Giant Tiger Prawn and Giant Freshwater Prawn

Penaeus monodon, Macrobrachium rosenbergii

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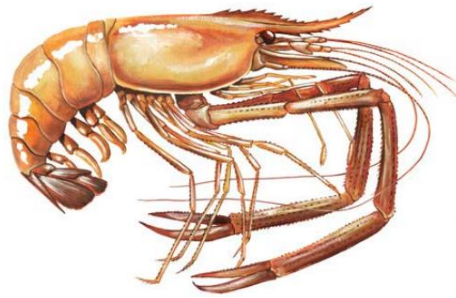

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Bangladesh

Ponds

Aquaculture Standard Version A3.2

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Seafood Watch Consulting Researcher

Final Seafood Recommendation

Recommendation - P. monodon

Criterion	Score	Rank	Critical?
C1 Data	8.86	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	0.27	RED	YES
C4 Chemicals	8.00	GREEN	NO
C5 Feed	9.74	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8X Source	–10.00	RED	NO
C9X Wildlife mortalities	–2.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**34.87**		
Final score (0–10)	**4.98**		

OVERALL RANKING

Final Score	4.98
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

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

Summary - *P. monodon*

The final numerical score for *P. monodon* grown in coastal and inland ponds in Bangladesh is 4.98 out of 10. Because of the impact that the *P. monodon* farming sector has on mangrove deforestation and saltwater intrusion, the Habitat Criterion has received a critical, Red rating. The Source of Stock Criterion also received a Red rating because of the industry's reliance on wild-captured broodstock. With two criteria rated Red, the final recommendation for Bangladesh farmed-raised *P. monodon* is Red, or "Avoid."

Recommendation – M. rosenbergii

Criterion	Score	Rank	Critical?
C1 Data	8.86	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	4.93	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	7.16	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8X Source	–10.00	RED	NO
C9X Wildlife mortalities	–2.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**36.96**		
Final score (0–10)	**5.28**		

OVERALL RANKING

Final Score	5.28
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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

Summary – *M. rosenbergii*

The final numerical score for *M. rosenbergii* grown in inland ponds in Bangladesh is 5.28 out of 10. Because of the reliance of this sector on wild-sourced fry and broodstock, the Source of Stock Criterion has received a Red rating. With one criterion rated Red, the final recommendation for Bangladesh farmed-raised *M. rosenbergii* is Yellow, or “Good Alternative.”

Executive Summary

This assessment was originally published in April 2017 and reviewed for any significant changes in June 2021. No changes were made to the body of the report. Please see Appendix 2&3 for details of review.

The United States imports more seafood and shrimp than any other nation and also has the highest per capita consumption of shrimp globally—with shrimp being the highest per capita seafood item consumed in the U.S. Three-quarters of global shrimp imports are destined for markets in the United States, Europe, and Japan. Globally, the most commonly cultured species is *Litopenaeus vannamei* (whiteleg shrimp), followed to a much lesser extent by *Penaeus monodon* (giant tiger prawn or black tiger shrimp) and *Macrobrachium rosenbergii* (freshwater prawn). The latter two species are cultured in Bangladesh. Presently, the E.U. is by far the largest volume importer of Bangladeshi shrimp. During 2015, global imports of shrimp into the U.S. amounted to 586,279 MT. For the same period, the United States imported 2,126 MT of shrimp from Bangladesh, with a value of USD 35 million, which represented 0.36% of total shrimp imports for the year.

Bangladesh, which is located in southern Asia between India and Myanmar, is the eighth-most populous country in the world (at the time of writing, the population is around 163 million) and the fifth-largest global aquaculture producer. It is a low-lying country, much of which is situated on the deltas of large rivers (the Ganges, the Meghna, and the Jamuna) that originate in the Himalayas and empty into the Bay of Bengal. It is also home to the Sundarbans, one of the world's largest mangrove forests. Shrimp farming[1] primarily occurs in the southwest of the country, where these extensive deltas have created a large, low-lying, submerged, brackish-water ecosystem, which is well suited to shrimp culture. *P. monodon* is a marine crustacean, whereas *M. rosenbergii* is widely distributed in both freshwater and brackish water; spawning and larval development of *M. rosenbergii* occurs in the 10–15 ppt salinity range and, although its further development would naturally occur in freshwater, it also grows well in low salinity, brackish water.

P. monodon production dominates shrimp culture in Bangladesh, accounting for around 60%–75% of exports. It has earned the name "white gold" for the income that it generates. By comparison, *M. rosenbergii* production is considerably less: the Bangladesh Department of Fisheries (DOF) reported that of the 113,527 MT of shrimp produced during the fiscal year 2013–2014, 63% were *P. monodon* and 37% were *M. rosenbergii*.

[1] Note that marine shrimp and freshwater prawns are often generically referred to as 'shrimp'. In this report, when the term 'shrimp farming' or 'shrimp' is used, this generally refers to farming of both species, unless it is obvious from the surrounding text that only marine shrimp is the subject of discussion.

In comparison to other shrimp and prawn farming nations, such as Vietnam and Thailand, the production system employed by most Bangladeshi producers is extremely extensive; in 2006, USAID reported that shrimp yields in Bangladesh were 17 times less than in Thailand, 7 times less than in China, and 5 times less than India. Presently, China produces more farmed shrimp and prawn than any other nation in Asia, followed (in descending order) by Vietnam, Indonesia, India, Thailand, Bangladesh, Myanmar, Philippines, Malaysia, and Cambodia. The higher productivity of other nations, in comparison to Bangladesh, can partly be attributed to the recent shift to *L. vannamei* culture in many Asian countries. *L. vannamei* is an introduced, non-indigenous species that was first commercially cultured in China and Taiwan in 1996, and it can be grown much more intensively and quickly than the target species in Bangladesh. Because of these production differences, *L. vannamei* is more competitive in the marketplace than other varieties of shrimp; over the last few years, Bangladesh has seen its market share diminish as sales of *L. vannamei* have surged. The Government of Bangladesh is coming under increasing pressure to allow *L. vannamei* cultivation in Bangladesh, but so far, the ban on *L. vannamei* culture is still in place because of the government's ecological concerns.

This Seafood Watch assessment involves a number of different criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability. The following is a brief summary of the key points discussed in each criterion.

Data

Data quality and availability on the shrimp and freshwater prawn farming sector in Bangladesh is generally high. As a developing nation, Bangladesh is the recipient of funding and assistance from numerous U.S. and E.U. government organizations and NGOs and, partly as a result of this attention, there is a large volume of peer-reviewed literature available on the shrimp and freshwater prawn farming value chain and associated aspects of the industry. The final numerical score for Criterion 1 – Data is 8.86 out of 10.

Effluent

Shrimp and freshwater prawn ponds in Bangladesh are typically net removers of nutrients from the environment, because studies have demonstrated that discharge water often has lower nitrogen and phosphorus loads than influent water. Since evidence demonstrates that effluent discharges from Bangladesh shrimp farms do not cause or contribute to cumulative impacts at the regional or waterbody scale, the final score for Criterion 2 – Effluent is 8 out of 10.

Habitat

The main impacts caused by shrimp farms in Bangladesh have been identified as coastal mangrove destruction and saltwater intrusion, which are primarily contributed to by *P. monodon* cultivation. The conversion of mangroves to shrimp ponds contributes to a decline in biodiversity and nursery habitats for multiple species, and removes a much-needed buffer against storm surges and cyclonic events. Saltwater intrusion is particularly destructive because it affects agriculture production and the availability of potable water. Because there is evidence of ongoing conversion of high value habitat for shrimp farming, the score for *P. monodon* for Factor 3.1 is 0 out of 10. In contrast, *M. rosenbergii* farms are located inland, often on lands previously converted for rice culture; academic literature generally considers their impact low-moderate, so the score for Factor 3.1 is 7 out of 10. Government policies are in place to govern the shrimp and freshwater prawn farming industry, and they are generally based on ecological principles, but they do not account for the cumulative impact of the industry and their enforcement is weak, which results in a Factor 3.2 score of 0.8 out of 10 for both species. The final score for Criterion 3 – Habitat is 0 out of 10 (which is a Critical "Red" rating) for *P. monodon* and 5 out of 10 for *M. rosenbergii*.

Evidence or Risk of Chemical Use

A variety of chemicals are used in Bangladeshi shrimp aquaculture with the aim of enhancing soil and water quality and implementing biological control of the pond, e.g., the containment of phytoplankton blooms, aquatic plant growth, and disease vectors, and the removal of unwanted wild fish. Although the aquaculture sector in Bangladesh has been expanding rapidly, the overall use of chemicals in shrimp and freshwater prawn farming is quite low compared to elsewhere in Asia because of the extensive production methods employed. Additionally, the risk of ecological impact from the chemicals used is also quite low. The final score for both *P. monodon* and *M. rosenbergii* is 8 out of 10.

Feed

The farming of *P. monodon* in Bangladesh is extensive, with little or no feed inputs, and the dietary requirements of this species are met only or mainly by the natural productivity of phytoplankton and zooplankton in the pond. When supplementary diets are provided, they are usually homemade, using locally available ingredients, sometimes with the addition of domestically sourced fishmeal. Wild-harvested freshwater apple snail meat *(Pila globosa)* is the dominant feed source provided to *M. rosenbergii*. Though the scoring of *P. monodon*'s on-farm feed practices has been done following all assumptions and standard values in the Seafood Watch Aquaculture Standard, the near-exclusive use of freshwater snail meat in *M. rosenbergii* culture necessitated minor modifications to scoring calculations.

Wild fish use in feeds for *P. monodon* culture is relatively low, therefore the Feed Fish Efficiency Ratio (FFER) for *P. monodon* is 0.01; the equivalent calculation for *M. rosenbergii*, based on snail meat inclusion, is 1.15. Around 80%–85% of fishmeal used in Bangladesh comes from local waters and, because both inland and marine fisheries are reportedly overexploited, the Sustainability of the Source of Wild Fish score (F5.1b) is –10 out of 10 for *P. monodon*. All of the freshwater apple snail meat used for *M. rosenbergii* cultivation is sourced domestically, and there is evidence that harvesting of these snails for freshwater prawn culture has contributed greatly to a decline in their population. The Sustainability of the Source of Wild Fish score (F5.1b) is therefore –10 out of 10 for *M. rosenbergii*. When these factors are combined, the final score for Factor F5.1 – Wild Fish Use is 9.97 out of 10 for *P. monodon* and 4.83 out of 10 for *M. rosenbergii.*

P. monodon supplementary feed is mainly derived from edible crops, but because most farmers rely on natural pond productivity, the net protein output on a national scale is more than 12 times the net protein input provided by supplementary feed. Because freshwater snails used in *M. rosenbergii* farming are not considered directly edible, their use results in a similarly high net gain in edible protein. For both species, the score for Factor 5.2 is 10 out of 10. Because supplemental feed inputs are minimal in *P. monodon* farming, it takes only 0.06 ha of ocean and land area to produce 1 MT of shrimp. For *M. rosenbergii*, an estimated 0.82 ha of freshwater ecosystem area is appropriated per MT of production. These area appropriations are considered low, and the Factor 5.3 score for both species is 9 out of 10.

Feed inputs for *P. monodon* are extremely minimal, which results in a final score for Criterion 5 – Feed of 9.74 out 10. Because larger quantities of feed inputs are used during production of *M. rosenbergii*, it has a correspondingly lower overall Criterion 5 – Feed score of 7.16 out of 10.

Escapes

The risk of farmed shrimp and freshwater prawn escaping from production systems in Bangladesh is high because ponds experience frequent flooding events. But individuals that do escape have either been collected from the wild or are the first generation progeny from wild broodstock, meaning that the likelihood of genetic disturbance caused by escapees is relatively low. Wild populations of *P. monodon* and *M. rosenbergii* are reportedly in decline, therefore the risk of ecological impact on these stocks caused by farm escapes, in terms of increased competition for wild habitat resources, is low. The final score for Criterion 6 – Escapes is 4 out of 10.

Disease; pathogen and parasite interactions

Disease has had a major impact on the global shrimp farming sector, causing mass mortalities and threatening the economic sustainability of the industry. Diseases in *P. monodon* and *M. rosenbergii* in Bangladesh have been reported to include white spot disease, black gill disease, and black or brown spot disease. *M. rosenbergii* additionally suffers from soft shell disease and disease associated with broken antennae and rostra. White spot syndrome virus (WSSV), which is the causative agent of white spot disease, is widely prevalent in the marine environment of Bangladesh and is the most significant of these ailments, both in terms of ecological and on-farm impact. WSSV is one of the major constraints to the economic viability and sustainability of *P. monodon* production because it is acute in nature and causes high mortalities, up to 100%, in a matter of weeks. Although this disease also affects *M. rosenbergii*, it is not fatal and individuals may become asymptomatic carriers. Diseases are reportedly not a major constraint to *M. rosenbergii* production, but the *P. monodon* sector is trapped in a vicious cycle in its efforts to combat white spot because wild-sourced broodstock (on which the sector relies) is a carrier of this disease and a high percentage of WSSV observed in hatchery-raised postlarvae shrimp (PLs) is likely a direct result of vertical transmission from wild parents. It is probable that WSSV entered Bangladesh via imported PLs during the early 1990s. Although there is no specific evidence that diseases are transmitted to wild populations from shrimp and prawn farms, this would seem likely, given the interconnectedness of farm and natural water bodies. But evidence shows that pathogens in farm populations do not appear to be amplified above levels found in the wild, so the score for Criterion 7 – Disease is 8 out of 10.

Source of Stock – independence from wild fisheries

At present, hatchery production of both *P. monodon* and *M. rosenbergii* relies entirely on wild broodstock, the quality and quantity of which is in decline. In the last few years, hatchery production of *P. monodon* has reportedly risen sufficiently to meet the demand of farmers; however, cultivation of *M. rosenbergii* relies heavily on wild-sourcing of juveniles. Hatchery production of *M. rosenbergii* has dropped significantly over the last few years, and current production statistics indicate that around 98.5% of *M. rosenbergii* PLs are wild-sourced with only 1.5% of demand being met by hatchery production. This represents a critical bottleneck to the sustainable operation or expansion of *M. rosenbergii* culture in Bangladesh. In the long term, neither wild collection of PLs nor reliance on wild broodstock is sustainable. Because there are significant differences in the source of fry for each production system (i.e., both impact wild broodstock but only *M. rosenbergii* production continues to stock wild juveniles), this criterion has been assessed separately for each species. Because the use of wild-sourced individuals for each sector is demonstrably unsustainable, the score for Criterion 8X – Source of Stock for both *P. monodon* and *M. rosenbergii* is –10 out of –10, which is a “Red” rating.

Wildlife and predator mortalities

The impact of *P. monodon* and *M. rosenbergii* farming on predators and other wildlife species in Bangladesh appears to be minimal, with only passive, exclusory control methods employed by farmers and the occasional use of pesticide prior to pond stocking. No population-level impacts have been reported, although mortality of individuals resulting from interactions with shrimp and freshwater prawn farms in Bangladesh may occur in exceptional cases. Thus, the final score for Criterion 9X – Wildlife and Predator Mortalities is –2 out of –10.

Escape of unintentionally introduced species

Although importation of *P. monodon* fry into Bangladesh did occur in the early 1990s, these cross-border shipments of fry no longer take place. A new hatchery initiative has recently started to use imported *P. monodon* SPF broodstock from Hawaii, although production numbers are presently insignificant. No evidence of importation of *M. rosenbergii* PLs has been identified, but diminishing local hatchery production of this species may increase the likelihood of this occurring. The risk of unintentionally introduced species escaping from *P. monodon* and *M. rosenbergii* farms in Bangladesh because of the international and trans-waterbody movement of animals is not presently a concern, and the final numerical score for Factor 10X – Escape of Unintentionally Introduced Species is 0 out of –10.

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Giant Tiger Prawn (Black Tiger Shrimp), *Penaeus monodon*
Giant Freshwater Prawn, *Macrobrachium rosenbergii*

Geographic Coverage
Bangladesh

Production Method(s)
Ponds (coastal, inland, mainly polyculture or alternated with rice culture)

Species Overview

Brief overview of *P. monodon*
P. monodon is a tropical marine shrimp that is indigenous to Bangladesh; it is found naturally in the Indian Ocean and the western Pacific (Indo-West Pacific), with a distribution range that includes much of Asia and reaches as far north as Japan and North Korea and as far south as Australia. The Food and Agriculture Organization (FAO) online species profile for *P. monodon* describes its preferred habitat to be brackish, estuarine environments, where it inhabits bottom mud or sand, and states that it can tolerate a range of salinities from 5–45 ppt and temperatures between 18°C and 35.5 °C. Although it can be cultivated commercially at salinities of 1–5 ppt, the optimal range is 15–25 ppt. *P. monodon* begins life offshore; this planktonic larval stage lasts 2–3 weeks, after which the larvae migrate toward the coast to the protection of mangrove swamps and estuaries where, over the next 6 months, they will complete their benthic postlarval and juvenile phases. They return to deeper water as adolescents and when ready to spawn; their depth range is 0–110 m. *P. monodon* can grow to over 33 cm, making it the largest shrimp that is commercially available. The common name, black tiger shrimp, derives from the distinctive black and white bands that extend around its carapace and abdomen.

Brief overview of *M. rosenbergii*
M. rosenbergii is indigenous to Bangladesh and has a wide distribution throughout the tropical and subtropical waters of the Indo-Pacific region, including parts of Oceania and some Pacific Islands. It has also been introduced to numerous other countries where it is cultured commercially. Its natural habitat is in rivers and estuaries, ponds, canals, lakes, and floodplains. According to New (2002), it is the largest species of this genus; males can grow to 32 cm and females to over 25 cm. Adult males can easily be identified by their extremely long claws; the genus name *Macrobrachium* means “large arms.” A range of environmental conditions, particularly temperature, affects growth rates. *M. rosenbergii* is a catadromous species, and gravid females migrate downstream to brackish water to hatch their eggs; the larval stage, which lasts several weeks, must take place in brackish water to ensure survival. If larvae hatch

in freshwater they will only live a few days if the salinity does not increase. Unlike Penaeid shrimp, which release fertilized eggs straight into the sea, the *M. rosenbergii* female carries her fertilized eggs in a brood chamber and keeps them protected and aerated for up to 3 weeks before they hatch and disperse as planktonic larvae. After the larval stage, they metamorphose into postlarvae (PLs), cease to be free swimming, and mainly crawl. Within a few weeks, they migrate upstream to freshwater and start to eat a wider range of organic materials; they are opportunistic, benthic omnivores and can also be cannibalistic. The depth range is 1–2 m. Chand et al. (2015) note that *M. rosenbergii* can be cultured in a wide salinity range from 0–15 ppt, with salinity becoming lethal at an average of 24.6 ppt. *M. rosenbergii* cannot be reared as intensively as its marine counterparts, at least not with current technologies, because it is territorial and its growth rates are not uniform (Asia-Pacific Fishery Commission 2014). Culture of this species is versatile in scale; it can be grown in large facilities but it is also suitable for artisanal farmers.

Production systems: Extensive and Improved Extensive

Extensive production systems dominate the aquaculture sector in Bangladesh, with the majority of farmers following traditional practices. These traditional methods are low maintenance, with little management input in terms of pond preparation (e.g., drying, plowing, liming, fertilization, water exchange and feeding), and they depend mainly on the natural productivity of the pond—although some supplementary feeds are often used, particularly in *M. rosenbergii* culture. In extensive systems, stocking densities are low and in the range of 0.2–1.5 PL/m^2 (2,000–15,000 PL/ha). Extensive production techniques are used for up to 80% of shrimp production; Rahman (2013) puts the figure at 90% and Debnath et al. (2016) states that 87.77% of farmers follow traditional methods, with an average production of just 280–300 kg/ha.

There is an organic shrimp culture initiative in Bangladesh, called the Organic Shrimp Project (OSP) (SEAT 2013a); it was started in 2005 by the Swiss Import Promotion Program (SIPPO) and is now overseen by WAB-Trading Limited, a German importation organization. By the end of 2012, there were 1,831 shrimp farmers certified organic per E.U. organic regulations and, in 2013, Sustaining Ethical Aquaculture Trade (SEAT) reported that the number of registered organic farms had grown to around 2,000. All organic farms follow extensive production practices. OSP farms are currently certified by Naturland (Paul and Vogl 2012).

The balance of farmers, who do not practice extensive culture techniques, follow a slightly modified version of these traditional methods, utilizing basic pond preparation, water treatment, and feeding strategies, and this method is referred to as improved extensive. Improved extensive systems stock 1–2.5 PL/m^2 (10,000–25,000 PL/ha) and corresponding yields are 350–500 kg/ha. To improve survival rates, some farmers have recently started to implement the use of a nursery net cage, called a *hapa*; newly stocked PLs are afforded better protection because they are kept in hapas for the first few weeks (Ahmed 2013a). There has been some experimentation with more intensive methods, in which stocking densities are increased to 5–10 PL/m^2 (50,000–100,000 PL/ha), commercial pelletized feeds are used, aeration systems are installed, and attention is given to waste removal, but this method requires much more investment and is not implemented in Bangladesh to any significant extent. Authors Rahman and Hossain (2009) report that there were 37 semi-intensive shrimp farms developed in Bangladesh in the early 1990s, which covered an area of 48 ha. These semi-intensive farms were funded by outside investors, who suffered large financial losses when the first outbreak of white spot disease occurred in 1994; the farms ceased operation and there was no further interest in development of semi-intensive farms (Rahman and Hossain 2009). More recently, Debnath et al. (2016) note that 0.23% of the culture area for shrimp is engaged in semi-intensive production.

Shrimp and freshwater prawn culture is mainly conducted in converted rice fields, which are known as *ghers*. In 2014, it was reported that 95% of shrimp and freshwater prawn farms were registered with the Department of Fisheries (DOF), with the assistance of the Bangladesh Quality Support Programme (BQSP), an E.U.-financed initiative (Akter et al. 2014). Gher systems are found in the south of the country and cover a total area of 275,277 ha. Of this area, 78% is used for *P. monodon* cultivation and the remaining 22% is used for farming *M. rosenbergii.* The average size of a freshwater prawn farm is much smaller (0.57 ha) in comparison to the average size of a black tiger shrimp farm (2.10 ha), which means that production from black tiger shrimp farms is greater but the number of freshwater prawn farms is higher (Belton et al. 2011). Bangladesh DOF statistics are provided in Table 1 and show the amount of hectares and volume of production for each species.

Table 1: Pond area and production volume statistics for aquaculture of *P. monodon* and *M. rosenbergii* (Source: Bangladesh Department of Fisheries Yearbook: Fiscal Year 2013–14 [1 July-30 June])

	Area (Ha)			**Shrimp/Prawn Production (MT)**		**Total (MT)**
District	***P. monodon***	***M. rosenbergii***	**Total Area**	***P. monodon***	***M. rosenbergii***	**Production**
Dhaka Div.	0.00	1,444.39	1,444.39	0.00	668.00	668.00
Khulna Div.	160,532.03	54,196.23	214,728.26	55,208.00	39,378.00	94,586.00
Barisal Div.	7,286.52	2,684.03	9,970.55	2,627.00	1,352.00	3,979.00
Rangpur Div.	0.00	10.92	10.92	0.00	3.00	3.00
Rajshahi Div.	0.00	7.97	7.97	0.00	2.00	2.00
Chittagong Div.	47,486.45	1,626.38	49,112.83	13,595.00	693.00	14,288.00
Sylhet Div.	0.00	2.31	2.31	0.00	1.00	1.00
Total	**215,305.00**	**59,972.23**	**275,277.23**	**71,430.00**	**42,097.00**	**113,527.00**

Polyculture is the norm in Bangladesh, with a variety of fish also being cultured simultaneously in shrimp and prawn ponds. Taken as a percentage of total volume of aquaculture production generated in shrimp and prawn ponds, *P. monodon* amounts to 33% and *M. rosenbergii* to 19.45% (Source: FRSS 2015).

The conditions on the tidal flood plain are not suitable for agriculture during the dry months of January to July; there is no freshwater available on the coast for irrigation, salinity levels in surface water and groundwater are high, and the soil becomes more acidic with sun exposure. During this high salinity period, farmers will often grow black tiger shrimp and euryhaline fish in the gher. When salinities drop between August and December, freshwater prawn and freshwater fish can be added and cultured along with black tiger shrimp, often with slightly salt-tolerant aman paddy planted in the elevated parts of the gher (Belton et al. 2011). Inland *M.*

rosenbergii farms sometimes grow boro rice concurrently with freshwater prawn during the dry season (Wahab et al. 2012). Table 2 describes typical shrimp and freshwater prawn culture system variables; these systems often integrate production with fish and/or rice and food plants (dike cropping).

Table 2: Typical shrimp and freshwater prawn culture system variables (Source: Jahan et al. 2015)

Technology & Type of Water Body	**Integration with Agriculture**	**Culture techniques and management practices**
Carp & prawn (commercial pond)	Integrated with pond dikes for dike cropping	**Species cultured:** Target species are carp and prawn polyculture with tilapia and local small fish species. **Culture period:** Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Extensive to semi-intensive.
Shrimp (gher)	No integration due to high salinity	**Species cultured:** Target species is shrimp polyculture with carp, tilapia and euryhaline brackish-water species. **Culture period:** Varies between locations. Generally, farmers stock in January–February and harvest in December–January. **Management practices:** Extensive.
Shrimp & rice (gher)	Alternate rice production when salinity becomes low; integrated with dikes for dike cropping	**Species cultured:** Target species is shrimp polyculture with carp, tilapia and euryhaline brackish-water species. Cultivation of a slightly salt-resistant transplanted Aman paddy in the elevated parts of the fields. **Culture period:** Generally, farmers stock in February–March and harvest in September–October. **Management practices:** Extensive.
Shrimp & prawn & rice (gher)	Starts with shrimp and during rainy season integrates prawn and rice for concurrent practice; integrated also with dikes for dike cropping	**Species cultured:** Target species are shrimp and prawn polyculture with carp, tilapia and some non-stocked fish species. Cultivation of rice in the elevated parts of the fields. **Culture period:** Varies between locations. Generally, farmers stock in March–April and harvest in November–December. **Management practices:** Semi-intensive.

Because the salinity of the gher fluctuates with the seasons, farmers can use the same system to produce a variety of crops throughout the year. According to Alam (2004), in coastal areas where *P. monodon* is cultured, it is normal for non-target species of shrimp and fish to make up a significant amount of production. The practice of polyculture increases the possibility of the main target species being predated upon and out-competed for the food that occurs naturally in the pond, but it also results in an increase in the total biomass yield. Polyculture spreads the risk if a shrimp disease issue arises, and contributes to economic and food security for shrimp farmers, with non-target species often being used to feed family members and farm laborers. Alam further comments that there are three main categories of farm ownership: individual owners, farm groups (about 50% of yields from both of these categories are from non-target species), and outsider lease operators; i.e., the farm is managed by operators who live outside the locality (this category was more inclined toward monoculture than the other two, but production was still only 63% of the target species).

System type	Species combination
Monoculture	Only shrimp cultured
Shrimp and paddy (gher) culture	Shrimp—February to August
	Paddy—August to January
	Paddy and shrimp sometimes cultured together (February to June)
Shrimp and salt culture	Salt—January to March
	Shrimp—March to November
Shrimp and prawn gher culture with paddy and fish	Shrimp—in dry season (Feb to Aug)
	Prawn (golda)—July to January
	Carp and paddy culture integrated with shrimp and prawn

Figure 1: Types of gher farming systems based on species combination and integration with agriculture (Source: Belton et al. 2011)

A rice field is converted into a gher by building a high dike around it (called a *polder*) and excavating a deep canal around it to retain water during the dry season. The flow of brackish, tidal water is controlled by sluice gates and canals, which connect to the estuaries. In the 1970s, which were the early days of modern shrimp and freshwater prawn culture in Bangladesh, wild fry were naturally introduced into the gher at high tides. Today, this has mainly been replaced by stocking either from wild collection or from hatchery production. Although wild-sourcing of fry was banned in 2000 (Verité 2009), culture of *M. rosenbergii* is still depends largely on wild-sourced PLs. Freshwater prawn and black tiger shrimp hatcheries are relatively new in Bangladesh; the first commercial hatchery was established in 1992 (Debnath et al. 2015). One of the main elements necessary to ensure future success in production of fry is the improvement of technical expertise in hatcheries.

In March 2015, *The Daily Star*, a newspaper in Bangladesh, released an article entitled "New shrimp farming system to boost yields," in which it reports that "a growing number of shrimp farmers and processors are giving up traditional farming practices and turning to improved aquaculture to boost yields and exports. Acreage of shrimp under a modern farming technology (semi-intensive shrimp farming) rose to 1,100 hectares this year from 800 hectares a year ago. The improved farming practices were seen only on 10 hectares of land in 2002, said Prafulla Kumar Sarker, district fisheries officer of Khulna, a hub for shrimp farming and pioneer in modern practices." It would therefore appear that there may be a trend toward adoption of more intensive production technologies in the future.

The Bangladesh Frozen Foods Exporters Association (BFFEA), the local trade organization that represents frozen food processors and exporters, states on its website that there are around 145 export-oriented seafood processors in Bangladesh.

Figure 2: Location of shrimp farms and fish processing industries in Bangladesh (Source: Bangladesh Frozen Foods Exporters Association [BFFEA]).

The shrimp and freshwater prawn farming sector in Bangladesh is expanding; production tripled between 1998 and 2008, and the cultivation area expanded from less than 20,000 ha to 275,277 ha between 1980 and 2014. The majority of farming occurs in the southwest of the country, particularly in Bagerhat, Satkhira, and Khulna, which together contribute 80% to total production (Morf 2014). The shrimp and freshwater prawn production value chain is complex and involves about 1.2 million people, with 4.8 million additional household members associated with the industry to some degree. There are middlemen and intermediaries involved throughout the chain, with the larger processors and producers occupying the higher end of the supply chain (USAID 2006).

Production Statistics

Aquaculture has developed rapidly in Bangladesh, and it is now ranked as the fifth-largest producer in the world (FAO 2014) with an annual percentage growth rate of 8.37% recorded between 2000 and 2012. In 2014, global aquaculture production of *P. monodon* and *M. rosenbergii* was 634,522 MT (75%) and 216,857 MT (25%), respectively. For the same year, aquaculture production of *P. monodon* in Bangladesh was 71,430 MT, which represented 11% of global production, making it the fourth-largest global producer of this species after Vietnam (27%), Indonesia (20%), and China (12%). By comparison, *M. rosenbergii* production in Bangladesh was 45,167 MT, which represented 21% of global production, making it the second-largest producer of this species after China (59%).

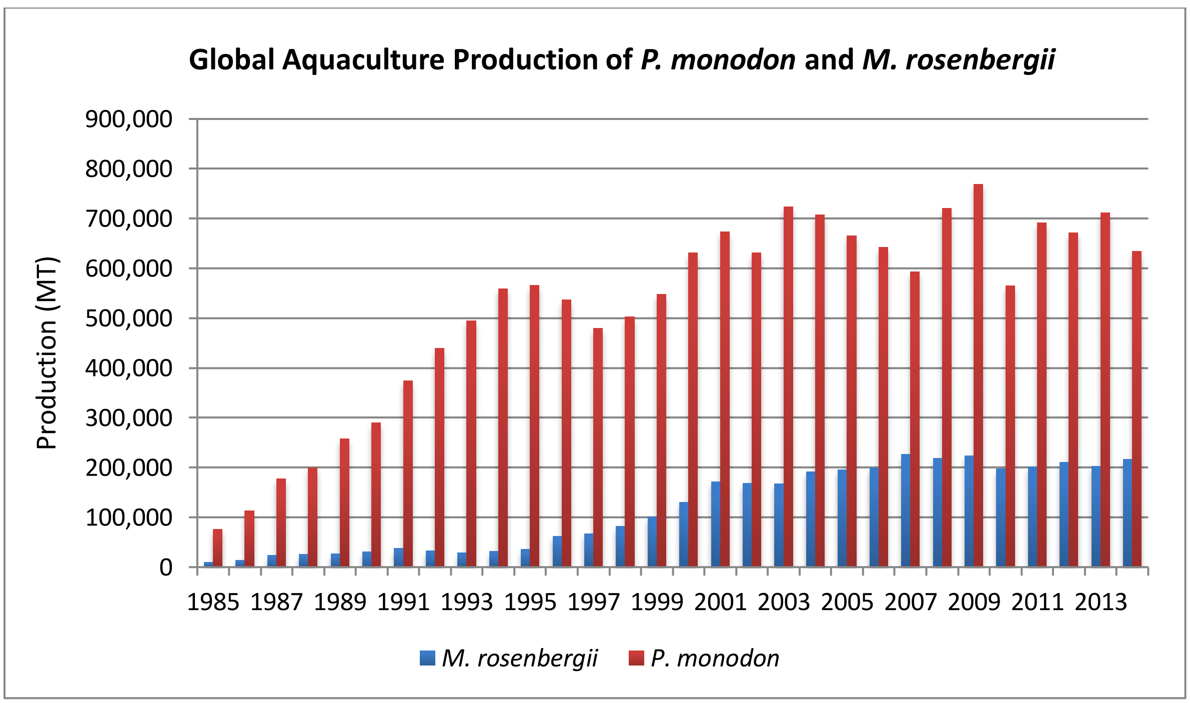


Figure 3**:** Global production of *P. monodon* and *M. rosenbergii* from 1985–2014 (Source: FAO 2014a. Fishery and Aquaculture Statistics [Global aquaculture production 1985–2014] [FishStatJ]).

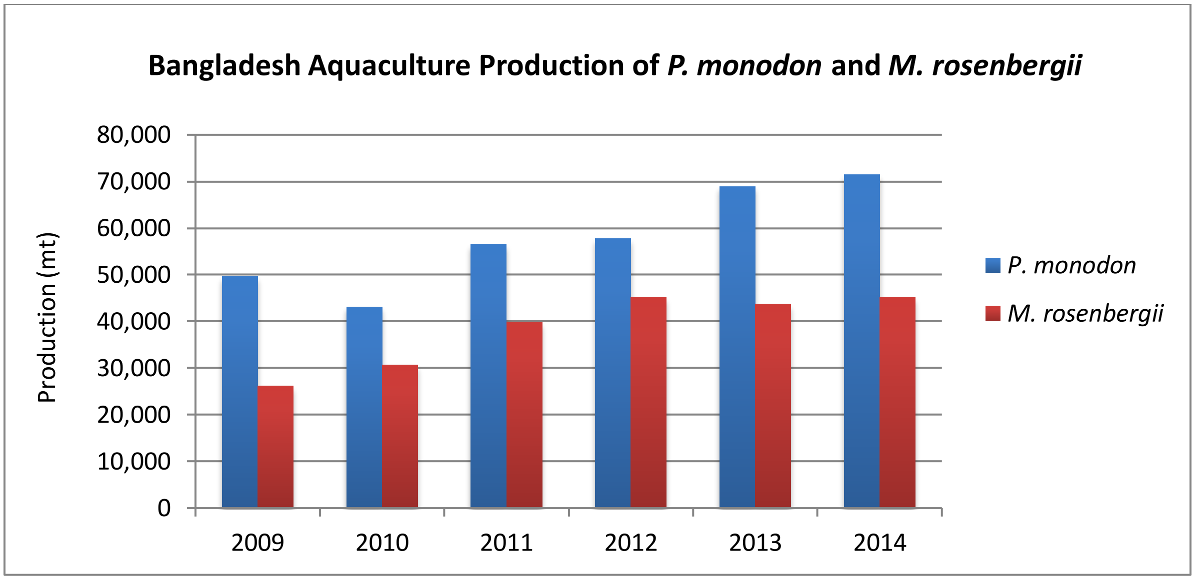


Figure 4: Production of *P. monodon* and *M. rosenbergii* cultured in Bangladesh from 2009-2014 (Source: FAO 2014a. Fishery and Aquaculture Statistics [Global aquaculture production 2009–2014[2]*] [FishStatJ]).

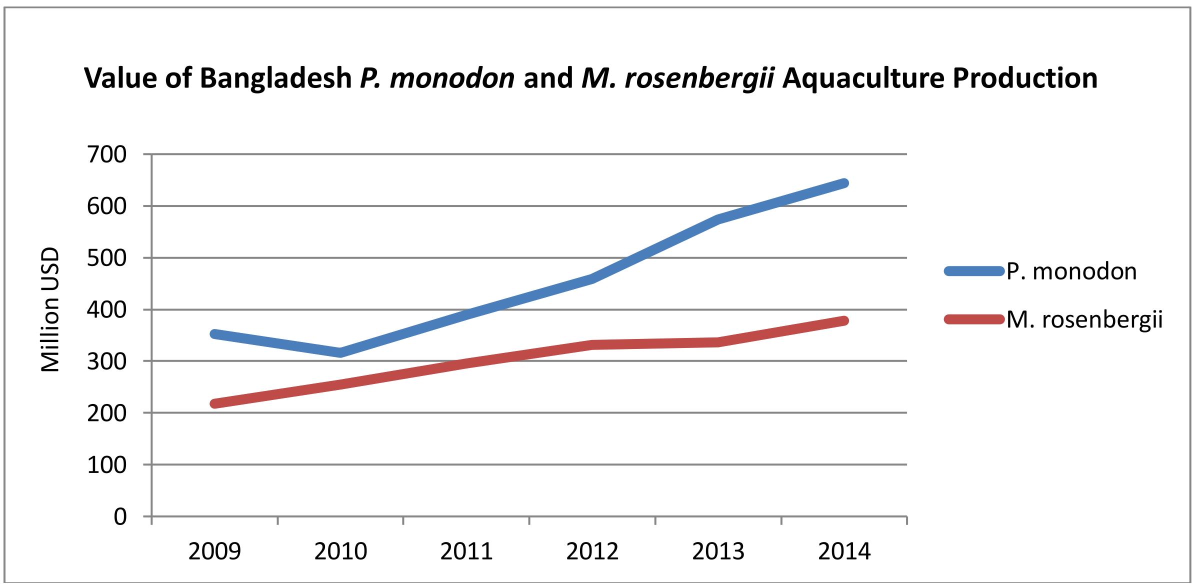


Figure 5: Value (USD) of *P. monodon* and *M. rosenbergii* cultured in Bangladesh from 2009–2014 (Source: FAO 2014a. Fishery and Aquaculture Statistics [Global aquaculture production 2009-2014] [FishStatJ]).

A recent report on the Asian shrimp sector (Portley 2016) highlights some interesting data concerning shrimp and freshwater prawn production in Bangladesh. In addition to using national and FAO statistics, the author of the report engaged local expertise to obtain trade and production data. This is helpful, because national statistics do not clearly differentiate farmed

[2] Note that prior to 2009, *P. monodon* was reported as part of *Penaeus* shrimps nei (not elsewhere included) in Bangladesh national aquaculture statistics reported to FAO; therefore, FishStatJ does not provide specific details on *P. monodon* production before this year.

shrimp from wild-caught, and U.S. import data use the generic term "shrimp" and are not species-specific. FAO FishStatJ statistics indicate that Bangladesh's combined production of *P. monodon* and *M. rosenbergii* in 2014 was 116,597 MT (representing 55% and 35% of total culture production, respectively), with a further 13,595 MT of cultured shrimp of other species also recorded, which comprised 2% *Metapenaeus monoceros* (common name: speckled shrimp, brown shrimp, Harina shrimp), 1% *Penaeus indicus* (Indian white prawn), 4% *Penaeus* shrimps nei (not elsewhere included), and 3% freshwater prawn/shrimp nei. These figures differ somewhat from those in Portley (2016), which puts the annual production figure of farmed shrimp at 148,200 MT for 2014 and lists slightly different percentages for the contribution of different species to this amount. It should be noted that FishStatJ also lists generic wild-capture of crustaceans, with 2014 production as follows: freshwater crustaceans nei, 45,928 MT; marine crustaceans nei, 47,668 MT.

It is important to note that because shrimp and freshwater prawn farming in Bangladesh is extremely extensive in nature, total production is partially achieved by naturally recruited shrimp and prawn species. There are at least 36 indigenous marine shrimp species and 56 species of freshwater prawn (Rahman 2015), including 10 species of *Macrobrachium*, although only *M. rosenbergii* is cultured commercially. In addition, monoculture is rarely practiced; Wahab et al. (2012) comment, with reference to *M. rosenbergii*, that "most farmers prefer prawn and fish polyculture with rice, combined with vegetables grown on dikes; a sustainable system which is eco-friendly and profitable." Another factor, which undoubtedly affects collection of accurate production statistics, is that about one-third of the shrimp cultured and caught in Bangladesh are consumed domestically; Wahab (2012) estimates that 70% of farmed *M. rosenbergii* is exported.

Table 3: 2014 trade data for both farmed and wild-caught shrimp plus freshwater prawn from Bangladesh (Source: Portley (2016) SFP, Report on the Shrimp Sector—Asian Farmed Shrimp Trade and Sustainability).

2014 Production and Trade Data for Bangladesh Shrimp and Prawn	
Farmed Production (MT)	148,200
Wild Production (MT)	92,917
Total Production (MT)	241,117
Export Volume (Product Weight, MT)	54,500
Export Volume (Live Weight, MT)	≈109,000
Exported Proportion	≈45%
Export Market Value (USD)	$500 million
Ratio Farmed: Wild of Exports (volume):	≈89:11
Ratio of Farmed Product that is Exported: Farmed Product that Stays on the Domestic Market	≈66:34

Import and Export Sources and Statistics

Approximately two-thirds of shrimp and freshwater prawn farmed in Bangladesh is exported and the E.U. is the largest volume importer. Shrimp and freshwater prawn is the second-largest export commodity of Bangladesh; in 2011, it accounted for 22.21% of total agricultural gross domestic product (GDP) and 2.73% of total export income.

Bangladesh export statistics and U.S. import data do not differentiate between species of shrimp or whether it is wild or farmed. But data from Portley (2016) indicate that 66% of total farmed shrimp production is exported and that exports of shrimp comprise approximately 90% farmed shrimp and 10% wild.

As U.S. shrimp imports have experienced a large shift toward *L. vannamei*, imports from Bangladesh have fallen significantly. Figure 6 shows the downward trend in volume and value that shrimp imports from Bangladesh into the U.S. have taken.

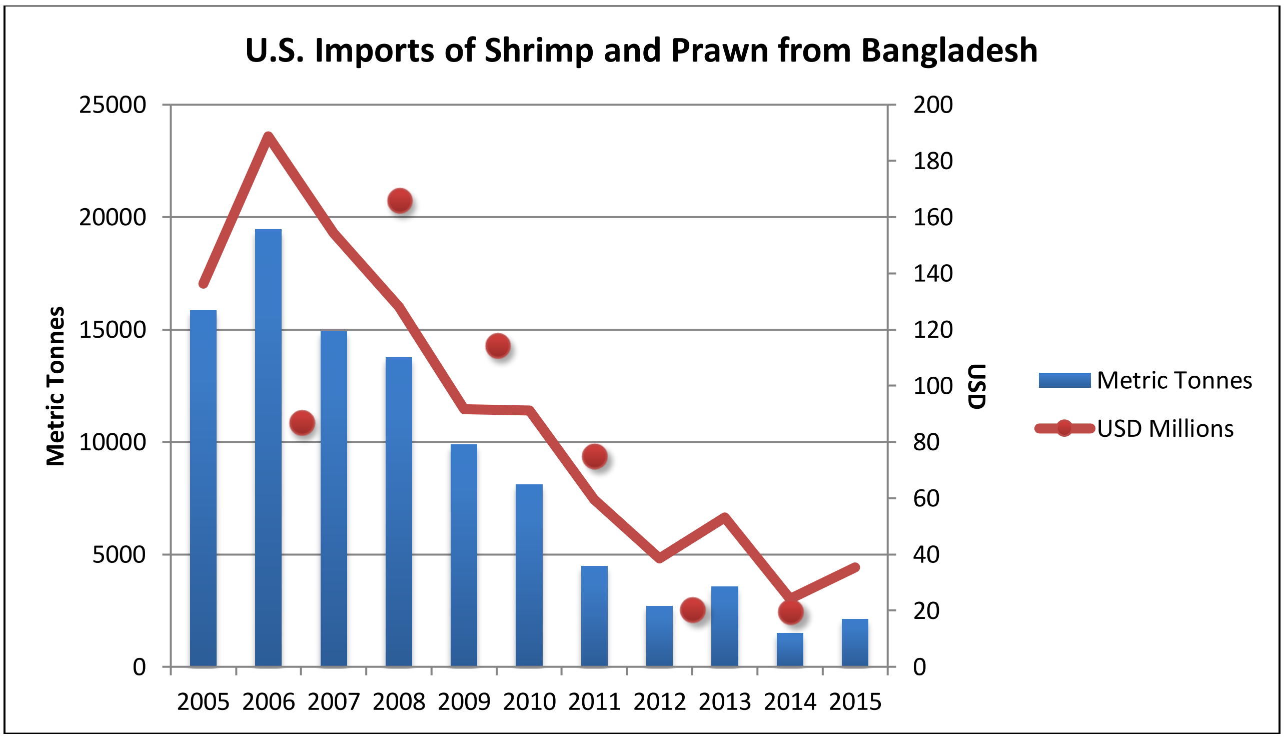


Figure 6: Quantity and value of Bangladesh shrimp and freshwater prawn imported into the U.S. between 2005 and 2015 (Source: USDA Economic Research Service).

Common and Market Names

Scientific Name	*Penaeus monodon*
Common Names	Black tiger shrimp, black tiger prawn, Asian tiger shrimp, tiger shrimp, tiger prawn, giant tiger prawn; known as bagda in Bangladesh
Scientific Name	*Macrobrachium rosenbergii*
Common Names	Giant freshwater prawn, giant river prawn, Malaysian prawn; known as galda or golda in Bangladesh

Product forms imported into the U.S.

Shell on (SO or "green headless shrimp"), peeled tail on (PTO), peeled undeveined (PUD), peeled and deveined (P&D), butterfly tail on (BTTY-TO).

Analysis

Scoring guide

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

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data Category	Data Quality	Score (0-10)
Industry or production statistics	10	10
Management	7.5	7.5
Effluent	7.5	7.5
Habitat	10	10
Chemical use	10	10
Feed	7.5	7.5
Escapes	5	5
Disease	10	10
Source of stock	10	10
Predators and wildlife	10	10
Introduced species	10	10
Other – (e.g., GHG emissions)	Not Applicable	n/a
Total		**97.5**

C1 Data Final Score (0–10)	8.86	GREEN

Brief Summary

Data quality and availability on the shrimp and freshwater prawn farming sector in Bangladesh is generally high. As a developing nation, Bangladesh is the recipient of funding and assistance from numerous U.S. and E.U. government organizations and NGOs and, partly as a result of their attention, there is a large volume of peer-reviewed literature available on the shrimp farming value chain and associated aspects of the industry. The following assesses the robustness and accessibility of data used to determine the final score for each criterion.

Justification of Rating

Effluent

A number of field surveys have been conducted in Bangladesh to evaluate the environmental impact of nutrient loading from the effluent of shrimp farms. Although these studies are not numerous, they are highly specific in their analyses of the ecological impact of shrimp farm effluent. Taken together, these surveys provide a good overview of effluent impacts from a variety of farms that stock either *P. monodon* or *M. rosenbergii*, or both concurrently, in different regions of Bangladesh. The fact that all authors concur in their conclusions, that nutrient loading from shrimp farms into the surrounding environment is insignificant, lends further credibility to the robustness of the data available on this criterion. A final score of 7.5 out of 10 has been assessed for data availability and quality as it pertains to Criterion 2 – Effluent.

Habitat

The two main habitat impacts discussed in this criterion are mangrove deforestation and saltwater intrusion, which apply primarily to *P. monodon* cultivation. Mangrove deforestation has been written about extensively in a global context, often referring specifically to Bangladesh. Since Bangladesh is home to the Sunderbans, the world's largest contiguous mangrove forest, there is a great deal of peer-reviewed literature available on this particular unique habitat, and further studies have been carried out to assess the impact of shrimp farming on other areas of mangrove forest within the country. Saltwater intrusion is primarily a result of climate change, a subject on which there is no shortage of reliable data. In Bangladesh, shrimp farming is cited as the secondary major cause of saltwater intrusion, so there is also high data availability on this topic. In contrast, literature on cultivation of *M. rosenbergii* often notes that it has moderate habitat impacts at the farm boundary level. The other aspect covered in this criterion is the content and enforcement of management measures—a subject that is covered in depth by several authors of peer-reviewed literature. A final score of 10 out of 10 has been assessed for data availability and quality for Criterion 3 – Habitat.

Chemical Use

A number of recent, detailed surveys have been conducted on chemical use in Bangladesh, and data on this criterion are readily available. A particularly comprehensive and recent study was conducted in Bangladesh between November 2011 and June 2012, which the author reports is the largest study of chemical use in Bangladesh to date. This comprehensive study collected data from almost 1,900 farms engaged in producing a variety of aquaculture species, including 310 shrimp farms, 134 shrimp and freshwater prawn farms, and 212 freshwater prawn farms. This document was invaluable in assessing this criterion, and its credibility was verified by cross-referencing data from other sources that also studied chemical inputs in shrimp and freshwater prawn farms in Bangladesh. A final score of 10 out of 10 has been assessed for data availability and quality as it pertains to Criterion 4 – Chemical Use.

Feed

Feed use in the Bangladesh shrimp and freshwater prawn sector is fairly minimal, but there is an abundance of literature on this topic. Numerous, easily accessible, in-country studies include an evaluation of feed quality and feed management practices used in Bangladesh. One particularly comprehensive and in-depth study was conducted during 2012 by WorldFish, as part of the USAID Feed the Future Aquaculture project. During this study, 24 enumerators analyzed the trends and behaviors of the aquaculture sector at large, including a detailed examination of the aquaculture feed-value chain in relationship to feed use and production. The high quality of data provided by this report was particularly useful in ascertaining accurate feed inputs for both species under consideration. Specific data on the protein content of feed inputs were obtained from an FAO study and analysis of aquaculture feeds used in Bangladesh. Information on the status of local wild-capture fisheries is also available, as is the fact that most fishmeal used in shrimp and freshwater prawn cultivation in Bangladesh is locally sourced; however, specific information is sparse about which species compose locally manufactured fishmeal. The plight of freshwater apple snail and its declining population has been written about in detail by a number of authors, especially about the impact that *M. rosenbergii* culture has on this species because of the heavy reliance on snail meat. Data availability, quality, and confidence in its content have therefore been assessed to be moderate-high with regard to feed use in Bangladesh. A final score of 7.5 out of 10 has been assessed for Criterion 5 – Feed.

Escapes

Although no data are available that actually quantify escape events from shrimp and freshwater prawn farms in Bangladesh, there is ample information concerning the indigenous nature of *P. monodon* and *M. rosenbergii*, the amount of wild fry versus hatchery reared PLs used in production, and the fact that all hatchery-produced fry are first generation. There is no comprehensive study available on the present health of wild *P. monodon* and *M. rosenbergii* stocks, but there is a substantial amount of data that indicates that these stocks are in decline. A final score of 5 out of 10 has been assessed for data availability and quality as it pertains to Criterion 6 – Escapes.

Disease; pathogen and parasite interactions

Disease has had a major impact on the global shrimp farming sector, causing mass mortalities and threatening the economic sustainability of the industry. The most significant disease affecting shrimp production in Bangladesh is white spot syndrome virus (WSSV), the causative agent of white spot disease (WSD). Prior to the recent emergence of early mortality syndrome (EMS), WSSV was considered to be the most significant disease threat to shrimp culture in Asia. It has been estimated that WSSV has caused global revenue losses in the range of USD 8 to 15 billion; as a result, there is a great deal of literature available on this topic. There are also numerous papers that address the effect of WSSV on shrimp culture in Bangladesh and the prevalence of this disease in the natural environment and in wild-sourced broodstock. One USAID-funded project, which was implemented by WorldFish, was of particular help in compiling the disease criterion for this report because of the comprehensive nature of its analysis. A final score of 10 out of 10 has been assessed for data availability and quality as it pertains to Criterion 7 – Disease.

Source of Stock

Shrimp and freshwater prawn farming is the second-largest foreign income earner in Bangladesh, so the hatchery aspect of the local shrimp farming value chain has attracted much attention and has been written about by many authors. Peer-reviewed literature was used to assess the wild collection of PLs and broodstock, plus the associated ecological impact of these activities, including their contribution to declining stocks and biodiversity as a direct result of overexploitation and large bycatch rates. A final score of 10 out of 10 has been assessed for data availability and quality as it pertains to Criterion 8X – Source of Stock.

Wildlife and predator mortalities

This criterion assesses the potential for aquaculture operations to directly or indirectly cause the death of predators or other wildlife that are attracted by the concentration of cultured aquatic animals present in a farm setting. The Bangladesh shrimp and freshwater prawn sector was scored favorably in this criterion, largely because of the lack of such mortalities evidenced in literature rather than any specific mention of such mortalities. The data reviewed for this report have generally been considered to be high quality, so it is noticeable that farm-induced mortalities (as they pertain to the focus of this criterion) have not been written about to any degree. The absence of data and discussion on this topic strongly suggests that such mortalities are not a regular concern or issue for the shrimp/prawn sector. Although predator and/or wildlife interactions are not commonly referred to in literature, there is ample discussion concerning the non-harmful, exclusory control measures that farmers have in place to exclude non-culture animals from ponds. Likewise, the occasional use of pesticides prior to pond stocking is readily mentioned in literature concerning this industry, as is the fact that incidentally recruited aquatic organisms often grow in the culture pond alongside target species. A final score of 10 out of 10 has been assessed for data availability and quality as it pertains to Criterion 9X – Wildlife and predator mortalities.

Escape of unintentionally introduced species

Both *P. monodon* and *M. rosenbergii* are native to Bangladesh, and broodstock of both species are exclusively wild-sourced from local waters—a fact that is frequently mentioned by numerous authors of peer reviewed literature. Likewise, there is a large body of literature available that describes fry collection in local waters and the production status of domestic shrimp and freshwater prawn hatcheries. Also well documented in literature is the devastating effect that importation of *P. monodon* fry into Bangladesh in the early 1990s had on production and the environment, because these cross-border movements of fry likely introduced WSSV to the country. Quite recent developments concerning the importation of SPF broodstock from Hawaii have been noted in grey literature; however, this is a nascent project, so it appears as if no peer-reviewed literature has yet been produced on this endeavor. The availability and quality of data on the *M. rosenbergii* sector is high, and notably does not contain evidence of fry importation of this species. A final score of 10 out of 10 has been assessed for data availability and quality as it pertains to Criterion 10X – Escape of unintentionally introduced species.

Conclusions and final score

Because data quality and availability on shrimp and freshwater prawn farming in Bangladesh is generally high, the overall score for this criterion is correspondingly high. But the data categories for Effluent, Feed and Escapes did not score 10 out of 10. The Effluent criterion received 7.5 because only four studies of effluent from shrimp and freshwater prawn farms in Bangladesh were identified and reviewed. Despite the relatively small number of effluent studies undertaken, these data were still considered to be highly credible because they were specific in nature and the various authors concurred in their conclusions. The Feed criterion also scored 7.5 out of 10 because there is an abundance of quality literature available concerning aquaculture feeding practices in Bangladesh, but there is a dearth of information pertaining to the status and health of local fisheries—particularly about stocks that contribute to the fishmeal used in shrimp and freshwater prawn diets. The criterion for Escapes scored 5 out of 10 because no specific data were identified that focused on quantifying escape events from shrimp and freshwater prawn farms. But data on other aspects of this criterion, such as the indigenous nature of the species being farmed and the source of these farmed stocks, were considered to be robust. The final numerical score for Criterion 1 – Data is 8.86 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: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0–10)	**8**	**GREEN**

Brief Summary

Shrimp and freshwater prawn ponds in Bangladesh are typically net removers of nutrients from the environment, because studies have demonstrated that discharge water often has lower nitrogen and phosphorus loads than influent water. Since evidence demonstrates that effluent discharges from Bangladesh shrimp farms do not cause or contribute to cumulative impacts at the regional or waterbody scale, the final score for Criterion 2 – Effluent is 8 out of 10.

Justification of Rating - Evidence-based assessment:

Because effluent data quality and availability is moderately high (i.e., Criterion 1 scores 7.5 out of 10 for the Effluent category), the Evidence-Based Assessment was utilized rather than the Risk-Based Assessment. Though the volume of evidence is not particularly large, the evidence that has been collected is specific to shrimp and freshwater prawn farms in Bangladesh, and the authors of these independently conducted studies are quite uniform in their conclusions, conferring a high level of confidence in their representation of the effluent impacts of this sector.

The first study (Rouf 2012) investigated the nutrient content (nitrogen and phosphorus) of influent and effluent water of three *P. monodon* farms, which were selected for the differences in the farms' hydrological locations (Farm 1: connected with river; Farm 2: connected with canal: and Farm 3: connected with other farms). Samples of water inputs and outputs were taken from each farm throughout their production cycle; water exchange rates were reportedly in the range of 2.2% to 14.9% of pond volume per day. Although the target species was *P. monodon*, a number of other species including *M. rosenbergii* were also either intentionally stocked or naturally introduced into the ghers. The author notes that the small amount of feed inputs used by farmers in this study were mainly homemade cereals. Tables 4 and 5 below show the results of this study.

Table 4: Effluent assessment—comparison of farms included in the study (Source: Rouf, 2012).

Pond no	Pond area (ha)	Depth (m)	Water exchange rate (%)	Stocking density (ha^{-1})	Survival rate (%)	Average Wt (g)	Gross production ($kg\ ha^{-1}yr^{-1}$)			
							P. monodon	*M. rosenbergii*	Fin fish	Total
1	2.4	0.8	66	8,398	44	28.0	105	49	34	188
2	1.3	0.73	30	16,055	50	29.0	264	31	228	523
3	0.3	0.75	15	29,640	49	32.0	323	290	185	798
Average	1.33	0.76	37	18,031	47.66	29.66	230.66 (45.85%)	123.33 (24.5%)	149 (29.6%)	503 (100%)

Table 5: Effluent assessment—average nutrient budget (per hectare basis) of shrimp ponds (Source: Rouf, 2012).

	TN		TP	
Inputs	$Kg\ ha^{-1}cycle^{-1}$	%	$Kg\ ha^{-1}cycle^{-1}$	%
Feed	10.65	21.1	2.94	9.3
Fertilizer	30.61	60.1	24.27	82.5
Shrimp fry	0.004	0.01	trace	trace
Paddy stable	1.47	3.3	1.25	5.4
Water supply	5.7	14.9	0.38	2.2
Rainfall	0.25	0.6	0.11	0.6
Total input	48.7	100	28.95	100
Outputs				
Shrimp harvest	9.7	20.2	0.86	2.5
Other fish harvest	6.45	13.1	1.16	3.5
Denitrification	6.35	13	0	0
Discharge water	5.6	14.6	0.36	2
Remainder (sediment)	20.6	39.1	26.66	92
Total output	48.7	100	28.95	100

This study found that input water had higher levels of total nitrogen (TN) and total phosphorus (TP) than output water, indicating that nutrients were retained in the ghers rather than being discharged into the wider environment. Concentrations of TP in both influent and discharge water were within an acceptable range for shrimp culture, whereas TN concentrations were not. The author suggests that the high levels of TN may be the result of high levels of ammonia nitrogen impeding the process of oxidation in the system. In this study, fertilizer was shown to be the highest nutrient input (60.1% TN:82.5% TP), followed by feed (21.1% TN:9.3% TP) and intake water (14.9% TN:2.2% TP); however, because of the biological processes occurring in the ponds, these production systems were found to be essentially TN and TP neutral. Also, only 33.3% of nitrogen and 6% of phosphorus were removed at harvest, with a large proportion remaining in the sediments (39.1% TN:92% TP). The author further comments, "the shrimp farming practice[s] in Bangladesh primarily use improved extensive farming methods. Farmers use low amount[s] of lime and fertilizers and the application of feed is rare to absent" and that the "traditional extensive system of shrimp farming does not provide any significant loading of nutrients to the surrounding coastal environment."

A similar study by Wahab et al. (2003), which assessed nine *P. monodon* farms, also concluded that extensive production systems do not contribute significant nutrient loading to the surrounding environment, pointing out that the systems evaluated depended on natural feed, with moderate use of fertilizers and manure. Table 6 provides details of one of the ghers monitored in the study. Inputs of nitrogen and phosphorus were found to be 14–21 times less than those used in intensive shrimp culture in Thailand, which relies on artificial, commercial feed, employs high water exchange rates, and has correspondingly higher effluent loads. Water exchange rates in this study were tidal-based and ranged between 0% and 10% of pond volume per day. Findings from this study indicate that extensive *P. monodon* ponds in Bangladesh producing less than 1,000 kg/ha are in fact net removers of nutrients from the environment, acting as a sink for nutrients and solids.

Table 6: Effluent assessment—brief estimate of the nutrient budget in Gher Soladana March–September 2001 (Source: Wahab et al. 2003).

Criterion	Total Nitrogen		Total Phosphorus	
	Kg/ha/cycle	%	Kg/ha/cycle	%
Fertilizer Input	40	67	10	71
Influent Water	20	33	4	29
Total Nutrient Inputs	60	100	14	100
Effluent Water Nutrients	8	13	3	21
Trapped in the system	52*	87	11	79

* A significant part of TN probably was lost to the atmosphere

Another similar study (Islam et al. 2004) examined water and sediments in five brackish-water ghers in southeast Bangladesh for the duration of a production cycle. The target culture species was *P. monodon*, although a number of other shrimp and finfish were also present in the ghers. The sizes of ponds in this study were between 12.2 and 13.0 ha, significantly larger than those in the Rouf study, which averaged 1.33 ha, although not as large as those evaluated in the Wahab study, which reportedly ranged from 40 to 100 ha. Daily water exchange rates were tidal-based and ranged between 10% and 20% per day.

Table 7: Effluent assessment—partial mass budget for total nitrogen and total phosphorus in semi-intensive shrimp ponds over a growing cycle of 150 days (Source: Islam et al. 2004).

	Total nitrogen		Total phosphorus	
	$kg\,ha^{-1}\,cycle^{-1}$	%	$kg\,ha^{-1}\,cycle^{-1}$	%
Input				
Fertilizer				
Cowdung (1000 $kg\,ha^{-1}\,cycle^{-1}$)	16.5	7.5	7.0	6.4
Urea/TSP (100 $kg\,ha^{-1}\,cycle^{-1}$)	46.7	21.2	20.0	18.2
Shrimp seed (15,000 $ha^{-1}\,cycle^{-1}$)	0.20	0.1	0.1	0.1
Feed (600 $kg\,ha^{-1}\,cycle^{-1}$)	36.0	16.3	9.0	8.2
Water (50% exchange/fortnight)	121.0	54.9	74.0	62.1
Total	220.4		110.1	
Output				
Effluent	137.4	62.3	48.8	44.3
Drainage	34.4	15.6	8.9	8.1
Harvest	26.6	12.1	3.6	3.3
Total output	198.4		61.3	
Trapped in the system	22.0	10.0	48.8	44.3

Cowdung: 1.65% N, 0.70% P; urea: 46% N; TSP: 20% P; Shrimp grower feed: 6% N and 1.5% P; Shrimp: 3% N and 0.4% P.

This study revealed high amounts of nitrogen and phosphorus in the intake water, accounting for the majority in the system. The author points out that this contrasts with other studies of semi-intensive shrimp culture systems, in which feed is the predominant source of nitrogen and phosphorus. Although the author identifies these production systems as semi-intensive, the stocking densities mentioned are all 15,000 PLs per ha, which is equivalent to 1.5 PL/m^2. Islam further clarifies that feed deliveries to the farms he surveyed were erratic, and that 600 k g/ha did not represent a typical amount of supplementary feed used by these systems over the course of a production cycle. In conclusion, the author reported that farmers producing around 1,000 kg/ha were shown to load the surrounding environment with nitrogen but also demonstrated a net removal of phosphorus.

A 5-month study in 2005 (Asaduzzaman et al. 2005) looked at *M. rosenbergii* farms in three districts: Mymensingh (north), Bagerhat (southwest), and Noakhali (southeast). Three varieties of culture practice were identified: 3% monoculture; 62% freshwater prawn/carp polyculture; and 35% freshwater prawn/carp/shrimp polyculture. *M. rosenbergii* eats larger-sized particles than *P. monodon*, so supplementary feeds are typically used when culturing this species. In this study, many farmers used boiled wheat or rice and oil cakes applied directly to the culture pond. Farm-made feeds, which comprised oil cakes, fishmeal, rice bran, wheat bran, boiled vegetables, and other ingredients, were used by 43% of farmers; commercial feeds (with an average protein/lipid content of 22/11) were used by 29%; and snail meat was used by 28%. Effluent discharge was monitored in one farm from each district; the data from this analysis are presented in Table 8.

Table 8: Effluent assessment—means (± SE) of effluent water quality parameters recorded from different farming areas (Source: Asaduzzaman et al. 2005).

Parameter		Noakhali Sadar	Bagerhat Sadar	Mymensingh	ANOVA
DO (mg l^{-1})	Mean ± S.E	5.51 (0.58)	5.66 (1.29)	4.77 (0.14)	NS
Ammonia-nitrogen (mg l^{-1})	Mean ± S.E	0.08 (0.02)	0.12 (0.04)	0.17 (0.08)	NS
Nitrite-nitrogen (mg l^{-1})	Mean ± S.E	0.008 (0.004)	0.008 (0.002)	0.010 (0.003)	NS
Nitrate-nitrogen (mg l^{-1})	Mean ± S.E	0.063 (0.017)	0.068 (0.023)	0.093 (0.050)	NS
Phosphate-phosphorus (mg l^{-1})	Mean ± S.E	0.19 (0.05)	0.22 (0.07)	0.22 (0.05)	NS

*All nutrients measured in effluent water were found to be at acceptable levels and did not seem to pose a direct threat to the recipient environment.

A recent report (Jahan et al. 2015) remarks that the most notable environmental impacts from sedimentation and nutrient loading occur from intensive systems with high inputs and outputs and correspondingly high rates of discharge; in Bangladesh, the koi, pangas, and tilapia industries represent the majority of intensive producers. Because black tiger shrimp and freshwater prawn producers employ mainly extensive and improved extensive production systems, their environmental impact in this regard is relatively much lower. Paul and Vogl (2011) also concur with the above studies, noting that extensive shrimp systems in Bangladesh reportedly produce less than 1 MT/ha of sediments a year, which have been found to act as a nutrient sink. Wahab et al. (2012) comment that, when concurrent culture with rice is practiced, the rice absorbs the nutrients produced in ghers.

The government's "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" (DOF and Bangladesh Shrimp and Fish Foundation 2015) provides guidelines for three core aspects of the shrimp value chain: hatcheries and farms, shrimp distributors, and processing plants. The codes are "intended to promote aquaculture production which meets international food safety standards, is sustainable, ecologically sound and socially responsible." The following excerpt details the effluent management guidelines for *P. monodon* farms, which do not differ significantly from those included in the section covering *M. rosenbergii* production.

Water Quality and Effluent Management:

- *Farms shall monitor effluent water at least bi-monthly to confirm the following required water quality parameters:*

Parameter	Units	Standard
pH	Standard pH units	6.0 – 9.0
Total suspended solids (TSS)	mg/L	Not more than 50
Soluble phosphorus	mg/L	0.1 or less
Total ammonia nitrogen (TAN)	mg/L	3.0 or less
5-day biochemical oxygen demand (BOD_5)	mg/L	30.0 or less
Dissolved oxygen (DO)	mg/L	5.0 or more

- *Farms shall treat the effluent water before discharging it into any open water system to assure that the BOD of the discharged water is not in excess of that of the open water.*

- *Water samples should be collected at a point where the effluent leaves the farm property. For farms with multiple effluent points a composite sample shall be collected.*

The section on biosecurity also contains the following:

Biosecurity:

- *Water exchange should be managed carefully and kept to a minimum when possible:*
  - *In order to not impact the environment with excess effluents.*
  - *To avoid introduction of potential disease carrying vectors (crabs, other shrimp species, etc.)*

And this is the section on sediment management:

Sediment Management:

Farms shall manage its sediment resulted from pond bottom, canals and settling basins within the farm but not throw them away into open water or others' land, causing ecological or social problems.

It should be noted that these codes are not enforced per se, but if a farm wishes to become Quality CoC certified, then it can apply to be audited by the DOF. Provided that it passes the audit and is found to be in compliance with the CoC (code of conduct), the farm can then have its product processed by a CoC-certified processing plant, thus obtaining the DOF Quality label. This initiative toward industry certification is intended to improve food security and product image, and is comparable to the domestic certification schemes of other shrimp-producing nations, such as the Thai Quality Shrimp certification and labeling scheme introduced by the Thai government in 2004 (van der Pijl and van Duijn 2012). Although producers can elect whether to become CoC certified, seafood products must be processed at approved facilities in order to be exported to the U.S. or the E.U.; in 2013, there were reportedly 96 government registered processing plants and, of these, 30 were USFDA green ticketed and 78 were E.U. compliant (Kabir 2013).

Conclusions and final score

Studies on effluents produced by shrimp and freshwater prawn farmers in Bangladesh indicate that, where feed and/or fertilizer are applied, they constitute the majority of nutrient inputs to the pond system, but their overall use is minimal, and culture water discharged from ghers typically has a lower level of nutrients than influent water. Because evidence demonstrates that effluent discharges from Bangladesh shrimp farms do not cause or contribute to cumulative impacts at the regional or waterbody scale, the final score for Criterion 2 – Effluent is 8 out of 10.

Criterion 3: Habitat

An interim update of this assessment was conducted in June 2021. This criterion was updated with new information. The interim update can be found in Appendix 2&3 at the end of this document.

Impact, unit of sustainability and principle

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

Criterion 3 Summary

P. monodon

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		0
F3.2a Content of habitat management measures	2	
F3.2b Enforcement of habitat management measures	1	
F3.2 Habitat management effectiveness		1
C3 Habitat Final Score (0–10)		**0**
Critical?	YES	**RED**

M. rosenbergii

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		7
F3.2a Content of habitat management measures	3	
F3.2b Enforcement of habitat management measures	2	
F3.2 Habitat management effectiveness		2
C3 Habitat Final Score (0-10)		**5**
Critical?	NO	**YELLOW**

Brief Summary

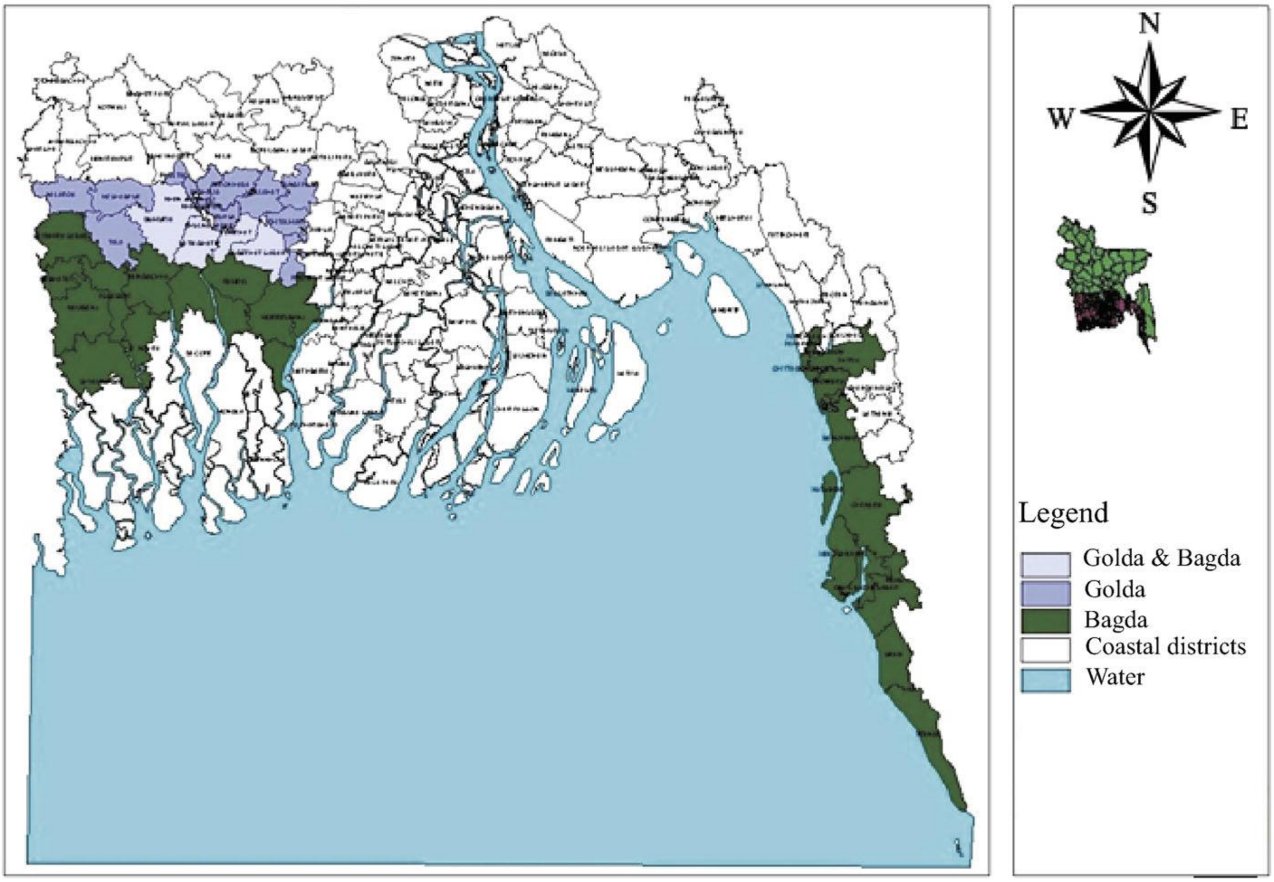
The main impacts caused by shrimp farms in Bangladesh have been identified as coastal mangrove destruction and saltwater intrusion, which are contributed to primarily by *P. monodon* cultivation. The conversion of mangroves to shrimp ponds contributes to a decline in biodiversity and nursery habitats for multiple species, and removes a much-needed buffer against storm surges and cyclonic events. Saltwater intrusion is particularly destructive because it affects agriculture production and the availability of potable water. Because there is evidence of ongoing conversion of high-value habitat for shrimp farming, the score for *P. monodon* for Factor 3.1 is 0 out of 10. In contrast, *M. rosenbergii* farms are located inland, often on lands previously converted for rice culture; academic literature generally considers their impact to be low-moderate, so the score for Factor 3.1 is 7 out of 10. Government policies are in place to govern the shrimp and freshwater prawn farming industry, and they are generally based on ecological principles, but they do not account for the cumulative impact of the industry and their enforcement is weak, which results in a Factor 3.2 score of 0.8 out of 10 for both species. The final score for Criterion 3 – Habitat is 0 out of 10 (which is a Critical score) for *P. monodon* and 5 out of 10 for *M. rosenbergii*.

Justification of Rating

Factor 3.1. Habitat conversion and function

This factor describes whether the functionality of ecosystem services has been maintained in the habitats where the assessed industry operates, or if the industry has contributed to a loss of ecosystem services, either historically (more than 15 years ago), in the recent past (less than 15 years), or is having an ongoing impact. The most significant impacts to the habitats in which Bangladeshi shrimp farms operate have been coastal mangrove destruction and saltwater intrusion. Although both of these impacts have been realized in saltwater and brackish-water environments dominated by *P. monodon* production, there is less concern for impacts in freshwater environments. For example, a study by Yasmin et al. (2010) concluded that "there was no significant impact on ecosystem and environment" in freshwater *M. rosenbergii* production. Wahab et al. (2012) note that "prawn farming does not essentially need to employ mangrove forests and it is environment-friendly compared with marine shrimp farming." Nesar and Garnett (2010) also comment that "(freshwater) prawn farming…has not been associated with any of the negative environmental consequences for which marine shrimp production has received so much criticism" but do point out that "unplanned conversion of rice fields to freshwater prawn farms may have negative impacts on water quality" and that freshwater prawn farming in rice fields has caused several aquatic plants and weeds to disappear and reduced available grazing land for livestock production.

Some farmers produce both *P. monodon* and *M. rosenbergii* in their ghers but, as the map in Figure 7 shows, these systems are not situated in proximity to coastal mangrove habitats but much farther inland, where the salinity of the water is low enough for freshwater shrimp to grow. Ahmed (2015) reports that "the mixed culture of prawns and shrimp is rare in coastal Bangladesh, as prawns grow in freshwater, while shrimp grow in brackish water." The dark green areas on the map represent *P. monodon* cultivation (*Bagda* is the Bengali name for this species) and *M. rosenbergii* (*Golda*) is represented by purple, with areas where both species are cultured represented by light purple. The white area below the *P. monodon* culture zone on the left of the map is the Sunderbans.



(Bagda = *P. monodon*; Golda = *M. rosenbergii*)

Figure 7**:** Map of Bangladesh showing coastal *P. monodon* and inland *M. rosenbergii* production areas (Source: Didar-Ul Islam and Bhuiyan 2016).

Mangrove Destruction

The Bengali Sunderbans is a UNESCO World Heritage Site; it is the largest contiguous mangrove forest in the world and is situated in both Bangladesh (62%) and in West Bengal, India (38%) (Rahman 2015). The Sunderbans, which covers 601,700 ha (just over 4% of the country's total land mass), constitutes 40% of the forest area of Bangladesh. This unique habitat is home to a wide variety of wildlife, including mammals such as the royal Bengal tiger *(Panthera tigris tigris)*, Gangetic dolphin *(Platanista gangetica)*, rhesus macaque *(Macaca mulatta)*, Indian fishing cat *(Felis viverrina)*, smooth-coated otter *(Lutra perspicillata)*, and spotted deer *(Axis axis)*; and reptiles such as the estuarine crocodile *(Crocodylus porosus)*, monitor lizard *(Varanus salvator)*, rock python *(Python molurus)*, and green turtle *(Chelonia mydas)* (Chowdhury 2015). The UNESCO website notes that the region is well managed and monitored. According to Paul and Vogl (2011), much of the mangrove destruction suffered by the Sunderbans occurred due to expansion of agricultural land before the expansion of the shrimp farming industry. One study (Giri et al. 2008), which focused on mangrove deforestation in a number of Asian countries, noted that conversion to aquaculture was the main cause of mangrove deforestation in many Asian countries, but not in Bangladesh; it attributed 77% of mangrove deforestation in Bangladesh to agriculture and 11% to aquaculture. Authors of this study also commented that the Sunderbans region is “relatively intact” due to the protection measures and reforestation programs implemented by the governments of Bangladesh and India and that, despite being adjacent to one of the highest population densities on Earth, the “areal extent” of the Sundarbans has not changed significantly in the last 25–30 years. This indicates that the farming of *P. monodon* in Bangladesh has not contributed to a historical or ongoing loss of ecosystem services in the Sunderbans. But, as can be seen in the satellite image below (Figure 8), there is a great deal of agricultural land on the periphery of the Sunderbans region. The dark green area of the image is the Sunderbans forest.

Figure 8: Satellite image of the Sunderbans region showing the location of adjacent *P. monodon* farms (Source: NASA image created by Jesse Allen, Earth Observatory, using data obtained from the University of Maryland’s Global Land Cover Facility (http://earthobservatory.nasa.gov/IOTD/view.php?id=7028)).

Although the Sunderbans is reportedly intact, Emch and Peterson (2006) comment that “implementation of water development projects and the introduction of shrimp farming have caused ecological change in the area adjacent to the Sundarbans.” Mangroves also grow along much of the coastline, outside the Sunderbans region, and the conversion of these mangrove wetlands to *P. monodon* ghers is ongoing. There are three mangrove forest zones in Bangladesh: the Sundarbans, the Chakaria Sundarbans (in the town of Cox's Bazar), and the coastal mangrove plantation (an afforestation initiative that was started in the 1960s, which presently comprises a net area of 132,000 ha). The Chakaria Sundarbans has suffered massive deforestation due to agriculture, *P. monodon* culture, and saltpan farming. In 1974, the area was near-virgin habitat, but from the late 1970s to the mid-1990s, the Bangladeshi government encouraged development in this area by leasing out land to farmers. By 1984, there were 3,456 ha under shrimp cultivation, increasing to 5,583 ha by 1994, and then dropping to 4,601 ha by 2012 (Rahman and Hossain 2015) (Alam et al. 2014). The eradication of mangroves and the construction of dikes and canals have an irreversible impact on the hydrological characteristics of an environment. Continued pressure on mangroves reduces habitat availability for numerous species and makes the mangroves less efficient as a buffer against storm surges and cyclonic events. Rahman et al. (2010) stated that "massive clearance of large areas of mangroves is taking place to construct shrimp ponds." In conclusion, *P. monodon* farms are undoubtedly a causative agent in the ongoing loss of functionality of mangrove habitats in Bangladesh, whereas *M. rosenbergii* farms, which are located farther inland, do not have the same impact on such ecosystems.

Saltwater Intrusion & Land Degradation

Because Bangladesh is at a very low elevation, particularly in the coastal south where land is at sea level, it is extremely prone to flooding and saltwater intrusion. Of additional concern is that sea levels are rising globally at a rate of 2–3 mm per year, but the effect is much more pronounced in Bangladesh, where the rate is 15.9–17.2 mm annually (Ahmed and Diana, 2015a). Bangladesh is also prone to violent storms and cyclones, and the salinity contamination from the associated storm surges remains in inland freshwater ponds, canals, and rivers for several years after storm events. It is important to note that saltwater intrusion has been a historic concern in Bangladesh; even in the 17th century, landowners were concerned about saltwater damaging their crops and they built embankments around their land to mitigate this risk (Islam 2006). More recently, it has been recognized that marine shrimp farming exacerbates this problem.

A recent International Monetary Fund report (IMF 2013) states that a key cause of secondary salinization of coastal land is the "inundation of brackish-water for shrimp farming" and further comments that the severity of salinity intrusion has increased and is expected to continue on this trajectory as sea levels rise. Continuous shrimp cultivation in agricultural areas has led to saltwater percolating into adjacent farmland, inhibiting the production of agricultural crops (Paul and Vogl 2011). This occurs because canals are dug to flood ghers with saltwater; because the ghers have previously been used as paddy fields, they are surrounded by agricultural land, which then also becomes imbued with saltwater. In practice, this has meant that many rice farmers have been forced to switch to aquaculture. Freshwater prawn farmers have also been adversely affected by saltwater intrusion, experiencing higher PL mortality rates and an increase in disease. Ahmed and Garnett (2010) list saline water intrusion as one of the constraints affecting freshwater prawn farmers in Southwest Bangladesh. Additionally, naturally occurring freshwater-dwelling plants and wildlife in the environment are declining as salinity levels increase (Ahmed and Diana 2015a). Livestock production has been negatively affected: higher mortality, reduced milk production, and a drop in birth weights have been observed and are linked to a decline in the availability of fresh drinking water and a reduction in the availability of fodder caused by increased soil salinity (Rahman et al. 2002). Chicken and duck production are also compromised by increased salinity. Many ghers are situated behind mangrove forests, next to wetlands and agricultural areas; inundation of ponds with saltwater has caused seepage into these adjacent lands and waterways, causing a decline in freshwater organisms (Hossain et al. 2013). Some species of aquatic birds, crabs, mollusks, oysters, fish, and turtles are in gradual decline because of salinity intrusion, as is the Indian bullfrog *(Rana tigrina)*, which is an important species for pest control in rice fields (Ahmed 2013b). Saltwater intrusion also has a detrimental effect on the availability of potable water.

In conclusion, the production of *P. monodon* in Bangladesh has resulted in substantial negative impacts on coastal mangrove habitats and soil salinity within the farm boundary. In contrast, consensus of recent literature considers the farm boundary environmental impacts of *M. rosenbergii* culture to be much less, because its culture typically takes place in locations that are not near coastal mangroves and were formerly converted for rice farming. For these reasons, the score for Factor 3.1 for *P. monodon* is 0 out of 10 and the score for *M. rosenbergii* is 7 out of 10.

Factor 3.2. Habitat management effectiveness

Factor 3.2 assesses the existence and enforcement of regulations or management controls that are in place to oversee the aquaculture industry under consideration and the effectiveness of these measures, with regard to the scale of the industry and in light of the habitats discussed in Factor 3.1.

Factor 3.2a: Content of habitat management measures

The government's "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" (DOF and Bangladesh Shrimp and Fish Foundation 2015) provides guidelines for hatcheries and farms culturing *P. monodon* and *M. rosenbergii*, feed mills, shrimp collection centers, ice plants, and processing plants. These codes are not enforced per se, but if a farm wishes to become Quality CoC certified, then it can apply to be audited by the DOF; if found to be in compliance, it can become certified accordingly. Certification is not presently a requirement for U.S. and E.U. markets, although these destinations only accept seafood products processed by pre-approved facilities. Each element of the shrimp value chain has its own specific CoC guidelines; for example, the following excerpt details site selection guidelines for *M. rosenbergii* farms:

ENVIRONMENTAL PROTECTION AND SUSTAINABILITY

The Macrobrachium farming industry will promote responsible and sustainable management practices to ensure the preservation and enhancement of the natural environment. Facilities shall not damage or alter the conditions of coastal wetlands, mangroves, or sea-grass beds or other ecological communities near the production site.

Site Selection saving mangrove and common property wetland:
Site selection for a shrimp farm shall be done in an environmentally suitable location. Site selection shall not result in destruction of public wetlands. Any new farm shall be located outside the wetland area and shall not cause any damage to neighboring aquatic resources.

- *Wetlands or other ecologically important habitats shall not be removed for the construction of ponds, canals or any other purpose.*

- *Any new farm shall be outside the mangrove area and shall not cause any destruction to neighboring mangrove cover.*
- *Any existing farm in a wetland area shall plant native plants on the strip of land, if existing and available to him, in between the adjacent river and the riverward dike of the farm.*
- *Farm shall not occupy any part of common property wetland or obstruct or interfere with the flowing canal.*
- *The site must permit easy transportation of farm inputs and outputs.*
- *Shrimp farm should be built in an environmentally suitable location and out of the flood prone area.*
- *The site must have easy access to good quality fresh or brackish-water, suitable for the culture of Macrobrachium.*
- *Operation of a shrimp farm shall not interfere with the natural environment and other normal activities of the location, including access to traditional fishing or gathering grounds for local inhabitants.*
- *Farm operations shall not pollute the environment.*
- *Farm must dispose of waste water in an environmentally acceptable way.*

The code of conduct guidelines for production facilities cover many other issues, such as PL source, drug and chemical management, soil/water conservation, water quality and effluent management, sediment management, feed and feed management, biosecurity, food safety, harvest and transport, standard operating procedures, farm design, construction and operation, traceability records, and social and labor issues.

The section of the code governing *P. monodon* culture includes the following section on soil and water conservation:

Soil/Water Conservation:
The opinion of the Best Aquaculture Practices (BAP) Program is that underground water resources may be used but with careful monitoring to insure that aquifers are not negatively affected.

- *Pond will use only surface water and shall not draw underground water for farming purpose.*
- *Farm construction and operations shall not allow any saline water to seep into neighboring agricultural land or cause salinization of underground water supplies (aquifers).*

The first fisheries policy in Bangladesh was implemented in 1950, but most policies have been put in place over the last few decades. Presently, the shrimp and freshwater prawn sector is governed by an array of organizations, which includes 17 ministerial divisions and 28 departments and agencies. The main governmental department concerned with aquaculture is the Department of Fisheries (DOF), which is under the direction of the Ministry of Fisheries and Livestock. Other organizations involved in the management of the shrimp and freshwater prawn sector are NGOs, local councils, shrimp cooperatives, and donor agencies. A total of 19 policies, ordinances, acts, rules, and laws with relevance to the fisheries sector were identified by Tasnoova et al. (2015) as management measures applicable to the shrimp and freshwater prawn farming industry. These are presented in Figure 9.

The Protection and Conservation of Fish Act, 1950	Conservation of fisheries resources as a whole. The text of the Act consists of 9 sections: Short title, extent and commencement
Embankment and Drainage Act, 1952	Protecting crops, not allowing cuts in embankments to produce shrimp
Bangladesh Water and Power Development Board Ordinance, 1972	Develop water management infrastructure for shrimp farming
Bangladesh Fisheries Development Corporation Act, 1973.	Bangladesh Fisheries Development Corporation is established for purposes of development of the fishing industry of Bangladesh.
Territorial Water and Maritime Zone Act, 1974	Conservation of marine fisheries
Allocation of functions to the Ministry of Fisheries and Livestock (Schedule 1 of the Rules of Business, 1975).	This Schedule defines the functions of the Ministry of Fisheries and Livestock relative to fisheries.
Protection and Conservation (Amendment) Ordinance1982	The amendments mainly concern definitions and technical matters.
Marine Fisheries Ordinance, 1983	
Fish and Fish Product (Inspection and quality control) Ordinance, 1983	Quality control fish and shrimp, mainly targeting export
Protection and Conservation Fish Rules, 1985	Regulations on protection and conservation of fish. The text contains 11 sections about various measures of protection and conservation
Manual for Land Management, 1990	Allocate unused state *(khas)* land to the landless on a permanent or temporary basis
Shrimp Estate (*mohal*) Management Ordinance, 1992	Allocate suitable state (khas) land for shrimp farming
Shrimp farm taxation Law, 1992	Imposing higher tax on shrimp land to cover cost of polder infrastructure
Bangladesh Environment Conservation Act, 1995	Conservation of natural resources and ensure eco-friendly development
Bangladesh Environment Conservation Rules, 1997	Conservation of natural resources and ensure eco-friendly development
Fish and Fish Product Rules, 1997	Quality control fish and shrimp, mainly targeting export
National Fisheries Policy, 1998	Conservation, management, exploitation, marketing, quality control and institutional development
Fish and Animal Food Act, 2010	Safe fish and animal feed production, processing, quality control, import export, marketing and transportation
Hatchery Act, 2010	Sustainable hatchery development to ensure quality fish and shrimp seed

Figure 9: Relevant fishery policies, laws, rules, acts, and ordinances in Bangladesh (Source: Tasnoova et al. 2015).

The FAO Code of Conduct for Responsible Fisheries, National Agriculture Policy, National Rural Development Policy, and Coastal Zone Policy are also relevant to the shrimp sector. As previously mentioned, the DOF is the primary government department responsible for overseeing policy implementation of habitat management measures. The government's "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" has recently been updated (DOF and Bangladesh Shrimp and Fish Foundation 2015). This code of conduct seeks to address environmental stewardship, social issues (legal and community), food and feed safety, and traceability. The document lists the main environmental issues to be addressed as follows:

1.) Mangrove and wetland destruction.
2.) Bio-diversity destruction by mass collection of shrimp post-larvae along with myriad of miscellaneous non-target aquatic organisms from the sea-shore and brackish-water rivers; the latter are just wasted.
3.) Effluent discharge often with heavy loads of silt and organic matter offsetting the balance of the aquatic environment.
4.) Releasing prohibited or harmful chemicals used in the shrimp or fish farms.
5.) Salinization of agriculture land.
6.) Releasing diseased farm animals or exotic species from the farm into the open environment.

The government of Bangladesh has also recently collaborated with the FAO in producing a "National Aquaculture Development Strategy and Action Plan," which includes the following aims:

The Strategy and Action Plan has four Strategic Objectives, three of which are based on the pillars of sustainable development, the fourth on the need to enable the three. Thus:

- *Social: To enhance the health and well-being of the people through the production of nutritious food and the development of productive and secure livelihoods.*
- *Economic: To stimulate more economic activities in rural communities, create more rural employment opportunities, increase incomes of rural households, and save or earn foreign exchange through import substitution or more export earnings.*
- *Ecological: To promote the conservation of aquatic biodiversity, enhancement of genetic resources, conservation of natural resources, and ecological resilience.*
- *Institutional: To establish the enabling environment and develop the capability to effectively manage the sector, provide the support services needed for sustainable and responsible development, and ensure equity and fairness in the allocation of production resources and distribution of benefits.*

Effective implementation of this plan would help address the institutional constraints and ecological issues that are currently impeding sustainable development in the shrimp and freshwater prawn farming sector. Overall, present management measures have been assessed as being limited: although they are based on ecological principles, they do not adequately address cumulative impacts on ecosystem services and habitat connectivity. The score for Factor 3.2a, Content of habitat management measures, is 2 out of 5 for both *P. monodon* and *M. rosenbergii*.

Factor 3.2b: Enforcement of habitat management measures
Although the DOF is the main government department concerned with aquaculture, there are 19 policies, ordinances, acts, rules, and laws with relevance to the fisheries sector, and there appears to be little integration between the government agencies that administrate these. This results in confusion in the implementation of policies and conflicting or replicated efforts by the various governmental departments (Afroz and Alam 2012). Many shrimp and freshwater prawn ponds have been constructed on land that was previously used for agricultural purposes, especially paddy fields, and presently there is no clear government directive or policy governing land use change. Some shrimp farms are on government-owned tidal lands, which are leased.

Afroz and Alam (2012) comment that "in coastal Bangladesh, agriculture, shrimp farming, salt production, forestry, shipbreaking yards, ports, industry, human habitation and wetlands are some of the uses in an area of only 47,000 km^2 inhabited by 36.8 million people. Land use in the coastal zone is diverse, competitive and conflicting," and "Bangladesh shrimp farming has been widely expanded in a vacuum of planning and regulation." The authors further refer to duplications and contradictions in policy-making caused by lack of coordination between government agencies. These authors suggest that cohesive governance of coastal resources could best be realized by the adoption of integrated coastal zone management, and further comment that "though land zoning and regulations of land use have been advocated for a long time, actions and/or steps in this regard are almost totally lacking." But Hossain et al. (2013) state that the government has recently "declared the zoning of shrimp areas" and is also preparing a coastal zone management plan to improve planning, control, and regulation, so an integrated coastal zone management plan may be implemented by the government in future.

At present, the regulatory framework for the shrimp and freshwater prawn sector is weak, and the capacity of the DOF to oversee implementation and enforcement of policies is limited, especially because there are multiple other governmental departments involved in various parts of the process, which further hinders an integrated and comprehensive approach to governance. The DOF is responsible for providing extension services, disseminating technical information, and conducting site visits so that issues can be flagged and acted upon. But the DOF does not have sufficient resources to effectively carry out these tasks (Chowdhury 2015). Some authors comment that the ineffective regulatory framework is perhaps the biggest challenge that needs to be addressed to overcome the detrimental effects of the shrimp and freshwater prawn farming sector in Bangladesh (Morf 2014) (Ahamed et al. 2012). Afroz and Alam (2012) echo this sentiment, stating "regarding shrimp farming in Bangladesh, legal problems and constraints fall into two categories: (i) confusion over the legal and institutional position of shrimp farming, and (ii) enforcement problems of existing laws. The first problem exacerbates the second." Paul and Vogl (2011) note that, although the government has formulated and amended various acts, there is a lack of policy enforcement, and they refer particularly to the following examples:

1.) Approval should be sought from the Bangladesh Water Development Board when farmers wish to introduce saltwater into a new pond but few farmers follow this rule.
2.) Shrimp fry collection from natural sources has been banned and importation of shrimp seed has been stopped, however wild collection of fry is still ongoing.
3.) Chemical and drug use is regulated and farmers are encouraged to apply sustainable pond management techniques but most farmers do not implement these measures.
4.) Shrimp farms should register with the Department of Fisheries and obtain a license, however a substantial number of farms have not done this.

Figure 10 compares the compliance of Bangladesh shrimp and freshwater prawn aquaculture with FAO guidelines concerning environmental integrity.

Minimum Substantive Criteria	Bangladesh Status
Environmental impact assessments should be employed, according to national legislation, prior to approval of aquaculture operations	According to national rules, any industry, projects or intervention that may have impact on environment, must undergo the Environmental Impact Assessment (EIA) and acquire certificate from the Department of Environment prior to run the establishment. The current shrimp culture system, because the farms are small scale and thought to have minimal effect to environment, is not practiced by this rule. But the processing plants have to submit EIA report for getting licence for operation. The local shrimp culture entrepreneurs are not aware of undertaking Environmental Impact Assessment studies. The shrimp farms are recently started to be considered to have mentioned negative effects of their present activities on the environment. Nonetheless, to intensify production, the farmers participate in trainings to increase technical knowledge, disease prevention, and improvement of management. In reality, however, a few of those apply their learning, despite the tendency to widely use insecticides, although they have been asked not to use it in the shrimp farm.
Aquaculture should have routine monitoring system to identify its impacts on biodiversity, habitats, ecosystem, soil, water, natural fish species etc. and have measures to mitigate them.	The waste production from this type of shrimp farming is not seriously affecting the environment. Aquatic weeds, phytoplankton, and algal blooms are the major sludge produced in shrimp farms. Farmers collect their sludge and dead fish and put them in farm dikes or at the elevated corner of the farm (Alam *et al.*., 2005). No routine monitoring system to identify such impacts on environment has been developed by the government yet. Few researches have been done to identify the impacts by universities and other research organisations. This type of impact monitoring is not possible for small scale farmers individually because of their comprehensive nature.
Aquaculture should encourage the use of native species and exotic species are only used that have low potential risk to the natural environment, biodiversity and ecosystem health.	The shrimp species used in Bangladesh aquaculture are mostly native. No exotic shrimp species recorded as cultured in Bangladesh since. Few farmers are interested about Whiteleg shrimp *(Penaeus vannamei)* which is cultured widely on Thailand and Vietnam but they could not introduce it in Bangladesh because of governments discourage.
Responsible use of hatchery produced seed for culture. Seed from the wild should only be used when collected using responsible practices.	The shrimp culture was completely dependent on the wild source for PL up to mid 90's. Considering wild fry collection method is not responsible rather devastating to the biodiversity, the government imposed ban on wild fry collection in 2000. By that time, several hatcheries were been established and currently 95% of PL comes from hatcheries.
Responsible use of feeds, feed additives, fertilizer, chemicals, veterinary drugs and antibacterials and no use of GMOs.	The use of feed is very much limited in shrimp aquaculture in Bangladesh. Artificial feed is only used in freshwater shrimp farms. The fertilizers used in shrimp farms include Cow dung, Urea, and Triple Super Phosphate (TSP). All these are mixed together and kept in a hole on the periphery of a shrimp farm for 2–3 months. It is then used during June and July. Lime, urea, TSP, di-ammonium phosphate, and muster cake are widely used as fertilizers maintaining no proper ratio to improve fertility of the pond. Cow dung is used as organic manure of which the major amount was imported from outside the area. The waste production and contamination as a consequence of the use of those inputs is very low. The use of additives, veterinary drugs are not remarkable but when used it does not seem that the application responsible. No use of GMOs' reported in shrimp aquaculture in Bangladesh.

Figure 10: Status of the Bangladesh shrimp and freshwater prawn sector's compliance with FAO guidelines in maintaining environmental integrity (Source: Islam S. 2008).

As can be noted from the above, although the government of Bangladesh is aware of the need for ecological stewardship and compliance with FAO guidelines, its enforcement of habitat management measures is minimal. Although an Environmental Impact Assessment (EIA) is a governmental requirement for shrimp and freshwater prawn culture activities, this is generally not performed, and there is no routine environmental impact monitoring in place. The DOF is responsible for providing extension services and conducting site visits, but it has limited resources with which to implement these strategies. A myriad of governmental agencies is involved in issues affecting the shrimp and freshwater prawn farming sector, so the relevant enforcement organizations and their activities are difficult to identify, and there is little evidence of monitoring and compliance data or of penalties for infringements of the law.

The score for Factor 3.2b, Enforcement of habitat management measures, is 1 out of 5 for both *P. monodon* and *M. rosenbergii*. When combined with the Factor 3.2a, Content of habitat management measures, which scores 2 out of 5, the final Factor 3.2 score is 0.8 out of 10 for both *P. monodon* and *M. rosenbergii*.

Conclusions and final score

P. monodon farming in Bangladesh occurs in the low-lying coastal floodplains. Culture of *M. rosenbergii* must take place farther inland because it is not a marine species. The siting of *P. monodon* farms in Bangladesh has caused a demonstrable loss of habitat functionality because of mangrove removal and saltwater intrusion, which appears to be ongoing. For this reason, *P. monodon* scores 0 out of 10 for Factor 3.1. *M. rosenbergii* farming takes place on moderately valuable habitats that were originally converted for rice farming, so production of this species has scored 7 out of 10 for Factor 3.1. In Bangladesh, aquaculture management measures are limited: although they are based on ecological principles, they do not encompass cumulative impacts on ecosystem services or account for habitat connectivity. This results in a score of 2 out of 5 for both *P. monodon* and *M. rosenbergii*. Although a regulatory framework is in place, enforcement measures are limited due to confusion over both existing legislation and the jurisdiction of the various government agencies involved, so the score for Factor 3.2b is 1 out of 5 for both *P. monodon* and *M. rosenbergii*. Factor 3.2a and Factor 3.2b combine to give a final Factor 3.2 management score of 0.8 out of 10 for both species. Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 0.27 out of 10 for *P. monodon* and 4.93 out of 10 for *M. rosenbergii*.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary

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

Brief Summary

A variety of chemicals are used in Bangladeshi shrimp aquaculture with the aim of enhancing soil and water quality and implementing biological control of the pond, e.g., the containment of phytoplankton blooms, aquatic plant growth, and disease vectors, and the removal of unwanted wild fish. Although the aquaculture sector in Bangladesh has been expanding rapidly, the overall use of chemicals in shrimp and freshwater prawn farming is quite low compared to elsewhere in Asia because of the extensive production methods employed. Additionally, the risk of ecological impact from the chemicals used is also quite low. The final score for both *P. monodon* and *M. rosenbergii* is 8 out of 10.

Justification of Rating

The use of chemicals in the Bangladesh shrimp and freshwater prawn sector is low and significantly less than in other Asian countries because of the extensive culture methods used. Furthermore, a study by Rico and Van den Brink (2014) confirmed that “besides the water exchange regime, the organic matter rich sludge and sediments of earthen ponds act as a sink of chemicals and play a fundamental role in reducing the environmental release of veterinary medicines, in comparison to other aquaculture production systems such as net pens or cages.” There are around 100 pharmaceutical companies in Bangladesh, and they sell an array of approximately 400 chemical and medical products for aquaculture (Alam and Rashid 2014). A recent comprehensive study (Ali et al. 2015), which attests to being the largest study of chemical use in Bangladesh to date, identified 34 different chemical products that were used by the farms being surveyed and classified them into four categories of use: water and soil treatment compounds, disinfectants, antibiotics, and pesticides. Table 9 shows the chemicals that were observed in use by shrimp and freshwater prawn farmers in different production scenarios during the study. Inputs that were used by 10% or more of farmers in a group have been indicated in bold.

Table 9: Chemicals used by shrimp and freshwater prawn farmers in Bangladesh and the percentage of farmers that use them (Source: Ali et al. 2015).

Chemical Type	Shrimp farms (%)	Shrimp and Prawn farms (%)	Prawn farms (%)
Water and soil treatment compounds (n = 7)			
Calcium oxide (quicklime)	**83**	**84**	**92**
Calcium carbonate	4.5	8.2	5.2
Zeolite	**32**	**48**	**21**
Sodium chloride (salt)	1.3	2	**10**
Sodium thiosulfate	0.32	1.5	1.9
Lactic acid	0.0	0.0	0.0
Unidentified	0.65	5.2	1.4
Disinfectants (n = 13)			
Sodium percarbonate	1.6	3	6.6
Hydrogen peroxide	1.6	7.5	**12**
Calcium peroxide	0.65	0.75	2.4
Tetra acetyl ethylene diamine (TAED)	0.32	0.75	0.47
Benzalkonium chloride (BKC)	0.65	0.75	0.94
n Alkyl dimethyl benzyl ammonium chloride	0.32	3.7	0.94
Tetradecyl trimethyl ammonium bromide	0.32	6.0	2.4
Chlorine	**19**	9.7	2.4
Potassium permanganate	3.9	6.7	5.2
Formaldehyde	0.65	0.75	0.94
Potassium peroximono sulfate	1.6	1.5	0.94
Copper sulfate	0.65	0.75	0.47
Unidentified	1.6	0.0	1.4
Antibiotics (n = 7)			
Amoxicillin trihydrate	0.0	0.0	0.0
Chlortetracycline	1.9	3	2.8
Oxytetracycline	1.3	2.2	1.9
Sulfadiazine	0.0	0.0	0.0
Sulfamethoxazole	0.0	0.0	0.0
Cotrimoxazole	0.0	0.0	0.0
Doxycycline	0.0	0.0	0.0
Pesticides (n = 7)			
Yucca plant extract	0.32	1.5	0.47
Rotenone	3.9	**32**	**34**
Malathion	7.7	2.2	1.9
Trichlorfon	0.0	1.5	0.47
Methylene blue	8.7	6.0	9.4
Fenitrothion	3.6	2.2	1.9
Malachite green	0.0	0.0	0.0

Water and Soil Treatment Compounds

The Ali et al. (2015) study found that all shrimp farmers used at least one product for water and soil treatment, most notably calcium oxide and zeolite. Calcium oxide is a naturally occurring and widely used liming compound (commonly known as quicklime) that raises the pH of the soil and promotes biological productivity and kills microorganisms, especially parasites. If a farmer does use lime, it is added to the pond between production cycles, during or after the drying out stage. A study by Boyd and Massaut (1999) on “risks associated with the use of chemicals in pond aquaculture” ranks calcium oxide as presenting a low environmental risk to the environment: if a large spillage of this chemical accidentally occurred, the receiving land or water body would experience an elevation in pH. Farmers use zeolite to remove ammonia, hydrogen sulfide, and carbon dioxide from pond water. When used in recommended dosages, these chemicals are non-toxic and have a short environmental lifespan. Boyd (2003) reports that, although shrimp farmers frequently use zeolite, it does not have any harmful impacts on aquatic organisms or soil. Furthermore, ponds are filled after application, so treatment compounds are not immediately discharged to the surrounding waterbody. Other products used for water and soil treatment include calcium carbonate and sodium chloride (salt). Boyd and Massaut (1999) rate calcium carbonate as presenting zero risk to the environment and salt as a low risk, because of its potential to increase the salinity of surface water and groundwater, although application volumes are unlikely to be high enough to have this effect.

Disinfectants

The Ali et al. (2015) study found that disinfectants, which are used to control bacteria and treat culture water, were used by 35% of shrimp and freshwater prawn farmers, 27% of shrimp farmers, and 25% of freshwater prawn farmers. The most frequently used disinfectants were potassium permanganate (a chemical used extensively in the water treatment industry), chlorine/chlorine releasing compounds, and oxidizing agents, such as hydrogen peroxide (a commonly used oxidizer, bleaching agent, and disinfectant) and sodium percarbonate (a granular form of hydrogen peroxide that is commonly used as a bleaching agent in laundry detergent). Boyd and Massaut (1999) rate the use of hydrogen peroxide or calcium peroxide as presenting a low environmental risk. Calcium peroxide does not persist in the environment for a prolonged period and is not known to bioaccumulate because it decomposes to form calcium hydroxide and oxygen. Likewise, hydrogen peroxide rapidly decomposes and does not accumulate in the environment: “the FDA considers the use of hydrogen peroxide as a waterborne therapeutant in intensive and extensive freshwater aquaculture operations constitutes no significant threat to the environment, the populations of organisms residing there, or public health and safety if receiving water concentrations do not exceed 0.7 mg/L on a short-term basis” (Bowker et al. 2016). Potassium permanganate and copper sulfate are currently approved by the FDA to “treat external protozoan or metazoan infestations as well as external bacterial or fungal infections on fish,” although further evaluations are to be conducted by the Center for Veterinary Medicine (CVM). Copper sulfate must be used judiciously because it can be toxic to fish, especially in waters with a low level of alkalinity (Bowker et al. 2016). In general, stocking densities and water exchange rates have a direct correlation with the release of aquaculture chemicals into the environment (Rico and Van den Brink 2014) but “relatively low levels of application of disinfectants and limited water exchange in Bangladesh equate to quite limited environmental impacts and ecological risks to non-target aquatic organisms" (Ali et al. 2015).

Antibiotics

Antibiotic use was found to be extremely rare, with minimal amounts of tetracyclines (chlortetracycline and oxytetracycline) reportedly used. The World Health Organization (WHO 2011) lists the tetracyclines as being highly important antimicrobials for human health. Although the use of tetracyclines (chlortetracycline, doxycycline, oxytetracycline, tetracycline) is approved by the FDA, Serrano (2005) notes that some coliforms, mycoplasmas, streptococci, and staphylococci have developed resistance to this group of drugs. These antibiotics are widely used in global aquaculture practices to treat a range of gram-positive and gram-negative bacterial issues (including gram-negative *Vibrio* spp.). The use of antibiotics in the different shrimp-producing groups in Bangladesh that took part in this survey were: shrimp and freshwater prawn (4%), freshwater prawn (3%), and shrimp (3%)—illustrating the rarity of use. Shrimp and freshwater prawn farmers that use antibiotics add them directly to the culture water in the event of a disease outbreak. Another recent study (Rico et al. 2013), which surveyed chemical inputs in aquaculture in Bangladesh, China, Thailand, and Vietnam, reported that only one shrimp farm in Bangladesh, in 66 interviewed, confirmed antibiotic use. It is worth noting that the extensive nature of production, coupled with the expense of antibiotics, makes use of such products outside the economic grasp of many resource-poor farmers. These data show that antibiotic use in Bangladeshi shrimp farming is of little concern with regard to environmental impact or the development of antibiotic resistant bacteria.

Pesticides

Rotenone was found to be the most widely applied pesticide used to kill unwanted fish (prior to stocking); 34% of freshwater prawn farmers and 32% of shrimp and freshwater prawn farmers reported using rotenone. Rotenone is a naturally occurring pesticide that is obtained from the roots of certain plants and it is widely used in organic farming and gardening. The compounds in rotenone naturally degrade before animals are stocked in the pond, although Boyd and Massaut (1999) rate this chemical as presenting a medium risk to the environment because of its toxicity. The organophosphate insecticide malathion (used to control parasite infestation and for killing nontarget organisms prior to stocking) was used by 8% of shrimp farms in this survey and has a relatively low toxicity. Although methylene blue is used in aquaculture as a treatment for fungal infections, it should be noted that it is not approved for use in U.S. shrimp farms because of the health hazard that it presents to some humans (it can induce hemolytic anemia) (Food & Water Watch 2008). Because pesticides are used to control predatory and unwanted organisms in ponds prior to stocking and are therefore not discharged, they pose little risk of impact to the ecosystem. But one study, which utilized a risk-based ranking of the chemicals used in an array of aquaculture production systems in Bangladesh, China, Thailand, and Vietnam, identified that parasiticide use in Asian aquaculture presents a higher ecological risk than use of antibiotics and disinfectants (Rico and Van den Brink 2014).

Legality of Chemicals Used

Several shipments of Bangladeshi *M. rosenbergii*, destined for the E.U. market, were rejected between 2005 and 2009 due to the detection of nitrofurans. This class of antibiotics is prohibited for use in food animals by most countries, including Bangladesh, because of its carcinogenic properties. To safeguard against a total ban on shrimp and freshwater prawn exports, the government of Bangladesh decided to suspend exports for 6 months and launched an investigation. This investigation appears to have been inconclusive. Shamsuzzaman and Biswas (2012) comment that the nitrofurans likely arose from one or all of the following scenarios: Indian PLs sourced on the black market; contaminated commercial feed; or a Bangladesh freshwater prawn hatchery using an old supply of nitrofuran drugs, retained from earlier days before the ban was put into effect. In any case, illegal chemical use no longer appears to be a concern. The survey by Rico et al. (2013) of chemical inputs used in aquaculture in Bangladesh, China, Thailand, and Vietnam found that chemicals banned nationally and by importing countries were not used in shrimp and freshwater prawn culture and were not available on the market— except for one farm found to be using the carcinogenic parasiticide/fungicide malachite green.

The DOF Code of Conduct and Guidelines on Chemical Use

Efforts toward the establishment of a code of conduct (CoC) and domestic certification scheme for the Bangladeshi shrimp sector have been in progress for some time (Islam and Bjarnason 2008). As a response to the E.U.'s rejection of numerous freshwater shrimp shipments in the 1990s, the government of Bangladesh formed an 18-member working committee that comprised concerned domestic and international entities, including the FAO, to address issues within the sector. Through the collaboration of this committee, a CoC for the Bangladesh shrimp industry was established in March 2011 (FAO 2012). In 2015, the CoC was revised and updated, paying particular attention to the importation requirements of international markets. The "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" (DOF and Bangladesh Shrimp and Fish Foundation 2015) includes guidelines for hatcheries and farms culturing *P. monodon* and *M. rosenbergii*. The following excerpt is from the section concerned with drug and chemical management for *M. rosenbergii* farms, which is almost identical to the section for *P. monodon* production systems.

Drug and Chemical Management:

- *Only drugs, including antibiotics, or chemicals, including artificially formulated growth hormones, approved on a national or international basis may be used for their approved uses.*
- *Antibiotics, drugs and other chemical compounds that are banned in Bangladesh and the country of export shall not be used. Of particular interest are chloramphenicol and the nitrofuran group. These antibiotics are banned in all countries and should never be used under any circumstances. The use of Malachite Green and Gentian violet is also prohibited for Macrobrachium.*
- *Chemicals or drugs, which are not banned but restricted due to their health hazard potentials, either in Bangladesh or the country of export, shall be avoided, or shall be used only to the extent permitted by the restrictions in place in Bangladesh and the country of export (such as EU maximum residue limits on certain substances).*

- *Drugs shall not be used for prophylactic or preventive purposes.*
- *Approved therapeutic or other pharmacologically active substances may be used as directed on product labels for control of diagnosed diseases or required management, not prophylactic or preventive purposes.*
- *The withdrawal period as prescribed by the pharmaceutical company for any curative medicine shall be followed.*
- *Feed to be used at hatchery either for brood shrimp or for larval stages shall be free from drugs that are prohibited – whether in Bangladesh or the country of exportation – or excessive levels of other hazardous chemicals (procuring safe feed is the responsibility of the hatchery operator).*
- *Farms shall only use nationally and internationally approved additives, preservatives and growth promoters.*

The section for *P. monodon* farms adds the following two guidelines:

- *A land having a history of agricultural pesticide contamination, particularly with long life pesticides, shall not be used.*
- *Agricultural pesticides with residual effects in shrimp shall not be used in the field used for agriculture-aquaculture rotation. Pesticides shall only be used to the extent compatible with regulations in force in Bangladesh and the country of export (such as maximum residue levels in force in the EU).*

Conclusions and final score

A number of recent detailed surveys have been conducted on chemical use in Bangladeshi aquaculture, and data on this criterion are readily available. Because of the predominantly extensive nature of shrimp and freshwater prawn farming in Bangladesh, on-farm chemical use is minimal. When chemical agents are employed, they are mainly limited to compounds and chemicals that are commonly used in animal health management and pose little risk of ecological impact if discharged. Because chemical use in the Bangladesh shrimp and freshwater prawn sector is minimal, the subsequent risk of ecological impact resulting from their use is also small. The final numerical score for Criterion 4 – Chemical Use is 8 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

P. monodon

Feed parameters	Value	Score
F5.1a Fish In: Fish Out ratio (FIFO)	0.01	9.99
F5.1b Source fishery sustainability score	–10.00	
F5.1: Wild fish use score		9.97
F5.2a Protein IN (kg/100 kg fish harvested)	1.17	
F5.2b Protein OUT (kg/100 kg fish harvested)	15.64	
F5.2: Net Protein Gain or Loss (%)	1,232	10
F5.3: Feed Footprint (hectares)	0.06	9
C5 Feed Final Score (0–10)		**9.74**
Critical?	NO	**GREEN**

M. rosenbergii

Feed parameters	Value	Score
F5.1a Fish In:Fish Out ratio (FIFO)	1.15	7.13
F5.1b Source fishery sustainability score	–10.00	
F5.1: Wild fish use score		4.83
F5.2a Protein IN (kg/100 kg fish harvested)	0.00	
F5.2b Protein OUT (kg/100 kg fish harvested)	15.54	
F5.2: Net Protein Gain or Loss (%)	1,554	10
F5.3: Feed Footprint (hectares)	0.82	9
C5 Feed Final Score (0–10)		**7.16**
Critical?	NO	**GREEN**

Brief Summary

The farming of *P. monodon* in Bangladesh is extensive, with little or no feed inputs, and the dietary requirements of this species are met only or mainly by the natural productivity of phytoplankton and zooplankton in the pond. When supplementary diets are provided, they are usually homemade, using locally available ingredients, sometimes with the addition of domestically sourced fishmeal. Wild-harvested freshwater apple snail meat *(Pila globosa)* is the dominant feed source provided to *M. rosenbergii*. The scoring of *P. monodon*'s on-farm feed practices has been done following all assumptions and standard values in the Seafood Watch Aquaculture Standard, but the near-exclusive use of freshwater snail meat in *M. rosenbergii* culture necessitated minor modifications to scoring calculations.

Wild fish use in feeds for *P. monodon* culture is relatively low, so the Feed Fish Efficiency Ratio (FFER, Factor 5.1) for *P. monodon* is 0.01; the equivalent calculation for *M. rosenbergii*, based on snail meat inclusion, is 1.15. Around 80%–85% of fishmeal used in Bangladesh comes from local waters and, because both inland and marine fisheries are reportedly overexploited, the Sustainability of the Source of Wild Fish score (F5.1b) is –10 out of 10 for *P. monodon*. All of the freshwater apple snail meat used for *M. rosenbergii* cultivation is sourced domestically, and there is evidence that harvesting this snail for freshwater prawn culture has contributed greatly to a decline in its population. The Sustainability of the Source of Wild Fish score (F5.1b) is therefore –10 out of 10 for *M. rosenbergii*. When these factors are combined, the final score for Factor F5.1 – Wild Fish Use is 9.97 out of 10 for *P. monodon* and 4.83 out of 10 for *M. rosenbergii.*

P. monodon supplementary feed is mainly derived from edible crops, but because most farmers rely on natural pond productivity, the net protein output on a national scale is more than 12 times the net protein input provided by supplementary feed. Because freshwater snails used in *M. rosenbergii* farming are not considered directly edible, their use results in a similarly high net gain in edible protein. For both species, the score for Factor 5.2 is 10 out of 10. Because supplemental feed inputs are minimal in *P. monodon* farming, it takes only 0.06 ha of ocean and land area to produce 1 MT of shrimp. For *M. rosenbergii*, an estimated 0.82 ha of freshwater ecosystem area is appropriated per MT of production. These area appropriations are considered low, and the Factor 5.3 score for both species is 9 out of 10.

Feed inputs for *P. monodon* are extremely minimal, which results in a final score for Criterion 5 – Feed of 9.74 out 10. Because larger quantities of feed inputs are used during production of *M. rosenbergii*, it has a correspondingly lower overall Criterion 5 – Feed score of 7.16 out of 10.

Justification of Rating

Feeds and feeding practices of the Bangladeshi shrimp and freshwater prawn farming industry are somewhat varied, with an array of strategies involving natural pond productivity, pond fertilization, homemade feeds, and use of commercial diets. Currently, shrimp and freshwater prawn farms in Bangladesh only use 2%–3% of domestically manufactured aquaculture feeds. But the total of formulated aquaculture diets produced in Bangladesh has recently increased; between 2008 and 2012, production has reportedly grown at a rate of 32% per annum

(Mamun-Ur-Rashid 2013b). Belton et al. (2011) note that the crude protein content of locally produced feed is frequently overstated on feed bags, but the FAO (2015) states that protein levels in domestically produced grower and finisher diets for freshwater prawn and shrimp feed are 22%–30%. Almost 80%–85% of the fishmeal content of domestically produced, commercial pelletized feed comes from local sources (Mamun-Ur-Rashid 2013a). To calculate feed inputs in this report, this percentage of protein inclusion in commercial feeds has been referenced, and an average of 26% protein and 17% fishmeal in commercial diets has been utilized. There are around 100 commercial feed mills in Bangladesh, but 8 to 10 large operators dominate this market segment, accounting for 60%–70% of production. Only 25%–30% of these feed mills produce shrimp and freshwater prawn feed (Ahmed 2013a).

For the purposes of this report, data on feed inputs for both *P. monodon* and *M. rosenbergii* were taken from a comprehensive survey of countrywide aquaculture behaviors and practices (Jahan et al. 2015). Data for this study were collected between November 2011 and June 2012 from 2,678 aquaculture operations, which included a detailed analysis of the onsite feeding practices of farmers producing *P. monodon* and *M. rosenbergii* in a variety of localities and systems. These data are presented in Table 10, and detail the application rate of ingredients used in feeds and the percentage of farmers using those ingredients to calculate a nationwide average of each ingredient's usage.

Table 10**:** Analysis of feeds used by *P. monodon* and *M. rosenbergii* production systems in Bangladesh (Sources: Jahan et al. 2015; *% of protein in feed inputs taken from Hasan et al. 2007).

	Feed ingredient application rate by species (kg/ha)		**Feed ingredient use by species (%)**		**Average quantity feed ingredient use by species (kg/ha)***		**Protein in food ingred.* (%)**
Feed Item	***P. monodon***	***M. rosenbergii***	***P. monodon***	***M. rosenbergii***	***P. monodon***	***M. rosenbergii***	
Rice bran	38	67	15	17	5.7	11.39	12.6
Rice products	26	97	23	17	5.98	16.49	8.4
Wheat products	7	302	5	44	0.35	132.88	15.35
Mustard oil cake	31	104	18	30	5.58	31.2	36.5
Fish meal	8	64	3	11	0.24	7.04	56.4
Soybean meal	0	47	0	5	0	2.35	45.2
Snail meat	0	1,580	0	51	0	805.8	52.5
Commercial feed	11	823	9	81	0.99	630.06	26
Homemade feed	3	38	1	3.47	0.03	0.9629	
Kitchen waste	0.25	0	1	0	0.0025	0	
Pulses	1	264	1	41	0.01	108.24	17.9
Other	2	8	5	3	0.1	0.24	
Total					**18.98**	**1,746.65**	

* Note: The average quantities of feed used per hectare have been calculated by multiplying the application rate by the percentage of farmers utilizing each feed input, then averaging this amount by the number of hectares under cultivation, per DOF figures for the fiscal year 2013–14, 1 July–30 June (these statistics can be found in Table 1).

Based on the feed-use data in Table 10, the economic FCR (eFCR) for each species has been calculated as shown in Table 11 (as noted earlier, the eFCR calculation for *M. rosenbergii* is based solely on snail meat inclusion).

Table 11: Calculation of the Economic FCR (eFCR) of *P. monodon and M. rosenbergii* cultured in Bangladesh (* Information on production data and area under shrimp cultivation sourced from Bangladesh Department of Fisheries Yearbook [Fiscal Year 2013–2014, 1 July–30 June] FRSS 2015).

	Total Production of all Farms*	**Feed Used by all Farms***	**kg feed use per kg of production**
	MT	MT	eFCR
P. monodon	71,430.00	4,087.03	**0.06**
M. rosenbergii	42,097.00	48,325.62 (snail only)	**1.15**

Feeding Practices – *P. monodon*

Extensive *P. monodon* farmers often do not use any supplementary feeds but rely on the natural productivity of the culture pond. As shown in the analysis of feeds table (Table 10), *P. monodon* farmers use an average of less than 19 kg/ha of feed (compared to nearly 1,747 kg/ha used by *M. rosenbergii* farmers). Quality feed inputs have a demonstrably positive effect on yields, but many farmers in Bangladesh do not have the financial capacity to implement such inputs. Often, farmers fertilize the culture pond with cow manure to increase productivity of phytoplankton and zooplankton; the use of chemical fertilizers is minimal, with some wealthier farmers using urea and triple superphosphate (TSP). When supplementary feeds are used, they often comprise low quality farm by-products such as rice bran, rice products (including cooked rice), wheat and wheat bran, and mustard cake oil (Jahan et al. 2015). Since rice is the most prominent cereal crop cultivated in Bangladesh, rice bran, a by-product of rice cultivation, is a popular supplementary feed used in aquaculture.

Feeding Practices – *M. rosenbergii*

Belton (2016) comments that, to achieve acceptable growth rates, *M. rosenbergii* (which typically eats larger-sized food particles than *P. monodon*) should be given supplementary feeds, such as snail meat, pelleted feed, or cooked rice. Wahab et al. (2012) note that supplementary feeds were not traditionally used in *M. rosenbergii* culture, but currently, supplementary feed is provided, particularly in improved extensive systems. The preferred supplementary feed used for *M. rosenbergii* culture is the freshwater apple snail *(P. globosa)* because it reportedly increases yields and is cheaper than homemade feeds, although its supply is irregular. As a result of its use, the number of freshwater snails in the proximity of *M. rosenbergii* farms has shown a marked decline due to overharvesting (Ahmed and Garnett 2010). The extensive *M. rosenbergii* farms surveyed in one study (Ahmed 2013a) were found to exclusively use snail meat as supplementary feed, at an annual rate of 1,454 kg/ha; freshwater snail meat has a protein content of 37%–68% and a lipid content of 6%–11%, which makes it suitable for freshwater prawns. Ahmed (2013a) also noted that, in addition to snail meat, improved extensive systems use locally available products to manufacture homemade feeds, consisting of rice bran (40% inclusion), mustard oil cake (30%), fishmeal (25%), and 5% of mixed oyster shell, salt, and vitamins. Other items that may be included in homemade feeds are boiled papaya, arum roots, and chickpeas. But to score this criterion, only snail meat has been considered in the calculations because of the dominance of its use by the *M. rosenbergii* sector and the deleterious, population-level impact that this practice has on *P. globosa*.

Factor 5.1 Wild Fish Use

Factor 5.1 combines the amount of wild fish that is used to produce the species under consideration (Factor 5.1a) with an assessment of how sustainable the source fishery is (Factor 5.1b).

Factor 5.1a Wild Fish Use – Feed Fish Efficiency Ratio (FFER)

Fishmeal inclusion levels, based on the analysis of feeds table above (Table 10), have been calculated as 2.19% for *P. monodon;* this aquatic counterpart of feed includes inputs from fishmeal, plus homemade feed (25% fishmeal inclusion) and commercial feed (17% fishmeal inclusion). The corresponding fishmeal (i.e., snail) inclusion level for *M. rosenbergii* has been calculated as 100%, because only snail feed inputs are being considered in scoring this criterion.

Table 12: Fishmeal (FM) inclusion level – *P. monodon*

	kg/ha	**kg/ha**	**kg/ha**	**Total FM/ha**	**% FM per/ha***
Feeds w/FM	FM	Commercial Feed	Homemade Feed		
P. monodon	0.24	0.1683	0.0075	0.4158	**2.19**

*Note: calculations are based on total feed inputs from Jahan et al. 2015.

Table 13: Fishmeal (snail) inclusion level – *M. rosenbergii*

	kg/ha	**kg/ha**	**kg/ha**	**Total Snail/ha**	**% Snail per/ha***
Feeds w/Snail	Snail	Commercial Feed	Homemade Feed		
M. rosenbergii	805.8	n/a	n/a	805.8	**100**

*Note: calculations are based on snail feed inputs from Jahan et al. 2015.

Table 14: Feed Fish Efficiency Ratio (FFER)—The parameters considered in determining wild fish use (Factor 5.1a) in *P. monodon* farms (fishmeal) and *M. rosenbergii* farms (snail meat) in Bangladesh and their corresponding values.

Parameter	***P. monodon*** **Data**	***M. rosenbergii*** **Data**
Percentage of fishmeal/snail meat from byproducts	0%	0%
Fishmeal yield (from wild fish/snail)	22.50%	100%
Fish oil inclusion level	0%	0%
Percentage of fish oil from byproducts	0%	0%
Fish oil yield	5.00%	5.00%
Economic Feed Conversion Ratio (eFCR)	0.06	1.15
Calculated Values		
FFER value (fishmeal/snail)	0.01	1.15
FFER value (fish oil)	0.00	0.00
Seafood Watch FFER Score (0–10)	**9.99**	**7.13**

To account for the reduction that occurs when whole fish is processed into fishmeal, Seafood Watch uses a fishmeal yield of 22.5% in scoring this factor (Péron G et al. 2010) (Tacon and Metian 2008). Likewise, Seafood Watch uses a value of 5% to calculate fish oil yield, based on an evaluation of typical, global reduction fisheries (Tacon and Metian 2008). The final FFER value (on which the final FFER score is based) is calculated by multiplying the fishmeal inclusion level by the eFCR, then dividing this amount by the fishmeal yield. Thus, the FFER value for *P. monodon* is rounded up to 0.01 and the resultant Factor 5.1a FFER score is 9.99, reflecting the low fishmeal inclusion rate used in *P. monodon* cultivation. Because there is no reduction or processing involved with the use of snail meat, the snail meat yield is calculated as 100% and the corresponding FFER value for *M. rosenbergii* is 1.15, resulting in a Factor 5.1a FFER score of 7.13.

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

<u>Sustainability of Wild Fish Use – *P. monodon*</u>
Approximately 80%–85% of fishmeal used in Bangladesh comes from local waters, which Mamun-Ur-Rashid (2013a) describes as being "manufactured from a variety of trash fish, crabs and other aquatic animals" and "very variable in nutritional composition." The balance of fishmeal used in Bangladesh is reportedly sourced from China, India, and Thailand (Hasanuzzaman et al. 2010). Specific data on the precise source of local fishmeal used in shrimp feed in Bangladesh are not forthcoming in literature concerning this topic, and there does not appear to be a specific reduction fishery targeted to fulfill local demand for this product. But Mahmud et al. (2012) mention that some local fishmeal is derived from cheoa fish *(Psudapocryptes elongates)*, a seasonally available, mudflat-dwelling, brackish-water species, which is presently assessed by the IUCN (International Union for the Conservation of Nature) as

a species of "Least Concern," and from "miscellaneous" fishmeal, which is obtained from fish, small shrimp, and crabs. This suggests that local fishmeal is derived from bycatch and miscellaneous, low value species, which are coincidentally and/or intentionally captured during general fishing activities.

Although both inland and marine fisheries are exploited locally, inland fisheries have traditionally been the most important source of protein for the people of Bangladesh. Presently, 83% of total fish production comes from inland resources (inland wild-capture makes up 28% and aquaculture accounts for 55%), compared to just 17% from marine capture (FRSS 2015). Currently, numerous species of inland fish are critically endangered or extinct; nonetheless, the inland waters of Bangladesh still represent one of the world's most diverse inland fisheries. A number of factors have negatively affected the abundance and health status of inland fish stocks, including the expansion of agriculture, the development of dams and flood-protection embankments, and an increase in fishing pressure; all these developments have taken their toll on wetlands, fish migration routes, and habitats. Further pressure has been placed on fisheries resources by expansion of the aquaculture and poultry farming sectors and their subsequent increasing demand for fishmeal (Bangladesh Delta Plan 2015). Although fisheries regulations are in place, such as the Fish Protection and Conservation Act 1950, they are extremely challenging to implement. Local inland capture fisheries have reportedly declined 50% since the 1970s, with a downward trend of 1.24% per year (Hossain 2014).

Marine capture of fish has increased slightly over the last decade, although its total contribution to fisheries production has declined. Reportedly, most commercially important marine species are now overexploited, and catches are in decline. Of the 17% of marine catch that composes total national fish production, artisanal fisheries account for around 90% and the balance is from industrial trawling on the continental shelf (Hussain and Hoq 2010). A number of surveys on the status of marine fisheries were conducted during the 1970s and 1980s, but there are no recent comprehensive data available concerning the status of marine and coastal fisheries in Bangladesh (Bangladesh Delta Plan 2015).

The score for Factor 5.1b – Sustainability of the Source of Wild Fish is -10 out of 10 for *P. monodon* because the source fishery for fishmeal is notably undefined and both inland and coastal fisheries have experienced a decline in health of stocks from overexploitation.

<u>Sustainability of Wild Fish (Snail) Use – *M. rosenbergii*</u>

There are around 450 species of snail in Bangladesh, but the freshwater apple snail *(P. globosa)* is one of the most commercially valued varieties. Although *P. globosa* is used extensively as a supplementary feed for *M. rosenbergii,* it is also used to feed ducks and catfish, and the calcium-carbonate-rich shell is used to make lime and animal feed additives. Snail meat was originally collected as a feed for duck cultivation, but as the popularity of *M. rosenbergii* farming grew, so did the use of snails as a supplementary feed for this species. By 2002, around 60% of harvested snails were already utilized by the freshwater prawn farming sector, with the remaining 40% used for duck feed (Sultana et al. 2002). Snail harvesting has developed into an important livelihood for many people in rural Bangladesh, and an analysis of the snail value chain reveals quite a degree of complexity (Nahid et al. 2013). The high dependency that *M. rosenbergii* production has on *P. globosa* has had a significant impact on snail numbers in the vicinity of farms, and overexploitation of this species has led to its gradual disappearance from wetlands in the southwest region (Azad 2008). One of the main snail collecting areas in Bangladesh is Chanda Beel, a large freshwater wetland where snail collection started in 1992. The marked decline in harvest volumes from Chanda Beel can be observed in Figure 11.

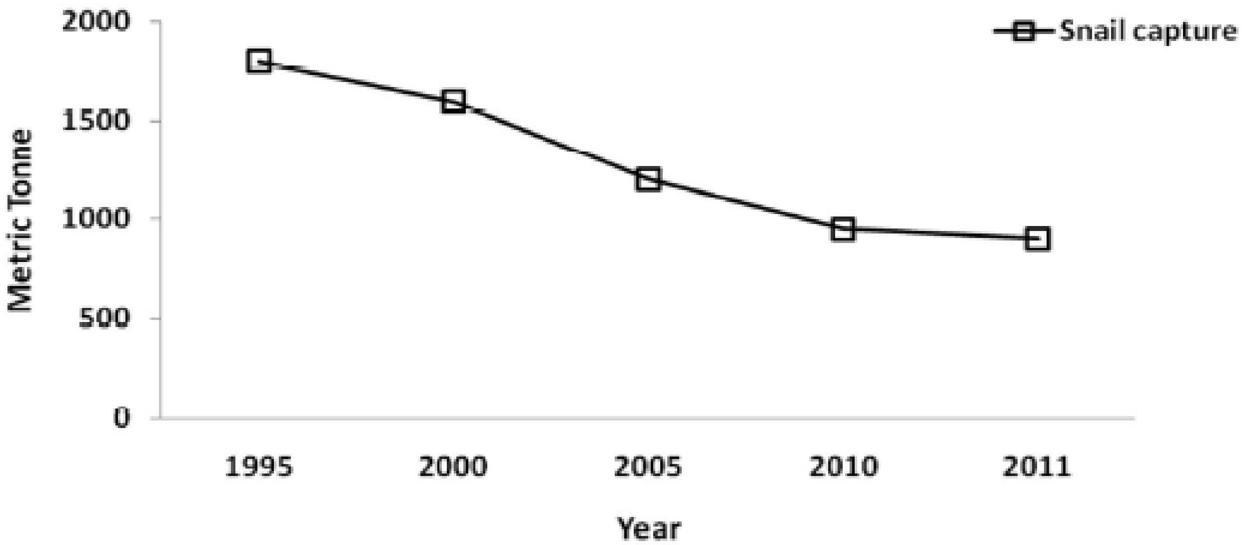


Figure 11**:** Downward trend in harvest volumes of *P. globosa* between 1995 and 2011 (Chanda Beel, Bangladesh) (Source: Nahid et al. 2013).

Nahid et al. (2013) comment that “overharvesting is believed to be the reason for the rapid disappearance of *P. globosa* from the wetland ecosystem of Chanda Beel” and further state that the “availability of snail is decreasing at an alarming rate in different water bodies” in Bangladesh. Snails are not available year-round; they are seasonally collected from June through November, after which the snails estivate, digging deep into the mud beyond the reach of harvesters. But the season when they are available coincides with the seasonal cycle of *M. rosenbergii* production. *P. globosa* plays important ecological roles as a natural water filter and a limit to the growth of aquatic plants (Nath et al. 2008). Although shells are often utilized to manufacture lime and animal feed additives, discarded shells can contribute to blockage of canals, which in turn affects the migration of fish and encourages mosquitoes to breed (Ahmed and Garnett 2010). The continued use of wild *P. globosa* is not a sustainable or ecologically sound practice. Interestingly, a number of authors suggest that this species may be a good candidate for commercial culture (Nahid et al. 2013) (Nath et al. 2008).

The score for Factor 5.1b – Sustainability of the Source of Wild Fish (Snail) is –10 out of 10 for *M. rosenbergii* because *P. globosa* numbers have been severely affected by overharvesting for freshwater prawn culture.

When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1 score of 9.97

out of 10 for *P. monodon* and 4.83 out of 10 for *M. rosenbergii*.

Factor 5.2. Net Protein Gain or Loss

Protein Inputs

Protein inputs can be broken down into three different categories: ocean/aquatic sources (in this case, fishmeal or snail), crop sources, and land animal sources. These inputs are further differentiated as to whether they are edible, i.e., suitable for human consumption. In scoring this factor, all inputs other than freshwater apple snails are presumed to be edible. Freshwater snails are generally not used as a food source for humans in Bangladesh, except by some local tribal groups (Nahid et al. 2013). Table 15 shows the percentages of each protein input that is used to culture *P. monodon* and *M. rosenbergii*.

Table 15**:** Source of protein inputs used to culture *P. monodon* and *M. rosenbergii* (snail only) in Bangladesh (Sources: based on an analysis of data from Jahan et al. 2015 and Hasan et al. 2007).

	P. monodon	***M. rosenbergii***
Source of Protein in Supplementary Feed	% Input	% Input
Protein from ocean/aquatic sources	8.38	100.00
Protein from crops (edible)	91.62	0.00
Protein from land animal sources (inedible)	0.00	0.00
Total % Protein	100.00	100.00

Protein Outputs

To determine the net protein efficiency of both species, it is necessary to factor in their harvested yield and utilized protein content. The average protein content of harvested *P. monodon* is 18.9% (Boyd et al. 2007) and it is 21% for *M. rosenbergii* (Tidwell et al. 2011). The average edible yield from harvested shrimp is 63% for *P. monodon* and 48% for *M. rosenbergii* (Tidwell et al. 2011).

Table 16: Net protein gain or loss—the parameters considered in determining the protein budget (Factor 5.2) of *P. monodon* (all feed inputs) and *M. rosenbergii* (snail meat only) farms in Bangladesh and their corresponding values.

Parameter	*P. monodon* Data	*M. rosenbergii* Data
Protein content of feed	19.57%	52.5%
Percentage of total feed protein from edible sources	100%	0%
Percentage of total feed protein from non-edible sources	0%	100%
Economic Feed Conversion Ratio	0.06	1.15
Edible protein INPUT per MT of farmed shrimp	11.7 kg	0.0 kg
Protein content of whole harvested shrimp	18.9%	21%
Edible yield of harvested shrimp	63%	48%
Utilized % of non-edible by-products from harvested shrimp	50%	50%
Utilized protein OUTPUT per MT of farmed shrimp	156.4 kg	155.4 kg
Net protein gain or loss	+1,232%	1,554%
Seafood Watch Factor 5.2 Score (0–10)	**10**	**10**

The protein component of feed used for *P. monodon* cultivation in Bangladesh is sourced from 8.38% aquatic ingredients, 91.62% crop ingredients, and 0% land animal ingredients. All the protein provided in supplemental feed is considered to be suitable for human consumption but, because of a high reliance on natural pond productivity, there is a large overall net edible protein gain of 1,232%, leading to a Factor 5.2 score of 10 out of 10 for *P. monodon*. Because only freshwater snail meat has been considered in scoring this factor for *M. rosenbergii*, 100% of *M. rosenbergii*'s protein inputs are considered to be aquatic in origin and unsuitable for human consumption. This results in an overall net edible protein gain of 1,554%, leading to a Factor 5.2 score of 10 out of 10 for *M. rosenbergii*.

Factor 5.3 Feed Footprint

This factor describes the approximate aquatic and terrestrial areas required to produce the aquatic, crop, and land animal feed ingredients necessary for production of 1 MT of farmed aquaculture product. These calculations are divided into two factors: one calculation for the ocean/aquatic area appropriated (F5.3a) and one for the terrestrial area appropriated (F5.3b) in production of feed ingredients.

<u>*P. monodon*</u>

The inclusion level of ocean/aquatic-derived ingredients in the composition of feeds used for *P. monodon* production makes up 2.19% of total external feed inputs (Table 12). Using the calculated economic FCR (Table 11) of 0.06 (note that this is *not* the biological FCR; the eFCR does not account for naturally occurring feed in the pond being consumed), plus the fixed values in the Seafood Watch Aquaculture Standard for ocean primary productivity, the equivalent of 0.03 hectares of ocean/aquatic area is appropriated for every MT of *P. monodon* production.

The inclusion level of crop ingredients in the composition of feeds used for *P. monodon* production makes up 97.27% of total external feed inputs, with 0% contributed by the inclusion of land animal ingredients. These data, coupled with a fixed Seafood Watch Criteria value of 2.64 hectares of land area necessary to produce 1 MT of crop ingredients, plus a fixed value of 2.88 as the conversion ratio of crop ingredients to land animal products, result in a calculation of 0.02 hectares of land area appropriated per MT of farmed *P. monodon.*

The combination of these two values (F5.3a and F5.3b) results in an overall feed footprint of 0.06 hectares per MT of farmed *P. monodon* production. This results in a final Factor 5.3 score of 9 out of 10 for *P. monodon*.

M. rosenbergii

Calculations for this factor are based solely on freshwater snail meat inclusion in the diets of cultured *M. rosenbergii*, so the inclusion level of ocean/aquatic-derived ingredients is considered to be 100% of total external feed inputs (Table 13). To score this factor, *P. globosa* is considered to be an aquatic animal (not a terrestrial animal) and the calculated economic FCR (Table 11) is 1.15. The fixed values in the Seafood Watch Aquaculture Standard for ocean primary productivity are based heavily on data and calculations done by a host of researchers (Talberth et al. 2006) (Boyd et al. 2007) (Alder et al. 2008) (Welch et al. 2010), particularly with reference to Pauly and Christensen (1995) and Pelletier et al. (2009), and the values have been calculated with typical reduction fisheries in mind (e.g., pelagic species such as anchovies, herring, menhaden, capelin, anchovy, pilchard, sardines, and mackerel). Typical reduction fisheries have a trophic level in the range of 3–4, whereas *P. globosa*'s average trophic level is between 2 and 2.5. The species profile of freshwater snails differs significantly from that of typical reduction fisheries in many other ways; for example, *P. globosa* is amphibious and thrives in areas where there is abundant aquatic vegetation, such as freshwater ponds, lakes, marshes, rice fields, and rivers. Because freshwater snails are supported by the primary production of freshwater/estuarine environments, these differences necessitate the use of more appropriate values to be used in scoring the primary productivity of this species. Ecosystems such as these have an average primary productivity of around 2.52 MT of carbon per hectare (Cloern et al. 2014). Research conducted by Pauly and Christensen (1995) determined that the harvested wet weight of 896,000 MT of freshwater-dwelling invertebrates and amphibians (a group to which freshwater apple snails would belong), with an average trophic level of 2.2, required a primary production value of 1.6 million MT of carbon. An extrapolation of these data can be used to estimate that 1.79 MT of carbon are necessary to support 1 MT of freshwater invertebrates (here, snails). Because snail meat is used whole (i.e., without reduction processing), this number (1.79 MT C) has been used as the primary production required for the production of 1 MT of *P. globosa*. Using these values, the equivalent of 0.82 hectares of aquatic area is appropriated for every MT of *M. rosenbergii* production.

Because only *P. globosa* has been considered in scoring this factor for *M. rosenbergii*, the land area appropriated per MT of farmed *M. rosenbergii* has been calculated as zero (F5.3b).

The combination of these two values (F5.3a and F5.3b) results in an overall feed footprint of 0.82 hectares per MT of farmed *M. rosenbergii*. This results in a final Factor 5.3 score of 9 out of 10 for *M. rosenbergii*.

Table 17: Inclusion of marine, crop, and land animal ingredients in diets used to farm *P. monodon* and *M. rosenbergii*, plus the ocean/aquatic and land areas necessary to support one MT of harvested product.

Parameter	***P. monodon*** **Data**	***M. rosenbergii*** **Data**
Marine/aquatic animal ingredients inclusion	2.19%	100%
Crop ingredients inclusion	97.27%	0%
Land animal ingredients inclusion	0%	0%
Ocean/aquatic area used per MT of farmed shrimp	0.03 ha	0.82 ha
Land area used per MT of farmed shrimp	0.02 ha	0.0 ha
Total area (hectares)	0.06 ha	0.82 ha
Seafood Watch Score Factor 5.3 (0–10)	**9**	**9**

Conclusions and final score

The final score for Criterion 5 is calculated by averaging the scores of all factors, with a double weighting applied to Factor 5.1. For *P. monodon,* the final score for Factor 5.1 is 9.97 out of 10, which reflects the extremely minimal amounts of wild fish products that are incorporated into feed for this species. *M. rosenbergii* production systems, which rely almost exclusively on freshwater apple snail feed inputs, have a final score for of 4.83 out of 10 for Factor 5.1. Factor 5.2 measures the net protein gain or loss by comparing protein inputs and outputs. For this factor, *P. monodon* has been scored 10 out of 10, because its production actually results in a more than 12-fold increase in edible protein, demonstrated by a net gain of 1,232%. This is because the limited supplementary feeds provided are mainly crop based (91.62%), and most nutritional requirements are met by the naturally occurring feeds in the culture pond. Similarly, *M. rosenbergii* production results in a 15-fold net protein gain, because freshwater apple snails are not considered edible, and results in a Factor 5.2 score of 10 out of 10. Factor 5.3 scored 9 out of 10 for *P. monodon* in consideration of the 0.6 ha of terrestrial and aquatic land appropriated for production of the feed used for 1 MT of its cultivation. Factor 5.3 also scored 9 out of 10 for *M. rosenbergii*, because 0.82 ha of aquatic area must be appropriated to produce 1 MT of harvested *M. rosenbergii*.

For *P. monodon*, Factors 5.1, 5.2, and 5.3 combine to give a final Criterion 5 – Feed score of 9.74 out of 10. For *M. rosenbergii,* Factors 5.1, 5.2, and 5.3 combine to give a final Criterion 5 – Feed score of 7.16 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

Escape parameters	Value	Score
F6.1 System escape risk	0	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		0
F6.2 Invasiveness		8
C6 Escape Final Score (0–10)		**4**
Critical?	NO	**YELLOW**

Brief Summary

The risk of farmed shrimp and freshwater prawn escaping from production systems in Bangladesh is high because ponds experience frequent flooding events. But individuals that do escape have either been collected from the wild or are the first generation progeny from wild broodstock, meaning that the likelihood of genetic disturbance caused by escapees is relatively low. Wild populations of *P. monodon* and *M. rosenbergii* are reportedly in decline, so the risk of ecological impact on these stocks caused by farm escapes, in terms of increased competition for wild habitat resources, is low. The final score for Criterion 6 – Escapes is 4 out of 10.

Justification of Rating

Factor 6.1 Escape risk

Geographically, Bangladesh is deltaic, low-lying, and extremely flood-prone; during an average year, one-fifth of the country experiences flooding and, in extreme flood events, over one-third of the country becomes affected. Even during drought years, 10% of the country suffers from flooding during the monsoon (Ahmed and Diana 2015b). Much of Bangladesh is situated on the Ganges-Brahmaputra Delta, one of the largest deltas in the world, where numerous large rivers meet, notably the Ganges, the Meghna, and the Jamuna. These rivers originate in the Himalayas and empty into the Bay of Bengal. Flooding in Bangladesh is prompted by numerous variables, including rainfall, coastal flooding, cyclone and storm surges, high river levels, backwater effect, poor drainage, and the effects of climatic change. With these factors in mind, loss of shrimp and freshwater prawn from culture systems is inevitable. Although farmers deepen their ghers and build dikes to prevent the escape of cultured animals, there is little they can do to mitigate escapes during extreme weather events, when floodwater breaches the earthen embankments surrounding their ponds.

Flooding presents a significant challenge to shrimp and freshwater prawn farmers in Bangladesh and would appear to be the main catalyst of escape events (Shameem et al. 2015) (Ahmed 2015) (Ahmed and Diana 2015a). Portley (2016) reports that "the Bangladeshi coastal zone is prone to floods and other natural disasters. Frequently, farmed shrimp escape to the wild during floods. However, impacts upon wild populations have not been studied." One study, which assessed the potential of relocating *M. rosenbergii* culture farther inland because of the climatic vulnerabilities of the coast, found that 83% of freshwater prawn farmers had experienced total or partial loss of their stocks from flooding (Ahmed and Diana 2015a). Another study, which focused on *P. monodon* farming in the Bagerhat district in southwest Bangladesh, reported that 80% of farms in the region had been hit by cyclones in recent years (Ahmed and Diana 2015b), likely resulting in flooding and subsequent escape events. Measures taken by farmers to prevent flood damage and soil erosion include dike cropping, increasing the height of embankments, and installing fencing and netting around their ponds (Ahmed 2015) (Shameem et al. 2015).

Because of the different characteristics and variability of farm locations, there is no fixed design used in the construction of shrimp and freshwater prawn farms in Bangladesh, and water exchange rates, which are generally tidal-based, vary from farm to farm, depending on the design, stage of production, and current environmental conditions. As detailed in the Criterion 2 – Effluents section of this report, average daily water exchange rates range between 2% and 30% of pond volume (Rouf 2012) (Wahab 2003) (Islam et al. 2004). The government's "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" (DOF and Bangladesh Shrimp and Fish Foundation 2015) provides guidelines for hatcheries and farms culturing *P. monodon* and *M. rosenbergii* and states, under the section concerned with broodstock management for hatcheries, "hatchery animals shall be adequately contained and their escape to the open water environment shall be adequately protected." Although the section concerned with farms does not specifically mention escapes, it does state that "shrimp farm[s] should be built in an environmentally suitable location and out of the flood prone area" and "shrimp ponds should have separate screened inlets and outlets and water should be carefully filtered to keep competitors, predators, and disease carrying organisms out." At present, regulations and reporting requirements concerned with the monitoring and reporting of escape events appear to be lacking in the regulatory framework governing the shrimp sector in Bangladesh.

Shrimp and freshwater prawn farms in Bangladesh operate in areas that are extremely flood-prone, so the risk of escape events occurring is extremely high. Subsequently, the score for Factor 6.1 is 0 out of 10.

Factor 6.2 Invasiveness

Both *P. monodon* and *M. rosenbergii* are native to Bangladesh, which somewhat lessens the risk of environmental impact posed by escape events. The broodstock used by hatcheries are exclusively harvested from the wild, which means that all hatchery-raised PLs are produced from wild parents. According to Debnath (2015), broodstock only survive for a maximum of 4–5 days (although they used to survive for up to 1 month), so hatchery-reared PLs are all first-generation only, and the likelihood of genetic disturbance from escapes of hatchery-reared animals is negligible. Although importation of shrimp fry from India and Myanmar reportedly occurred in the past (USAID 2006), a more recent study states that this practice has been stopped (Hossain et al. 2013). In addition, it is likely that these imported fry were highly, if not entirely, genetically similar to those produced by broodstock captured locally in Bangladesh, because PLs from these nations also originate from the Bay of Bengal.

In addition to potential genetic impacts, the potential impact that escapes may have on their wild counterparts in terms of ecological disturbance and competition (i.e., competing for food and habitat) must be considered. In the case of escapes of farmed-raised shrimp and freshwater prawns, which have originally been sourced from the wild as juveniles, their return to the natural environment is of little concern. But hatchery-raised PLs potentially pose such a threat because they were not originally part of the natural ecosystem.

Until recently, around half of the *P. monodon* fry stocked in farms in Bangladesh were wild-sourced and half were hatchery-raised; however, 100% of demand is now met by hatchery production (Debnath et al. 2016). Despite this increase in the use of hatchery-produced PLs, it is unlikely that these first-generation domesticated shrimp would competitively threaten wild shrimp. Targeted and incidental wild collection of this species has been taking place since the early days of shrimp farming in Bangladesh, and this has had an adverse effect on population levels—ultimately resulting in a population that is not resource-limited, but limited by fishing pressure. Ahmed and Troell (2010) comment that "larvae fishers, who are also involved in capture fisheries, expressed concern over declining catches of prawns, shrimp, and fish. They estimated a 25% decline during the past 5 years."

Hatchery production of *M. rosenbergii*, in comparison, has shown a marked decline in recent years, despite an increase in the volume of farmed product. Recent statistics indicate that in 2014, only 27 million *M. rosenbergii* PLs were produced by 27 hatcheries (FRSS 2015), compared to 100 million PLs produced by 38 hatcheries in 2010 (Ahmed and Garnett 2010). In addition to dwindling hatchery production of *M. rosenbergii*, Khan et al. (2014) report that in the wild there is (similar to *P. monodon*), a "reducing trend in the effective population size" of this species. With this in mind, it seems that escaped *M. rosenbergii* do not present a significant competitive threat to wild freshwater prawns in terms of habitat and food availability.

P. monodon and *M. rosenbergii* are both native to Bangladesh and, because wild populations of these species are in decline and not resource-limited, escapees have a low risk of presenting a significant competitive threat to wild shrimp and freshwater prawns. The score for Factor 6.2 for both species is 8 out of 10.

Conclusions and final score

In Bangladesh, shrimp and freshwater prawn ponds experience frequent flooding events, which result in a high risk of escape, so the score for Factor 6.1 is 0 out of 10. But these species are native to Bangladesh and PLs used in production are either wild or first-generation, so hatchery-reared, escaped individuals do not represent a genetic threat to their wild counterparts. Additionally, wild stocks of *P. monodon* and *M. rosenbergii* are evidently in decline; therefore, escapees do not pose a threat to wild shrimp and freshwater prawns in terms of competition for food or habitat. For these reasons, Factor 6.2 is scored 8 out of 10. Factors 6.1 and 6.2 combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Disease Evidence-based assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	8	
Critical?	NO	**GREEN**

Brief Summary

Disease has had a major impact on the global shrimp farming sector, causing mass mortalities and threatening the economic sustainability of the industry. Diseases in *P. monodon* and *M. rosenbergii* in Bangladesh that have been reported include white spot disease, black gill disease, and black or brown spot disease. *M. rosenbergii* additionally suffers from soft shell disease and disease associated with broken antennae and rostra. White spot syndrome virus (WSSV), which is the causative agent of white spot disease, is prevalent in the marine environment of Bangladesh and is the most significant of these ailments, both in terms of ecological and on-farm impact. WSSV is one of the major constraints to the economic viability and sustainability of *P. monodon* production, because it is acute in nature and causes high mortalities, up to 100%, in a matter of weeks. Although this disease also affects *M. rosenbergii*, it is not fatal, and individuals may become asymptomatic carriers. Diseases are reportedly not a major constraint to *M. rosenbergii* production. But the *P. monodon* sector is trapped in a vicious cycle in its efforts to combat white spot, because wild-sourced broodstock (on which the sector relies) are carriers of this disease, and a high percentage of WSSV observed in hatchery-raised PLs is likely a direct result of vertical transmission from wild parents. It is probable that WSSV entered Bangladesh via imported PLs during the early 1990s. There is no specific evidence that diseases are transmitted to wild populations from shrimp and prawn farms, but this seems likely, given the interconnectedness of farm and natural water bodies. Still, evidence shows that pathogens in farm populations do not appear to be amplified above levels found in the wild, so the score for Criterion 7 – Disease is 8 out of 10.

Justification of Rating
Because disease data quality and availability is good (i.e., Criterion 1 scored 10 out of 10 for the disease category), the Seafood Watch Evidence-based assessment was utilized.

Diseases Identified in Bangladesh *P. monodon* and *M. rosenbergii* Production
A survey of the characteristics of the aquaculture sector in Bangladesh (Jahan et al. 2015) reported that both tiger shrimp (29% of farmers surveyed) and freshwater prawn farmers (38%) had experienced disease setbacks in the previous year, with the percentage experiencing disease problems over the previous 5 years reported as 50% (black tiger shrimp) and 64% (freshwater prawn), respectively. Table 18 shows the diseases reported by farmers during the survey.

Table 18**:** Disease occurrences reported by *P. monodon* and *M. rosenbergii* farmers in Bangladesh (Source: Jahan et al. 2015).

Disease Name	Symptoms as Reported by Farmers	Species Affected
White spot disease	White spots on carapace, shell and tail, gill damage, sluggish movement, move to water surface, gather near the pond dike, reduced food intake, reduced preening activities, loose cuticles, reddish discoloration	*P. monodon* and *M. rosenbergii*
Black gill disease	Black gills, bacterial erosion on carapace and gill, less appetite, lethargic	*P. monodon* and *M. rosenbergii*
Black or brown spot disease	Black or brown spots on shell, tail and gills; lethargic, less appetite	*P. monodon* and *M. rosenbergii*
Antenna and rostrum broken disease	Antenna and rostrum broken, removal of the rostrum and antenna, lethargic	*M. rosenbergii*
Soft shell disease	Shell is thin and persistently soft, dark spots on shell, shell is rough and wrinkled, lethargic, slow growth rate	*M. rosenbergii*

The impact of disease on *M. rosenbergii* culture is of much less concern than its impact on *P. monodon* production. Wahab et al. (2012) comment that "the incidence of disease outbreaks in prawn culture is still insignificant in Bangladesh." Nesar and Garnett (2010) identify black spot as the most common disease in *M. rosenbergii* culture and state that it causes discoloration of the shell and impacts marketability—it is caused by a bacteria (and sometimes by fungi) and can also cause mortality. By contrast, disease has had a crippling impact on commercial *P. monodon* production in Bangladesh. One of the major constraints to the economic viability and sustainability of *P. monodon* farming in Bangladesh is white spot syndrome virus (WSSV), the causative agent of white spot disease (WSD). The presence of WSSV in culture ponds is mainly caused by the introduction of infected PLs, either of wild or hatchery origin. WSSV can be classified into two types: type one, which affects *P. monodon* (and all cultured Penaeid species, particularly in Asia) is acute in nature, causing high mortalities (up to 100%) in a matter of weeks; type two, which affects *Macrobrachium* sp., wild crabs, and wild lobsters, is not fatal but individuals that become infected carry the disease without displaying symptoms (Debnath et al. 2012). This virus is now endemic to Bangladesh and has caused numerous *P. monodon* farms to cease production from the heavy losses incurred (Rahman and Hossain 2009). It has been estimated that WSSV has caused global revenue losses in the range of USD 8–15 billion (Aquaculture Directory 2016). Prior to the recent emergence of early mortality syndrome (EMS, also called acute hepatopancreatic necrosis syndrome or AHPNS), WSSV was considered to be the most significant disease threat to shrimp culture in Asia. EMS has had a catastrophic effect on culture of *L. vannamei* (culture of this species is not permitted in Bangladesh) and, even though this disease can also affect *P. monodon*, it does not appear to have spread to Bangladesh.

Emergence of White Spot Syndrome Virus (WSSV) in Bangladesh

WSSV is a pervasive disease that affects decapod crustaceans. After emerging in Fujian Province of China in 1992, WSSV was soon also identified in Taiwan and Japan. Subsequently, WSSV spread suddenly and swiftly throughout Asia and the Americas (Walker and Winton 2010). In the early 1990s, the potential profits of the shrimp-farming sector attracted the attention of investors, leading to a number of semi-intensive production units being set up. This increased the demand for PLs and encouraged business-minded individuals to source *P. monodon* PLs from abroad; importation started in 1992, mainly from Thailand and Taiwan (Monwar et al. 2013). This likely led to the first incident of WSSV in Bangladesh, which occurred in 1994 in Cox's Bazar; it was detected in a semi-intensive production system, which was subsequently closed down permanently. By 1996, the disease had proliferated and eventually affected 90% of extensive *P. monodon* farms, causing production to drop to 20%. Similar drops in production due to WSSV occurred in 1997–1998 and again in 2001 (Debnath et al. 2014). The emergence of WSSV in Bangladesh halted initiatives toward intensification of the industry and is the main reason for the prevalence of extensive production techniques employed by the sector today. Nowadays, PLs are no longer imported (Hossain MS et al. 2013).

Present Status of WSSV in Bangladesh

Karim et al. (2011) report that WSSV seems to be more prevalent in southwest Bangladesh than the southeast, and suggest that this may be due to a difference in salinities, with lower salinities experienced by the more disease-prone farms in the southwest. Low salinity and/or a sudden decrease in salinity can result in shrimp becoming stressed and appears to be a more favorable environment for WSSV replication. This theory is echoed in a separate study by Debnath et al. (2014), which found that broodstock collected farther out in the Bay of Bengal in deeper water demonstrated lower levels of WSSV infection than those collected from shallow areas closer to the coast—suggesting that fluctuations in water quality parameters, particularly salinity and temperature, were perhaps the reason for higher rates of WSSV detected in shrimp collected from inshore waters (Debnath et al. 2014). This link between salinity fluctuation and outbreaks of WSSV is also noted in another study, which additionally commented that farms in the study area that did not use supplementary feeds were at more risk (38.9%) than those that did

(8.3%), and that proximity of cattle to the culture pond also increased susceptibility to WSSV to 43.1%, compared to 4.2% when cattle were not in the vicinity (Islam et al. 2014). Shrimp are also exceptionally vulnerable to pathogens after molting, because it takes some time for the new shell to mineralize and harden. Ahmed and Diana (2015b) point out that another potential vector for the entry of disease into shrimp farms is the influx of flood water; aquatic animals washed into ghers during floods may harbor pathogens and parasites, and the water itself may be polluted, leading to water quality issues and the increased risk of disease outbreaks. The Karim et al. (2011) study identified the following factors that affected the likelihood of farmers experiencing losses due to WSSV:

- Financial resources—poorer farmers were more likely to have badly maintained ghers and inadequate biosecurity, which increased susceptibility to disease;
- Older and also larger ghers were more susceptible to WSSV, perhaps because maintenance of these ghers was more difficult;
- Not removing sludge from the bottom of the gher increased susceptibility.

One study of the *P. monodon* hatchery sector in Bangladesh (Debnath et al. 2015) notes that, because Bangladesh is one of the few countries in Asia that has not switched to production of *L. vannamei*, it presently has the most *P. monodon* hatcheries in the region that are in active production. All local shrimp hatcheries are members of the Shrimp Hatchery Association of Bangladesh (SHAB). These hatcheries are entirely dependent on wild-sourced broodstock, of which the condition, fecundity, and survival are in decline. This may possibly be due to poor handling, since the methods of collecting broodstock have changed somewhat, but another possibility is that wild shrimp may now be exposed to more viruses. Despite the observation that broodstock quality has declined, the incidence of WSSV in broodstock has not increased commensurately with this decline, perhaps because other pathogens are contributing to broodstock quality deterioration or because those that were infected died and were discarded before WSSV tests were performed at the hatchery. It was also noted that there was a seasonal relationship (based on 9 years of collected data) with the incidence of WSSV in broodstock: the hot, dry, and early rainy season, which is experienced from the end of March until June (and causes salinity fluctuations), was when WSSV was observed to peak in broodstock. A similar trend was observed in PLs, suggesting that a high percentage of WSSV observed in PLs is a direct result of vertical transmission from broodstock. This study concluded that specific pathogen-free (SPF) broodstock may be the solution to the problem, but points out that the costs involved are high. Although a number of semi-intensive *P. monodon* farms were established in the early 1990s, these farms suffered particularly large financial losses when WSSV hit the industry in 1994, and they subsequently closed (Rahman and Hossain 2009). Debnath et al. (2015) further comment that if semi-intensive farming resumes, then this could make production of SPF PLs more economically viable. The incidence of WSSV in broodstock between 2005 and 2013 is shown in Figure 12.

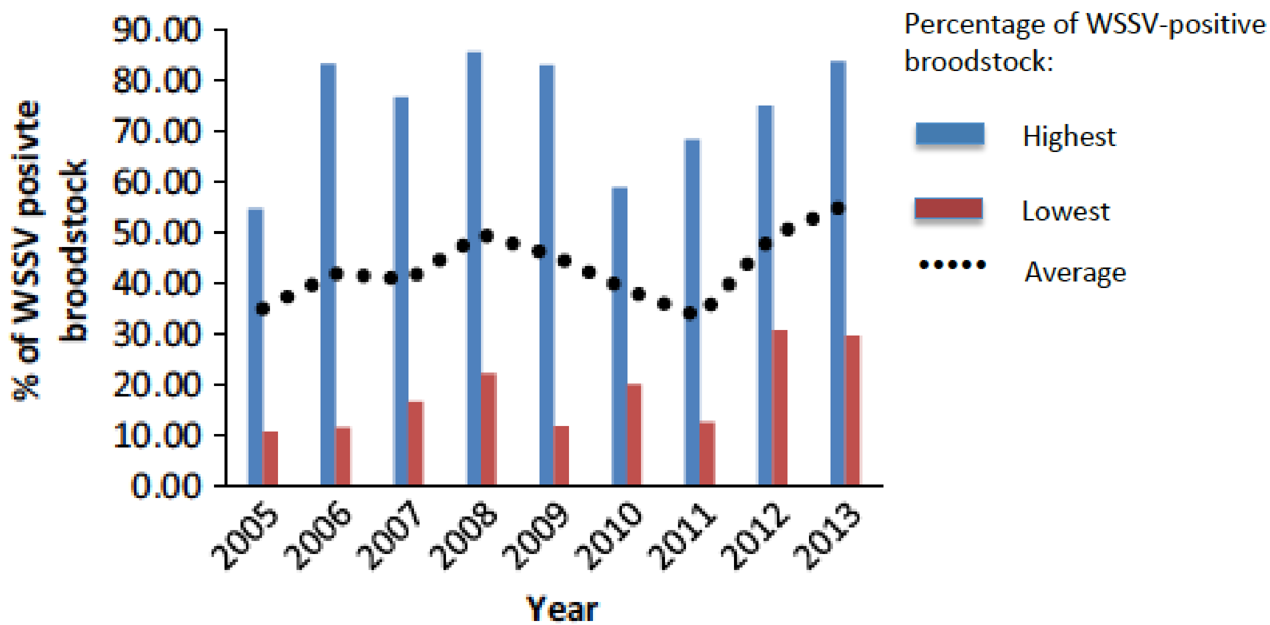


Figure 12**:** The incidence of WSSV in Bangladesh hatchery *P. monodon* broodstock between 2005 and 2013 (Source: Debnath et al. 2015).

Another paper by Debnath et al. (2012) comments that the incidence of WSSV was much lower in hatchery-raised PLs than in wild ones, most likely because of the routine use of formalin, to control parasites in hatcheries. A more recent paper by Debnath et al. (2016) states that an analysis of data collected between 2005 and 2014 revealed that 36.19% of hatchery-produced PLs were infected with WSSV and that, during this period, an average of just 24% of PLs survived through to harvest.

WorldFish commenced a 5-year Feed the Future Aquaculture Project in Bangladesh in 2011, and has been instrumental in the implementation of PCR (polymerase chain reaction) labs in a number of hatcheries, to enable them to test for the presence of WSSV (WorldFish 2013). Between 2012 and 2013, the WorldFish program, through its AIN (Aquaculture for Income and Nutrition) project, has provided training in Best Management Practices (BMP) to 50,000 farmers, resulting in an average production increase from 270 kg/ha to 402 kg/ha for participants (Debnath et al. 2016). Wahab et al. (2012) comment that, because *M. rosenbergii* farms were not economically affected by WSSV, there was a marked increase in the number of farms culturing this species in the wake of the onset of WSSV. Figure 13 shows a comparison between WSSV infection in wild *P. monodon* PLs and hatchery-raised PLs.

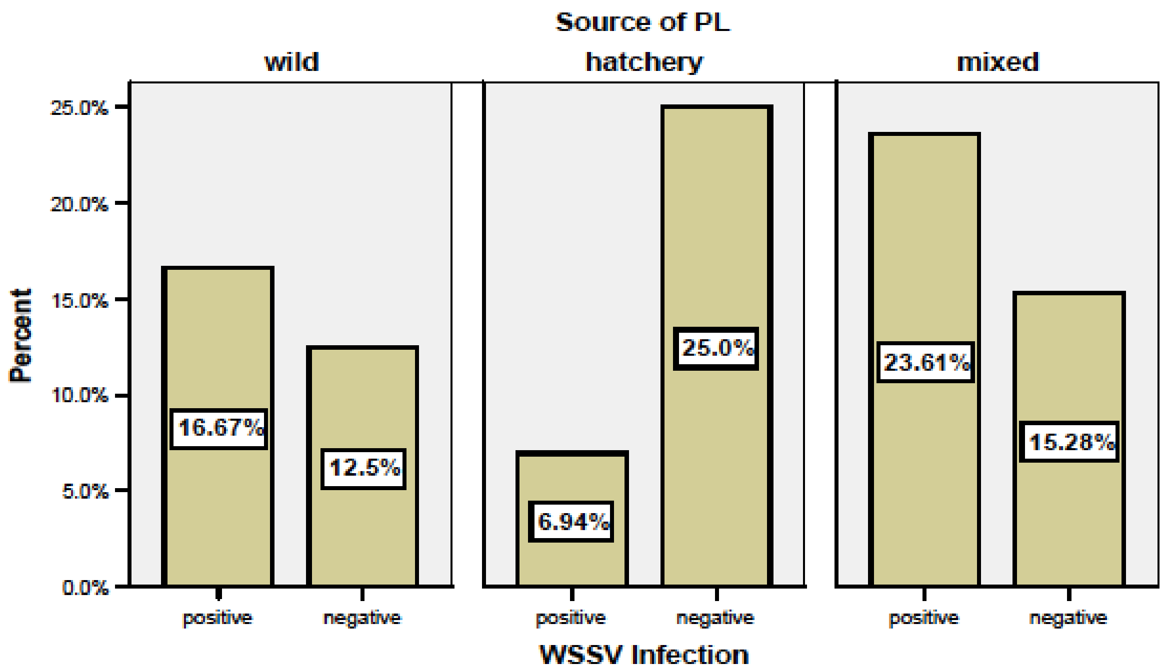


Figure 13: Percentage of WSSV infection observed in wild vs. hatchery raised *P. monodon* PLs (Source: Islam HMR et al. 2014).

Regulatory Framework Governing Disease Management in the Bangladesh Shrimp Sector

The relevant section of the government's "Code of Conduct For Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh" (DOF and Bangladesh Shrimp and Fish Foundation 2015), which provides guidelines for hatcheries and farms culturing *P. monodon* and *M. rosenbergii*, lists "releasing diseased farm animals or exotic species from the farm into the open environment" as one of a number of environmental concerns pertaining to the sector. The section that contains guidance for *P. monodon* and *M. rosenbergii* farms states: "disease can cause heavy losses and can be difficult to control and isolate when disease management is lacking, when traceability of PL supplies is limited and when the design of water supply/flushing structures is poor. Poor pond water quality management also leads to higher levels of animal stress and disease-related mortality." Following this section, there are a number of different guidelines, including sections concerned with PL source, microbial sanitation, and traceability, that contain the following:

PL Source:

- *Farmer shall use only PCR-negative and disease-free healthy hatchery PL.*

Microbial Sanitation:

- *Untreated human sewage (including household waste water) shall not be released from the farm or neighborhood into local ecosystems or the ponds.*
- *Only fertilizers that are approved nationally and internationally shall be used in ponds. For instance, cow dung, poultry litter and human wastes shall not be used as fertilizers.*
- *No animals or birds shall be allowed inside the farm premises.*

- *No run off water likely to carry microbiological hazards, contaminants or disease shall be allowed to enter the ponds (e.g., residue from nearby agriculture or aquaculture or animal husbandry); no equipment likely to carry microbiological hazards, contaminants or disease shall be used.*

<u>Traceability Records</u>
Farm shall maintain records on the occurrence of diseases that may affect the safety of shrimp.

The section on "broodstock origin" notes that hatcheries should "use only local species collected from the local environment" and that hatcheries "shall use only mature brood shrimp collected from outside the 40 m exclusion zone." The section on broodstock health states that a health-monitoring plan, plus related control procedures, should be in place and that all broodstock should be tested for viruses, pathogens, and contaminants, and that records of these tests should be maintained. Hatcheries are also required to "dispose of infected or dead shrimp, either by burning or burying [at a] safe distance from the hatchery." Concerning biosecurity, the code states: "since most disease outbreaks can be traced to the importation of infected stocks or the use of unscreened wild (ocean-caught) stocks, it is imperative that hatcheries implement robust biosecurity measures to prevent inadvertent contamination of the facility. These measures shall address personnel as well as broodstock and PL items." The section on biosecurity continues with a variety of measures that should be implemented, including that "hatchery discharge water must be treated to eliminate potential disease organisms" and "all vessels or tanks used to transport PL shall be thoroughly cleaned and disinfected prior to re-use for PL shipment." A further requirement, listed under the section on traceability, states that the "hatchery shall maintain records on the occurrence of diseases that may affect the safety of shrimp products."

The degree to which hatcheries and farms comply with the code of conduct (COC) is unclear, and there does not appear to be a publicly available record showing certified operations—although this may be because the current version of the code was only recently implemented. The DOF and the Bangladesh Shrimp and Fish Foundation originally formulated the code in 2011 and an updated version was released in August 2015. The recent update was developed in consultation with GAA (Global Aquaculture Alliance) and JIFSAN (Joint Institute for Food Safety and Applied Nutrition), a joint initiative of USFDA and the University of Maryland, plus the international law firm Sidley Austin (The Independent 2015). To achieve certification, hatcheries and farms must first request to be audited by the DOF; provided they pass the audit and are found to be in compliance with the COC, then farmers can have their product processed by a COC-certified processing plant, thus obtaining the DOF Quality label, which certifies their product for export. As noted earlier in this report, this initiative toward industry certification is intended to improve food security and product image, and is comparable to the domestic certification schemes of other shrimp producing nations, such as the Thai Quality Shrimp certification and labeling scheme introduced by the Thai government in 2004 (van der Pijl and van Duijn 2012). Although producers can elect whether to become CoC-certified, it is mandatory that seafood products be processed at approved facilities to be exported to the U.S. or the E.U.; in 2013 there were reportedly 96 government-registered processing plants and, of these, 30 were USFDA green ticketed and 78 were E.U. compliant (Kabir 2013).

The Risk of Re-transmission of Disease from Bangladesh Shrimp Farms to Local Wild Species

There is no specific evidence that various on-farm diseases experienced by shrimp and freshwater prawn farmers in Bangladesh are transmitted to wild populations; although, with regard to WSSV, there is abundant evidence that this disease exists in both wild *P. monodon* and *M. rosenbergii* stocks, plus other decapod crustaceans. It is likely that WSSV entered Bangladesh in 1994 via imported PLs from Thailand and/or Taiwan, but this was not conclusively proved. Hossain et al. (2001) detected WSSV in 49% of wild-caught shrimp during a study undertaken in May 2000, which tested wild *P. monodon* plus other wild shrimp and crustaceans. This study, which was the first study in Bangladesh to use PCR to detect WSSV, concluded that WSSV is "widely prevalent in the marine environment" of Bangladesh. In addition to the wild shrimp and prawn species that tested positive for WSSV infection (*P. monodon*, *P. semisulcatus*, *P. indicus*, *M. monoceros*, *M. brevicornis*, *Palaemon styliferus*, and *M. rosenbergii*) and crabs (*S. serrata* and *P. intermedius*), this study noted for the first time that *P. styliferus*, *M. monoceros*, *M. brevicornis*, and *P. intermedius* were asymptomatic carriers of WSSV, as had already been observed in infected *M. rosenbergii*. Such species have been referred to as "reservoirs" of WSSV in the natural environment. Given that numerous wild species are carriers of WSSV but do not succumb to the disease, there is a causality dilemma as to whether the virus first arose from infected farm-raised shrimp and freshwater prawn or from wild sources. Currently, the primary vector of WSSV into shrimp and freshwater prawn farms is either via hatchery-raised fry from infected wild broodstock or wild-caught PLs. No similar studies were identified hat focused on the detection of other shrimp and prawn diseases in natural ecosystems in Bangladesh.

A new project, initiated by the University of Southampton and funded by Global Research Partnership Aquaculture, aims to investigate and understand how the environment can help control disease risks in fish and crustacean aquaculture in Bangladesh and India. The project will analyze how culture pond conditions can be used to control the spread of two "devastating pathogens of decapod crustaceans and freshwater fish in Asian aquaculture"—namely, WSSV and epizootic ulcerative syndrome (EUS). Dr. Chris Hauton, Associate Professor in Ocean and Earth Science at the University of Southampton and Principal Investigator of the project, said, in reference to WSSV: "[C]urrently, there is no effective means of controlling this globally significant pathogen that has been proven at farm scale. Our current best option is to understand how the environment controls disease progression in shrimp ponds, as a means to reduce the risk of infectious outbreak. This knowledge, incorporated into guidelines for best management practice, will allow for the development of novel intervention strategies to be implemented in the future" (Aquaculture Directory 2016).

Conclusions and final score

Although a number of diseases affect shrimp and freshwater prawn culture in Bangladesh, WSSV is the predominant disease that is of ecological concern. This disease swept across Asia and the Americas after its discovery in Fujian Province, China in 1992, causing widespread mortalities in decapod crustaceans and heavily affecting *P. monodon* culture in Bangladesh. In comparison, diseases of M. *rosenbergii* are insignificant and, even though M. *rosenbergii* is a carrier of WSSV, this virus is not fatal to it. Historically, it seems likely that WSSV entered

Bangladesh in the early 1990s when PLs were imported from abroad to stock newly developed, semi-intensive production systems, although evidence shows that WSSV has been endemic in local, wild populations of decapod crustaceans for some time. Presently, wild shrimp and prawn are a primary source of WSSV transmission into culture ponds; a number of studies indicate that domestically produced *P. monodon* fry display significantly lower rates of infection than wild, and a high percentage of WSSV observed in hatchery-raised PLs is a direct result of vertical transmission from wild broodstock. Given the interconnectedness of shrimp and prawn farm water bodies with water bodies in the natural environment, it can be assumed that disease transmission likely occurs, but pathogens in farm populations do not appear to be amplified above levels found in the wild. The final numerical score for Criterion 7 – Disease is 8 out of 10.

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

An interim update of this assessment was conducted in June 2021. This criterion was updated with new information. The interim update can be found in Appendix 2&3 at the end of this document.

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

P. monodon

Source of stock parameters	Score	
C8 Independence from unsustainable wild fisheries (0–10)	–10	
Critical?	NO	**RED**

M. rosenbergii

Source of stock parameters	Score	
C8 Independence from unsustainable wild fisheries (0–10)	–10	
Critical?	NO	**RED**

Brief Summary

At present, hatchery production of both *P. monodon* and *M. rosenbergii* relies entirely on wild broodstock, the quality and quantity of which is in decline. In the last few years, hatchery production of *P. monodon* has reportedly risen sufficiently to meet the demand of farmers; however, cultivation of *M. rosenbergii* relies heavily on wild-sourcing of juveniles. Hatchery production of *M. rosenbergii* has dropped significantly over the last few years, and current production statistics indicate that around 98.5% of *M. rosenbergii* PLs are wild-sourced, with only 1.5% of demand being met by hatchery production. This represents a critical bottleneck to the sustainable operation or expansion of *M. rosenbergii* culture in Bangladesh. In the long term, neither wild collection of PLs nor reliance on wild broodstock is sustainable. Because there are significant differences in the source of fry for each production system—i.e., both impact wild broodstock but only *M. rosenbergii* production continues to stock wild juveniles—

this criterion has been assessed separately for each species. But because the use of wild-sourced individuals for each sector is demonstrably unsustainable, the score for Criterion 8X – Source of Stock for both *P. monodon* and *M. rosenbergii* is –10 out of –10.

Justification of Rating

In the early days of shrimp farming, PLs were only sourced from the wild; during the 1950s in Bangladesh, shrimp were trapped in ponds on a high tide and then on-grown. As the industry has developed, this “trap and hold” technique of sourcing fry has largely been replaced by either active wild collection or hatchery production.

Recent Trends in Hatchery Production of *P. monodon*

In 2002, the ratio of supply from wild fry compared to that from hatchery fry was reportedly 50:50 for *P. monodon* (Nuruzzaman 2002); however, the *P. monodon* hatchery sector has made significant progress in the intervening years. Culture of *P. monodon* “is presently totally dependent on hatchery produced PL and the hatchery sector has enough production capacity to fulfill the farm demand”; however, “hatchery production is totally dependent on wild-caught broodstock from the Bay of Bengal” (Debnath et al. 2016), and the reproductive performance of these broodstock is in decline (Debnath et al. 2015). DOF figures for 2014 *P. monodon* hatchery production show that 11.58 billion *P. monodon* fry were produced in 2014 (FRSS 2015). Yearly rates of broodstock use and PL production of *P. monodon* between 2007 are 2013 are shown in Figure 14.

Year	Number of broodstock received by hatcheries	PL production (billion)	Number of PL produced per broodstock received
2007	150 833	8.35	55 359
2008	168 059	8.9	52 958
2009	106 382	7.12	66 929
2010	202 223	12.09	59 773
2011	163 640	9.99	61 022
2012	148 084	7.41	50 065
2013	172 032	7.68	44 643

Figure 14: Yearly broodstock use and PL production of *P. monodon* between 2007 and 2013 (Source: Debnath et al. 2015).

Production of *P. monodon* PLs has clearly been a challenge in Bangladesh. During the period 2010–2013, the percent of hatcheries that were fully operational declined from around 60% to 40%, and the number of nonoperational and partially operational hatcheries increased (Debnath et al. 2015). The chronological development of *P. monodon* hatcheries and their production status is shown in Figures 15 and 16.

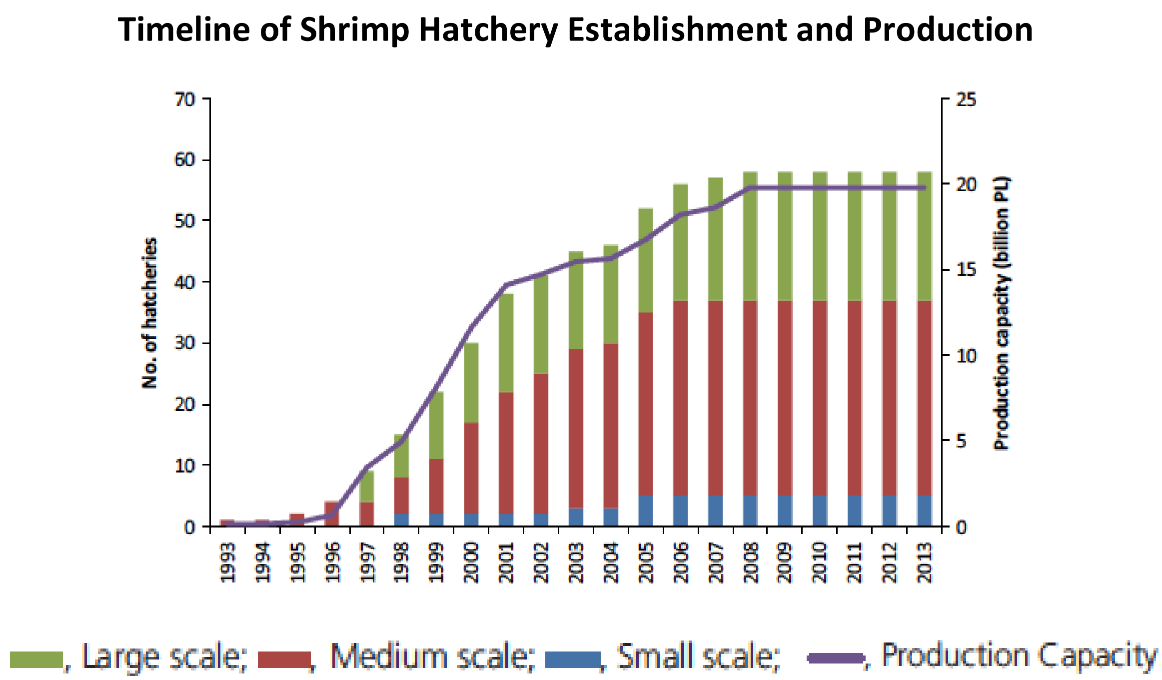


Figure 15: Establishment of *P. monodon* hatcheries in Bangladesh by year and production capacity (Source: Debnath et al. 2015).

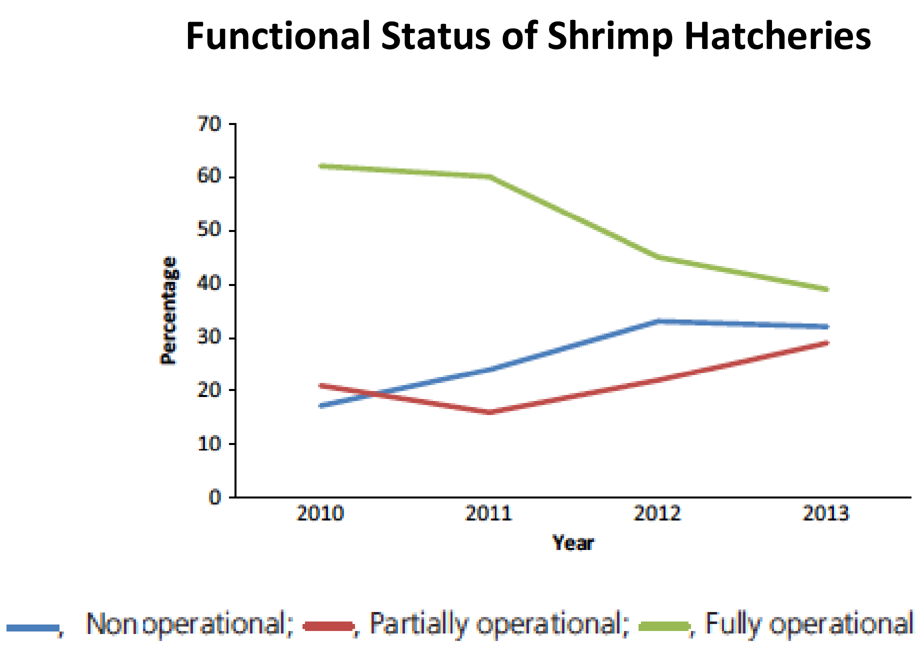


Figure 16: Yearly *P. monodon* hatchery production status(Source: Debnath et al. 2015).

It should be noted that the *P. monodon* hatchery sector in Bangladesh is presently undergoing a change. With support from the government and the Bangladesh Shrimp and Fish Foundation (BSFF), MKA Hatcheries Ltd. in Cox's Bazar has recently started to import SPF broodstock from

Moana Technologies in Hawaii (FFPI 2014). The original broodstock used for this project were reportedly collected from the Bay of Bengal and the Andaman Sea. This initiative has been assisted financially by USAID's Feed the Future Partnering for Innovation program (implemented by Fintrac) and USAID's Aquaculture for Income and Nutrition project (AIN) (implemented by WorldFish). MKA staff have benefited from hatchery training provided by Moana Technologies and appear to be making good progress. As a result of this initial success, USAID plans to continue funding the endeavor, through the AIN project, and to distribute 200 million SPF PLs to smallholder farms that meet the appropriate environmental standards (FFPI 2015). MKA claim that they have the capacity to produce 500 million PLs per year (Inter Press Service News Agency 2016), although realization of this ambition may take some time, because no reference is made to current production volumes. In 2010, the government introduced a new law stating that hatcheries in Bangladesh must supply SFP PLs; this was not possible at the time the law was enacted, but may become a reality soon.

<u>Recent Trends in Hatchery Production of *M. rosenbergii*</u>

In 2002, 90% of stocked *M. rosenbergii* PLs were wild-sourced (Nuruzzaman 2002). By 2010, there were 81 *M. rosenbergii* hatcheries but only 38 of these were operational, fulfilling just 20% of demand with a total production of 100 million PLs (Ahmed and Garnett 2010). Two years later, in 2012, Wahab et al. reported an annual production of 108 million PLs, which provided 15% of demand; this study commented that mass mortality often occurred suddenly within 2 months of stocking hatchery-raised PLs, and that poor quality and availability of broodstock may be one of the main problems contributing to the lack of quality hatchery-raised PLs (Wahab et al. 2012). Government statistics indicate a much-reduced production of 27 million PLs from 27 hatcheries in 2014. These data are indicative of critical problems with PL production in the *M. rosenbergii* sector, and there is a severe production deficit relative to demand. Numerous authors note (Ahmed and Diana 2015a) (Gain et al. 2015) (Wahab et al. 2012) (Ahamed 2012) (Ahmed and Garnett 2010) that *M. rosenbergii* farmers prefer wild-sourced PLs because they are more robust than hatchery-reared ones and availability from hatchery production is limited. Since early 2011, it has been acknowledged that the *M. rosenbergii* hatchery sector is experiencing significant production problems, and this has also been noted in production facilities elsewhere, including neighboring India (Briggs 2013).

<u>Percentage of Industry PL Demand met by Hatcheries in Bangladesh</u>

In 2015, there were 60 *P. monodon* hatcheries in operation (Debnath et al. 2016) and 81 *M. rosenbergii* hatcheries—though only 21 were operational, because of a lack of skilled manpower and of insufficient wild broodstock (Ahmed and Diana 2015a). Government statistics indicate that, in 2014, the number of hatcheries producing each species was slightly different, with 55 *P. monodon* and 27 *M. rosenbergii* in operation. The 2014 hatchery production of both species is shown in Table 19.

Table 19**:** Annual hatchery production of *P. monodon* and *M. rosenbergii* PLs in Bangladesh during 2014 (Source: FRSS 2015 (Bangladesh Department of Fisheries Yearbook—Fiscal Year 2013–2014, 1 July–30 June).

Source of Production	***P. monodon*** **(no. of hatcheries)**	Hatchery PL Production (millions)	***M. rosenbergii*** **(no. of hatcheries)**	Hatchery PL Production (millions)
Govt. Hatchery	8	843	11	2.7
Private Hatchery	47	10,745	16	24.3
Total	55	11,588	27	27

The most current data available on the source of *P. monodon* PLs indicate that 100% of farm demand is currently met by hatchery production (Debnath et al. 2016) (Hussain and Hoq 2010). In contrast, hatchery production of *M. rosenbergii* is declining and, in 2014 (based on national production figures, average harvest size, and average survival rate), hatcheries only supplied an estimated 1.5% of PLs required for the harvest volume achieved. The factors used to calculate this for both species are shown in Table 20.

Table 20**:** Percentage of industry PL demand met by hatcheries in Bangladesh in 2014 (Source: Production figures: FRSS 2015 (Bangladesh Department of Fisheries Yearbook); Average Harvest Weight *(P. monodon)*: Seafood Watch, Monterey Bay Aquarium 2004; Average Harvest Weight *(M. rosenbergii)*: Wahab et al. 2012; Average Survival Percentage *(P. monodon)*: Debnath et al. 2016; Average Survival Percentage *(M. rosenbergii)*: Gain et al. 2015).

	P. monodon	***M. rosenbergii***
Production (MT)	**71,430**	**45,167**
Average Harvest Weight (g)	35	85
No. of PLs Harvested, Based on av. Weight	2,040,857,143	531,376,471
Average Survival (%)	30	59
No. of PLs Stocked, based on % Survival	6,802,857,143	1,771,254,902
No. of PLs Provided by Hatcheries	11,588,000,000	27,000,000
% of PL Demand Met by Hatcheries	**100+**	**1.5**

Wild Fry Collection of *P. monodon* and *M. rosenbergii*

The Government of Bangladesh banned wild fry collection for both species in September 2000 (Verité 2009) (Ahmed and Troell 2010) because of ecological, social, and economic concerns; however, because of a lack of alternative income streams for those who engage in wild collection of PLs and an insufficient hatchery supply of fry, the ban was never effectively enforced. In 2006, USAID reported than an estimated 425,935 people were involved in fry catching during the peak season, and that about 50% of all shrimp fry was wild-caught. This report also noted the comments of some fry collectors, who claimed that an indeterminate amount of fry entered Bangladesh across the border from India and, to a lesser extent, from Myanmar (USAID 2006). A more recent study notes that this practice has been stopped (Hossain et al. 2013). Recently, the government has also initiated a ban on wild-capture of PLs in the Bay of Bengal for 65 days each year, commencing in May, which is the peak time for wild fry collection (Bangladesh Business April 2016) (FFPI 2015) (FFPI 2014) (Inter Press Service News Agency May 2016). Given that *P. monodon* hatcheries have recently been able to fulfill 100% of farm demand (Debnath et al. 2016), this factor ought to have commensurately reduced larval fishing pressure on wild *P. monodon* PLs.

There is a seasonality to fry collection; the main months for collecting fry are mid-November to mid-July, with catches often doubling around the full moon. In the Sunderbans region, 83% of residents are fry collectors (Islam 2015), a fact that demonstrates the government's challenge in enforcing a total ban on wild collection of PLs. Larval fishing is an important livelihood for many of the country's poorest people, particularly when there is increasing population pressure in the coastal zone and there are no alternative employment opportunities. A study of climate change impacts on postlarval fishing in coastal Bangladesh (Ahmed et al. 2013) highlights the fact that freshwater prawn larvae are particularly sensitive to changes in environmental parameters caused by climate change, and that numbers of wild, postlarval freshwater prawns are in decline. One study (Ahmed and Troell 2010) found that most wild collectors were concerned about declining catches and that catches had diminished by 25% in the previous 5 years. There is a high mortality rate incurred with wild collection of fry; fishing for PLs results in a particularly high amount of bycatch because of the fine mesh size that is used, and it is particularly destructive because it takes place in the nursery grounds of many different species. Bycatch ratios in Bangladesh and other countries are shown in Table 21.

Table 21**:** Bycatch ratios of freshwater prawn and shrimp larvae in Bangladesh and other countries (Source: Ahmed & Troell 2010).

Freshwater prawn/Shrimp: bycatch	Country	References
Prawn larvae: bycatch = 1:942	Bangladesh	Ahmed (2010)
Shrimp larvae: bycatch = 1:1,341	Bangladesh	EJF (2004)
Shrimp larvae: bycatch = 1:525–1,666	Bangladesh	Hoq et al. (2001)
Shrimp larvae: bycatch = 1:80–100	Bangladesh	Dev et al. (1994)
Shrimp larvae: bycatch = 1:47–999	India	Primavera (1998)
Shrimp larvae: bycatch = 1:475	Malaysia	Chong et al. (1990)
Shrimp larvae: bycatch = 1:15–330	Philippines	Primavera (1998)

Ahamed et al. (2012) comment that "several studies have shown that the amount of by-catch from the harvesting of wild [shrimp and] prawn PL is the highest of any fishery in the world and it is estimated that over 98 billion of larvae and zooplankton are discarded by every year, globally," and "the crude and indiscriminate harvesting of wild PL involves removing a large proportion of several species of shellfish, finfish and other pelagic biota as by-catch" that is "discarded on the river banks and shores of the harvested water bodies."

Status of Wild Stocks of *P. monodon* and *M. rosenbergii* in Bangladesh

To determine the impact of larval fishing and wild broodstock use on wild fisheries, it is necessary to assess the status of these wild stocks. Fisheries in Bangladesh can be divided into three distinct groups: marine capture, inland aquaculture, and inland capture. According to the Fisheries Statistical Yearbook of Bangladesh, the total aquatic productivity of Bangladesh in 2014 was 3,548,115 MT, to which marine capture contributed 595,385 MT, inland capture contributed 995,805 MT, and inland aquaculture contributed 1,956,925 MT (FRSS 2014). Although this is good, general data, there does not appear to have been a comprehensive assessment of the status and health of Bangladesh wild fisheries, without which it is difficult to accurately gauge the environmental impact that using wild broodstock and wild PLs has on wild stocks.

FAO wild capture statistics are available for Bangladesh; however, the relevant sections that *P. monodon* and *M. rosenbergii* fall under are generic in nature and do not disaggregate the species in question, but report them in two groups of either freshwater crustaceans nei or marine crustaceans nei. Furthermore, there are no FAO data available for freshwater crustaceans nei prior to 2008. Although these data do not provide a conclusive insight into the status of wild Bangladesh *P. monodon* and *M. rosenbergii* stocks per se, they do show that the capture of marine crustaceans, a group that includes *P. monodon*, has remained fairly stable in recent times, whereas the capture of freshwater crustaceans, a group that includes wild *M. rosenbergii*, has peaked and plummeted dramatically over the last few years. Interestingly, the Fisheries Statistical Report of Bangladesh for fiscal year 2014–2015 (FRSS 2015) reports that the total amount of marine shrimp captured during this period was 47,668 MT, which is exactly the same amount of "marine crustaceans nei" recorded by the FAO for this period (i.e., these are the same data), and of this amount, 3,240 MT was *P. monodon*, 30,899 MT was Harina shrimp *(Metapenaeus monoceros)*, 4,367 MT was Indian white prawn *(Fenneropenaeus indicus)*, and 9,162 MT was "others." FRSS figures for 2014 do not list an equivalent volume of wild-captured *M. rosenbergii;* instead, this statistic is buried generically under headings such as "shrimp and prawn," thus making it impossible to discern an accurate wild-capture figure for this species. Figure 17 shows the quantity of wild crustaceans captured in Bangladesh waters and reported to the FAO between 2008 and 2014.

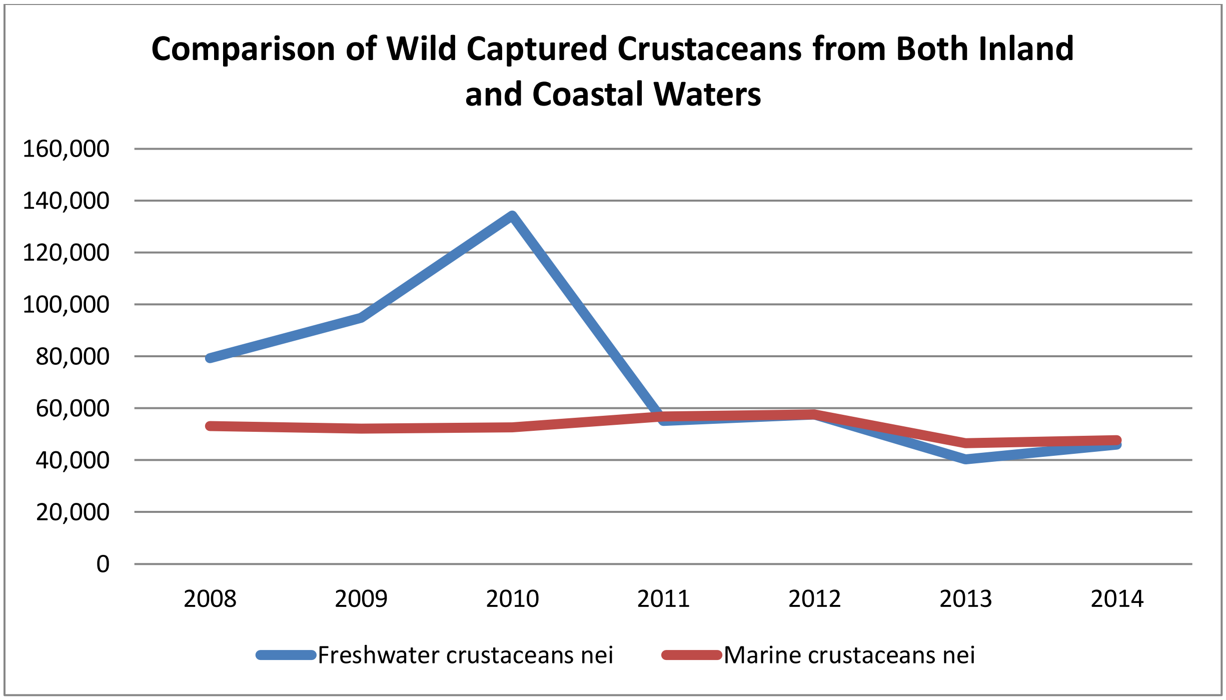


Figure 17**:** Wild-capture of freshwater and marine crustaceans in Bangladesh from 2008–2014 (Source: FAO 2014a, Fishery and Aquaculture Statistics [Global capture production 2009–2014] [FishStatJ]).

Despite the lack of an official stock and health status study on Bangladesh wild *P. monodon* and *M. rosenbergii*, many authors of scientifically reviewed literature have noted a decline in these species over the years. In the mid-1990s, Khan et al. (1995) commented, with regard to marine fisheries in Bangladesh, "overall shrimp catches have dropped in recent years. The problem is further compounded by the increasing exploitation of shrimp seed from inshore and estuarine waters to meet the demand of expanding shrimp culture activities." These authors also comment that "production from inland capture fisheries has been on the decline in recent years, due to over-exploitation and habitat degradation" and go on to specifically mention an observed decline in prawn numbers and the fact that there is "considerable overfishing of broodstock." Clearly. there has been an observable decline in wild stocks of shrimp and freshwater prawn for some time. Slightly more recently, Hoq et al. (2001) reported that "our results indicate that the recruitment of other shrimps, finfishes and macro-zooplankton components of the aquatic food chain will severely decline within the next few years as the consequence of extensive *P. monodon* shrimp PL collection. It is essential that the shrimp postlarvae reach the small creeks and brackish waters of the estuaries to find shelter and food. The recruitment of shrimp in the deep sea is directly dependent on the survival of these juveniles in the mangrove nursery grounds. If these are reclaimed and/or juveniles are captured, this will negatively reflect on the adult population. This scenario will also apply to finfish larvae, indiscriminately exploited with the targeted *P. monodon* PL, with disastrous effects on artisanal and commercial fisheries in the near future."

Concerning *M. rosenbergii* broodstock, Ahmed and Troell (2010) comment: "the actual stock recruitment of prawn in the sea is directly dependent on the survival of the larvae and their return to the sea. However, due to massive larvae fishing, the return of prawn to the sea may have been reduced, potentially leading to the scarcity of broodstock [that has been reported by fishers]." Although it would seem clear that both *P. monodon* and *M. rosenbergii* wild stocks are negatively affected by shrimp and prawn aquaculture in Bangladesh, this fact is not reflected in the FAO's "Review of the State of World Marine Fishery Resources" (FAO 2011); the report notes that *P. monodon* is fully exploited in neighboring India but does not include Bangladesh in this list, although it does mention other species that are overexploited in Bangladesh.

Conclusions and final score

P. monodon

Hatchery production of *P. monodon* has recently sustained adequate production levels to meet the demands of this sector, which in turn ought to have ended wild larval fishing of this species. It is also quite likely that SPF hatchery-produced *P. monodon* PLs will soon be widely available to the industry, moving this sector further toward independence from wild resources. But *P. monodon* hatcheries presently source 100% of broodstock from the wild, and the reproductive performance and abundance of these wild broodstock is reportedly in decline. Seafood Watch considers the use of wild broodstock to be ecologically unsustainable, unless the number used and the sustainability of the source can be demonstrated to be of minimal concern, which is clearly not the case for *P. monodon*. The final numerical score for Criterion 8X – Source of Stock is –10 out of –10 for *P. monodon*.

M. rosenbergii

Hatchery production of *M. rosenbergii* also relies totally on wild broodstock, and the quantity of PLs being produced by this sector is in decline, with the majority of *M. rosenbergii* PLs being wild-sourced. The proportion of wild-caught *M. rosenbergii* PLs fluctuates somewhat from year to year; however, 2014 statistics indicate that only 1.5% was hatchery-supplied during this period. Wild-sourcing of fry has had a notable impact on multiple species inhabiting the environments from which they are collected, because bycatch rates are so high. The collectors themselves have noted a decline in the availability of these naturally sourced PLs. Based on this evidence, neither the use of wild broodstock nor the use of wild PLs is a sustainable practice for the *M. rosenbergii* sector, so the final numerical score for Criterion 8X – Source of Stock is –10 out of –10 for this species.

Criterion 9X: Wildlife and predator mortalities

Impact, unit of sustainability and principle

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

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

Criterion 9X Summary

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

Brief Summary

The impact of *P. monodon* and *M. rosenbergii* farming on predators and other wildlife species in Bangladesh appears to be minimal, with only passive, exclusory control methods employed by farmers and the occasional use of pesticide prior to pond stocking. No population-level impacts have been reported, although mortality of individuals resulting from interactions with shrimp and freshwater prawn farms in Bangladesh may occur in exceptional cases. Thus, the final score for Criterion 9X – Wildlife and Predator Mortalities is –2 out of –10.

Justification of Rating

Globally, the range of anti-predator measures employed by aquaculture farmers can be broadly classified into three different categories of control: exclusory, frightening, and lethal. Literature on shrimp and freshwater prawn farming in Bangladesh does not mention a great deal on the subject of predator control methods or associated predator mortalities, which suggests that predation does not represent a significant problem, perhaps because of the low stocking densities employed. The use of frightening or lethal predator control measures was not identified in literature, although passive, exclusory methods are implemented, such as the installation of fencing and netting around ponds (Ahmed 2015) (Shameem et al. 2015). The Code of Conduct (DOF 2015) for the shrimp aquaculture industry in Bangladesh offers the following guidance to *P. monodon* farmers, with reference to the implementation of exclusory predator control measures:

- *Shrimp ponds should have separate screened inlets and outlets and water should be carefully filtered to keep competitors, predators, and disease carrying organisms out.*
- *A fine mesh fence, at least two feet high and buried six inches into the ground, can be built around the perimeter of the shrimp farm to keep out virus carrying crabs and other small animal pests.*
- *Gates and barriers should be constructed to keep dogs and farm animals out.*
- *No animals or birds shall be allowed inside the farm premises.*

The CoC does not offer any further guidance to farms or hatcheries concerning predator or wildlife interactions, and there does not appear to be any requirements for mortalities of any kind to be reported.

It should be noted that some farmers use rotenone (Ali et al. 2015), a chemical pesticide that is used to kill unwanted and predatory fish, prior to stocking the gher. When pesticide is not used, some juvenile aquatic organisms may enter the pond with the fill water, and thereby become trapped in the pond, where they will continue growing until the pond is harvested.

Although *P. monodon* and *M. rosenbergii* culture no doubt have an impact on wildlife in terms of habitat degradation, generation of bycatch during PL and broodstock collection, etc., this criterion is concerned with the primary interaction of wildlife species within the farms themselves. Literature concerned with the Bangladesh shrimp farming sector mentions little in this regard, although Ahmed & Garnett (2010) comment that farmers chase aquatic birds and ducks away from ponds and that there is no alternative habitat for these species.

Conclusions and final score

This criterion is a measure of the mortality, whether deliberate or accidental, inflicted upon predator and wildlife populations that are attracted into the farm vicinity because of the presence of cultured aquatic animals. In Bangladesh, the risk of this type of impact is low, because only passive exclusory predator-control measures appear to be utilized, no evidence of lethal control or of population-level impacts have been identified, and wildlife is typically chased away rather than killed. Although the Bangladesh shrimp farming sector may attract or interact with predators or other wildlife, effective management and non-harmful prevention measures are in place, so mortalities are limited to exceptional cases. With these factors in mind, the final numerical score for Criterion 9X – Wildlife Mortalities is a deduction of –2 out of –10.

Criterion 10X: Escape of unintentionally introduced species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10	
F10Xb Biosecurity of source/destination	0	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

Although importation of *P. monodon* fry into Bangladesh did occur in the early 1990s, these cross-border shipments of fry no longer take place. A new hatchery initiative has recently started to use imported *P. monodon* SPF broodstock from Hawaii, although production numbers are presently insignificant. No evidence of importation of *M. rosenbergii* PLs has been identified, although diminishing local hatchery production of this species may increase the likelihood of this occurring. The risk of unintentionally introduced species escaping from *P. monodon* and *M. rosenbergii* farms in Bangladesh because of the international and trans-waterbody movement of animals is not presently a concern, and the final numerical score for Factor 10X – Escape of Unintentionally Introduced Species is 0 out of –10.

Justification of Rating

In the early 1990s in Bangladesh, the potential of the shrimp farming sector attracted new investment from entrepreneurs, resulting in a number of new, semi-intensive production units being set up. This development led to an increased demand for and a subsequent scarcity of domestically sourced PLs. Consequently, this supply deficit inspired traders to import PLs, mainly from Thailand and Taiwan. Meanwhile, in China, the first-ever case of white spot disease (WSD) was recorded in 1992, and soon the disease was also reported in Taiwan. White spot syndrome virus (WSSV) first appeared in Bangladesh in 1994–1995, likely as a result of PL importation. The recently established, semi-intensive *P. monodon* production systems were particularly hard-hit by the emergence of WSSV; they suffered severe economic losses, which resulted in a total collapse of these nascent business ventures (Monwar et al. 2013). This incident is largely responsible for the prevalence of small-scale, extensive farms, which still dominate the industry today.

According to USAID (2006), fry collectors historically reported that some PLs also made their way into the domestic supply chain from India and Myanmar, although quantities were unknown and undocumented. Currently, farmers are wary of imported fry, and Hossain et al. (2013) state that the practice of PL importation has been stopped. Although no evidence of *M. rosenbergii* importation has been identified, Briggs (2013) comments that, if hatchery production problems remain unresolved in this sector, then “heavy illegal capture of wild PL, plus illegal importations are likely.”

One progressive *P. monodon* hatchery has recently started to import SPF broodstock from Hawaii; the impetus for this initiative was the USAID Feed the Future Partnering for Innovation grant program and the development of a partnership between Moana Technologies of Hawaii and MKA Hatchery in Cox’s Bazar, Bangladesh. The source broodstock were reportedly initially collected from local waters (Bangladesh Business 2016). PLs produced from the imported broodstock are reportedly free of all pathogens listed by the World Organisation for Animal Health (OIE 2016) and no antibiotics are used in their production (FFPI 2015). It should be noted that, although SPF broodstock are free from specific pathogens, they are not guaranteed to be free from all pathogens. The contribution of *P. monodon* PLs from this source is negligible at present; in September 2015 it was reported that “hatchery production has averaged over one million fry per day and in a 200 day hatchery season that would translate to production of 200 million shrimp fry—200 million shrimp fry will provide disease free shrimp to 10,000 traditional shrimp farmers” (FFPI 2015). Even when this ambition is realized, this would still account for less than 3% of the *P. monodon* PLs that were stocked during 2014 (see Table 20 in Criterion 8X).

Conclusions and final score

Importation of *P. monodon* fry in the early 1990s likely introduced WSSV to Bangladesh, causing the collapse of locally emerging, semi-intensive farms and favoring the predominance of extensive culture techniques, which still dominate the sector today. *P. monodon* fry importation reportedly no longer takes place, and farmers are apparently wary of such fry because of its association with disease. A new hatchery initiative is using imported *P. monodon* SPF broodstock from Hawaii; at present, production numbers are negligible but this may change in the near future. No evidence of importation of *M. rosenbergii* PLs has been identified, although if problems with local hatchery production of this species are not resolved, this may encourage importation of PLs. The risk of unintentionally introduced species escaping because of the international and trans-waterbody movement of animals is not presently a concern. The final numerical score for Criterion 10X – Escape of unintentionally introduced species is 0 out of –10.

Overall Recommendation

The overall recommendation is as follows:

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

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

P. monodon

Criterion	Score	Rank	Critical?
C1 Data	8.86	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	0.27	RED	YES
C4 Chemicals	8.00	GREEN	NO
C5 Feed	9.74	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8X Source	–10.00	RED	NO
C9X Wildlife mortalities	–2.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**34.87**		
Final score (0-10)	**4.98**		

OVERALL RANKING

Final Score	4.98
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

M. rosenbergii

Criterion	Score	Rank	Critical?
C1 Data	8.86	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	4.93	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	7.16	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	8.00	GREEN	NO
C8X Source	–10.00	RED	NO
C9X Wildlife mortalities	–2.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**36.96**		
Final score (0-10)	**5.28**		

OVERALL RANKING

Final Score	5.28
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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

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About Seafood Watch®

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

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

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

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

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Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[3] 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 broodstock thereby avoiding the need for wild capture
- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving

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

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

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

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

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

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

Appendix 1 - Data points and all scoring calculations

Note that of the 10 criteria, 7 are scored identically for *P. monodon* and *M. rosenbergii*, but 3 are scored differently: Criterion 3 – Habitat; Criterion 5 – Feed; and Criterion 8X – Source of Stock.

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	10
Management	7.5
Effluent	7.5
Habitats	10
Chemical use	10
Feed	7.5
Escapes	5
Disease	10
Source of stock	10
Predators and wildlife	10
Unintentional introduction	10
Other – (e.g. GHG emissions)	n/a
Total	**97.5**

C1 Data Final Score (0-10)	**8.86**	**GREEN**

Criterion 2: Effluents

Effluent Evidence-Based Assessment

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

Criterion 3: Habitat - *P. monodon*

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	0

Factor 3.2 – Management of farm-level and cumulative habitat impacts

3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	**0.8**

C3 Habitat Final Score (0-10)	**0**	**RED**
Critical?	YES	

Criterion 3: Habitat – *M. rosenbergii*

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	7

Factor 3.2 – Management of farm-level and cumulative habitat impacts

3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	**0.8**

C3 Habitat Final Score (0-10)	**5**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

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

Criterion 5: Feed – *P. monodon*

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In:Fish Out (FIFO)	
Fishmeal inclusion level (%)	2.19
Fishmeal from by-products (%)	0
% FM	2.19
Fish oil inclusion level (%)	0
Fish oil from by-products (%)	0
% FO	0
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	0.06
FIFO fishmeal	0.01
FIFO fish oil	0.00
FIFO Score (0-10)	**9.99**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-10
Calculated sustainability adjustment	-0.01
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**9.97**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	19.57
eFCR	0.06
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	100.00
Feed protein from NON-EDIBLE sources (%)	0.00
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.9
Edible yield of harvested fish (%)	63
Use of non-edible by-products from harvested fish (%)	100
Total protein input kg/100 kg fish	1.1742
Edible protein IN kg/100 kg fish	1.17
Utilized protein OUT kg/100 kg fish	15.64
Net protein gain or loss (%)	1,232
Critical?	NO
F5.2 Net protein Score (0-10)	**10**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	2.19
eFCR	0.06
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	0.03
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	97.27
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	0.06
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.02
Total area (Ocean + Land Area) (ha)	0.06
F5.3 Feed Footprint Score (0-10)	9

Feed Final Score

C5 Feed Final Score (0-10)	**9.74**	**GREEN**
Critical?	**NO**	

Criterion 5: Feed – *M. rosenbergii*

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In:Fish Out (FIFO)	
Fishmeal inclusion level (%)	100
Fishmeal from by-products (%)	0
% FM	100
Fish oil inclusion level (%)	0
Fish oil from by-products (%)	0
% FO	0
Fishmeal yield (%)	100
Fish oil yield (%)	5
eFCR	1.15
FIFO fishmeal	1.15
FIFO fish oil	0.00
FIFO Score (0-10)	**7.13**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-10
Calculated sustainability adjustment	-2.30
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**4.83**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	52.5
eFCR	1.15
Feed protein from fishmeal (%)	100.00
Feed protein from EDIBLE sources (%)	0.00
Feed protein from NON-EDIBLE sources (%)	100.00
Protein OUTPUTS	
Protein content of whole harvested fish (%)	21
Edible yield of harvested fish (%)	48
Use of non-edible by-products from harvested fish (%)	100
Total protein input kg/100 kg fish	60.375
Edible protein IN kg/100 kg fish	00.00
Utilized protein OUT kg/100 kg fish	15.54
Net protein gain or loss (%)	1,554
Critical?	NO
F5.2 Net protein Score (0-10)	**10**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	100
eFCR	1.15
Carbon required for aquatic feed ingredients (ton C/ton fish)	*1.79*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.52*
Ocean area appropriated (ha/ton fish)	0.82
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	0
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.15
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.00
Total area (Ocean + Land Area) (ha)	0.82
F5.3 Feed Footprint Score (0-10)	9

Feed Final Score

C5 Feed Final Score (0-10)	**7.16**	**GREEN**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	0	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape Risk Score (0-10)	**0**	
6.2. Invasiveness score (0-10)	**8**	
C6 Escapes Final Score (0-10)	**4**	**YELLOW**
Critical?	**NO**	

Criterion 7: Diseases

Disease Evidence-based assessment (0-10)	8	
Disease Risk-based assessment (0-10)		
C7 Disease Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Criterion 8X: Source of Stock – *P. monodon*

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

Criterion 8X: Source of Stock – *M. rosenbergii*

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

Criterion 9X: Wildlife and predator mortalities

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

Criterion 10X: Escape of unintentionally introduced species

F10Xa live animal shipments score (0-10)	10.00	
F10Xb Biosecurity of source/destination score (0-10)	0.00	
C10X Escape of unintentionally introduced species Final Score (0-10)	**0.00**	**GREEN**
Critical?	n/a	

Appendix 2 – Interim Update *P. monodon*

An Interim Update of this assessment was conducted in June 2021 in the most-up-to-date Seafood Watch Aquaculture Standard Version 4.0. 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 the Habitat and Source of Stock criteria for *P. monodon* pond production. 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.

Interim Update Scoring Summary
Results of the interim update support the findings of the previous assessment - the Overall Recommendation for shrimp (*P. monodon*) grown in ponds in Bangladesh remains Avoid with a Red rating. The recommendation and rating are driven by two red criteria assessed in the interim update, Criterion 3 – Habitat and Criterion 8x – Source of Stock. According to the Seafood Watch standard, two red criteria automatically result in a Red rating and an Avoid recommendation.

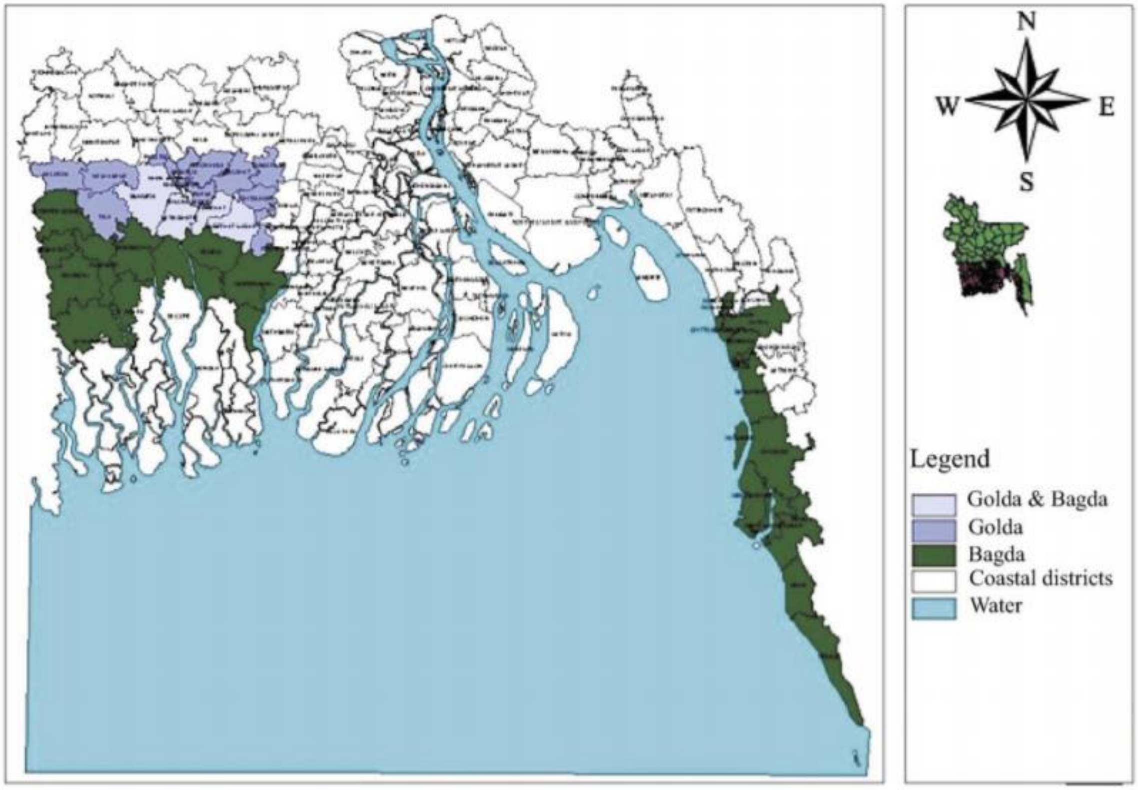
Criterion 1 – Data
Overall, data availability and quality for Bangladesh was considered low for Criterion 3 – Habitat and Criterion 8X – Source of Stock. For Criterion 3 – Habitat, some useful information was available detailing insight into land use change through time and the type of habitat impacted, but data for habitat management and enforcement were incomplete with outstanding knowledge gaps such as: the process for new farm siting, ecological considerations for new farm siting, regulatory conditions, permits for farms, registration of farms, and the enforcement of habitat management measures. Insight was mainly gathered from peer reviewed literature and the United Nations Food and Agriculture Organization (FAO). For Criterion 8X – Source of Stock, updated information about the source of broodstock was not readily available, and information about wild *P. monodon* catch rates, gear types used, bycatch, etc. was unavailable. As a result, the availability and quality of data is considered low.

Criterion 3 – Habitat

Factor 3.1 Habitat Conversion and Function

<u>Land Conversion</u>

The Southwest coastal districts Khulna, Bagerhat and Satkhira are the dominant giant tiger prawn (*P. monodon)* producing areas in Bangladesh, accounting for 79% of total shrimp production in 2015 (Akber et al 2017). Some production also occurs in the Southeast part of the country (see Figure 1).



(Bagda = *P. monodon*; Golda = *M. rosenbergii*)

Figure 1: Map of Bangladesh showing coastal *P. monodon* and inland *M. rosenbergii* production areas Source: Nuruzzaman M, 2006.

Development of the shrimp farming industry began in 1980 in the Southwest coastal districts where land use consisted of primarily agriculture, forest, villages and urban areas and rivers. From 1980 to 2016 the proportion of these land use categories in the Southwest coastal districts of Khulna, Satkhira and Bagerhat changed from a dominantly agriculture use to a near equal use between agriculture and aquaculture (see Figure 2). The study does not delineate between the different types of aquaculture, but given the dominance of shrimp farming in this area as well as its suitable biophysical conditions - shrimp farming is assumed to be a driver for much if not all of the land use change to aquaculture production. One important reason for land use conversion was due to economic opportunities. Aquaculture's relatively rapid expansion from 5,053 ha in 1980 to an estimated 277,085 ha by 2016 was incentivized by the higher economic returns of growing *P. monodon* instead of rice and/or other crops (Akber et al 2018). As a result, farmers converted their agricultural lands to shrimp ponds (Parvin, et al, 2016; Islam et al 2017; Akber et al 2018). Currently, it is unclear if shrimp culture land expansion is ongoing, and if so, what types of habitats are being converted.

Ecological impacts resulting from the conversion of agriculture land to shrimp ponds are numerous and include the net loss of ecosystem services and excessive saltwater intrusion to the region (Paprocki and Cons, 2014; Akber et al 2018; Parvin, et al, 2016). The social cost of shrimp farming in some of these communities include the reduction of food and economic resiliency as well (Paprocki and Cons, 2014). Despite these ecological and social impacts, the expansion of the shrimp farming industry did not dramatically alter the mangrove land use coverage of the Sundarbans (see Figure 2).

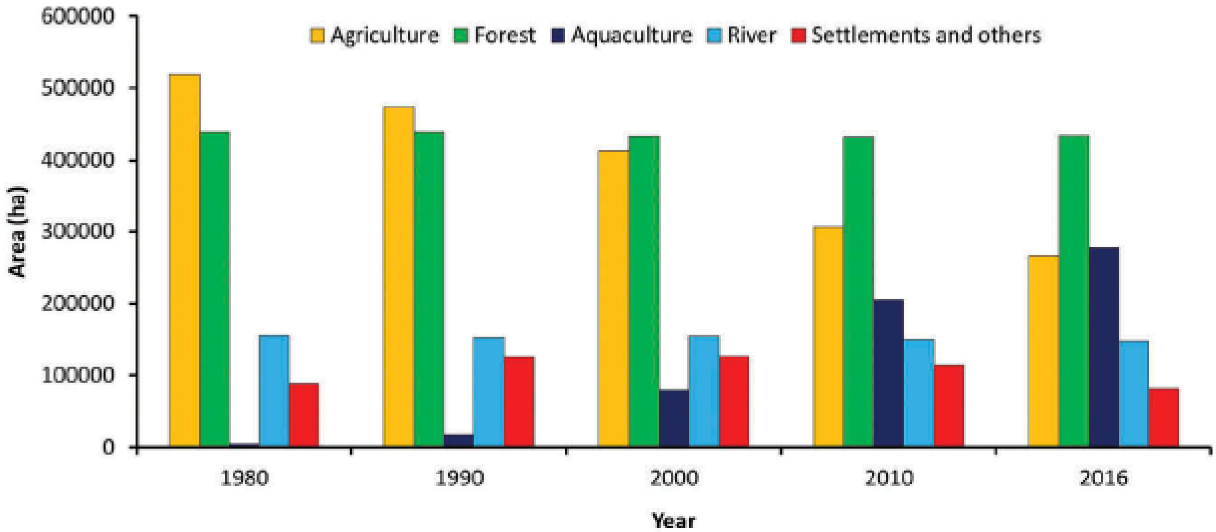


Figure 2 Land use map of each land use derived from Landsat MSS and TM in 1980, 1990, 2000, 2010 and 2016. Source: figure was captured from Akber et al. 2018.

The conversion of mangrove forest habitat in the Sundarbans is prohibited. The Sundarbans forest reserve is a UNESCO world heritage site and is legally protected by the Bangladesh Wildlife Act 1974, and the Forest Act 1927 which control activities within the reserve including "entry, movement, fishing, hunting, and extraction of forest produces." (UNESCO, 2021). However, according to Bangladesh's Soil Research Development Institute report from 2000 to 2010, an estimated 50,000 hectares of Sundarbans mangrove forest were converted to shrimp [*P. monodon*] aquaculture production and other purposes (Islam and Bhuiyan, 2016; Islam et al 2017 citing Rahman & Rahman, 2013). But these estimates do not align with Landsat imagery conducted by Akber et al 2018 and by the Clark Lab at Clark University, which estimate total land use change of the Sundarbans at 4,892 ha from 1980-2016 (Akber et al 2018) and 65.6 ha from 1999 to 2018 (Clark Lab at Clark University).

Although the Sundarbans reserve remains intact, the Chakaria Sundarbans in the Southeast was altered. Prior to 1999, an estimated 10,000 ha of its coastal wetlands and mangrove forests were converted for *P. monodon* shrimp farming which included the alteration of the hydrological function of the landscape (Hossain, Lin and Hussain, 2001; Amhed et al 2017). The impact of this land use conversion is both direct through land use change and indirect in its impacts to saltwater intrusion and social disruption. In a Guardian article by Joanna Lovatt in 2016, the article quotes a long-time resident of the Chakaria Sundarbans area: "This place used to be known as the Sundarbans of Chakaria, it was a mangrove forest," he says. "But now, there is almost no green left. All the mangroves are gone. Even the grass is dying." (quote by Dr Mohammad Iqbal from Lovatt, J., 2016).

<u>Saltwater Intrusion</u>

Saltwater intrusion in the Southwest and Southeast regions of Bangladesh is caused by a multitude of drivers but is largely due to severe storms. According to the Climate Risk Index published by Eckstein et al 2021, Bangladesh is ranked 7^{th} globally for most affected by extreme weather events from 2000 – 2019. Exacerbating the effects of increasing coastal inundations and cyclone frequency and severity is the increase in seasonal drought and irregular rainfall patterns. Together, these factors are causing an increase in salinity in soil, freshwater, and wetlands/estuaries (Ahmed 2013; Hossain et al. 2013; Paul and Vogl 2011; Ahmed and Diana 2015a; Morshed et al. 2020). However, compounding the issue of saltwater intrusion is the construction and operation of brackish water *P. monodon* farms.

A report by the International Monetary Fund in 2013 identified brackish water shrimp farming as a key cause "for secondary salinization of coastal lands" in Bangladesh (IMF, 2013). Furthermore, Parvin et al. (2016) attribute some burden of salinization in the Southwestern region of Bangladesh to shrimp pond development and claim "salinization is the most acute problem in southwestern coastal areas." Impacts of saltwater intrusion from both brackish water shrimp farms and an altering climate in the Southwest and Southeast region of Bangladesh include: reduced soil fertility for crop farming, altered drinking water quality, reduced productivity of fruit trees, which have all ultimately affected food security and human nutrition for residents in the area (Lovatt, J., 2016; Paprocki and Cons, 2014; Morshed et al. 2020). As a result of a loss of these ecosystem services, residents are exerting more pressure on the resources of the Sundarbans (Islam et al 2017). The impact of saltwater intrusion to the habitat and residents near shrimp farming remains ongoing.

Factor 3.1 Conclusion

Prior to shrimp farming, land use in the Southwestern and Southeastern districts of Bangladesh consisted of primarily agriculture, forest, villages and urban areas and rivers. Incentivized by relatively higher economic returns, aquaculture development – specifically shrimp farming – converted agriculture land to aquaculture use. In the Southwestern districts, aquaculture land use increased from 5,053 ha in 1980 to an estimated 277,085 ha by 2016. The expansion of the shrimp farming industry did not dramatically alter the mangrove coverage of the Sundarbans, but in the Chakaria Sundarbans in the Southeast an estimated 10,000 ha of coastal wetlands and mangrove forests were converted for *P. monodon* farming prior to 1999. Currently, it is unclear if expansion is ongoing, and if so, what types of habitat are being converted.

Since roughly 80% of *P. monodon* production occurs in the Southwest and the construction of brackish water ponds was due to the conversion of previously modified habitat of agricultural land, the typical habitat value according to the Seafood Watch Aquaculture Standard is low.

The ecological impacts of brackish water *P. monodon* farming are considered ongoing due to saltwater intrusion to the surrounding environment. Although *P. monodon* farming is not the single activity driving saltwater intrusion in the area, it is considered a key cause. The specific impacts of saltwater intrusion are many, and they result in a functional degradation of healthy soil and its ability to support local flora and fauna, as well as degrade freshwater resources.

In the Seafood Watch Aquaculture Standard, the ongoing loss of low value habitat functionality results in a Factor 3.1 Habitat Conversion and Function score of 3 out of 10.

Factor 3.2 Farm Siting Regulation and Management

Factor 3.2a: Content of habitat management measures

The aquaculture sector is governed by an array of regulatory bodies that "protect fish, land, and agricultural land." (Morshed et al. 2020).

The Ministry of Fisheries and Livestock (MoFL) is the leading legislative institution for fisheries and aquaculture under the Government of Bangladesh (Rahman et al. 2018) and "has overall responsibility for fisheries and aquaculture development, management and conservation." (FAO FAO NALO, n.d.). The Department of Fisheries, working under the MoFL, is the lead implementing agency, with "…activities related to extension, management, project implementation, training and human resource development, enforcement of laws and regulations, conservation, quality control, registration and certification, fishing licenses, fisheries awareness building and motivation, support to policy formulation, and administration." (Rahman et al. 2018). Additionally, to help with research and training of aquaculture farmers under the DoF, there is the Bangladesh Fisheries Research Institute (Rahman et al. 2018; FAO FAO NALO, n.d.). Other national agencies include the Department of Environment and the Ministry of Land. The Department of Environment (DoE) operates under the Ministry of Environment and Forest (MoEF) and helps to minimize and mitigate environmental pollution (FAO NALO, n.d.). The Ministry of Land (MoL) helps facilitate the acquisition and leasing of land and water bodies, and is implemented through a local management structure FAO NALO, n.d.).

> "Bangladesh is divided into six Administrative Divisions. Each Division is placed under a Divisional Commissioner and is further subdivided into Districts with a District Commissioner as the chief administrator. Below the district level there are Thanas, which is the fourth layer of government administration in the country. The Additional Commissioners in charge of Revenue in the Administrative Divisions, the Additional Deputy Commissioners in charge of Revenue in the Administrative Districts and the Assistant Commissioners of Land in the Thanas perform functions relating to the management of land. Appeals against the decisions of the Commissioners are heard in the Land Appeal Board, established under the Land Appeal Board Act (1989). In addition, the Land Reform Board, established under the Land Reform Board Act (1989), supervises the functioning of land administration offices and the implementation of land reform measures. Both entities are under the administrative control of MoL." (FAO NALO, n.d.)

Other organizations involved in the governance of the shrimp and freshwater prawn sector are NGOs, local councils, shrimp cooperatives, and donor agencies.

The basic legislation governing shrimp aquaculture production in Bangladesh is the National Fishery Policy of 1998 and the National Shrimp Policy of 2014. According to the United Nations Food and Agriculture Organization (FAO), the National Fisheries Policy of 1998 (NFP) is a key piece of legislation governing Bangladesh shrimp aquaculture production and

> "was adopted to develop and increase fish production through optimum utilization of resources, to meet the demand for animal protein, to promote economic growth and earn foreign currency through export of fish and fishery products, to alleviate poverty by creating opportunities for self-employment and by improving socio-economic conditions

> of fisher folk, and to preserve environmental balance, biodiversity and improve public health."

The NFP also bans the conversion of mangrove habitat for shrimp production (Akber et al. 2017; FAO NALO, YEAR). The National Shrimp Policy of 2014 is targeted to promoting more sustainable shrimp aquaculture production and practices while improving socio-economic factors (Akber et al. 2017). Both the National Fisheries Policy and the National Shrimp Policy "identified the requirements of Land Zoning for shrimp cultivation." (Akber et al. 2017).

However, it is unclear what are the specific requirements and the process for aquaculture development. Attempts to review the content of the NFP and the National Shrimp Policy were unsuccessful as both documents were unable to be obtained. But, according to the FAO, "There is no authorization or registration system of aquaculture facilities. Aquaculture on government-owned land is practiced under a system of lease of land and water bodies from the government...Generally, leases are issued for 3 year periods for the purpose of aquaculture. The lease is given to the highest bidder after an auction process." (FAO NALO, n.d.). There are shrimp ponds on private land as well, but the process for obtaining and developing private land for shrimp production is unclear.

There are environmental protections to mitigate industry and project development. The National Environment Policy was created in 1992 for "the protection, conservation and development of the environment and to ensure maintenance of environmental quality in all development activities." (FAO NALO, n.d.). The Environmental Protection Act of 1995 designated and defined ecological critical areas and land use activity restrictions on critical areas, but it is uncertain where the critical areas are and if shrimp farms are sited and developed in these areas or not. The Environment Conservation Rules of 1997 mandates "all new industries and projects must apply for an Environmental Clearance Certificate", yet it does not include aquaculture projects (FAO NALO, n.d.).

There are voluntary guidelines for the shrimp aquaculture industry and agricultural production. There is a Code of Conduct "For Various Segments of the Aquaculture Based Shrimp Industry in Bangladesh" that was drafted in 2015 and provides guidelines for shrimp farmers and others in the value chain. The Code of Conduct (CoC) program is voluntary. To become CoC certified, a farm can apply to be audited by the DOF; if found to be in compliance, it can become certified accordingly. Also, the *Feed the Future Bangladesh Aquaculture and Nutrition Activity – Handbook on Environmental Compliance* was created to help educate and implement mitigation techniques for agricultural development – including shrimp pond aquaculture (Rahman, M. 2019).

Overall, the legislative foundation for habitat management and ecological considerations exists, but is lacking in implementation and clarity as "the regulations are applied to shrimp farming in an ad hoc manner" and the different legislative pieces at times contradict one another (Morshed et al. 2020). Based on the limited literature that was available, it is unclear what the management system is for developing an aquaculture farm. The process for farm siting, obtaining permits, and the ecological considerations for new and existing farm operations is unclear. There is legislation (e.g. Environmental Protection Act, Environment Conservation Rules) that implement environmental protections and environmental impact assessments prior to industry and project development, but its application to the aquaculture industry is unclear. Although the National Fisheries Policy of 1998 and the National Shrimp Policy of 2014 are reported to identify land zoning priorities for aquaculture purposes, it is unclear how this is implemented, whether it is for both private and public lands, and to what degree environmental considerations are considered. Further, according to Akber et al. (2017), the government has been unable to achieve the legislative goals to promote sustainable shrimp farming development as outlined in the National Shrimp Policy of 2014.

As a result, the content of habitat management measures appears minimal as the management system is unclear. Therefore, Factor 3.2a Content of habitat management measures scores 1 out of 5.

Factor 3.2b: Enforcement of habitat management measures

Enforcement of habitat management measures in Bangladesh is minimal. There is little new information readily available since the completion of the 2017 Bangladesh shrimp assessment. Therefore, the findings of the previous assessment appear to be consistent with current practices. The DOF is responsible for providing extension services and conducting site visits, but it has limited resources with which to implement these strategies. Many other governmental agencies are involved in issues affecting the shrimp and freshwater prawn farming sector, so the relevant enforcement organizations and their activities are difficult to identify, and there is little evidence of monitoring and compliance data or of penalties for infringements of the law. Significant uncertainty exists about the scale of agencies, their abilities to enforce regulatory measures that protect habitat, and the compliance by farmers to habitat management measures. As a result, the score for Factor 3.2b – Enforcement of habitat management measures remains 1 out of 5.

Criterion 3 – Habitat Conclusion

Overall, the impacts of brackish water *P. monodon* farming are ongoing due to saltwater intrusion to the surrounding environment. Although *P. monodon* farming is not the single activity driving saltwater intrusion in the area, it is considered a key cause "for secondary salinization of coastal lands" (IMF, 2013). The impacts of saltwater intrusion are many, but it degrades the functionality of healthy soil and its ability to support local flora and fauna, as well as degrades freshwater resources. Due to the shrimp industry's operation, the impacts are ongoing. Developing shrimp ponds was done primarily by converting agricultural land, which is considered a low habitat value. In the Seafood Watch Aquaculture Standard, the ongoing loss of low value habitat functionality results in a Factor 3.1 Habitat Conversion and Function score of 3 out of 10.

The content of habitat management measures appears minimal as the management system is unclear. Therefore, Factor 3.2a Content of habitat management measures scores 1 out of 5. Enforcement of habitat management measures in Bangladesh is minimal and significant uncertainty exists about the scale of agencies, the abilities to enforce regulatory measures that protect habitat, and the compliance by farmers to habitat measures. As a result, the score for Factor 3.2b – Enforcement of habitat management measures remains 1 out of 5.

The scores for Factor 3.1 (3 out of 10) and Factor 3.2 (0.4 out of 10) are combined to result in a score of 2.13 out of 10 for Criterion 3 – Habitat for *P. monodon*.

Criterion 8X - Source of Stock

There is little new information readily available since the completion of the 2017 Bangladesh shrimp assessment. Therefore, the findings of the previous assessment appear to be consistent with current practices. Although there are efforts to improve *P. monodon* production with SPF technology and a closed life cycle broodstock, the industry still appears to be 90-99.9% reliant on wild broodstock with the sustainability of the stock unknown.

Private and public investments aim to improve the genetics and availability of SPF post larvae and broodstock. In 2019, Hendrix Genetics and the Bangladesh Shrimp and Fish Foundation (BSFF) signed an MoU to "share knowledge in the development of black tiger shrimp production in Bangladesh" (Hatchery International, 2019). Updates to the results of this project, so far, do not appear to be publicly available. With support from the government and the Bangladesh Shrimp and Fish Foundation (BSFF), MKA Hatcheries Ltd. in Cox's Bazar started to import SPF broodstock from Moana Technologies in Hawaii (FFPI 2014). The original broodstock used for this project were reportedly collected from the Bay of Bengal and the Andaman Sea. This initiative has been assisted financially by USAID's Feed the Future Partnering for Innovation program (implemented by Fintrac) and USAID's Aquaculture for Income and Nutrition project (AIN) (implemented by WorldFish). MKA staff have benefited from hatchery training provided by Moana Technologies and appear to be making good progress. As a result of this initial success, USAID plans to continue funding the endeavor, through the AIN project, and to distribute 200 million SPF PLs to smallholder farms that meet the appropriate environmental standards (FFPI 2015). MKA claim that they have the capacity to produce 500 million PLs per year (Inter Press Service News Agency 2016), although realization of this ambition may take some time because no reference is made to current production volumes. As of 2021, "*P. monodon* broodstock and production of specific pathogen free seed in the country is needed." (AftabUddin et al. 2021). These projects and efforts appear promising and would help to alleviate the need to capture wild *P. monodon* for broodstock, however, there is little information available demonstrating the success of these projects currently. Therefore, it appears the industry in Bangladesh is reliant on wild broodstock for PLs to supply grow out ponds throughout the region.

Seafood Watch considers the use of wild broodstock to be ecologically unsustainable unless the number used and the sustainability of the source can be demonstrated to be of minimal concern. Information regarding the sustainability of wild *P. monodon* broodstock (e.g., stock status, catch rates, gear types used, bycatch, etc.) is limited. The previous assessment in 2017 reported a decline in wild *P. monodon* abundance through time due to fishing pressure and habitat degradation, but the evidence was anecdotal (Khan et al 1995; Hoq et al. 2001). While *P. monodon* in neighboring India are considered fully exploited (FAO, 2011), the precise status of the wild *P. monodon* population in Bangladesh was not readily available.

As a result, the Bangladesh *P. monodon* hatchery industry is considered 90-99.9% reliant on wild broodstock of unknown ecological sustainability. The final score for Criterion 8x – Source of Stock – is -9 out of -10.

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Appendix 3 – Interim Update *M. rosenbergii*

An Interim Update of this assessment was conducted in June 2021. Interim Updates focus on an assessment's limiting (i.e. Critical, Red or lowest scored) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review evaluates the Habitat and Source of Stock criteria. 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.

Interim Update Scoring Summary

Results of the interim update support the findings of the previous assessment and the Overall Recommendation for Giant Freshwater Prawns grown in ponds in Bangladesh remains Good Alternative with a Yellow rating. The recommendation and rating are driven by one red criterion assessed in the interim update, Criterion 8x – Source of Stock, and one yellow criterion, Criterion 3 – Habitat.

The red rating for Criterion 8x Source of stock is due to the source of Bangladesh *M. rosenbergii* hatchery and post larvae 90-99.9% reliant on wild *M. rosenbergii* of unknown ecological sustainability, which is of high ecological concern to Seafood Watch.

The yellow rating for freshwater prawn farming is due to the fact farms operate on previously modified habitat (e.g. agricultural land), and there is no evidence agricultural land has loss functionality due to freshwater *M. rosenbergii* production. Therefore, the ecological impacts appear moderate at worse. The regulation and enforcement of habitat measures is unclear. The content of habitat management measures appears minimal as the management system is unclear and significant uncertainty exists about the scale of agencies, their abilities to enforce regulatory measures that protect habitat, and the compliance by farmers to habitat management measures.

Criterion 1 – Data

Overall, data availability and quality for Bangladesh was considered low for Criterion 3 – Habitat and Criterion 8X – Source of Stock. For Criterion 3 – Habitat, data for habitat management and enforcement were incomplete with outstanding knowledge gaps such as: the process for new farm siting, ecological considerations for new farm siting, regulatory conditions, permits for farms, registration of farms, and the enforcement of habitat management measures. Insight was mainly gathered from peer reviewed literature and the United Nations Food and Agriculture Organization (FAO). For Criterion 8X – Source of Stock, updated information about the source of broodstock was not readily available, and information about wild *M. rosenbergii* catch rates, gear types used, bycatch, etc. was unavailable. As a result, the availability and quality of data is considered low.

Criterion 3 – Habitat

Factor 3.1 Habitat Conversion and Function

There is little new information readily available documenting the ecological impact of *M. rosenbergii* pond production in Bangladesh to agricultural land and the surrounding habitat since the 2017 assessment.

As documented by Islam and Tabeta, 2019, freshwater *M. rosenbergii*, or prawn, production operates on agricultural land seasonally. In the wet months, prawns are grown, and in the dry months, rice is grown. Since freshwater prawn farming is practiced on previously modified habitat (e.g. agricultural land), and there is no evidence agricultural land has loss functionality due to freshwater *M. rosenbergii* production, the ecological impacts appear moderate at worse. As a result, there is no new information readily available suggesting the previous findings for Factor 3.1 Habitat conversion and function are incorrect.

F3.2: Farm siting regulation and management

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

The aquaculture sector is governed by an array of regulatory bodies that "protect fish, land, and agricultural land." (Morshed et al. 2020).

The Ministry of Fisheries and Livestock (MoFL) is the leading legislative institution for fisheries and aquaculture under the Government of Bangladesh (Rahman et al. 2018) and "has overall responsibility for fisheries and aquaculture development, management and conservation." (FAO NALO, n.d.). The Department of Fisheries, working under the MoFL, is the lead implementing agency, with "…activities related to extension, management, project implementation, training and human resource development, enforcement of laws and regulations, conservation, quality control, registration and certification, fishing licenses, fisheries awareness building and motivation, support to policy formulation, and administration." (Rahman et al. 2018). Additionally, to help with research and training of aquaculture farmers under the DoF, there is the Bangladesh Fisheries Research Institute (Rahman et al. 2018; FAO NALO, n.d.). Other national agencies include the Department of Environment and the Ministry of Land. The Department of Environment (DoE) operates under the Ministry of Environment and Forest (MoEF) and helps to minimize and mitigate environmental pollution (FAO NALO, n.d.). The Ministry of Land (MoL) helps facilitate the acquisition and leasing of land and water bodies, and is implemented through a local management structure FAO NALO, n.d.).

> "Bangladesh is divided into six Administrative Divisions. Each Division is placed under a Divisional Commissioner and is further subdivided into Districts with a District Commissioner as the chief administrator. Below the district level there are Thanas, which is the fourth layer of government administration in the country. The Additional Commissioners in charge of Revenue in the Administrative Divisions, the Additional Deputy Commissioners in charge of Revenue in the Administrative Districts and the Assistant Commissioners of Land in the Thanas perform functions relating to the management of land. Appeals against the decisions of the Commissioners are heard in the Land Appeal Board, established under the Land Appeal Board Act (1989). In addition, the Land Reform Board, established under the Land Reform Board Act (1989), supervises the functioning of land administration offices and the implementation of land reform measures. Both entities are under the administrative control of MoL." (FAO NALO, n.d.)

Other organizations involved in the governance of the shrimp and freshwater prawn sector are NGOs, local councils, shrimp cooperatives, and donor agencies.

The basic legislation governing shrimp aquaculture production in Bangladesh is the National Fishery Policy of 1998 and the National Shrimp Policy of 2014. According to the United Nations Food and

Agriculture Organization (FAO), the National Fisheries Policy of 1998 (NFP) is a key piece of legislation governing Bangladesh shrimp aquaculture production and

> "was adopted to develop and increase fish production through optimum utilization of resources, to meet the demand for animal protein, to promote economic growth and earn foreign currency through export of fish and fishery products, to alleviate poverty by creating opportunities for self-employment and by improving socio-economic conditions of fisher folk, and to preserve environmental balance, biodiversity and improve public health."

The NFP also bans the conversion of mangrove habitat for shrimp production (Akber et al. 2017; FAO NALO, n.d.). The National Shrimp Policy of 2014 is targeted to promoting more sustainable shrimp aquaculture production and practices while improving socio-economic factors (Akber et al. 2017). Both the National Fisheries Policy and the National Shrimp Policy "identified the requirements of Land Zoning for shrimp cultivation." (Akber et al. 2017).

However, it is unclear what are the specific requirements and the process for aquaculture development. Attempts to review the content of the NFP and the National Shrimp Policy were unsuccessful as both documents were unable to be obtained. But, according to the FAO, "There is no authorization or registration system of aquaculture facilities. Aquaculture on government-owned land is practiced under a system of lease of land and water bodies from the government...Generally, leases are issued for 3 year periods for the purpose of aquaculture. The lease is given to the highest bidder after an auction process." (FAO NALO, n.d.). There are shrimp ponds on private land as well, but the process for obtaining and developing private land for shrimp production is unclear.

There are environmental protections to mitigate industry and project development. The National Environment Policy was created in 1992 for "the protection, conservation and development of the environment and to ensure maintenance of environmental quality in all development activities." (FAO NALO, n.d.). The Environmental Protection Act of 1995 designated and defined ecological critical areas and land use activity restrictions on critical areas, but it is uncertain where the critical areas are and if shrimp farms are sited and developed in these areas or not. The Environment Conservation Rules of 1997 mandates "all new industries and projects must apply for an Environmental Clearance Certificate", yet it does not include aquaculture projects (FAO NALO, n.d.).

There are voluntary guidelines for the shrimp aquaculture industry and agricultural production. There is a Code of Conduct "For Various Segments of the Aquaculture Based Shrimp Industry in Bangladesh" that was drafted in 2015 and provides guidelines for shrimp farmers and others in the value chain. The Code of Conduct (CoC) program is voluntary. To become CoC certified, a farm can apply to be audited by the DOF; if found to be in compliance, it can become certified accordingly. Also, the *Feed the Future Bangladesh Aquaculture and Nutrition Activity – Handbook on Environmental Compliance* was created to help educate and implement mitigation techniques for agricultural development – including shrimp pond aquaculture (Rahman, M. 2019).

Overall, the legislative foundation for habitat management and ecological considerations exists but is lacking in implementation and clarity as "the regulations are applied to shrimp farming in an ad hoc manner" and the different legislative pieces at times contradict one another (Morshed et al. 2020). Based on the limited literature that was available, it is unclear what the management system is for developing an aquaculture farm. The process for farm siting, obtaining permits, and the ecological considerations for new and existing farm operations is unclear. There is legislation (e.g. Environmental Protection Act, Environment Conservation Rules) that implement environmental protections and environmental impact assessments prior to industry and project development, but its application to the aquaculture industry is unclear. Although the National Fisheries Policy of 1998 and the National Shrimp Policy of 2014 are reported to identify land zoning priorities for aquaculture purposes, it is unclear how this is implemented, whether it is for both private and public lands, and to what degree environmental considerations are considered. Further, according to Akber et al. (2017), the government has been unable to achieve the legislative goals to promote sustainable shrimp farming development as outlined in the National Shrimp Policy of 2014.

As a result, the content of habitat management measures appears minimal as the management system is unclear.

Factor 3.2b: Enforcement of habitat management measures

Enforcement of habitat management measures in Bangladesh is minimal. There is little new information readily available since the completion of the 2017 Bangladesh shrimp assessment. Therefore, the findings of the previous assessment appear to be consistent with current practices. The DOF is responsible for providing extension services and conducting site visits, but it has limited resources with which to implement these strategies. Many other governmental agencies are involved in issues affecting the shrimp and freshwater prawn farming sector, so the relevant enforcement organizations and their activities are difficult to identify, and there is little evidence of monitoring and compliance data or of penalties for infringements of the law. Significant uncertainty exists about the scale of agencies, their abilities to enforce regulatory measures that protect habitat, and the compliance by farmers to habitat management measures. As a result, Factor 3.2b – Enforcement of habitat management measures appears minimal.

Criterion 3 – Habitat Conclusion

Overall, the impacts of freshwater *M. rosenbergii* farming to habitat appear moderate at worse. There is no new evidence since the previous assessment in 2017 that suggests the impacts of freshwater prawn farming have majorly impacted agricultural land – the primary land use area *M. rosenbergii* production operates on. Therefore, there is no new information which suggests a change in the Factor 3.1 Habitat Conversion and Function is needed.

The content of habitat management measures appears minimal as the management system is unclear. The enforcement of habitat management measures in Bangladesh also appears to be minimal and significant uncertainty exists about the scale of agencies, the abilities to enforce regulatory measures that protect habitat, and the compliance by farmers to habitat measures.

As a result, the overall rating of *M. rosenbergii* grown in ponds in Bangladesh for the Habitat criterion appears to be Yellow and remains the same as the 2017 assessment.

Criterion 8X - Source of Stock

There is little new information readily available since the completion of the 2017 Bangladesh shrimp assessment. Therefore, the findings of the previous assessment appear to be consistent with current practices. The industry still appears to be largely reliant on wild broodstock and collection of wild post-larvae. Information regarding the ecological sustainability of the *M. rosenbergii* fishery (e.g., stock status, catch rates, gear types used, bycatch, etc.) is limited. As a result, the source of Bangladesh *M. rosenbergii* hatchery and post larvae is considered 90-99.9% reliant on wild *M. rosenbergii* of unknown ecological sustainability. As a result, the rating of *M. rosenbergii* grown in ponds in Bangladesh for Criterion 8X – Source of Stock criterion appears to be Red and remains the same as the 2017 assessment.

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