e.g., IPNV), there are no requirements to notify or keep records of disease, and no monitoring data for any disease incidence or on-farm prevalence are publicly available. The US Fish and Wildlife Service does conduct pathogen monitoring on wild fish in waterbodies through the country under its National Wild Fish Health Survey, and searches of the database[3] return results suggest that on-farm diseases at HSB farms cannot be tied to those pathogens present in the wild. For example, a search of monitoring results for the pathogens noted to occur on farms that have also been sampled for in the wild (*A. salmonicida*, *E. tarda*, *F. columnaris*, IPNV) show that there have been zero detections in 423 samples from 1997 to 2016 across the state of Texas. Similarly, in North Carolina, search results show that there have been zero detections in 788 samples for *A. salmonicida*, *E. tarda*, and IPNV from 1999 to 2016. In order for producers to export to Canada, they must be USDA-APHIS certified as disease free on a yearly basis. In order to maintain registration for export, producers are subject to unannounced compliance inspections throughout the year. Data showing how many producers are exporting to Canada are not available, but the largest US HSB producer (Ekstrom Aquaculture LLC) does so and has provided copies of current APHIS Registration as an Export Facility.

Conclusions and Final Score

The possibility for on-farm amplification of disease and subsequent transfer to the surrounding environment exists, with potential vectors being escaped individuals, discharged water/sediment, and animals (birds, snails, wild fish). Although there is currently no evidence that disease transmission to wild species has occurred, several diseases are reported to have occurred on farms with no data available that allow for an estimation of typical disease prevalence or intensity on farms. Anecdotal evidence suggests such prevalence is low, as does the absence of antibiotic treatments. In order to export product to Canada, farms must be certified as disease-free by USDA-APHIS; this requires all disease events to be documented and reported and requires sworn affidavits to affirm the reports. Farms employ robust health and biosecurity protocols (e.g., disease-free fingerling sourcing, quarantine, not allowing equipment to be used on multiple sites, disinfection of hauling trucks, etc.) and typically have low rates of water discharge. There is some indication that on-farm biosecurity measures also prevent pathogen transmission to wild species, since wild fish health monitoring has demonstrated an absence of on-farm diseases to be present in the wild, though not all pathogens are tested for and it may be unclear how sampling locations and farm sites sit in proximity. Ultimately, on-farm disease prevalence is low, water exchange is low, and health and biosecurity measures are robust.

The final numerical score for Criterion 7 – Disease is 7 out of 10 for both ponds and tanks.

[3] https://ecos.fws.gov/wildfishsurvey/database/nwfhs/basicform

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

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

Ponds and Tanks

Source of stock parameters	Score	
C8X Independence from unsustainable wild fisheries (0-10)	0	
Critical?	NO	GREEN

Brief Summary

HSB fry and fingerlings are all hatchery raised. Broodstock fish are both domesticated and sourced from the wild, and efforts are being made to develop improved genetic lines. Overall reliance on wild broodfish is low, and there is good evidence to suggest that the numbers of fish taken for broodstock do not have a detrimental effect on wild stocks. For these reasons, the final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

Justification of Rating

As noted, sunshine HSB are the progeny of male *M. saxatilis* and female *M. chrysops*, and though HSB contrast most other hybrid species in their achievement of fertility (Hodson 1989) (Tate 1995), all commercial foodfish production is dependent on hybridization via artificial propagation (i.e., strip-spawning) (Dasgupta and Thompson 2013) (FAO 2016). As such, the source of both *M. saxatilis* and *M. chrysops* must be evaluated. According to McGinty and Hodson (2008), HSB hatcheries use wild-caught or domesticated stock, or a mixture of both.

Though some authors have proposed that across the HSB industry, the great majority of broodstock are wild caught and "industry efforts to domesticate the parent species of the HSB have been fairly limited in scope" (Fuller et al. 2017), there is evidence of the contrary. The life cycle of both species has been closed (McGinty and Hodson 2008) (FAO 2016). There is a current project at the Harry K. Dupree Stuttgart National Aquaculture Research Center (*Developing Nutritional, Genetic and Management Strategies to Enhance Warmwater Finfish Production*) that aims to obtain adult white bass from their native range and produce improved (for commercial production) genetic lines (USDA-ARS 2015). Similarly, North Carolina State University has domesticated lines of both white and striped bass broodstock (McGinty and Hodson 2008).

McGinty and Hodson (2008) state that most striped bass males used by hatcheries are domesticated. If wild striped bass are sourced, they are collected via pound nets and/or hook and line, and each facility typically sources between 10 and 30 males; females, due to a decreased gamete quality stemming from the stress of capture, are almost never sourced from the wild. The Seafood Watch assessment of the striped bass pound net and hook and line fisheries resulted in Good Alternative (Yellow) and Best Choice (Green) recommendations respectively, and the stock status is ranked as "low" concern (Green) (Seafood Watch 2016). Ultimately, taking of small numbers of striped bass for introduction of new genetic stock is not thought to be problematic.

Despite the aforementioned white bass domestication efforts at the Stuttgart research center in Arkansas, and the several-generations domestication effort at NC State, it seems the majority of white bass broodstock are sourced from the wild. According to McGinty and Hodson (2008), most hatcheries will take between 100 and 300 wild females (and some may take 10 to 30 males) per season. White bass are predominantly taken by hook and line from lakes and reservoirs in the Tennessee and Mississippi river drainages. There is the possibility that fish are also being taken from Lake Erie (H. Daniels, pers. comm. February 2017), a practice that was purported to stop in 2007 due to disease issues with viral hemorrhagic septicemia (VHS) which is a notifiable disease—however, this has not been confirmed. Although deciphering USDA Census of Aquaculture (2014) statistics can be difficult (i.e., one facility may qualify for being counted in more than one producer category), it is clear that there are no more than 19 hatcheries sourcing wild bass; considering that relatively few white bass are taken for the HSB industry, and the white bass is listed on the IUCN red list as "Least Concern," removal for broodstock is not considered to be an ecological risk in terms of affecting wild stock.

In addition, all fry and fingerlings are hatchery produced and therefore independent from wild stock.

Conclusions and Final Score

Hybrid *Morone* are partially produced from domesticated broodstock lines that have been bred over several years. White bass females and striped bass males are still sourced from the wild for broodstock, but there is evidence to suggest that both white bass and striped bass fisheries are in good stock health and that numbers taken for broodstock diversification are relatively low. Because all fingerlings/juveniles stocked for grow-out are hatchery-raised, and the number of broodstock sourced from the wild does not impact the population status of those species and can be considered to be sustainable, the final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

Criterion 9X: Wildlife and predator mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with farm sites.

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

Criterion 9X Summary

Ponds

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	-2	
Critical?	NO	GREEN

Tanks

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	-1	
Critical?	NO	GREEN

Brief Summary

Birds (cormorants, pelicans and great blue herons) are the most likely nuisance species on HSB farms. All can prey on fish, and herons are part of the life cycle of the yellow grub, a parasite that lowers the marketability of fish. However, permits for lethal control of nuisance species are tightly regulated and the main methods of control are non-lethal. There is no evidence to suggest non-compliance on the part of the producers. Pond production occurs entirely outdoors, but some tank production occurs indoors which limits the potential for wildlife interaction and the necessity to use lethal control. The final score for Criterion 9X – Predator and Wildlife Mortalities is -2 out of -10 for ponds and -1 out of -10 for tanks.

Justification of Rating

Ponds in which HSB are raised tend to be large and open, with little possibility for prevention of wildlife from using the habitat. Wild animals are potentially problematic as they can do direct damage to the crop by predation, with certain species having the potential to inflict significant losses on the population. They also have the potential to transmit pests and pathogens, either onto the farm, or off it and into wild populations, threatening biosecurity. Certain species (the great blue heron *Ardea herodius* and the ram's horn snail *Planorbella trivolvis*) also act as hosts for life-cycle stages of the HSB parasite *Clinostomum* spp. (the yellow grub), and controlling these intermediate hosts becomes necessary for control of the grub (Lane and Morris 2010). In general, birds tend to be the greatest threat on HSB farms.

Although HSB farms exist across the US, approximately two-thirds are located in the southeastern states. The following list is therefore more representative of species common and/or problematic to HSB production in those states.

1) Double-crested cormorant (*Phalacrocorax auritus*). The neotropic cormorant (*P. brasilianus*) can also be problematic but is far less abundant than the double-crested cormorant and also prefers smaller prey. These species can eat up to 0.5 kg of fish per bird per day, and forage as far as 15 miles from the roost.
2) Great blue heron (*Ardea herodius*). These can eat 0.35 kg of fish per day but seem to predate weak or sick fish and are not thought to do great damage to stock (Barras 2007).
3) White and brown pelicans (*Pelecanus erythrorhunchos, P. occidentalis*). Farms have year-round vulnerability to predation by white pelicans, during day and night—and birds will adapt to harassment. Each bird may take up to 3 kg of fish per day (Ekstrom, pers. comm. 2019, making the potential for damage considerable. Brown pelicans seem to do less damage, eating mostly non-commercial schooling fish (Barras 2007). Since 2009, the brown pelican has been removed from the Endangered Species Act list.
4) Other species: Wood storks (*Mycteria americana*); white ibis and other ibises; various herons and night herons; various egrets. Wood storks are protected by the Endangered Species Act (ESA) east of Alabama (AL, FL, GA, MS, NC, SC), and where they are present other birds may not be "shot or hazed" (Barras 2007).

Predator control

The Migratory Bird Treaty Act protects all fish-eating birds under federal law and permits are required for both lethal and non-lethal control. Non-lethal methods of control include roost disturbance, propane exploders, pyrotechnics, scarecrows, use of dogs, lights, and/or lasers, and harassment patrols. Certain species become habituated relatively quickly, requiring various tactics used in rotation. It is advised that non-lethal methods be backed-up by lethal methods in certain cases in "integrated bird management" (Barras and Godwin 2005), but in no case may lethal methods be used in isolation.

Populations of double-crested cormorant, brown pelican, white pelican, and great blue heron are all listed as IUCN "Least Concern," with a trend of increasing population size (Birdlife International 2016a) suggesting that controlled and monitored lethal take will not be (and has not been) detrimental to these species' populations. Wood storks, black crowned night herons, little blue herons and anhingas are similarly listed as "Least Concern," but their population trends are decreasing, or in the case of the yellow heron, stable (Birdlife International 2012a,b,c, 2016b, 2017). Only the wood stork is currently protected by the ESA.

Otters (*Lontra* spp.) and nutria (*Myocastor coypus*) can cause significant damage at aquaculture facilities but are not a frequent pest (Daniels, undated). The USFWS or its state derivatives issue permits for shooting nuisance animals under certain conditions and where they are not listed as endangered. For example, Florida Fish and Wildlife Conservation Commission allows permits for taking of depredating animals (including otter and nutria) only where the damage to livestock is taking place and only by prior contact with the Commission to inform of the planned activity and date (Florida Fish and Wildlife Commission 2017).

Farmers are not required to make public the numbers of animals taken by lethal means, but they must strictly comply with the depredation permits issued and detailed records must be kept, which must be submitted to the USFWS each year. According to one producer (J. Ekstrom, pers. comm. July 2017), cormorants, herons, and pelicans are the most significant predatory threats to production. He operates under a USFWS bird depredation permit, which authorizes limited lethal take of certain species as part of a program of non-lethal harassment and scare tactics, and strictly complies with the terms of the permit. It is the opinion of one industry expert (H. Daniels, pers. comm. February 2017) that producers are generally compliant and use the proper channels in regard to controlling nuisance species on farms.

Tank production facilities are located both indoors and out, and it is typically easier to protect stock by non-lethal means (i.e., preventing access of predators to facilities). One producer in North Carolina (fully indoor tank system) stated that they have not had any problems with predators except one incident with a bear when the doors to the facility were open during summer (resolved by shutting the doors). Colorado Catch have outdoor tanks (conversion to a fully indoor system is about to begin) but report no problems with predators with the exception of raccoons eating fish feed at night; in this case they are tolerated and no action is taken. Flow-through tanks and raceways are often outdoors, however, and it is unknown what proportion of tank producers have indoor facilities. In both cases, the risk of wildlife and predator mortalities was considered low, meaning that the aquaculture operation may interact with predators or other wildlife, but effective management and prevention measures limit mortalities to exceptional cases.

Conclusions and Final Score

Wildlife interactions are common in the case of birds in pond production systems; however, non-lethal methods of control are generally used, and lethal methods are tightly regulated. Tank systems are both indoors and outdoors, and access of predatory or nuisance wildlife tends to be more limited with little reported need for intervention. The final numerical score for Criterion 9X – Predator and Wildlife Mortalities is -2 out of -10 for ponds and -1 out of -10 for tanks.

Criterion 10X: Escape of secondary species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

Ponds and Tanks

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments (%)		1	
F10Xb Biosecurity of source/destination		9	
C10X Escape of secondary species Final Score		**-0.90**	**GREEN**

Brief Summary

Trans-waterbody movement of fish from hatcheries to growout sites is likely high; however, the biosecurity measures at the source (i.e., hatcheries) is also high and results in a low risk of introducing secondary species during transport. Of note, the widespread stocking of HSB into reservoirs and lakes in almost every state means that the potential contribution of aquaculture to unintentional spread of secondary species is small by comparison to the wild stocking program. Therefore, despite high trans-waterbody movements, the final deductive score for Criterion 10X – Escape of Secondary Species is -0.9 out of -10 for pond and tank systems.

Justification of Rating

Factor 10Xa International or trans-waterbody animal shipments

According to the latest US Census of Aquaculture, there are 10 hybrid striped bass hatcheries listed as producing "stockers" and nine listed as producing "fingerlings or fry" that supply the (approximately) 68 farms producing harvest-size fish (USDA 2014). These facilities are likely to be double-counted in some cases, since farms may produce both stockers and fingerlings/fry. Though the Census does not detail the location distribution of the hatcheries, there is evidence that these facilities are scattered across the southeastern US; however, it appears that fry and fingerling production is heavily dominated by one farm (Keo Fish Farm Inc., Arkansas). Because facilities producing harvest-size fish are indeed scattered across the country, spanning 20 states (USDA 2014) in multiple watersheds/drainage basins, it is clear that trans-waterbody shipments of hybrid striped bass do regularly occur. Although it is not possible to accurately estimate this figure, the dominance of Keo Fish Farm Inc. as a fry/fingerling producer, coupled with the facts that 1) Arkansas has only 3 other HSB farms, and 2) a large amount of HSB production occurs between Texas (greatest quantity of fish produced) and North Carolina (greatest number of farms) leads to a high estimate of 80 to 89.9% of trans-waterbody movements.

Because an estimated 80 to 89.9% of production is reliant on trans-waterbody animal movements, the score for Factor 10Xa is 1 out of 10.

Factor 10Xb Biosecurity of source/destination

Biosecurity is more challenging in the open environment of ponds than in tank-based facilities, particularly those located indoors. Nonetheless, there are various common and specific strategies undertaken at both in order to minimize the risks of introducing species unintentionally. Non-native and invasive species are major threats to biodiversity worldwide, and aquatic environments have been vulnerable to invasions (Hill 2011). Hitchhiking species (fish, invertebrates, plants, and pathogens) may be transferred between waterbodies when fish are initially stocked to the farm, as a result of discharge of water from the farm, and by vectors that move between waterbodies such as wild animals and humans. The SRAC/NCRAC factsheets provide information on biosecurity measures (Dvorak 2009) (Yanong and Erlacher-Reid 2012) (Yanong 2013), non-native and invasive species as related to aquaculture (Hill 2011) (Zajicek et al. 2009), and the Lacey Act (Rumley 2012).

The Lacey Act is the main federal regulation relating to possession and transport of “injurious species.” Regarding HSB production, grass carp (used for control of aquatic vegetation in ponds) are listed as a potential aquatic nuisance species and their cultivation and transport is regulated under this legislation. Some states do not allow grass carp at all, while others do, with additional precautionary measures in place. For example, grass carp are permitted in Texas and North Carolina but must be certified as 100% triploid. A permit is required from the Texas Parks and Wildlife Department for any stocking of grass carp, while in North Carolina the receipt from the certified triploid distributor is considered sufficient unless stocking more than 150 fish, or at a density greater than 15/acre, in which case an application to the North Carolina Wildlife Resources Commission is necessary.

The import and spread of non-native pathogens and parasites is managed by the USDA Animal and Plant Health Inspection Service (APHIS), by state agriculture agencies, and by federal and state natural resource agencies. Overall, methods for control are goal-oriented rather than process-oriented and rely on BMPs being implemented at farm level, giving each facility owner/manager the possibility to tailor operations to their site. Many of the relevant protocols have been detailed elsewhere in this report but are re-capped here. In general, they relate to reducing susceptibility to disease (animal management/husbandry), reducing or eliminating exposure to and transfer of pathogens (pathogen management and vector management), and reducing or eliminating transfer and/or escape of non-native species.

General biosecurity measures:

- Obtain healthy stock and maintain immunity through good husbandry
- Use of a “clean” water source (groundwater, spring water) or treat the water prior to use
- Hazard Analysis Critical Control Point (HACCP) analysis and biosecurity planning
- Clear protocols for sanitation and disinfection (foot baths, dips for equipment, signage indicating higher risk areas)
- Routine health and disease screening, rapid response to signs of disease (diagnosis and treatment), prompt removal of moribund and/or dead fish and proper disposal
- Control access of wild animals (pest and predator control)
- Mitigative measures in place for prevention of escapes
- Certification of disease-free stock
- Diseases and nuisance species should be checked for pre- and post-live hauling

Biosecurity at Keo Fish Farm (source farm—hatchery and fingerling production):

- All eggs are treated with iodine
- Saline dip for fry prior to stocking ponds for fingerling production
- Fingerlings are treated with a saline dip or potassium permanganate prior to shipping
- Trucks are cleaned with hot, high-pressure water and dried prior to and after hauling
- No fish, equipment or vehicles from a facility with lower disease status are allowed onsite
- Ponds are drained, dried, and disked prior to refilling
- No “wild” water is used for filling ponds, i.e., sterile water is used
- Ponds are situated outside of the 100-year floodplain
- Risk of escape is prevented with heavy duty PVC mesh screens on overflow pipes
- Biannual inspections for notifiable diseases by the USDA APHIS—disease free certification
- Annual inspections for aquatic nuisance species (ANS) and certification

In general, Mike Freeze, owner of Keo Fish Farm, states that they have very few difficulties with disease and that, in general, disease issues are all secondary infections as a result of stress or suboptimal environmental conditions (M. Freeze, pers. comm. September 2017). Antibiotics are not used on the farm and have not been used for approximately 20 years.

Biosecurity measures at Ekstrom Aquaculture LLC (destination farm—pond), as detailed in Criteria 6 and 7, include:

- Use of groundwater (pathogen and wild fish free) rather than surface water
- Sourcing fingerlings from a hatchery that is certified disease free for diseases of concern
- Sanitizing hauling trucks before loading
- Disallowing equipment from other farms

- Controlling vectors such as birds and snails
- Levee tops and standpipes are above any conceivable flood event
- Galvanized expanded steel screens are fitted in internal drain structures
- Levees are maintained with two ft of freeboard to prevent overtopping
- The farm is located outside the 100-year floodplain

Despite these measures, some secondary fish species do end up in the ponds; occasionally there will be small populations of sunfish, mudcats, or gizzard shad. It is believed that these may be introduced by birds or perhaps introduced with the fingerlings. They are controlled by drying ponds in between crops and poisoning any remaining puddles prior to refilling with either rotenone or chlorine (J. Ekstrom, pers. comm. July 2017). None of these species is listed as a Nuisance Aquatic Species; the fact that they (and any pathogens they may be carrying) are native to the regions and waterbodies in which HSB farms are situated, with their escape from ponds likely prevented by the measures detailed above, means their risk of unintentionally introducing species not native or present in those watersheds is zero.

Biosecurity measures at a North Carolina farm and Colorado Catch Farm (destination farms—tanks) include:

- General biosecurity measures outlined above
- Use of sterile well water
- Fingerlings supplied from a single hatchery with disease free certification
- Quarantine of initial fingerling stock + precautionary saline treatment (or a more specific treatment if required)
- Escapement is prevented by tank design—the only way fish can escape is if a tank overflows, in which case the fish are out of water and will die

<u>Biosecurity of grow-out facilities</u>
Due to the fact that HSB ponds have generally low water discharge with BMPs and biosecurity measures in place (Yanong 2013), the biosecurity of the destination of the transported animals scores 6 out of 10.

Although tank systems in general tend toward increased biosecurity potential (Yanong 2012), the fact that the proportion of RAS versus flow-through production is not known, and with the absence of water treatment systems such as UV or ozone prior to wastewater release, the score for Factor 10Xb is also 6 out of 10 for tank production systems.

<u>Biosecurity of hatcheries</u>
Although it cannot be guaranteed that all hatcheries have the same measures in place, due to the best-practices documented above together with the guaranteed disease-free status, the score for source of stock (i.e., hatcheries) is 9 out of 10.

Conclusions and Final Score

Though data are unavailable to indicate the exact degree to which the industry relies on trans-waterbody movement of fingerlings, it is estimated to be the majority, leading to a score of 1 out of 10 for Factor 10Xa. Though the destination of fish movements (i.e., growout sites) have generally good biosecurity, those at the hatchery are considered robust and result in a score of 9 out of 10 for Factor 10Xb.

The final numerical score for Criterion 10X – Escape of Unintentionally Introduced Species is -0.9 out of -10 for both pond and tank production.

Overall Recommendation

The overall recommendation is as follows:

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

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

Ponds:

Criterion	Score	Rank	Critical?
C1 Data	7.73	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.00	GREEN	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	4.47	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	7.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-2.00	GREEN	NO
C10X Secondary species escape	-0.90	GREEN	
Total	**48.30**		
Final score (0-10)	**6.90**		

OVERALL RANKING

Final Score	6.90
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK

GREEN

Tanks:

Criterion	Score	Rank	Critical?
C1 Data	7.73	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.00	GREEN	NO
C4 Chemicals	8.00	YELLOW	NO
C5 Feed	5.39	YELLOW	NO
C6 Escapes	8.00	GREEN	NO
C7 Disease	7.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Secondary species escape	-0.90	GREEN	
Total	**50.22**		
Final score (0-10)	**7.17**		

OVERALL RANKING

Final Score	7.17
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK

GREEN

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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.

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

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Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[4] 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

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

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

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

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

Appendix 1 - Data points and all scoring calculations

Criterion 1: Data Quality and Availability

Ponds and Tanks

Data Category	Data Quality (0-10)
Industry or production statistics	10
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	7.5
Feed	7.5
Escapes	7.5
Disease	5
Source of stock	7.5
Predators and wildlife	7.5
Secondary species	7.5
Other – (e.g., GHG emissions)	n/a
Total	**85**

C1 Data Final Score (0-10)	**7.73**	**GREEN**

Criterion 2: Effluent

Ponds and Tanks

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Criterion 3: Habitat

Ponds and Tanks

Factor 3.1 Habitat conversion and function

F3.1 Score (0-10)	7

Factor 3.2 Management of farm-level and cumulative habitat impacts

3.2a Content of habitat management measure	5

3.2b Enforcement of habitat management measures	5
3.2 Habitat management effectiveness	**10**

C3 Habitat Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Ponds and Tanks

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

Criterion 5: Feed

Ponds

5.1 Wild Fish Use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	16
Fishmeal from by-products (%)	0
% FM	16
Fish oil inclusion level (%)	7
Fish oil from by-products (%)	0
% FO	7
Fishmeal yield (%)	26
Fish oil yield (%)	9
eFCR	2.1
FIFO fishmeal	1.29
FIFO fish oil	1.63
FIFO Score (0-10)	**5.92**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-3
Calculated sustainability ajustment	-0.98
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**4.94**

Critical?	NO

5.2 Net Protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	41
eFCR	2.1
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	59.63
Feed protein from NON-EDIBLE sources (%)	40.37
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.4
Edible yield of harvested fish (%)	45
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	86.1
Edible protein IN kg/100kg fish	51.34
Utilized protein OUT kg/100kg fish	19.22
Net protein gain or loss (%)	-62.56
Critical?	NO
F5.2 Net Protein Score (0-10)	**3**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood		
Inclusion level of aquatic feed ingredients (%)		23
eFCR		2.1
Carbon required for aquatic feed ingredients (ton C/ton fish)		*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)		*2.68*
Ocean area appropriated (ha/ton fish)		12.56
5.3b Land area appropriated per ton of seafood		
Inclusion level of crop feed ingredients (%)		47.04
Inclusion level of land animal products (%)		26.2
Conversion ratio of crop ingredients to land animal products		*2.88*
eFCR		2.1
Average yield of major feed ingredient crops (t/ha)		*2.64*
Land area appropriated (ha per ton of fish)		0.97
Total area (Ocean + Land Area) (ha)		13.54
F5.3 Feed Footprint Score (0-10)		5

Feed Final Score

C5 Feed Final Score (0-10)	**4.47**	**YELLOW**
Critical?	**NO**	

Tanks

5.1. Wild Fish Use

Feed Parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	16
Fishmeal from by-products (%)	0
% FM	16
Fish oil inclusion level (%)	7
Fish oil from by-products (%)	0
% FO	7
Fishmeal yield (%)	26
Fish oil yield (%)	9
eFCR	1.75
FIFO fishmeal	1.08
FIFO fish oil	1.36
FIFO Score (0-10)	**6.60**
Critical?	NO
5.1b Sustainability of source fisheries	
Sustainability score	-3
Calculated sustainability adjustment	-0.82
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**5.78**
Critical?	NO

5.2 Net Protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	41
eFCR	1.75
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	59.63
Feed protein from NON-EDIBLE sources (%)	40.37
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.4
Edible yield of harvested fish (%)	45

Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	71.75
Edible protein IN kg/100kg fish	42.79
Utilized protein OUT kg/100kg fish	18.24
Net protein gain or loss (%)	-57.37
Critical?	NO
F5.2 Net Protein Score (0-10)	**4**

5.3. Feed Footprint

5.3a Ocean area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	23
eFCR	1.75
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	10.47
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	47.04
Inclusion level of land animal products (%)	26.2
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.75
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.81
Total area (Ocean + Land Area) (ha)	11.28
F5.3 Feed Footprint Score (0-10)	6

Feed Final Score

C5 Feed Final Score (0-10)	**5.39**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

Ponds and Tanks

6.1a System escape Risk (0-10)	8
6.1a Adjustment for recaptures (0-10)	0
6.1a Escape Risk Score (0-10)	**8**
6.2. Competitive and genetic interactions score (0-10)	**9**

C6 Escapes Final Score (0-10)	**8**	**GREEN**
Critical?	**NO**	

Criterion 7: Disease

Ponds and Tanks

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	7	
C7 Disease Final Score (0-10)	**7**	**GREEN**
Critical?	NO	

Criterion 8X: Source of Stock

Ponds and Tanks

C8X Source of stock score (0-10)	0	
C8 Source of Stock Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Criterion 9X: Wildlife and Predator Mortalities

Ponds

C9X Wildlife and Predator Score (0-10)	**-2**	
C9X Wildlife and Predator Final Score (0-10)	**-2**	**GREEN**
Critical?	NO	

Tanks

C9X Wildlife and Predator Score (0-10)	**-1**	
C9X Wildlife and Predator Final Score (0-10)	**-1**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of Secondary Species

Ponds and Tanks

F10Xa live animal shipments score (0-10)	1.00	
F10Xb Biosecurity of source/destination score (0-10)	9.00	
C10X Escape of Secondary Species Final Score (0-10)	**-0.90**	**GREEN**
Critical?	n/a	