Monterey Bay Aquarium Seafood Watch®

Pangasius

Pangasianodon hypophthalmus

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Vietnam

Production System – Ponds

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Disclaimer

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About Seafood Watch®

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

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

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

Guiding Principles

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

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

- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy-intensive production systems (e.g. promoting more energy-intensive closed recirculation systems).

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

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

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

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

Final Seafood Recommendation

(see exception for ASC and GAA certified pangasius products below)

Criterion	Score (0-10)	Rank	Critical?
C1 Data	5.56	YELLOW	
C2 Effluent	3.00	RED	NO
C3 Habitat	4.25	YELLOW	NO
C4 Chemicals	CRITICAL	CRITICAL	YES
C5 Feed	7.66	GREEN	NO
C6 Escapes	5.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	8.00	GREEN	
C9X Wildlife mortalities	-3.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**34.47**		
Final score	**4.31**		

OVERALL RANKING

Final Score	4.31
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

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

Summary

The final numerical score for pangasius in Vietnam is 4.31 out of 10 which is in an initial yellow range, however there are two red criteria scores, one of which is Critical, which results in an overall red rating; and an "Avoid" recommendation (see certification exception note below).

Note – ASC, GAA and Naturland certified pangasius from Vietnam are considered to be equivalent to a yellow "Good Alternative" recommendation.

Executive Summary

This assessment was originally published in December 2016 and reviewed for any significant changes in March *2021. Please see Appendix 2 for details of review.*

Over one million metric tons (mt) of pangasius (i.e., the Mekong River fish or striped catfish, *Pangasianodon hypophthalmus)* is produced annually in Vietnam (1.4 million mt reported in 2012, and 1.1 million mt predicted in 2015). The industry's development has been characterized by periods of rapid growth and dramatic shifts in production practices. In the 1990s pangasius was produced typically on a small scale in ponds, but volumes rapidly increased as the industry expanded into net pen culture in the early 2000s. The industry then made a rapid transition back to pond culture in the mid- to late 2000s, with the area of ponds increasing from 1,250 ha in 1997 to 9,000ha in 2007. The introduction of much deeper ponds (~4m) in the late 2000s enabled further increases in production volumes without greatly increasing the total farming area.

Pangasius farming in Vietnam has been described as the most intensive and productive food production system on earth. With extremely high stocking densities possible with this species, very high yield figures of up to 600 mt per hectare of pond area are possible (although approximately 300 mt/ha is more typical). This is classified as hyper-intensive animal production by the UN Food and Agriculture Organization (FAO), and is a defining characteristic of the industry in Vietnam. It is also a factor affecting the industry's potential environmental impacts. Various Vietnamese and international development projects have been (and are being) undertaken in Vietnam, and the industry is actively working on improving practices through regulation, farmer training, best practices, and farm-level certification at the national and international level. Pangasius is now one of Vietnam's most important export crops by volume and value; the US and Europe are both important markets and Vietnam exports pangasius to over 145 countries.

This Seafood Watch assessment involves a number of different criteria covering potential 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[b].

Regarding data availability, a variety of sources are apparent; while direct industry and government data are somewhat limited, the industry has been the subject of considerable academic study and reporting for international development projects. Overall, across the various criteria covered in this Seafood Watch assessment, the data availability is moderately good for pangasius aquaculture in Vietnam, i.e. it is deemed to give a reliable and reasonably

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[b] The full Seafood Watch aquaculture criteria are available at: *http://www.seafoodwatch.org/cr/cr_seafoodwatch/sfw_aboutsfw.aspx*

up-to-date representations of the industry and its impacts; data gaps are present but considered non-critical; the final Data Criterion score is 5.8 out of 10.

Hyper-intensive pangasius production generates a large amount of soluble and particulate wastes. There are two main activities that result in the discharge of pangasius wastes from the farms: the daily exchange of pond water and the disposal of concentrated pond sludge. The total wastes produced by the pangasius industry can be considered small compared to the total nutrient loads in the Mekong as a whole, and small compared to total nutrient runoff from other crops (e.g., rice). Furthermore, the action of settlement in ponds may actually result in improved water quality values for some parameters in daily water discharges (e.g., total suspended solids) when compared to the incoming water from the sediment-laden Mekong River. However, the discharge of concentrated sludge wastes from the pond bottoms continues to be a high concern. The appropriate disposal of sludge wastes is increasing in Vietnam (for example fertilizing agricultural land), but according to expert opinion, and despite government regulations to the contrary, many farms (potentially the majority of small farms) continue to illegally dump sludge wastes directly into rivers or canals adjoining the farms.

While the daily discharge of pond water appears unlikely to contribute substantially to nutrient loads in the river as a whole, the illegal sludge dumping at the local level contributes to the cumulative pollution and deteriorating water quality in the tributaries and canals of the delta and represents a high concern. Calculations on effluent loads in combination with the effectiveness of the regulatory system to manage potential cumulative impacts result in a high concern in the Seafood Watch criteria and the Effluent Criterion has a score of 3 out of 10.

With regard to potential habitat impacts, pangasius farming is located on riparian land along two major branches of the lower Mekong River. It occupies a small fraction of the delta, and has largely replaced intensively farmed arable land (which had been the primary cause of the historical loss of ecosystem services and habitat functionality). Despite regulations to manage pangasius aquaculture zonation and farm siting, legal requirements have not always been followed and unauthorized and/or high densities of farm facilities have become established. Combining the habitat conversion score with the effectiveness of the regulatory system gives a final score for the Habitat Criterion of 4.25 out of 10.

Publically reported data on chemical use in Vietnam is not available, but recent academic studies show chemical use in Vietnamese pangasius culture is high (compared to many other aquaculture systems, but broadly similar to their use in terrestrial livestock). A broad range of antibiotics are used, in addition to pesticides and disinfectants. The antibiotics used include several that are characterized as critically- and highly-important for human health according to the World Health Organization (WHO). Shipments of pangasius fillets to Europe continue to be rejected due to the presence of nitrofuran (antibiotic) residues (17 rejections in Europe in 2014); and although these rejections represent a minor component of total pangasius shipments, they indicate some ongoing use of this group of antibiotics, which have been banned in Vietnam and in the major receiving countries.

Frequent water exchanges and sludge disposals discharge free and bound antibiotic residues and their metabolites into the environment, and while recent studies show the direct toxic effects in receiving waters are unlikely to be severe, the effects on microbial communities of single and combinations of antibiotics remain poorly understood. The development of widespread resistance to multiple antibiotic treatments by important pangasius pathogens is a clear indicator of the overuse of antibiotics on pangasius farms, and there is a high concern regarding the discharge into the Mekong of highly- and critically-important antibiotics for human health. In the Seafood Watch criteria, when developed resistance includes highly- and critically-important antibiotics, the score is zero and "Critical."

The majority of Vietnamese pangasius are fed commercial feeds utilizing low inclusion levels of fishmeal and fish oil. Terrestrial crop ingredients constitute the bulk of the feed. A Feed Conversion Ratio (FCR) value of 1.6 is considered average, and with low fishmeal inclusion and zero fish oil, the "fish in: fish out" (FIFO) ratio is less than 1 (0.36). Data on the source of fishmeal used in pangasius feeds in Vietnam is scarce and feed mills are likely to include trash fish of unknown (but likely poor) sustainability in addition to better-known international sources such as Peruvian anchovy and Chilean salmon byproducts. There is a substantial loss of edible protein (60%) in the conversion of feed to harvested pangasius, however, with low use of marine ingredients and high levels of crop ingredients forming the bulk of the feed, the overall feed score is high: 7.66 out of 10.

Pangasius farms in the Mekong Delta do have measures in place to minimize escapes, however, there are multiple points along the production chain where fish could potentially escape. Pangasius are native in the Mekong, and although they have been domesticated to a certain extent over multiple generations, hatchery-reared pangasius are currently considered to have little genetic difference to wild stocks. Therefore, although genetic and ecosystem impacts from escapees on wild fish may occur, they are considered a moderate to low risk within the delta's remnant wild *P. hypophthalmus* population. The final score for the Escapes Criterion is 6 out of 10.

The predominant health management problems in hyper-intensive pangasius farms are infectious bacterial diseases. Pathogens and parasites on farms originate from water taken into the facility during pond filling and water exchanges, and the potential for horizontal transmission between farms appears to be high. The effects of amplified levels of pathogens in water subsequently discharged from farms are unclear; especially the transfer from cultured pangasius to wild pangasiids and other fish populations. Disease and parasites are present in wild pangasiids and other fish populations, but little evidence is available to claim that such parasitic and disease episodes have increased or have significantly impacted wild populations as a direct result of current pangasius culture. Until vaccines become common place and are demonstrably effective in hyper-intensive systems, the Disease Criterion score is 4 out of 10.

All fingerlings for growout operations come from Vietnamese hatcheries. Domestically held broodstock are usually replaced every 3 years and sourced primarily from populations kept by hatcheries or from other delta farms. There is a continued (but relatively limited) trade in wild-caught broodstock being used in pangasius breeding, often from Cambodia from small remaining populations of wild pangasius. The Source of Stock score is therefore 8 out of 10 as the industry is largely independent of wild fisheries for stock.

Pangasius farms in Vietnam are considered likely to attract a variety of predators, typically birds, however, data on mortalities are not available. Expert opinion considers mortality numbers to be low, and unlikely to affect the population sizes of the species present. The score for this 'exceptional' Wildlife and Predators Criterion is a deduction of -3 out of -10.

Hatchery raised fingerlings are frequently transported between sites within the Mekong Delta, and some imports of pangasius broodstock occur from the Mekong in Cambodia; however, for the purposes of assessing the risk of accidentally transporting non-native species during live animal shipments, these are not considered to be movements across different waterbodies. The score for the exceptional Criterion 10X is a deduction of 0 out of -10.

Overall, while this assessment recognizes the efforts underway in Vietnam to improve the management of pangasius production through industry development, regulation, farmer training, international development projects, and farm-level certification at the national and international levels, significant environmental concerns remain, particularly with respect to the illegal dumping of sludge wastes, and the overuse of a range of antibiotics including several listed as highly- and critically-important for human health.

Farm-level certification is increasing in Vietnam, and Seafood Watch recognizes the better practices stipulated and verified by satisfying the requirements of robust certification schemes. Seafood Watch has (in a separate assessment[c]) assessed a number of aquaculture certification schemes and currently considers the following standards to be equivalent to a yellow "Good Alternative" recommendation:

- Aquaculture Stewardship Council (ASC)
- Global Aquaculture Alliance (GAA) Best Aquaculture Practices standards (2,3 and 4-star)
- Naturland organic standards

The ASC is currently considered to certify approximately 20% of Vietnamese pangasius (195,000mt certified in 2013 from approximately 1 million mt total production in Vietnam), and GAA, approximately 3% of annual production (approximately 30,000 mt). Volumes of Naturland certified pangasius are not currently known. Therefore, approximately 23% of Vietnamese pangasius production certified to ASC and GAA standards is considered equivalent to a yellow "Good Alternative" Seafood Watch recommendation.

The remaining pangasius production in Vietnam has a numerical score of 4.3 out of 10 in this Seafood Watch assessment, but due to a red score for the Effluent Criterion and a critical score in the Chemical Use Criterion, the final recommendation is a red "Avoid." As industry practices continue to improve along with developments in national and international certification

[c] See http://www.seafoodwatch.org/seafood-recommendations/eco-certification

schemes in Vietnam, Seafood Watch expects the proportion of yellow “Good Alternative” pangasius to continue to increase.

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Introduction

Scope of the analysis and ensuing recommendation

Species: *Pangasianodon hypophthalmus* (Sauvage, 1878)
The term 'pangasius' is used in this report to describe the *species* *P. hypophthalmus.*

Geographic coverage: Vietnam
Production in Vietnam is primarily within the Mekong River Delta (MRD) in the southern-most region of Vietnam (8°33'–10°55'N, 104°30'–106°50'E)/

Production methods: Ponds (earthen)

Species overview:

Figure 1.The Mekong

(According to Nguyen 2009):
Pangasius hypophthalmus is one of several native, freshwater catfish species found in the Chao Phraya River (Thailand) and the lower-middle Mekong River basin (Cambodia, Laos, Thailand and Vietnam)(Figure 1). In the Mekong River there are thought to be two populations of *P. hypophthalmus*; one above and one below the Khone Falls on the Cambodian/Laos border. *P. hypophthalmus* is a migratory species and the lower Mekong population (Cambodian and Vietnamese stocks) migrate hundreds of km annually between several upstream sites in northern Cambodia below the Khone Falls and the feeding grounds on the Mekong floodplain (the Mekong Delta) and the Tonle Sap Lake in Cambodia. Spawning is intimately tied to the monsoon season, from May to August, adult fish then migrate back to the feeding grounds and larvae drift to nursery floodplains located near these feeding grounds.

P. hypophthalmus is a large (up to 1.3 m total length and 44 kg in weight) omnivorous species feeding on algae, plants, zooplankton, insects, fruit, crustaceans and fish. The species grows approximately 1 kg per year, and first reproduces around 3.5-4 years old. Fecundity ranges between 112,000-140,000 eggs per kg of body weight, with full maturity reached at 10 years (IUCN 2013).

The omnivorous nature and favorable growth rates of *P. hypophthalmus*, coupled with the fact that it can tolerate low dissolved oxygen (it is a facultative air-breather[d]), high turbidity and

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[d] *Facultative air-breathing fish need to breathe air only when aquatic conditions do not favor aquatic respiration (Graham 1997). P. hypophthalmus possesses both well-developed gills and a modified swim bladder that functions as an air-breathing organ indicating a high capacity for both aquatic and aerial respiration (Lefevre et al. 2011).*

reach marketable size (800g-1 kg) in 6-8 months have made it particularly appealing for aquaculture, and the species has been introduced for aquaculture production in several other Asian countries including, Bangladesh, China, India, Indonesia, Myanmar (Hall and Johns 2013) and the Philippines.

Wild populations of *P. hypophthalmus* were once an important fishery and food source in Cambodia, Laos, Thailand and Vietnam but are now declining. Over-exploitation, habitat degradation (including spawning ground) and changes in water quality and flow are the major threats to this species. Future plans to dam the Mekong could disrupt the species life cycle, as it appears to rely on flow and/or water quality to facilitate migrations, cue spawning, and aid in the dispersal of young fish. As such, the IUCN has classified this species as 'endangered' in accordance with criteria laid down in the IUCN Red List: Categories and Criteria Version 3.1.

Production statistics

Vietnamese pangasius aquaculture has developed markedly and, in scarcely a decade, pangasius has risen from a low production base for local consumption to one of Vietnam's most important export crops by volume and value; unparalleled in its speed and scale by any other aquaculture species to date (Belton et al. 2011). Pangasius production in the Mekong Delta, Vietnam is now one of the biggest freshwater aquaculture industries globally, De Silva et al. 2010, De Silva and Phuong 2011.

The Food and Agriculture Organization (FAO) has categorized Vietnamese pangasius production as hyper-intensive, and Belton et al. (2011) described pangasius as the most intensive and productive food production system on earth.

As shown in Figure 2, current production in 2014 is approximately 920,000 metric tons, varying annually from a peak in 2012 of 1,415,750 mt with a predicted 1.1 million mt in 2015 (surveyed values and predictions from Tveretas 2013). This volume is produced at a high intensity on a farming area of only 5,910 hectares (ha) (De Silva and Phuong 2011). This is possible due to intensive, high-density culture, enabling production figures of over 200-300 mt per ha per crop; [and with around 1.45 crops per year] as much as 400-600 mt per ha per year (SFP[1] 2013). This is categorized by the Food and Agriculture Organization (FAO) as hyper-intensive due to the very high stocking densities and production per unit area (Genschick 2014).

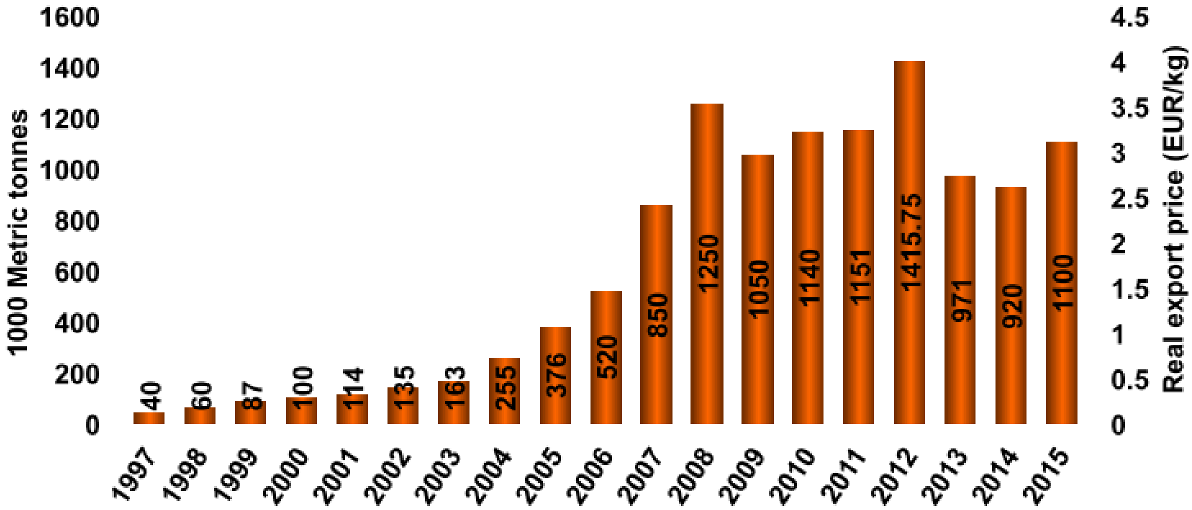

Figure 2 – Pangasius production in Vietnam 1997 to 2013, with predictions for 2014 and 2015. Graph from Tveretas 2013 – GAA GOAL Conference.

The Vietnamese government seeks to have 1.5-2 million mt of pangasius produced by 2020, as specified in the 'Vietnam Aquaculture Plan 2010-2020' (Dung[1] 2012).

Production system and locational overview

Intensive pond aquaculture of pangasius, which now represents over 95% of current pangasius production (SEAT 2011), has a complex value chain divisible into four independent but highly integrated sub-sectors: hatchery seed production, fry to fingerling rearing (nursery), grow-out, and ultimately processing.

Pangasius growout farming is the focus of this Seafood Watch assessment, and is located on the banks of the two major branches of the lower Mekong River: the Tien Giang (upper) and the Hau Giang (lower), and on the associated tributaries, channels and canals, which form a myriad of inter-connecting waterways. Pangasius aquaculture is dominated by five provinces in the delta, namely (and in order of production volume): Dong Thap, An Giang, Can Tho, Ben Tra and Vinh Long—the first two provinces represented 53.8% of 2011s total production; all five represented 87.6%.

After a rapid change in Vietnam from a net pen culture system to earthen ponds for pangasius around 2005, the total area of ponds has remained relatively stable for the past few years (at around 6,000 ha), and although the actual number of farms has decreased, the average farm size and pond depth has increased (Little and Murray 2011). The change in pond depth from approximately 2 m to 3.5-4 m has greatly increased the total volume of ponds available for production. Pangasius farming is trending toward more integrated operations that vertically incorporate seed, nursery, growout and processing systems with the largest integrated producer/processor companies now occupying farm sites ranging from 20 to 40 ha (authors' pers. observation 2012). However, most farms are still relatively small, covering an average area of less than 5 ha.

Eco-certification status

The use of 3rd party international certification schemes within pangasius aquaculture has been growing since 2010, triggered in part by criticism of the industry by the Worldwide Fund for Nature in the form of a red sustainability ranking, and a subsequent agreement to "move towards certification" in the Vietnamese pangasius industry (Genschick, 2014).

The three main certification bodies and the volumes of live weight pangasius production they have/do certify are detailed below:

- Aquaculture Stewardship Council (ASC): 110,000–120,000 mt in QII 2013 (Fransen, pers. com. 2013) = approx. 10% of 2012 production. This figure rose 69% to 195,942 mt by QIV 2014 (Geerts, pers. com. 2014) = approx. 20% of 2013 production
- Global Aquaculture Alliance (GAA): 29,174 mt (Lee, pers. com. 2013) = approx. 2.5% of 2012/2013 production
- GlobalG.A.P. (GG): 240,000 mt (Weymann, pers. com. 2013/2014) = approx. 20% of 2012/2013 production

Generally, certification has been attained by the largest producers/farms, and many of these hold certificates from more than one scheme (therefore, the total live weight production of pangasius certified as of 2012/2013 should not be taken as the sum of all three schemes). This tendency toward large farms has been linked to an increase in the market dominance of industrial farming in Vietnam, and to the detriment of small household farms (Trifkovic, 2014).

The Vietnamese government, Vietnam Fisheries Society (VINAFIS) and the Vietnam Association of Exporters and Processors (VASEP) (with assistance from independent bodies such as WWF and IDH/SNV) have committed the industry to achieve 100% of farmed pangasius under one of the available certification schemes by 2015, with at least 50% certified under the ASC (WWF 2012).

US Import statistics

Pangasius was virtually unknown as a food fish outside Asia until the early 2000s. However, since then, export-orientated production of the fish has seen rapid growth. In addition to the EU market, pangasius continues to gain popularity in North America—its flaky white flesh, firm texture and neutral flavor have been widely accepted by consumers in the U.S. as a low cost alternative to the indigenous channel catfish (*Ictalurus punctatus*) (Belton et al. 2011). Pangasius is currently (2013 data) listed as the sixth most preferred seafood in the US, according to the National Marine Fisheries Service (NMFS 2014)

Vietnamese pangasius is exported to over 145 countries (VASEP, 2012), and earned Vietnam US$1.74 billion in 2012 (VASEP[2] 2013). Exports to the US have been steadily rising since 2006, and the US imported 20.6% of Vietnam's 2012 production, worth US$359 million (VASEP[2] 2013).

Common and market names
Vietnamese cat fish are typically known as catfish, pangasius, striped catfish, basa, swai or tra, but may also be sold as cream dory, iridescent shark, silver striped catfish, sutchi catfish, Vietnamese catfish or Vietnamese river cobbler.

Product forms
The main product form of pangasius is the fillet in various cuts including belly on/off, trim on/off, etc. (Kiet, pers. com. 2013). Products such as whole fish, steaks and slices are also available and, according to some processors, demand is now growing for products such as frozen industrial block (Newton et al. 2012). In recent years, processors have also been seeking to differentiate their product lines/ranges and add value, with products such as breaded fish now produced (VASEP 2012).

Analysis

Scoring guide

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

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	7.5	7.5
Predators and wildlife	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**50**

C1 Data Final Score	**5.6**	**YELLOW**

Summary

Due to the large scale of production of pangasius in Vietnam, a variety of data sources are available; while direct industry and government data is somewhat limited, the industry has been the subject of considerable academic study and international development projects. Overall, across the various criteria covered in this Seafood Watch assessment, the data availability is moderately good for pangasius aquaculture in Vietnam (i.e., it is deemed to give a reliable and reasonably up-to-date representations of the industry and its impacts), however, data gaps are present but considered non-critical. The final Data Criterion score is 5.8 out of 10.

Justification of Ranking

The pangasius industry in Vietnam has a variety of sources available at the industry and government level, and has been the subject of considerable academic study. In addition, industry and international development projects represent reliable sources of information and data.

Data on industry/production statistics is derived primarily from industry and government sources, but collated by the FAO or by independent analysts such a Tveretas (2013). The locational focus of the industry within the Mekong Delta is reliably reported by various authors (e.g., Bosma et al. 2009). Score 10 out of 10.

Although there is a significant water quality monitoring effort in the Mekong Delta, little of the monitoring data is publically available. However there has been significant academic study of the impacts of pangasius aquaculture on water quality plus key expert personal communication for this assessment and therefore there is considered to be sufficient evidence available to understand the risk of impacts from daily water exchanges and from the dumping of sludge wastes from the ponds. Therefore although in-country water quality monitoring data is not readily available, the data score for effluent is 7.5 out of 10.

Information on the habitat dynamics of pangasius farming in the Mekong Delta is largely available from academic studies and historical reports (e.g., Bosma et al. 2009, Little et al. 2013) (data score 7.5 out of 10).

While information on prohibited and restricted chemicals is available from industry sources (e.g., VASEP 2012), little data on the quantities used are available from the industry and data availability is limited to recent studies by international authors (e.g., Andrieu et al. 2015, Rico and Van den Brink 2014) (data score 5 out of 10).

Public information on feed composition is not typically available, but academic references (e.g., Tacon et al. 2011), in addition to personal communication with feed industry experts, resulted in a data availability score of 5 out of 10 for feed.

Limited data is available on escapes or their potential impacts (data score 2.5 out of 10), and while basic information on disease concerns are available from a production perspective, little is known about the prevalence of disease and/or potential impacts on wild species in the Mekong (data score 2.5 out of 10). With little information available on predators and wildlife mortalities, the data score for this criterion is also 2.5 out of 10. Information on the source of stock with respect to hatchery production is widely available, but the impacts of ongoing collection of broodstock in Vietnam and Cambodia are less well known (data score 7.5 out of 10).

Overall, across the various criteria in this Seafood Watch assessment, the data availability is moderately good for pangasius aquaculture in Vietnam (i.e., it is deemed to give a reliable and reasonably up to date representations of the industry and its impacts), however, data gaps are present but considered non-critical. The final Data Criterion score is 5.6 out of 10.

Criterion 2: Effluents

Impact, unit of sustainability and principle

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

Criterion 2 Summary

Effluent Full Assessment

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	48.64		
F2.1b Waste discharged from farm (%)	80		
F2 .1 Waste discharge score (0-10)		6	
F2.2a Content of regulations (0-5)	2.5		
F2.2b Enforcement of regulations (0-5)	1.0		
F2.2 Regulatory or management effectiveness score (0-10)		0.9	
C2 Effluent Final Score		**3.00**	**RED**
Critical?	NO		

Pangasius farming in Vietnam represents hyper-intensive production and generates a large amount of soluble and particulate wastes. There are two main activities that generate effluents: the daily exchange of pond water and the removal of pond sludge. The action of settlement in ponds may result in improved values for some water quality parameters in daily water discharges when compared to the incoming water from the sediment-laden Mekong River, however, the discharge of concentrated sludge wastes continues to be a high concern. While the appropriate disposal of sludge wastes is increasing (for example, fertilizing agricultural land), the majority of farms continue to illegally dump sludge wastes directly into rivers or canals adjoining the farms despite government regulations to the contrary. While this represents a minor contribution to the total nutrient loads in the Mekong River, sludge dumping at the local level contributes to the cumulative pollution and deteriorating water quality in the rivers and canals of the delta and represents a high concern. Calculations on effluent loads in combination with the effectiveness of the regulatory system to manage potential cumulative impacts confirm the high concern in the Seafood Watch criteria and the Effluent Criterion has a score of 3 out of 10.

Justification of Ranking
The Food and Agriculture Organization (FAO) categorizes pangasius production in Vietnam as hyper-intensive due to the very high stocking densities and production per unit area (Genschick 2014). The production of nutrient wastes can also be considered to be intense and are discharged from the ponds in two main forms: as soluble and suspended particulates in daily water exchanges, and as concentrated sludge deposits from the pond bottoms or settling ponds at less frequent intervals.

Daily pond water exchange
The exchange of pangasius pond water is undertaken to partially remove dissolved and suspended waste materials and pollutants in the water column (e.g., from fish excretion, nutrients leached from feed, occasional treatment chemical residues, etc.) and to replace water lost through evaporation and seepage. Anh et al. (2010) reported that a daily water exchange of 30% is recommended in pangasius growout ponds (20% during the first 3-4 months, 40% during the last 2-3 months), but Bosma et al. (2009) noted that in practice, farmers daily exchange around 7% and do so 24 times per month on average. More recently, Murray et al. (2013) reported average water exchanges of 36.2% per day with the actual discharge lasting approximately 6.5 hours (quoted in Rico and Van den Brink, 2014).

The total volume of water this equates to for the entire pangasius growout industry is large, yet considered to be a small fraction of the total discharged by the Mekong River. For instance, Bosma et al. (2009) calculated (based on the water exchange rates and the lowest annual flow rate of the two main rivers through the Mekong Delta (i.e., a discharge of 475,000 km^3 per year)) that approximately 0.0005% of the water of the Mekong River would be diverted through pangasius ponds per year.

It appears that farm effluents from daily water exchanges (as opposed to concentrated sludge disposal) are unlikely to cause major impacts to the nutrient and silt-laden Mekong. For example, Bosma et al. (2009) showed waste water from daily exchange had relatively low concentrations of nutrient pollutants and, after compiling data from several pangasius waste water studies, Anh et al. (2010) showed that average values of daily pangasius pond exchange water quality parameters did not generally exceed the Vietnamese surface water quality standards; however, it should be noted that there was found to be variation among ponds and producers, which led to the conclusion that there are probably many individual ponds where the standards are exceeded (Anh et al. 2010); a conclusion supported by a 2007-2009 Sustainable Fisheries Partnership water quality survey (SFP[1] 2013), and Genschick (2014) who noted (in references quoted therein), that biological and chemical oxygen demand can reach eight times higher than the level required under the A1 quality standard defined by the National Technical Specification on Environmental Standards.

Pond sludge and removal
Only part of the suspended solid waste (10%–30%) in ponds will be removed when water is exchanged (Bosma et al. 2009). The remaining fish feces, uneaten feed and suspended matter brought into the system from the turbid waters of the delta eventually settle at the bottom of

production ponds forming a layer of sludge. The volume of sludge produced annually is lower than daily exchange wastewater, but concentrations of pollutants in sludge are much higher. Approximately 8,000m³ of sludge collects per ha per growth cycle and is removed every 1-2 months (SEAT 2012). From calculations based on total farming area, it has been estimated that around 48.7 million m³ of pond sludge was generated by the pangasius industry in 2012 (justification is detailed in Appendix 3). Concentrated waste discharges lead to high levels of biological and chemical oxygen demand and nutrient discharges (Anh et al. 2010). A great deal of the contribution that the pangasius effluents add to water pollution depends on the way farmers manage their pond sludge (VASEP, 2012)

Producers are prohibited from dumping pond sludge directly into waterways and, according to national legislation, every farmer must set aside part of the farm area for treating wastewaters before they enter the river (Khoi 2011). However, Hoe (2008) noted that this is nearly impossible in practice, and at that time (2008), less than 10% of fish farms had sedimentation ponds. Phan et al. (2009) reported 80% of pangasius farms do not treat wastewater and discharge water and sludge into rivers and canals. More recently, Khoi (2011) reported that many small-scale farmers, particularly those that were not affiliated to large pangasius producers or members of a fisheries association, did not adhere to the regulations and 55% of the 200 pangasius producers surveyed discharged their waste directly into the river. At the present time, expert opinion indicates that the bulk of independent farmers, especially those located along main rivers are still thought to discharge wastewater and sludge directly into these waterways (De Silva, pers. com. 2013).

Contribution of pangasius aquaculture wastes to water pollution

Rapid urbanization and industrialization has affected water quality across Vietnam, and issues related to pollution and the quality of its waterways are increasing. For example, Wilbers et al. (2014) state it is widely known that the quality of surface water in the region is threatened by a variety of pollutants from both natural and anthropogenic sources, and Genschick (2014) notes water quality is decreasing due to a cumulated effect from aquaculture and socio-economic development in general. Before 2000, the year pangasius expanded and intensified, local people were able to use the river water for cooking, which is no longer possible due to pangasius culture (Vo Thi Lang et al. 2009 and referenced in Genschick 2014). Yet it is also interesting to note that the water quality of the Mekong, which despite recent changes still remains largely unindustrialized, has also been considered to be clean compared to that of most European rivers (Little et al. 2012).

At the river scale Bosma et al. (2009) point out that in the worst case scenario pangasius farming contributed less than 0.001% to N and P to the rivers overall nutrient load, and as the Mekong discharges an average of 160 million mt of sediments annually (Baran and Guerin, 2012), quantities of sediments from pangasius ponds are likely to be minor in relation to total river discharges. It can also be noted that pangasius effluents account for a relatively small volume when compared to the potential runoff of N (and P) from fertilizers used in agriculture across the MRD; intensive rice farming annually uses some 2 million mt of chemical fertilizers and 500,000 mt of pesticides (Partners for Water 2011). Agricultural inputs are also added to by industry and domestic water discharged from the 17.4 million delta inhabitants (NGTK 2012). Nevertheless, while Anh (2010) considers overall emissions from pangasius farms to be less than 1% of the Mekong, local authorities have been reported to consider aquaculture to be one of the major pollution sources in the Mekong Delta (Sebesvari et al. 2012 – referenced in Genschick 2014) where surface freshwater sources are being increasingly polluted.

Bosma et al. (2009) also suggest that water quality in the Mekong River, between 2005 and 2008, changed little, even though this period saw the greatest expansion in pangasius production. However, river-wide assessments may ignore the potential for local impacts from individual or multiple farms. For example, Genschick (2014) notes aquaculture farms are spread widely throughout the area and are not located solely at the main branches of the Mekong River; thus many farming sites are located on smaller rivers or canals that have lower runoff volumes and, therefore, have less limited dilution capacity for wastewater absorbance. Belton et al. (2011) report the discharge of sludge can potentially cause local pollution problems when it is discharged into surface waters, and significant declines in water quality in the vicinity of clustered pangasius ponds; however, they also describe these impacts as temporary.

A recent modelling study by Rico and Van den Brink (2014) identified pangasius farming areas of the delta as potential hot-spots for environmental pollution due to their intensive discharge of untreated effluents; and these were seen to be exacerbated in the dry season (i.e., in periods of low flow) (Trieu and Lu 2014). According to the FAO (2014), local eutrophication impacts due to high-intensity pangasius production in the Mekong Delta cannot be denied.

Water Quality Monitoring

To assess pollution levels in the Mekong Delta MARD (since 1999) has assigned the Sub-Institute for Water Resources Planning (SIWRP) to implement and monitor (monthly) surface water quality. Monitoring parameters include silt composition, nutrition components, components indicative of organic pollution and micro pollutants (Partners for Water 2011). Established in 1985, every two months a network of 48 Mekong River Commission (MRC[e]) stations monitor physical and chemical parameters of waters along the Mekong mainstream and its tributaries. It currently has 10 stations in the Vietnamese Mekong Delta. Unfortunately, the results and data from this monitoring do not appear to be readily available for public access.

Alternatives to discharging untreated wastes

Reducing the sludge levels by around 90% (Bosma et al. 2009) is possible with proper sludge management (De Silva and Phuong 2011). A developing aspect of pangasius waste management is that not all the effluents produced are returned directly to delta waters; a proportion is

[e] Initiated in 1957 as the UN-founded Mekong Committee, the MRC was officially formed in1995 between the governments of Cambodia, Lao PDR, Thailand and Vietnam, for joint management and development of the river. (www.mrcmekong.org)

treated and/or diverted to other farming systems (De Silva et al. 2011). Many arable farmers in close proximity to ponds often directly receive pangasius wastewater and sludge (authors' pers. observation 2012), and irrigating paddy fields with wastewater is seen as an effective technology for pollution reduction (Trieu and Lu 2014). Khoi (2011) reported that out of 200 pangasius farmers, 23% and 4.5% discharged their wastewater into rice paddies and orchards respectively, and effluents can save around 30 kg per ha of N, P and potassium currently applied as inorganic fertilizers (Phung et al. 2009).

Wastewater is also passed through settlement ponds and/or is filtered through constructed wetlands utilizing fast growing harvestable aquatic plants such as water hyacinth and Chinese water spinach (Boyd et al. 2011); these trap finer suspended solids and assimilate dissolved nutrients in the wastewater stream. At least 20% of current pangasius production is under international certification (see earlier eco-certification status section) whose standards include measures intended to ensure wastes from certified facilities are treated and/or disposed of in a responsible manner. The fate of effluent streams from non-certified production is direct discharge into the environment

As well as certification, best management practices (BMPs) and zonal management initiatives that stipulate better waste management have been, or are being introduced (NACA 2011, SPF[1] 2013).The increasing number of initiatives to organize small-scale farmers into producer groups will have significant impacts on the fate of effluents by enabling, for example, water intake and discharge calendars (De Silva and Phuong 2011), as will the initiatives for creating communal wastewater treatment ponds by pooling land resources (Khoi 2011). A number of initiatives are also underway to determine the best methods of utilizing pond wastes as well as making them a possible source of income for the fish farmer (SEAT 2012). The feasibility of large-scale sludge collection to produce industrial quantities of organic fertilizer (De Silva, pers. com. 2013) is being investigated, as is bio-gas generation (Le 2011).

Seafood Watch Scoring

While it is clear that aquaculture practices contribute to water pollution, the negative effects of pangasius pollution occur on a relatively small scale yet contribute, in a cumulative form, to the regions overall pollution, creating a large-scale problem. The region's water pollution has reached a critical threshold that threatens the viability of aquaculture itself as wells as other livelihoods that rely on water related ecosystem services (Genschick 2014).

Assessing pangasius aquaculture's contribution can clearly be shown to be complex. The Seafood Watch criteria have two assessment options, the first is evidence-based, which is used when sufficient data or conclusions of academic study clearly indicate the impacts involved; the second is a calculation assessment based on the amount of wastes discharged from the farms per ton of production and the effectiveness of the management or regulatory scheme to control the risks of cumulative impacts from total discharges from farms and regional industries. As the situation is complex in Vietnamese pangasius production, both assessments will be conducted to maximize robustness.

Evidence-based Assessment

It is clear that substantial and inappropriate (and illegal) disposal of sludge wastes continues to occur in Vietnamese pangasius culture. Although it can be demonstrated that the total quantities of effluent discharged is small in relation to the total load in the Mekong, it is highly likely that these cause and/or contribute to local and/or regional cumulative impacts. This leads to an initial score of zero out of ten in the Seafood Watch criteria; however, it is clear that a portion of the industry does dispose of their sludge in an environmentally benign manner. For the purposes of this assessment, it is assumed that the approximately 20% to 25% of production certified to international standards disposes of sludge appropriately (based on volumes certified to ASC and GAA). In addition, it is considered that some (non-certified) farms dispose of sludge properly, however the quantity is unknown. Considering the information on impacts above, it is considered likely that there will be frequent contributions to local and area-based cumulative impacts; therefore, the final score, according to the rapid assessment, is 3 out of 10, and a "Red" high concern due to the ongoing illegal disposal of sludge wastes.

Calculation-based assessment.

The Seafood Watch criteria assess the amount of waste produced by the fish and then the amount of that waste that is discharged from the farm. The effectiveness of the regulatory system in managing wastes from multiple farms and the industry as a whole is used to assess the potential cumulative impacts from the industry as a whole. These aspects are discussed below in relation to pangasius in Vietnam.

De Silva et al. (2010) estimated that pangasius production in the Mekong Delta discharged 50,364 mt of N and 15,766 mt of P in 2008 (based on the median nutrient discharge levels for commercial feed). According to the Seafood Watch criteria based on feed protein content (27%), FCR (1.6), calculations on nitrogen inputs and outputs, and protein content of harvested pangasius (12. 8%) (for references see Feed Criterion) result in a biological waste figure of 48.64 kg of N produced per mt of pangasius production (Factor 2.1a). This results in an estimate of 57,600 mt of N waste having been generated by 2012's 1.2 million mt of pangasius production.

Not all of this waste produced by the fish will be discharged from the ponds. In the Seafood Watch criteria, 51% of wastes in typical exchanging pond systems are considered to be broken down in the ponds, however, as pangasius production is unusual in its very high stocking density, calculations based on nutrient dynamics in typical aquaculture ponds are unlikely to be accurate. Therefore, a similar value for net pen systems will be used in this assessment; that is, 80% of the wastes produced by the fish is considered to be discharged from the ponds (Factor 2.1b). For reference, this equates to 46,080 mt of N discharged from the 2012 pangasius production and, although slightly less than De Silva's (2010) estimate of 50,364 mt for 2008, this value will be used in this assessment (and may reflect improving practices in the use of settling ponds or other methods of appropriate sludge disposal). The waste discharge score, according to the Seafood Watch criteria, is 6 out of 10.

The Vietnamese government has promulgated several regulations relating to aquaculture and its development, and has had legislature in place since 2008 wherein MARD sets out national regulations on aquaculture zones and establishments[f], put in place in order to control and manage issues such as siting, water quality, solid waste management, chemical usage and environmental protection (VASEP 2012). The regulations are specific to aquaculture and, according to this author's experience, are moderately applicable to individual sites, but only partly relate to cumulative impacts and ecological limits, and moderately cover occasions of peak discharge (e.g., sludge). Scoring for these aspects is shown in Appendix 1, and the content of regulations has been awarded 2.25 out of 5.

While enforcement organizations are apparent, there are concerns with illegal disposal of sludge, and little evidence of penalties and active enforcement over the entire production cycle. Some farms have been established in unauthorized areas and on unsuitable sites (Khoi 2011), increasing farm density to an unsuitable level, contributing to cumulative and in-combination impacts (SFP[1] 2013). Scoring for these aspects is also shown in Appendix 1 and the enforcement of regulations has been awarded a value of 1.0 out of 5. As a result, a 'regulatory or management effectiveness' score of 0.9 out of 10 for pangasius effluent has been generated.

Combining the waste discharge score per ton of production with the effectiveness of the regulatory system to control local and regional cumulative impacts, results in a final score for the Effluent Criterion of 3 out of 10 according to the calculation-based assessment, and a "Red" high concern reflecting potential impacts of the ongoing, illegal disposal of sludge wastes.

Effluent Criterion Final Score

The final scores of both the evidence-based and the calculation-based assessments were 3 out of 10, and this is the final score for the Effluent Criterion.

[f] Decision No. 70/2008/QD-BNN, 06/05/2008: Regulation on Tra Fish Rearing Zones and Establishments

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		5.00	
F3.2a Content of habitat regulations	2.75		
F3.2b Enforcement of habitat regulations	2.50		
F3.2 Regulatory or management effectiveness score		2.75	
C3 Habitat Final Score		**4.25**	**YELLOW**
Critical?	NO		

Pangasius farming is located on the banks of the two major branches of the lower Mekong River in the MRD. Pangasius aquaculture occupies a small fraction of the delta, and has largely replaced intensively farmed, arable land (which has been the cause of ecosystem services and habitat functionality loss). Despite regulations being in place to manage pangasius aquaculture zonation and farm siting, legal requirements have often been flouted and subsequent unauthorized and/or high density facilities have become established. Combining the habitat conversion score with the effectiveness of the regulatory system gives a final score for the Habitat Criterion of 4.25 out of 10.

Justification of Ranking

Factor 3.1. Habitat conversion and function

The Mekong Delta is now a highly modified and controlled agricultural landscape, and its hydrology is well managed. During the dry season, flow in the Mekong River is insufficient to prevent saline intrusion (Deltares 2009) and seasonal flooding occurs across large tracts (between 1.2 million and 1.8 million ha, depending low and high flooding years) and lasts from two to six months with water depths ranging from 0.5 m to 4m (Bosma et al. 2009). Of the delta's total area, 84.5% is classified as agricultural land, with 76.8% of this under the production of terrestrial crops—both annuals (including rice) and perennials (GSO 2011).

Historically, much of the delta was heavily forested. Away from the main river channels, short tree scrubland covered the majority of the delta, forming a continuous canopy of deciduous species. In the southern depression, peat forest dominated, and in the central floodplains—where pangasius farming takes place today—freshwater swamp forest covered the area

(Pilgrim 2010).The conversion of the Mekong Delta's marshes and forests by humans has been underway for hundreds of years. Major engineering works for drainage and irrigation were initiated by French colonialists (Kakonen 2008) and continue today. More than 30,000 km of inter-connecting canals crisscross the delta (FAS 2012). Almost 80% of the Mekong Delta deforestation occurred over a hundred years ago (between 1880 and 1920), in the space of 30-40 years (Little 2013). Today, forest cover (including plantations) occupies less than 8% of the delta (GSO 2011).

This transformation of the region was primarily to develop rice mono-culture. By the 1930s, the delta had already become one of the major rice producing regions of the world (Kakonen 2008), and produces 50% of Vietnam's 44 million mt of rice production over the period of three annual harvests (US GAIN[2] 2013) from 1.93 million ha (47.6%) of the delta (GSO 2011). Land under intensive rice mono-culture can suffer biodiversity losses through habitat loss and extreme usage of fertilizers, pesticides and insecticides (UNDP, 2010), although rice fields may be used as staging or feeding grounds by migrating bird species (Ramsar, 2010). Loss of original habitat and over-exploitation within the delta has led to a number of once abundant wetland species to become threatened with regional or global extinction (Pilgrim, 2010), and most sensitive natural biodiversity has long been extirpated due to historic habitat loss or over-exploitation.

The total land used for pangasius farming is 6,000 ha, or 60 km^2, only 0.15% of the total area of the delta, and pangasius culture occupies less than 0.5% of the flooding area of the region (Bosma et al. 2009). Pangasius aquaculture has converted land from one form to another, but this conversion has generally been intensive cropland, of rice paddies or orchards, into ponds. Although this reshaped the landscape of the delta again (Genschick 2014), it has generally not replaced natural habitats or land-use that supported significant biodiversity or important native species, this loss is a legacy of prior arable cultivation and is an historic transformation. Current overall biodiversity in the delta is still being investigated (Cong et al, 2013), but Bosma *et al* (2009) estimate the reduction in terrestrial biodiversity in the Mekong Delta due to the pangasius sector is around 0.24%.

Overall, pangasius aquaculture is not seen as having affected the overall habitat function of the Mekong Delta to a large extent, even though it could be argued it has reduced the amount of land which could potentially be re-forested or used for edible crops, particularly rice production (it has reduced agricultural land by 0.17%). Bosma *et al* (2009) assume that this has not resulted in [rice] production being relocated elsewhere in the delta (and encroaching on remaining natural landscapes) because of low margins due to rice overproduction and farmers' looking for alternative income sources. In the Seafood Watch criteria, pangasius aquaculture is therefore deemed to have had a moderate impact on habitat conversion and function, and a Factor 3.1 score of 5 out of 10 has been awarded.

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

Vietnamese land law specifies that all land belongs to the government, but individuals are allowed to exchange, transfer, lease, inherit, and mortgage their land-rights (Khoi, 2011).

Farmers and land-owners have used these rights to either convert their own land or lease their property to create pangasius farms.

The Vietnamese government has promulgated several regulations relating to aquaculture and its development, and has had legislature in place since 2008 wherein MARD sets out national regulations on aquaculture zones and establishments[g], put in place in order to control and manage issues such as siting, water quality, solid waste management, chemical usage and environmental protection (VASEP, 2012). Local authorities in major pangasius provinces (e.g. An Giang, Can Tho, Dong Thap) also have zonal management plans and specify the areas where pangasius farming is permitted as well as the necessary farm site characteristics (e.g. situated along large rivers/waterways, no further than 300m away from the river bed, etc.) (Khoi, 2011). Scores for specific aspects of the regulatory content are provided in Appendix 1, and Factor 3.2a 'Content of habitat regulations' has been assigned a score of 2.75 of out 5.

Although these are legal requirements, some producers have flouted these laws and established farms in un-authorized areas and on unsuitable sites (Khoi, 2011). Local authorities have subsequently had issues keeping track of the independent farmers and determining the precise numbers of establishments in some locations. Factor 3.2b 'Enforcement of habitat regulations' has been assigned a score of 2.5 of out 5.

Increases in pangasius production planned by the Vietnamese government will probably be achieved through a combination of technological advances, BMPs and more efficiency in the industry achieved through increased vertical integration (Dung[2], 2012). Expansion of farming area may occur, but it will probably not be to the same extent, nor in the same *ad hoc* manner as was sometimes seen in the past. The increasing maturation of the industry has and will lead to bigger farms and more of the remaining small farms under formal contracts with larger producer/processor companies to supply fish. This increasing sector maturity has, and will lead to better legal adherence. Increasing international certification, which often insist on codes of conduct that are beyond the current obligations as laid down by Vietnamese authorities are seen as an important step to increase legal adherence and reduce detrimental non-conformance both currently and in the future.

Overall a habitat 'Regulatory or management effectiveness' score of 2.75 out of 10 has been generated for this Factor 3.2.

Habitat Criterion Final Score

Pangasius aquaculture occupies a small fraction of the delta, and has largely replaced intensively farmed arable land (which has been the cause of ecosystem services and habitat functionality loss) and has reduced terrestrial biodiversity. Despite regulations being in place to manage pangasius aquaculture zonation and farm siting, legal requirements have often been flouted and subsequent un-authorized and/or high densities of facilities have become

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[g] Decision No. 70/2008/QD-BNN, 06/05/2008: Regulation on Tra Fish Rearing Zones and Establishments

established. Combining the habitat conversion score with the effectiveness of the regulatory system gives a final score for the Habitat Criterion of 4.25 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**0.00**	
C4 Chemical Use Final Score	**0.00**	**Critical**
Critical?	NO	

Chemical use in Vietnamese pangasius culture is high. A broad range of antibiotics are used, in addition to pesticides and disinfectants. Antibiotics include a number of critically- and highly-important drugs for human health. Shipments of pangasius fillets to Europe continue to be rejected due to the presence of residues of antibiotics banned in Vietnam (nitrofurans). Frequent water exchanges and sediment disposals discharge free and bound antibiotic residues into the environment, and while the direct toxic effects in receiving waters are unlikely to be severe, the effects on microbial communities of single and combinations of antibiotics is poorly understood. The overuse of antibiotics has led to widespread resistance to a number of treatments by important pangasius pathogens, and there is a high concern regarding the discharge into the Mekong of highly- and critically-important antibiotics for human health.

With hyper-intensive production of pangasius in Vietnam, the development of resistance to a number of antibiotic treatments is a clear indication of their overuse and misuse. In the Seafood Watch criteria, when developed resistance includes highly- and critically-important antibiotics, the score is zero, and “Critical.”

Justification of Ranking

Antibiotics applied in aquaculture production may be released into the environment and contribute to the deterioration of surrounding aquatic ecosystems (Rico et al, 2015). Rico and Van den Brink (2014) identified the pangasius farming areas of the Mekong Delta as potential hot-spots for environmental pollution due to their widespread use of veterinary medicines and their intensive discharge of untreated effluents, and stressed the need to monitor and further assess the ecological effects of selected aquaculture antibiotics on streams impacted by pangasius catfish effluents.

According to Andrieu et al. (2015), and references therein, the intensification of pangasius production practices has been accompanied by the outbreak of several bacterial and parasitic infestations, which in turn has led to the introduction of a wide array of veterinary medicines for their prevention and treatment. Eventually, residual concentrations of veterinary medicines used in pangasius production can be released into the environment by untreated effluent and sludge discharges, and have raised concerns about their potential toxic effects on aquatic ecosystems surrounding the farms. The pace of aquaculture development has often been faster than the development of regulations for aquaculture chemicals (Rico et al. 2012).

Recent surveys by Phu et al. (2012) and Rico et al. (2013) highlight the fact that a variety of different types of aquaculture chemicals and medicines are utilized in pangasius aquaculture. Rico et al. (2013) collated information on the application of aquaculture chemicals and drugs from thirty-two pangasius farms (85% of which were uncertified by independent 3rd party schemes, and with the majority producing fish for international markets). They reported that 100%, 78%, 44%, 41% and 38% of the farms use antibiotics, disinfectants, parasiticides, feed additives (including plant extracts), and probiotics respectively.

Types of Chemical used

Of primary concern to the Seafood Watch assessment are the potential impacts from antibiotic and pesticide (i.e., parasiticides) use. The most important diseases in pangasius aquaculture are bacterial; of these *Edwardsiella ictulari* is the most problematic, with antibiotic administration being the main method of treatment (Crumlish, pers. com. 2013). Therefore, antibiotic use is the focus of this assessment.

Rico and Van den Brink (2014) documented 30 different types of chemicals used in Vietnamese pangasius culture. These included 7 disinfectants, 19 antibiotics and 3 pesticides. Among the 19 antibiotics reported, at least 8 are listed as “critically important to human health” by the World Health Organization (WHO 2011) (e.g., amoxicillin, ampicillin, enrofloxacin*, ciprofolaxin*, colistin, apramycin, gentamycin, kanamycin, levofloxacin and rifampicin). The list also includes others that are classified as “highly important to human health” (e.g., timethoprim, oxytetracycline, sulfadiazine, doxycycline, thiamphenicol and others).
* According to Andrieu et al. (2015), their earlier surveys and studies resulted in enrofloxacin and ciprofloxacin being banned for use in Vietnamese aquaculture (VMARD 2012) due to the significant number of international market rejections related to food safety alerts, and it is therefore expected that their use has seen a significant decline.

Table 1 in the regulatory section below shows the list of banned and restricted antibiotics in Vietnam. A search of Europe’s “Rapid Alert System for Food and Feed” (RASFF) database[h] shows that, during 2014, there were approximately 17 border rejections of pangasius from Vietnam due to residues of nitrofuran antibiotics—banned in Vietnam. This represents a potentially

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[h] European Commission RASFF database portal: https://webgate.ec.europa.eu/rasff-window/portal/?event=searchForm&cleanSearch=1

small amount of total product and use considering the scale of pangasius imports to Europe, but is further evidence of concern regarding antibiotic use in Vietnam.

For reference, three parasiticides (pesticides) are also listed by Rico and Van den Brink (2014): azadirachtin, ivermectin and praziquantel.

Quantities used

Overall, detailed information on the types and quantities of aquaculture chemicals currently used in pangasius culture need to be collated and should include application patterns in hatcheries, nurseries and broodstock production (Rico et al. 2013) to determine their distribution, fate and ecotoxicological/environmental risk in the Mekong Delta (Rico et al. 2012, Rico and Van den Brink 2009). The information currently available indicates the percentage of farms using antibiotics varies, but is typically high; Rico et al. (2013) reported 100% of the Vietnamese pangasius farms surveyed used them, and noted seventeen different antibiotic compounds, belonging to 10 different antibiotic classes, were used on the farms they surveyed, with the average farm using three different antibiotics. According to Bosma et al. (2011), 0.15 kg (i.e., 150 g) of medicines and antibiotics are used per mt of (live weight), while Rico et al. (2013) states that the current amount of antibiotics used per mt of pangasius is around 0.093 kg (93 g, equating to approximately 93 tons of total antibiotics used annually in the Mekong to produce current production of approximately 1 million mt).

Short-comings in farmer knowledge and training often lead to a limited awareness of prudent drug and chemical use, multiple applications and multi-use (particularly of antibiotics) and the lack of adherence to proper therapeutic regimes. For instance, only 57% of growout farmers and 40% of nursery farmers followed the instructions on the product label while the remainder used the substances according to their own experiences (Phu et al. 2012). Rico et al. (2013) found that there is a link between the high frequency use of antibiotics and little or no formal aquaculture training among farmers. However, Khoi (2011) noted that farmers who were affiliated to a large producer and those who were in a fishery association tended to seek aquatic health specialist advice regarding disease/chemical usage. They also tended to follow good farming practice in regards to chemical handling and usage. Those farmers without those affiliations were less likely to seek advice. Training programs have been initiated.

An important step forward in April 2013 was the licensing by MARD of the ALPHAJECT® Panga 1 vaccine; the first vaccine against *E. ictulari* (fishupdate 2013). The use of such a vaccine should lead to a noticeable reduction in antibiotic use within five years (Crumlish, pers. com. 2013).

Potential impacts

With respect to chemical residues in harvested fish, Vietnam has had a national monitoring program for certain harmful residues in aquaculture products (exports) since 2000 (VASEP 2012). Most processing companies also inspect and analyze their own pangasius inputs and the resultant processed products in company laboratories, to ensure they are fit for export to the respective country/customer (Suzuki and Nam 2013). However, with appropriate withdrawal periods, the lack of residues in harvested fish do not reflect a low level of antibiotic use, or a low level of discharge into the environment. While the usage of antibiotics per ton of pangasius production is not considered to exceed their use in terrestrial livestock (Rico et al. 2013,Pew Charitable Trusts 2013), Andrieu et al. (2015) indicate that the discharge of untreated effluents from pangasius catfish farms should be considered as an important pathway of antibiotic pollution into the aquatic environment.

Environmental Impacts

The fate and impact of antibiotics in the aquatic environment has received relatively little study; Anh et al. (2010) considered the impacts of aquaculture chemicals on the surrounding environment to be uncertain and noted concerns about the impacts of aquaculture chemicals in surrounding ecosystems will continue to increase in future years. The use of antibiotics and other chemicals in pangasius aquaculture remains high and Andrieu et al. (2015) indicates the discharge of untreated effluents from pangasius catfish farms should be considered as an important pathway of antibiotic pollution into the aquatic environment. It is estimated that approximately 75% of the antibiotics administered in aquafeed enter the culture environment through excretions of the fish and through leaching from uneaten, medicated feed (Lalumera et al. 2004), however, the organic sludge and sediments act as a sink for chemicals and plays a fundamental role in the environmental release of veterinary medicines (Rico et al. 2014). While Rico et al. (2014) estimate approximately 25% of applied antibiotics are discharged (across a variety of systems), they note a requirement for further evaluation of sludge disposal in Vietnamese pangasius production.

Rico et al. (2012) noted that as antibiotics are most toxic to microorganisms and primary producers, antibiotic pollution may affect planktonic organisms and natural bacterial communities. However, after specific studies on enrofloxacin (ENR) use in pangasius farms in Vietnam, Andrieu et al. (2015) concluded that the administration of ENR for treating bacterial diseases in Pangasius catfish farms is not likely to result in major risks for non-target aquatic organisms, inhabiting water bodies receiving farm effluents.

Studying a broad range of antibiotics, disinfectants and parasiticides for different aquaculture systems in Asia, Rico et al. (2014) clearly identified pangasius culture in Vietnam as the scenario resulting in the highest ecological risks. Antibiotics represented the highest concern. Rico et al. (2014) also noted that important ecosystem-related processes such as carbon utilization, photosynthesis, or nutrient metabolism might be affected by antibiotic concentrations that are below, or in the order of magnitude of those calculated in their study of Vietnamese pangasius production. Andrieu et al. (2015) also emphasized that further investigations must be dedicated to assess potential consequences for microbial communities and associated ecological functions, as well as to evaluate the contribution of antibiotic residues to the development of antibiotic resistant bacteria in the environment. The potential impacts from combinations of antibiotics from the broad range of treatments used in Vietnamese pangasius production is an additional, but poorly studied, and ongoing concern when these chemicals are discharged in combination into water bodies.

Development of Resistance
An important concern has been the development of resistant strains of bacteria (Rico *et al*, 2012). Bacillary necrosis of pangasius (BNP) caused by *Edwardsiella ictaluri* is considered to be the most serious disease affecting pangasius in Vietnam; Gravningen, (2012) reported bacterial strains of *E. ictulari* (and to a lesser extent *A. hydrophilia*) have been exhibiting resistance to the main types of antibiotics used. More recently, Nguyen (2014) showed that all Vietnamese isolates of *E. ictulari* showed a high level of resistance to a variety of antibiotics (oxolinic acid, sulfadimethoxine/ormetoprim (Romet), oxytetracycline and amoxicillin).

The broad range of antibiotics used in Vietnamese pangasius production, including a number of treatments listed as highly- and critically-important for human health, inevitably create a high concern for the transfer of the genetic components of resistance to human pathogens when discharged alone, or in combination into the Mekong.

Regulations
The pace of aquaculture development has often been faster than the development of regulations for aquaculture chemicals (Rico et al. 2012), and prior to 2008 the delineation of mandates with regard to the management of drug and chemical production, their distribution and their practical use in Vietnamese aquaculture were poorly defined at both the ministerial and the provincial level (Tai 2012). Institutional change in the management of aquaculture occurred in 2008, and areas of responsibility are now more clearly defined; MARD is now responsible for the oversight of aquatic health management in Vietnam with the Dept of Animal Health and the Directorate of Fisheries (Dan and Khoa, 2011).

Vietnam is now completing a 5-year national strategy for the development of aquatic animal health (2011-2015), which aims to build and strengthen management systems to improve technical capacities, (e.g., epidemiology, surveillance, disease control, quarantine/inspection, and veterinary medicine management (Dan and Khoa 2011)).

The Vietnamese government issues regulatory measures and updates lists of banned and restricted chemicals and veterinary medicines for aquaculture (VASEP[1] 2013). Banned and restricted chemical and biological products in Vietnam fishery/aquaculture and export products as detailed by VASEP (2012) are given in Table 1[i]. As described above, it must be noted that many of these agents are listed in the WHO document 'Critically Important Antimicrobials for Human Medicine' (WHO 2011).

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[i] *Circular No. 15/2009/TT-BNN, 17/03/2009: lists of banned and restricted chemical and biological products. This Circular has been updated (e.g., on 11/11/2010 and 16/02/2012) to include other compounds (VASEP 2012).On 05/31/2013 MARD issued the Circular 28/2013/TT-BNNPTNT regulating the list of veterinary drugs allowed to circulate in Vietnam. It takes effect 07/15/2013 and replaces the previous circulars (VASEP 2013)*

Table 1. Banned & restricted fishery and aquaculture chemicals in Vietnam (VASEP 2012, Rico et al. 2013).

LIST OF CHEMICALS & ANTIBIOTICS BANNED FOR VETERINARY USE:

1. Chloramphenicol (a.k.a.: Chloromycetin; Chlornitromycin; Laevomycin, Chlorocid, Leukomycin)
2. Furazolidon&Nitrofurans metabolites (Nitrofuran, Furacillin, Nitrofurazon, Furacin, Nitrofurantoin, Furoxon, Orafuran, Furadonin, Furadantin, Furaltadon, Payzone, Furazolin, Nitrofurmethon, Nitrofuridin, Nitrovin)
3. Dimetridazole (a.ka.:Emtryl)
4. Metronidazole (a.k.a.: Trichomonacid, Flagyl, Klion, Avimetronid)
5. Diptrex (a.k.a.: Metriphonat, Trichlorphon, Neguvon, Chlorophos, DTHP DDVP (a.k.a.: Dichlorvos, Dichlorovos)
6. Eprofloxacin
7. Ciprofloxacin
8. Ofloxacin
9. Carbadox
10. Olaquidox
11. Bacitracin Zn
12. Tylosin phosphate
13. Green Malachite
14. Gentian Violet (Crystal Violet)

LIST OF CHEMICALS & ANTIBIOTICS RESTRICTED FOR USE IN FISHERY PRODUCTION & TRADING:

MRL ppb: Maximum Residual Limits (parts per billion)

No.	Chemical, Antibiotic	MRLs (ppb)
1.	Amoxicillin	50
2.	Amhicillin	50
3.	Benzylpenicillin	50
4.	Cloxacillin	300
5.	Dicloxacillin	300
6.	Oxacillin	300
7	Oxolinic	100
8.	Colistin	150
9.	Diflubenzuron	1000
10.	Teflubenzuron	500
11.	Emamectin	100
12.	Erythromycine	200
13.	Timicosin	50
14.	Tylosin	100
15.	Flofenicol	1000
16.	Lincomycine	100
17.	Neomycine	500
18.	Paroomycin	500
19.	Spectinomycin	300
20.	Chlortetracycline	100
21.	Oxytetracycline	100
22.	Tetracycline	100
23.	Sulfonamide (all types)	100
24.	Trimethoprim	50
25.	Ormetoprim	50
26.	Tricainemethanesulfonate	15-330
27.	Danofloxacin	100

Adherence to legal requirements with respect to export markets has been shown to be swift in Vietnam (De Silva 2012). For instance, the EU hygiene rules, which protect public health, are some of the strictest in the world and imported pangasius must conform to them. Such compliance is demonstrated for instance by the marked reduction in recent years of Rapid Alert Notifications[j] (RANs) issued by the European Union on pangasius imports (De Silva and Phuong 201, Little et al. 2011, Little et al. 2012). However, although Rico et al. (2013) reported that chemicals and antibiotics banned under the Vietnamese national regulations and in major

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[j] RANs are issued on the grounds of unauthorized food treatment/additives, unauthorized establishment, temperature control/spoilage, pesticides, pathogenic micro-organisms, packaging defective/incorrect, other veterinary medical products, organoleptic aspects, labeling absent/incomplete, heavy metals, antibiotics, allergens, and adulteration/fraud. Non-compliance with ANY of the above will result in the rejection of the food consignment (De Silva 2012)

seafood importing countries, including the US, are not applied on pangasius farms and neither are they available on the market, a search of the European Commission's Rapid Alerts for Food and Feed (RAFFS) (2014) shows residues of banned antibiotics (nitrofurans) continue to be a cause of rejections of imported pangasius from Vietnam.

From an environmental perspective, Vietnamese regulations are aimed primarily at food safety, and do not appear to effectively regulate the frequency of use, total quantities used, or the discharge of antibiotics alone or in combination into the environment. Rico et al. (2012) described Vietnamese legislation as too heavily focused on risk-benefit analysis, which is dominated by economic and food safety issues (Rico et al. 2012), and not focused enough on the potential risks to the ecosystem health.

Conclusions

Chemical use in Vietnamese pangasius culture is high. In addition to pesticides and disinfectants, a broad range of antibiotics are used. Reported antibiotics used in Vietnamese pangasius include a number of critically- and highly-important drugs for human health. Frequent water exchanges and sediment disposals discharge free and bound antibiotic residues into the environment and, while the direct toxic effects in receiving waters are unlikely to be severe, the effects on microbial communities of single and combinations of antibiotics is poorly understood. There is a high concern regarding the discharge into the Mekong of highly- and critically-important antibiotics for human health.

With hyper-intensive production of pangasius in Vietnam, the overuse of antibiotics is clearly demonstrated by the development of widespread resistance to a number of treatments by important pangasius pathogens. In the Seafood Watch criteria, when developed resistance includes highly- and critically-important antibiotics, the score is critical, meaning the overall recommendation must be a red "Avoid."

Quoting Andrieu et al. (2015): "*Given the large number of antibiotics that are currently used in pangasius catfish production in the Mekong Delta region of Vietnam and the lack of regulations controlling their environmental discharge, further monitoring of aquaculture antibiotics in aquatic ecosystems and cost-effective methods for reducing their environmental discharge are urgently required*."

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: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	0.36	9.11	
F5.1b Source fishery sustainability score		-8.00	
F5.1: Wild Fish Use		8.83	
F5.2a Protein IN	27.99		
F5.2b Protein OUT	12.80		
F5.2: Net Protein Gain or Loss (%)	-54.27	4	
F5.3: Feed Footprint (hectares)	2.66	9	
C5 Feed Final Score		**7.66**	**GREEN**
Critical?	NO		

The majority of Vietnamese pangasius are fed commercial feeds that utilize low inclusion levels of fishmeal (FM) and fish oil (FO). Terrestrial crop ingredients constitute the bulk of the feed. A feed conversion ratio (FCR) value of 1.6 is considered average, and with low FM inclusion and zero FO, the "fish in: fish out" ratio is less than 1 (0.36). Data on the source of fishmeal used in pangasius feeds in Vietnam are scarce and likely to include trash fish of unknown (but likely poor) sustainability in addition to better-known international sources, such as Peruvian anchovy and Chilean salmon byproducts. There is a substantial loss (60%) of edible protein in the conversion of feed to harvested pangasius, however, with low use of marine ingredients and high levels of crop ingredients forming the bulk of the feed, the overall feed score is high; 7.66 out of 10.

Justification of Ranking

Factor 5.1. Wild Fish Use

Although farmers still utilize farm-made diets to some extent (around 9% of pangasius feed production today is from this source) (Serene, pers. com. 2013), industrial compound feeds have long been recognized by producers as more effective. The growth of commercial aquafeed milling has risen sharply in Vietnam (Merican and Huong 2010, Hall and Johns 2013). Today over thirty companies produce industrial pangasius feed in the MRD (ICAFIS pers. com. 2013), with 2012 production around 1.95 million mt (Serene, pers. com. 2013).

Within the pangasius industry, Dung (2012) reported a feed conversion ratio (FCR) of 1.6 in the growout stage of production, although lower values (1.45–1.2) are attainable but difficult to maintain (Serene, pers. com. 2013; Fegan, pers. com. 2013). Rico and Van Brink (2014) used a FCR value of 1.69. In the initial development phases of the pangasius industry, growout farmers prepared their own feed, using a range of locally available ingredients, but FCRs were high (2-3). The intermediate value of 1.6 from Dung (2012) is used in this assessment.

Fishmeal (FM) inclusion levels in pangasius feeds have decreased by half in the last 10 years; whereas growout diets used to contain 15%–20% FM, they now contain an average of 5%–10% and continue to fall (Jackson, pers. com. 2013). Feeds with inclusion levels down to 2%–3% are now available (Fegan, pers. com. 2013). Communication with feed industry experts has led to an average of 5% FM and 0% fish oil (FO) inclusion for pangasius growout diets being used in this report. Protein sources from terrestrial animals (e.g., meat, bone, blood meal, poultry byproduct meal) are utilized (Serene, pers. com. 2013), but no percentage inclusion rates are available and usage is considered relatively small. Therefore, protein sources have not been considered in this evaluation.

While noting that the inclusion level of FM in pangasius feed is low on a percentage of feed basis, the total industry-wide volumes of FM used are significant. Sourcing of FM in East and SE Asia, including Vietnam, is generally from what are known as 'trash fish' fisheries (both marine and freshwater)—where many different species of fish and invertebrate are caught in trawls, either as bycatch or as directed fisheries (often unregulated) to provide material for feed (both terrestrial livestock and aquaculture) and other products (Lee-Harwood 2010, REBYC 2013). The majority of FM in Vietnamese pangasius feeds is derived from such fisheries (Fegan, pers. com. 2013, REBYC 2013), both domestic or imported, from within the region (Jackson, pers. com. 2013), such as Indonesia, S Korea, Myanmar, Thailand, etc.

The situation is improving, with reported imports of Peruvian anchovy FM (with a FishSource score of ≥6 in 2013) (SFP[2] 2013) now available in Vietnam (Jackson, pers. com. 2013) and reports that Tomboy/Skretting produced about 10,000 mt of ASC compliant pangasius feed in 2011 (vietnamseafoodnews[3] 2011). Bosma et al. (2009) state that FM originating from capture fishery byproducts (other than trash fish), are incorporated in Vietnamese FM, but volumes are not specified. In 2010, the Vietnamese tuna fleet caught 37,000 mt and Vietnam imported another 42,000 mt of tuna for processing (CBI 2012). Tuna byproducts for inclusion in Vietnamese FM appear to be available, but rates are unknown. In addition, fish oil produced from Chilean farmed salmon processing byproducts are also reported to be used by some feed companies in Vietnam (Corey Peet, personal communication, February 2015).

A 'fish in: fish out' (FIFO) ratio is a measure of the dependency on wild fisheries for feed ingredients, using the ratio of the amount of wild fish used in feeds ('fish in') to the harvested farmed fish ('fish out'). With low levels of marine ingredients in feed, the calculated FIFO value for fishmeal is 0.36, meaning 0.36 mt of wild fish need to be caught to supply the fishmeal to grow one mt of pangasius. The 'FIFO' score from 0-10 (Factor 5.1a) is therefore high for pangasius with 9.11 out of 10. With increased data on byproduct ingredient use and inclusion levels, this score could improve further.

With the significant concerns regarding the sustainability of many of the fisheries providing FM in pangasius aquafeeds, 'Source Fishery Sustainability Score' (Factor 5.1b) of -8 out of -10 has been awarded and applies a negative adjustment to the FIFO score. The use of more accountable sources of fishmeal (i.e., Peruvian anchovy) has typically been driven by the needs of international certification (e.g., the Aquaculture Stewardship Council standards).

After the adjustment of the FIFO score by the sustainability score, a score of 8.83 out of 10 has been generated for Factor 5.1 'Wild Fish Use,' due primarily to the low inclusion levels of FM in commercial pangasius diets and high FIFO ratio, even though the exact source of this ingredient is often unspecified and is largely of unknown sustainability.

Factor 5.2. Net Protein Gain or Loss

Allocating fixed values to commercial aquafeed is difficult as feed formulations vary based on market price and availability of ingredients (Fegan, pers. com. 2013), however, given the dominance of commercial feed in pangasius culture, an example of a 'typical' ingredient-based, industrial pangasius growout feed (26%–28% crude protein) has been formulated and verified by feed industry experts (Table 2). As Table 2 details, commercial growout feeds for pangasius consist almost entirely of vegetative matter (92%) with FM accounting for 5% of ingredients. The figure of 'net protein gain or loss' for pangasius culture derives from the balance between the edible proteins included in the feed and the edible proteins harvested in the processed fish (the fillet) or used for other purposes.

Table 2. 'Typical' Commercial Pangasius Grow-out Feed (26%–28% Crude Protein) Formulation & Ingredient Sources (Formulation based on author's research 2013)

Ingredient	**Percentage Inclusion**	**Ingredient Source/Imports**
SBM/other Oilseed (OS) Meals (e.g., Canola/Sunflower/Rape/DDGS)	**40%** (e.g., 20% SBM/ 20% other OS meals)	SBM imports—Argentina: 52%; India: 19%; Brazil: 12%; China: 10%; US: 4%; others: 2%[a] DDGS imports—US: +90%[a]; Rape - India[e]
Cassava/Tapioca	**20%**	Vietnam: majority (total estimated cassava production 2012: 10.3m mt)[b]; also China & India[e]
Rice Bran/Broken Rice	**22%** (e.g., 16% Rice bran/ 8% Broken rice)	Vietnam: majority (total rice production Vietnam in2011/2012: 44m mt[c]. Rice bran = 10%; broken rice = 9% of rice composition). Also Thailand & India[e]
Wheat Bran/Feed Wheat	**10%** (e.g., 7% Wheat bran/	Wheat bran imports—China, India, Germany[e] Feed wheat imports—Australia: 92%; India: 4%; Pakistan/Ukraine: 2%[b]

	3% Wheat)	
Fishmeal & Fish Oil	**5%** FM &**0%** FO	FM—Vietnam: 45%; Peru: 28%; Thailand: 17%; S. Korea: 5%; others: 5%[d]. Also Indonesia, Myanmar, India[e]
Other (e.g., vitamins, minerals, anti-oxidants, inorganics, etc.)	**3%**	Other imports—China, France, India, Taiwan, US, Switzerland[e]
	100%	
Abbreviations: SBM—Soybean meal; DDGS - Distillers Grains with Solubles; m - million		
[a] US GAIN[1], 2013 [b] FAO, 2012 [c] US GAIN[2], 2013 [d] Jackson, IFFO, pers.com. 2013 [e] Bosma et al. 2009		
Formulation checked by pers. com. with Mr. Le Tuan Kiet, Aquatic Feed QC Manager Hoang Long Seafood Processing Co. Ltd, VN., & Dr. Daniel Fegan, Regional Technical Manager, Cargill Feeds, Thailand, 2013; Dr. Philippe Serene, ex-CEO Proconco, Vietnam		

Vietnamese feeds for pangasius use mostly plant materials as the main source of protein. The Seafood Watch criteria includes an adjustment to allow for the improved protein quality from harvested pangasius verses the plant ingredients. The main crude protein (CP) sources, their average CP levels (derived from Tacon et al. 2009) and their percentage utilization in the 27% CP average formulation in Table 3 are given below:

- Trash fish FM, Vietnam (~48% CP) at 5% inclusion—contributes 8.9% of the CP in the diet
- Soybean meal (SBM) (~48% CP) at 20% inclusion—contributes 35% of the CP in the diet
- Other oilseed meals (~40% CP) at 20%—contributes 29.6% of the CP in the diet
- Other ingredients contribute the remaining 27.5% CP in the diet

It is debatable whether all the crop ingredients in the pangasius diet detailed above are “edible” sources of protein (e.g., SBM may not be edible, but the soy it derives from is); however, for this report they have been classified as such. The protein content of whole, harvested pangasius is around 12.8% wet weight (Begum et al. 2012; Newton, pers. com. 2013) and commercial processing fillet yield is around 35%–40% (Sang et al. 2009) of the whole fish depending on the cut (Ramirez 2007).

Some 780,000 mt of pangasius byproducts (~65% of the 1.2m mt of live weight production) were produced in 2012. Around 5% pangasius byproducts enter the human food chain; trimmings are made into fishballs; heads, stomachs, etc., are eaten (this additional human food usage has been added as part of the fish’s edible yield). Collagen, gelatin and peptides for medical purposes are rendered from skin and skeletons and have increasing commercial prospects (Newton et al. 2012), as does biodiesel production from the oil (e.g., www.enerfish.eu). The majority of pangasius byproducts are processed into FM and FO. Pangasius FM (around 53%) goes into animal feed (Nguyen 2010), for use in both domestic and overseas markets (Newton, pers. com. 2013). Some of the pangasius FM could potentially end up back in pangasius diets, but no current evidence supports this, and instances are thought to be very low.

All these protein dynamics combined give a 'net protein gain or loss' value of -59.9, in other words, approximately 60% of the edible proteins included in the feed are lost during pangasius production. This equates to a score of 4 out of 10 for Factor 5.2.

Factor 5.3. Feed Footprint

Many of the ingredients currently used in pangasius feed, including those components with the lowest feed footprint (i.e., crops) are imported. Although domestic supplies of rice products, and cassava are plentiful, supplies of domestic oilseeds are small and grains such as wheat are nonexistent (US GAIN 2013[2]). Large volumes of these materials are imported into Vietnam (with an estimated average shipping distance of 7,107 km) (Bosma et al. 2011) to meet the growing domestic demand from human consumption and the feed industry (both terrestrial and aquaculture).

According to Bosma et al. (2011), the transportation of feedstuffs contributed to around 20% of the total impact from the feed production in toxicity categories, but its contribution to other emissions, such as global warming, was small. A US GAIN[1] (2013) report states that in 2012 Vietnam imported:

- 1.3 million mt of full fat soybeans (domestic production was around 172,000 mt).
- 2.46 million mt of SBM (plus 920,000 mt produced domestically from Vietnamese and imported soybeans), with 10% of the 3.42 million mt of SBM available being used in aquaculture feed production.
- 1.9 million mt of other oilseed meals (demonstrating that Vietnams feed millers are substituting more expensive ingredients such as SBM, with lower cost proteins in their feeds such as canola, sunflower and rape meals).

Huysveld et al. (2013) recently conducted a 'resource use analysis' on a major pangasius producer in Vietnam. Results showed that feed input (particularly the main ingredients used at present, i.e., SBM, wheat and rice) and its production chain are key factors for improving overall resource use efficiency in intensive pangasius farming. They state the continued need to utilize plant ingredients instead of marine and terrestrial inputs in feed, but stress the crucial importance of R&D into alternative plant ingredients and the optimization of traditional plant ingredient production processes. Feed inputs and production were also highlighted as a major concern in terms of life cycle impact assessment in intensive pangasius culture by Kluts et al. (2012).

It is worth noting that 100% vegetarian pangasius diets are feasible. However, these feeds are less attractive to farmers as they lack a 'fishy' smell and are eaten more slowly by the fish and also have slightly higher FCRs. Producers tend to believe that feeds with animal/fish proteins are better, which makes it difficult to promote vegetarian feeds and educate farmers (Fegan, pers. com. 2013). With improved formulation, vegetarian diets are expected to attain the necessary FCR values and, together with more favorable environmental and cost implications, be readily available on the market in the next few years.

According to the Seafood Watch criteria, the low inclusion of FM (5%) and the high proportion of crop ingredients (92%) in commercial Vietnamese pangasius feeds results in a low 'feed footprint' value of 2.6 ha, and therefore a high score of 9 out of 10 for this factor.

Feed Criterion Final Score

Combining the three feed factors gives an overall feed score of 7.66 out of 10 and reflects the low use of wild fish in the feeds and the predominance of crop ingredients.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		4.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		6.5	
C6 Escape Final Score		**5.00**	**YELLOW**
Critical?	NO		

Pangasius farms in the Mekong Delta do have measures in place to minimize escapes, however, there are multiple points along the production chain where fish could potentially escape. Pangasius are native in the Mekong, and although they have been domesticated to a certain extent over multiple generations, hatchery-reared pangasius are currently considered to have little genetic difference to wild stocks. Therefore, although genetic and ecosystem impacts from escapees on wild fish may occur, they are considered a low risk within the delta's remnant wild *P. hypophthalmus* population. Despite the hyper-intensive scale of production, the final score for the Escapes Criterion is 6 out of 10.

Justification of Ranking

Factor 6.1a. Escape risk

Robust data on aquaculture escape numbers (and associated recapture and mortality figures) are rarely available, and this is true regarding escapees from pangasius ponds. Lorenzen et al. (2012) estimate typical escape figures for cultured fish are in the order of 2%–4% per year, but this encompasses different aquaculture practices and cannot be specifically linked to pangasius pond culture. Actual data on pangasius escapees may be available in the future through the monitoring and recording of escape levels insisted upon by current certification schemes (e.g., ASC 2012; GAA 2010).

Escapes are generally inadvertent occurrences. There are two principal means for minimizing impacts of escaped fish on wild populations: effective containment, and the genetic manipulation of the culture fish (incorporating traits into the fish that reduce its performance in the wild or induce sterility in the fish) (Lorenzen et al. 2012). In the case of pangasius culture, the former measure is currently seen as the most practical to minimize potential impacts of escaped stock (Penman, pers. com. 2013).

Siting of farms to reduce the risk of flooding and breach of containment dykes will have some impact in reducing the potential for escapes (i.e., pangasius farms are located in only 0.5% of the flooding regions of the Mekong Delta (Bosma et al. 2009)). It is important to ensure that dyke heights are calculated and maintained to minimize the risk of overtopping in the rainy season. Identifying the causes of escapes, proper use and maintenance of containment gear (e.g., grills on individual pond inlets and outlets, as well as trapping devices on main discharge channels), staff training and BMPs are also important factors (Lorenzen et al. 2012).
Many farms in the Mekong Delta do have the necessary measures in place, particularly physical barriers, to minimize escapes (authors pers. observation 2012) and development/conservation NGO representatives, working with pangasius in the delta state that escape figures from farms, are low to minimal (e.g., Minh; Quoc, pers. com. 2013). However, water is exchanged frequently and many ponds do drain externally at harvest, and there are other points along the production chain at which fish could potentially escape (e.g., loading and unloading of live fish from wellboats). These factors deem the escape risk as moderate, and a Factor 6.1 'Escape Risk' score of 4 out of 10 has been assigned.

Factor 6.1b. Invasiveness
Wild populations of *P. hypophthalmus* have been decreasing ahead of the major on-set of pangasius farming due to issues such as over-exploitation and changes in water quality brought about by agro-chemicals and domestic waste discharges of a growing Mekong Delta population (NGTK 2012). Other impacts include changes to the species major nursery grounds through human development (De Silva, pers. com. 2013).

It is thought that current captive bred pangasius have little effect on the wild population in the delta (Nguyen 2009). Ecosystem impacts from escaped farmed pangasius may occur to some extent through competition for food and habitat with wild fish, but this is considered low within the deltas remnant wild population. Hatchery-reared pangasius stocks have also been shown to have few genetic differences to wild stocks (Nguyen 2009), and cultured fish that are more similar in genetic make-up to wild stocks reduce the risk to wild stocks through the dilution of genetic diversity and/or hybridization with related species.

Evidence to date suggests that any impacts on the genetic diversity of wild *P. hypophthalmus* and related species, has not resulted from interactions with escaped hatchery-reared stocks (De Silva and Phuong, 2011). The impacts escapees may have on breeding behavior (through competition for wild breeding partners) is also considered low; wild pangasius are migratory, undertaking spawning migrations up river as a result of cues given by environmental changes tied to the monsoon season (e.g., water level/ flow, turbidity, etc.) (MRC 2006). It is unclear whether captive-bred pangasius possess this innate ability to recognize such cues (Penman, pers. com. 2013), therefore, there is a potential for weakening the fitness of the wild populations if genetic traits, relating to reduced inability to migrate, are transferred into the remnant wild populations.

Increased captive breeding will progressively affect the genetic make-up of farmed pangasius as traits are selected to improve aquaculture performance, disease resistance, or improve traits such as increased salinity tolerance (necessary to cope with predicted increases in saline water intrusion into the delta due to climate change) (Hall and Johns 2013). Such increased ‘domestication’ tends to make the fish less fit and subsequently less able to survive outside the culture environment (Lorenzen et al. 2012). Continued monitoring of wild and hatchery stocks of pangasius is warranted, coupled with long-term, scientifically based broodstock management (De Silva and Phuong 2011) to adequately quantify the risk of genetic impact from farmed to wild fish.

Escaping pangasius are considered to have few direct ecological impacts on the Mekong (e.g., predation, competition for food or breeding, disturbance of habitats and so on) and, therefore, the ‘Invasiveness’ score is 6.5 out of 10. Combining the ‘Escape Risk’ score with the ‘Invasiveness’ score gives a final score for the Escape Criterion of 5 out of 10.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	4.00	
C7 Disease; pathogen and parasite Final Score	**4.00**	**YELLOW**
Critical?	**NO**	

The predominant health management problems in hyper-intensive pangasius farms are infectious bacterial diseases. Pathogens and parasites on farms originate from water taken into the facility, and the potential for horizontal transmission between farms appears to be high. The effects of amplified levels of such parasites and bacteria in water subsequently discharged from farms are unclear; especially the transfer from cultured pangasius to wild pangasiids and other fish populations. Disease and parasites are present in wild pangasiid and other fish populations, but little evidence is available to claim that such parasitic and disease episodes have increased or have significantly impacted upon wild populations as a direct result of current pangasius culture. Until vaccines become common place and demonstrably effective in hyper-intensive systems, the Disease Criterion score is 4 out of 10.

Justification of Ranking

The potential for disease development in a population depends on the contact rate between infectious and susceptible animals and the frequency of that contact is dictated by the population density (Reno 1998). Fish culture systems are all essentially designed to confine fish within facilities that create environmental conditions conducive to fish growth and survival through the supply of nutrients and the disposal of wastes while controlling predator and diseases (Lorenzen et al. 2012). However, by the very nature of confining fish in high densities, aquaculture facilities can act as amplifiers of pathogens. If the culture water of an aquaculture facility is more directly connected to open water and/or does not pass through stages of settlement, filtration, or other treatment, (i.e., if the method of culture is more environmentally open, such as cages, pens or ponds with direct water discharges), then the risks of parasite and disease transfer to wild fish may be increased.

In pangasius aquaculture the predominant health management problems are caused by infectious bacterial diseases. According to Crumlish (pers. com. 2013) and Dung[2] et al. (2008) the most important bacterial diseases in pangasius aquaculture are due to infections by:

- *Edwardsiella ictulari*—causing bacterial necrosis of pangasius or BNP

- *Aeromonas* species—causing motile *aeromonas septicaemia* or red spot disease
- *Flavobacterium columnare*—causing saddle-back lesions

E. ictulari is the most commercially serious and frequently occurs in fish of all ages (Dung[1] et al. 2008). Around 70% of production sites suffer at least one outbreak of *E. ictulari* infection during a production cycle (Crumlish, pers. com. 2013), and *E. ictulari* and *A. hydrophilia* can cause 30%–50% mortality in cultured fish (Gravningen 2012). According to Tran et al. (2014), mortality rates can be up to 80% when these disease outbreaks occur. Still, average mortality levels on pangasius farms today are around 20%, although those farms with better management and fish health regimes (e.g., certified facilities) are lower (authors' pers. observation 2012).

Pangasius diseases and parasites on farms originate from water taken into the facility and by those diseases and parasites that are present in Mekong Delta waters (Crumlish, pers. com. 2013; Dung[2] et al. 2008).The effects of potentially raised levels of such parasites and bacteria in water discharged from farms are unclear; especially transference from cultured pangasius to wild pangasiids and other fish populations. Another concern involves the transfer of parasite and disease agents that have evolved, causing increased virulence/resistance to treatments, which has been demonstrated in pangasius culture recently (Gravningen 2012).

Diseases result from a series of complex interacting variables of the host, pathogen, and environment (Hedrick 1998). Disease and parasites are present in wild pangasiid and other fish populations, due to their very presence in Mekong Delta waters, but little evidence is available to claim that such parasitic and disease episodes have increased or have significantly impacted upon wild populations as a direct result of current pangasius culture. Survey results in 2004 revealed that wild pangasiid fish were not suffering from more diseases as an impact of contact with cultured pangasiid catfishes (Poulson et al. 2008).This is particularly interesting as cages, the most environmentally open culture system, were the dominant production system at the time.

Current data on disease levels in wild *P. hypophthalmus* and the impacts aquaculture may have had on the species are not available, but De Silva (pers. com. 2013) states that within the current low volumes of wild-caught *P. hypophthalmus* landed (in all riparian countries of the Mekong Delta), no cases or clear signs of the major bacterial infections or diseases that affect the industry today were observed. Hogan (per. com. 2013), a leading authority on endangered Mekong Delta catfish populations, also states that he has never noticed obvious signs of disease on wild pangasiid fish caught in Cambodia, Lao PDR and Thailand. Current documented evidence to support these statements, however, is unavailable.

Basic data on the abundance, ecology, and conservation status of pangasiids is lacking (Hogan 2011), therefore direct threats to wild fish from pangasius aquaculture discharges and escaped stock that may harbor such raised parasitic and/or infectious disease agents are unclear and more research into this area is needed. Improved health and disease management through better fingerling quality, the increased adoption of BMPs and international certification, the use of new vaccines, further reductions of escapes and careful disposal of dead fish will help lower any potential risk of disease and parasite transmission to wild and threatened fish populations.

Crumlish (pers. com. 2013) suggests that although no clinical viruses have been found in pangasius aquaculture, there is always the potential risk of new viral diseases developing. While heightened disease transmission may occur directly from more environmentally open systems, Kurath and Winston (2011) state it is unlikely that potential new strains of diseases such as viruses can invade and persist within low-density wild populations. Data suggest that transmission tends to be local and that epidemics among wild populations are not reported (Midtlyng et al. 2006). Future potential/risks from a new disease to the decreasing numbers and densities of wild *P. hypophthalmus* (for example, the two known critically endangered pangasiid fish species: the Mekong giant catfish (*Pangasianodon gigas*) and the giant pangasius (*Pangasius sanitwongsei*) (Pilgrim 2010)) may be less significant than initially perceived. Far more pressing threats to wild pangasiids are from capture fisheries and potential dam building projects (Hogan, pers. com. 2013). More research on the current population status of wild pangasiids is needed, as is increased pangasius broodstock screening for potential viral risks (Crumlish, pers. com. 2013).

Overall, there is little evidence of negative impacts that pangasius aquaculture may have had on the disease risks to wild fish in the Mekong Delta. The fact that diseased wild fish would be much more apparent in this relatively contained riverine environment (compared to coastal or open ocean species for example) further supports this conclusion.

There appears to be increasing levels of health management taking place through technological advances, better fingerling quality through increasingly better broodstock management, and growing BMP and certification adoption. Nevertheless, the current pond production system is open to introductions of local pathogens; on farm disease-related mortalities are common and many farms directly discharge wastewater, which may have raised parasite and bacterial loads.

In light of these issues, the final score for the Disease Criterion is 4 out of 10.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations.*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	80	
C8 Source of stock Final Score	**8.00**	**GREEN**

All fingerlings for growout operations come from Vietnamese hatcheries. Domestically held broodstock are usually replaced every 3 years and largely sourced from populations kept by hatcheries or from other delta farms. There is a continued (but relatively limited) trade in wild-caught broodstock being used in pangasius breeding, often from Cambodia from small remaining populations of wild pangasius. The Source of Stock score is, therefore, 8 out of 10, as the industry is largely independent of wild fisheries for stock.

Justification of Ranking

Traditionally in Vietnam, wild-caught seed of pangasius were stocked in backyard or 'latrine' ponds and the resultant production consumed domestically. In the early stages of pangasius culture, fry and fingerlings of *P. hypophthalmus* and other species were caught in the Mekong River using small bag nets or 'dai.' Such fisheries existed in Cambodia and in the An Giang and Dong Thap provinces of Vietnams Mekong Delta. In 1994, the Cambodian government banned the collection of wild seed, as did the Vietnamese government in 2000 (Nguyen 2009).

Research on the artificial propagation of pangasiid fish first started in 1978-1980, initially through Vietnamese efforts but subsequently as a joint EU/Vietnam project (Davy et al. 2010). In 1995, artificial spawning techniques closed the life cycle of *P. hypophthalmus* (Figure 3 details the main steps in pangasius artificial propagation), and the development of a commercial hatchery sector began from 1998 onwards (Sinh and Hien 2010). This was the vital ingredient to enable the successful and rapid growth of Vietnamese pangasius aquaculture.

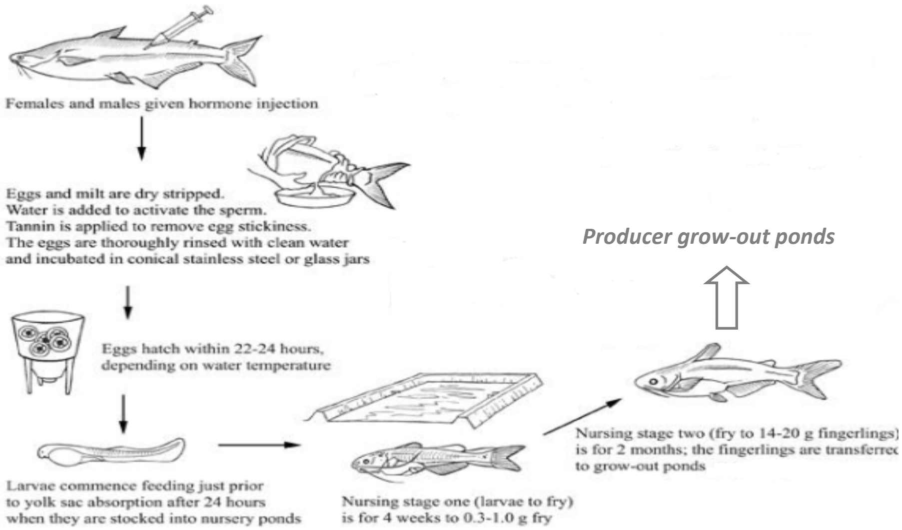

Figure 3. Artificial Pangasius Propagation Spawning, Fry & Fingerling Production (Adapted from FAO 2010)

Producers now source all their fingerlings for growout operations from Vietnamese hatcheries located in the MRD, and the FAO (2010) reports that hatchery produced seed has now entirely replaced seed from wild sources. Hatchery and nursery farmers are generally independent sub-sectors of the pangasius industry (though the recent trend in integration has seen many of the large producer/processor companies take fry production in-house, and contract nursery farmers to raise their own fingerlings under contract). Sinh and Hien (2010) report there were 93 hatcheries (governmental and private) in the Mekong Delta in 2008, supplying over 52 billion fry. ICAFIS (pers. com. 2013) report a higher number of pangasius hatcheries in the delta today, at around 148 facilities.

Domestically held broodstock are usually replaced every 3 years (Hall and Johns 2013) and, according to Sinh and Hien (2010), are largely sourced (80%) from the large broodstock populations kept by hatcheries or from other delta farms. However, most hatcheries that breed pangasius still need to recruit new stock and these are sourced from the wild (Pilgrim 2010). Sinh and Hien (2010) report some 6.3% of newly recruited pangasius broodstock are wild caught; Bui et al. (2010) puts this figure at around 20% in those hatcheries surveyed.

Most wild-caught broodstock originate in Cambodia (Nguyen 2009). Cambodian *P. hypophthalmus* stocks were considered abundant in the 1990s but now considered in decline (IUCN 2011). Although pangasius is not considered to be threatened with extinction (Pilgrim 2010), broodstock capture can have significant impacts in small wild populations (Lorenzen et al. 2012), and pangasiid fish populations may also be placed under increased pressure in the future (e.g., disruptions to migration routes and changes to spawning grounds) due to the potential impacts of dam building currently being considered along the Mekong River (Hall and Johns 2013).

Broodstock management varies widely in the hatchery sub-sector, and there is a need to put in place a long-term, scientifically based management plan (De Silva and Phoung 2011) that does not rely on the occasional replenishment of wild-caught individuals, but without compromising the survival and growth characteristics of hatchery progeny (Hall and Johns 2013). Broodstock from farm origins has been reported to produce 30% more eggs than wild-caught fish (Biu et al. 2010), and efforts to improve the quality of the pangasius broodstock in the delta are underway by the government. The Research Institute for Aquaculture No. 2 recently (2011) distributed 101,000 pangasius broodstock fish to eight Mekong Delta provinces, with plans to distribute another 30,000-40,000 annually until 2014. The initiative is part of an on-going MARD program to create a high-quality broodstock population in the delta (vietnamseafoodnews[1] 2012).

Despite 100% of the farmed pangasius produced in Vietnam being hatchery reared, there is a continued trade in wild-caught broodstock being used in pangasius breeding. In recognition of this latter issue, a final score of 8 has been assigned to the ’Source of Stock’ criterion.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on populations of the affected species, either predators or other wildlife. (This is an 'exceptional' factor that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact).

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
Criterion 9X Wildlife and predator mortality Final Score	**-3.00**	**GREEN**
Critical?	NO	

Pangasius farms in Vietnam are considered likely to attract a variety of predators, typically birds; however, data on mortalities are not available. Expert opinion considers mortality numbers to be low and unlikely to affect the population sizes of the species present. The score for this exceptional criterion is a deduction of -3 out of -10.

Justification of Ranking

Most of the habitats in the Mekong Delta were once extensive, and species ranged widely across the region. As the delta is now primarily agricultural land, few small sites of known global conservation significance remain; for instance, only four sites of international importance (i.e., Ramsar[k] and UNSECO[l]) have been designated to date (Figure 4). Remnant populations of rarer species are usually found in locations that are either protected or in less densely populated areas outside provinces with high agricultural production and the highest human population densities—the same provinces that support the majority of the pangasius industry.

The Mekong Delta is home to some 386 species of birds, 400 species of fish and 24 species of mammals (Dung 2012). Species that do remain tend to be small, widespread, resilient and adaptable, while semi-aquatic species such as reptiles (e.g., turtles) and fish are often heavily exploited (Pilgrim 2010), and many are endangered. Table 3 details the most recent numbers of threatened species in each group in the delta region, according to Pilgrim (2010) and Cong et al. (2013). Some of these species will be piscivorous and may pose predatory threats to pangasius farming.

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[k] *The Convention on Wetlands (Ramsar, Iran, 1971), a.k.a the "Ramsar Convention" is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (www.ramsar.org).*

[l] *Biosphere reserves are sites established by countries and recognized under UNESCO's Man and the Biosphere (MAB) Programme to promote sustainable development based on local community efforts and sound science; seeking to reconcile conservation of biological and cultural diversity and economic and social development through partnerships between people and nature (http://www.unesco.org)*

On the whole, pangasius farms have not been established in or next to areas of current conservation significance (see Figure 4) and are unlikely to have had significant biodiversity impacts from their siting (Pilgrim 2010).

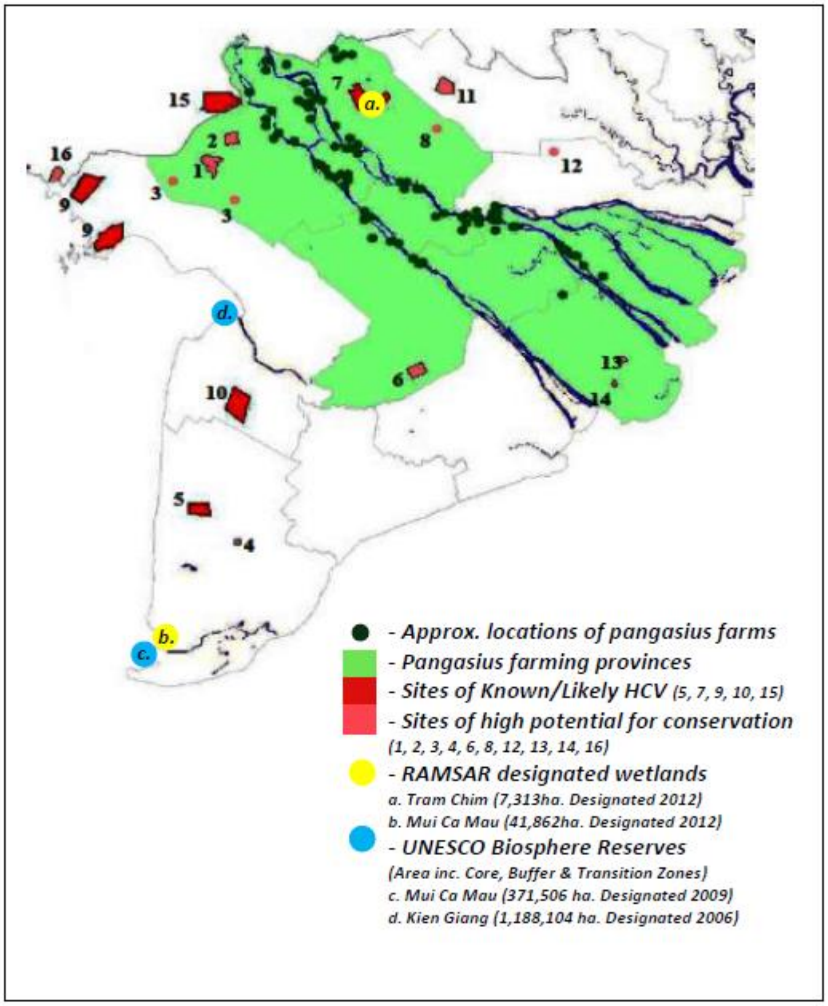

Figure 4. Conservation in the Mekong Delta: Sites of known or likely ‘high conservation value’ (HCV) and ‘potential conservation significance’ in the Mekong Delta, including Ramsar & UNESCO (adapted from Pilgrim 2010, Ramsar 2013, UNESCO 2013).

Table 3. Number of endangered species in the Mekong Delta

Group	Pilgrim, 2010	Cong *et al*, 2013
Plant	34	11
Invertebrate	-	1
Amphibian	8	1
Reptile	-	16
Fish	7	11
Bird	7	21
Mammal	12	14
TOTAL	68	69

- Pilgrim (2010) figures based on available data, literature review & author's best judgement
- Cong *et al* (2013) figures based on IUCN, Vietnamese national authorities & other related organizations information; literature search, and Participatory Rapid Appraisal (PRA) in the field

In terms of biodiversity, farms provide better habitat for some species than the rice paddies they have replaced, and may appear to support abundant wildlife owing to their attraction to fish-eating birds. However, these species are generally common and widespread (e.g., cormorants and egrets) (Pilgrim 2010, Cong et al. 2013). Although there is potential for increased biodiversity on land used for pangasius farming (e.g., the establishment of aquatic bird colonies on un-utilized land), most farms are small, space is at premium, and significant biodiversity benefits on farm sites are unlikely. There is, however, significant potential for the industry to have positive biodiversity impacts away from farm sites through financial or in-kind contributions (Pilgrim 2010), particularly in those areas of conservation value that remain in the delta (Figure 6),.

Fish farms, by their very nature, are attractive to fish-eating predatory species, as they are seen as readily available sources of food. Although many farms deploy methods to deter predators (e.g., fencing, netting over ponds, constant human and animal presence (e.g., farmhands and guard dogs) etc.) the risk is present, and wildlife mortalities may occur, whether premeditated or inadvertent. Data on predation rates and industry losses due to predation are currently not available for pangasius farming in the Mekong Delta, however, the instances of wildlife/predator mortalities are thought to be low (De Silva, pers. com. 2013; Minh, pers. com. 2013). Species that may be targeted as nuisance predators are more than likely to be species common in the region, such as cormorants (Pilgrim 2010; Quoc, pers. com. 2013), and to some extent, reptilian species such as monitors lizards (De Silva, pers. com. 2013).

Nocturnal animals such as hairy-nosed otters and fishing cat (both globally endangered), as well as aquatic turtles, have historic ranges encompassing the main pangasius culture provinces but again are thought to have long been dislodged from such areas (Pilgrim, 2010) via historic habitat loss for agriculture, over-exploitation and human population pressure.

Nevertheless, it should not be assumed that just because such rare species are not seen, that they are not present. No data have been found, however, to suggest that pangasius aquaculture has affected such species/populations and the impact of pangasius culture is thought to be low to moderate in this respect. The final score for the Exceptional Criterion 9X is a deduction of -3 out of -10 as some mortality is likely to occur, but unlikely to be at levels that would have population level impacts on affected species.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments. (This is an 'exceptional' criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.)

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
Factor 10Xa International or trans-waterbody live animal shipments (%)	0.00	
Factor 10Xb Biosecurity of source/destination	10.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Although hatchery raised fingerlings are transported within the Mekong Delta, and some imports of pangasius broodstock occur from Cambodia, these are not considered to be movements across different waterbodies for the purposes of assessing the risk of accidentally transporting non-native species during live animal shipments. The score for the Exceptional Criterion 10X is a deduction of zero out of -10.

Justification of Ranking

Factor 10Xa International or trans-waterbody live animal shipments

The pangasius industry has integrated independent sub-sectors (hatchery, nursery, growout and product processing) and these are linked through coordinated transportation by water. Specially designed, 20-30 mt capacity boats transfer live fish and are a size (14-23 m long) which allows them to navigate the dense network of Mekong Delta channels along the pangasius production chain. The total number of boats catering to the whole of the pangasius sector in the Mekong Delta is estimated at around 2,800 (Bui et al. 2013).

The reliance of the industry on trans-waterbody shipments is greater than 90%; however, these fish movements are all within the Vietnamese Mekong Delta and are not international or trans-waterbody. It must be noted that newly recruited pangasius broodstock are wild caught and often originate in the Cambodian Mekong (Nguyen 2009) (see Criterion 8); but again, this is deemed as the same waterbody and not a trans-waterbody movement. As such, the score awarded to Factor 10Xa is zero percent.

Factor 10Xb Biosecurity of source/destination

All of the inter-linking sub-sectors of the pangasius industry are located within the Vietnamese Mekong Delta, as is the transportation of fish between them. No international live shipments are undertaken via water. As such, the 'source' and the 'destination' are one and the same, and the biosecurity score for Factor 10Xb is 10 out of 10.

The risk of unintentional, non-native/introduced species transference from one area of the delta to another is low, as any undesirable species that are possibly transferred along with pangasius are native to the region already. The risk of disease transference within the delta is also seen as low as stock is conditioned and prepared for transportation (e.g., losses from disease ridden, unhealthy stock during journeys would be too great, and end users would not accept such poor quality fish), and many of the aquatic pathogens that cause diseases in pangasius are already widespread, possibly endemic within the regions waters (Crumlish, pers. com. 2013; Dung[2] et al. 2008).

With no international or trans-waterbody live pangasius movements, the score for the exceptional Criterion 10X is a deduction of 0 (out of -10).

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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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Useful Websites

www.aquafeed.com
www.asc-aqua.org - The Aquaculture Stewardship Council
www.efeedlink.com
www.enaca.org - Network of Aquaculture Centres in Asia-Pacific (NACA)
www.enerfish.eu
www.fao.org - Food and Agriculture Organization, UN
www.gaalliance.org - Global Aquaculture Alliance
www.globalgap.org - GlobalG.A.P.
www.icafis.org - International Collaborating Centre for Aquaculture and Fisheries Sustainability
www.idhsustainabletrade.com - The Sustainable Trade Initiative
www.intrafish.com
www.iucn.org - International Union for the Conservation of Nature
www.montereybayaquarium.org - Monterey Bay Aquarium and Seafood Watch
www.mrcmekong.org - Mekong River Commission
www.panda.org - World Wide Fund for Nature
www.pangasius-vietnam.com
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www.rebyc-cti.org – Strategies for Trawl Fisheries Bycatch Management
www.seafdec.org - Southeast Asian Fisheries Development Center
www.seatglobal.eu - Sustainable Ethical Aquaculture Trade
www.snvworld.org - Netherlands Development Organization
www.sustainablefish.org - The Sustainable Fisheries Partnership
www.thefishsite.com
www.unesco.org - United Nations Education, Scientific and Cultural Organization
www.vasep.com.vn - Vietnam Association of Seafood Processors and Exporters
www.vietfish.com
www.vietnamseafoodnews.com
www.worldfishcenter.org

Appendix 1: Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	7.5	7.5
Predators and wildlife	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**50**

C1 Data Final Score	5.6	YELLOW

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	27
eFCR	1.6
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	12.8
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	69.12
N in each ton of fish harvested (kg)	20.48
Waste N produced per ton of fish (kg)	**48.64**

Factor 2.1b - Production System discharge score

Basic production system score	0.8
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.8**

80% of the waste produced by the fish is discharged from the farm/s

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

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Moderately	0.5
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Partly	0.25
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Partly	0.25
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc.?	Moderately	0.25
		2.25

Factor 2.2b - Enforcement level of effluent regulations or management

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

F2.2 Score (2.2a*2.2b/2.5)	**0.9**

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

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	5

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

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Partly	0.25
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1
4 - Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Partly	0.25
		2.75

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Mostly	0.75
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Moderately	0.5
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Moderately	0.5
		2.5

F3.2 Score (2.2a*2.2b/2.5)	**2.75**

C3 Habitat Final Score	**4.25**	**YELLOW**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	CRITICAL	
C4 Chemical Use Final Score	CRITICAL	RED
Critical?	YES	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a - Fish In: Fish Out

Fishmeal inclusion level (%)	5
Fishmeal from byproducts (%)	0
% FM	5
Fish oil inclusion level (%)	0
Fish oil from byproducts (%)	0
% FO	0
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.6
FIFO fishmeal	0.36
FIFO fish oil	0.00
Greater of the 2 FIFO scores	0.36
FIFO Score	**9.11**

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

SSWF	-8
SSWF Factor	-0.28

F5.1 Wild Fish Use Score	**8.83**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	27
eFCR	1.6
Feed protein from NON-EDIBLE sources (%)	9.25
Feed protein from EDIBLE CROP sources (%)	90.75
Protein OUTPUTS	
Protein content of whole harvested fish (%)	12.8
Edible yield of harvested fish (%)	38.25
Non-edible byproducts from harvested fish used for other food production	100

Protein IN	27.99
Protein OUT	12.8
Net protein gain or loss (%)	-54.2721
Critical?	NO
F5.2 Net protein Score	**4.00**

5.3. Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	5
eFCR	1.6
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	2.08

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

Inclusion level of crop feed ingredients (%)	95
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.6
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.58

Value (Ocean + Land Area)	**2.66**

F5.3 Feed Footprint Score	**9.00**

C5 Feed Final Score	**7.66**	**GREEN**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**4**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0

Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**4**

6.1b. Invasiveness

Part A – Native species

Score	2

Part B – Non-Native species

Score	**2.5**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g., by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	4.5

F 6.1b Score	**6.5**

Final C6 Score	**5.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Disease

Pathogen and parasite parameters	Score	
C7 Biosecurity	4.00	
C7 Disease, pathogen and parasite Final Score	**4.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	80	
C8 Source of stock Final Score	**8**	**GREEN**

Exceptional Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-3.00**	**GREEN**
Critical?	NO	

Exceptional Criterion 10X: Escape of unintentionally Introduced Species

-

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	0.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Appendix 2: Key Stages in the Development of Pangasius Culture in the MRD

(De Silva and Phuong 2011, Davy et al. 2010)

- 1940 - 1950: Tra catfish (*P. hypophthalmus*) culture in began in An Giang and Dong Thap provinces in small, 'backyard' ponds using wild-caught fingerlings.
- 1978–1980: Research into induced spawning of catfish began.
- 1981–1982: The first trials of intensive catfish culture conducted by a farmer in Can Tho city using wild-caught fingerlings.
- 1995: The technique of induced spawning in catfish was successful.
- 1996–1999: Intensive catfish farming in ponds expanded gradually to other Mekong Delta provinces. First trials of catfish culture in cages, with another local species, *Pangasius bocourti* (Basa catfish) and in pens were conducted. Both production systems used wild-caught and now hatchery-reared fingerlings.
- 2000–2004: Intensive culture of catfish in ponds and cages expanded rapidly. Hatchery-reared fingerlings met the demand from farmers. Production techniques and productivity significantly improved, and farmers gradually shift from farm-made to commercial feeds.
- 2005–Present: Collapse of *P. bocourti* cage and pangasius pen culture, and the significant expansion and productivity improvements in *P. hypophthalmus* pond culture.

Appendix 3: Calculations on sludge production

a. Justification of Pangasius Pond Production Volumes:

KNOWN:

- *Whole fish production = 1,200,000 mt*
- *Total pangasius farming area = 6,000 ha*

ASSUMING:

- *Ponds OR Total Water Surface Area (WSA) = approx. 70% of total farming area = 4,200 ha*
- *Pangasius farms have approx. 1.45 production cycles (crops) per year (i.e. approx. 8 months per crop)*

THEREFORE:

- *Production of whole fish per ha of WSA = 286 mt x 1.45 crops = 415 mt of whole fish per ha per year*
- *4,200 ha WSA / 1.45 crops = 2,896 ha WSA under production at any one time*
- *2,896 ha WSA x 415 mt of whole fish = 1,200,000 mt*

b. Justification of Pangasius Annual Water Exchange Volumes:

KNOWN:

- *475,000 km^3 minimum annual water flow through the two main river of the Mekong Delta, Vietnam*

ASSUMING:

- *Ponds OR Total Water Surface Area (WSA) = approx. 70% of total farming area = 4,200 ha = 42,000,000m^2*
- *7% daily water exchange rate*
- *Average 4 m grow-out pond depth*
- *415 mt of whole fish production per ha per year*

THEREFORE:

- *42,000,000 m^2 WSA x 4 m = 168,000,000 m^3 of water in pangasius ponds x 7% daily exchange = 11,760,000m^3 per day exchanged x 288 days per year (i.e. 24 days in every month) = 3,386,880,000 m^3 per year OR 3.38 km^3 per year*
- *3.38 km^3 / 475,000 km^3 x 100 = 0.00071% of the water of the Mekong River diverted through pangasius ponds*
- *3.38 km^3 of water / 1,200,000 mt of whole fish production = 2,816 m^3 of water used per mt of whole fish = 2,861 l of water is diverted from the Mekong River per kg of whole fish produced*

c. Justification of Pangasius Pond Sludge Production:

KNOWN:

- *Whole fish production = 1,200,000 mt*
- *Total pangasius farming area = 6,000 ha*
- *8000m^3 of sludge is produced per ha per crop x 1.45 crops per year (i.e. approx. 8 months)= 11,600 mt sludge per ha per year*

ASSUMING:

- *Total Water Surface Area (WSA) = approx. 70% of Total Farming Area = 4,200 ha*

RESULTANT SLUDGE PRODUCTION PER YEAR FROM PANGAIUS FARMS:

- *4,200 ha total WSA under pangasius production x 11,600m^3 of sludge = 48,700,000 m^3 per year*

d. Justification of Certified Pangasius Farming Area & Sludge Production:

KNOWN:

- *Whole fish production = 1,200,000 mt*
- *Minimum volume of whole pangasius production certified (i.e. GlobalG.A.P.) = 240,000 mt = 20% whole fish production*
- *Total pangasius farming area = 6,000 ha*

ASSUMING:

- *Total Water Surface Area (WSA) = approx. 70% of Total Farming Area = 4,200 ha*

THEREFORE:

- *240,000 mt / 415 mt per ha whole fish production = 578 ha WSA under production at any one time x 1.45 crops per year = 839 ha WSA utilized for certified pangasius production per year*
- *839 ha represents the 70% pond area, therefore 1,200 ha = total farming area certified*
- *Total certified farming area = 1,200 ha OR 20% of total pangasius farming area (1,200 ha / 60 farms = 20 ha average farm size OR 14 ha average WSA (i.e. 70%))*

RESULTANT SLUDGE PRODUCTION PER YEAR FROM NON/CERTIFIED PANGAIUS FARMS:

- *4,200 ha total WSA under pangasius production x 11,600m^3 of sludge = 48,700,000 m^3 per year*
- *839 ha WSA certified farms x 11,600m^3 of sludge = 9,730,000m^3 of sludge per year OR 20% of the total sludge produced by the pangasius industry per year*

Appendix 4 – Interim Update

An Interim Update of this assessment was conducted in March 2021. Interim Updates focus on an assessment's limiting (i.e. Critical or Red) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review evaluates Criterion 4 Chemical Use. No information was found or received that would suggest the final rating is no longer accurate. No edits were made to the text of the report (except an update note in the Executive Summary). The following text summarizes the findings of the review.

Criterion 1 – Data

Overall, data availability and quality for pangasius production in Vietnam was considered low-moderate for Criterion 4 - Chemical Use. A temporal gap in literature is apparent regarding the industry's application of antimicrobials, types of antimicrobials used, and accessibility to antimicrobials since the assessment was published in 2014. Additionally, more detailed information to better describe and attribute production practices of different segments of the pangasius farming industry in Vietnam, specifically antimicrobial use, was not available. Experts from the industry, academia, NGOs and in-country researchers were all contacted and provided varying levels of input and feedback. As a result, the availability and quality of data is considered low-moderate.

Criterion 4 – Chemical Use

Since the publication of the 2014 SFW assessment of pangasius raised in intensive ponds, antimicrobial use appears to remain ubiquitous in the Vietnamese aquaculture industry although more recent publications are needed on this topic. Lulijwa et al. (2019) found that Vietnam had the highest number of antimicrobial compounds used (39) for aquaculture production in all of Asia, but their review is reflective of publications from 2005 to 2012. There are 30 antimicrobials and chemicals allowed but restricted for use in Vietnam (MARD, 2014; Circular 10/2016), and 24 antimicrobials and chemicals banned from use, which include ciprofloxacin and fluoroquinolones, such as enrofloxacin (Chen et al. 2020; MARD, 2016; MARD, 2014, Circular 10/2016) (see Table 1 and Table 2). It appears access to antimicrobials is not strictly controlled, as farmers may purchase antimicrobial products from local stores without a prescription (Chen et al. 2020; Strom et al. 2019; Braun et al. 2019) and given the difference between antimicrobials used (39) and allowed for use (30), it appears that illegal use of antimicrobials may exist.

Table 1: List of Restricted Chemicals and Antimicrobials In Vietnam Aquaculture. (MARD, 2014; Circular 10/2016).

List of Restricted Chemicals and Antimicrobials (n=30)		
Amoxicillin	Emamectin	Paromomycin
Ampicillin	Erythromycin	Sarafloxacin
Benzylpenicillin	Florfenicol	Spectinomycin
Chlortetracycline	Flumequine	Sulfonamides
Cloxacillin	Lincomycin	Teflubenzuron
Colistin	Neomycin	Tetracycline
Danofloxacin	Ornetoprim	Tilmicosin
Dicloxacillin	Oxacillin	Trimethoprim
Difloxacin	Oxolinic acid	Tricainemethanesulfonate
Diflubenzuron	Oxytetracycline	Tylosin

Table 2: List of Banned Chemicals and Antimicrobials In Vietnam Aquaculture. (Circular 10/2016).

List of Banned Chemicals and Antimicrobials (n= 24)		
Aristolochia spp and derivatives	Dapsone	Glycopeptides
Chloramphenicol	Deltamethrin	Ipronidazole
Chloroform	Diethylstilbestrol (DES)	Metronidazole
Chlorpromazine	Dimetridazole	Nitrofuran (including Furazolidone)
Ciprofloxacin	Enrofloxacin	Other Nitroimidazoles
Clenbuterol	Fluoroquinolone family	Ronidazole
Colchicine	Gentian Violet (crystal violet)	Trichlorfon (Dipterex)
Cypermethrin	Green Malachite (Malachite blue)	Trifluralin

Therefore, current government effectiveness to control the use of antimicrobials appears limited, and weak regulation can allow for overuse, creating a risk for emerging bacterial resistance (Strom et al. 2019). Although enrofloxacin has been banned for use in aquaculture since 2016, it is still used in aquaculture products (Braun et al. 2019; Chi et al. 2017) including pangasius (Ström et al. 2019). It is also suggested that the extensive list of permitted antimicrobials "makes it difficult to control their use and likely to increase the risk of irrational use and environmental pollution" (Binh et al. 2018). Additionally, one study found that the majority of aquaculture products that contained antimicrobial compounds used for pangasius culture inaccurately reported the concentrations of the active ingredients by more than ±10% (Phu et al. 2015), a pattern still observed more recently for whiteleg shrimp production (Tran et al. 2018). There is a Vietnamese National Action Plan (NAP) for management of antimicrobial use and control of antimicrobial resistance in livestock production and aquaculture 2017- 2020 "which involved the Ministry of Health and the Ministry of Agriculture and Rural Development (MARD) with the support of WHO, FAO and other organizations for the period from 2013 to 2020." (Binh et al. 2018). However, the NAP is limited by a lack of monitoring of antimicrobial residues in the environment, which is "essential for the overall NAP to fight against antimicrobial resistance."

Since 2014, there have been limited studies evaluating on-farm antimicrobial usage, and there is no evidence to suggest that farm practices of antimicrobials have changed significantly. In a 2014 survey of 30 intensive pangasius farmers in the Chau Thanh district, Dong Thap province, restricted antimicrobials (e.g. amoxicillin, trimethoprime, ciprofloxacin, oxytetracycline, and florfenicol) were "commonly used", and 70% of interviewed farmers reported using the prohibited antibiotic enrofloxacin (Long et al. 2015). These authors further noted that barriers to accesses were low and dosage application were not strictly followed (Long et al. 2015). A more recent survey (Strom et al. 2019) of small-scale pangasius producers, whose product was destined for local and export markets, found that antimicrobials were commonly used. Sixty-nine percent of pangasius producers reported to use antimicrobials, 15% were "unsure" if they had, and more than half had not received any training on their proper use. Farmers reported to use antimicrobial products both prophylactically and when clinical symptoms were observed. Clinical symptoms or mortalities are most frequent within the first months of transfer to grow-out ponds, and the application of antimicrobials is commonly applied between 1-3 months after stocking of fingerlings. Farmers reported to typically administer antimicrobial treatment for 3 days after onset of clinical symptoms, although 5 to 7 days was usually recommended by local salesmen. If clinical symptoms did not improve, farmers typically switched to a different antimicrobial. The majority of farmers reported reduced effectiveness of antimicrobial treatment over time. Antimicrobials most commonly used by tilapia and pangasius farmers "were different combinations of sulfamethoxazole/trimethoprim and amoxicillin." Banned antimicrobials such as enrofloxacin were still being used by pangasius farmers as well. In a separate study (Nakayama, 2017), the antimicrobials gentamicin and tetracycline were stated as being used by pangasius farmers, while residue of sulfamethoxazole, sulfadimidine, and trimethoprim were all found at pangasius ponds. A more recent survey, conducted by IDH in 2019 of pangasius farmers in the Mekong Delta, found some pangasius farmers (i.e. ~32% of survey respondents) applied compounds from the fluoroquinolones family (i.e. enrofloxacin and levofloxacin) to treat diseased pangasius, but was only applied during the juvenile stage. The antimicrobial family of fluoroquinolones are banned from use in Vietnam. These surveys and publications represent, to the best of our knowledge, the most up to date information on the usage of antimicrobials by pangasius farmers. Although these studies may not adequately address the differences between factions of the industry (large verse small scale production), or, potentially, a clear picture of current practices – it is the best information at hand.

A search of the European Union's Rapid Alert System for Food and Feed (RASFF) portal for Vietnamese pangasius since 2014 revealed 8 import rejections for antimicrobial residue of the following: (1) ofloxacin, and (7) nitrofuran and nitrofurazone. Altogether, there are nine different antimicrobials documented, four of which are critically important antimicrobials for human medicine, four are highly important antimicrobials for human medicine, and one is an important antimicrobial for human medicine (see Table 2).

Table 2: Documented antimicrobial use from primary literature and RASFF portal for farmed pangasius in Vietnamese ponds since 2015 and the WHO classification of its importance for human medicine.

Antimicrobial	***WHO Classification***
Nitrofurans	*Important*
Sulfamethoxazole	*Highly Important*
Sulfadimidine	*Highly Important*
Trimethoprim	*Highly Important*
Tetracycline	*Highly Important*
Enrofloxacin	*Critically Important*
Gentamicin	*Critically Important*
Amoxicillin	*Critically Important*
Ofloxacin	*Critically Important*

Overall, without any meaningful changes to increase barriers to antimicrobials or other measures to tighten control of their use, governance of antimicrobial usage in Vietnam does not appear to have changed significantly since 2015. Although there have been limited studies in recent years, farm-level practices appear to be consistent with the practices in 2015. Without publicly available chemical use data available, the quantity or frequency of antimicrobial use in the Vietnamese pangasius industry are ultimately unknown, but farmer surveys indicate highly and critically important antimicrobials are applied both prophylactically and/or once symptoms are observed. Although there are no new studies found to determine whether the documented development of resistance to a number of antimicrobial treatments is still relevant, the continued indiscriminate, ubiquitous and prophylactic use in the industry indicates that resistance is still likely. In the Seafood Watch Aquaculture Standard, when developed resistance includes highly and critically important antimicrobials, illegal use of antimicrobials are applied, and/or critically important antimicrobials are used in significant or unknown quantities, the conservation concern is considered “Critical.”

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