Aquaculture Expansion in Ecologically Sensitive Environments

Case Study: North Western Coastal Regions of Sri Lanka

November 2022

The Pearl Protectors

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An Initiative of the Pearl Protectors

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THE PEARL PROTECTORS

The Pearl Protectors is a volunteer-based and non-profit marine conservation organisation in Sri Lanka. Established in 2018, The Pearl Protectors seek to mitigate the impacts of anthropogenic activities on the marine environment, reduce plastic pollution and promote sustainable practices through youth engagement, volunteerism, awareness and advocacy.

Projects undertaken by The Pearl Protectors over the years entail the launching of the 'Pearl Protector Approved' Accredited Standardisation Certificate to promote a plastic-free dining culture; the annual construction of a Christmas tree out of discarded plastic bottles to highlight single-use plastic pollution; school education programmes; ecobrick workshops; coastal cleanups including the Nurdle Free Lanka Initiative; and social media campaigns to inspire action towards protecting the marine environment.

The purpose of this advocacy initiative in preparing case studies is to emphasize the impacts of prevailing aquaculture practices and to promote sustainable resource utilization. The authors and contributors of this report are volunteer researchers.

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THE MANGROVE CONSERVATION AND SUSTAINABLE LIVELIHOOD FORUM (MCSL)

Mangrove Conservation and Sustainable Livelihood Forum (MCSL) of Sri Lanka is a coalition of environment conservation organizations dedicated towards protecting the mangrove ecosystem in Sri Lanka. Founded in 2020, the forum consists of following members: Wildlife Nature Protection Society (WNPS), Environment Foundation Limited (EFL), Federation of Environmental Organizations (FEO), Parrot Fish Collective, Lanka Environment Fund (LEF), and The Pearl Protectors.

The forum has facilitated a national platform towards highlighting key challenges various mangrove ecosystems are facing while proactively contributing towards conserving mangroves. The forum has also brought in various stakeholders, experts and individuals with interests towards advocating towards better policies in protecting the mangrove eco system in Sri Lanka. They have engaged with several globally recognized mangrove organizations including the Global Mangrove Alliance (GMA) and the Mangrove Action Project (MAP) who have shared technical expertise.

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1 Acronyms

ACIAR	Australian Centre for International Agricultural Research
DWC	Department of Wildlife Conservation
FAO	The Food and Agriculture Organisation of the United Nations
FFPO	Fauna and Flora Protection Ordinance
GOM	Gulf of Mannar
IHHNV	Infectious hypodermal and haematopoietic necrosis virus
IK	Indigenous Knowledge
IUCN	International Union for Conservation of Nature
NAQDA	National Aquaculture Development Authority of Sri Lanka
NOAA	National Oceanic and Atmospheric Administration
OTC	Over the Counter
PA	Protected Areas
SPF	Specific Pathogen Free
PL	Post Larval
USMSFP	US Marine Shrimp Farming Program
WSSV	White Spot Syndrome Virus
YHV	Yellow head virus

PART 1

Shrimp farming: Sri Lanka

Context and Impacts

2 Executive Summary

Aquaculture has been recognised for its contribution to global food security. Ongoing development requires transformative changes in policy, natural resource management, investment, innovation and environmental considerations to achieve sustainable and equitable outcomes.

This report aims to examine the current status of the shrimp industry in Sri Lanka, with a focus on the introduction of *Litopenaeus vannamei* species in aquaculture. An extensive literature review has been conducted, supported by a field visit to aquaculture facilities along the North Western coastal regions of Sri Lanka to gain valuable insights and traditional knowledge from local communities on their experiences in aquaculture practices.

The Vidataltivu Reserve boasts a complex ecosystem of national and international significance, and it has been highlighted as a primary case study in this report. Comprehensive environmental consideration and sustainable management practices must be tabled and extensively assessed, prior to the further expansion of aquaculture activity.

3 Overview of Shrimp Farming in Sri Lanka

Shrimp farming in Sri Lanka became one of the fastest growing industries in the 1980's (Munasinghe et al., 2010). Although large-scale shrimp farming was dominant from the late 1970's to mid 1990's, small scale shrimp farming has persisted since then. Rapid and uncontrolled shrimp farming development occurred between 1992-1996, as a result of high economic return and attractive public investments. Over 9000 kg / ha/ year were produced in classical earthen ponds. Small scale farms less than 1.0 ha were established which encroached lagoons and ecologically sensitive areas including salt marshes, coconut plantations, mangroves and intertidal mud flats. Due to poor environmental planning and a lack of inadequate regulatory enforcement, the rapid expansion led to over 47% of farms operating illegally without proper licenses. A lack of coastal zone management resulted in the 'self pollution effect' and from 1996, the shrimp industry was subject to disease breakouts and numerous environmental issues (Drengstig, 2020).

Sri Lanka has a 1700 km of coastline comprising of sheltered bays and lagoons which have been recognised as optimal sites for aquaculture development (Drengstig, 2020). Pioneer farms were established around Chilaw Lake and along the north western coast with rapid expansions up to the Puttalam lagoon (Munasinghe, 2010, Dahdouh-Guebas et al., 2001). Common shrimp species cultured includes the black tiger shrimp (*Penaeus monodon*) Small scale projects have also cultivated the white-leg shrimp (*Penaeus vannamei*) and freshwater giant shrimp (*Macrobrachium rosenbergii*) along the eastern coast of the country.

Figure 1 shows an increasing trend in aquaculture production between 1990 and 2019, by an estimated 5,720 Mt. In 2019, shrimps farmed through aquaculture methods, contributed to 27% of total output. As reflected in **Figure 2**, the number of ponds and allocated land for aquaculture has also been steadily rising in the Northern part of Sri Lanka over the last decade, following the end of the civil war conflict in the region.

Shrimps				
Year	**Aquaculture**	**Wild Capture**	**Total**	**Exported Quantity**
1990	680	4,470	5,150	1,855
1995	3,600	8,000	11,600	2,781
1999	3,820	7,680	11,500	2,715
2000	4,360	7,540	11,900	4,855
2001	3,540	7,360	10,900	3,941
2002	2,560	9,820	12,380	3,202
2003	3,360	10,190	13,550	4,467
2004	2,390	10,730	13,120	2,462
2005	1,570	4,680	6,250	1,800
2006	2,480	7,840	10,320	1,837
2007	3,580	7,320	10,900	2,023
2008	2,230	9,240	11,470	854
2009	3,550	13,110	16,660	1,432
2010	3,480	17,640	21,120	1,262
2011	4,150	22,680	26,830	1,380
2012	3,310	26,730	30,040	1,078
2013	4,430	29,230	33,660	1,625
2014	5,150	23,940	29,090	2,001
2015	7,090	20,090	27,180	1,341
2016	6,030	19,720	25,750	1,667
2017	4,630	17,620	22,250	1,844
2018	8,180	16,970	25,150	1,984
2019	6,400	16,930	23,330	2,115

Figure 1: Shrimp Production (Mt) 1990 - 2019
Source: Statistics Unit, Ministry of Fisheries

District	Description	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Puttalam	No of Ponds	2,350	2,186	2,279	2,903	4,235	4,184	4,016	3,221	4,155	3,264
	Area (Ha)	1,186	1,077	1,202	1,347	2,038	2,011	1,890	1,576	1,987	1,626
	Production (Mt)	3,319	3,940	3,022	4,180	4,850	6,702	5,825	4,307	7,776	5,437
Batticaloa	No of Farms	-	-	-	-	-	-	65	-	76	66
	No of Ponds	18	-	107	137	224	-	186	195	192	178
	Area (Ha)	38	49	123	225	205	-	109	128	121	110
	Production (Mt)	161	208	270	250	300	388	205	323	404	421
Mannar	No of Farms	-	-	-	-	-	-	-	-	-	-
	No of Ponds	-	-	-	-	-	-	-	-	-	23
	Area (Ha)	-	-	-	-	-	-	-	-	-	22
	Production (Mt)	-	-	-	-	-	-	-	-	-	542
Other	No of Ponds	-	-	-	-	-	-	-	-	-	-
	Area (Ha)	-	-	-	-	-	-	-	-	-	-
	Production (Mt)	-	2	18	-	-	-	-	-	-	-
Total	No of Farms							65		76	
	No of Ponds	2,368	2,186	2,386	3,040	4,459	4,184	4,202	3,416	4,347	3,465
	Area (Ha)	1,224	1,126	1,325	1,572	2,243	2,011	1,999	1,704	2,108	1,758
	Production (Mt)	3,480	4,150	3,310	4,430	5,150	7,090	6,030	4,630	8,180	6,400

Figure 2: Shrimp Production by Area and Production - Mt (2010 - 2019)
Source: National Aquaculture Development Authority of Sri Lanka (NAQDA)

Other notable events in the aquaculture industry in Sri Lanka include:

- The National Aquatic Resources Research and Development Agency (NARA) was established by NARA Act of No. 54 of 1981, and is the national institute responsible for coordinating and carrying out research, management activities and development on aquatic resources in Sri Lanka (NARA, 2022).

- Andriesz Mariculture Ltd. was set up as the first intensive shrimp farm in Sri Lanka, in 1989, and they pioneered the culture and propagation of the lagoon (mud) crab. The crab industry was initiated on a small scale, in the early 1990's and is now a profitable industry in several costal regions of Sri Lanka. The industry involves the capture of just molted crabs (mud and water crabs) from the wild, and fattening them in captivity with shark heads, fish offal and cockles prior to sale. Fattened crabs are sold locally and exported to Pacific and Southeastern countries (Sandika & Hirimuthugoda, 2011).

- Sri Lanka's sea cucumber industry is known to have been in existence over the last thousand years, where processed species appear to be taken out to China as commodities when trade routes existed between China, India and Sri Lanka (Hornell, 1917). Beche-de-mer is the major commodity produced and entire annual production is exported (Dissanayake and Wijeyaratne, 2007).

  It operates all year and alternates across the Northern, Eastern and North western costs, with an estimated 5000 fisher families dependent on production as their primary source of income. There have been 24 sea cucumber species recorded in Sri Lanka's coastal waters (Prasada, 2020). It has been highlighted that stocking densities have declined as a result of continued fishing efforts, with estimated population populations of the commercial species to be less than 30 per ha. Smaller size and immature species further contributes to excessive fishing pressures (Dissanayake and Stefansson, 2012)

- Since May 1996, the industry has been impacted by severe outbreaks of White Spot Disease which results from an acute viral infection due to accumulation of waste. Cumulative mortalities amounting to 100% were documented across farms along the Puttalam Lagoon. Surrounding farms became non functional within in a 3 month period due to the rapid spread of disease. Shortly after December 1996, a second disease outbreak occurred, impacting approximately 90% of farmers with heavy financial burdens having to close down farms (Senarath and Visvanathan, 2001).

- In 1999, the National Aquaculture Development Authority (NAQDA) was established under the National Aquaculture Development Authority Act (No 53 of 1998), mandated for the task of developing the inland fisheries and aquaculture sector of Sri Lanka whilst ensuring sustainable development and ensuring food security

- The aquaculture industry was impacted by volatile boom and bust cycles, particularly between 1998 and 2004, as a result of multiple disease breakouts. Large areas across the coastal belt were deemed unsuitable for farming and the number of farmers reduced dramatically (Drenstig 2020).

- The Coastal Aquaculture Monitoring and Extension Unit of NAQDA was established in 2004, in Battuluoya to regulate and monitor coastal aquaculture and the shrimp industry in the Districts of Gampaha and Puttalam (NAQDA, 2022).

- The primary brackish water aquaculture species in Sri Lanka is *Penaeus monodon* which targets the export market. In 2018, the Litopenaeus vannamei species was introduced. NAQDA implemented a management plan which assessed post larvae quality as a mandatory requirement with the objective of sustaining a better harvest with the absence of disease and infections (Premarathna et al. 2020). Due to requests made by Sri Lanka Aquaculture Development Association (SLADA) and shrimp farmers, NAQDA has since, introduced *L. vannamei* to Sri Lanka.

- In 2011, the Minister for Fisheries and Aquatic resources granted permission to initiate a pilot project to culture *L. vannamei* in Sri Lanka and as a result SPF *L. vannamei* was introduced to Kottage area in Arachchikattuwa, Puttalam district in 2012.

- After several meetings and discussions with multiple stakeholders including NARA, NAQDA and private shrimp farmers in 2018, with the permits issued from the Department of Fisheries and Aquatic Resources and Department of Animal Production and Health, permission was granted to Taprobane Frozen Food (Pvt) Ltd to import 120 *L. vannamei* broodstock to Sri Lanka from Hawaii, USA.

- An ACIAR supported research project was established to focus on the long term sustainability of inland aquaculture and its contribution to the improvement of rural livelihoods in the northern regions of Sri Lanka. The project aims to introduced a science based, robust management regime for finish species and Culture Based Fishery of the giant freshwater prawn. Long term outcomes include improved productivity and profitability of both male and female incomes, sustainability and equity whilst creating a positive outlook on overall rural wellbeing. The Small Research Activity commenced in 2017 and is currently on schedule until 2023 (ACIAR, 2021).

- An Aquaculture industrial Park with an area of 1728 ha was proposed in Mannar with the primary objectives of aquaculture investment, economic development and sustaining food security (NAQDA, 2018). However the offshore fish farming initiative was subject to ongoing land clearance issues and high costs of production and could not be implemented.

- The Vidataltivu Reserve in Mannar, was declared a Nature Reserve in 2015. NAQDA requested for the Reserve to be degazetted to pave way for an aquaculture development project with proposed revenue of $1 billion USD, with interest expressed from Malaysia, China, Singapore, and Japan in potential aquaculture produce (NAQDA, 2019)

3.1 The National Invasive Alien Species (IAS) Policy

A species which has been introduced outside of its typical geographic range and has the potential to survive and then procreate is considered an alien species. An alien species that is considered to be invasive, contributes to environmental harm and is referred to as an IAS ((McNeely et al. 2001).

As per Monterey Bay Aquarium's Seafood watch 2015-2021 statistics, farmed *L. vannamei* is ranked red and is classified with an "Avoid" recommendation for countries including China, India, Mexico, Nicaragua and Mexico owing to several factors including the common "escapes" criterion. Numerous cases have been reported for escaped *L. vannamei* from aquaculture production facilities into non-native waters including Texas, South Carolina, and Hawaii, USA (Balboa *et al.*, 1991; Wenner *et al.*, 1991); Thailand (Briggs *et al.*, 2004); Venezuela (Pérez *et al.*, 2007); Brazil (Loebmann *et al.*, 2010); Vietnam (Binh *et al.*, 2009) and Southern Gulf of Mexico coast (Wakida-Kusunoki *et al.*, 2011). According to Briggs et al., 2004, planned releases and escapes have resulted in the existence of an *L. vannamei* population in the wild in the Philippines.

Shrimps can escape in a variety of ways while being harvested from open ponds, during water exchange and flooding events, as well as from hatcheries and while being transported. Weight disparities between harvested and collected specimens (12 to 39g), as well as the distance between farming areas and the capture location, may be indicators that this species can survive in the wild (De Silva et al., 2021). Given that *L. vannamei* can tolerate a wide range of salinities and pH levels, its capacity to thrive in the wild may give rise to ecological issues such resource competition, reproduction, and disease outbreak. According to studies conducted, *L. vannamei* has the possibility of interacting with local species through food competition, either through exploitative or interfering competition (De Silva et al., 2021).

Due to complexity and difficulty in screening, although there is no solid evidence to identify *L. vannamei* as an invasive species or not, researchers have suggested the possibility of establishing populations outside of its natural geographic distribution, since once released mature individuals may still be able to mate in the wild and allow for natural reproduction of escapees.

Therefore following and maintaining an effective, advanced and updated invasive species policy is critical for the conservation and management of biodiversity. A major goal of the National Invasive Alien Species (IAS) Policy of Sri Lanka is to build a coordinated strategy that prevents, detects, responds, and manages the risks of *Invasive Alien Species* to the economy, environment, and society. This policy is accomplished through an effective and efficient institutional framework.

Main objectives include:

1. Reducing the impact of IAS on society, the economy, and ecosystems
2. To support international efforts through national actions to manage IAS
3. To inform all interested parties about the national attitude and top priorities for resolving IAS-related issues
4. To maintain stakeholder awareness of the dangers posed by IAS and encourage stakeholder participating in the response to it
5. To encourage knowledge transfer, increased productivity, and sustained economic development in pertinent industries by reducing IAS risks

This protocol is mainly structured to address key areas such as:

- Ensuring public awareness of IAS access points, invasiveness, environmental effects, and management tactics

- Promote the creation of outreach and education programs aimed at gaining public support for early detection and quick actions

- Establishment of an efficient, institutional coordination mechanism, ensuring a well-organised risk management process, effective enforcement of rules, and monitoring of IAS entry and control across all sectors, in accordance with national and international standards.
- Ascertain the creation and upkeep of a national database that contains data on identification, risk assessment, invasiveness, impact, and management techniques of IAS and providing public open access to the resources.

- Recognising the need for stakeholder institutions to increase their capacity for IAS risk assessment and early warning systems in terms of both personnel and physical resources.

- Research on establishing instruments to forecast the invasiveness of alien species, methods / technologies to restrict impacts or dangers of introduction of IAS to minimal levels, and logistical and financial assistance are in place.

- Boost surveillance efforts by establishing a coordinated monitoring network in locations with a high IAS risk in order to find and report incursions.

- Risk assessment, stakeholder consultation, and prioritisation are used to inform decision-making about containment, control, and eradication of IAS as well as the identification of integrated management strategies for IAS.

- Encourage research towards containment, control, and eradication strategies and technologies for priority IAS

3.2 Environmental Impacts: Shrimp farming

Over the last 30 years, the expanding shrimp aquaculture industry in Sri Lanka has dramatically altered the coastal landscape. Unsustainable shrimp culture leads to the exploitation of natural resources, which in turn result in socio-economic harm and major impacts have been well documented, both locally and internationally (Bergquist, 2007). Major environmental concerns include:

- **Clearing of mangrove forests to support aquaculture farms**: Mangroves are commonly found in intertidal zones of temperate, tropical and subtropical coastal rivers, bays and estuaries and grow in fine sediments deposited by tides and rivers. These ecosystems play a critical role in preventing erosion by stabilising sediment and soils within intertidal zones through their extensive root structures and serve as buffer zones from cyclones and storm events. They provide habitat and food for ecologically and economically important aquatic species, migratory birds, crustaceans and molluscs (Figure 3). Additionally they are a primary source of organic matter to the coastal zone and contributes to enhanced marine productivity which inevitably supports commercial fisheries.

  The establishment of shrimp farms in the District of Puttalam resulted in over 50% of healthy mangrove forests being removed from the area (Dahdouh-Guebas et al., 2002). Important habitat for marine ecosystems and a buffer zone was severely compromised due to loss of mangroves. Due to the nature of their anaerobic conditions in intertidal sediment and soil, and primary productivity, mangroves play a significant role in carbon sequestration in the intertidal zone (Hoque et al., 2011). Additionally, organic carbon can be sequestered in below ground root and above ground plant biomass. The construction of these shrimp farms led to removal of both above and below ground carbon (Donato el al., 2011) .

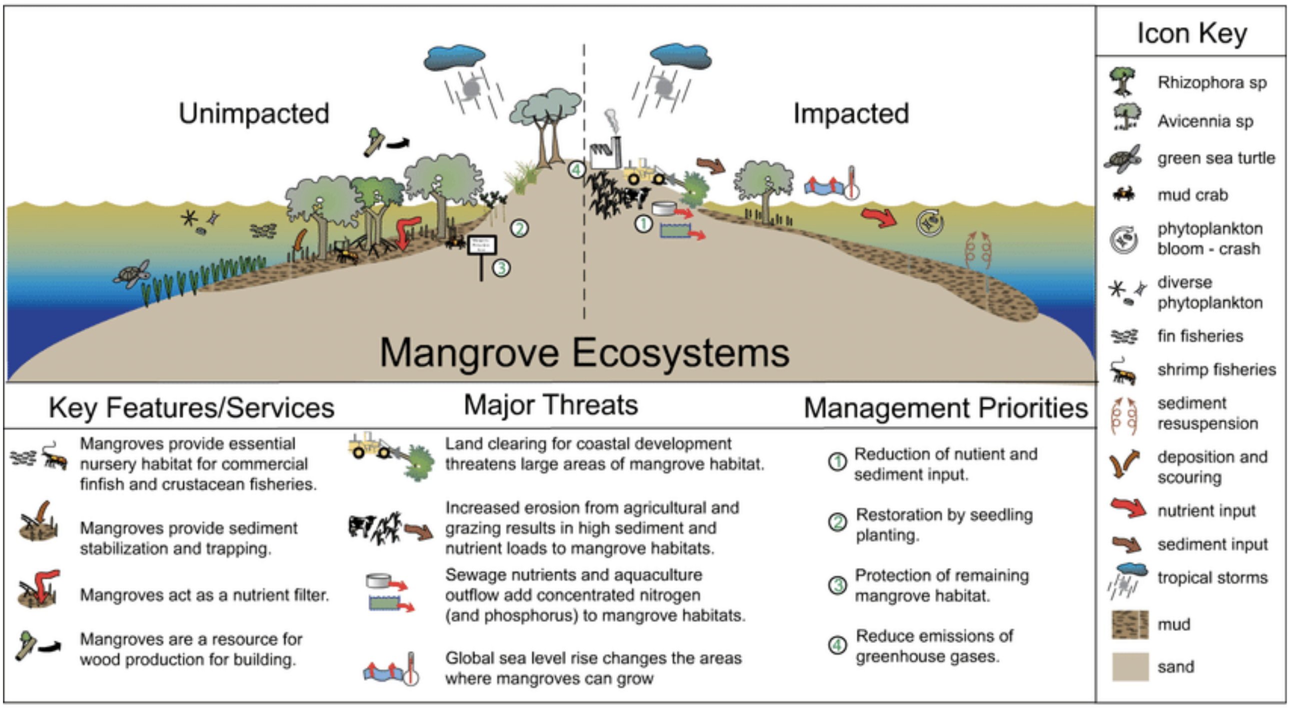


Figure 3: Ecosystem services, threats and management priorities for Mangrove Ecosystems
Source: University of Maryland

- **Water Pollution:** Organic contamination can occur from shrimp farming. Poor quality artificial feed can be used which does not reach required stability in the water. Large amounts of feed can escape from shrimp intake and convert into organic pollutants. Disinfection, water conditioners and antibiotics are often used in pounds which have adverse impacts on the aquatic environment. Poor water quality can also stem from the inappropriate design of ponds. This is common where shrimp ponds are intensively managed and sewerage is generated beyond its self cleaning capacity (Biao, 2017). The discharge and use of water in ponds is widely associated with the issue of water pollution. At each water exchange, waste water is then discharged to surrounding surface water, which carries pollutants including fertilisers, chemicals and feed.

A primary issue in Sri Lanka is the unplanned development of inlet-outlet canals within the shrimp farming system, where it is not uncommon for effluent from one farm is be pumped into adjoining farms. The discharge of pond effluent has deteriorated water quality as water is taken in and extracted into the same source of water, often with little to no treatment procedure. The inter connected lagoon between Puttalam and Chilaw serves as a key source of brackish water for farms where water pollution and disease outbreaks are a major concern.

- **Eutrophication and sediment runoff:** Non consumed feed as a result of overfeeding, decomposition of organisms, over fertilisation and lixiviation of aquaculture feed contribute to organic enrichment in the water column (Burford et al., 2001; Focardi et al., 2005). Several studies have shown that only 20% - 50% of nitrogen supplemented to cultured organisms is retained as biomass and the remainder is incorporated into sediment or the water column (Jackson et al., 2003). The discharged effluent cause a wide range of flow on impacts including phytoplankton blooms, burring, undesirable odours, toxic microalgaes (red tides), and pathogens at the discharge sites. In particular, nitrogen and phosphorous from aquaculture ponds, have led to proliferation of benthic and pelagic algal species. Algal blooms are frequently associated with depletions of oxygen concentrations, to levels unsuitable for fish, crab, and shrimp, resulting in hypoxia events (Kemp et al., 2005).

  The development of shrimp farming along the coast of Sri Lanka has amplified environmental issues in brackish water. Field surveys found shrimp pond sediment in the North Western Province of Sri Lanka including three natural wetland from Sinnapaduwa, Pulichchcikulama and Nalladarankattuwa which received direct effluent and phosphorus concentrations were detected (Gunawardena et al., 2009). For several decades, high concentration of contaminants, nutrients and low levels of dissolved oxygen was widespread in the Dutch Canal system which served as a primary water source for over 70% of shrimp farms in Sri Lanka. Hypernutrification and microbial loops were also found to have a negative feedback effect on aquaculture operations.

- **Salinisation and acidification of soil**: Soil composition in abandoned shrimp farm sites, often remain hypersaline, eroded and acidic. These soils are not conducive for agriculture and are deemed unusable for long periods of time. The application of chemicals and lime, used in aquaculture may modify the physiochemical properties of the soil which further exacerbates the problem. The establishment of shrimp farms can dramatically alter physical and chemical properties of land. Land use can change from clearance of mangroves to accommodate aquaculture ponds. At the end of their life cycle, ponds are frequently abandoned, resulting in barren and unproductive land which is both challenging and expensive to rehabilitate.

Figure 4: Abandoned Shrimp Farm - Muthupanthiya Lagoon, Udappuwa & Chilaw
Source: Silva et al., 2013

An assessment of shrimp farms undertaken in 2012, in the surrounds of the Puttalam Lagoon, highlights that over 90% of ponds are non functional. Shrimp farming practices had altered the hydrology of the sites and contributed to acid sulphate soils and high levels of unproductive salinity. The deserted ponds were unsuitable for agricultural purposes and approximately 10 hectares have been converted to salt pans and a small marginal percentage to coconut plantations (Bournazel et al., 2015).

- **Impact to native ecosystems due to introduction of exotic species:** Displacement of native species, biological contamination, spread of pathogens, and competition for food and space are some of the negative consequences, associated with exotic species (Gonzalez-Ocampo et al., 2006). Shrimp escape may occur during water exchange, harvest of open ponds, during transportation, from hatcheries or during flood events (Briggs et al., 2004). Species including *Litopenaeus vannamei* is native to the Eastern Pacific Coast (North of Peru, Mexico to Tumbes and the Gulf of California) and is considered an exotic specie in the Asia Pacific region. *L. vannamei* is known to potentially compete with native shrimp given its faster and aggressive nature. Additionally the species have also been known to spread alien pathogens including the Taura Syndrome Virus (TSV) to native shrimp populations.

- **Salt water intrusion:** Shrimp cultivation has raised serious concerns around the impacts of sea water intrusion into adjacent agricultural lands. It is common for ponds to be constructed for shrimp farming in close proximity to crop growing areas and freshwater wetlands. Saltwater intrusion can severely reduce supplies of freshwater for human consumption and pasture, while extensively contaminating waterways which can lead to loss of poultry, fodder and crops. Prolonged inundation can halt mineralisation and fixation of free nitrogen, which impairs fertility of soil composition. Excessive saline water can enter plants through osmosis which can further exacerbate issues caused by physiological drought conditions.

- **Use of antibiotics and chemical products**: To sustain it's economic viability profitability and prevent loss of cultured stock, shrimp aquaculture is strongly dependent on the application of disinfectants, artificially formulated feed, soil treatment, pesticides, algicides and other feed added substances. These products are used for disease prevention, water treatment and sanitisation of hardware.

3.3 Socio-Economic Impacts: Shrimp farming

Aquaculture development has been historically proposed in Sri Lanka, as a mechanism to diversify rural incomes through generation of employment. However, from a social and economic perspective, there are numerous downstream impacts to be considered.

- **Resource conflicts & creation of Resource Sinks:** The use of natural resources has been a consistent issue between shrimp farmers and other agricultural and freshwater fish farmers, who are economically affected due to loss of yield as a result of the environmental repercussions of shrimp farms. Shrimp culture practices increase salinity of crop lands and freshwater bodies which lead to conflicts, where water is considered a scarce resource (Subasinghe, 2006). Pen and cage culture is also dependant on natural food, and conflicts can arise with artisanal fisher farmers. Critical evaluation in terms of the opportunity cost of aquaculture development must be determined prior to its establishment due to its significant labour and capital investment. Market failures can have an adverse impact, particularly in rural communities where aquaculture tends to be concentrated with minimal adaptive capacity. A 'Resource Sink' is likely where lack of planning and management can result in low labour and resource productivity, with little economic benefit generated (Neiland, 1991)

- **Occupational Safety and Health Hazards:** The shrimp farming industry has been associated with occupational hazards due to a lack of regulations and policies. Over 87% of aquaculture production is based in developing nations and most often do not comply with industry standard occupational safety measures (Waite et al., 2014). Incorrect application of chemical products including antibiotics, inorganic fertilisers and pesticides can increase vulnerability to respiratory diseases (bronchitis, asthma), skin diseases and other allergic conditions which are detrimental to the human health (Erondu & Anyanwu, 2005). Additionally, seepage of untreated waste water, generated through shrimp aquaculture, can pose a threat to local communities.

- **Increasing costs to farmers**: Surveys conducted in the district of Puttalam suggested that in recent years, poor shrimp growth rates associated with feed quality and poor PL were observed. Increased variations in the weight of shrimp and body size were reported at harvest. Poor weight gains required farmers to lengthen cropping periods, which increased costs and lowered profitability (Munasinghe et al., 2010).

- **Lack of support:** Shrimp farmers in north western provinces of Sri Lanka, were poorly supported in terms of health management services, with NAQDA as the only principal service available. Monitoring of biosecurity practices, diagnostic services and broodstock screening is undertaken by the agency, however limited to only a small subset of pathogens (Munasinghe et al., 2010). Veterinary services were unavailable to aquaculture farmers and private laboratory facilities were deemed too expensive.

- **Lack of technical expertise:** Chemical and feed supply companies provided free consultations with relation to farm management and water quality in the district of Puttalam, however farmers were hesitant in receiving this advice due to conflict of interests between health advice, appropriate background and training of the consultants and motives in selling of specific products (Munasinghe et al., 2010)

- **Cost of biosecurity measures:** Smallholder farmers have been disproportionately constrained in their ability to introduce biosecurity mechanisms due to economic and financial pressures (Halwart et al., 2003). Rural development is based on a smallholder agricultural economy and development of shrimp farms in both low and middle income countries have been coupled with considerable issues including environmental degradation, exclusion of small scale farmers and disease outbreaks.

Since the importation and cultivation of SPF *L. vannamei* broodstock was approved by the Government of Sri Lanka in 2019, there has been a shift in interest from P. monodon to *L. vannamei.* The next section will examine key biological characteristics, stocking densities, SPF evaluation and pathogens in the context of *L. vannamei.*

4 Biological Characteristics of Whiteleg Shrimp (*L.vannamei*)

The Pacific white shrimp (*Litopenaeus vannamei*) is one of the most commercially sold and economically important aquaculture species. It belongs to the Phylum *Athropoda*, Family *Penaeidae*, of the Genus *Litopenaeu* and are cultivated in intensive, semi-intensive or extensive systems.

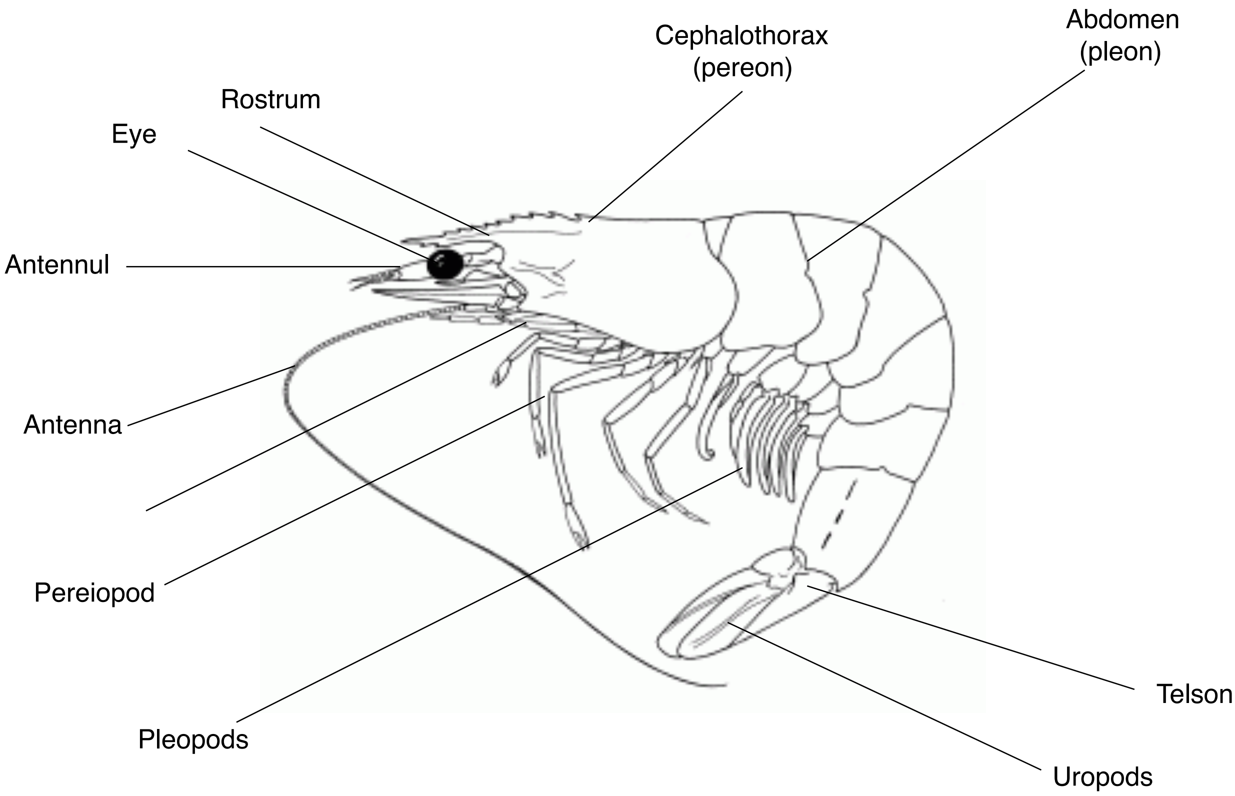


Figure 5: Morphology of *Litopenaeus vannamei* (Corteel et al., 2013)

The species has a moderately long rostrum, with 7-10 dorsal and 2-4 ventral teeth. The petasma in mature males is semi open and symmetrical and mature females have open thelycum. They complete six nauplii, three protozoeal, and three mysis stages and are characteristic of a translucent white coloration which is dependant on feed, substratum and turbidity of water. *L. vannamei* can grow to a maximum size of 23 cm with females growing larger and faster than males.

Native to the Eastern Pacific Coast from Mexico through Central and South America, the white leg shrimp live and spawn in open oceans, in tropical marine habitats where water temperatures average > 20 °C. Post larvae tend to migrate inshore to lagoons, estuaries and mangrove areas during juvenile, adolescent and sub-adult stages (FAO, 2022).

Defining features of the white shrimps from other decapods include the similar size of the front-most section of the abdomen to the rest of the sections and five pairs of abdominal appendages adapted for swimming. The *L. vannamei* specie are characterized as omnivorous scavengers and considered to be less aggressive and carnivorous in comparison to *P. monodon*. The wild species prefer clayey loam soil where the females can grow up to 120g and the males up to 80g in size.

Under controlled culture conditions, the shrimps are bred until they weigh 20 g within 100-120 days which is dependant on the stocking density. The optimal temperature for their growth ranges from 30 and 34 ° C with a dissolved oxygen level above 4.5 ppm. The shrimps are characterized with a tolerance level between 0 to 50 ppt for salinity level and a pH range between 7 to 9 with an optimal growth at pH 8.0 (Praveena, 2018). In comparison to *P. monodon, L. vannamei* shrimps require low protein food and retain the potential to grow at a faster rate in intensive culture conditions and in high density pond systems in Asian Earthen ponds. The species are amenable to culture in stocking densities of 150/m^2 in pond cultures and 400/m^2 in controlled recirculated tank cultures (Briggs et al., 2004).

4.1 Stocking Densities

Optimal stocking densities are critical for maintaining a positive balance between density and growth rate to achieve maximum biomass with minimal incidence of behavioural and physiological issues (Ayyat et al., 2011). Given that stocking density is inversely proportional to shrimp growth, crowding can impact growth and survival as a result of their stress response, which can reduce metabolism, increase pressure on natural food resources and a rise in total feed costs. *L. vannamei* can be successfully cultivated at salinity levels of 5 - 35 ppt and ideal salinity ranges from 15 - 25% (Ponce-Palafox et al., 1997).

Additionally, they are highly susceptible to pathogens and their survival, growth and stocking densities of the shrimps are primary concerns in the industry. *L. vannamei* shrimps can be generally stocked at densities ranging from 150 to 600 shrimps m^{-3}, post larvae are reared in densities as high as 1556 shrimps m^{-3} and shrimps are transported in maximum densities of 5-40 shrimp L^{-1}. Research has indicated that such high densities result in pathogen outbreaks, poor water quality and negative production, growth and survival. Shrimps reared at densities higher than 20 and 40 shrimp L^{-1} were shown to have higher mortality rates and were lower in resistance against WSSV and V. alginolyticus - a marine bacterium.

Shrimps reared at densities of 10, 20, 30 and 40 shrimp L^{-1} experienced lower immune parameters of total haemocyte count, hyaline and granular cells, and phenoloxidase and lysozyme activities. Reduced immune parameters subsequently lead to decreased resistance to pathogens (Lin et al., 2015). High stocking densities can increase cumulative mortality and higher densities can alter stress levels in organisms which has a strong correlation with disease outbreaks and the transmission of diseases (Raja et al., 2015).

4.2 Specific Pathogen free Evaluation

Over the decades, shrimp farmers have faced significant economic losses as a result of viral diseases. The U.S Marine Shrimp Farming Program (USMSFP) have developed novel techniques to mitigate these impacts, through the introduction of specific pathogen resistant (SPR) and specific pathogen free (SPF) shrimp, along with biosecure production methods that are reliant on the exclusion of pathogens. In the early 1990's, U.S. farmers observed Runt Deformity Syndrome in *Litopenaeus vannamei*, characteristic of cuticular deformities and reduced growth rates, caused by hypodermal and hematopoietic necrosis virus (Moss et al., 2003)

The process of developing a SPF stock generally involves the collection of wild shrimp, which are then assessed in a primary quarantine facility for specific listed pathogens. The shrimps are repeatedly examined and characterized as pathogen free through the use of intensive surveillance protocols, which originate from broodstock characterized with rigid and controlled founder population development protocols (Briggs, 2004). Common pathogens for which testing is undertaken include WSSV, TSV, YHV and Infectious IHHNV.

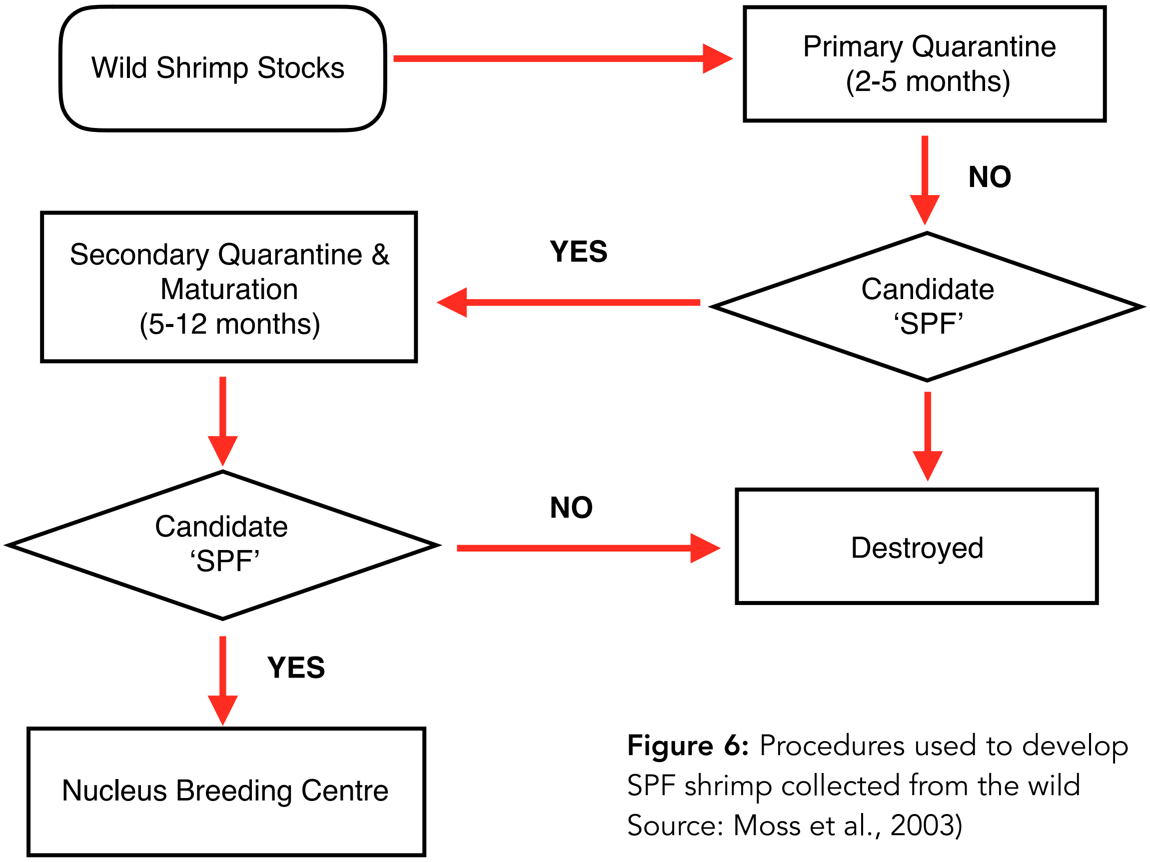


Figure 6: Procedures used to develop SPF shrimp collected from the wild Source: Moss et al., 2003)

4.3 Pathogens and Disease

The development of SPF stocks resulted in a significant rise in U.S. farmed shrimp production. However, other viral diseases including Taura syndrome virus (TSV) were identified in mid 1995, requiring researchers to initiate selective breeding programs to develop TSV resistant Pacific white shrimp (Moss et al., 2003). Although profitability and production improved, it was soon acknowledged that shrimp breeding for resistance against single viral pathogens may not be the most effective solution over the longer term.

Until 2018, *Penaeus monodon* was the primary commercially cultured shrimp species in Sri Lanka. Seed production was dependant on wild captured native broodstock. White Spot Disease was highly prevalent amidst wild collected broodstock and the industry was impacted by significant disease outbreaks and post larvae shortages. In 2016, the National Aquaculture Development Authority introduced Specific Pathogen Free (SPF) broodstock, which was imported from Thailand (Priyadarshana et al., 2020). SPF status can only provide assurance against the present status of the species, free from a specific list of pathogens and do not warrant its future pathogen resistance or status to novel viral diseases. The guarantee of disease-free culture after stocking of pathogen free post larvae is yet another widely held belief.

However, pathogens could enter the culture environment horizontally through:

- Intake of water
- Persisting pathogens in the soil
- Introduction of aquatic vectors - crabs, through intake water
- Mechanical carriers
- Contaminated personnel, animals, farm inputs - live feed, semi-moist feed

DISEASE	AGENT	TYPE	SYNDROME
White spot (WSD); also known as WSBV or WSSV	Part of the white spot syndrome baculovirus complex (recently renamed in a new family as a nimavirus)	Virus	Acutely infected shrimp show reduced food consumption; lethargy; high mortality of 100% within 3–10 days of onset of clinical signs; loose cuticles with white spots of 0.5–2.0 mm diameter, most apparent inside the carapace; moribund shrimp often have pink to reddish-brown colouration due to expansion of cuticular chromatophores & few if any white spots
Taura Syndrome (TS); also known as Taura syndrome Virus (TSV) or red tail disease	Single-stranded RNA virus (Picornaviridae)	Virus	Occurs during single moult in juvenile shrimp beginning 5–20 days after stocking, or has a chronic course over several months; weakness, soft shell, empty gut & diffuse expansion of red chromatophores in appendages; mortality varies 5–95%; survivors may have black lesions, & remain carriers for life
Infectious Hypodermal & Haematopoietic necrosis (IHHNV), causing Runt Deformity Syndrome (RDS)	Systemic parvovirus	Virus	Low mortality for resistant *P. vannamei*; however, reduced feeding, growth & feed efficiency; cuticular deformities (bent rostrum – RDS) occurs in <30% of infected populations, increasing variance of final harvest weight & reducing market value
Baculoviral Midgut Gland Necrosis (BMN); also known as midgut gland cloudy disease, white turbid liver disease, & white turbidity disease	Non-occluded enteric baculovirus	Virus	Infects larval & early PL stages, causing high mortality; white turbidity of hepatopancreas caused by necrosis of tubule epithelium; larvae float inactively on surface; later stages show resistance; positive broodstock are source of infection
Vibriosis	*Vibrio* spp., particularly *V. harveyi* & *V. parahaemolyticus*	Bacteria	May cause various important syndromes, such as luminescence & the so-called zoea-2 & bolitas syndromes In hatchery; seen as luminescence in water &/or shrimp body; disruption of gut; fouling of body; reduced feeding & high mortality In ponds, high levels of vibrios are associated with red discoloration of shrimp (especially tails) & internal & external necrosis; low feeding & chronic mortality; often a secondary infection resulting from poor environmental management; weakens shrimp which become susceptible to viral infections

Figure 7: Pathogenic diseases *L. vannamei* (Source: FAO, 2022)

Frequent outbreaks brought about by various pathogens cause significant production and economic losses with consequential impacts on employment, social welfare and international markets . Over 20 viruses have been documented to be 'pathogenic' to shrimp including *L. vannamei* species and have been recognised by international bodies including the FAO (Figure 7).

Given the nature of a shrimps' non-specific immune system and their ability to act as carriers, diseases and subsequent outbreaks have posed a constant threat to the shrimp farming industry. Diseases are generally classified as infectious or noninfectious. Etiological agents that causes infectious diseases in shrimps range from virus, bacteria, fungi to adverse environments, nutritional deficiencies and algal toxins. Growth of the shrimp industry in Sri Lanka has been negatively impacted by three main reported viral diseases - White spot disease, Yellowhead disease, and Monodon Bacculoviral disease (Athula et al., 2020).

Environmental stressors and overstocking are attributed to disease outbreaks and national and international transfer of brood stock, seed and larvae can also contribute to the widespread of pathogens globally (Ahamed et al., 2017). Bacterial and viral diseases have adverse effects on the culture species with a global production loss of approximately US$15 billion between 1997 and 2012 (Flegel, 2012). In particular, viral diseases including White spot syndrome virus, Taura syndrome virus and Yellow head virus have caused significant economic losses, amounting to approximately USD 6 billion in 2016 (Rizan et al., 2018,). In addition, the disposal of the dead organisms contributes further to the economic loss (López-Téllez, 2018).

PART 2

Field Survey Insights: Shrimp Farming - North Eastern Provinces of Sri Lanka

5.1 Field Survey: Objectives & Methodology

A research team from *The Pearl Protectors* conducted a preliminary field survey with the key objective of gathering primary data to study the current status and future trends of the shrimp farming industry in Sri Lanka. The three day survey, commenced from 5.30 am on Friday 27th May 22 and concluded at 9.00 pm on Sunday 29th May 22. The extent of the survey locations spanned from Negombo to Vidatalativu and Mannar Island, and included 13 shrimp farms, 1 *L. vannamei* brood stock facility, 3 shrimp hatcheries, 2 seafood factories, and a feed importer. The survey highlighted many previously undetermined facts and issues relating to the shrimp farming industry in Sri Lanka.

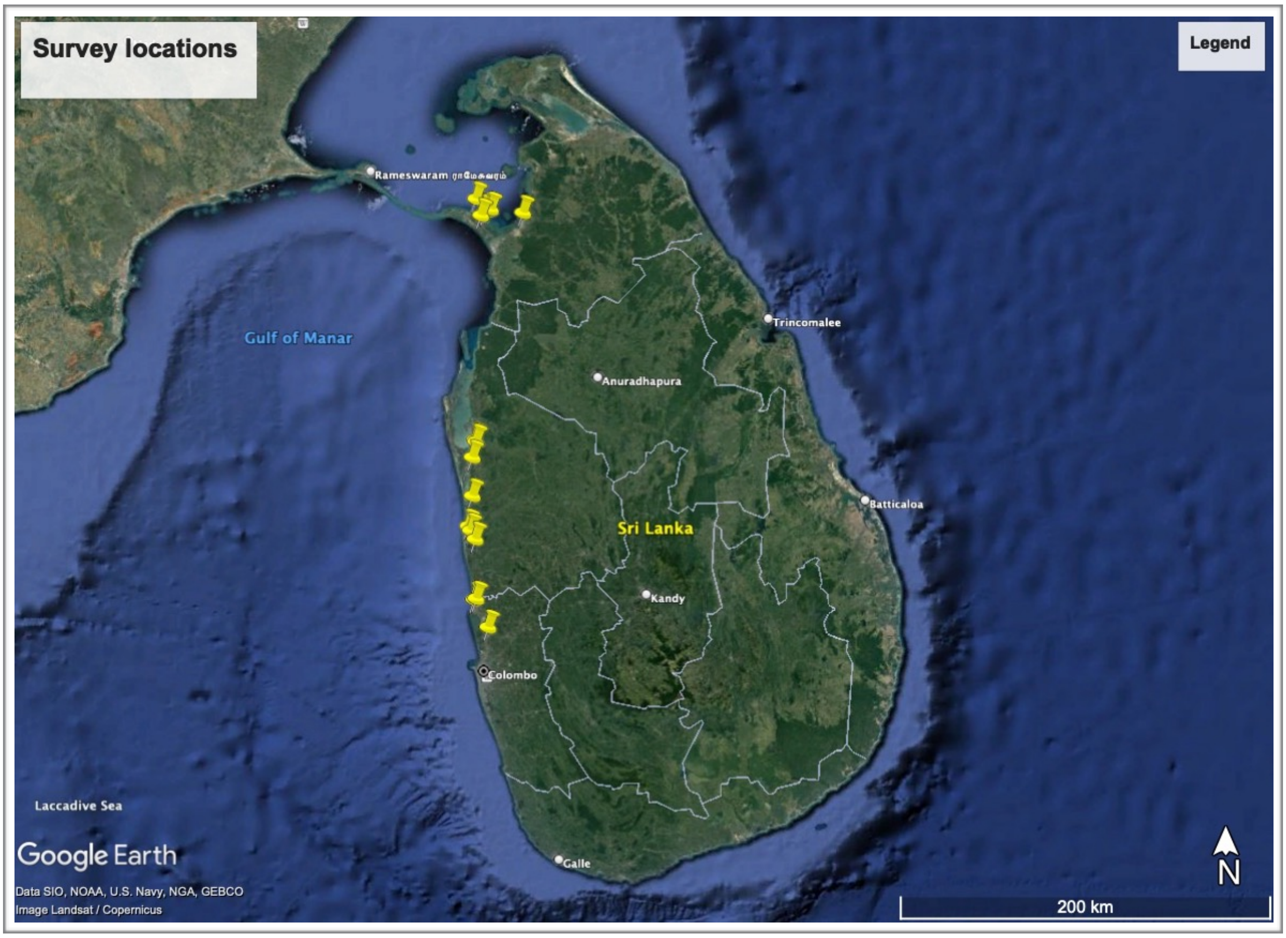


Figure 8: Survey Sites (North-western Provinces); Source: The Pearl Protectors

5.2 Results and Field Observations

Questionnaires for the interviews were designed by the research team at the Pearl Protectors and used a combination of open, semi-open and closed questions. Community interviews were conducted with fishing communities, fishery society representatives, District Church representatives, social activists, village communities, environmental activists, fishery traders, sea cucumber farmers and eco-tourism representatives across Negombo, Thoduwawa, Pesale, Erkalampitty and Vidataltivu.

The following topics were provided as guidance to encourage farmers and other stakeholders to express their true experiences, perceptions and any available data with relation to shrimp farming practices.

- Length of time in the aquaculture industry
- Type of Shrimp Farming undertaken (Small, Medium, Intensive, Semi-Intensive)
- Species cultivated
- Capacity and intensity
- Experience with culturing *L. vannamei*
- If yes, are they currently farming *L. vannamei*
- If continuing, what is their rationale to farm *L vannamei*
- If not, reasons for abandoning farms
- Experiences faced during the process
- Preferences between *L. vannamei* and other shrimp species
- Where is post larvae purchased
- Feed availability
- Intended markets (local or international demand)
- Personal comments and general views of stakeholders

- **Monoculture of *L. vannamei* :** Shrimp farms which culture *P. monodon* were not found in the site locations which were surveyed. It was suggested that a SPF *P. monodon* hatchery in Marawila has been established. Farmers declared that they did not consider purchasing SPF *monodon* PL from the said hatchery due to trust issues with the proprietors, which involved the number of PL, preventing farmers from selecting PL from desired tanks and unavailability of PL in large numbers. Farmers showed interest in culturing *P. monodon* due to its high market value, however, a lack of available PL has directed them towards *L. vannamei* culture, as an alternative. Some farmers preferred *L. vannamei* over *P. monodon* due to its high stocking density and ease of culturing the species. The owner of the *P. monodon* hatchery in Marawila confirmed that they have now shifted to *L.vannamei*, giving up *P. monodon*

Figure 9: *L vannamei* Hatchery; Source: The Pearl Protectors

Figure 10: A mud pond (Extensive Methods); Source: The Pearl Protectors

Figure 11: A polythene line pond (Intensive Methods); Source: The Pearl Protectors

- **Disease Outbreaks:** Several diseases were observed and noted from farmer interviews during the survey. Black gill syndrome, Running Mortality Syndrome (RMS), White Fecal Syndrome (WFS), White muscle & Muscle cramp, Hepatopancreatic Microsporidian Enterocytozoon Hepatopenaei (EHP), Early mortality syndrome (now referred to as Acute hepatopancreatic necrosis disease (EMS)), White spot disease, Acute hepatopancreatic necrosis disease and Vibrio infections were noted. Existence of diseases were mainly observed in small scale farmers groups. Diseases were also evident in mud pond culture systems, and farms established with polythene lining pond systems, claimed no diseases have been observed so far. Farmers also suggested the use and application of 'OTC like' medicines in the event of such disease outbreaks. NAQDA has been involved in the sample collection of diseased shrimps for further investigation and research.

Figure 12: *L.vannamei* shrimp with Black Gill Disease; Source: The Pearl Protectors

- **Escape to the natural environment:** During flood incidents and harvesting periods, large numbers of *L. vannamei* have been accidentally released into natural water bodies. Fishermen and farmers claimed to have been harvesting *L. vannamei* from lagoons and freshwater bodies. It was suggested that farmers are not well equipped to mitigate and manage escape incidents, particularly in rainy seasons. The research team also investigated species at the Negombo fish market, where *L. vannamei* prawns had been extracted from the Negombo lagoon. Black gill disease were also evident in shrimps at the market stalls. According to the fish vendors, these were shrimp species which had escaped from the farms. Shrimp farmers also stated that in prior flooding events, shrimps have been washed away from farms and people were observed, attempting to capture them using the nets in the lagoon.

Figure 13*:* Lagoon harvested *L.vannamei* at Negombo fish market
Source: The Pearl Protectors

Figure 14: Shrimp with Black gill disease at Negombo fish market
Source: The Pearl Protectors

- **Observed Technologies:** Primary technologies observed in *L. vannamei* culture were Sewage siphoning, oxygen boosters, polythene layering of bottom and walls of the pond (0.5mm-1mm), well covered bird nets, paddlers, oxygen blowers, raised circular tanks with polythene covering, raised tanks in sand platforms and high stocking in technologically sophisticated tanks. A few claimed full recirculation of water by treating water in treatment tanks and rearing fish and sea cucumbers in waste tanks. Culturing sea cucumber and Tilapia allowed them to feed on sediments and others acknowledged that excess water flows out during periods of heavy rainfall. Due to high stocking densities, significant quantities of sewage and waste are generated when compared with *P. monodon.*

Figure 15*:* A circular culture tank with bottom centre drain facility
Source: The Pearl Protectors

Figure 16*:* Oxygen Blower
Source: The Pearl Protectors

Figure 17*:* Paddlewheels
Source: The Pearl Protectors

- **Source of *P. monodon* species:** Factories obtained *P. monodon* from wild capture, and are not sourced through any cultured shrimps. During the survey, the team observed two fish processing plants. According to Executives from fish processing factories, *L. vannamei* shrimps are not currently being exported, due to poor export market demand, adding that even if anticipated demand were to increase it would occur at a very slow rate. Their reasoning for this belief, is that *L. vannamei* shrimp are widely farmed globally, and countries such as India and Vietnam are a strong competitor with a low unit price in comparison to Sri Lanka. High costs of production made it more challenging to compete in the global market. It was further pointed out that *P. monodon* shrimps have a much higher export market demand compared to *L. vannamei* due to consumer taste preferences. Currently, the price range was Rs. 1200 /- per kg for *L. vannamei* and approximately Rs. 3500 /- per kg for *P. monodon.* Factories are targeting *L. vannamei* at local market instead, in the prevalence of very low demand of *L. vannamei* in international market.

Figure 18*:* Packaged and frozen *L.vannamei*
Source: The Pearl Protectors

Figure 19: Seafood processing factory
Source: The Pearl Protectors

- **Prohibition of broodstock:** Farmers claimed government circulars were provided, which banned the holding of wild capture *P. monodon* brood stock. Although interest was shown in culturing *P. monodon,* the government has issued an order prohibiting the rearing of brood stock collected from wild waters.

- **Observed comparisons between *L. vannamei* and *P. monodon*:** Farmers, hatchery owners and factories claimed high market value for *P. monodon* compared to *L. vannamei*. Other participants claimed their taste preference leant towards *P. monodon*. However, high stocking densities, availability of adequate PL, ability to consider partial harvesting and the ability to harvest *L. vannamei* irrespective of its weight has attracted farmers choice.

- **Perceptions on the future of culture:** Small scale farmers who carried out culture activities in mud ponds felt uncertain about the future state, due to ongoing prevalence of disease and exorbitant costs. Large scale farmers with advanced technology were better place and equipped to expanding culture practices. Some small-scale farmers were interested in shifting towards *P. monodon,* however companies including Taprobane claimed such a shift would prove to be a failure. Intensive farmers and brood stock importers also raised concerns on importation of brood stock after 6 months, due to the existing dollar and economic crisis. Feed companies involved in importation raised the same issue, suggestive of inadequate government support in operations including the unavailability of fuel. The majority of respondents were very satisfied with the service provided by NAQDA in popularizing the *L. vannamei* culture.

- **Political Support:** Direct political support appeared to be given to intensive farmers in Northern area. Visits from political representatives were reported in large scale farms and the community raised concerns, highlighting the political support received to companies to not be held accountable for illegal activities such as waste water discharges, importation of brood stock without permission and the acquisition of state lands without proper regulations.

- **Broodstock importation and maintenance:** Companies involved in brood stock importation claimed they import SPF brood stock from Thailand and Hawaii with permission and supervision of NAQDA. After a 6 month period, they have to reimport another batch to ensure optimum performance of PL. Special separate facilities have been constructed and constant monitoring of workers was in place. It was stated that the importation of 200 broodstock would cost approximately 80 lakhs, and subject to continue rising due to deteriorating exchange rates.

Figure 20: *L.vannamei Broodstock*
Source: The Pearl Protectors

Figure 21: *L.vannamei Eggs*
Source: The Pearl Protectors

- **Existing Conflicts:** A conflict between villagers of Erkalampitty and the Taprobane company was observed due to the sewage disposal problem. Taprobane claimed that they practice full recirculation of water, however villagers claimed that the company disposed sewage water between 10.00 pm and 3.00am into the open lagoon environment. They also claimed experiencing health problems including rashes, loss of biodiversity, reduced fish catch and unemployment amongst the fishing community. Taprobane refused all allegations made by villagers and they claimed to assist with provision of employment and community projects to help schools and low income communities. The villagers claimed only ~5-6 locals were recruited for the farm and remainder are external recruits. The local community also raised concerns around the acquisition of farm land with the aid of political representatives, for which there are ongoing legal proceedings on this matter.

- **Species cultured in polythene lined ponds:** *L. vannamei* cultured in polythene lined ponds were found to appear darker than its mud pond cultured counterparts. Pond lining is a very beneficial form of infrastructure to ensure shrimp farm biosecurity. Shrimp producers can further boost production efficiency by using plastic-lined ponds, which can support more production cycles each year. During the survey, shrimps reared in polythene lined ponds and mud ponds were well observed and it was clear that *L. vannamei* raised in polythene

Figure 22: *L.vannamei* cultured in polythene lined ponds
Source: The Pearl Protectors

Figure 23: *L.vannamei* cultured in mud ponds
Source: The Pearl Protectors

According to some of the respondents, the acquisition of fresh land for shrimp culture is essential for increased performances, although others opposed this view. Two main reasons supported this opinion: the fertility of the soil in fresh lands and the reduced susceptibility of shrimp to disease. Other participants felt that water quality and proper maintenance is crucial for successful shrimp farming.

- **Perceptions from the Vidataltivu local community**: The community was unaware of the proposed shrimp farm development in the Vidataltivu reserve. Generally, they were indifferent to shrimp farming however showed interest in sea cucumber farming around Vidatalativu. Additionally, locals were unaware of any land acquisition proposals to cultivate shrimp in the region. They are mainly engaged in lagoon fisheries, which target crab species including the Blue swimming crab (*Portunus pelagicus*) Mud crab (*Scylla serrata*) and half beaks (*Hemiramphus* sp.) from the lagoon. Emerging sea cucumber farming was observed and people have been transporting sea cucumbers to the Jaffna area, to introduce them to grow out ponds. Onsite preparation of Beche de mer was observed and locals mentioned that they could earn more from sea cucumber cultivation than from projects such as shrimp farming, with projected profits of ~ Rs. 200,000. Further, they requested assistance to conduct sea cucumber farming in their lagoon area. It was their widely held belief that, the cultivation of sea cucumber does not cause any harm to the environment.

Figure 24: Sea cucumbers for grow out farms
Source: The Pearl Protectors

Figure 25: Beche de mer preparation
Source: The Pearl Protectors

- **Buy back methods led by Taprobane:** The survey team observed that this method is now being implemented in many shrimp farms. In this method, the shrimp farmers are supplied with *L. vannamei* PL and shrimp feed by Taprobane. They raise the shrimps and sell the harvest back to Taprobane. According to shrimp farm owners, this is a good option for them as it is less risky and less costly. Even in farms who do not perform buy-back method with Taprobane, it was observed that the most widely used feed is Taprobane feed.

- ***P. monodon* cultivation:** Although motivation was shown in the move towards *L. vannamei,* many showed interest in culturing *P. monodon* if proper methods were established, similar to those in *L. vannamei.* However problems in unavailability of SPF *P. monodon* hatcheries, conflict of interests between hatchery owners and farmers, low stocking density etc have proved to be the main obstacles. According to most shrimp farm operators, brood stock management firms including Taprobane, deliver high-quality SPF *L. vannamei* PL on a regular basis. This is one of the main reasons why they have a preference to farm *L. vannamei* shrimps. However, due to the high demand for *P. monodon* shrimps in the export market, it was revealed that many shrimp farm owners are also interested in *P. monodon* farming. However, one of their major issues is a scarcity of high-quality SPF *P. monodon* PL suppliers. Some shrimp farmers, on the other hand, have no intention of farming *P. monodon* shrimps. This is due to the fact that growing *L. vannamei* shrimps has several advantages over growing *P. monodon* shrimps.

Figure 26: Shrimp feed provided by Taprobane
Source: The Pearl Protectors

- **Other observed marine organisms**: Other organisms such as fouling organisms, crabs, and birds were observed in some shrimp farms, despite biosafety procedures.

Figure 27: *Fouling organisms observed in culture ponds*
Source: The Pearl Protectors

5.3 Discussion

Summary of Community Responses: The overall results of the interviews were categorised into 8 key themes as outlined below, which highlight various degrees of concern between the culture of *L.vannamei* and *P. monodon*. Responses were graded between: 'No comment; Highly not satisfied; Unsatisfied; Neutral; Satisfied and Highly Satisfied'

Concern	***L. vannamei***	***P. monodon***
Availability of PL	Satisfied	Unsatisfied
Disease occurrence	Satisfied	Highly unsatisfied
Stocking density	Satisfied	Unsatisfied
Availability of feed	Satisfied	No comment
Market value	Neutral	Highly satisfied
Size of the shrimp during culture period	Satisfied	Satisfied
Competent authority support	Highly satisfied	Highly not satisfied
Overall easiness of culture	Satisfied	Not satisfied

Figure 28: Comparisons between cultured species
Source: The Pearl Protectors

Detailed and systematic investigation is highly recommended in the area due to a lack of credible data on *L. vannamei* species in Sri Lanka. Environmental, social and economic concerns raised by farmers, companies and interested individuals should be taken in to consideration in any proposal to expand this culture. Although farmers have been well equipped with culture knowledge from competent authorities, information on worst case scenarios must be disseminated, including re-structuring of farms when cultivating introduced species.

Escapes events, disease occurrences and unavailability of adequate biosecurity measures must be thoroughly addressed. Large companies are better placed in managing the future of this culture, however there is considerable uncertainty amongst rural small scale farmers. This may be attributed to political backing and increasing of cost of inputs. It was accepted and obvious that culturing *L. vannamei* results in large quantities of sewage compared to *P. monodon*. It is important to address waste management issues as inappropriate release to the natural environment is considered detrimental to the sustainability of marine ecosystems and human wellbeing. Large scale farmers claimed to be recirculating water by allowing organisms such as Sea cucumbers and Tilapia to biodegrade sewage, however further investigation is required. Tackling fast culture cycles with immense amount of sewage are highly questionable. Overflow of sewage systems during rainfall events, questions this method to a further extent.

During the observations it was evident that sewage canals are in bad conditions with stagnant water conditions leading to unfavourable microorganism growth. Despite the grade of the farm sewage, the condition of the water canals can be deemed a major concern for sustainable growth. Improving *P. monodon* culture by introducing SPF brood stock will attract farmers to the culture of native species as many are willing to shift towards *P. monodon.*

The Taprobane shrimp farm has been established in the Vidataltivu area, with plenty of land that can be easily acquired to commence start shrimp culture. This particular stretch of land will experience a comparatively less amount of pressure from local communities due to a lower population living in the surrounds. This was evident after questioning villagers regarding operational procedures, processes and any existing problems with the farm. Despite the grade or the location, conducting awareness sessions to local communities on the culture impacts is considered as a timely need. It is also critical that preference for use of existing land, surrounding the farm is given for any proposed expansion of the industry, rather modification to the ecologically significant Vidataltivu nature reserve.

PART 3

Case Study:

Vidataltivu Reserve, Mannar

6 Protected Areas of Northern Sri Lanka

The establishment of Protected Areas (PA) are considered to be a key strategy in tackling ecological degradation (Edgar et al., 2014). PAs contribute to the protection of natural ecosystems, biodiversity and stimulation of sustainable development (Barbier, 2010). The Targets for PAs have been set under the Convention on Biological Diversity, in the Aichi target 11, to cover at least 17% of inland water and terrestrial area by 2020, and at least 30% of land and sea areas by 2030 (CBD, 2020).

A recent survey highlighted a network of several National Parks, Sanctuaries, Nature Reserves and Proposed elephant corridors in close proximity to each other, across the Northern landscape of Sri Lanka, including:

- **Madu Road National Park:** Designated a sanctuary on 28 June 1968 under the Fauna and Flora Protection Ordinance (No. 2) of 1937, spanning 26,677 ha
- **Vidataltivu Nature Reserve:** Marine Protected Area declared in 2016 by the Department of Wildlife Conservation and supports extensive seagrass meadows, the Maldiva Bank coral reef and mangrove species.
- **Delft Island National Park:** Designated a national park on 22 June 2015 with an area of 1,846 ha. Wild ponies are found within the Park.
- Adam's Bridge National Park: Designated a national park on 22 June 2015 with an area of 18,990 ha. Many migratory birds follow the Adam's Bridge - Mannar Island route and sand dunes of Adam's bridge are important breeding grounds for bird species including the brown noddy. Marine life around the shallow waters include turtles, dugongs and dolphins (Rodrigo, 2015).
- **Chundikkulam National Park and Lagoon:** Designated a bird sanctuary in 1938 and is surrounded by sea grass beds and mangrove swamps. The Lagoon attracts a range of migratory waterbirds.

- **Vidataltivu Nature Reserve:** Spans 291.8 sq.km and was declared a Marine Protected Area in 2016 and contains extensive areas of mangroves, sea grass meadows and coral reefs

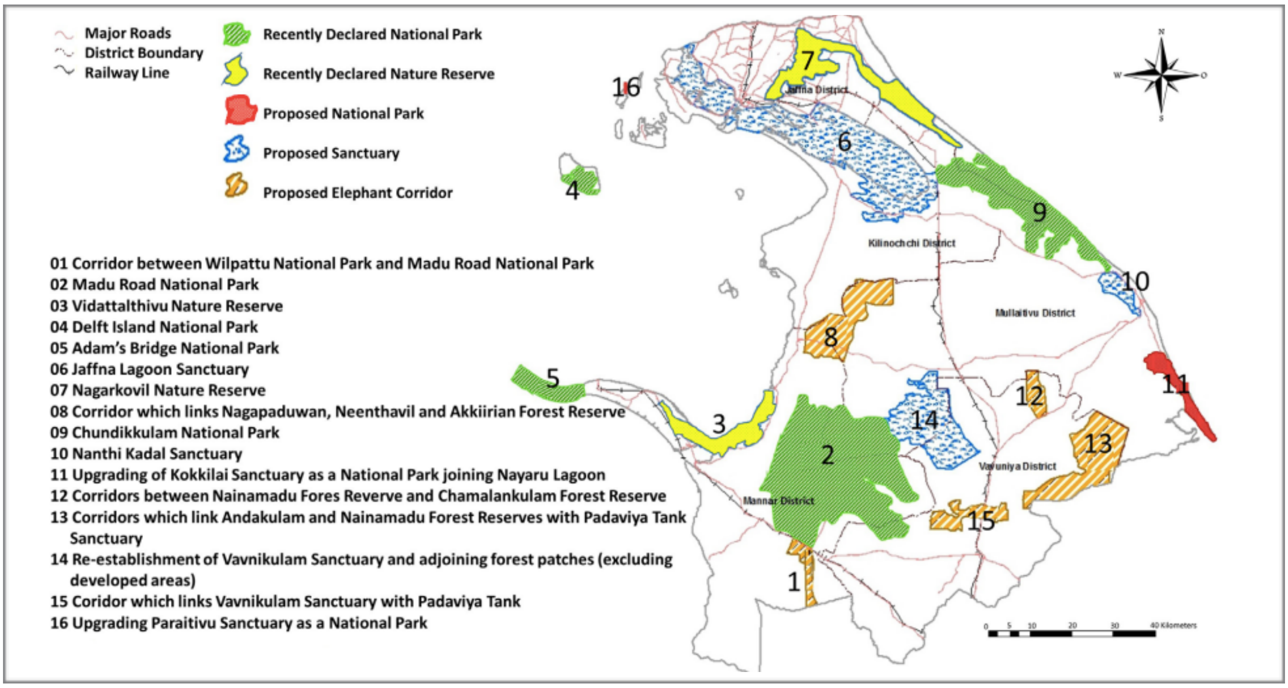


Figure 29: National Parks, Nature Reserves and Sanctuaries, Northern Sri Lanka

Source: Wanniarachchi, 2011

- **Wilpattu National Park**: Forms a significant part of the Greater Northern landscape, spanning 131,693 hectares and is one of Sri Lanka's oldest National Parks, initially declared a Sanctuary in 1905, and later designated a National Park in 1938. A study recorded 137 bird species across 49 families, including 3 endemic species and 25 winter visitors. Additionally, a globally threatened species *Leptoptilos javanicus* (Lesser Adjutant) also formed part of the avifaunal assemblage. Five major aquatic and six terrestrial habitats were identified within the survey including: Dry Mixed Evergreen Forest, Thorn Scrub, Scrub, Scrub on Sand, Floodplain, Riparian Forest, Mangroves, Salt Marshes, Freshwater Holes, Brackish Water Waterholes and Seasonal small Tanks (Weerakoon & Goonatilleke, 2007).

6.1 Site Location: Vidataltivu Reserve

Vidataltivu is a coastal region located in Manthai West divisional secretariat division of Mannar District, Northern Province, Sri Lanka. The region is composed of a rich assemblage of marine ecosystems with fringing mangroves, lagoons, intertidal flats and sandy shores. Arid-mixed evergreen forest and paddy cultivation are also present (Figure 30). The Vidataltivu Nature Reserve covers an area of 1595.6 ha of mangove, 8,680 ha of seagrass and 665.8 ha of coral reef habitat and the adjoining Vidataltivu Lagoon spans an area of 386 ha (IUCN, 2020). Additionally the IUCN has identified the area, as one of the most mangrove rich locations within the Mannar District, containing 7 out of 22 mangrove species recorded in Sri Lanka (IUCN, 2006).

The Vidataltivu Nature Reserve spans an extent of 29,180 hectares and was declared a 'nature reserve' under the Fauna and Flora Protection Ordinance (FFPO) No. 22 of 2009, by Gazette Extraordinary Notification No. 1956/13 on March 1, 2016. The area was also identified as requiring protection by the Strategic Environmental Assessment (SEA) of the Northern Province, conducted in 2012. The Department of Wildlife Conservation (DWC) is the primary government agency responsible for management and conservation of the Reserve including the implementation of Wildlife Policies in Sri Lanka and the FFPO.

The Vankalai Sanctuary is located in close proximity to the Nature Reserve and covers an area of 4,839 ha and supports highly productive ecosystems and species diversity. It was declared a Sanctuary by the Department of Wildlife Sri Lanka in 2008 and is listed as a RAMSAR Wetland of international importance. The site provides living habitat and important feeding grounds for a large number of water birds and annual migrants which use the lagoon, tidal flats and salt marshes on arrival and exit from Sri Lanka (RAMSAR, 2010).

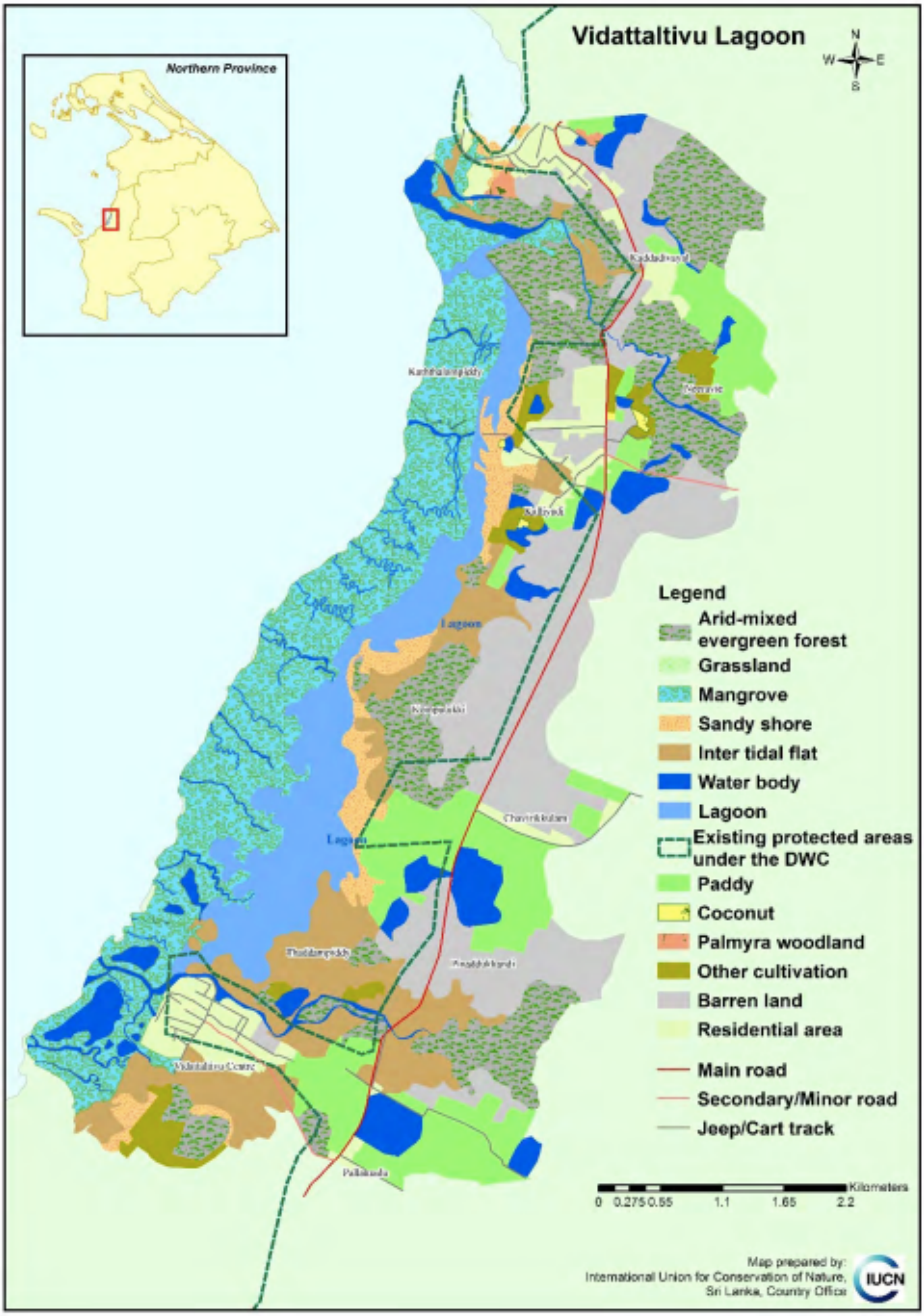


Figure 30: Land use in Vidataltivu, Manner (IUCN, 2020)

6.2 Geomorphology

The Mannar Basin is located to the northwest of Sri Lanka and consists of continental to transitional crust and Precambrian metamorphic rocks (Desa et al., 2006). The soil type surrounding the Vidataltivu Reserve is primarily Solodized Solonetz and Solonchaks, dominant in areas covered with short grass, bare ground, scattered trees and some halomorphic species. Parent material is composed of semi-recent marine clay alluvium and typically occurs on flat tidal plains. Another soil type found in the area is Grumsols, present in thorny scrubs and short grass savannahs, formed on parent rock of ponded sub recent clay alluvium over decomposed Archaen quartzitic rock (Moorman & Panabokke, 1961). In terms of its coastal geomorphology, Sri Lanka is situated on a continental shelf which has an average width of 20 km, and the Gulf of Mannar is over 1,820 metres deep (Madduma Bandara, 2007).

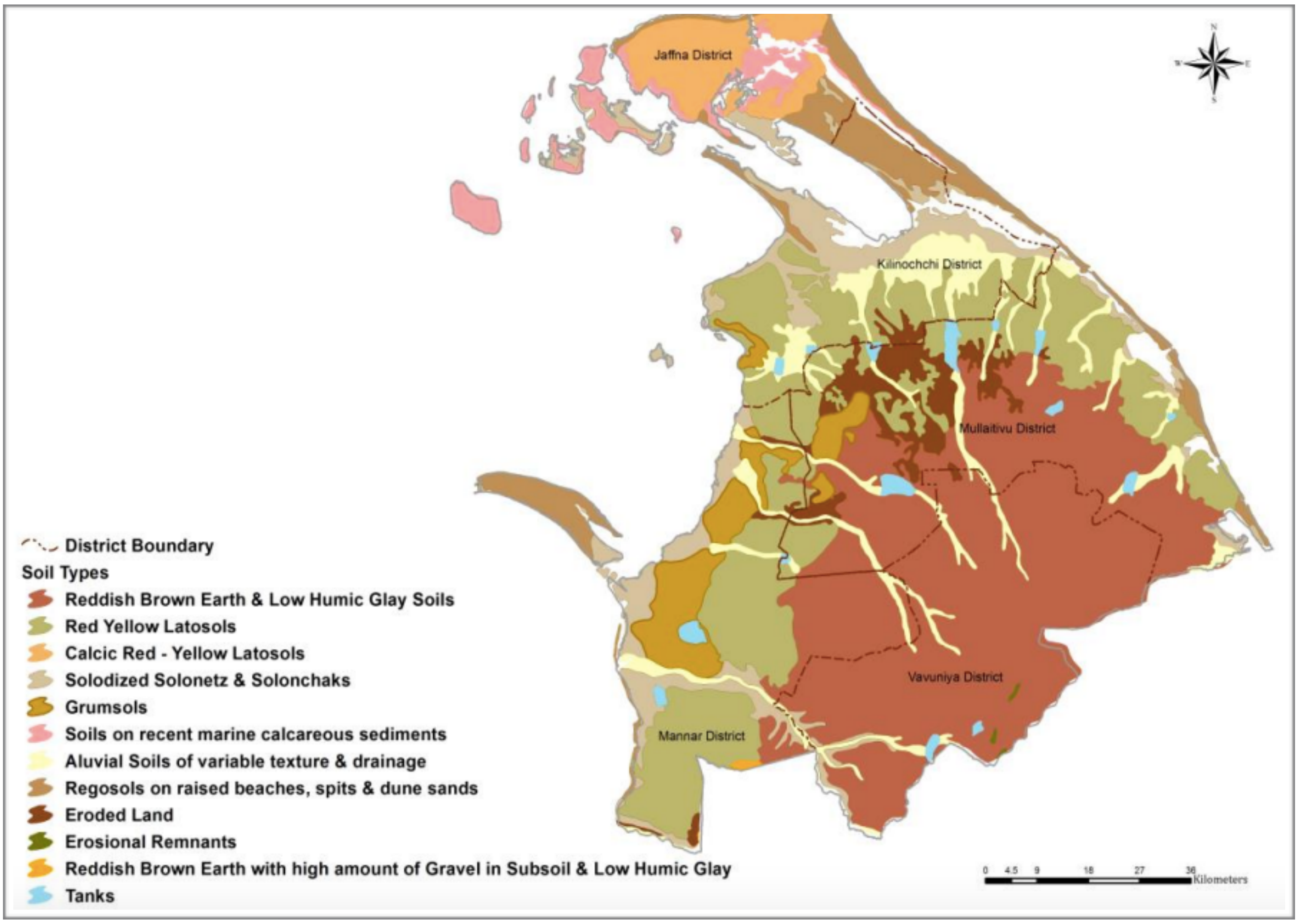


Figure 31: Soils of the Northern Province (UDA & Department of Agriculture, 2010)

6.3 Climate and Hydrology

Vidataltivu is located within the Arid Zone of Sri Lanka where average rainfall is typically 650 mm per annum. Seasonal rainfall is concentrated from October to November in the Second Inter Monsoon (SIM) and from December to February during the North East Monsoon. Approximately 42.7% of rainfall is received during the SIM, where depressions of pressure, cyclonic wind circulation, convection and convergence activity results in widespread and intense rainfall (Rajendram, 2019). Average mean temperature can range from 28^{O}C - 33^{O}C (BOBLME, 2015). Recent climatic variations involving the intensity and occurrence of extreme climatic events including drought and floods are significantly increasing in Sri Lanka. The District of Mannar was severely affected by drought, as recently as 2019, where 63,115 persons and 18,074 families were severely impacted (Disaster Management Centre, 2019). A large section of the Reserve is low lying and is susceptible to extensive inundation during the north-east monsoon.

The main rivers which drain into the Gulf of Mannar include the Kal Aru, Aruvi Aru and Moderagam Aru. Additionally, the two main lagoons along the coastline are the Periya Kalapu and Vidataltivu Lagoon (IUCN, 2010).

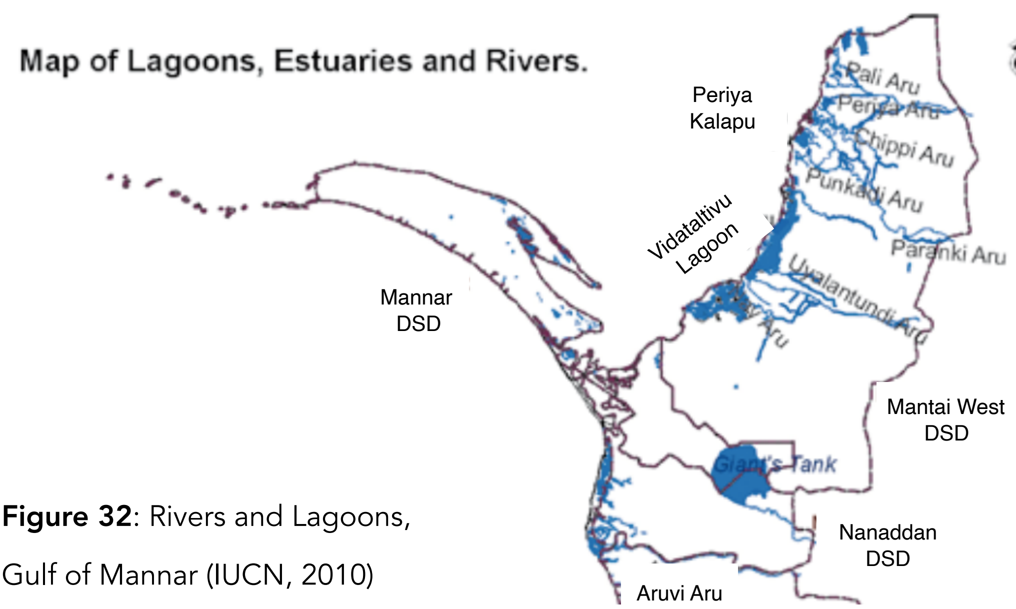


Figure 32: Rivers and Lagoons, Gulf of Mannar (IUCN, 2010)

6.4 Coral Reefs

Spatial analysis has exhibited suitable coral habitat across Sri Lanka. In particular, results across the northern provinces (Gulf of Mannar - North and South of Adam's Bridge) confirmed substantially more conducive environments for coral reef assemblages. The reef systems consist of high live coral cover, abundance and diversity of reef organisms. Major reef systems located in close proximity include the 'Bar Reef', recognised by the International Union for Conservation of Nature (IUCN) / National Oceanic and Atmospheric Administration (NOAA) as a 'High Regional Priority Area (Arachchige et al., 2017) and other significant reefs including Vankalai, Silavatturai, Arippu, Cheval Bank, Pearl Banks and Maldiva Bank (Figure 33).

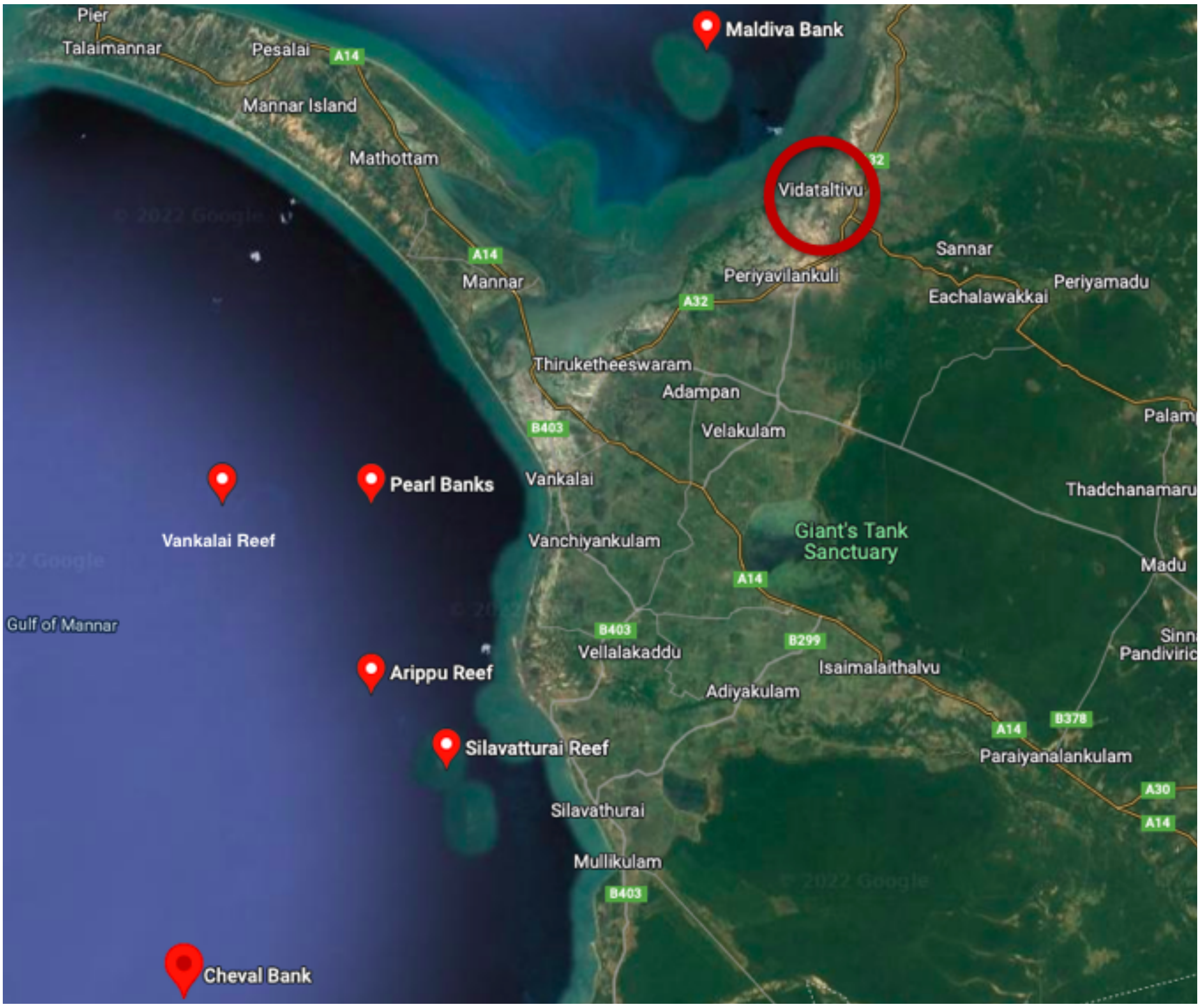


Figure 33: Proximity of Vidataltivu to major reef systems

Research conducted in the South Indian section of the GOM Biosphere Reserve confirms 117 species across 14 families and 40 genus (UNDP, 2001). The reef systems commonly located here are 'patch reefs' and located offshore between 1 - 10 km from the coastline. The Sri Lankan section of the GOM region is dominated by massive, branching and foliose corals belonging to genus Acropora, Echinopora, Montipora, Pocillopora and Porites (Rajasuriya et al., 1998). Stony corals were recorded in the southern GOM and famous pearl banks closer to Silavatturai and Vankali. The patch reefs are extensive beach rock and sandstone reef habitats and support a diverse range of marine life.

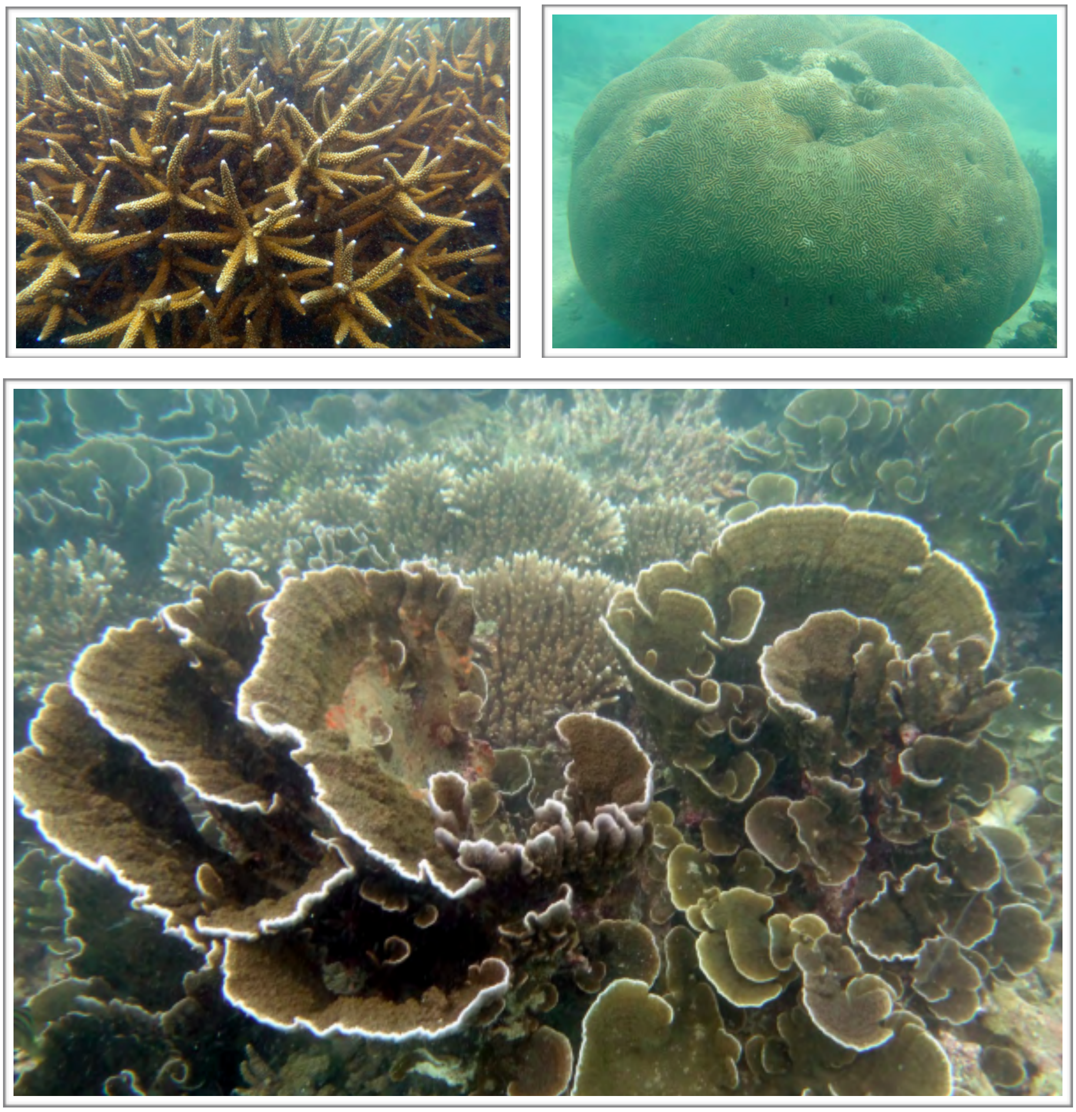


Figure 34: Branching coral Acropora, Massive Coral Platygyra sinensis & Foliose coral Montipora (Rajasuriya, 2015/2016)

A recent study which surveyed the status of coral reefs in the Northern provinces of Sri Lanka presented newly recorded species, as confirmed by DNA Bar-Coding, in the GOM which include:

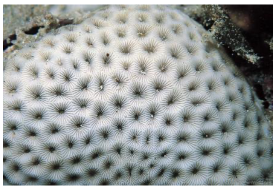
Family	***Genus***	***Species***	***Photo Identification***
Acroporidae Verrill, 1901	*Acropora Oken, 1815*	*Acropora digitifera Dana, 1846*	
	Astreopora Blainville, 1830	*Astreopora myriophthalma Lamarck, 1816*	
	Montipora Blainville, 1830	*Montipora informis Bernard, 1897*	
Merulinidae Verrill, 1865	*Cyphastrea Milne Edwards & Haime, 1848*	*Cyphastrea microphthalma Lamarck, 1816*	
Poritidae Gray, 1842	*Goniopora de Blainville, 1830*	*Goniopora minor Crossland, 1952*	
Siderastreidae Vaughan & Wells, 1943	*Siderastrea Blainville, 1830*	*Siderastrea savignyana Milne Edwards & Haime, 1849*	

Figure 35: New coral species - Gulf of Mannar Region (Arulananthan et al., 2021); Corals of the World Organisation

VULNERABILITIES

i. **Salinity**: Seawater salinity and temperature have been continuously recognised as limiting environmental factors for the growth and survival of reef corals (Vaughan, 1914). Studies have outlined that some of the most sensitive corals, susceptible to bleaching events, included branching corals such as *Acropora*, surveyed close to Vidataltivu (Marshall & Baird, 2000). High temperatures have been recorded in GOM coastal waters, as a result of low water depth. Increased evaporation and sunlight reaching the bottom of the ocean floor has contributed to elevated salinity levels.

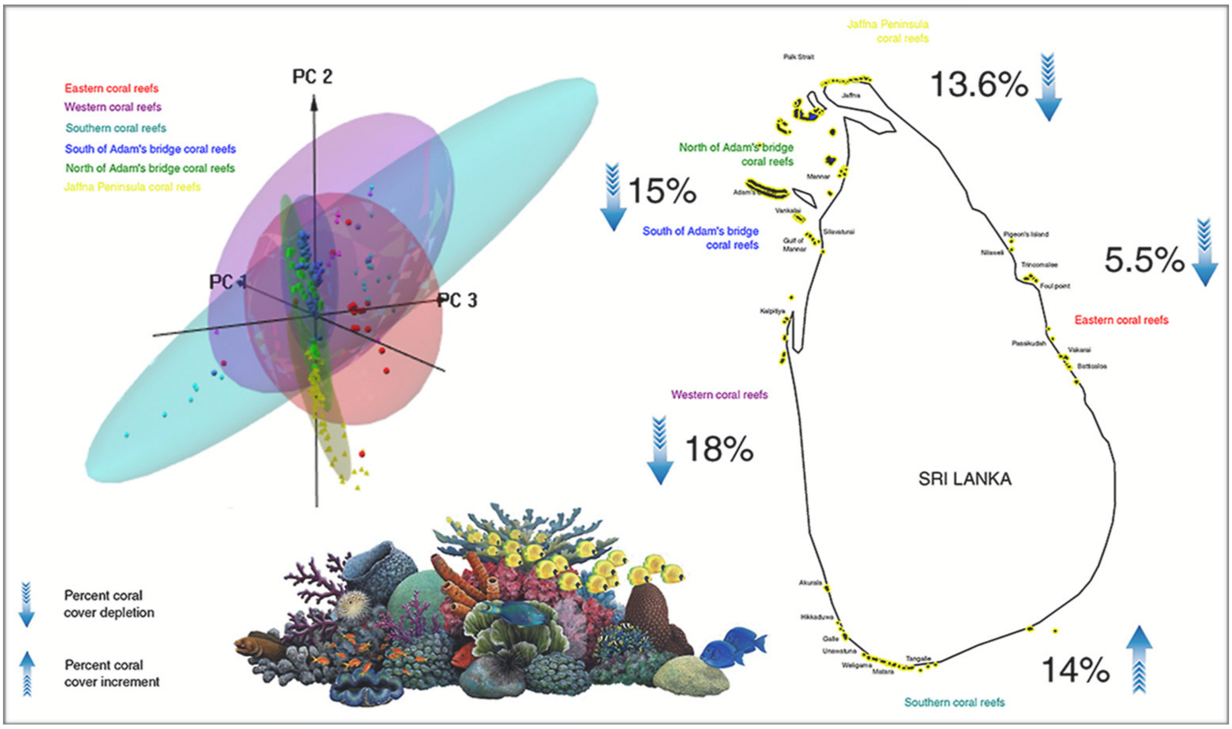


Figure 36 : Distribution of coral reef assemblages & coral cover changes (Ellepola et al., 2021)

As highlighted in Figure 36, models suggest a higher rate of coral cover depletion by an estimated 15.39% in the Mannar region by 2050, as a consequence of temporal changes to environmental and geophysical factors presented under future climate change scenarios (Ellepola et al., 2021).

ii. Sediments: Sediments are deemed one of the most damaging pollutants on reef systems and may be either deposited on coral surfaces or remain suspended in water. They can contain nutrients, toxicants and nutrients which have been evidenced to negatively impact coral health (Fabricius, 2005; Jones et al., 2016). There is heightened risk associated with discharge of effluent into sea waters, given the shallow nature of the water, coupled with low limits of nutrient tolerance. Reefs in Mannar have been rated *highly vulnerable* due to its narrow tolerance ranges, where minor perturbations in environmental or geophysical conditions could be detrimental to corals (Ellepola et al., 2021). Sediment can impact corals throughout their lifecycle. Increased and extended exposure can depress coral conditions, health and survival across multiple pathways (Figure 37).

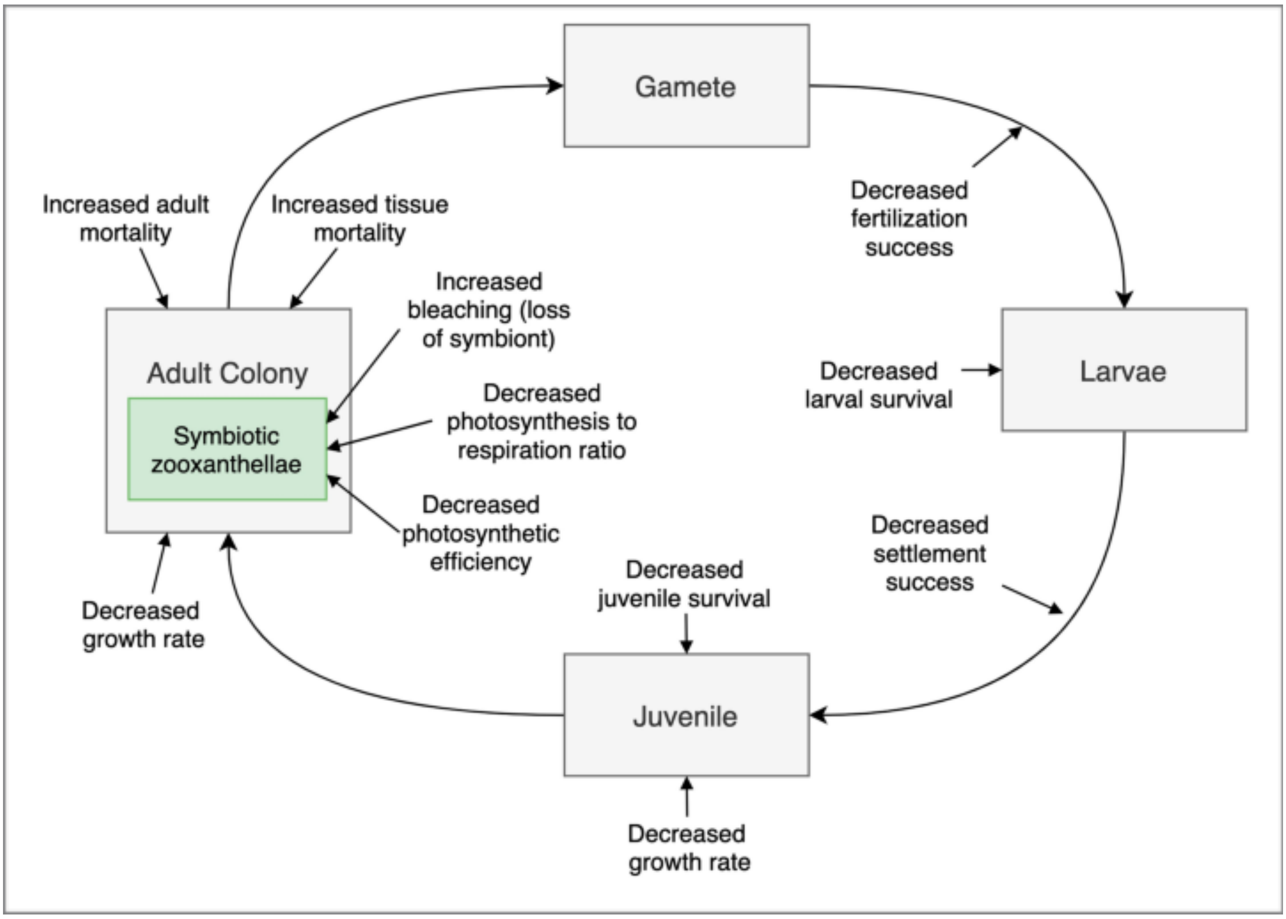


Figure 37: Development stages (grey) & coral endosymbiont (green) ; Biological responses to sediment represented by arrows towards life cycle stage (Tuttle & Donahue, 2022)

In addition to the above, coral structures and larvae are also subject to numerous adverse impacts in response to sediment stress through a variety of biological mechanisms.

Adverse Effects	Summary
Reduced fertilisation of coral gametes	Sediment can affect viability of gamete, reduced success of fertilisation, decreasing chances of population maintenance and recovery
Mortality of coral larvae	Suspended sediment decreases intensity and availability of light in the water column, reducing larval survival. Reduction in photosynthetic efficiency of symbionts (larval) for extended time frames can result in larval mortality
Reduced settlement of coral larvae	Light quantity and quality are key site selection factors for coral larvae. Settling on upper exposed surfaces in low light levels leads to a higher risk of coral abrasion by deposited and suspended sediment
Decrease in photosynthesis-to-respiration ratio of adult corals	The rate of production (photosynthesis) to respiration, defined by P/R may decrease where a reduction in gross photosynthesis occurs as a result of low light in turbid waters or increased respiration due to higher metabolic activity responding to exposure of sediment exposure
Reduced photosynthetic efficiency of adult corals	Corals are reliant on symbionts for upto 90% of their energy. Reduced photosynthetic efficiency is thought to be an early indicator of coral bleaching and can result from physical damage to coral tissue due to shearing in turbid high sediment waters.
Bleaching of adult corals	Sediment induced bleaching may occur when suspended or deposited sediment results in decreased energy state which may induce symbiont expulsion from prolonged exposure and leave corals sensitive to bleaching

Figure 38: Effects of Sediment exposure on Corals (Tuttle & Donahue, 2022)

6.5 Seagrass Meadows

Seagrasses are a functional group of marine flowering plants which support marine food webs by providing essential habitat, while playing a crucial role in balancing human livelihoods and coastal ecosystems (Mtwana Nordlund et al., 2016). Seagrass meadows provide breeding, nursery and feeding grounds for commercially important fish, shellfish and marine invertebrates and are critical in sustaining coastal fisheries (Spalding et al., 2003). Dependant on light for photosynthesis, the most productive seagrass beds were located in the shallow coastal waters of Mannar with a maximum approximate depth of 3 metres. The area lies beyond the belt of mangroves fringing the Vidataltivu Reserve. The main seagrass meadows in the North western Province are found in the Palk Bay from Mannar Island to Kiranchi (IUCN, 2020). It's estimated extent in the GOM and Palk Bay is 55.15 km^2 and 175.2 km^2 respectively (Raja et al., 2012; Manikandan et al., 2011). Common species found included *Enhalus acaroids, C. serulata, Cymodacea rotundata, Syringodium isotifolium, H. uninervis and Halodule pinifolio* (Kumara & Udagedara, 2013).

Figure 39: Seagrass meadow, Vankalai, Gulf of Mannar (Rajasuriya, 2020)

Other significant ecosystem services provided by seagrass beds include:

- Changing patterns and reducing speeds of currents and sediment transportation playing a pivotal role as a stabliser, similar to the the function of mangrove vegetation and sand dunes (Jagtap & Rodrigues, 2004)

- Acting as a carbon sink through the sequestering carbon dioxide from the atmosphere and serving as a primary producer in shallow coastal regions.

- Provision of essential shoreline and reduction of coastal erosion through the complex root structure present in seagrass beds which stabilises and secures sediment (Björk et al., 2008).

- Trapping of heavy metal and nutrients by reducing water movements, allowing for improved water quality for fish communities and corals (Manikandan et al., 2011) . They provide substratum for epiphytes and are a critical food source for marine herbivores including green sea turtles and dugongs.

The IUCN Status of Dugongs in Sri Lanka is classified as 'Critically Endangered' and strictly protected under the Fauna and Flora Protection Ordinance. Distribution of the dugong is mostly restricted to the Palk Bay and Gulf of Mannar (Ilagakoon et al., 2008). The Dugong is found in coastal waters and is a migratory herbivorous marine mammal belonging to the Family Dugongidae (Order Sirenia) and is the only living species under this Family. The average adult can grow to a length of 3 metres and weigh between 250 - 400 kg. It has a slow reproductive rate, reaching sexual maturity at an estimated 10 years. It's diet is primarily seagrasses with a preference for species under Halodule and Halophila genera (IUCN, 2022). Major threats to their habitat in Sri Lanka include destructive fishing practices including blast fishing and bottom trawling, use of gill nets, hunting for meat and destruction of seagrass meadows.

Figure 40: Critically Endangered Dugong dugon
(Fergus Kennedy, Conservation Sri Lanka)

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i. **Eutrophication**: Of all anthropogenic disturbances, it has been widely recognised that eutrophication-induced mortality coupled with phytoplankton and seaweed blooms, is most destructive to seagrasses (Burkholder et al., 2007). Excessive nitrogen stimulates the growth of macroalgae, phytoplankton and epiphytes which limit sunlight which is vital to the process of photosynthesis. Shrimp aquaculture is mostly reliant on external nutrients from commercial suppliers or on-farm formulated feeds. Significant quantities of undigested or unconsumed feed from shrimp feeding accumulate at the bottom of ponds and are decomposed by microorganisms (Thorber, 2010). This leads to an increase in biological oxygen demand. Fertilisers introduced to promote primary production mostly contain high levels of phosphorous and nitrogen which are the principal elements in eutrophication of aquaculture wastewater.

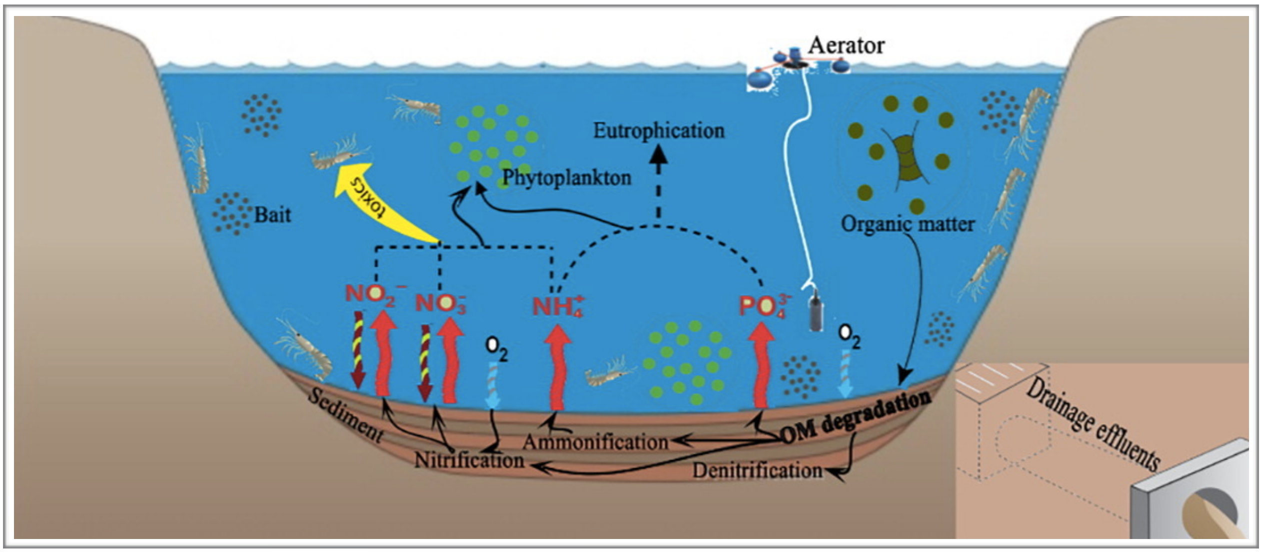


Figure 41: Aquaculture pond effluent as a major contributor of eutrophication (Yang et al., 2017)

ii. **Sulphides**: Hydrogen sulphide (H2S) can be generated in shrimp ponds when organic matter decomposes as a result of dead vegetation, uneaten feed, micro algae and cyanobacteria. This can result in accumulation of high sulphide in the sediment and result in high concentrations of hydrogen sulphide in the pore water (Frederiksen et al., 2007) which can threaten benthic flora and fauna. High decomposition of organic matter leads to an increase of pore water pools of nutrients releasing phosphate and ammonium to the water column (Holmer et al., 2008). Where an increase in microbial production of sulphide in the sediments in close proximity to net cages, sulphide invasion into seagrass tissue has been shown to be a key factor in sudden seagrass die off and decline events (Carlson et al., 1994; Seddon et al.,2000)

6.6 Mangroves

Mangrove forests provide a range of environmental and social ecosystem services, whilst supporting livelihoods, biodiversity conservation and human welfare (Figure 42). They provide a cost effective solution against natural threats including storm surges, coastal erosion and tsunamis and assist with the mitigation of climate change through its high carbon storage potential.

Additionally, the conservation of mangrove ecosystems contribute to UN Sustainable Development Goals and other international targets through sequestration of green house gases as 'blue carbon'. This can further assist with fulfilling commitments laid out by International Treaties including the UNFCCC Paris Agreement and Convention on Biodiversity Aichi Targets (IUCN, 2020).

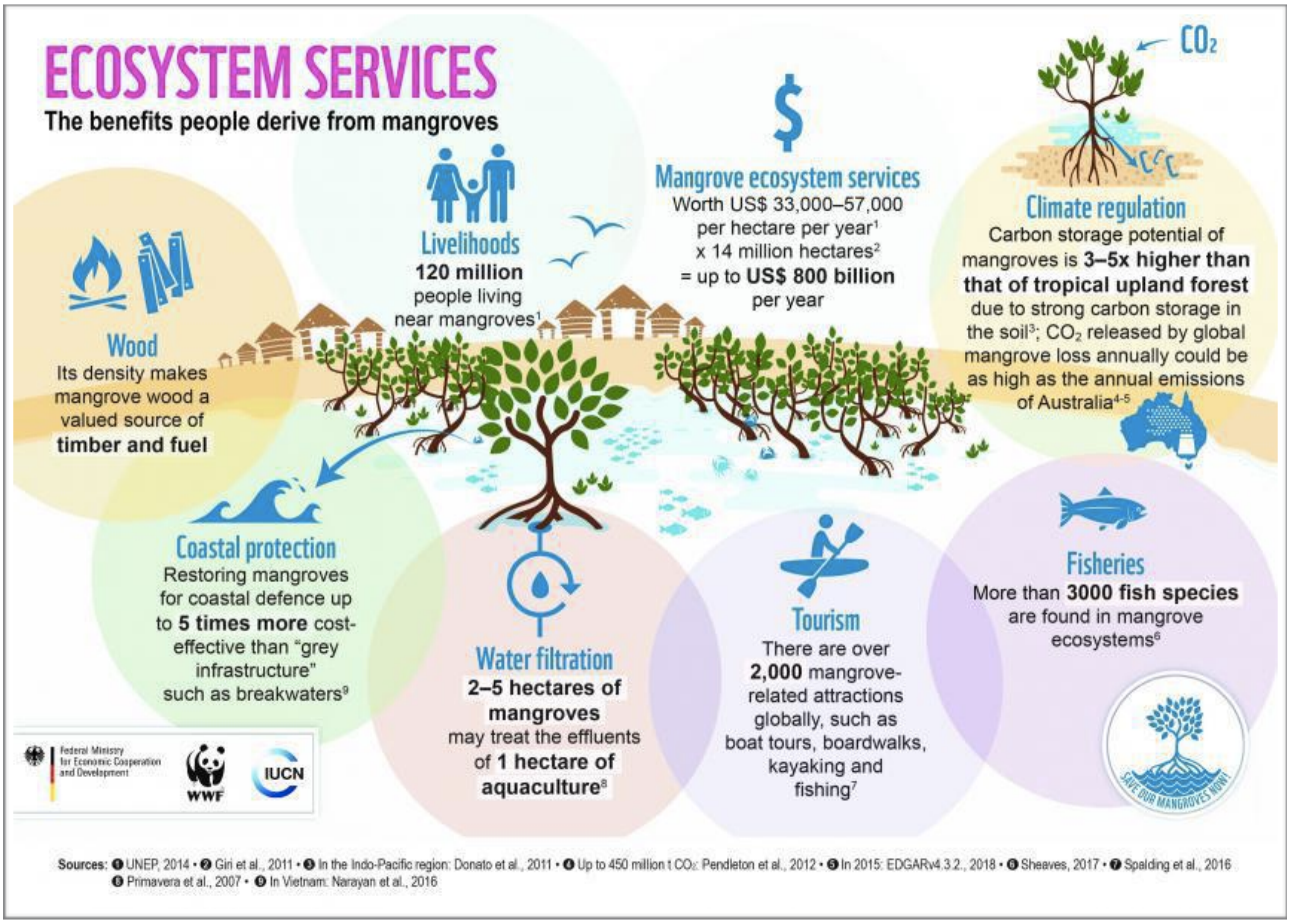


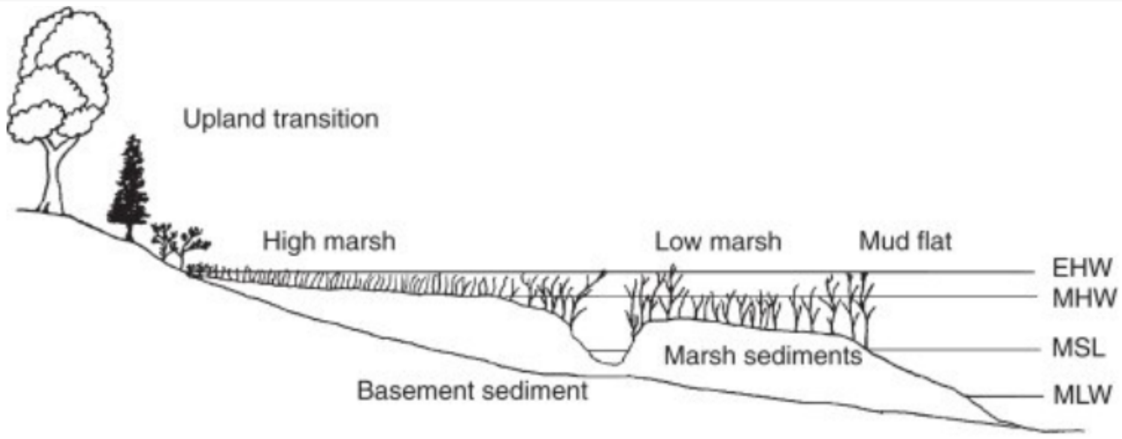
Figure 42: Ecosystem services - Mangrove vegetation (IUCN, 2018)

The Vidataltivu Reserve represents a complex coastal ecosystem and is protected due to its mangrove vegetation and biodiversity values. Scientific surveys conducted in the area showed 7 species of mangrove: *Avicennia marina* (70.15%), *Rhizophora mucronata,* (20.99%), *Ceriops tagal* (6.57%), *Bruguiera cylindrica* (0.52%), *Lumnitzera racemosa* (0.66%), *Pemphis acidul*a (0.79%) and *Excoecaria agallocha* (0.32%). Stand densities of mangroves, in the site were recorded as 1,602±154 trees/ha, 2,678±202 stems/ha, 64,852±19,816 seedlings/ha and 337±86 saplings/ha (Cooray et al., 2018). The class distribution of the stem diameters highlighted an exponential distribution which suggested the Vidataltivu Reserve is an uneven aged forest and characteristic of continuous regeneration. The complex and fragile mangrove ecosystem is subject to a number of anthropogenic pressures including select harvesting of mangroves. Extraction of mangrove wood has been recorded in Thondaimanaru and mangroves in the Vidataltivu Lagon are being cut down for use in brush piles for the aggregation of squid and fish by inhabitants from Pallimunai on Mannar Island.

Figure 43: *Avicennia marina*: Dominant mangrove species, Vidataltivu (GOM Conservation Team, 2011)

6.7 Salt Marshes and Tidal Flats

Salt marshes and tidal flats, commonly referred to as mud flats are ecosystems, formed as a result of deposited soft sediment by ocean tides or river run off, and located in the inter-tidal zone (Figure 44). They can be submerged in periods of high tide and exposed to air during low tides. Salt marshes have higher salt tolerant halophytic plants whereas Tidal flats are mostly vegetated by algae. Although subject to erosion, roots of plants in salt marshes assist with keeping sediments intact, mitigating impacts (IUCN, 2022).



EHW = extreme high water, MHW = mean high water, MSL = mean sea level, MLW = mean low water

Figure 43: Zonation from a Mud flat to a Salt marsh (Teel, 2001)

Blue green photosynthetic bacteria found in these coastal environments play a critical role in the food web and are highly productive organisms. Other species found on tidal flares include flatworms, roundworms, tiny crustaceans, and benthic organisms including shellfish, crabs and mussels. Shore birds and wading birds can be found on the surface. It is estimated that 27,520 ha of salt marsh is found across Sri Lanka, with the largest strip found between the Vankalai and Mantai coastal belts, in the Manner District. There has been 56 species of vegetation recorded within these coastal ecosystems (IUCN, 2022).

The Vankalai Sanctuary in Mannar was declared a sanctuary by the Department of Wildlife Sri Lanka in 2008 and a RAMSAR wetland of international importance in 2010. This site covers an area of 4,839 hectares and consists of several ecosystems which range from arid zone thorn scrubland, arid zone pastures and maritime grasslands, sand dunes, mangroves, salt marshes, lagoons, tidal flats, sea-grass beds and shallow marine areas. The sanctuary supports high species diversity and also sustains the livelihoods of fisheries-dependent communities in the area (RAMSAR, 2010).

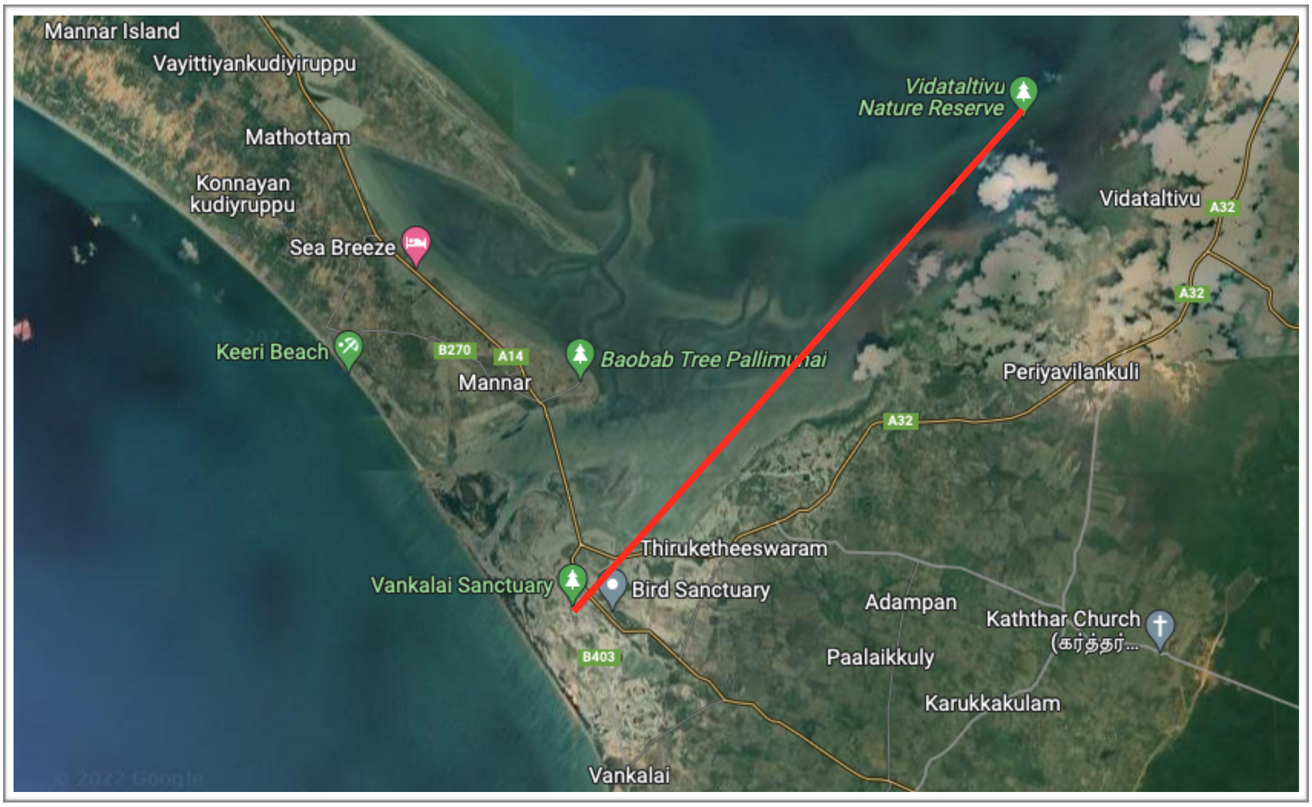


Figure 45: Proximity of Vankalai Sanctuary to Vidataltivu Reserve (Google Maps, 2022)

The islands of Kalliaditivu and Puliyantivu are located within the Vankalai Bird Sanctuary. Salt marshes, tidal flats and mangroves are the dominant ecosystems observed in Kalliaditivu Island. Similarly, salt marshes, mangroves, mixed evergreen forests are found in Puliyantivu Island. The sites provide important habitat to a large diversity of species (Figure 46 & 47) and feeding grounds for several migratory birds including the greater flamingo *(Phoenicopterus roseus)* and black-headed gull *(Larus ridibundus).*

Species	Total	Description
Flora Species	14	**Dominant plants include:** *Suaeda maritima* *Salicornia brachiata* *Avicennia marina* *Rhizophora mucronata*
Faunal Species	120	5 species of dragonflies 4 species of butterflies 20 species of reptiles 81 species of birds 10 species of mammals **Notable terrestrial species:** 3 species of endemic snakes: Flowery wolf snake *(Lycodon osmanhilli)*, Checkered keelback (*Xenochropis asperrimus and Xenochrophis cf. piscator*). **5 other species (Listed Nationally Vulnerable):** Wart snake *(Acrochordus granulates)*, Greater painted snipe *(Rostratula benghalensis)*, Kentish plover *(Charadrius alexandrines)*, Small pratinocole *(Glareola lacteal)* and the Indian pipistrel *(Pipistrellus coromandra)* **3 species (Listed Nationally Near Threatened):** Paddy field parasol *(Neurothemis intermedia)*, Eurasian collared dove *(Streptopelia decaocto)* and black-crowned night heron *(Nycticorax nycticorax)* **2 species (Listed Data Deficient):** Rainbow mud snake *(Enhydris enhydris)* and Bombay gulf sea snake *(Hydrophis mammilaris)*

Figure 46: Record of Species: Kalliaditivu (IUCN, 2022)

Species	Total	Description
Flora Species	27	**Dominant plants observed in salt marshes:** Suaeda maritima Suaeda monoica
Faunal Species	120	2 species of dragonflies 10 species of butterflies 1 species of amphibian 26 species of reptile 65 species of birds 8 species of mammals **3 endemic species:** Common lankaskink *(Lankascincus fallax)*, Checkered keelback *(Xenochrophis asperrimus)* and Checkered keelback *(Xenochrophis cf. piscator)* **1 species (Listed Nationally Endangered):** Oriental pratincole *(Glareola maldivarum)* **2 species (Listed Nationally Vulnerable):** Kentish plover *(Charadrius alexandrinus)* and Small pratincole *(Glareola lactea)* **2 species (Listed Nationally Near Threatened)** Drongo cuckoo *(Surniculus lugubris)* and Eurasian collared dove *(Streptopelia decaocto)* **1 species (Listed Data Deficient)** Collared sea snake (Hydrophis stricticollis)

Figure 47: Record of Species: Puliyantivu (IUCN, 2022)

Figure 48: Migratory Greater flamingo *(Phoenicopterus roseus), Vankalai* (Mithun Senanayake)

Figure 49: Migratory Bar-tailed godwits *(Limosa lapponica), Vankalai* (Sriyanie Miththapala)

7.1 History and Context

The village of Vidataltivu dates back over 400 years, as inscribed on a stone plaque in Saint James Church. Historical texts outline that the fishermen from Yalpanam, Allaipip and Navali settled in the area after pursuing fishing activities and hence developed as a Catholic fishing village. Its name was derived from 'Vidathal' trees, also referred to as 'thorny trees', found on its shores.

Year	Key Events
2010 - 2015	People returned home and focused on rebuilding their lives and houses with the aid of the Indian Housing Scheme and Arabian Housing Scheme
2009 - 2010	Final war period : Families were displaced due to the ongoing civil war and were allowed to return to Vidataltivu in December 2010.
2008 - 2009	Norway Peace Talk Period: 210 Christian Families and 12 Muslim Families returned to live in the village and resume fishing activities.
1999 - 2008	All families forced to leave the village due to ethnic conflict (taken to refugee camps in India and Sri Lanka). Land mines spread across the village.
1983 -1999	Initial period of ethnic conflict. Fishing and other livelihoods were disturbed. Over 500 Muslim families left the village.
1972 - 1983	Central Government supports fishing operations. Vidataltivu FCS was one of the societies, strengthened. Fishermen received loans to extend fleets and buy fishing gear and engines. Fish catch sold in Colombo. Fisheries thrived and village infrastructure improved. In 1983, a training hall with a capacity of 60 people was constructed.
1950 - 1970	Traditional fishing boundary extended beyond Sali (coral reef area) to Moornampitty. A Fishing Cooperative Society was started with the aim of direct marketing fish and sea cucumber FCS went dormant due to undercutting by Sea Cucumber Agents who wanted monopoly of the Sea Cucumber trade Fish catch increased but did not have a market. The volume was so great and it was not possible to locally dry the catch and eventually had to burn it

Figure 50: Timeline of Key Events in Vidataltivu
Source: Hoon et al., 2015

7.2 Socio-economic drivers: Population & Primary Industry

The village of Vidataltivu is administered under four Niladhari divisions. The table below shows official data from the Nildhari office on population by sex, and household. A total of 936 households are registered according to records, however this relates to residents prior to the civil conflict in the northern part of Sri Lanka (BOBLME, 2015).

Name of GN division	No of households	Sex wise population		Total population
		Males	Female	
Vidathaltivu West	156	286	294	580
Vidathaltivu North	124	198	235	433
Vidathaltivu Center	341	694	739	1433
Vidathaltivu East	315	601	636	1237
Total	**936**	**1779**	**1904**	**3683**

Figure 51: Population details by Gram Niladhari District; Source: BOBLME, 2015

Fishing is the primary occupational activity carried out along the coastline of Mannar, with 90% of villagers involved in lagoon fisheries only. Other seasonal fisheries related occupations were also recorded including sea cucumber fishing, shank fishing, crab fishing, prawn fishing, fish drying, set net fishing, agriculture (rice) farming, and carpentry.

Small scale fishing predominantly takes places within customary boundaries including 1,300 ha of lagoon and adjoining reef areas and shallow water. Fishing takes place through the year and varies in accordance with the seasonal availability of species. Wind patterns can restrict the use of small scale craft between August and October, at which time most fisherman swap to other on shore employment opportunities including agriculture (BOBLME, 2015). Given the diversity of species and ecosystems in the lagoon and near shore marine environment, exploitation of fisheries can occur during peak periods. Sea lotus, sea cucumber and sea shells provide an alternate source of income when fisheries resources are unavailable.

Indigenous knowledge, also referred to as traditional knowledge is based on accumulated observations, philosophies and methodologies which have been passed down through generations . It forms part of customary legal systems, spiritual beliefs and cultural values (Berkes et al., 2000). The Aichi Target 18 states *'By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels'.*

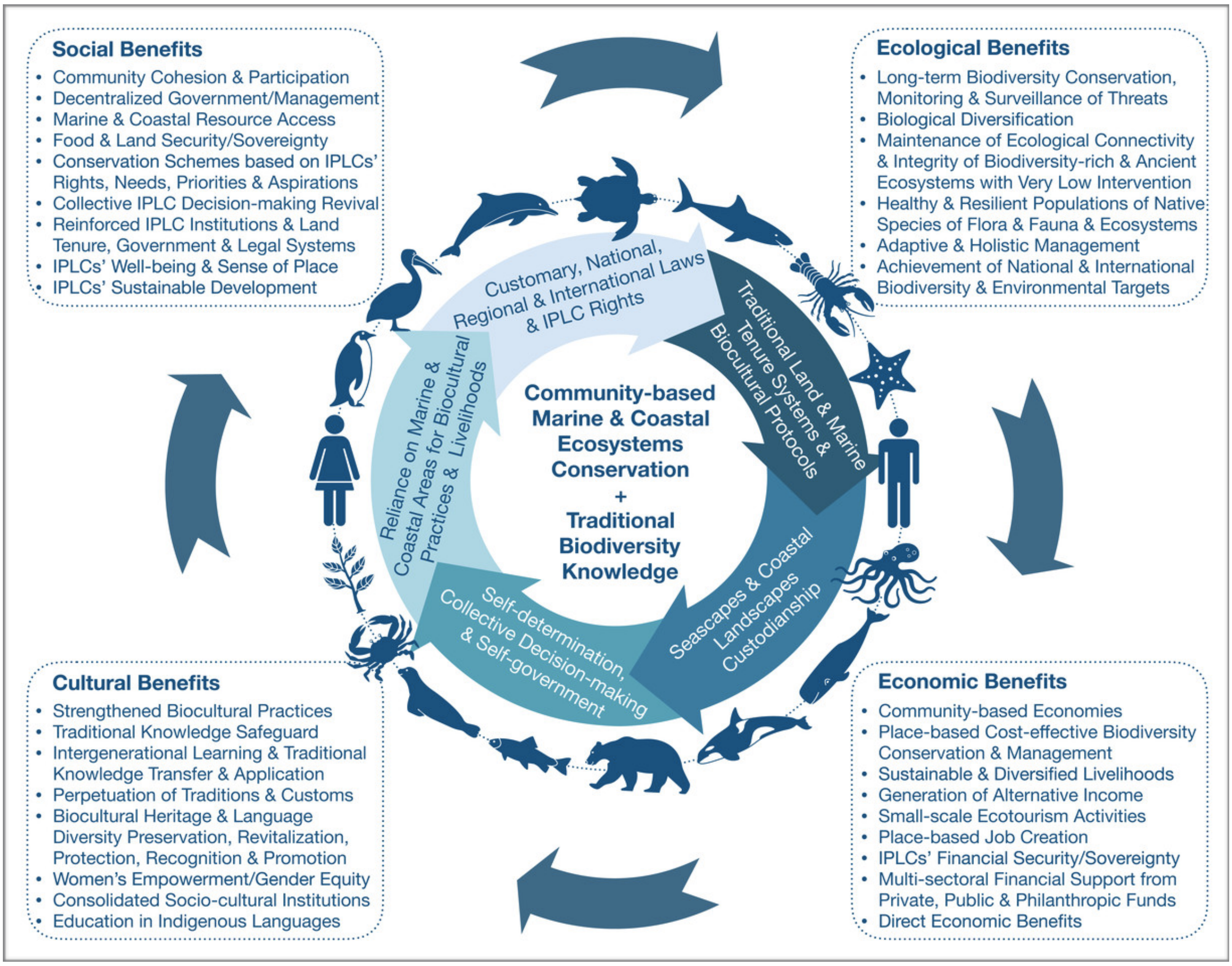


Figure 52: Benefits of incorporating Indigenous Knowledge in Conservation (Fajardo et al., 2021)

7.3 Traditional Knowledge

The fishing community in Vidataltivu have rich traditional knowledge of the marine ecosystems and fisheries resources in the local area based on their experiences and those of their prior generations. In line with indigenous customary boundaries, they have divided Vidataltivu into 4 main eco regions:

- Mangrove region (1 fathom)
- Sea grass bed (1.5 fathoms)
- Sandy region (2 fathoms)
- Coral areas (3.5 fathoms)

Individuals from the local fishing communities were clearly able to distinguish the location of channels, fishing grounds, seagrass beds and conch shells. Additionally they reference a detailed sea resource map, verified through diving excursions, which document their detailed knowledge of the composition and configuration of the sea bed. Based on current observations, they agreed that mangroves were relatively well managed apart from a few logging incidents.

The community use their extensive knowledge of the stars, winds, tides, temperature and moon phases to aid their fishing practices. Local fisherman may use techniques including skin diving for sea cucumber, sea lotus, seashells and lobsters. The villagers follow a 'catch based system' in lieu of a wage exchange system. Operational expenses including food and diesel are deducted, prior to sharing their catch (Hoon et al., 2015).

8 Outlook for Aquaculture

Aquaculture is one of the fastest growing industries, globally. The majority of development occurred over the last 50 years and in recent decades and environmental degradation, stemming from unsustainable aquaculture practices has been at the centre of many environmental debates and is evolving into a growing concern. The Brundtland Commission, defined sustainable development as "use of the environment and resources that meets the needs of the present without compromising the ability of future generations to meet their own needs"

In a Sri Lankan context, NAQDA in collaboration with the Ministry of Fisheries of the North Western Province has introduced a set of Better Management Practices (BMPs) relating to pond preparation and filling, seed selection and stocking, health management and water quality management (Weerakoon, 2007). The BMPs are based on numerous empirical observations, provincial, national and international regulations and guidelines.

Compulsory gazetted regulations have been introduced including 2 months fallow period, drying and cleaning the pond bottom before stocking, PCR and PL quality test, removal of sediment before stocking, use of bird nets and the use of lime and dolomite after cleaning the pond bottom (NAQDA, 2011; Weerakoon, 2007). Figure 53 outlines mandatory, facilitated and outlined BMPs in the North Western Provinces.

Mandatory BMPs	Facilitated BMPs	Voluntary BMPs
Following two months fallow period	Usage of stock tank	Ploughing and harrowing the pond
Drying and cleaning the pond bottoms	Fertilizer application to pond water	Dolomite and lime application to pond water
Removal of sediments from culture ponds	Aerate the pond water from stocking date of PLs	Water exchange during crop cycle
Use of lime and dolomite to pond bottom	Vitamins, minerals application	Separate equipment for ponds
Use of birds net	Test for pH, salinity, alkalinity	Other precautions for crabs
PCR and PL quality test (Before stocking)	Peripheral fence for crabs Use of probiotics	

Figure 53: Better Management Practices, North Western Province (NAQDA, 2011)

Key research priorities and proposed innovative solutions for aquaculture practices in Sri Lanka, have been identified and outlined, which may contribute to reaching sustainable outcomes in the industry (Jayasinghe et al. 2012).

Managing health of shrimp culture

- Correct identification of pathogens
- Identification of carriers of virus species (incl. novel viruses)
- Investigation of measures to minimise the risks of disease outbreaks
- Rapid diagnostic methodologies
- Strict biosecurity and quarantine processes to prevent disease transmission
- Additional research on viral outbreaks locally and globally

Physical considerations

- Processes to improve the efficiency of physical treatments
- Improved engineering designs for the construction of treatment / sedimentation tanks
- Effective storage times and appropriate mesh sizes for filtering water

Chemical considerations

- Determining effective doses of chemicals for different pathogens
- Measure to minimise impacts of chemical treatment on the marine and terrestrial environment (negative consequences on species, plankton collapses)
- Measures to improve productivity in ponds, post chemical treatment
- Organic alternatives to chemical treatments and antibiotics to minimise impacts on ecosystems and human consumption

Biological considerations

- Identify and assessment organisms for biological treatment under varying degrees of physio-chemical conditions
- Investigate effective stocking densities and appropriate ratios of treatment in culture areas

Managing sediment runoff and problem soils

- Identify, map and assess problem soils for shrimp culture
- Measurements of sediment quality, sedimentation rates, identification of measures to improve sediment condition and control runoff

Determination of carrying capacity of the environment

- Comprehensive assessment of carrying capacity in aquaculture expansion, farm density, stock density, stocking size, culture cycle and water quality
- Improvement of on farm management procedures
- Pollutant loadings
- Trends in water quality changes

Development of legal and policy frameworks

- Coastal zone management planning
- Develop standards for effluent quantities
- Environmental protection licence procedures
- Improve Environmental Impact Assessment in line with international guidelines
- Penalties / fines where protocol is not followed harmful practices are incorporated

The above considerations in the aquaculture industry, are exacerbated by the complexity and uncertainties of climate change, which can negatively impact socio ecological systems in aquaculture operations. Policy makers, natural resource managers, investors, farmers and local communities need to take collective action and, be able to adapt to these rapid and unprecedented changes while responding with innovative and sustainable solutions to harness opportunities and mitigate ongoing challenges faced in the industry.

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