Performance Report -2021

National Aquatic Resources Research and Development Agency

Crow Island

Colombo 15

Contents

1. Inland Aquatic Resources and Aquaculture Division

Project No	Project/Activities	Responsible by	Initial allocation (Rs.Mn)	Revised budget (Rs.Mn)
1.1	Application of biofloc technology (BFT) to tilapia fingerling production using different carbon sources.	E.D.M. Epasinghe	1.831	1.666
1.2	Improving mangrove crab (*Scylla serrata*) aquaculture through better feed and health management with special reference to popularize the use of formulated feed for crab farming.	M. G. I. S. Parakrama, A. D.W. R. Rajapakshe, P. P. M. Heenatigala	0.921	0.849
1.3	Formulation of Artificial Feed for sandfish;*Holothuriascabra* Grow-out Farming in Sea Pen in Northern Province in Sri Lanka	P. Mythilly, A.M. C. Pradeep, C.B.Medagedara, E.D.M.P. Epasinghe, P. A. D. Ajith Kumara	1.8	1.017
1.4	Development of culture techniques and identification of culture grounds for pearl oyster resources in North & East coasts regard to regain the pearl industry in Sri Lanka.	Pradeep Chathuranga C.B Medagedara	1.0	1.2
1.5	Preliminary study on cultivate local *Aretemiaspp* as a collaborative project with PalatupanaSaltern, Lanka Salt Limited, Hambantota.	E.D. M. Epasinghe U.A. N. W. Ubeysinghe	1.89	0.892
1.6	Development of Breeding Technology on High Value exotic Ornamental Fish	N.P.Harshani Deepakumari	2.5	2.7
1.7	Science & Technology application for the improvement, quality enhances to boost the export oriented endemic ornamental fish industry of Sri Lanka and conservation of rare fish species.	R. R. A. Ramani Shirantha	2.0	1.387
1.8	Science & Technology application for the improvement, quality enhances to boost the export oriented endemic ornamental fish industry of Sri Lanka and conservation of rare fish species.	D.M.S.Sugeeshwari, K.K.T.Nuwansi	1.2	0.726
1.9	Study the effect of different hydroponic culture techniques for the growth performances of aquatic plants in aquaponic recirculation systems	K.K.T.Nuwansi	1.0	1.088
1.10	Development of culture techniques and study the growth performances of *Tubifex* worm, in different organic media	M. Epasinghe P.Mythily	0.5	0.70
1.11	Study on survival of *Macrobrachiumrosenbergii* stock in culture based fisheries in Bandagiriya and Ridiyagama tanks in Hambantota district, Sri Lanka.	M. Gammanpila, W. Rajapakshe, N. B. P.Punyadewa, K. W. R. R. Amaraweera Representative from NAQDA / Hambantota	1.2	1.030

1.12	Investigation of Grass Carp (*CtenopharyngodonIdella)* breeding procedure to find out the reason for low hatchability.	A.M.A.N. AdhikariWasanthaRajapakshe	0.855	0.636
1.13	Estimation of carrying capacity of perennial reservoirs for net cage culture of fry to fingerling stage of commonly cultured food fish species in Sri Lanka.	A.M.A.N.Adikari J.S.Jayanatha R.Srikrishnan	2.0	1.270
1.14	Promoting community-based oyster culture in Mannar area.	A.S.L.E. Corea C. B Medagedara	1.94	1.994
1.15	Enhancements of community base seaweed culture-through the appropriate seed bank and assessment of their ecological important (Carbon sequestration and habitats improvement).	J. S. Jayanatha	2.58	1.847
1.16	Disease monitoring, prevention and monitoring water quality conditions for health management in shrimp aquaculture industry in Sri Lanka.	P.P.M. HeenatigalaLakshikaJayasekara, Pradeep Chathuranga	4.0	4.20
1.17	Surveillance of disease prevalence in aquaculture with special reference to ornamental fish, Mud Crab (*Scylla serrata*) and Giant Fresh water Prawn (*Macrobrachiumrosenbergii*) in selected areas of Sri Lanka.	A.D.W.R.Rajapakshe	1.765	1.333
1.18	Establishment of Epidemiology unit at National Aquatic Resources Research and Development Agency (NARA) and Establishment of a PCR laboratory facility for shrimp aquaculture research at Pambala and shrimp disease monitoring unit at Baththuluoya, Chilaw.	P.P.M. Heenatigala, WasanthaRajapaksha, B. M. L. P.Jayasekara	0.7	0.518

1.1 Application of biofloc technology (BFT) to tilapia fingerling production using different carbon sources.

Responsible Officer : E.D.M. Epasinghe

Budget Allocation (Rs) : 1.831M

Revised Budget (Rs.) : 1.666 M

Introduction:

Improving productivity is one of the main priorities in the development of aquaculture and in particular tilapia farming. The intensification of production systems is seen as the easiest way to reach this goal. Fish farming with BFT has some advantages over traditional fish farming, among which are that it requires little or no water exchange, has less environmental impact, includes the recycling of nitrogen compounds, the synthesis of bacterial biomass and the supply of a highly nutritious complementary food (Lima, *et al.*, 2018).

BFT makes it possible to minimize water exchange and water usage in aquaculture systems through maintaining adequate water quality within the culture unit, while producing low cost bioflocs rich in protein, which can feed for aquatic organisms and decrease of water treatment expenses (Crab, *et al.*, 2012).

In previous two experiments were carried out to find out the feasibility of growing tilapia in BFT. Initially in 2019, first experiment with tilapia was conducted to find out the suitable carbon sources for growing tilapia fingerling to advanced fingerling stage. Thereafter in 2020, as per the collaborative studies done with the NAQDA, the second experiment was steered to increase the stoking density of fingerlings using mostly performed carbon sources in the previous experiment. It revealed that the normal stocking density (40 fingerlings/ m^3) could be increased by 50 %. In this experiment, same strategy will be implemented in order to evaluate its feasibility in the indoor condition.

Objective:

Explore the possible contribution of biofloc technology application to tilapia fingerling production in Sri Lanka

Specific Objectives:

Evaluation of most suitable carbon source/s for maintaining suitable water quality for tilapia fingerling culture.

To evaluate most suitable carbon source/s which gives good performance in tilapia fingerling culture

Evaluation of effect of BFT on health status of fish.

Materials and methods:

Arrangement of experiment tanks and fish stocking.

The circular 21 fiberglass reinforced plastic (FRP) tanks were arranged in aquaculture research Centre (ARC) giving indoor condition and total culture period was eight weeks. FRP tanks with a capacity of 800 L weree used and constant aeration system were maintained for 24 hours.

Tilapia fry were acclimatized for 1 week prior to the experiment. In the tanks with the bioflocs, water was not be exchanged during the experiment period. However, the water was added to maintain the water capacity due to evaporation loss. Aeration was provided throughout the experiment. Commercial feed (Prima tropical fish feed, contained crude protein = 42%, crude protein = 10%, crude fibre = 4%) was provided daily in each tank at 5% of the total body mass. Daily feed rations were split into two equal amounts and given to all the tanks two times a day at 1000 am and 1500 pm.

ii. Treatments

Biofloc is formed using wheat flour (WF), molasses and 50:50 mixtures of WFMOL by maintaining a C/N ratio at 20.

iii. Water quality parameters and biometric indices

Water quality parameters and biometric parameters were measured as per the table below.

Water quality evaluation were done based on T, pH, DO, TAN, NO_2^-, NO_3^-, Volume of water used (to change water). Growth performance of tilapia were examined using Body weight, body length and survival rate. Floc Volume (FV), TSS, Morphology of floc and Proximate composition of floc were used to evaluate floc quality.

Results:

The results of the study revealed that MOL, WF and WEMOL showed higher final body weight compared to control also MOL, WF and WFMOL showed higher final body length compared to control.MOL, WF and WFMOL showed higher weight gain compared to control.MOL, WF and WFMOL showed higher specific growth rate compared to control but Feed conversion ratio of different treatments were no significant difference among treatments (p>0.05).WF showed highest mortality and lowest survival rate compared to other treatments.

Table 1: Water quality parameters among different carbon sources

	Carbon source				
Parameters	CON	MOL	WF	WFMOL	SE
pH	6.17^a	6.77^c	6.40^b	6.23^a	0.04
DO (mg L^{-1})	8.45^a	7.85^b	8.03^c	7.78^b	0.04
Temperature ^{0}C	27.11	27.14	27.16	27.12	0.02

TAN (mg L^{-1})	1.72^a	0.45^c	2.91^b	1.31^a	0.18
NO^-_2 (mg L^{-1})	0.51	0.44	0.61	0.78	0.15
FV (mL L^{-1})	0.10^a	7.44^b	0.36^a	5.74^b	1.5
TSS (mg/L)	18.12^a	143.26^b	66.00^{ab}	175.26^b	38

Growth Performances among different fish densities

40 m^{-3} and 50 m^{-3} fish density showed higher final body weight compared to 60 m^{-3} and 70 m^{-3}densities.

There was no significant difference among different fish densities ($p>0.05$). Final body length, Specific growth rate and weight gain were not significant difference among different fish densities ($p>0.05$). Survival and mortality rates also were not significant difference among different fish densities ($p>0.05$)

Conclusions:

Addition of molasses with 40- 50 m^{-3} fish densities, positively effect on growth parameters, maintaining better water quality, higher survival rates in the GIFT tilapia

Constrains:

Due to the COVID 19 lockdown situation, evaluation of effect of BFT on health status of fish couldn't be completed.

Progress:

Financial:57.5% Physical: 77%

1.2 Improving mangrove crab (Scylla serrata) aquaculture through better feed and health management with special reference to popularize the use of formulated feed for crab farming

Officer/s responsible	: M. G. I. S. Parakrama, A. D.W. R. Rajapakshe, P.P. M. Heenatigala
BudgetAllocation(Rs.)	: 0.921M
Revised Budget (Rs.)	: 0.849 M

Introduction:

Scylla serrata, is a very popular crab species because of its size, meat quality, high price and export potential. Natural stock of the crabs in the country is decreasing drastically as the fishing increasing due to the high demand in the export/ local market. Also, people use wild collected water crabs (molted crabs) for fattening purposes and getting quick income instead of culturing farm produced crablets.

However, recently emerged crab hatcheries are now functioning and the availability of seed is no more a problem, appropriate formulated feed for the culture practice are the most important issue for the development and propagation of crab culture industry in Sri Lanka. Further, farming of hatchery produced crabs can be a good solution for the proper management of natural stocks in Sri Lanka. As the use of trash fish is the traditional method for feeding crabs up to harvesting stage and the availability of trash fish being a limiting factor due to its seasonal changes, an economically profitable nutritious feed is a timely need for the enhancement/ development of the new field. As the imported manufactured feed cost is the highest operating cost in semi-intensive aquaculture practices, the lower profit being the limitation to the development to the industry. Accordingly, introduction of economically feasible, good quality nutritious feed for crab culture is an urgent option to enhance the crab production in Sri Lanka. Also, the information and precaution measures of the possible disease problems in the crab culture practices will be a timely need for the better management of the system.

Objective/s:

To introduce a quality feed for crab culture in mud ponds

To identify the disease problems in crab culture systems

Activities carried out during the period

Three feed formulae were developed, prepared and proximate analysis was done at laboratory level. Water stability test done for observing the life time of the feeds in water without changing the quality and leaching of nutrients in to water.

Three Crab cages completed for stocking 24 crabs in each cage, in single cell. (Each cage is with 24 small parts, each crab can accommodate in each cell). Cages are done at the site at Negombo. Trial started as for checking the possibility of culturing them in the lagoon water. (As still culture crabs are having severe mortalities in the lagoon, so farmers are not culturing crabs from more than 2 years in the lagoon). However, there were several trials started and collapsed due to lower salinity in the lagoon. During year 2021, there were huge rainy seasons throughout the year and the salinity in the lagoon remained very low for a long duration.

Feed formulation, price and protein analysis of experimental feeds prepared

Ingredient	Feed 1	Feed 2	Feed 3
Fish meal	25	10	-
Soyabean meal	10	15	20
Shrimp meal	22	17	12
Meat n bone meal	-	15	20
Wheat flour	10	10	10
Rice polish	23	23	28
Fish oil	7	7	7
Vit/ min	3	3	3
Protein %	41%	35.7%	31.2
Price/kg	156.25	151.75	143.75

Constrains:

Covid situation affect the research and couldnot engage in the research properly. Dissemination of knowledge to people was done when they were in need. Booklets preparedrelated to crab culture and many other related activities.

Progress:

Financial: 25.6%

Physical: 58%

1.3 Formulation of artificial feed for sand fish;Holothuria scabra grow-out farming in sea pen in northern province in Sri Lanka

Officer/s responsible : P.A.D.Ajith Kumara, P. Mythilly, A.M. C. Pradeep, C.B. Medagedara,

Budget Allocation (Rs.) : 1.8 M

Revised Budget (Rs.) : 1.017 M

Introduction

Sandfish (*Holothuria scabra*) are common in shallow tropical waters and usually find less than 20 m deep water. Their favourable habitats are seagrass beds with muddy substrata. Even though, huge demand and high market value for *H. Scabra* when increased the number and scale of its culture, still both nursery culture as well as grow-out culture faces challenges in low survival and growth rates of cultured juveniles to reach marketable size (> 320g). Sea cucumber culture practice solely depends on naturally available feeds on sea bed, and the continuous culture leads growth retardation by nutrition depletion after several years of farming at same sites. These usually appear to be places that are very heavily farming, usually using "on bottom" methods that have been subjected to considerable direct, secondary, collateral or indirect damage. Such places may recover after a few fallow years but it is not viable due to unavailability of back up sites for continuation of culture practices.Therefore, sediment enrichment and introduces formulated feeds will aids in improved growth and survival rate of sea cucumbers at a infertile substrate.

Specific Objective/s:

Formulation of cost effective quality feed

Exploratory effect of micro-habitat conditions and detailed mapping of suitable areas for sea cucumber farming

Monitoring of commercial sea cucumber farming

Dissemination of technical *know-how* to stake-holders through training and technical assistance

Activities proposed to be conducted during the period:

Facilities construction, maintenance & rehabilitation (Kalpitiya and Jaffna)

Feed development (ingredient collection, formulation, feed preparation, proximate analysis)

Experimental culture trials (field trials in Jaffna lagoon, indoor hatchery trials in Kalpitiya)

Monitoring of selected pen enclosure programmes with habitat improvement

Monitoring of commercial farming practices

Detailed soil/water sample analysis

Suitable site selection, zonation and demarcation

Awareness and training programmes

Report writing, publications

Activities carried out during the period:

Facilities development and Logistic arrangements

Two files were prepared and submitted for procurement process at the beginning of the year one each for chemical and feed ingredients purchasing respectively but only the latter was obtained. However, as unavailability of some feed ingredients with the suppliers these were purchased from open market.

Nine net roles (15m*1.2m) weaved with attaching 1mm fine meshed net in order to avoid animal escape when facilities (sea pen) are constructing (**Fig.1**). Fiber tanks at NARA RRC Kalpitiya were partitioned and conditioned to carry out indoor feeding trials (**Fig.2**). Juveniles purchasing work arranged from hatchery at Ariyalei, Jaffna.

Fig.1. Weaved net with small meshed nets

Fig.2. Partitioned fiber tanks at RRC Kalpitiya feed trials

Feed development

Feed ingredients were obtained after completion of procurement procedure. Then ingredients were stored properly in warehouse ensuring optimum protection from pests. They were analyzed for find proximate compositions. Two feed formulae were developed accordingly. Proximate test also conducted for two developed feeds. Protein compositions were 30% and 28% respectively. As per the instructions given by State Secretary on 31.08.2021 during project discussion meeting the developed feed formulae would be changed being replaced animal protein from plant protein sources. According to that seaweed or sea grasses will have to use replace fish meal. Feed formulae adjusted accordingly but either process of new feed ingredients obtaining or formulation didn't attend.

Experimental culture trials

It was proposed that to conduct in house culture trials at hatchery premises of NARA in Kalpitiya while field trials at sea cucumber open water farm in Jaffna. However, as country was locked down time to time due to Covid-19 situation field trials were unable to conduct. Travel restrictions, not enough time for complete culture cycle as well as expected salinity variations due to upcoming monsoonal period simultaneously prevented to initiate culture trials.

4 & 5. Conducting and monitoring of commercial farming practices and a selected pen enclosure culture programme with habitat improvement

Seven commercial farms visited and monitored during the field visit in February, 2021. Issues identified related to growth retardation of some commercial farming. The most probable reason is lack of natural feeds because the organic matters contents in soil samples were 0.05- 1.1%. And these ranges are far below to the acceptable level for sea cucumber farming. Routine monitoring work has to be done throughout the culture period to get firm conclusions. However, as field experiment didn't start, the study of habitat improvement and its impact on growth, survival and behavioral changes of sea cucumber juveniles also not studied.

Detailed soil sample analysis

A one week rapid assessment programme was carried out at Jaffna lagoon in February, 2021 to study the site suitability for culture of different cultivable species. Five zones were identified as possible areas during the desktop study through the analysis of primary data obtained by NARA since 2009. Twenty four numbers of sediment samples, 22 no's of water samples were analyzed in the laboratory. Meanwhile 60 no's of *in situ* readings relevant to water quality and oceanographic parameters, visual and under water visual observations particular to sea bottom and off bottom conditions were recorded. Micro habitat conditions in relation to particulate organic matters and grain sizes that are subject to sea cucumber farming were evaluated accordingly. These results were in cooperated for the site selection programme described in following chapter.

Site selection, Zonation and Demarcation:

Five special areas in Jaffna lagoon were selected initially for this preliminary survey after doing desktop study. The primary data collected by NARA since 2009 and other studies were used for this analysis. The field survey covered 3000 hectares of Jaffna lagoon and open sea area. Physical, oceanographical, biological & ecological samples were tested /collected during the survey carried out in February, 2021 as described under section 6. Ten numbers of zonal maps prepared for sea cucumber, sea bass and seaweed mariculture there accordingly. Suitable areas of 1900 ha, 2120 ha and 1050 ha for sea cucumbers, sea bass and seaweeds were identified respectively. These zones were mapped and documented with GPS coordinates (**Fig. 3**).

Identified area of sea cucumber farming further plotted in to 100-acre blocks (19 No's). One model farm, total extent is 100 acre which consist of 80 no's one acre block and 20 acres 2 no's blocks with appropriates buffer zones was designed and the map was given to MFAR. Out of 1900 blocks 450 were demarcated by NARA and Sri Lanka Navy by the end of year 2021 for sea cucumber farming in Jaffna (**Fig. 4**).

Fig. 3. Potential area for mariculture in Jaffna lagoon

Fig.4. Proposed100 acre sea cucumber farm unit for large scale investors

Outputs

Formulation of sea cucumber feeds

Identified potential species for mariculture in Jaffna lagoon

Initial zonal plan for Jaffna lagoon for mariculture

Designing of mariculture facilities for large scale investors

Dissemination of technical *know-how* to stake-holders through training and technical assistance, technical reports, media communications and paper publications

Constraints:

Project activities were carried out on and off after 05th of May 2021 because country totally locked down due to New Year third Covid-19 wave. After third Covid wave office re-started 2nd August 2021. However, the following day as few members of Division staff were infected, two third of staff were quarantined. However, from after 18thAugust to 04th of October country locked down totally once again. Although project work started hereafter with minimum staffs some provincial travelling barriers as well as unavailability of accommodation at government circuit bungalows in Jaffna adversely affect to carry out experimental field trials. During this period RRC Kalpitiya in where we have planned to conduct field experiment were closed due to several staff members suffered from Covid-19. Apart from that I myself was infected with Covid-19 in mid of October and home quarantined till end of October. After recovered I was not totally fit for field work owing to side effect of the Corona virus. As such project proposal was revisited and cut off some distance field activities. Nevertheless, under these uncertainty conditions project activities were unable carry out continuously but did on and off whenever access to reach office. When obtained feed ingredients laboratory analysis such as ingredient sorting, pre-preparation, grinding and proximate analysis were done and accordingly although, we have developed two feed formulae we were unable to field test because no sufficient duration to completed culture cycle as well as no proper climatic conditions at the end of year.

Remarks

Project activity plan has to revised and re-submitted due to Covid situation. As experimental (indoor & open water) culture trials didn’t perform procurement work of chemical purchasing wouldn’t process.

Progress:

Financial : 68%   Physical: 65%

1.4 Development of culture techniques and identification of culture grounds for pearl oyster resources in North & East coasts regard to regain the pearl industry in Sri Lanka

Officers responsible : Pradeep Chathuranga, C.B Medagedara

Budget Allocation (Rs.) : 1 M

Revised Budget (Rs.) : 1.2 M

Introduction

Natural pearls of Sri Lanka, obtained from the North Western coasts (Mannar Pearl Banks and surrounds), were once world reknown during ancient times for their high quality and lustre. In historical times, Arab traders congregated in the island during pearl fishing seasons to collect the precious goods (Mahroof, 1992, Strack, 2008) and only these merchants and Pearl traders and divers from South India benefited from this precious bioresouce. As the colonial powers (final British rule ending in 1948) established themselves, harvesting and trade were controlled and exploited by them resulting in the fishery being depleted in 1907. Technology is now available to obtain Marine pearls through the application of Marine Aquaculture technologies. Community-based aquaculture of pearl oysters and production of marine pearls and related products (e.g. mother-of-pearl handicrafts) are now succesfully practiced in many developing countries and demonstrated as economically feasible (Beckman,2006; Hawes, 2006). Countries such as India, Fiji, Philippines, Thailand, Tonga, Mauritius have commenced and developed their pearl farming industries, using these for economic benefit and as a climate change adaptation strategy

Main objective

Develop suitable culture techniques for pearl oyster community-based culture

Specific Objective/s

Identification of suitable culture grounds in the East coast

Technology transfer through pearl research group

Methodology (Study area, Field sampling, data collection and analysis)

Wild collected 8000 of pearl oyster samples to deposit in Trincomalee/ Cod Bay area for experimental culture site.

Pearl oyster samples were measured for growth performance analysis

Water samples and plankton samples were collected for Environmental analysis

Prepare Pearl oyster rafts for accommodate transported oysters from Silwathura

Results:

Activities carried out:

According to the water quality parameters and environmental parameters, Trincomalee / Cod Bay area selected as for the experiment pearl oyster culture site in the East coast, Sri Lanka.

Collected 8,000 of Pearl oyster (*Pinctada fucata*) species from Silawathura pearl oyster bed in 20 meter depth

Figure 1: Wild Pearl oyster collection from Silawathura sea area

Stocked collected pearl oysters in prepared plastic boxes (75 pearl oysters for each box) on 17.03.2021 at Cod Bay sea area in Trincomalee

Figure 2: Stocking of Pearl oysters in prepared Plastic Boxes (75 pearl oysters for each box)

pearl oyster plastic boxes were attached to the prepared pearl oyster rafts (06 rafts) at Trincomalee sea (15 pearl oyster boxes per raft)

Figure 3 : Stocked pearl oyster boxes in Floating pearl oyster rafts

Pearl oysters were tagged for further analysis

Figure 4: Pearl oyster Tagging and Measuring for further analysis

Survival rate of Pearl oysters in Cod Bay culture site is 93.75%

Number of spatfall 1125

Figure 5: spats collected from Cod Bay after 09 months from the previously stocked pearl oysters

Total number of pearl oysters In Cod Bay 8625

06 Number of pearl oyster rafts prepared in 2021 in Cod Bay / Tincomalee

Figure 6: Pearl oyster Rafts in Trincomalee / Cod Bay area

Average size of pearl oysters stocked in Cod Bay sea area

Average length (mm)	54.5 ± 3.5
Average Width (mm)	43.85 ± 0.15
Average Height (mm)	10.7 ± 3.3
Average body weight (g)	± 0.57

Outputs & outcomes

Outcome:

Development of suitable raft, pearl oyster culture structures and spat attachment materials

To check the identified secondary culture grounds against experimental pearl oyster raft culture

Receiving of expertise knowledge regarding technical and scientific issues in pearl oyster culture.

Output:

Introduce non-traditional aquaculture to fisher communities.

Diversification of cultured aquatic organism species in mariculture industry in Sri Lanka

Initiate pearl oyster farming in selected culture ground with suitable culture techniques.

Conclusion

Pearl farming is an attractive business venture because of the high value of the final product.

With the exception of the grafting process, pearl farming is a relatively simple form of aquaculture because pearl oysters do not require artificial feeds, complicated farm structures or constant attention.

If properly managed, pearl farming will not harm the environment and can increase the wild pearl oyster population and fish species over a period of years, as shown from the literature.

For these reasons, pearl culture may be the best opportunity for business development.

Recommendations

Trincomalee / Cod Bay culture site preferred for pearl oyster culture in east coast in Sri Lanka

Progress:

Financial : 100% Physical: 81 %

1.5 Preliminary study on cultivate local Artemia spp as a collaborative project with PalatupanaSaltern, Lanka Salt Limited, Hambantota.

Officers Responsible : E.D.M. Epasinghe, Scientist, NARA

U. A. N. W. Ubeysinghe, Production Manager, Lanka Salt Limited

Budget Allocation (Rs.) : 1.89 M

Revised Budget (Rs.) : 0.892 M

Introduction:

Among the live diets used in the larviculture of fish and shellfish, nauplii of the brine shrimp Artemia constitute the most widely used food item. Annually, over 2000 metric tons of dry Artemia cysts are marketed worldwide for on-site hatching into 0.4 mm nauplii. Indeed, the unique property of the small branchiopod crustacean Artemia to form dormant embryos, so- called 'cysts', may account to a great extent to the designation of a convenient, suitable, or excellent larval food source that it has been credited with. Those cysts are available year- round in large quantities along the shorelines of hypersaline lakes, coastal lagoons and solar saltworks scattered over the five continents. After harvesting and processing, cysts are made available in cans as storable 'on demand' live feed.

At present, Artemia is being produced and exploited on the five continents. Despite this, a large part of the cyst market is still supplied by harvests from one location, the Great Salt Lake. This situation makes the market still extremely vulnerable to climatological and/or ecological changes in this lake, which has been illustrated by the unusually low cyst harvests in the seasons 1993-1994 and mainly 1994-1995.

Live food such as Artemia is considered to be an essential part of many crustacean and finfish hatcheries. Majority of the local requirement of Artemia is fulfilled by imported Artemia cysts in vivid brands though there are naturally occurred brine shrimps in the local salterns. A canned 425 g of cysts cost is varying from 8500.00 LKR to 10,500.00 LKR. It directly affected on the ornamental production in the country. Reports revealed that there are 8000 ornamental fish farmers around the country. This was identified by the presidential task force for “Task Force for Economic Revival and Poverty Alleviation” and NARA was appointed to conduct research studies on farming Artemia. The local production of Artemia cysts is co-inside with the local salt production. As a result of this, collection of brine shrimp cysts restricted to few months of the year. It in can be identified as a main drawback of integrated production of brine shrimp with salt production which is negatively effect on commercial level Artemia production. Therefore, one of the possible solutions in order to overcome this matter is cultivating Artemia. In this scenario, it does not integrate with salt and solely Artemia. This research will be conducted with the collaboration of Lanka Salt Limited, Hambanthota. An agreement will be signed between NARA and LSL for widening the mutual understanding and to be grabbed future opportunities.

Salt farms in Sri Lanka are athalassohaline in nature, located in semi-arid areas and have a suitable climate for Artemia culture. Natural populations of Artemia could be found in the Hambantota, Bundala and Palavi areas and it completely parthenogenetic. Even though commercial culture of cyst production offers high potential in Sri Lanka in view of large quantities of Artemia imported in to Sri Lanka for the used in commercial hatcheries. It is estimated that about 11 000 ha are available for land-based coastal aquaculture other than shrimp, among that about 1 000 ha for Artemia culture (FAO, 2006). In current situation Sri Lanka parthenogeneticArtemia cultured inhabits only in solar saltern in Hambantota, Puttalam. However, natural Artemia could not be seen in the Mannar and Elephant pass salterns under Manthai Salt Limited

Main objective

Increase the availability of locally available Artemiaspp for the aquaculture industrialists in the country.

Specific Objective/s

Identification of local Artemiaspp using PCR techniques

Identification of existing soil and water quality in culture ponds of PalatupanaSaltern

Identification of suitable feed for adult Artemiaspp

Identification of suitable culture conditions for locally available Artemiaspp

Providing technical support, monitoring and evaluation of Artemia production of Artemia farmers under "Artemia Village programme jointly conducted by NARA –NAQDA-DIVISIONAL SECREATRIAT PUTTALAM

Knowledge sharing with other Saltern

Methodology (Study area, Field sampling, data collection and analysis)

Study was planned to conduct in PalatupanaSaltern,Hambantota. For the above mentioned study, MOU was revised many times with 2 part legal officers to sign.

The identification of local Artemia spp. was performed using PCR techniques in the molecular laboratory, MBRD, NARA. Identification of existing soil quality characteristics such as pH, electrical conductivity, texture of the soil, organic matter, total phosphorus and total potasium availability was performed in culture ponds by Grain legumes and oil crops research and development center, Department of Angunakolapelessa..

Activities proposed to be completed during the period

Introduction of Artemia spp. to Mannar and Elephantpass salterns under Manthai Salt Limited

Monitoring and evaluation of growth and cyst production with salt production, operations.

Purchasing requires consumables and chemicals,

Commencement and conducting the experiment,

Collecting data set

Analysing data set

Report writing and publication

Results:

Activities carried out:

Location wise species identification: The local Artemia collected from Palatupana was identified as *Artemia franciscana* by sequencing data.

Soil quality evaluation: Mean pH of the soil in culture ponds was 7.9±0.3 which is slightly alkaline in nature considered as suitable soil for the Artemia cultivation (Anh et al., 2009). Other factors such as available phosphorus and potassium levels were 4.0±2.3 ppm and 362 ± 60 ppm respectively.

Introduction Artemia to Manthai Salt Limited: This could not be performed. The management of Manthai Salt Limited still not granted their permission to inoculate Artemia into the DC pon ds in two locations (Mannar Saltern and Elephantpass saltern).

Discussion is being progressed in ministerial level in order to complete this task.

Evaluation of water quality: Not completed. Electricity supply from internal supply of LSL should be provided to the experimental site in order to use water pumps for filling water to the experimental ponds. Procurement processes are being progressed by LSL.

Outputs & outcomes:

Site selection was performed with NAQDA for Artemia cultivation at Pallivasalthurai, Kalpitiya areas where abandoned prawn farms located.

One day training program was conducted in the concept of Artemia cyst pre-processing techniques at Palatupana saltern premises, Hambantota with 17 Beneficiaries.

“Community awareness” meeting was held at Divisional secretariat, Trincomalee to promote Artemia cultivation around the country

Technical support with regular monitoring Artemia village programs (includes site selection and specification needed for Artemia plant construction, etc)

Conclusions:

By conducting proper training to Artemia farmers and cultivators on cyst processing in order to keep them for a long period without the quality deteriorate, how to obtain better hatchability and process of canning practically. With proper training, hatchability of the cysts increased and maximum utilization of cysts along with wastage of cysts minimized when hatching them at the end user’s places.

Recommendations:

To promote Artemia cultivation around the country, it is suggested to progress in ministerial level in order to successfully inoculate Artemia in salterns.

For the strengthening of Sri Lankan aquaculture sector in long term concern all government organization like NARA, NAQDA, Department of Fisheries andaquaculture, and CCD must undertake the responsibility to utilize that land area with maximum sustainable.

Constraints:

Salterns / Farmers reluctant to inoculate Artemia in Salterns

Delays in signing MOU between 2 parties (NARA and LSL)

Progress:

Financial : 53.4% Physical : 81 %

1.6 Development of Breeding Technology on High Value exotic Ornamental Fish

Officers responsible : N. P. Harshani Deepakumari

Budget Allocation (Rs.) :2.5 M

Revised Budget (Rs.) : 2.7 M

Introduction :

Aquarium keeping is one of the most popular of hobbies with millions of enthusiasts worldwide. Together all countries of the European Union and United State have the largest market for ornamental fish. The vast majority of ornamental fishes in the aquarium trade are from freshwater origin and farm-raised (Leal et al. 2015). Most of the ornamental fish is sourced from developing countries in the tropical and sub-tropical regions (Andrew C.2006). As a result of advancements in breeding, transport and aquarium technology, more and more species are being added every year.

The ornamental fish industry in Sri Lanka has a long history, which began with small-scale and has now developed into a thriving export industry which provides significant income and employments to many people. Sri Lanka as a country has highest export potential in exporting ornamental fishes to the world (Wijesekara R.G.S and Yakupitiyage A. 2001). Guppy, Neon tetra, Platy, Swordtails, Molly, Angels, Goldfish, Zebra danio, and Discus are the main ornamental fish species dominating the Sri Lankan export market. Out of these species, 60% of the total exports consist of Guppy, Swordtail, Platy, and Molly (EDB). But there are high demand for the new varieties of ornamental fish hence development of new varieties and breeding of them in the country is paramount.

Usage of new varieties with more export incentives can increase the income of the industry in Sri Lanka. In this sense, ornamental fish exporters have to depend on the imported brood stock and their natural breeding behaviors of new varieties of high value species and it is a matter of concern for the development of the industry. In order to ensure the continuous supply of new varieties and sustain the growth of the industry, it is absolutely necessary to focus about the breeding techniques of the high demand ornamental fish species. Thereby fish exporters can produce more fish for the export market.

Main objective:

Develop breeding technologies for high value ornamental fish verities (collaborate with NAQDA)

Specific Objective/s :

Develop breeding technologies for high value ornamental fish verities (collaborate with NAQDA)

Methodology (Study area, Field sampling, data collection and analysis):

Project of development of breeding technology on high value ornamental fish species was requested by ornamental fish exporters association from NARA and NAQDA. Responsible party to import high value exotic fish varieties is NAQDA and NARA planned to purchase the species that imported. Twelve varieties were requested to purchase from NAQDA. In this project we planned to develop Breeding technologies on the requested species. But due to prevailing condition in the country NAQDA unable to import fish varieties yet and still process is going on. On upon arrival of brooders quarantine should be going on. Therefore out dated fish breeding tank system was renovated. Live feed culturing was started for the feeding of brood stock and larvae and carryout. Feed for brooders were purchased. But the experiment for imported varieties was not conducted due to unavailability of brooders. Induce breeding was planned to performed on brooders after conditioning them until sexually mature.

Activities proposed to be completed during the period :

Develop breeding technologies for high value ornamental fish verities (collaborate with NAQDA)

Determine the fertility rate of eggs which is obtained under developed technologies.

Results:

Activities carried out:

Proposed experiment was unable to conduct because requested fish varieties were not imported by NAQDA. But the initial preparation for the study was done. Under this out dated fish breeding tank system was renovated, live feed of r the brooders and larvae were cultured and maintained. Until arrival of imported high value species, for the development of breeding technology, fish brooders were bought from local market and conditioning them is going on. Development of breeding technology for high demand exotic fish varieties will be done in 2022.

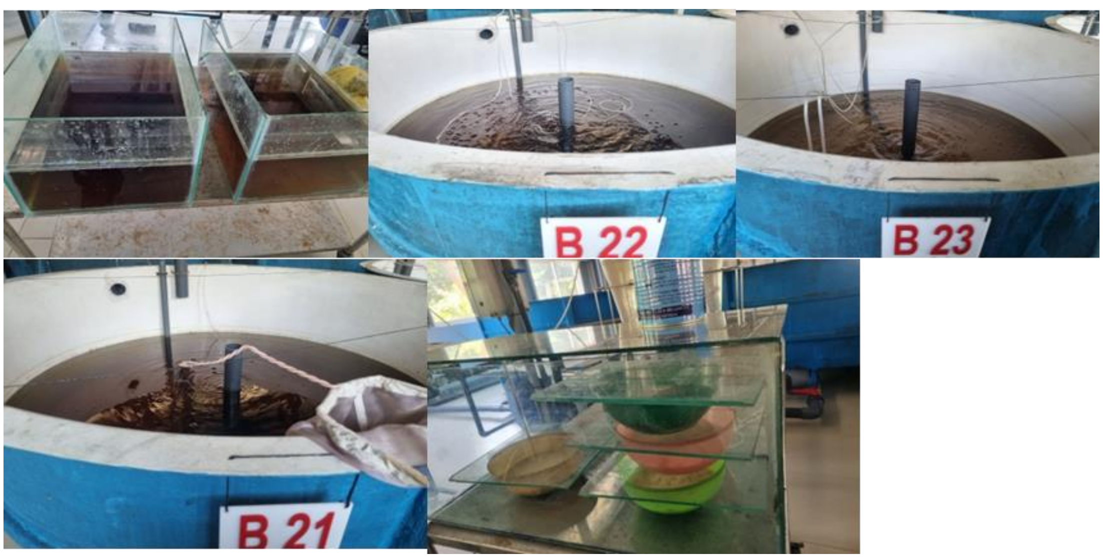


Figure 1: live feed cultures for brooders and larvae

Figure 2: renovated out dated fish breeding tanks system

Figure 3: ongoing study with the brooders bought from local market

Outputs & outcomes:

Out Put:

Out dated fish breeding tank system was partially renovated.

Live Feed cultured are available for commercial farmers.

Out Comes:

Proposed outcome was to find out best breeding technologies for high value ornamental fish species which is imported by NAQDA, to increase the quality and quantity of brood stock and fish to create a vibrant export market of ornamental fish. But it was unable to fulfill due to unavailability of broodrs.

Constraints:

Due to pandemic situation requested fish varieties were not received and there is a shortage of high value brooders of fish in local market. Therefore few verities were bought and conditioned for the breeding. But continuous monitoring and feeding was not happened because of lockdown and disease outbreak also happened. Therefore this project is planned to continue in 2022.

Progress:

Financial: 10.4 Physical:21%

1.7 Science & Technology application for the improvement, quality enhances to boost the export oriented endemic ornamental fish industry of Sri Lanka and conservation of rare fish species.

Responsible Officer(s) **:** Ramani Shirantha

Budget Allocation(Rs.) : 2.0 M

Revised Budget (Rs.) : 1.387 M

Introduction

Export oriented ornamental fish industry of Sri Lanka is identified as a high profitable trade through which the country can earn foreign exchange. Our endemic fishes of ornamental values are being exported to over 25 countries for more than 50 years but industry has not maximized the revenue. Many of the eye-catching endemic fishes are threatened and protected. Their wise and sustainable use therefore, should govern by a national institution as uncontrolled unreported wild brooder collection can lead to further population decline in wild. Under this scenario NARA has to pay a key role delivering Science and Technology innovation and timely supplying adequate enough quality brooders for different stakeholders. Based on a request made by the Ornamental Fish Export Association of Sri Lanka, a total of seven fish species namely, *Malpulutta kretsiri* (Ornate paradise fish) and *Belontia signata* (Comb tail) of family Osphro nemidae, and *Pethia bandula* (Bandula barb), *P. cumingii & P. reval* (Cumingi's barb), *Devario pathirana* (Barred danio) , *Rasboroides vaterifloris* & *R. palidus* (Fire rasbora) and *Garra ceylonensis*(Stone sucker) have been selected for S&T innovation and brooders supply in order to promote their wise use and increase their contribution for particular industry development.

This project directly linked with SDG Goal 14 (Life below water- *Conserve and sustainably use the oceans, seas and marine resources for sustainable development)* NARA has a goal to ensure technology application on wise use aquatic biodiversity of Sri Lanka by 2030. Moreover National Target 2 of National Biodiversity Strategic Action Plan (NBSEP) 2016 -2022 of Sri Lanka which was formulated to reduce habitat loss, degradation, fragmentation has proposed NARA as a primary institution to identify vulnerable species, and ecosystems and to develop potential mitigation and adaptation strategies. NBSEP intends to full fill the Achi Target 10 and Sustainable Development Goals 14 and 13. Further the NBSEP Target 4 is to reduce species loss significantly, for that NARA is to develop *ex situ* conservation facilities. The proposed project complied with those targets. This project also intends to full fill the Achi Target 10. Present project is directly in line with the sections 4.2.2 and 4.3.11 of National Fisheries and Aquaculture Policy that respectively ensure conservation of aquatic biodiversity in inland waters and promote the production and export of live ornamental fish.

Main objective

Boost the sustainable use of Sri Lanka endemic fishes in tropical ornamental fish sector and livelihood development in small scale fish exporters and adopt strategies to conserve most vulnerable fishes and ecosystems.

Specific Objective/s

Sustainable use of threatened endemic ornamental fish species of Sri Lanka through Science and Technology application.

Supply quality brooders of seven endemic fishes for ornamental fish breeders/exporters

Quality improvement in captive breeding technology of *Malpullutta kretsiri*

Identify, develop conservation strategies, and implement re-enforcement program for threatened endemic fish species.

Methodology (Study area, Field sampling, data collection and analysis)

It was planned to renovate the damaged out-door cement tank system with properly fixed shade net and encircling a net around the entire tanks system as soon as possible in order to avoid poaching. However, this part got delayed unexpectedly, thus top roofed nets were fixed in 3*5 tanks, and set up for breeding with 1/3 submerged aquatic plant cover. Since May 2022 they are being used as outdoor breeding tanks except for *Devario pathirana* which were reared under deep care in indoor aquarium. By end of June recollection of brooders had to be done as the last year collected brooders showed poor fecundity > 15 offspring. All were replaced with novel stocks collected from Kitulgala - Yatiyantota, Matale-Badulla, Bambarawana-Hiniduma, Morawaka-Akuressa, Ruwanwella area. Breeding trails were performed from time to time under COVID locked-down condition by applying environment manipulation procedure but expected induced breeding trails could not be performed for *Garra ceylonensis*.

The quality assurance was done by checking behavior, observing exo-parasite and other symptoms of any disease biweekly and infection of White Spot was noted in *D. pathirana* and then treated and kept under heater condition. Breeding trails not succeed. Breeding of Malpulutta kethsiri started in June, but succeeded and still in progress.

The project was also intended to estimate stocks specific population parameters of endemic fishes in two river basin Mahaweli and Kelani to assess climate change impact, but population data could obtain only in two successive months i.e. March and April. So that, this part had to be cease due to difficulty in collecting field data.

Activities proposed to be completed during the period

Renovation and upgrading of indoor and outdoor aquarium facilities

Literature survey on captive breeding technology development of labyrinth-form fish species

Brooder collection from the wild, acclimatization, rearing and sexing.

Fish and larvae rearing, feeding and quality improvement

Conduct conservation strategy development trails, experiment on rare endemic with breeding technology, quality improvement and aquarium condition development for research and awareness purposes

Conducting awareness programs/technology transferring program for different stakeholders

Supply quality brooders for the stakeholders

Results: Activities carried out:

Endemic fish breeding of seven endemic fishes to supply quality brooders

Larval rearing tanks of *Pethiabandula*

Since the quality of brooders has dropped due to deficient in proper care under COVID-19 scenario, breeding trails of 10 endemic ornamental fish species were carried out with newly collected brooders. Only brooder collection and acclimatization were done for breeding technology development of*Garraceylonensis.* Captive breeding trails were not successful so far but experiments are still in progress.

Fixed name board in Nawata, Yatiyantota to build awareness on threatened fish species *Pethiareval*.

A total of five awareness/name boards of two vulnerable fish species *Pethiareval* and *Systomusasoka* were fixed in Yatiyantota and Kitulgala areas. Fixing of name broads on selected rare endemic fishes in Matale and Badulla districts planned, consent letters from WDC, Forest Conservation Department, Irrigation Department and relevant Pradeshiya Sabha and Division Secretariats were obtained, name boards prepared.

New locality of critically endangered fish sp. *Systomus martenyni* was recorded in Ridimaliyadd aHepola Oya which is out of known range.

Newly recorded locality of *Systomus martenstyni*-HepolaOya

One officer was trained on fish biodiversity and conservation issues as per request made by DS/ Dehiovita in Kegalle district.

Barbonymus schwanenfeldii

Barbonymus schwanenfeldii was recorded in Mahaweli River with density 12.5 individuals/m^2 in Heen Ganga at Knuckles area. Finding was shared with the BDS, IAS committee and Mahaweli authority.

Upgraded culture and fish rearing facility at the indoor aquarium and outdoor net house.

Abandoned out-door tanks renovated with top roofed net.

Outputs & outcomes

Quality brooders of the following fish species now available for sale/supply to breeders or introduce into the natural environment for stock enhancement.

Fish species	No of pairs available
Belontia signaa	15
Dawkinsia srilankensis	20
Pethia bandula	15
Pethia cumingii	60
Pethia nigrofaciata	50
Pethia reval	35
Puntius titteya	100
Rasbora vaterifloris	25
Total pairs	**320**

> 400 individuals of *P. reval* stock at reinforcement site in Yatiyantota and nearly 150 individuals *P. nigrofasciata* stock at reinforcement site Dehiovita.

Constraints

COVID locked–down and essential quarantine affected the project activities in May to September.

Progress:

Financial : 64.7%   Physical   66.4%

1.8 Micro propagation technique development for the selected aquatic plants and production of Aquatic plants for the community and In vitro propagation of *Kappaphucus alvarazii*

Responsible Officer(s) : D. M. S. Sugeeshwari, K. K. T. Nuwansi,

Budget Allocation **(Rs.)** **:** 1.2 M

Revised Budget (Rs.) : 0.726M

Introduction:

As this ornamental aquatic plant industry, has focused to the export market, it is very much importance to get large number of plant production. This could be achieved by using micro propagation techniques. Hence the National Aquatic Resources research and development agency, plant tissue culture laboratory has undertaken various research to develop protocol for the selected aquatic plants and conducting mass production of aquatic plants to the plant house of the NARA.

There are five species of *Aponogeton* occurring in Sri Lanka and except *A. crispus* other species are in IUCN Red list. But there is a huge demand for these species for world market. (Amarawansha T.W.G.J.C *et al*, 2015).

Nymphaea "Midnight" is a type of high valued water lily which cannot be propagating vegetative. Hence, aquatic plant growers have made request for the development of micro propagation technique for this species.

Kappaphycus alvarezii is the most important macro algae for K-Carrageenan production. Repeated vegetative propagation has become a reason for the decrease of growth rate, carrageenan yield and gel strength. (Wilson T.L.Y, *et al*, 2013).Hence, micropropagation has been suggested

Main objective:

To develop micro propagation technique for selected aquatic plants.

Specific Objective/s

To Identification of specific protocol for explant sterilization of *Nymphaea "Midnight"*

To Identification of specific medium composition for shoot initiation and shoot multiplication of *Aponogeton* Species and *Nymphaea "Midnight".*

To Identification of specific medium composition for rooting of *Aponogeton* Species.

To Identification of suitable culture condition for optimum growth of thallus of *Kappaphycus alvarezii* in laboratory conditions.

Methodology (Study area, Field sampling, data collection and analysis)

Development of sterilization protocol for *Aponogeton cryspus and A. natans*

Sterilized seed transferred to a Murashige and Skoog (MS) medium with growth regulators. Then generated shoots transfer to liquid MS media for rhizome generation. Then the rhizome transfer into media for callus generation.

Figure 1: Shoots generated from rhizome of *Aponogetoncryspus*

Development of sterilization protocol for *Nymphaea "Midnight"*

Rhizome selected as an explant. Ex plants first wash with liquid soap and then under running tap water. Then it washed with 70% ethanol for 1 minute and washed with different concentrations of commercial sodium hypochlorite solutions and hydrogen peroxide for different time. Then culture in liquid MS medium to check the survival of the ex plants. Then the suitable sterilization method selected and used it for ex plant sterilization. After sterilization procedure completed, ex plants cultured in liquid MS Medium with different concentrations of Growth Regulators for shoot initiation.

Figure 2:Generated shoots of *Nymphaea "Midnight"*

Development of sterilization protocol for *Kappaphycus alvarezii*

Sterilized ex plants were cultured in sterilized sea water medium and provided growth promoters and aeration. Different concentrations of growth regulators were used to select the best one for generated shoot growth.

Initiation of mass production of *Cryptocoryne wenditii and Anubias barteri*var.*Nana.*

Shoots of *Cryprocoryne wenditii and Anubias barteri*var. *Nana* were cultured in MS medium for shoot generation and then do the sub cultures.

Activities proposed to be completed during the period

Development of shoot generation and shoot multiplication of *Aponogeton cryspus* and *Aponogeton natan*

Development sterilization protocol and shoot initiation of *Nymphaea "Midnight"*

Development of shoot growth protocol for *Kappaphycus alvarezii.*

Initiation of mass production of *Cryprocoryne wenditii and Anubias barterivar.Nana.*

Results:

Activities carried out:

Development of sterilization protocol for *Aponogeton cryspus and A. natans*

Seeds has elected as explants. After the sterilization ex plants were cultured in Liquid Murashige and Skoog Medium with Plant Growth Promoters. Shoots generated. Then generated shoots were culture in MS Medium with PGR for Rhizome development. Generated rhizomes were cultured in MS Medium with PGR for callus. Formed Callus was cultured for Shoot Generation with MS medium.

Development of sterilization protocol for *Nymphaea "Midnight"*

Selected ex plant was Rhizome. Different concentrations of Sterilizers (Clorox, Hydrogen Peroxide) were used to develop the protocol for sterilization of explants. Then rhizome segments were cultured in Liquid MS Medium with PGR for shoot initiation. Shoots were generated.

Development of sterilization protocol for *Kappaphycus alvarezii*

Different concentrations of PGR were used in Sterilized Sea water medium for shoot initiation.

Out Put:

Developed protocol for Aponogeton Species mass production

Out Come:

Increase the production in Aquatic Plant industry.

Conclusions

Best medium coposition for shoot initiation of Aponogeton was liquid MS with Benzyl Adenine Purine and Naphthalene Acetic Acid in 1:1 Rati

Constraints

Laboratory contamination occurred and hence it took certain time period to condition the growth room for research work.

Effect for continuous research performance form the situation with Covoid19 .

Progress:

Financial : 32.3% Physical 50%

1.9 Study the effect of different hydroponic culture techniques for the growth performances of aquatic plants in aquaponic recirculation systems

Responsible Officer(s) : Dr. K. K. T. Nuwansi,

Budget (Rs.) : 1.0 M

Revised Budget (Rs.) : 1.088 M

Introduction:

Aquaponic systems are re-circulating aquaculture systems that incorporate the production of plants without soil. It requires substantially less water quality monitoring than separate hydroponic or recirculating aquaculture systems. So it is better to produce aquatic macrophytes aquaponically as the local and international demand for aquatic plants has shown a steady increase during past several years. It is already cultivated the aquatic plants in hydroponically and less attempts taken in aquaponics. Thus it would be beneficial to find out the possibilities of cultivating aquatic macrophytes for a low cost and environmentally friendly manner.

Aquatic plant going to use in this study is *Anubiasbarteri* var. *nana ''petite''*.It is a man-made cultivated variety originally developed from *Anubiasbarteri* var. *nana* and has great aquascaping potential for every aquarium (George et al., 2015). *Anubias* plant does not require much attention and has high demands in the aquarium industry because of its minimal light requirements and hardy nature. Potted *Anubias* plant could be sold to more than 300 rupees in Sri Lanka market. As it is soilless culture technique it can compete well even in the export market for higher price due to absence with soil borne pathogens.

In this experiment *Anubias* grown hydroponically and it is a highly productive method of growing plants without using soil. Also it leads to conservation of water and land resources while protecting the environment (Cotchakaew et al., 2015). The slow growth rate is one of the major constrains possess in *Anubia s*plant. The suitable culture technique can be affected for the plant growth and by selecting the most suitable culture technique the growth could be enhanced. Thus the study was focused to find out most appropriate culture technique for the hydroponic cultivation of *Anubias*.

Considering the hydroponic culture techniques there are three basic ways of it as floating raft method (deep water culture technique), nutrient film technique (NFT) and gravel bed system. Among these techniques, systems like nutrient film technique further minimizes the space used to culture and it can be develop or modified as vertical farming system which increase the production in a unit area. If *Anubias* plant performs well in NFT system the production could be enhanced by doing vertical farming. So in this study attempt will be taken to find out which hydroponic system is most suitable for the cultivation of *Anubias* and further evaluate the possibility of NFT to cultivate this selected aquatic plant.

If these hydroponics systems combine with fish tanks and allow the system to recirculate it would be a good attempt to produce duel products at the end of the culture period. It will help to reduce the cost of artificial fertilizer and at the end of the culture period farmer would be able to gain two varieties of harvests instead of one. Also, this type of production systems are environmentally friendly and leads to sustainable aquaculture production which having minimum environmental impacts. So

Anubias can be cultivated in a low cost and efficient technology. Guppy (*Poecilia reticulata*) is the selected fish species in this study and it is hardy fish species which has very good demand in the export market. Most of the small scale fish farmers in Sri Lanka interested to cultivate aquatic plants together with ornamental fish and they requested to introduce a technology which can cultivate plants and fish in a limited space. So the system should be a simple and easy to prepare by the farmer instead of using complex one. Thus, the combination of these two systems would be beneficial to them, to have low cost duel production and this attempt would be a great opportunity to them to upgrade their systems.

Main objective:

To find out the best culture technique for the growth of *Anubias barteri* var. *nana "petite"*

Specific Objective/s:

To study the effect of culture techniques for the growth performance of *Anubias barteri*var. *nana "petite*"

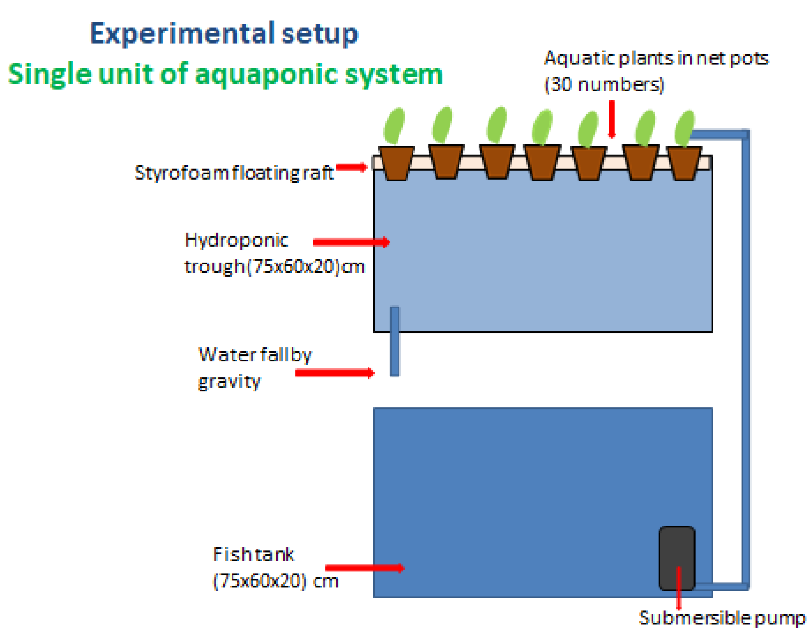
To study the effect of culture techniques for the growth performances of the ornamental fish sp. that cultivated aquaponically with the plant

Methodology (Study area, Field sampling, data collection and analysis)

Experiment carried out in NARA Head office Aquatic plant poly-tunnel.

Constructing and the modification of the system-

Typical aquaponic system (single unit)



Treatments –

Treatments	No of replicates
Deep water culture technique	3
Media based system	3
Nutrient film technique	3

Diagrammatic representation of the 3 treatments

The system modified according to the above diagrams.

Time duration: 6 months

Selected plant species: *Anubias barteri* var. *nana* (petite)

Stocking density of the plants: 30 plants per unit

Size of the plant: 5g-10g

Selected fish species: Guppy (*Poecilia reticulata*)

Stocking density: 2 fish per liter

Substrate for net pots: coconut husks

Parameters to be measured (fortnightly sampling)

Water quality

Chlorophyll a

Chlorophyll b

Carotenoids

pH

Conductivity

Nitrate

Phosphate

Potassium

Plant growth parameters

weight of the plant (at the end)

leaf length

leaf width

numbers of leaves

root length

rhizome length

Fish growth parameters

Weight of the fish

Length of the fish

According to the above-mentioned parameters the best system will be selected.

Activities proposed to be completed during the period

It is proposed to build vertical farming system of aquatic plants to maximize the production of unit area and it will be a good solution for the immerging problems for land and water resources.

Results:

Activities carried out:

According to the preliminary studies, among selected concentrations 0.005mg/L found as the suitable concentration and the coconut husk media found as the most suitable substrate which is a low cost, locally available media for the hydroponic cultivation of *Anubias* spp. and also wood scrapings found to be an effective media when it is available in the environment. Thus, pieces of coconut husks used as the substrate media for all three treatments.

Initial Measurements

Mean wet weight	-0.49±0.02g
Number of leaves	-7.54±2.3
Leaf length	-(1.82±0.33)cm
Leaf width	-(1.17±0.32)cm
Root length	-(2.38±0.69)cm
Rhizome length	- (1.35±0.41)

With the COVID pandemic situations regular sampling and monitoring was could not happens, thus this project as extended to year 2022.

Outcomes

Supply good quality aquaponically produce aquatic plant production to the local and foreign market

Outputs

Development of the culture techniques for better and sustainable aquaculture practices in Sri Lanka.

Conclusions

As the project was not fully compleated couldn‘t get the overall conclusion. But choosing the correct culture technique among these 3 techniques will increase the growth rate as well as production of unit area.

Recommendations

It is further recommended to choose other ornamental fish varieties such as Koi carp which is well adapting for the aquaponic systems to diversify the production.

Also high demanded other aquatic plants also can be selected to study with different ornamental fish varieties to broaden the production capacity.

Constraints:

With the COVID pandemic situations regular sampling and monitoring was could not happens, thus, daily maintaining only done in the 3rd and 4th quarter of the year and continuous sampling was not carried out.

Progress:

Financial : 28.3%   Physical: 40 %

1.10 Development of culture techniques and study the growth performances of Tubifex worm, in different organic media

Responsible Officer(s) : M. Epasinghe, P.Mythily

Budget Allocation (Rs.) : 0.50 M

Revised Budget (Rs.) : 0.70 M

Introduction:

Larviculture of several fishes has enlarged into multimillion dollar industry. As there are many researches on going to identify the dietary requirement in larval culture, early larval stages and brooders mainly depends on live feed for their growth performance, survival and higher reproductive rate. Artificial feeds cannot compete with live feed in terms of its nutrional quality, acceptance, digestibility and other factors. Among the different types of live feed available, Tubifex make an ideally suited diet for ornamental fish culture.

Tubifex is used in early feeding of the juveniles and brooders in the ornamental fish industry. Naturally, it can be found in sewage fed water channels or the habitat which is enriched with organic matters. According to Anlauf and Mooffitt (2008) two Tubificids, Tubifex spp. and *Limnodrilush offmeisteri* co-occur in silt-clay and fine sands sediments in the habitat like intermountain watershed. Habitats of low dissolved oxygen concentration receiving heavy sewage pollution have been found to host significant quantity of Tubificid worms. As revealed from the study by Oplinger et al (2011) compared to other natural food such as Daphnia, the nutrient content of Tubifex is higher and has an equal nutritional quality to Artemia sp.

The culture of Tubifex has become a necessity in view of the fact that the wild collection was found to be contaminated with heavy metal pollutants(Singh et al., 2007) and lack of Tubifex worm purity, along with the chance of transmission of fish pathogen from sewage fed water channels (Mandaletal., 2018). Culture of Tubifex in captivity is necessary to meet demand, provide a reliable supply and to assure human and animal health.

Main objective

To assure the sustainable tubifex production all over the year and thereby assure fish health.

Specific Objective/s

To find out the environmental conditions of the place where Tubifex are naturally present

Identification of species with sequencing techniques

To find out suitable culture techniques for cultivating Tubifex worms

To find out the most suitable organic media for optimal growth of Tubifex sp.

Methodology (Study area, Field sampling, data collection and analysis)

Field study:

Initially, to find out the wild Tubifexsp availability ground, site inspections were carried out in Boralesgamuwa, Peliyagoda and around Nuwareliya areas (According to the datas collected from wild Tubifex collectors). Around Nuwareliya areas, three different sites were studied. In each sites three different stands were selected to gather data on soil and water quality characteristics. Water parameters such as Water temperature, pH (Membrane pH meter)DO (Winkler titration), NH3 and water depth with Soil parameters such as organic content(oven dried method), pH and texture were analyzed using standard methods

Worm identification:

The collected species were separated according to their morphology and single species worms was obtained and Species conformation was performed in MBRD, NARA with sequencing techniques

Culture system

For cultivating species, crates were fabricated with continuous water flow through systems

Media for culture

5 different types of culture media were collected to feed the tubifex worms. Rice bran, Rice polish, Soybean meal, fish meal, and degraded vegetable

Activities proposed to be completed during the period

Collection of worms and acclimatization process

Identification of worm

Fabrication of GI rack for culture

Collection of culture media

Proximate analysis of tubifex,

Preliminary analysis of wild environment

Commencement of culture

Data collection

Analyzing data set

Report writing and publication

Results:

Activities carried out:

Collection of culture media

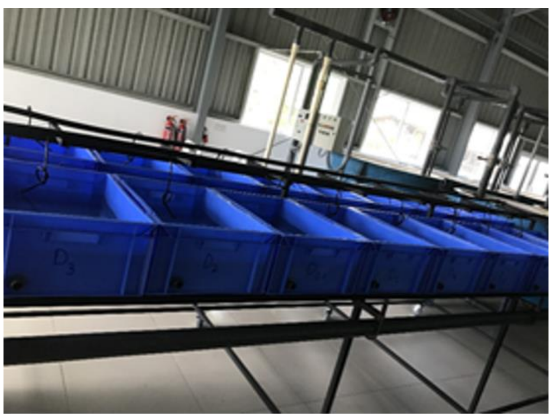
5 different types of culture media were collected to feed the tubifex worms. Rice bran, Rice polish, Soybean meal, fish meal, and degraded vegetables were selected to feed the worms

Preliminary analysis of wild environment

Tubificids worm identified in wild

According to the data collected from wild Tubificids worm's environmental condition, texture of two sites were identified as sandy soils and other one was loamy sand (Based on the USDA particle-size classification).The highest mean organic content was observed as 3.53% considered as productive soil. The minimum Dissolved oxygen observed within three sites is 3.2±0.2mg/ L. These data were used in the Laboratory cultivation of Tubifex

• Fabrication of GI rack for culture



System design for continuous culture

To commence the culture, GI rack was fabricated with continuous water flow through system.

Identification of worm

Sequence of the worms were identified as *Limnodrilushoffmeisteri*. (Tubificids worm).

Commencement of culture

Worms in pre cultivation/ acclimatization period

Outputs & outcomes:

Proper Culture system was fabricated for the cultivation of tubifex

Conclusions:

Pure culture with a particular genus may prove to be more profitable than the others. Hence identification of specific genera can be stated as a landmark toward development of sustainable culture technique for tubificid worms

Recommendations:

As Tubificid worms are one of the best quality live foods in intensive aquaculture widely used for feeding of certain fish larvae to produce stockable sized seeds in the hatcheries as well as in the rearing of aquarium/ornamental fishes. Pure culture identification gives a way for the development of sustainable culture techniques.

Identifying the species of Tubificids worms used in ornamental industry and culturing particular genus may prove to be more profitable than mixed culture.

Constraints:

Discontinuous culture due to pandemic situation

Seasonal availability of the worms gives barriers in collection and natural ground identification

Trial and errors due to environmental conditions

Progress

Financial : 18.7% Physical: 41 %

1.11 Strategies to increase survival of *Macrobrachium rosenbergii* stock in culture based fisheries in two selected reservoirs in Hambantota district, Sri Lanka.

Responsible Officer(s): M. Gammanpila, W. Rajapakshe, K.W.R.R. Amaraweera and representative from NAQDA / Hambantota

Objectives:

- Provides strategies to increase recapture rate of *M. rosenbergii* production in perennial reservoirs that help to enhancement of income of rural communities for strengthening the rural economy that achieve food security and improved nutrition of rural communities.

Activities carried out:

The study was conducted to introduce strategies to increase survival rate and recapture rate of *M. rosenbergii* culture in Kattakaduwa and Bandagiriya tanks, southern Sri Lanka.

Existing information (hatchery condition, disease monitoring, number of post larvae stocked, stocking density- prawn larvae/ha, stage and size of post larvae release, timing of stocking & release method, month & frequency of releasing, average age at harvest, present recapture rate, fishing gear specification used for harvesting prawn (gill net, cast net, trap, twine thickness, color of net), any other alternative fishing gears used, mesh size, height of gill nets, fishing intensity, monthly catch data (total fish/prawn production, species, Catch Per Unit Effort and yield, season), length-weight relationship, sex ratio of *M. rosenbergii* culture in two tanks were collected.

Background information of the reservoirs, including monthly variation of water quality, reservoir morphology, area and catchment area of the reservoirs, full supply water level, average depth of the reservoirs, water level during rainy and dry season, bottom condition of the reservoirs (sand, muddy or presence of stumps), Hydro climate factors (rain fall, strong winds, high temperature) and pattern of water discharge for agricultural purpose were also collected.

To increase of post larvae survival three net pens size of $500m^2$ each were constructed in Kattakaduwa wewa. Total number of 24 traps were introduced as an alternative fishing gear to fishermen of Kattakaduwa and Bandagiriya tanks.

Major Findings and outputs

The mean catch, in kg per craft/single operation was considered as the catch per unit effort (CPUE) with respect to each craft and gear type. For the gillnet fishery, the highest production (760 kg) and highest CPUE (0.84 kg/boat) were recorded in Bandagiriya tank during month of August when lowest water level was recorded. Accordantly highest production (102.4 and 141.7 kg) was recorded during September and October and highest CPUE (1.8 kg/boat) was recorded during October in Kattakaduwa tank. Comparatively highest mean water depth (212 cm) and Chlorophyll-a (9.56 mg/m^3) were recorded in Kattakaduwa tank compared with 157 cm and 7.25 mg/m^3 recorded in Bandagiriya tank. The lower secchi depth value (26.9 cm) was recorded in Bandagiriya tank compared with 60.8 cm recorded in Kattakaduwa tank. Length-frequency distribution pattern of fresh water prawn catch shown that 45% of prawn catch were represents by 25 -30 cm length group in both tanks.

The daily income of fishers who used alternative fishing gear during the off season has been increased up to 1000-1500 Rs/day.

The project will continue to year 2022.

Recommendations

The recommendation will be based on the catch data after introducing traps and releasing of larger post larvae during next year.

Progress: **Financial:** 100 % **Physical:** 84%

Constraints:

Covid-19 epidemic situation sampling wasn't carried out during 2 months period of the year. Lack of supplying post larvae, heavy rainfall resulted in a delay in stocking post larvae in Kattakaduwa wewa.

Due to renovation, the earthen pond facility for stocking post-larvae was not provided by the NAQDA.

1.12 Investigation of Grass Carp (*Ctenopharyngodon Idella*) breeding procedure to find out the reason for low hatchability

Responsible Officer(s) : A. M .A. N. Adhikari, Wasantha Rajapakshe

Budget Allocation(Rs.) : 0.855 M

Revised Budget (Rs.) : 0.636 M

Introduction:

Low hatchability and survival rate are the crucial drawback in *Ctenopharyngodon idella* (Grass carp) breeding in Sri Lanka, even though it follows recommended hormonal induced breeding protocols. High mortality has also been a problem during the early yolk sac stage in many hatcheries. The causes are often unknown and complex, but water condition and egg quality could be the reason for high deformations and mortalities during embryogenesis and the early yolk sac of larvae (Cobar et al., 2011). Ca^{+2}, Mg^{+2}, Na, and K are especially important during early development. After the insemination of egg with sperm, Ca^{+2}, Mg^{+2}, Na, and K plays a critical role in a complex series of changes necessary for metabolic activation of the eggs, fertilization, and cell cycle control. The heavy metals are most common in many water sources; they may affect the early stages of fish development especially on egg quality, hatchability, and larval quality (Noha et al., 2009). Fish eggs reveal wide fluctuations in composition and quality, mainly because of variability caused by individual female conditions and by overripening processes. Therefore, the influence of the variability in egg composition on viability is needed to examine. Many morphological parameters and biological parameters are used to evaluate the egg quality of the fish (Lahnsteiner et al., 1999). Thus, the present study is planning to examine the water quality of hatchery water and the gamete quality of *Ctenopharyngodon idella.*

Specific Objective:

To assess the water quality parameters in *Ctenopharyngodon idella* breeding hatchery under the currently used induced breeding process

To assess the egg quality of the *Ctenopharyngodon idella* under the current brood-stock management process

Methodology:

Location:

The study was conducted in the Fish hatchery of National Aquaculture Development Center Dambulla.

Sample collection

Physico chemical parameters of water

Physico-chemical parameters were measured in the brood stock tanks, sediment tank and water source of the hatchery. Three surface water samples were collected and Ca^{+2}, Mg^{+2}, Na, K, PO_4, Total dissolved solids (TDS), Zinc, Lead, Cadmium, total alkalinity, and total hardness will be measured before every breeding trails following standard protocol. In suit, measurements will be taken for water temperature, pH, conductivity, and transparency.

Sample collection for monitoring health condition

Brood stock quality was assessed by monitoring clinical symptoms. Water samples were collected from brood stock tank and spawning tank for microbial analysis. (Three samples from below the surface and the middle of the water column).

Results:

Physicochemical parameters of the sampling sites are illustrated in table 1.

Parameters	Inlet	Stock Tank	A6 Pond	B1 Pond	B8 pond
Alkalinity (mg/l)	86	61.2	100.8	101.2	104.4
pH	6.9	7.82	7.8	7.95	7.9
Temperature ^{0}C	28	30	28.9	29.8	29.9
Unionized ammonia (mg/l)	0.0006	0.0008	0.0168	0.0134	0.0116
Available Phosporus (mg/l)	0.51	0.98	0.53	0.97	0.94
Nitrite (mg/l)	0.013	0.018	0.019	0.011	0.009
Nitrate (mg/l)	0.3	0.2	0.8	0.7	0.5
Conductivity (µs/cm)	168	210	250	267	272

All physicochemical parameters of different site of the hatchery were ranged within the acceptable level for bloodstock management, hatching of fish eggs and growth of early larval stages of fish. Highest available phosphorus was recorded in stock tank and lowest was recorded in inlet water. Highest available phosphate levels of the stock tanks may be create by decomposing of organic debris presence stock tank bottom.

Heavy metals and trace elements recorded in hatchery water are shown in table 2.

Test/Unit	**Inlet**	**Stock Tank**	**Brood stock tank**	**LOD**
Zinc (mg/l)	ND	ND	ND	0.02
Lead (mg/l)	ND	ND	ND	0.01
Cadmium (mg/l)	ND	ND	ND	0.001
Sodium (mg/l)	2.9	ND	ND	0.5
Potasium (mg/l)	3	1.6	1.8	-
Magnesium (mg/l)	11	7.6	9.5	-
Calcium (mg/l)	17.2	15.1	16.8	-

ND: Not detected LOD: Limit of Determination

According to the results heavy metals such as Zinc, Lead and Cadmium were not detected in any places in Grass carp hatchery. Trace elements (Sodium, Potassium, Magnesium and Calcium) were recorded in acceptable range for fish growth, egg development, spawning, hatching of egg of Grass carp.

Microbiological analysis revealed that the bacterial growths are high in A6 and B1tanks.Pure cultures were stocked for identification the etiology of bacteria. No any Cyclops were found in the test samples.

The studies on variability in egg composition on viability, morphological parameters and biological parameters to evaluate the egg quality of the fish were unable to carry out. The study area was under locked down condition since COVID 19 pandemic situation. And also female fish were not matured enough to carry out the hormonal induced breeding.

Conclusion:

Observed parameters of water quality indicated that water of the Grass carp hatchery is suitable for spawning, embryogenesis and early larval development of the grass carp.

Constrain:

Egg sample collection wasn't completed in breeding season due to the lockdown situation of the country.

Progress:

Financial: 40.3% Physical: 37%

1.13 Estimation of carrying capacity of perennial reservoirs for net cage culture of fry to fingerling stage of commonly cultured food fish species in Sri Lanka.

Officer/s responsible : A. M. A. N. Adikari, J.S.Jayanatha, R.Srikrishnan

Budget Allocation(Rs.) : 2.0 M

Revised Budget (Rs.) : 1.270 M

Introduction:

Cage culture in inland reservoirs is an emerging technology particularly in the Asian region of the world, in which fishes are reared from fry to fingerlings, fingerling to table size while captive in an enclosed space that maintains the free exchange of water with the surrounding water body (Karnatak and Kumar 2014). However, the method of cage culture of fry to the fingerling stage in reservoirs has still not been tried out extensively in Sri Lanka (Jaymana 1979). Cage culture of fry to fingerling in inland reservoirs is proving very useful for in situ rearing of fish fingerlings for stocking. It also facilitates as an effective management tool for the reservoir fishery management through enhancing the fish stocking program (Biswas et al., 2015). Due the minimum scientific knowledge, relevant authority (NAQDA) for culturing fish in cages in the reservoirs is facing several issues, so NAQDA requested a scientific study for further development of this system in order to enhance the in-situ rearing of stocking materials to uplift the stocking program of inland reservoirs of country. Water carrying capacity also is a very effective measure to develop sustainable net cage fish cultivation in a reservoir water body, in which amount of fish biomass that can be produced by fish farming activities in net cages without increasing the fertility of the water can be assessed (Simanjuntak and Muhammad 2018). Thus, the determination of reservoir carrying capacity for fish farming activities in floating net cages is essential for the development of this emerging aquaculture operation in Sri Lanka. Thus, this study is planned as a collaborative research to determine the carrying capacity of reservoirs for net cage culture while maintaining optimum fish stocking density.

Objectives:

Identification of optimum stocking density for fry to fingerling rearing in cage

Identification of suitable feeding rate for fry to fingerling stage cultured under cage culture system in reservoirs

Assess the amount of nutrient loading to the reservoirs by cage culture practices

Assess the required period for the degradation of accumulated nutrient load

Assess the net carrying capacity of perennial water bodies in Sri Lanka

Activities carried out (Methodology):

Study area

The study was conducted in Daduruoya reservoir, Ridiyagama reservoir (Major perennial reservoir) and Hakwtunawa reservoir, Bandagiriya reservoir (Medium perennial reservoir).

Site selection

Bathymetric survey

Site selection was done based on the bathymetry and water and sediment quality of the reservoirs. Manual depth sounding tool was used to carry out the bathymetric survey.

Sample collection

Water samples were collected from the places where the required water depth occurred. Water samples were taken as surface and bottom samples. In suit measurements were taken for water temperature, pH, conductivity, and transparency. Dissolved oxygen, total hardness, total alkalinity, nitrate-N, phosphate-P, chlorophyll a, and phytoplankton and zooplankton density were analyzed following standard protocol to ensure the Physico- chemical parameters of the reservoir water.

Sediment samples were collected using an Ekman-Brige dredge and allowed to air- dry in shade, ground to fine powder, strained through 0.5 mm mesh sieve and again air- dried. Sediment quality parameters, soil texture, pH, organic carbon, available nitrate, and available phosphorus were taken following standard protocol.

Feed formula preparation

Feed with Crude Protein (CP) 30% were formulated using locally available feed ingredients.

Results:

Major perennial and medium perennial reservoir which have a surface area 1,000 ha or more at Full Relief Level (FRL) were selected for the study. Prior to the introduction of cage culture to a water body three major factors have to be taken into account such as water depth, water quality and water current. Thus, following things were taken into consideration. Before carried out the bathymetric survey, discussion was held with members of fisheries society of each reservoirs to avoid or minimizing user conflicts. Sites which have heavy weed infestation, difficult to access, nearness to dense human habitation, industrial and agricultural area, sensitive area like wildlife habitat and were avoided at the preliminary stage of the site selection (figure 1). According to the bathymetry survey, water depth of the selected sites as below (table 1).

Table 1: Average water depth of selected sites of each reservoirs.

Reservoir Name	Daduruoya reservoir	Hakwatunawa reservoir	Ridiyagama reservoir	Badagiriya reservoir
Average water depth (m)	8±2	7±4	9±1	9±2

According to the previous studies, recommended depth for cage culture in reservoir is 5-10 m. Therefore, the areas which has average water depth 7-9m were selected as the site for cage culture.

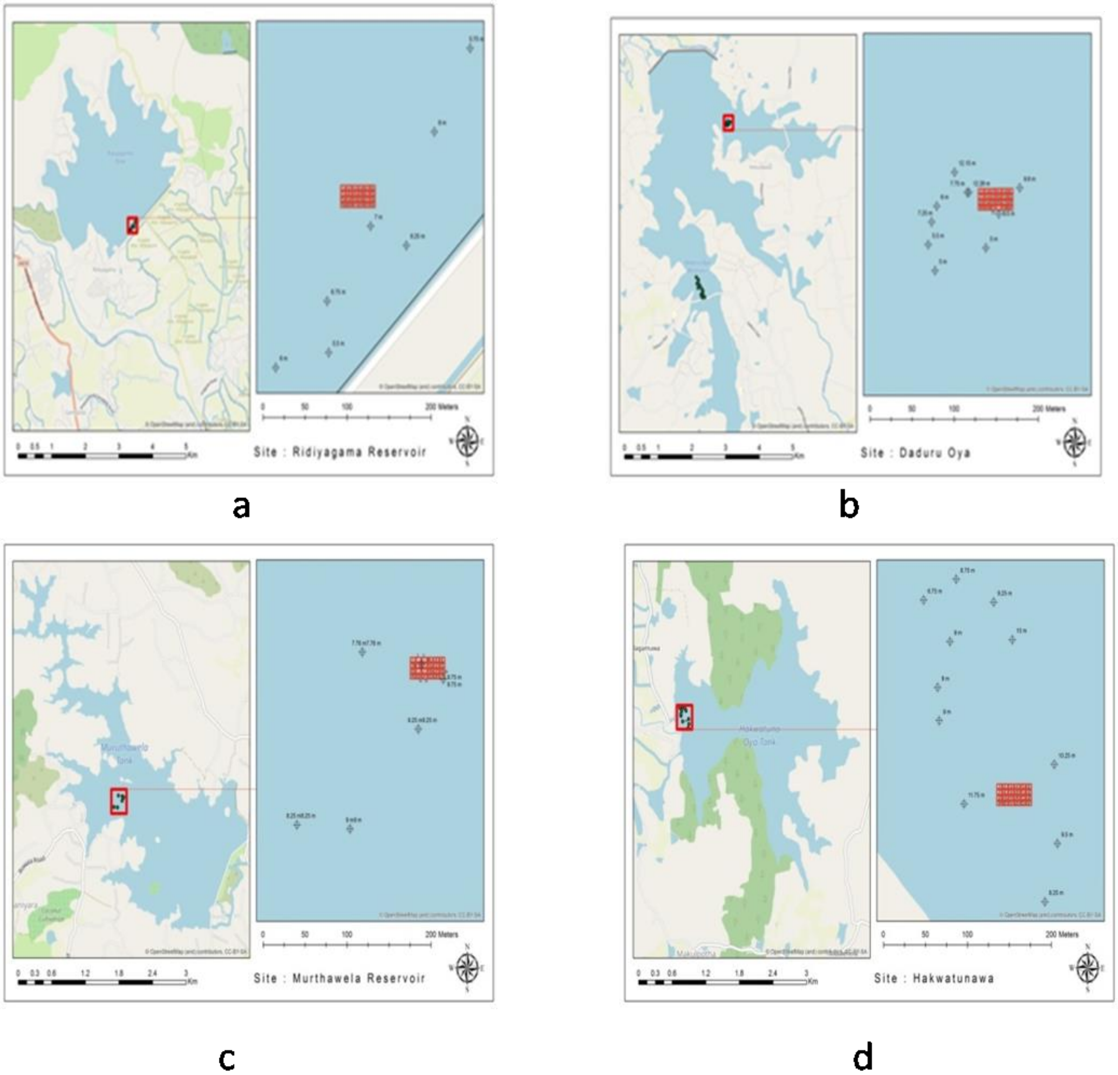


Figure1: Cage sites of reservoirs.

Table 2 illustrate the recorded value of physicochemical parameters of surface and bottom samples of each reservoir. Water temperature and pH of all four reservoirs are in the acceptable limit for fish culture. Maximum and minimum pH values were recorded as 7.6 and 6.4 respectively. DO concentration of all reservoirs are in suitable level for carryout the cage culture practices. Highest conductivity and alkalinity were recorded in Hakwatunawa reservoir (medium perennial) in Kurunegala district. Total Ammonia Nitrogen (TAN), nitrate and nitrite of all four reservoirs are recorded in acceptable level for fish culture. Total phosphorus (TP) and Chlorophyll a (Chl a) content of water directly related to the nutrient content of reservoir and those parameters are important physicochemical parameters need to be considered in cage culture practices in reservoirs. Because the effluent of cage culture operation directly discharge to the surrounding water body and it will cause to increase the nutrient content of the water and it lead to eutrophication condition. Highest TP content (0.07 mg/l) was recorded in Hakwatunawa reservoir and lowest value (0.015 mg/l) was recorded in Ridiyagama reservoir. The recommended TP levels for cage culture in reservoirs is less than 0.1 mg/l.

Table 2: Physicochemical parameters of reservoirs

Water quality parameters	Daduruoya reservoir		Ridiyagama reservoir		Hakwatunawa reservoir		Murthawela reservoir	
	SS	BS	SS	BS	SS	BS	SS	BS
Temperature (^0C)	27.8	25.2	30.43	28.5	28.3	26.5	30.7	28.5
pH	7.1	6.8	7.6	6.3	7.6	6.1	6.4	5.3
Conductivity (µS/cm)	241.6	687	260	583	303	7.5	289	472
Alkalinity (mg/l)	123.3	157.8	162.2	176	185.5	184.4	62	60
DO (mg/l)	6.8	6.3	7.8	5.2	7.2	5.9	7.3	7.6
NH_3 (mg/l)	0.1	0.19	0.08	0.13	0.10	0.16	0.04	0.06
NO^-_3 (mg/l)	0.13	0.23	0.167	0.133	0.167	0.133	0.04	0.06
NO^-_2 (mg/l)	0.007	0.015	0.0037	0.001	0.004	0.004	0.006	0.006
TP (mg/l)	0.03	0.05	0.015	0.017	0.07	0.16	0.015	0.02
Secchi disk reading (cm)	112	-	102	-	145	-	103	-
Chl a (mg/l)	13.49	-	23.6	-	18.6	-	24.17	-

Sediment quality parameters of all four reservoirs are illustrate in table 3 and parameters were recorded in acceptable range for cage culture.

Table 3: Sediment quality parameter in reservoirs

Sediment quality parameters	Daduruoya reservoir	Ridiyagama reservoir	Hakwatunawa reservoir	Murthawela reservoir
Soil pH	5.5	6.7	6.4	6.1
Conductivity (µS/cm)	560	1728	1420	870
Organic carbon	7.8%	12.8%	9.5%	12.05%
TP (mg/100g)	22.1	31.3	28.1	26.2

Locally available ingredients such as Peliyagoda fish meal, Corn, rice bran, soya bean and shrimp head meal were used for feed preparation and required ingredients were purchased.

Site selection of all four reservoirs and purchasing of feed ingredients were completed at the end of the May 2021. Although we finished site selection, NAQDA didn’t provide cages and other floating structures on time due to delay of tender procedures. Therefore, field trails couldn’t be carried out.

Conclusion:

Water quality and sediment quality of selected reservoirs are suitable for cage culture of fry to fingerling and sites which have an average water depth of 5-9 m is recommended.

Progress:

Financial: 62.4% Physical: 40%

Constraint:

Study couldn't be continued due to unavailable of cages and other floating structures on time.

1.14 Feasibility studies on promoting community based oyster culture in Mannar area

Responsible Officer(s) : A.S.L.E. Corea C. B Medagedara

Budget Allocation (Rs.) : 1.94 M

Revised Budget (Rs.) : 1.994 M

Introduction

Edible oyster culture has commenced in the Puttalam district and few community projects are ongoing. To increase the spat availability a new oyster reef was built in Kalpitiya . In view of expanding the culture practices it was decided to explore the possibility of oyster culture in Mannar district. It could increase the house hold income of fisher families and promote nontraditional aquaculture methods. Since the activities can be done by women it would provide self employment opportunities for women. Presently fishermen collect oyster from natural reefs in Manner. However this is seasonal as the quantity is limited when collected from the wild.

Goals and objectives

Increase the commercial bivalve culture among fisher communities to increase household income and opportunities specially for women

Results

Expanding commercial oyster culture

Possible oyster culture areas in Mannar were selected on suitable environmental parameters and 3 sites were selected in Achchankulam, Arippu and Devanpiddy. Discussions with the fisher communities were carryout before culture trials were commenced and community in arippu was not interested in participating. Therefore trials were carried out on achchankulam and devanpiddy

Selected areas were surveyed for present oyster reefs and spat availability. Spat collectors were deployed near natural oyster reefs. At Achankulm Spat availability was 21 4 / 1200cm^2, and at Devanpiddy it was 24 6/ 800 cm^2 during the mid year season on PVC and tile collectors. (April to September as the area could not be visited during COVID restrictions) Water quality continued in optimal levels during sampling.

Water quality in sampling sites

	Achchankulam	Devanpiddy	Kalpitiya
Salinity (ppt)	10 - 30	07 - 38	16 - 32
Water depth (cm)	23 - 82	16 - 98	60 - 122
Temperature (^oC)	27 - 32	27 - 33	27 - 31
pH	8.1 – 8.4	8.0 – 8.5	8.0 – 8.2
Nitrate	0.03 – 0.37	0.07 – 0.82	0.04 – 0.18
Ammonia	0.004 – 0.011	0.008 – 0.041	0.003 – 0.013
Nitrite	0.002 – 0.009	0.004 – 0.012	0.003 – 0.006

Growth studies showed a very high growth rate at Devanpiddy. 6.42mm/ month and at Achchankulam the growth rate was 5.11mm/ month . Mean stocking length at both places was 36.8± 0.58mm. Mean length after 8 months was 81.72± 2.18mm at Devanpiddy and 77.28 ±1.98.mm. Racks at Devanpiddy were damaged in November due to floods and some culture baskets were lost. All racks were renovated at both places in November to prevent further destruction. Survival at the end of 8 months was 93.3% at Devanpiddy and 83.5% at Achchankulam.

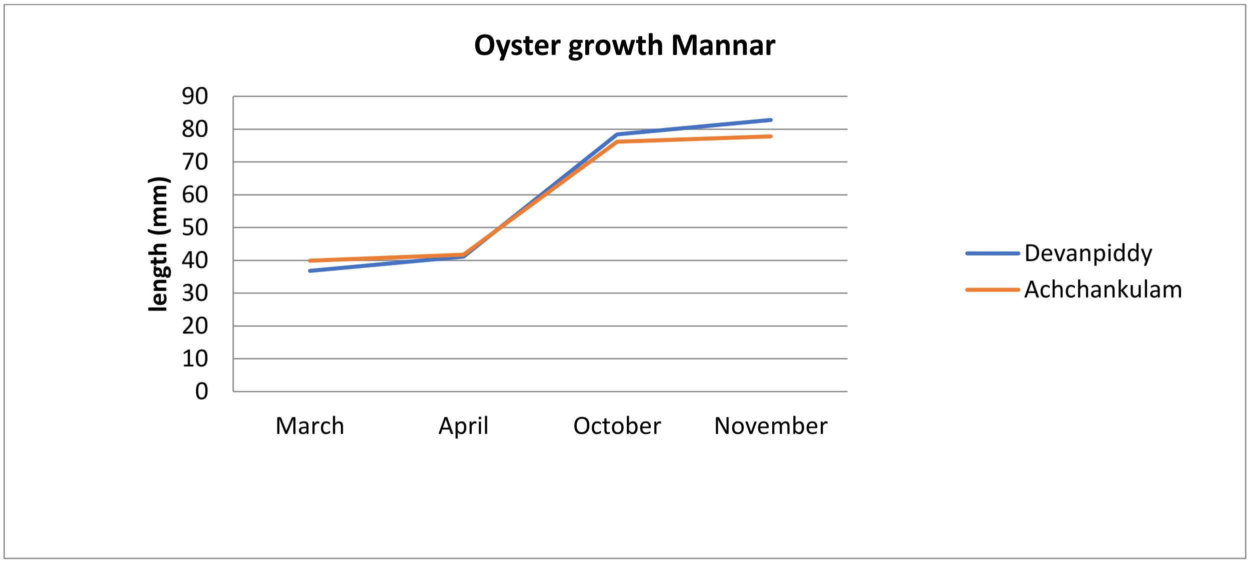


Figure 1: Growth trends during the 8 month period

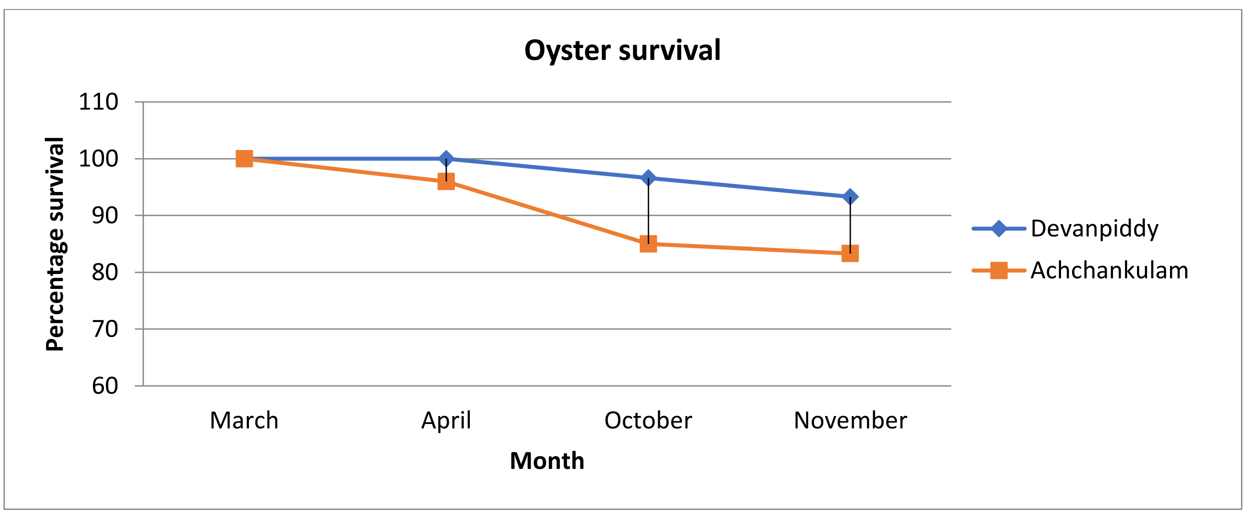


Figure 3: Oyster survival during the 8 month period

Monitoring new reefs at Kalpitiya

The new reef constructed in Kalpitiya was monitored for survival and spat production. Survival of brood stock was 89.4% and recruitment was 16/ 2.5m3. The number of spat collected in the collectors were highest during October being 32/800 cm^2

Knowledge dissemination - Awareness program

One awareness program was held at Devanpiddy for knowledge dissemination at the beginning of culture program and was participated by 9 persons.

Output

Development of community based oyster culture in 2 places in Mannar district

Outcome

Increased aquaculture production

Constraints:

Inability to work with communities during COVID situation as fisher folk were not happy to entertain outsiders.

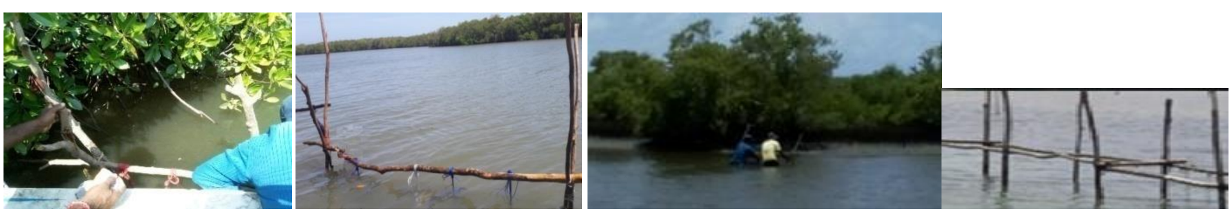
Requested chemicals and equipment were not received.

Adverse climatic conditions during the latter part of the year causing floods damaged culture racks.

Site selection Mannar

Achchankulam & Devanpiddy

Culture racks



Achchankulam & Devanpiddy

Workshops for women **Oyster growth**

Devanpiddy Oysters at Achchankulam after 8 months

Spat collection

Spat collector near Kalpitiya new reef Spat collector Achchankulam

Progress:

Financial : 62.4% Physical : 70%

1.15 Enhancements of community base seaweed culture-through the appropriate seed bank and assessment of their ecological important. (Carbon sequestration and habitats improvement).

Officer/s responsible : J. S. Jayanatha

Budget Allocation (Rs.) : 2.58 Mn

Revised Budget (Rs.) : 1.847 M

Introduction:

The rising of earth temperature is critical issue in present and future; one of the main strategies to control rising earth temperature is increase of Carbon uptake (sequestration capacity extent). This study aimed to estimate the carbon sequestration from atmosphere by taking advantages of seaweed and plants. Seaweed is potential marine vegetation which can be use solar radiation for bio-fixing of Carbon dioxide source into living tissue as biomass. Through the photosynthesis, microalgae can convert inorganic Carbon into their in their biomass and transferring through the food web in herbivores (Erlania and Radiarta 2015, Jensen et al., 2018). The using raw material for produced fertilizer is most popular among the countries. Therefore, main trend to collect wild *Gracilaria salicornia* from Mannar region. To be sustainable utilization availability of biomass of this species must be estimates.

Main objectives:

Established seed bank to carter to community base requirement.

Rapid assessment of *G. saliconia*in Mannar – Kiranchi area

Determination of ecological carbon fixing rates in different culture species

Specific Objective/s:

estimation of carbon sequestration in *K. alverazii*,

unit biomass calculation of *G. saliconia*

Methodology (Study area, Field sampling, data collection and analysis)

The Carbon sequestration of seaweed/macro algae was estimated using the oxygen exchange method. The *Kappaphycus alverezii* green and brown strains were used. Thallus sections weighted 10g were inserted into clear bottles filled with seawater and incubated for 3 hours with 3 tree replicates to seaweed and bottles were attached to the seaweed culture lines.

The bottles filled with ambient water (with usual seawater with phytoplankton) were used as control. After 3 hours titration was used to ensure the oxygen exchange in the each bottles, results converted to Carbon sequestration. The total carbon sequestration each cycles was estimated.

The estimation of carbon sequestered in *Kappaphycus* biomass calculation was done measuring carbon content.

Thus carbon sequestration was calculated using formula described by Muraoka,2004.

C seq=A×S×P-B ratio × C

total area of cultivation site=20 acres

standing stock of *kapphycus* (g/m2)

P-B ratio: implies with production-biomass

C: carbon content (%)

SGR = {(Wt/W0)1/t -1}×100%

where: SGR = specific growth rate (%/day), Wt = final weight (g), W0 = average initial weight (g), t = length of cultivation (days).

Sampling procedures-

Quadrate (0.25m^2 ,n=67) measurements of fresh weight biomass were made for the dominant area. Quadrates were haphazardly thrown, with all macro algae removed ad obtained fresh weight. The central location transects were recorded using GPS unit. Species were identified and divided into groups for weighing in the boat.

Study area-

Collections were made at Kiranchi area, shore is characteristics by soft and brain coral rich area. The Rocky tidal pools of various sizes important for different micro-and macro algae distribution.

Plant collection-

The algae collection was made in 2021 during the low tide from January-March due to Covid-19 pandemic. Sampling for biomass estimation was carried out according to Buriyo (1999).

Activities proposed to be completed during the period

assessment of *G. saliconia* biomass,

carbon sequestration from *K. alverazzi*

Results:

Activities carried out:

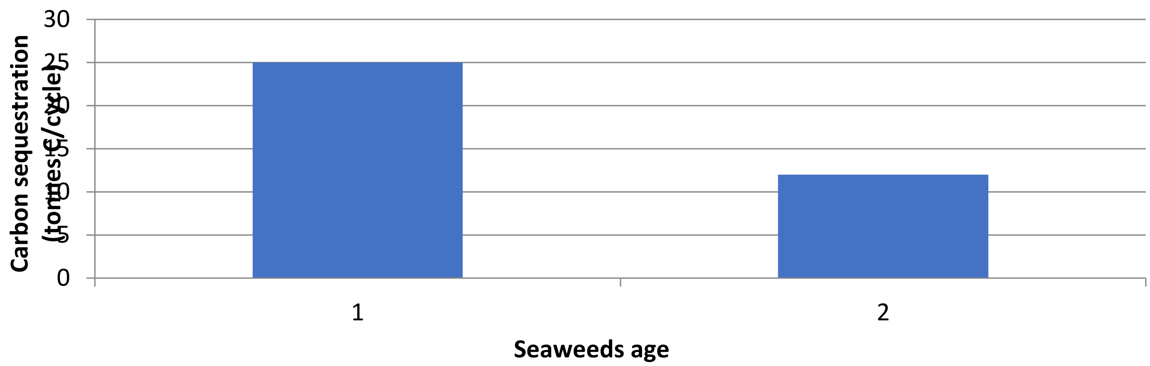
Total surveyed area =16.75m^2

Total number of quadrates(n) = 67

Total fresh weight = 178738g

Total weighing plants =389

Fresh biomass during the survey along the inter tidal areas =10670.93g/m^2



1 - 25 days, **2** - 45 days (20 acres extent production)

Fig.1 Carbon sequestration in *K. alverazii* with different harvesting stage.

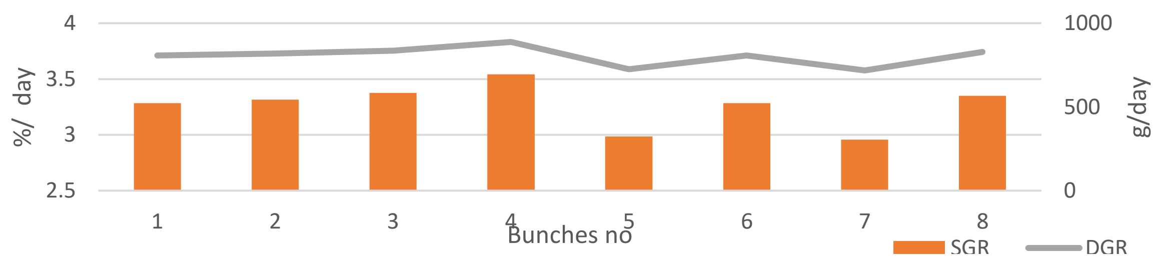


Fig-2 Adult seaweed growth increment during the study

Outputs & outcomes

The production of *G.salicornia* could be targeted to only few members in kiranchi area. Fresh biomass during the survey along the inter tidal areas =10670.93g/m^2

The *K.alverazii* has shown highest sequestration process during the young stage.

Increasing number of production units would be advantages to climate change mitigation process.

Conclusions

The harvesting if wild *G.salicornia* could be achived upto 50% of the thier bundance.

The K.alverazii aquaculture needto be suppply technical support for incrasing farming extent.

Recommendations

The harvesting quantity need to be control around 50% from the total and licensing method and follow up measures must be taken before devastating seafloor.

Constraints-

Regular monitoring and quantification have not been conducted during the covid situation.

Progress:

Financial : 52.8 Physical : 60%

1.16 Disease monitoring, prevention and monitoring water quality conditions for health management in shrimp aquaculture industry in Sri Lanka

Officer/s responsible : LakshikaJayasekara, Pradeep Chathuranga, P.P.M. Heenatigala,

Budget Allocation (Rs.) : 4 Mn

Revised Budget (Rs.) : 4.20 M

Introduction

Aquaculture remains highly vulnerable to adverse impacts of disease. Disease outbreaks in recent years have affected marine shrimp farming in several countries around the world. In the early days of shrimp aquaculture, pathogens were largely limited to specific geographic locations. However, the rapid growth of the industry and the associated globalization of trade led to the emergence of serious diseases in Asia (spherical baculo-virus (SB), yellow head disease (YHD) and white spot disease (WSD)). The majority of these diseases have caused significant production issues in shrimp farming regions distant from their original site of emergence.

Disease plays a major role in limiting shrimp production from aquaculture. Approximately 40%of potential penaeid shrimp production is estimated to be lost to infectious diseases each year (Stentiford *et al*., 2012). Approximately 60% of disease-associated losses in shrimp aquaculture are attributed to viruses, with bacteria accounting for a further 20%.As noted by Stentiford*et al.* (2012), the emergence and rapid spread of serious diseases of penaeid shrimps on a regional and global basis has resulted primarily from poor industry practices, including the careless trans-boundary movement of brood stock and PL of unknown or poorly known health status and the common practice of siting shrimp production facilities near natural water bodies where transfer of pathogens between cultured stocks and wild decapods crustaceans continues to contribute to the emergence of new diseases, even in originally SPF stocks of penaeid shrimp. In the future, improved siting of farms in bio-secure settings is expected to contribute to a reduced emergence rate of significant pathogens in penaeid shrimp (Flegel, 2012).

Concerning the high growth rate and stocking density, *L. vannamei*,a non-native shrimp species has been very recently introduced to our shrimp culture systems and imported SPF brooders are used for the seed production. However the effect of this species on our culture system is not known. *L. vannamei* has been identified as the carrier for number infectious diseases. It is now being apparent that many of the introductions and movements of aquatic animals have been responsible for the introduction and spread of aquatic animal pathogen species into new geographical areas and hosts. Once established in natural environment and hosts, such pathogens are almost impossible to eradicate. Thus close monitoring of *L. vannamei* culture in Sri Lanka is an urgent requirement for disease prevention and management in the culture system.

Luminescent vibriosis is one of the major disease problems in shrimp culture. As luminous vibrios affect serious mortalities in shrimp larval rearing systems, it is imperative that measures for their control be developed. Chemical treatment of luminous vibriosis among shrimp larvae is quite limited because of the ineffectiveness of existing and readily available drugs, possible development of resistance in bacteria, it appears that the best method would still be prevention, with particular concentration on rigorous water management and sanitation to prevent the entry of luminous vibrios through the culture water.

Main objective

Activity 01: Disease monitoring, prevention and health management in *L. vannamei* culture

Activity 02: Bio -Control of *Luminous Vibrios* in Shrimp hatchery systems.

Objective/s

Activity 1:

Monitoring/ identify the disease outbreaks in *L. vanamei* culture systems.

Identify the suitable preventive and control measures to minimize the virus disease out breaks in shrimp aquaculture.

Minimize losses from disease outbreaks through early disease diagnosis.

Recommend suitable control measures and corrective actions for the disease identified

Develop of database on disease outbreaks in shrimp aquaculture

Activity 2:

Identify the roots of infections /associated factors causing the luminous disease outbreaks with respect to biosecurity measures.

Evaluate the water treatment system and their effectiveness.

Identify the suitable preventive and control measures to minimize the bacterial disease outbreaks in shrimp hatcheries.

Methodology

Activity 01: Disease monitoring, prevention and health management in *L. vannamei* culture

Samples were collected representing all 5 shrimp culturing zones and background data collected with the help of pre developed questionnaire.

DNA was extracted using extraction buffer of IQ 2000 test kit WSSV detection test kit

PCR was performed with Test kit IQ 2000.

Identification of disease positive shrimps.

Diseases monitored under the disease monitoring programme

White spot disease (WSSV)

Infectious Hypodermal and Haematopoietic Necrosis disease (IHHNV)

<u>Activity 02:</u> Bio -Control of *Luminous Vibrios* in Shrimp hatchery systems

Hatcheries (A grade, B grade and C grade) selected to conduct the study with the help of SLADAA.

Background information of all hatcheries collected with the help of pre developed questionnaire

Water treatment systems of all hatcheriesmonitored.

Several sampling carried out.

Total vibrio count (TVC), of the samples collected carriedout in the laboratory.

Sequencing based bacterial identification carried out to identify the pathogenic bacteria when required.

Recommending corrective actions and management plans.

Activities proposed to be completed during the period

<u>Activity 01/02</u>

Activities targeted for the year included; Procurement of Test kits (PCR), chemicals, consumables and equipment

Sample and data collection from shrimp farms/hatcheries

Laboratory analysis (PCR analysis for diseasesand Bacteriology analysis).

Results:

Activity 1:

Procurement of consumables /chemicals /commercial diagnostic kits

Shrimp samples collected from 300 sampling points of 100 grow out ponds, representing all 05 Zones, for PCR analysis from farms ranging from Grade A, Grade B^+, Grade B, and Grade C.

Extraction of DNA done for all 300 samples by pooling to get 100 DNA samples of respective ponds as well as WSSV and IHHNV testing done for the samples.

Diagnostic kits for other diseases acquired, in view of continuity of the project.

Figure1: Percentages of grouped samples as per stocking density (Unit: animals/ m^2)

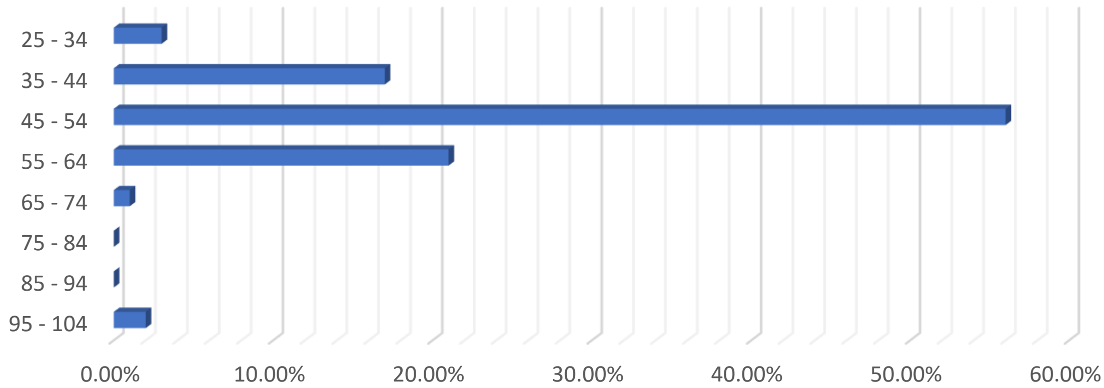


Figure 2: Prevalence analysis on WSSV with current data

WSSV - Negative	94.00%
WSSV - Positive (Severe)	1.00%
WSSV - Positive (Moderate)	4.00%
WSSV - Positive (Light)	1.00%

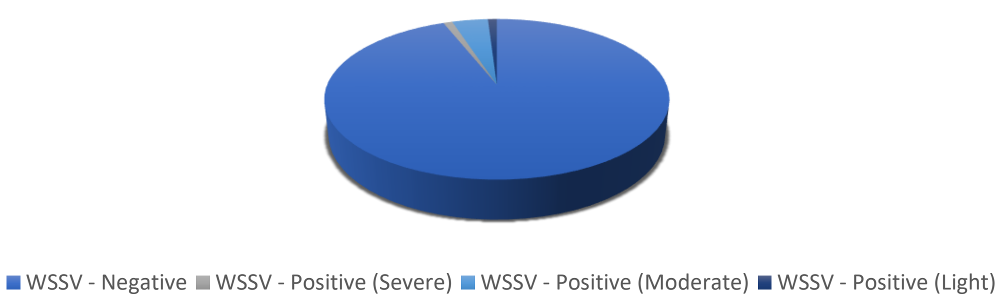
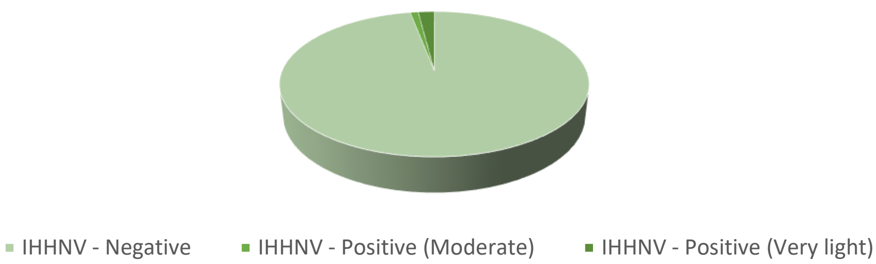


Figure 3: Prevalence analysis on IHHNVwith current data

IHHNV - Negative	97.00%
IHHNV - Positive (Moderate)	1.00%
IHHNV - Positive (Very light)	2.00%



Activity 2:

Procurement of consumables /chemicals

Water samples collected from 52 sampling points (including initial tank, chlorinated tank, post-UV treatment, post-larval tank) to represent 11 hatcheries for bacteriology analysis of 52 samples.

Areas samples collected from

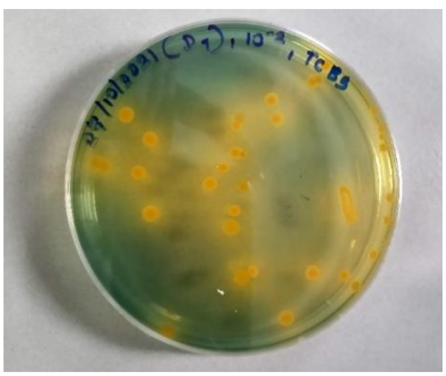
Thoduwawa road, Ambakandawila, Chillaw

Analysis

Vibrio positive samples: 16

Rate positive/analyzed: (16/52) 30.76%

Figure 4: Vibrio isolated from water samples collected from shrimp hatcheries



Outputs & outcomes

Output:

Generate prevalence information on accurate information of the disease circulating in the shrimp farming industry and hatcheries

Strengthening the disease diagnostic capacity at NARA dealing with related research on aquaculture bio technology.

Outcome:

Generating data for formulating and improving regulations for better disease management techniques, that could ultimately safe guard the sustainability of shrimp aquaculture and shrimp production in Sri Lanka.

Conclusions

With current data generated, we have observed an annual prevalence of the respective diseases as follows; *White spot syndrome virus* (*WSSV)* to be prevalent 6%, whereas, *Infectious Hypodermal and Haematopoietic Necrosis Virus* (IHHNV) to be prevalent 3%;

Recommendations

Acquire longitudinal and continuous data over several years to confirm and establish thefigures as the annual prevalence rate of the industry for the respective diseases (WSSV, IHHNV).

Expansion of PCR diagnosis of shrimp diseases further for the diseases for which, commercial diagnostic kits are procured (Taura syndrome (TSV), Yellow head disease (YHV), Necrotizing Hepatopancreatities (NHP), Acute Hepatopancreatic Necrosis disease (AHNDP))

Expansion of bacteriology analysis to further tests including Total Plate Count.

Constraints

The pandemic and island-wide imposed lock down resulted in an year long delay, in procurement of disease diagnostic kits/ chemicals/ consumables. As such, the commercial diagnostic kits for testing 4 other shrimp diseases were acquired only in last month of the year.

Due to lack of human resource, and island-wide imposed lock down sample collection and analysis for bacteriology analysis (activity 2) was limited to final quarter of the year.

Initially the project included another component (activity 3) for Monitoring water quality condition in Effluent and Estuarine Water source in Shrimp Farming area in North western province, however, due to lack of human resource, and island-wide imposed lock down sample collection and analysis was hindered.

Progress:

Financial :95.3%   Physical : 98%

1.17 Surveillance of disease prevalence in aquaculture with special reference to ornamental fish, Mud Crab (*Scylla serrata*) and Giant Fresh water Prawn (*Macrobrachiumrosenbergii*) in selected areas of Sri Lanka.

Officer/s responsible : A. D. W. R. Rajapakshe

Budget Allocation (Rs.) : 1.765 Mn

Revised Budget (Rs.) : 1.333 M

Introduction:

Diseases are one of the major constrain in ornamental industry. Among these diseases Bacterial, viral and parasitic infections can be found. Parasitism is one of the most impacting problem in aquaculture industry and it is well established in ornamental fish industry that bacterial infections are responsible for heavy losses from the farm level to the hobbyist tanks (Hettiarachchi, D.C and Cheong,C.H;1994.).

The effect of parasitism in fish result poor growth /production and the susceptibility to secondary infections (Scholz, 1999).Most parasitic diseases harm the quality of fish which directly affects the marketable price of fish. Therefore attempt will be made to determine the prevalence of gill and skin parasites in most common fresh water ornamental fish species and investigate the bacterial infections in ornamental fish in these two district by characterizing the pathogen and to determine the sensitivity of the bacteria involved to commonly used antibiotics with a view to provide the farmers with the information on effective treatments.

Activity 1: Surveillance on Disease condition of wild and cultured Mud Crabin Western and North Western Province in Sri Lanka

Mud crab farming is being popularized among Sri Lankan farmers at present. Most of the mud crabs are been collected from the wild. There is a good demand for Mud Crab in the local and export markets. Pond culture and vertical crab farming are being practiced in coastal areas in Sri Lanka mainly in lagoon areas such as Negombo, Chilaw and Puttlam. Frequent disease incidence have been recorded in cage culture and vertical farming practices of mud crab. Nevertheless systematic surveillance on crab disease incidences has not been so far carried out in Sri Lanka.

Therefore this study will be focused on the prevailing disease conditions of wild and cultured crab in selected areas and attempt will be made to diagnose the etiology.

Activity 2: Surveillance of disease prevalenceof Giant Fresh Water Prawn (*Macrobrachium rosenbergii*) in two hatcheries and selected tanks in Hambantota District.

Giant Freshwater Prawn, is a main candidate for aquaculture in inland waters due to the attributes of becoming gravid in captivity, availability of established techniques for seed production in hatcheries and grow-out culture (Ariyaratne & Amaraweera, 2015). This species has recently emerged as an important shellfish species for culture in south Asian countries after the significant losses observed in penaeid shrimp culture during mid-1990s due to viral diseases (Hasanuzzaman et al. 2009). Faced with increasing disease problems in penaeid shrimp culture, farmers turned to freshwater prawn farming. Freshwater prawns were considered relatively less susceptible to diseases. However, with intensification of culture and increased world trade of the farmed species, emerging diseases are beginning to constitute an increasingly serious health problem in freshwater prawn culture (Pillai, and Bonami, J.R, 2012). National Aquaculture Development Authority (NAQDA) also has stocked *M. rosenbergiil* arvae in minor perennial reservoirs and has obtained poor survival (J.M. Asoka, Pers. Comm. 2007).Therefore attempt will be made to identify the disease conditions of fresh water prawn larvae and adult in selected places.

Objectives:

Understanding the commonly encountered disease conditions in ornamental industryand investigate the therapeutic and control measures.

Study the seasonality of the parasites and bacteria inhabiting in selected ornamental fish species.

Aware the farmers to identify ornamental disease conditions& to apply control measures and to inform or bring the samples with desired transportation methods.

Investigation on disease conditions of wild & cultured Mud Crab and Fresh water prawn in Sri Lanka

Activities carried out (Methodology)

Conducted Literature survey on prevailing disease condition in ornamental, crab and *Macrobrachium* industry.

Selected sites from Negombo, Chilaw, Kalutara, Matara and Hambantota.

Collected Samples and information from each sites at monthly intervals.

Analyzed the samples in the laboratory and identified the parasite and bacteria cultures.

Clinical and histopathological observation were carried out.

Conduct challenge experiment in the laboratory for the bacteria extracted from guppy fish.

Findings

Water Quality results obtained from disease infected farms

Ornamental Farms

Site No.	pH	DO (mg/l)	Tem. (C°)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
1	7.20	6.8	25.8	0.3	0.154	0.8
2	7.01	5.9	26.5	0.89	0.214	0.9
3	7.08	6.4	25.5	0.91	0.356	1.3
4	7.05	6.2	26.1	0.59	0.169	1.1

Crab Farm (Chilaw)

Pond	Alkalinity (mg/l)	pH	Salinity ppt	Ammonia (mg/l)	$PO4^-$ (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
1	100	7.52	8	0.04	0.09	0.016	1.5
2	107	7.48	8	0.01	0.66	0.009	0.5
3	118	7.62	9	0.03	0.85	0.01	0.4

Negombo Lagoon

Fig. 1 : Sample collection and microbiological analysis

Limited field visit were conducted for crab an Macrobrachium disease investigations.Bacteria isolated from the samples and should be identify the species level by sequencing.Mainly focused on the guppy disease condition in Kalutara district and collected water and fish samples.Investigations revealed that the isolated bacteria are non pathogenic by challenge studies. Therefore it is suspected that due to viral infection and samples were submited to CAADDAR for futher investigations.

Conclusions

Further studies needed foe better conclusion.

For guppy disease condition , there should be a collobaration with NAQDA,CADDAR

Outputs

Isolated bacteria for guppy are non pathogenic.

External parasites are not prominant in aquarium fish

Progress:

Financial :30.9% **Physical** : 40%

Constraints:

Unable to continue the project work due to COVD 19 impact.

Cage culture activities were reduced due to the heavy rain conditions in Negombo .

1.18 Establishment of Epidemiology unit at National Aquatic Resources Research and Development Agency (NARA) and Establishment of a PCR laboratory facility for shrimp aquaculture research at Pambala and shrimp disease monitoring unit at Baththuluoya, Chilaw.

Officer/s responsible : P.P.M. Heenatigala, WasanthaRajapaksha, B. M. L. P. Jayasekara

Budget Allocation (Rs.) :0.7 Mn

Revised Budget (Rs.) : 0.518 M

Introduction:

NARA is the premier institution for Scientific Research in Conservation, Management and Development of Aquatic Resources in Sri Lanka, it aims for high quality research and training and disease diagnostic capacity in aquaculture sector to satisfy the present and future scientific and technological demand of the fisheries sector. In order to achieve this goal,

critical research and facilities, infrastructure enhancements and academic gaps and shortfalls of the institution must be ameliorated and/ or eliminated.

As currently there is no establishment in Sri Lanka specifically for epidemiology of fish health, to provide advisory and consultancy services on scientific and technological matters relating to the aquatic animal health management and conservation development of aquatic resources. Thus, establishing an epidemiology unit of aquatic animals, at NARA is timely and an urgent requirement for the development of the aquaculture sector of the country and at the same time utilize the existing aquatic resources effectively.

More over as the key research and development institute related to aquatic resources, expanding the disease diagnostic and monitoring capabilities of NARA up to regional level, by establishing regional units as centres for aquaculture disease monitoring and management would be mandated for the sustainable aquaculture development. Through that NARA will be able to provide expert support in more rapid, efficient and effective manner in aquatic animal disease monitoring as well as diagnosis in aquaculture facilities in every region and imported and exported aquatic animals

Objectives:

Provide rapid and better aquaculture health extension services through conducting applied research, quarantine, surveillance and bio-security programs.

Upgrade and enhance laboratory diagnostic services for finfish and shellfish clients.

To enhance the institute’s ability to adopt and use advance technologies with knowledgeable staff.

To build a more efficient, effective and highly motivated team which enhance the institute’s position.

Establish a fully equipped PCR facility at Pambala and decentralise the PCR reaction load carried out at NARA premises and easy access to farmers for the NARA disease diagnosis services.

Activities carried out (Methodology)

Purchasing work for required chemicals for epidemiology work were completed.

4 site visits carried out to select the suitable location to establish PCR laboratory at Chilaw area

Condition of the available machines /equipment at North western provincial (NWP) regional resources development authority was assessed. Report on acquirable equipment, further necessary equipment to establish a laboratory and staff requirement is prepared.

2 meetings were held with the managing director of NWP regional resources development authority, Pambala to obtain facility to accommodate PCR laboratory Pambala.

1 meeting with NWP regional resources development authority, Pambala and secretary to the minister was held as further discussion.

As the previously agreed site offered by NWP regional resources development authority, Pambala is not availableanda different location with semi constructed establishment at Mundalama was proposed by NWP regional resources development authority.

After visiting the site, the total financial requirement for construction, maintenance and acquiring necessary facilities, machines and staff, was assessed.

Outcome:

As the space that had been previously used for activities of the PCR laboratory is now being used for tissue culture purposes by the staff of Regional Resources Development Authority, NWP, Pambala, an abandoned establishment at Mundalama was proposed to be used for the laboratory for NARA. Accordingly, the NARA team visited to the Mundalama said place (Figure1).After visiting the site, it was decided that should the NWP reach an agreement with NARA to provide the facility to NARA, NARA could renovate/ establish additional construction to develop the facility as a PCR laboratory. In such case, NARA would newly recruit two research assistants, a laborer/ helper and a security officer to maintain the laboratory. As an incentive for providing the premises, in case of commercializing the PCR testing services provided by NARA for shrimp farmers at the facility, the possibility of channeling a certain percentage of any profit generated, to North Western Provincial Council was also discussed.

Fig 1: Site visit Mundala to establish PCR laboratory

NARA team sent an official request to the NWP office, to obtain the establishment long term.

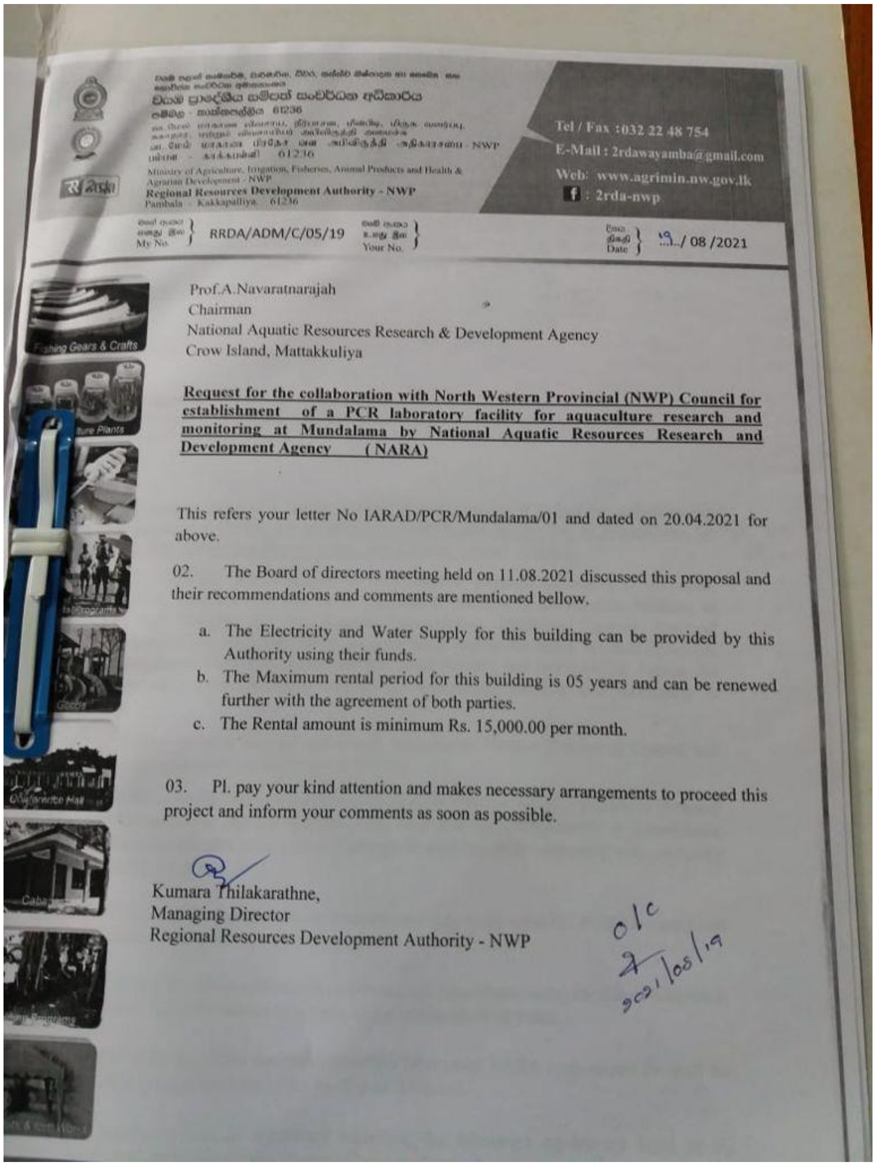
And the board decision (Annexure 2) given by the NWP was as follows.

The electricity and water supply for the building will be provided by NWP using their funds.

The maximum rental period for the building was 05 years and agreed to renew further with the agreement of both parties.

NARA has to pay Rs. 15,000.00 per month.

<u>Annexure 2:</u>



වයඹ ප්‍රාදේශීය සම්පත් සංවර්ධන අධිකාරිය

Ministry of Agriculture, Irrigation, Fisheries, Animal Products and Health & Agrarian Development - NWP
Regional Resources Development Authority - NWP
Pambala - Kakkapalliya 61236

Tel / Fax :032 22 48 754
E-Mail : 2rdawayamba@gmail.com
Web: www.agrimin.nw.gov.lk
: 2rda-nwp

My No. RRDA/ADM/C/05/19 Your No. Date 19../ 08 /2021

Prof.A.Navaratnarajah
Chairman
National Aquatic Resources Research & Development Agency
Crow Island, Mattakkuliya

Request for the collaboration with North Western Provincial (NWP) Council for establishment of a PCR laboratory facility for aquaculture research and monitoring at Mundalama by National Aquatic Resources Research and Development Agency (NARA)

This refers your letter No IARAD/PCR/Mundalama/01 and dated on 20.04.2021 for above.

02. The Board of directors meeting held on 11.08.2021 discussed this proposal and their recommendations and comments are mentioned bellow.

a. The Electricity and Water Supply for this building can be provided by this Authority using their funds.
b. The Maximum rental period for this building is 05 years and can be renewed further with the agreement of both parties.
c. The Rental amount is minimum Rs. 15,000.00 per month.

03. Pl. pay your kind attention and makes necessary arrangements to proceed this project and inform your comments as soon as possible.

Kumara Thilakarathne,
Managing Director
Regional Resources Development Authority - NWP

o/c
2021/08/19

Progress:

Financial : 25.6% Physical : 40%

Constraints:

The previously agreed site offered by NWP regional resources development authority, Pambala is not available anymore as it is been planned to use for tissue culture laboratory expansion by the said authority.

COVID pandemic condition limited the targeted activities.

2 Marine Biological Research Division

No	Project Title	On going	New
2.1	Monitoring and assessment of small pelagic fishery resources	Ongoing	
2.2	Monitoring and assessment of large pelagic fishery resources	Ongoing	
2.3	Study of some biological and fisheries aspects of selected edible finfish species in the demersal fishery in the South-eastern coast of Sri Lanka	Ongoing	
2.4	Biological and fisheries aspects and population characteristics of data poor Anchovy fishery in West Coast, Sri Lanka.		New
2.5	Study of biology, fisheries and population structure of common shark species of Sri Lanka and the status of shark fin trade.	Ongoing	
2.6	Sea urchin fishery development in Sri Lanka.	Ongoing	
2.7	Sea cucumber fishery assessment in Northern and Northwestern waters	Ongoing	
2.8	Spiny lobster fisheries management, in situ conservation of berried spiny lobsters and lobster fattening	Ongoing	
2.9	Assessment of ecosystem health using bio-indicators associated with nutrient enrichment and sedimentation on some targeted coral reefs in Sri Lanka		New
2.10	Studying the fisheries and marine mammal interactions and declaration of marine mammal protected areas in Sri Lanka	Ongoing	
2.11	Strengthening marine fisheries data collection in Sri Lanka	Ongoing	
2.12	Fisheries independent surveys in the coastal areas in Sri Lanka	Ongoing	
2.13	DNA barcoding of marine fish species found around Sri Lanka.		New

2.1 Monitoring and assessment of small pelagic fishery resources

Introduction

Coastal fisheries in Sri Lanka primarily target small pelagic species but also other species including large pelagic and demersal fish. The small pelagic group represents over seventy marine species found in Sri Lankan waters. However, the key target species groups in the fishery are sardines, herrings, anchovies and mackerels. Unsustainable fishing practices exist in the fishery such as effort increase, night fishing during spawning seasons and use of smaller mesh size gillnets operated targeting immature fish.

Small pelagic fish species form an important part of the animal protein requirements of Sri Lankans while contributing over 40% to the marine fish production of the country. The small-scale artisanal fishermen operated with small meshed gillnets and outboard engine Fiber Reinforced Plastic (OFRP) boats mostly targeting small pelagic fish species. Surrounding nets are also used in some districts. In addition, the beach seine, a traditional fishing gear operates seasonally in Sri Lanka, also catches a considerable quantity of small pelagics. However, at present, there remains a doubt in the potentiality of coping with the unprecedented challenge of rapidly growing food demands under the unsustainable fishing practices and deteriorating environmental conditions with limited small pelagic resources.

Marine Biological Resources Division (MBRD) of NARA has been monitoring small pelagic fish landings over a number of years with the aim of assessing the status of the resources with the key objective of ensuring the long-term sustainability of the resources. MBRD continued the port sampling data collection program at major and minor small pelagic fish landing sites in Sri Lanka in 2021 despite the COVID-19 pandemic situation. Further, the biological study on Big eye scad *Selar crumenophthalmus* and Indian mackerel, *Rastrelliger kanagurta*, of the west coast of Sri Lanka were conducted. These investigations help to provide the needful recommendations for the sustainable utilization of the small pelagic resources.

2. Officer/s responsible:

Dr. S.S.K. Haputhantri, Dr. R.P.P.K. Jayasinghe, Ms. K.H.K. Bandaranayake, Mr. Madhura Weerasekara, Ms. Udari Ayesha and Ms. Dilukshani Gayathri

3. Main objectives

Collect and analyze catch and effort data, fishery-related parameters and biological data to assess the small pelagic fishery resources

Assess the status of key stocks in the West coast

Establish strategies for development / management of small pelagic fishery resources.

Provide management recommendations for sustainable utilization of relevant fishery resources.

4. Specific objective/s:

Updating the small pelagic database for commercially important species

Carryout biological studies for selected key species

5. Materials and methods

Data collection

The small pelagic fishery data collection was carried out at major and minor landing sites of the island according to the new sampling scheme developed under the Sri Lanka- Norway bilateral project. The data collection included reporting fish landings by species, details on fishing operations: fishing time (true fishing time and total fishing time), gear operated depth, number of fishing devices used and their sizes (for example, number of net pieces used in the gillnet fishery and their mesh sizes). In addition, biological data (length-frequency data) of key species were collected. The data collected by tablet software is stored in a database maintained by the Department of Fisheries and Aquatic Resources (DFAR).

Biological data analysis of commonly caught small pelagic species

The samples of the Big eye scad *Selar crumenophthalmus* and Indian mackerel, *Rastrelliger kanagurta* were collected from Beruwala, Negombo and Chilaw landing sites. Length (SL, TL) and body depth of all the individuals were measured to the nearest 0.01 mm, body weight was weighed to the nearest 0.1 gram. Growth coefficient (b) and condition factor (K) were analyzed to get the length-weight relationship of each of the species and sex was determined by internal examination. Maturity of gonads was macroscopically examined from the weight, colour, shape of the gonad. Percentage of mature fish were plotted against length frequency and the size at which 50% and 95% of the fish attain maturity were calculated to find out the size at maturity. Size at first sexual maturity was assessed using the following equation: P = A (1+e (-r (Lt-L50)))-1; where P is the proportion or ratio of reproductive females for each size class; A is the curve asymptote; Lt is the total length (cm) and L50 is the size at first maturity (Nelson et al 2009) in Solver function in MS Excel.

CPUE standardization

The historical fisheries data collected since 2000 was made use of for assessing the stock status of key small pelagic stocks on the west coast. Accordingly, the catch per unit effort (CPUE) of 80ported sardinella (*Amblygaster sirm*) in the small meshed gillnet fishery operated with OFRP boats on the west coast was standardized by Generalized Linear Models (GLM) using the Delta-log normal approach. The CPUE data of *A. sirm* were first prepared in the form of catch in kilograms per boat per hour and this was used as the response variable for CPUE standardization. The categorical predictor variable considered are year (20 levels: 2000, 2001, …, 2019), season (4 levels, 1: January – March; 2: April -June, 3; July – September; 4: October - December), district (3 levels: Kalutara; Negombo; Chilaw), total fishing time (TFT) (4 levels: 1: < = 6; 2: 6> and <=12; 3: 12> and <=18; 4: >18), gear operated depth (FD) (5 levels: 1:1< and >=20; 2: >20 and <=40; 3: >40 and <=60; 4: >60 and <=80; 5: >80) and number of net pieces (NNP) used (5 levels:1: 1 -10; 2:11-20; 3:21-30; 4:31-40; 5:41-50).

Stock assessment of *A. sirm* using JABBA and LBSPR

JABBA (Winker et al., 2018) is a generalized Bayesian State-Space Surplus Production Model. Default JABBA features include: 1) an integrated state-space tool for averaging and automatically fitting multiple catch per unit effort (CPUE) time series; 2) data-weighting through estimation of additional observation variance for individual or grouped CPUE; 3) selection of Fox, Schaefer, or Pella-Tomlinson production functions; 4) options to fix or estimate process and observation variance components; 5) model diagnostic tools; 6) future projections for alternative catch regimes; and 7) a suite of inbuilt graphics illustrating model fit diagnostics and stock status results (Winker et al., 2018).

Data poor stock assessment methods have been developed for assessing the fish stocks and length-based spawning potential ratio (LBSPR) is a widely applied method (Hordyk et al., 2014; Hordyk et al. 2015a & 2015b; Prince et al., 2015). This approach is a cost-effective method to assess data poor fisheries using length-frequency data (Hordyk et al., 2014; Hordyk et al. 2015a & 2015b). Accordingly, the LBSPR model always needs minimal data: length composition and life history information with regard to the species concerned. Normally, life history parameters such as L_∞, k and M are estimated with uncertainties. Therefore, stochastic LBSPR in which SPR is defined with an uncertainty of L_∞ and M/k is better than the deterministic SPR in which SPR is estimated without considering the uncertainty of life-history parameters.

Annual catch estimates and normalized CPUE indices of *A. sirm* were made use for the stock assessment conducted using JABBA. Since the estimated CPUE index at the beginning of the time series of spotted sardinella was low, the first data point was excluded. The stock assessment models were constructed in an open-source environment, JABBA (Winker et al. 2018).

A sensitivity analysis with regard to hyperdepletion and effort creep with the uncertainty in the catch estimates was carried out. Accordingly, each model was run for 300,000 iterations, sampled with a burn-in period of 50,000. The estimated values for management reference points (MSY, B/B_{msy}, and F/F_{msy}) with respect to different input data were explored accordingly. The sensitivity was examined with the Schaefer, just for a reference case.

SPR requires some input values based on life-history parameters which are natural mortality (M), growth coefficient (K), asymptotic length (L_∞), and length at 50% maturity (L50) and 95% maturity(L95). The below values are average values in the life history parameters of *A. sirm* for the west and southwest coasts of Sri Lanka obtained from FishBase (Fröese and Pauly, 2020):

L_∞=25.3,

k=1.58,

M/k=1.95,

L50=15.45 (Karunasinghe and Wijeyaratne 1998),

L95=16.6

In addition, the length data file used for LBSPR assessment comprises of length data of *A. sirm* in 2002-2006, 2008 -2009 and 2018 – 2020. In order to describe the uncertainty of SPR estimation, a bootstrap in which one thousand iterations were run specified prior distributions for the M/k with CV 0.2, K with CV 0.1, and L_∞ with CV 0.1. The limit and target reference points were set at 20% and 40% of the SPR respectively.

6. Results and discussion

The standardized CPUE indices were obtained using the results of Bernoulli-based and Gaussian-based GLM models (Figure 1). The lowest standardized CPUE indices were respectively reported at the end and start of the time series (Figure 2).

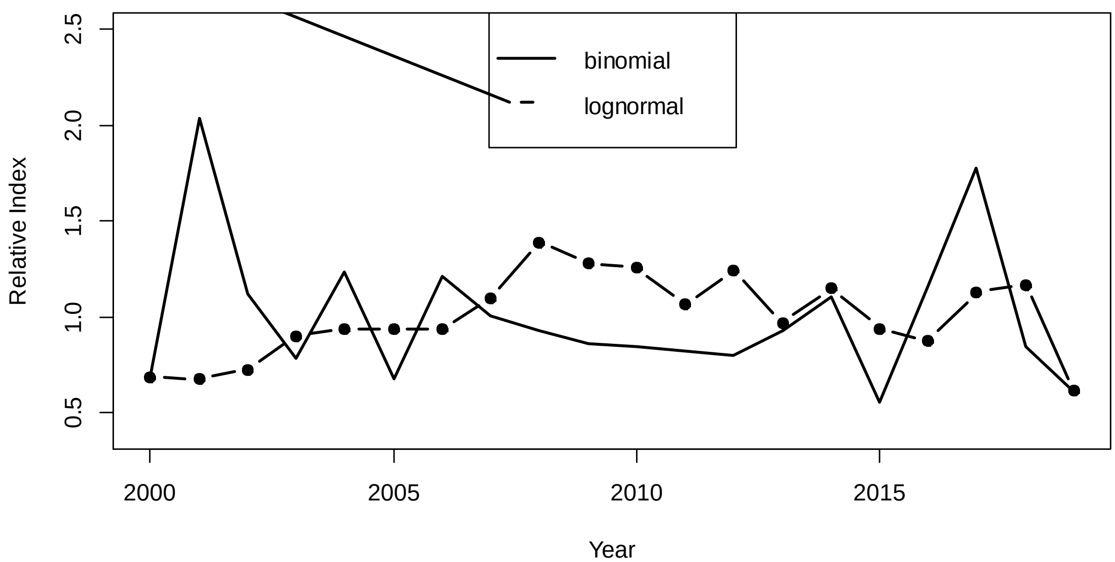


Figure 1: Estimated relative indices of *A. sirm* in the west coast small mesh gillnet fishery, Sri Lanka using Bernoulli-based and Gaussian- based GLM models

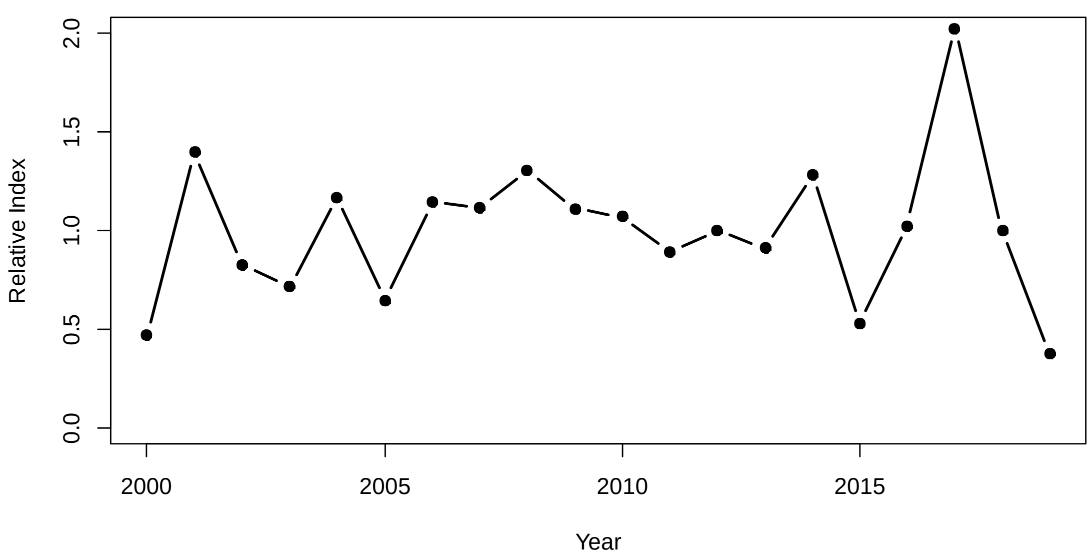


Figure 2: Standardized catch per unit effort (CPUE) of *A. sirm* in the west coast small mesh gillnet fishery, Sri Lanka using the delta-lognormal method. Values were scaled by dividing their means.

The results of the JABBA worst-case assessment for spotted sardinella on the west coast of Sri Lanka indicate that the stock is overfished and subject to overfishing (Figure 3).

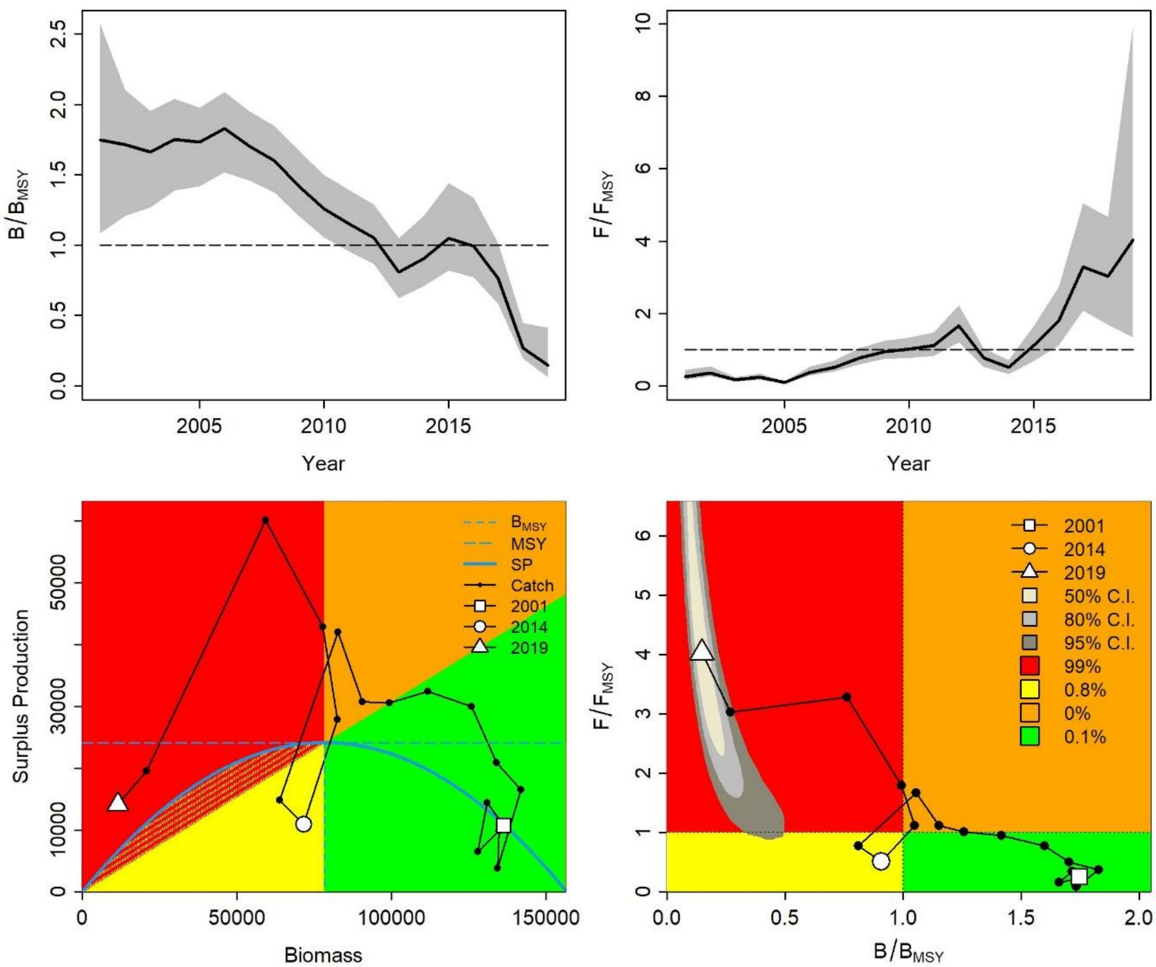


Figure 3: Trajectories of (a) B/BMSY (top left) and (b) F/FMSY (top right) for spotted sardinella in the west coast, Sri Lanka (2000-2019). Grey shading indicates 95% credibility intervals, (c) JABBA SP-phase plot showing estimated surplus production curves and catch/biomass trajectories as a function of biomass shown for the worst-case scenario. MSY estimates are illustrated with 95% C.I.s (grey shaded area) (bottom left) (d) Kobe phase plot for the JABBA worst-case scenario showing the estimated trajectories (2000–2019) of B/BMSY and F/FMSY. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend (bottom right).

The Base case scenario produces a B/B_{msy} trajectory more than 1 except in 2018 (Figure 4).

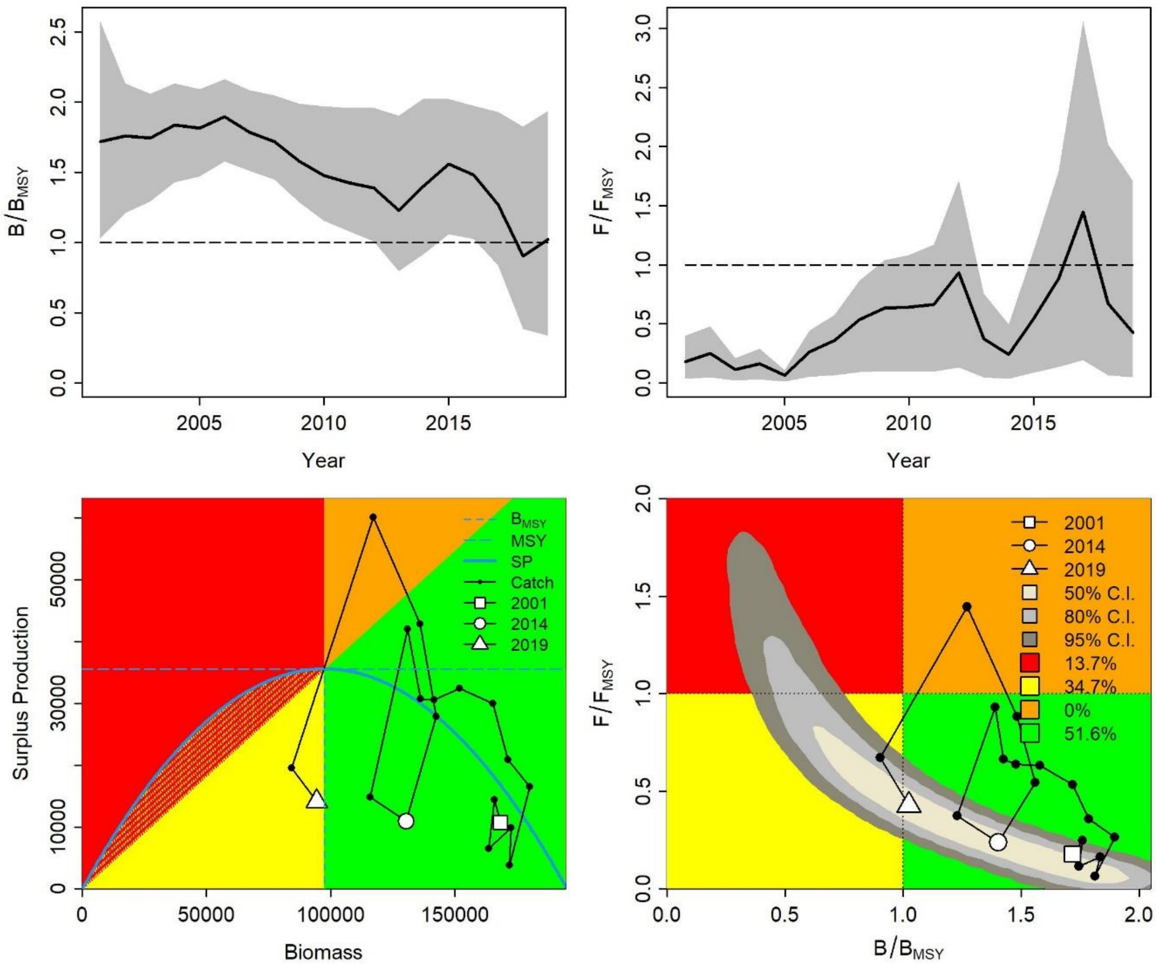


Figure 4: Trajectories of (a) B/BMSY (top left) and (b) F/FMSY (top right) for spotted sardinella in the west coast, Sri Lanka (2000-2019). Grey shading indicates 95% credibility intervals, (c) JABBA SP-phase plot showing estimated surplus production curves and catch/biomass trajectories as a function of biomass shown for the Base case scenario. MSY estimates are illustrated with 95% C.I.s (grey shaded area) (bottom left) (d) Kobe phase plot for the JABBA Base case scenario (R2) showing the estimated trajectories (2000–2019) of B/BMSY and F/FMSY. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend (bottom right).

Among different years considered under the study for the spoted sardinella assessment conducted using stochastic LBSPR, the respective stock remained relatively in a healthy state in 2005, 2006, 2008 and 2009 compared to other years (Figure 5). The worst-case in which median SPR has reached the limit reference point was reported in 2020. This suggests that the stock is no longer sustainable at the current exploitation level and strong management measures are needed at this critical stage to rebuild the spotted sardinella stock in the west coast.

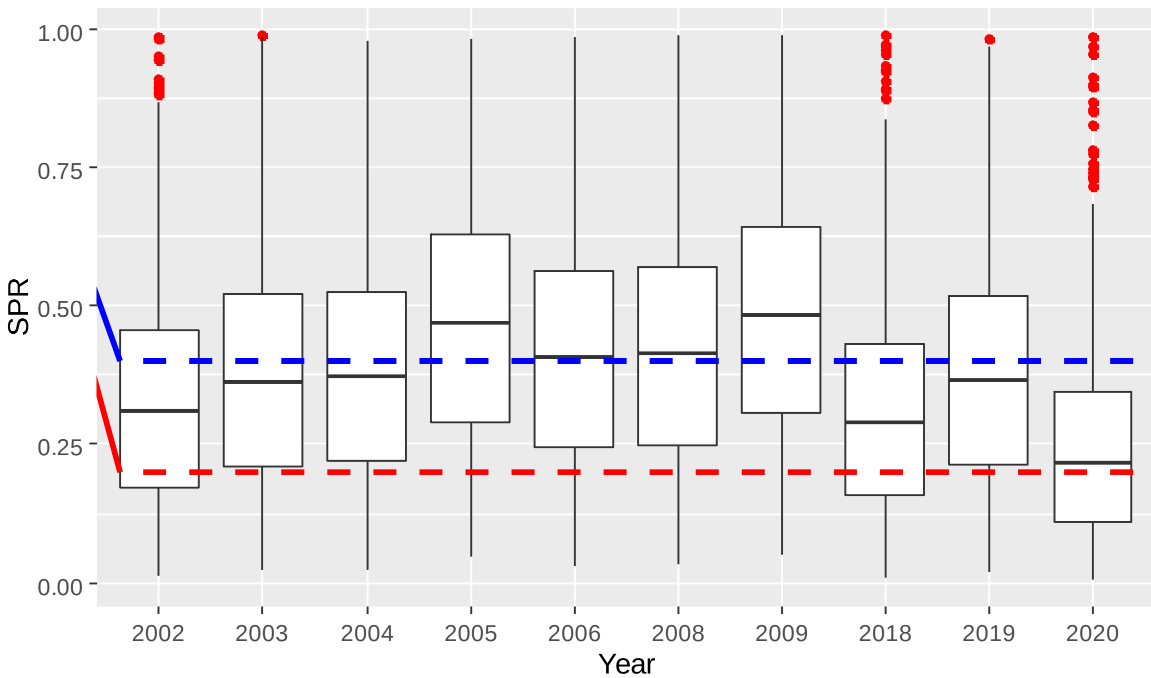


Figure 5: Box plots for summarizing the results of stochastic LBSPR assessment of spotted sardinella in the west coast, Sri Lanka (2000-2019)

Biological study of Big eye scad, *Selar crumenophthalmus* and Indian mackerel, *Rastrelliger kanagurta*

The total length of the Big eye scads ranged between 125 mm – 250 mm with a mean of 201.85 2.80, which shows negative allometric growth (b<3). The total length of the Indian mackerel ranged between 160 mm – 261 mm, with the mean of 219.71 3.43 showing the Positive allometric growth (b>3). Size at maturity (TL50) of big eye scads was 241 mm, and size at maturity (TL50) of Indian mackerel was observed to be 210 mm.

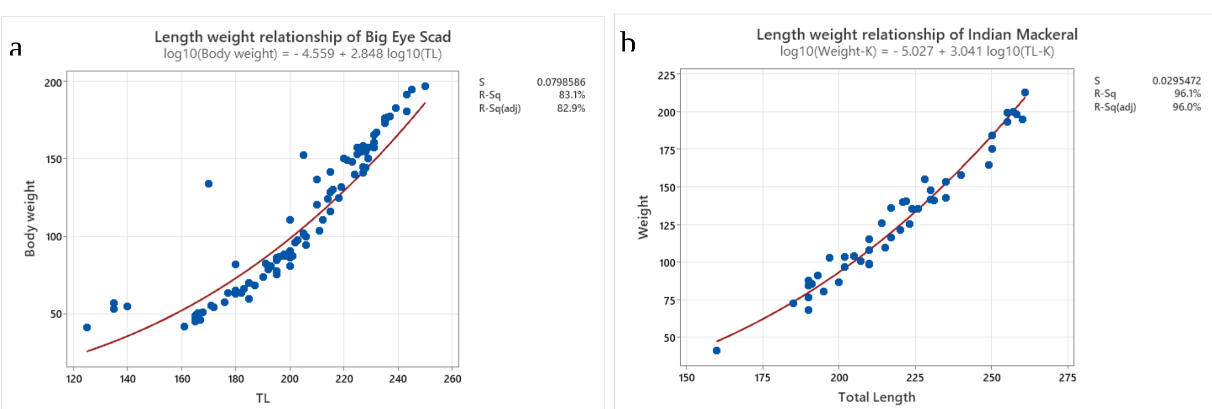


Figure 6: Length weight relationship of a) Big eye scad and b) Indian mackeral

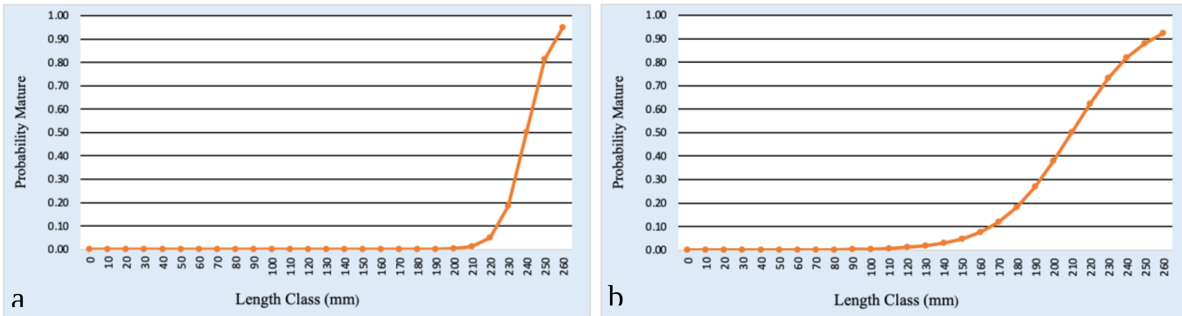


Figure 7: Size at maturity a) Big eye scad and b) Indian mackeral

The study was planned to be conducted by obtaining the samples from every month but the prevailed pandemic condition and banning of fishing announced with the XP pearl environmental disaster caused the discontinuation of data collection.

7. Conclusions and recommendations

Small pelagic fishery is conducted by the small mesh gillnets in the west coast, Sri Lanka and plays a vital role and is extremely important in small-scale fisheries in Sri Lanka.

The key target species in this fishery are spotted sardinella (*Amblygaster sirm*) and sardinella species comprising of *Sardinella albella, Sardinella gibbosa* and *Sardinella longiceps.*

The increased fishing effort in terms of operated boats in the small pelagic fishery has adversely affected the biomass of key species and the study highlights the necessity of formulating and implementing a fishery management plan that will cap effort where it currently is.

Other unsustainable fishing practices exist in the small pelagic fishery that should be controlled or banned. For example, night fishing conducted during the spawning season of the key small pelagic species and the use of smaller mesh size gillnets targeting immature fish. The Average number of net panels used for a fishing operation also has been increased over the study period (2000 – 2019).

A strong annual fluctuation in the CPUE of *A. sirm* was observed with the highest catch rates in 2017.

The stock assessment conducted using stochastic LBSPR for spotted sardinella revealed that Spawning Potential Ratio (SPR) has declined up to the limit reference point in 2019 and the study highlights the necessity of introducing appropriate management strategies such as controlling the fishing effort via introducing appropriate area and time closures to rebuild the stock.

Given the highly uncertain CPUE data (schooling of small pelagics indicate that hyper depletion is probably occurring when using Purse Seines while fishing), we built different assumptions of hyper stability in the model. The models indicate the stocks are either fully exploited or overfished depending on the scenario assumed. Given the highly uncertain nature of the data and the assessments, we recommend capping the catch at 25k for *Ambligaster sirm.* The effort should be controlled to achieve these targets.

According to the results, Big eye scad (*Selar crumenophthalmus*) and Indian mackerel (*Rastrelliger kanagurta*) show allometric growth, while Indian mackerel shows positive allometric growth and negative allometric for big eye scad. However, in conclusion both the species grow disproportionately when considering the length weight relationship.

Size at first maturity was recorded as 241 mm, 210 mm for Big eye scad (*Selar crumenophthalmus*) and Indian mackerel (*Rastrelliger kanagurta*) respectively. It shows the minimum length at which the species should be caught, which ensures there will be no more growth overfishing. However, the study will be done continuously to get more scientific information and provide concrete recommendations.

Based on this study and other best available information regard to this fishery, the following recommendations were made for sustainable management of these resources:

Recommend introducing appropriate minimum mesh size regulations to minimize the growth overfishing.

Introduce appropriate area and/ or time closures to overcome the catching of spawners during the peak spawning season(s).

Regulate the number of Purse seine nets that can be used in the fishery. This should never be allowed to increase more than the present level of effort. A further reduction in nets would help rebuild the stocks to sustainable levels.

Other effort control measures also need to be taken to rebuild the possibly depleted stocks:

Not issuing new licenses for gillnet fishing operations

Alternate livelihoods for other fishermen should be considered.

Subsidies are not provided to support the fishing operations conducted targeting small pelagic species

Formulate and implement a fisheries management plan for the west coast small pelagic fishery.

Other gears such as purse seine which catch small pelagic as well need to be regulated.

Decisions regarding the conservation, management and development of small pelagic fishery resources in the west coast should be based on scientific evidence.

Progress:

Financial : Physical :

2.2 Monitoring and assessment of large pelagic fishery resources

Introduction

The offshore and high sea fisheries in Sri Lanka are conducted targeting highly migratory large pelagic species such as tuna and tuna-like fish. Some vessels operating in the coastal fishery also target large pelagic species. Sri Lanka is historically a tuna-catching nation. The records indicate that tuna fishing has played a vital role in the tradition and culture of Sri Lanka. The major group in the tuna fishery in Sri Lanka is tropical tuna which mainly comprises of three species: yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and skipjack tuna (*Katsuwonus pelamis*). *Auxis thazard* (frigate tuna), *Auxis rochei* (bullet tuna) and *Euthynnis affinis* (kawakawa) are the major neritic tuna species found in Sri Lankan waters, while *Scomberomorus commerson* (Narrow- barred Spanish mackerel) is dominating the species associated with neritic tuna. The other important group of fish reported in large pelagic fish production in Sri Lanka is the billfish which includes 3 species of marlins (Indo-Pacific Blue Marlin (*Makaira mazara*), Black Marlin (*Makaira indica*) and Striped Marlin (*Tetrapturus audax*)), one species of sailfish (Indo-Pacific Sailfish, *Istiophorus platypterus*) and a single species of swordfish (*Xiphias gladius*). In addition, several shark species are recorded as a bycatch in the tuna fishery.

Port sampling and fisheries statistics

Large Pelagic Port sampling is a collaborative fisheries data collection programme implemented by the Marine Biological Resources Division (MBRD) of NARA, Department of Fisheries and Aquatic Resources (DFAR) and Statistics Unit of Ministry of Fisheries (MoF) for obtaining large pelagic fish landing data. Large pelagic resources mainly comprise of tuna and tuna-like species. The large pelagic port sampling survey in Sri Lanka was started in the 1990's by NARA and the project is conducted continuously with the objective of obtaining catch and effort data and biological data on large pelagic fish, in particular on tuna and tuna-like fish.

IOTC data submission and attending working parties organized by IOTC

It is a mandatory requirement to submit large pelagic fisheries data to the Indian Ocean Tuna Commission (IOTC). The data collected annually via the port sampling programme needs to be analyzed and then submitted to the IOTC before 30th June. This is a collaborative attempt of the Statistics Unit of MoF, DFAR and the MBRD of NARA. We were able to submit the production estimations of 2020 as per the required formats adhering to the deadline. The tuna and tuna-like production of Sri Lanka in 2020 was estimated at 107,857 t, of which 84% is composed of coastal production taken within EEZ (Figure 1).

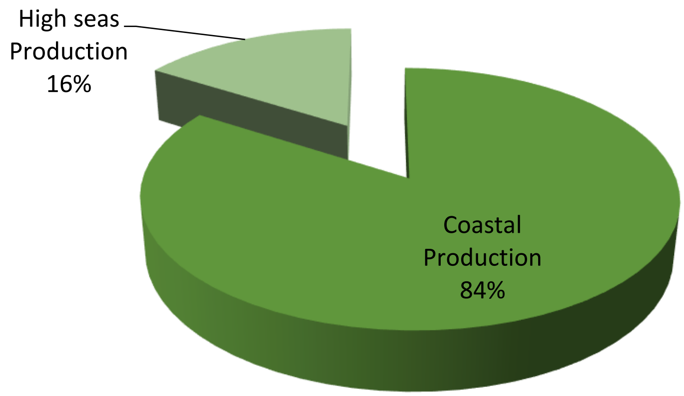


Figure 1: Large pelagic production of Sri Lanka in 2020 by subsectors

The highest proportion of the catch within EEZ was taken by gillnets followed by longline (Figure 2), while in high seas the highest catch was recorded by Longline (Figure 3). The declining trend in the relative contribution of the gillnet production with respect to previous years was evident for the discouraging trend of gillnet usage in the Sri Lankan large pelagic fishery (Figure 4).

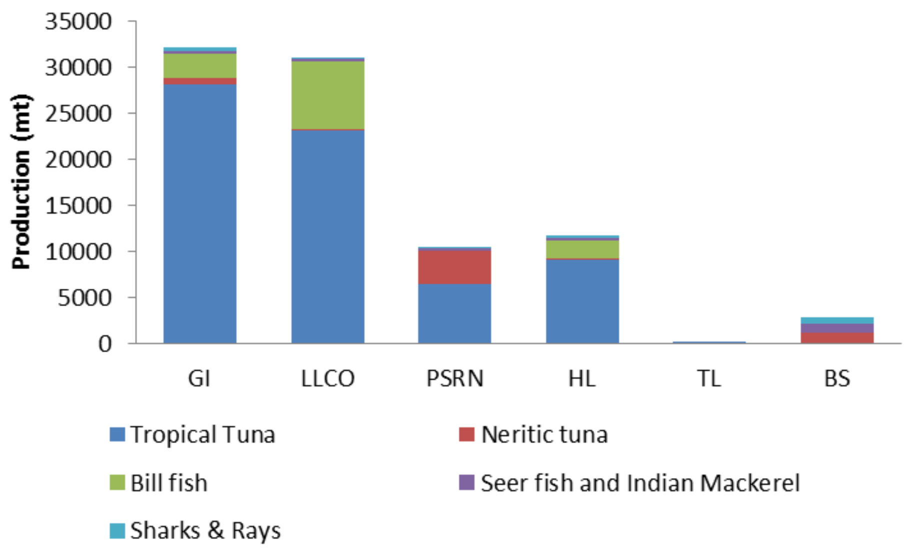


Figure 2: Large Pelagic Production in the EEZ of Sri Lanka in 2020 (GI – Gill net, LLCO- Coastal long line, PSRN- Purse Seine Ring net, HL- Hand line, TL- Troll line, BS- Beach seine)

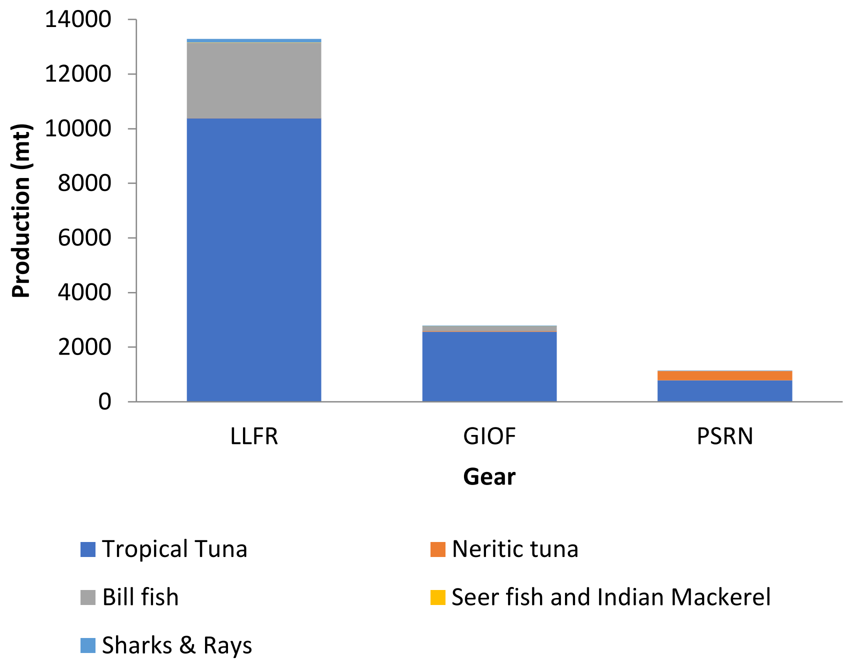


Figure 3: Large pelagic production in Sri Lanka in high seas in 2020 (LLFR- Fresh Tuna Long Line, GIOF – Off shore Gill net, PSRN- Purse seine Ring net)

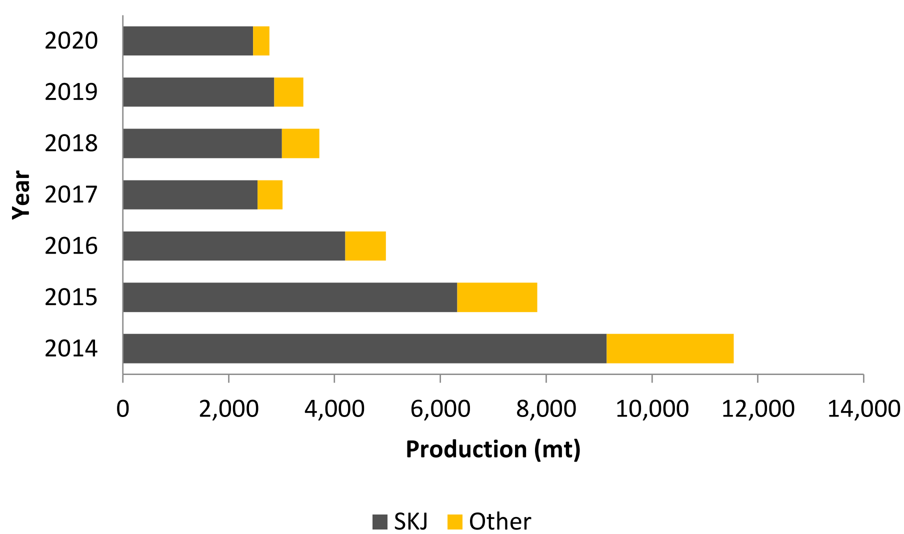


Figure 4: Trend of off shore gill net production in Sri Lanka from 2014 to 2020

Among the species, skipjack tuna, yellowfin tuna and swordfish show respectively larger contributions in the production (Figure 5).

The data submitted to IOTC needs to comply with the resolutions 15/02 implemented by the IOTC. In the submission, catch and effort data, length-frequency data, information on discards and vessel information are provided in detail as per the requirements of the resolutions. As a result of complying with the resolutions relating to data submission, Sri Lanka was able to achieve an 89% compliance rate in 2019. This is a great achievement when compared to our past records and compliance records of other coastal states in the Indian Ocean.

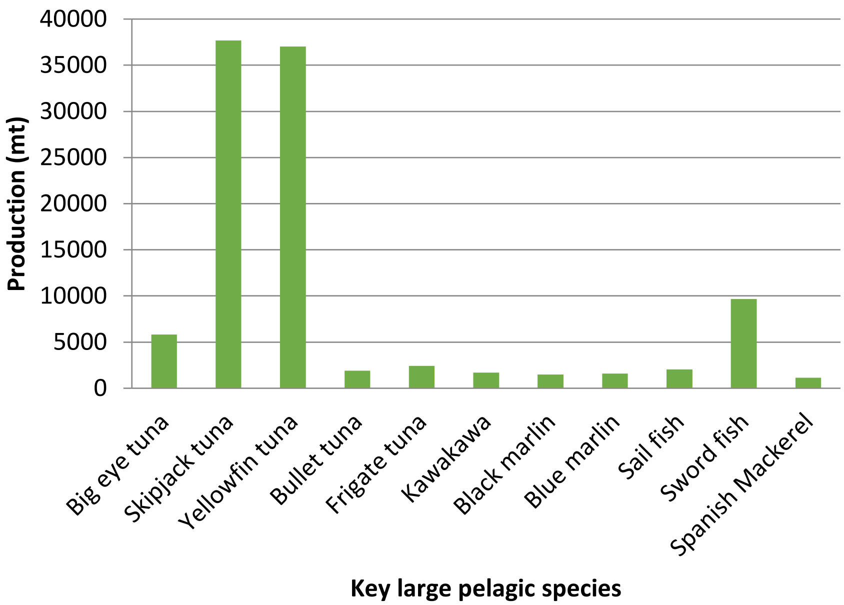


Figure 5: Large Pelagic Production in Sri Lanka by species in 2020

The scientists, who worked particularly in the project, participated in online IOTC working parties which are annually organized to address the different aspects with regard to the conservation and management of the species in the tuna fishery. The key priority areas to be concerned about in the future prospects of the fishery are:

How to comply with the IOTC catch reduction resolution of Yellowfin tuna in upcoming years

Comply with Resolution 19/01 where gillnet should be set at 2 m depth below the surface (use submerged gillnets) by 2023

Stock assessments of the species, namely, *Istiophorus platypterus* (Thalapatha), *Makaira nigricans* (Nil Koppara) and *Scomberomorus commerson* (Ahin Thora) revealed that those stocks are overfished or subject to overfishing in the Indian Ocean, hence future management endeavours should be more focused towards those species.

Progress:

Financial : Physical :

2.3 Study of some biological and fisheries aspects of selected edible finfish species in the demersal fishery in the South-eastern coast of Sri Lanka

Introduction

Rock fishes which are a part of the reef fishery resource, collectively known locally as '*gal malu*', is a major part of the demersal catch from the coastal waters. Among the rock fish, groupers and snappers are popular marine food fish of highest market value in many parts of the world. Few are currently being exported in frozen form. Most of the fish product exporters are now seeking to boost up the export of these fishes, especially to China and Europe.

Though, there is an increasing trend for export of the rock fish, there are no guidelines/ regulations such as minimum size for capture, gear regulations etc. Furthermore, as several fishing methods are in use, selectivity of each gear type with respect to the size of fish varies. Also, due to the lack of such information, fish stocks are in a threatened condition since there is a risk of harvesting immature fish. Further, the lack of species-specific data for these species is a major issue not only in Sri Lanka but also in the Asian region. These species-specific fisheries and biological data are vital for assessing their conservation status as well as for designing and implementing management measures.

The present study was conducted to identify some important reproductive biological aspects of two edible reef fish species; *Epinephelus undulosus* and *Lutjanus fulviflemma*; and to understand the present status of the demersal fishery in South-eastern coast of Sri Lanka. The main objective of the study was to provide management recommendations for the proposed management plan for the demersal fishery in South-eastern coast of Sri Lanka, which will be formulated in collaboration with the Government of Norway under the Norway-Sri Lanka bilateral project.

Methodology

To fulfil the study objectives, a fish landing site-based, fishery-dependent survey was conducted. Monthly field visits had been planned to be conducted to the selected landing sites for the demersal fishery in Kalmunai and Tangalle fisheries districts (Figure 1).

A

B

Figure 1: A: Selected landing sites in Kalmunai fisheries district; B: Selected landing sites in Tangalle fisheries district

During the field visits the following data were collected.

✓ Species composition in the commercial catch

✓ Total weight of each species in the catch

✓ Species-specific data on length and weight

✓ Data on gear type used, gear size, number of hooks per operation, hook size etc.

✓ Species composition, the abundance of reef-associated fish

Fish samples of *Epinephelus undulosus* and *Lutjanus fulviflemma* were collected for the assessment of reproductive biological aspects and for the genetic analysis. In the laboratory, Total Length (TL), Standard Length (SL), Total weight (TW), Somatic weight (SW), Gonad weight, weight of the liver were measured. Further the sex and the gonad development stage were determined for each specimen under consideration of methods described in earlier studies. The genetic study was conducted on the collected two edible reef fish species to identify the species and nucleotide level variation and to study the phylogenetic relationship among species.

However, due to the Covid-19 situation in the country, monthly field visits could not be conducted from March to June and from October to December in 2021.

Results and Discussion.

According to the findings of the study in the rest of the year, 14 species were recorded in the demersal fishery catch in Kalmunai fisheries district among which *Lethrinus* spp. recorded the highest contribution by weight to the total catch at 51.11% (Figure 2).

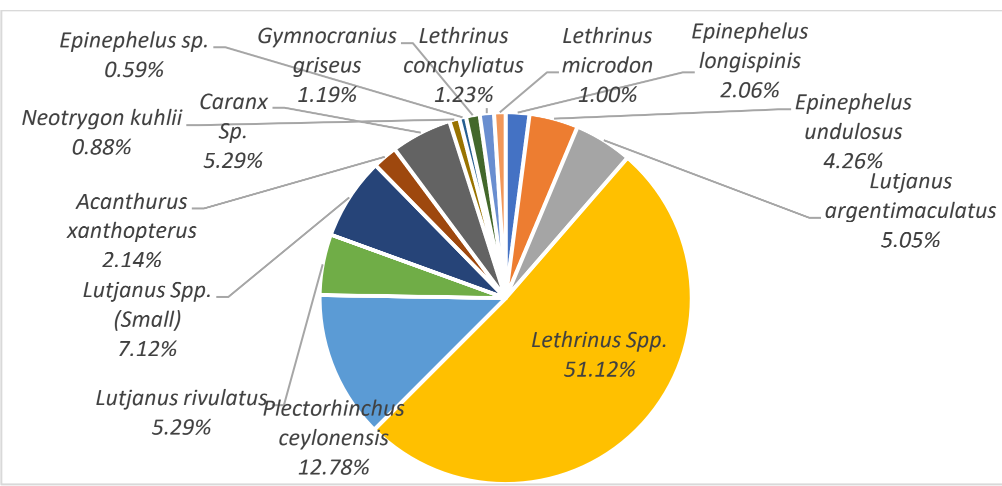


Figure 2: Species composition in the demersal fish catch in Kalmunai fisheries district.

In Tangalle fisheries district, 19 species were recorded in the demersal fish catch among which *Lutjanus quinquelineatus* recorded the highest contribution with 17.14% to the total catch (Figure 3).

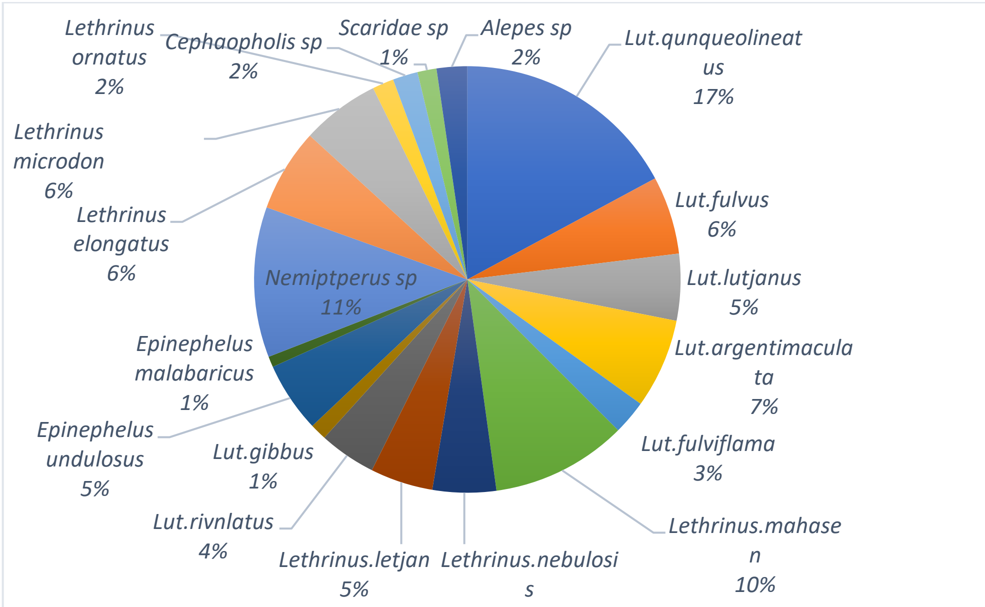
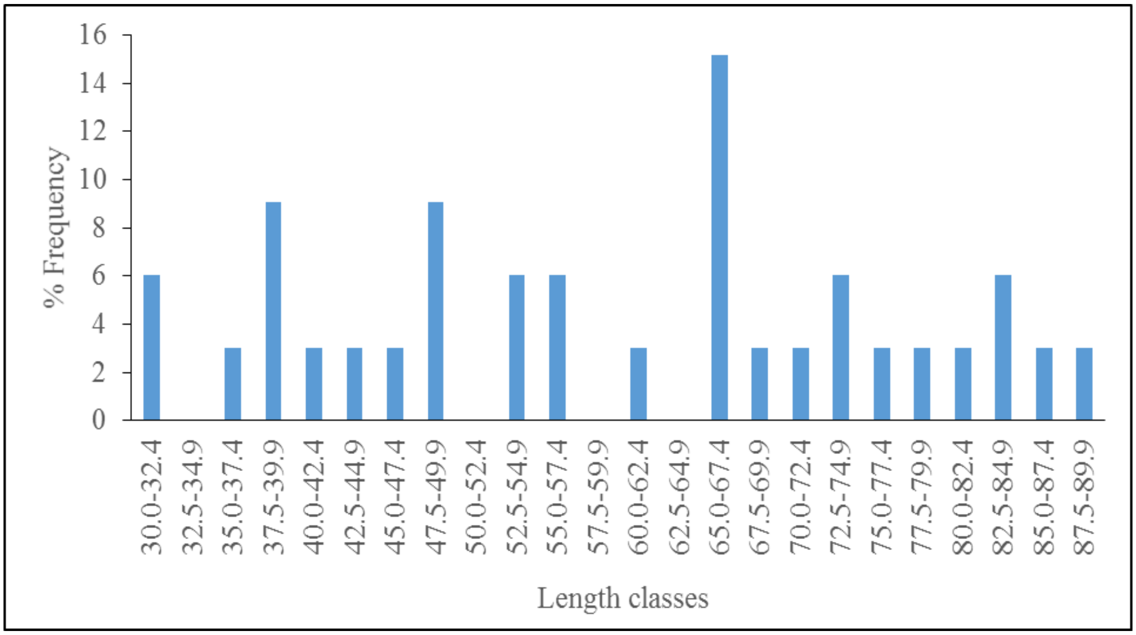


Figure 3: Species composition in the demersal fish catch in Tangalle fisheries district.

Fishers had used hook sizes of no: 6, 7, 8, and 9 for the bottom set longline fishing operations. Further, they had used 500 to 1000 hooks for one fishing operation, based on the size of the hook. (Larger the hook size, smaller the number of hooks per long line).

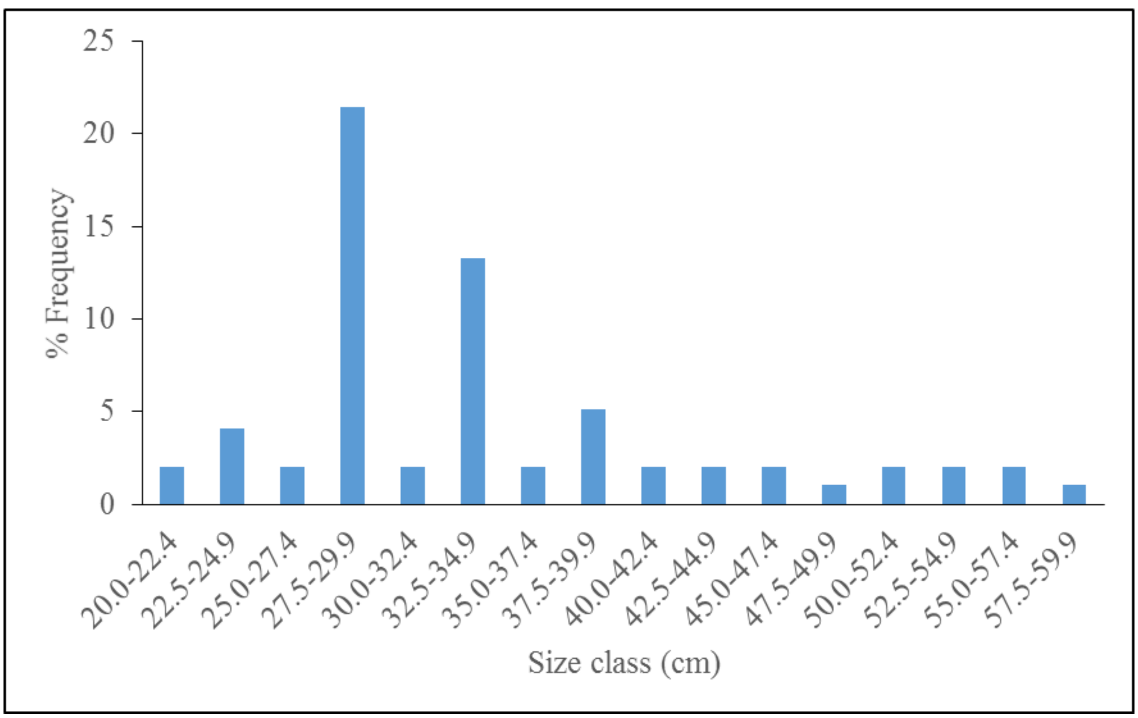
The average CPUE in the study period was estimated at 30.37 kg/boat/day. Considering the three dominant species in the catch; *Lethrinus olivaceus*, *Lethrinus microdon* and *Lethrinus lentjan* in Kalmunai fisheries district, the recorded average sizes (TL) were 60.11 ± 18.5 cm, 51.14 ± 10.2 cm and 30.63 ± 4.6 cm respectively (Figure 4). The size at maturity for these three species is 34 cm (TL), 29.1 cm (TL) and 18 cm (TL) respectively. Accordingly, all the specimens of these two species in the commercial catch were mature ones and there was no apparent threat of capturing immature individuals of these species in Kalmunai fisheries district.

According to the genetic studies, it was found that within the samples that had been previously identified as *Lutjanus quinquelinatus*, were composed of two species; *Lutjanus quinquelinatus* and *Lutjanus rufolineatus.* Similarly, according to the DNA sequencing results, samples of *Lutjanus fulviflamma* were composed of both *Lutjanus fulviflamma* and *Lutjanus johnii*. However, due to the inconsistency of samples, a conclusion cannot be made on the reproductive biological aspects and genetic aspects of the selected fish species in the demersal fishery.



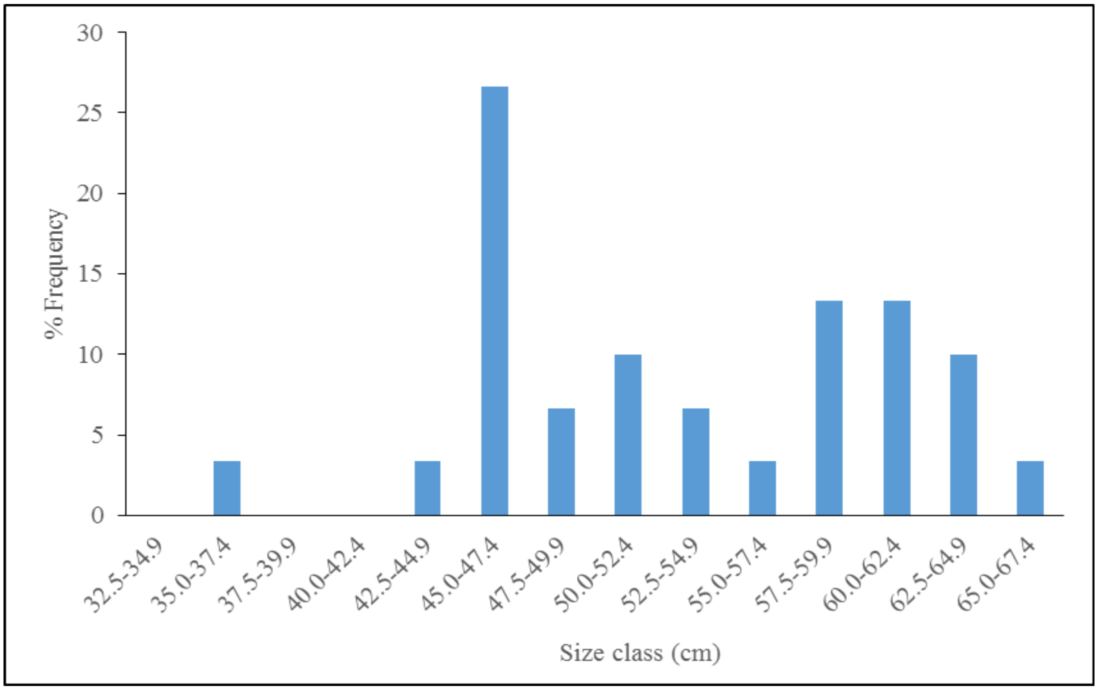
% Frequency
0
2
4
6
8
10
12
14
16
30.0-32.4
32.5-34.9
35.0-37.4
37.5-39.9
40.0-42.4
42.5-44.9
45.0-47.4
47.5-49.9
50.0-52.4
52.5-54.9
55.0-57.4
57.5-59.9
60.0-62.4
62.5-64.9
65.0-67.4
67.5-69.9
70.0-72.4
72.5-74.9
75.0-77.4
77.5-79.9
80.0-82.4
82.5-84.9
85.0-87.4
87.5-89.9
Length classes

A



% Frequency
0
5
10
15
20
25
20.0-22.4
22.5-24.9
25.0-27.4
27.5-29.9
30.0-32.4
32.5-34.9
35.0-37.4
37.5-39.9
40.0-42.4
42.5-44.9
45.0-47.4
47.5-49.9
50.0-52.4
52.5-54.9
55.0-57.4
57.5-59.9
Size class (cm)

B



C

Figure 4: Size composition in the catch; A: *Lethrinus olivaceus*; B: *Lethrinus lentjan*; C: *Lethrinus microdon*

However, due to the inconsistency of samples, a conclusion cannot be made on the reproductive biological aspects and genetic aspects of the selected fish species in the demersal fishery. It is suggested to continue the study to achieve the objectives of the study.

Conclusions

As almost all the specimens represented in the commercial catch, there was no apparent threat of capturing immature individuals of *Lethrinus olivaceus*, *Lethrinus lentjan* and *Lethrinus microdon* in Kalmunai fisheries district. Due to the inconsistency and inadequacy of the samples, it was not possible to conclude on some of the biological aspects such as size at maturity, spawning season…etc. These results emphasize that it is really important to carry out a comprehensive genetic study for a range of reef fish species in Sri Lankan coastal waters. Further, the current study highlighted the fact that there are inaccurate data recordings in the field due to similar morphological appearances among reef fishes. Therefore, it is necessary to update the existing fish identification guides, with new findings of the genetic study results. These will improve the precision of the data collections and final results. Further, all these findings confirm the usefulness of DNA barcoding of reef fishes in Sri Lankan waters to improve the scientific knowledge as well as to improve the accuracy of the final result of reef fish data collections. It is recommended to continue the data and sample collection of the demersal fishery in the South-eastern coast of Sri Lanka in order to evaluate and monitor the fishery which will be ultimately helpful for the formulation of the management plane for a sustainable fishery for the demersal fishery resources.

Progress:

Financial : Physical :

2.4: Biological and fisheries aspects and population characteristics of data-poor Anchovy fishery in West Coast, Sri Lanka.

Introduction

Anchovies have made a notable contribution to the world marine capture fisheries production. The Anchovy production was recorded as 5.735 Mt in 2017 in the world. They are one of the prominent fish species in small pelagic fish production of Sri Lanka. Anchovies of the genus *Stolephorus* contribute significantly to the coastal fish landings of the country. Among them, *Stolephorus insularis*, *Encrasicholina heteroloba* and *Stolephorus commersonii* are the species with high commercial interest. Anchovy was recorded as the second highest contributor in the small pelagic landings of the country according to the national fisheries statistics. However, less attention has been given to monitor the anchovy fishery in Sri Lanka. As a fishery with high commercial interest and considering the ecological significance of the group, it is important to prepare and implement an effective fisheries management plan in order to manage the fishery in a sustainable way as well as to sustain the livelihood of small-scale coastal fishers.

Despite the significant economic importance of this species, little information is known, either on its biology or population characteristics. Also, the data available on anchovy fishery and its biological aspects are infrequent (according to the data collected from 2011-2019 by NARA). To establish a management plan, a comprehensive study on its biology, population characteristics and fishery aspects are needed. To gain a better understanding of the anchovy, studies of their reproductive biology and other aspects are needed. Also, knowledge of the present stock status is also of paramount importance to avoid overfishing. As such, this study aims to assess the stocks, biology and fisheries aspects of the Anchovy fishery with the intention of identifying the necessity of management measures to sustain the valuable anchovy fishery in the west coast of Sri Lanka.

Specific Objective/s:

Study the reproductive biological aspects and fisheries aspects of Anchovy fishery

Study the population characteristics and identify the current level of exploitation

and prescribe guidelines for sustainable fishing: suitable gear/ mesh size for catching, time of the year suitable for harvesting, catch limits and specific areas of fish breading and spawning

Methodology

Fisheries data collection

Sampling was carried out at minor and major landing sites in Negombo and Chilaw coastal fisheries districts in the west coast where anchovy is landed, during the period of January to December, 2021 at a two-week frequency except few unavoidable occasions such as fishing band due to Express Pearl ship incident. On each sampling day, 50-60% of Fiberglass Reinforced Plastic (FRP) boats that operated for the anchovy fishery were sampled randomly. The sampling was done as soon as the catches were sorted. The total number of FRP boats operated for the anchovy fishery was also counted on each sampling day. Normally the fishing activities are not carried out on Sunday and the number of fishing days per month was estimated excluding Sundays. Total anchovy catch was recorded per boat basis to estimate catch per unit effort (CPUE). Catch Per Unit Effect (CPUE), Length-weight relationship, Sex ratio, Size at maturity and Stock assessment were performed. Total catch, gear type, boat type, fishing time, number of net pieces used for each of the species were recorded in order to find out the CPUE.

Data was collected and recorded as per the boat registration number. Apart from the catch and effort data, number of net pieces, mesh size of the gill nets, total trip duration, true fishing time, number of fishermen per boat, fuel cost per trip were also recorded from each sampling boat. Sampling was done once in every two-week frequency.

(a)

(b)

(c)

Plate 01: (a), (b), & (c) Anchovy fishery in West coast from sea to consumers

Biological data collection and statistical analysis

Anchovy samples were collected randomly from landed boats. For each sampling day, a total weight of at least 1kg for each species was sampled, which should cover at least 80-100 fishes from randomly selected boats representing all the mesh sizes. The collected samples were packed in ice and transported to the laboratory of the Marine biological resource Division of NARA for further analysis.

In total 2,110 individuals were collected from small mesh drift gillnets from the major landing sites in Negombo and Chilaw fishery districts, during the period of January - December 2021. Length (SL, TL) of all the individuals were measured to the nearest 0.01 mm, body weight was weighed to the nearest 0.1 gram. Growth coefficient (b) and condition factor (K) were analyzed to get the length-weight relationship of each of the species (Andamari & Milton, 1998; Olurin & Aderibigbe, 2006). Sex was determined by internal examination. Stages of maturity (at least 50 for each stage) were macroscopically examined from the weight, colour, shape, and transparency of the gonad (Andamari et al., 2002; Parvez & Nabi, 2015). Percentage of mature fish were plotted against length frequency and the size at which 50% and 95% of the fish attain maturity were calculated to find out the size at maturity. Size at first sexual maturity was assessed using the following equation: P = A (1+e (-r (Lt-L50)))-1; where P is the proportion or ratio of reproductive females for each size class; A is the curve asymptote; Lt is the total length (cm) and L50 is the size at first maturity (Nelson et al 2009) in Solver function in MS Excel. For the stock assessment, spawning potential ratio were determined by Length Based Spawning Potential Ratio (LBSPR) model and biomass dynamic model using catch and effort data (Hordyck et al., 2014 and 2015). All statistical analyses were significant at 5% ($p<0.05$) and was done using MS Excel and Minitab statistical software.

(a)

(b)

Plate 02: (a) & (b) sample analysis

Results

Reproductive Biology and Population Characteristics of Anchovy

<u>Sex ratio distribution</u>

Figure 1 shows the sex ratio distribution of *E. heteroloba* caught off Negombo and Chilaw. It was observed that the overall sex ratio in the catch was 1:1.32 (F: M) for *E. heteroloba*. According to Figure 1, the sex ratio varied with fish length classes, and female dominance was observed from 62 mm to 65 mm of total length. On the other hand, male dominance was observed from 83 mm to 86 mm of total length and 86 mm to 89 mm length classes. Such differences may be attributed to various causes, sometimes temperature may have an influence on sex determination (Conover and Kynard, 1981), different growth rates and vulnerability towards the fishing gear with sex and availability of food and habitat preference of male and female can impact on this sex ratio of the catch (Vicentini and Araujo, 2003). However, number of individuals of those length classes were numerically insufficient to produce a reliable conclusion.

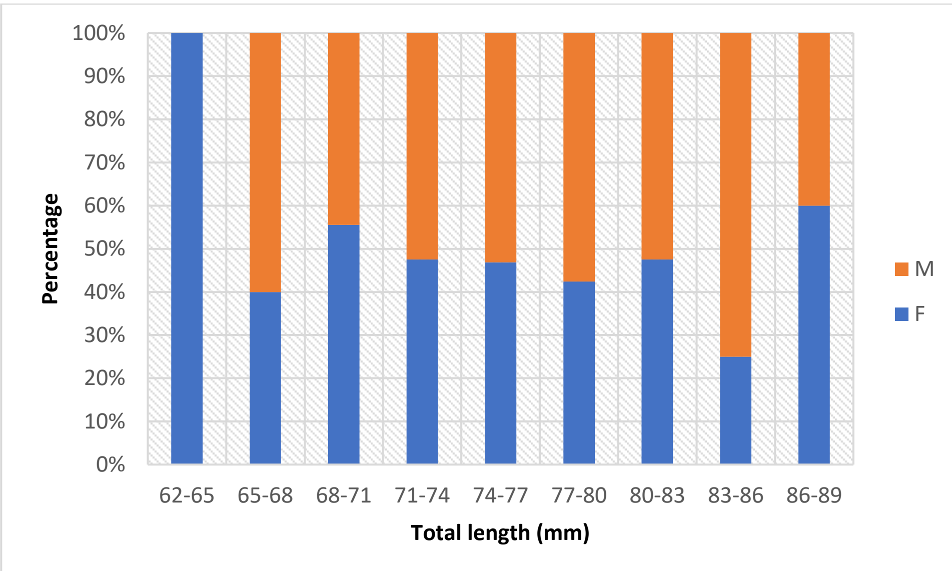


Figure 4: Sex ratio distribution of E. heteroloba

It was observed that the sex ratio in the catch was 0.84:1 (F: M) for *S. commersonii*. According to the figure, most of the length classes show the theoretical sex ratio. Even though it seems like slight female dominance in the population, the ratio is nearly equal to the theoretical sex ratio (1:1).

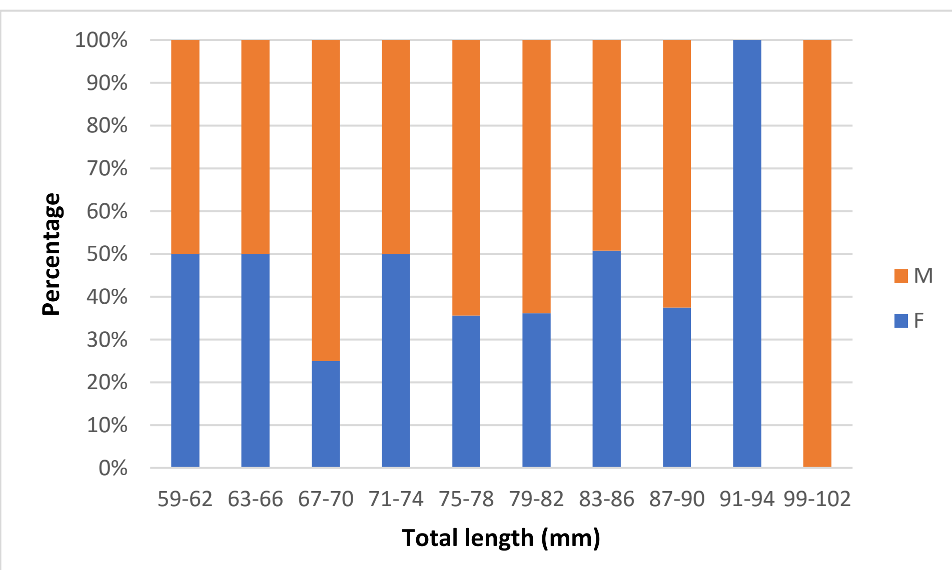


Figure 5: Sex ration distribution of S. commersonii

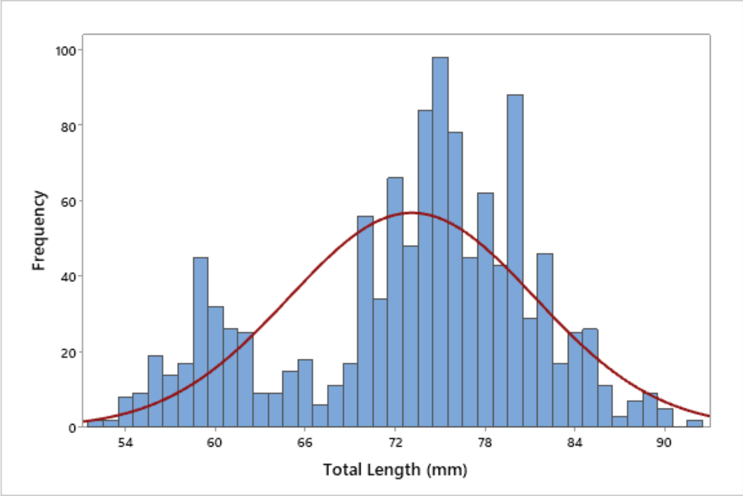


Figure 3: Length frequency distribution of E. heteroloba

Maturity identification

After the sex determination, the classification of the ovary of the female Anchovy into various stages was done based on macroscopic observations such as gonad appearance and colour. Based on such morphological features, 5 maturity stages were identified for females. Stages I (immature) and II (developing) were considered as immature and stage III, IV and V were considered as mature. For males, only three stages were identified.

Length frequency distribution

Length frequency distribution of *E. heteroloba*

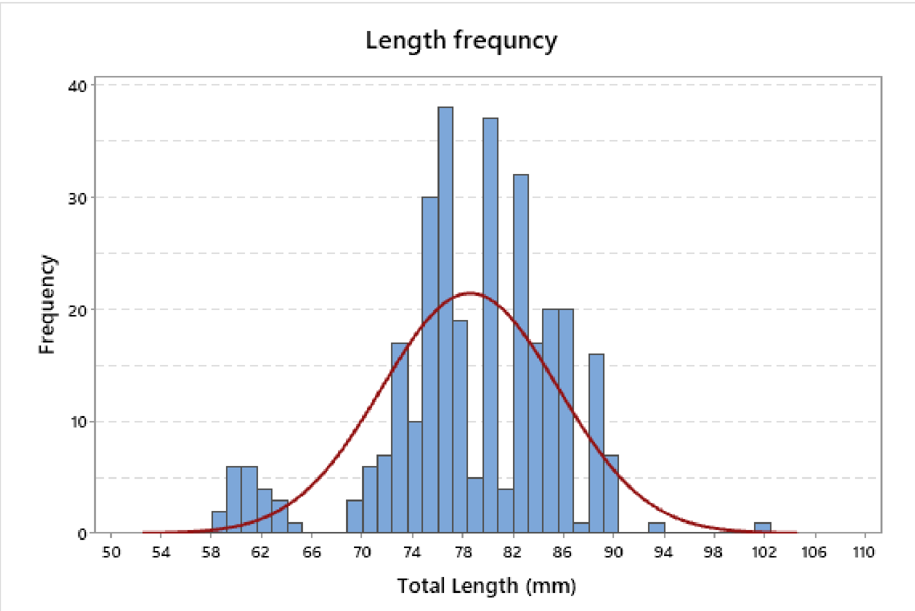
Figure 3 shows the length frequency distribution of *E. heteroloba* during the study period. Total Length of *E. heteroloba* ranged from 52-92 mm with a mean of 73.11±8.19 mm. The length-frequency data does not follow the normal curve and it was slightly skewed left (Skewness = -0.55). This is largely due to the outlier (larger size of *E. heteroloba*) at the right of the figure.

Length frequency Distribution of *S. commersonii*

Figure 4 illustrates the length-frequency distribution of *S. commersonii* in off Negombo and Chilaw. While *S. commersonii* ranged from 59-110 mm with a mean of 78.55±7.01 mm. The length-frequency data does not follow the normal curve and it was slightly skewed left (Skewness = -0.65). This is largely due to the outliers (some larger size of *S. commersonii*) at the right of the figure. It shows that the mean total length of *S. commersonii* is slightly higher than the mean total length of *E. heteroloba* in the western coastal waters of Sri Lanka. It also shows that the used gill net is more selective towards these size range. Size range of the fish depends on the type of fishing gear and mesh size of the fishing gear used for sampling as well.

Length-weight relationship

Figure 4: Length frequency distribution of S. commersonii



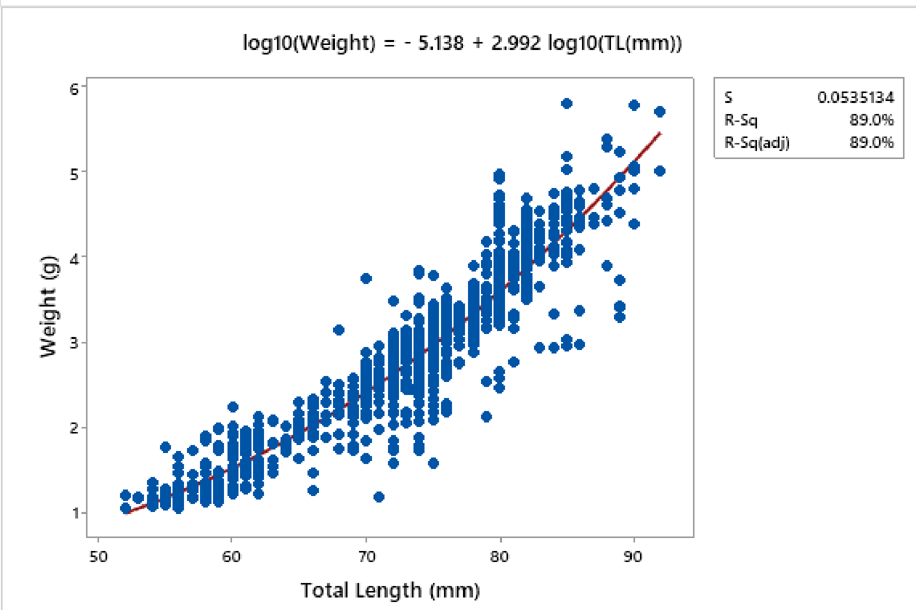


Figure 5: Length-weight relationship of E. heteroloba

Figure 5 shows the length-weight relationship of *E. heteroloba*. The length-weight relationship was analyzed by Simple Linear Regression using log transformed data. Result for the *E. heteroloba* showed Log W = -5.138 + 2.992 log TL and it was also observed, Log W = -4.943 + 2.892 log TL for male and Log W = -5.256 + 3.052 log TL for female.

Fish are said to exhibit isometric growth when length increases in equal proportions with body weight for constant specific gravity. The regression co-efficient for isometric growth is 3 and when it is less than or greater than 3 then it explains allometric growth (Olurin, 2006). According to the exponential relationship of present study, 'b' value is 2.892 and 3.052 for male and female. It means *E. heteroloba* in the studied area shows allometric growth. In addition, for *E. heteroloba* it was noticed, positive allometric (b>3) growth and negative allometric growth (b<3) for female and male correspondingly. There was no significant statistical difference (P>0.05) in male and female regression co-efficient for both the species studied.

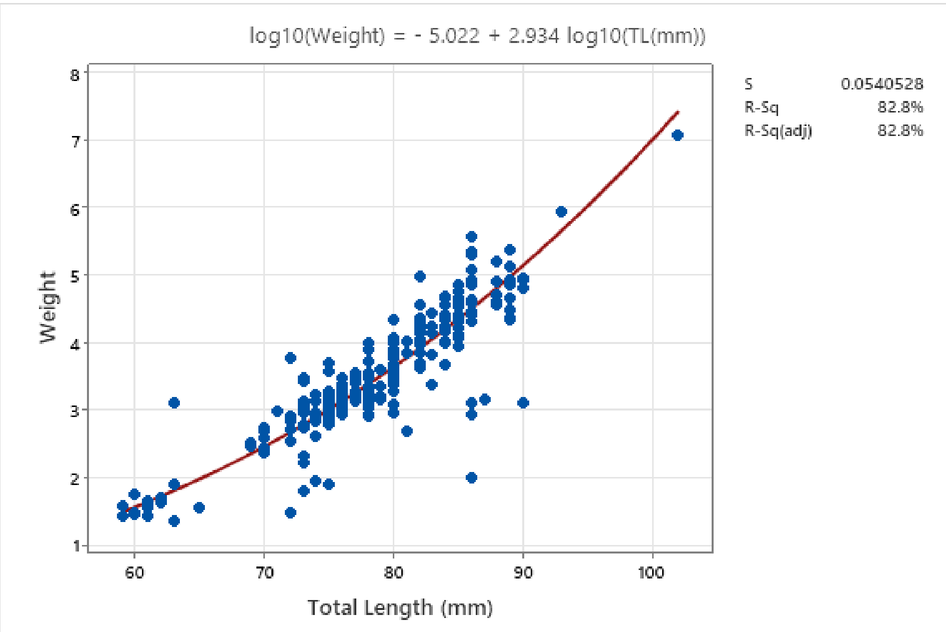


Figure 6: Length-weight relationship of S. commersonii

The Length-weight relationship of *S. commersonii* is presented in figure 6. It indicates the relationship as, Log W = -5.022 + 2.934 log TL. Also Log W = -7.028 + 2.1246 log TL and log W = -6.031 + 1.124 log TL for male and female of *S. commersonii* respectively. The results illustrate negative allometric growth (b<3) for *S. commersonii*. The length–weight relationship in fishes is affected by several factors, including season, habitat, gonad maturity, sex, diet and stomach fullness and health (Tesch, 1971), all of which were not accounted for in the present study. However, it can be concluded that, reproductive output of anchovy species studied in the west coast of Sri Lanka increases disproportionately with size increases.

<u>Size at maturity</u>

Size at maturity of *E. heteroloba*

Figure 7 shows the size at maturity curve of female *E. heteroloba*. According to the curve, size at which 50% of the individuals were matured and size at which 95% of the individuals were matured was estimated. Size at first maturity (L_{50}) was observed as 74.4 mm of total length and 95% of the individuals of *E. heteroloba* got matured in 83.6 mm of total length in the West coast of Sri Lanka.

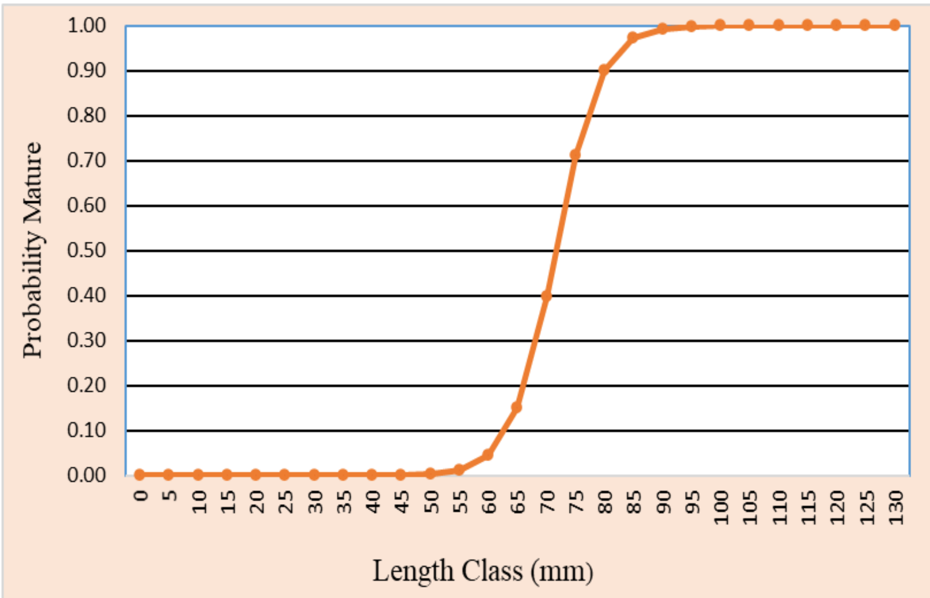


Figure 7: Size at maturity of E. heteroloba

Size at maturity of *S. commersonii*

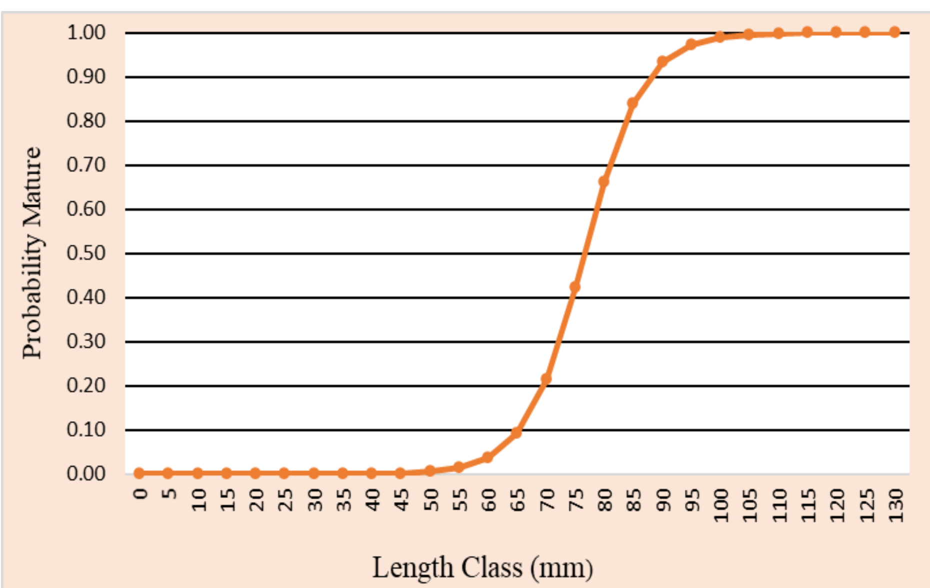


Figure 8: Size at maturity of S. commersonii

Figure 8 shows the size at maturity curve of female *S. commersonii*. Size at first maturity (L_{50}) was observed as 76.6 mm of total length and 95% of the individuals of *S. commersonii* got matured at 91.5 mm of total length in west coast of Sri Lanka.

<u>Stock status</u>

Stock status of the *E. heteroloba* in the west coast of Sri Lanka was assessed based on Length Based Spawning Potential Ratio (LBSPR) model developed for data-limited fisheries and available on the "<u>Barefoot Ecologist's Tool Box"</u> website (Adrian and Prince, 2015).

A stock is considered to be over-fished when its spawning stock biomass per recruit or spawning potential ratio falls below 20 percent, and not fully exploited if this value is above 40 percent of the unfished biomass. Stocks with values between 20 and 40 percent are referred to as the above reference point, these reference points were estimated based on the conventional stock assessment method (Adrian and Prince, 2015).

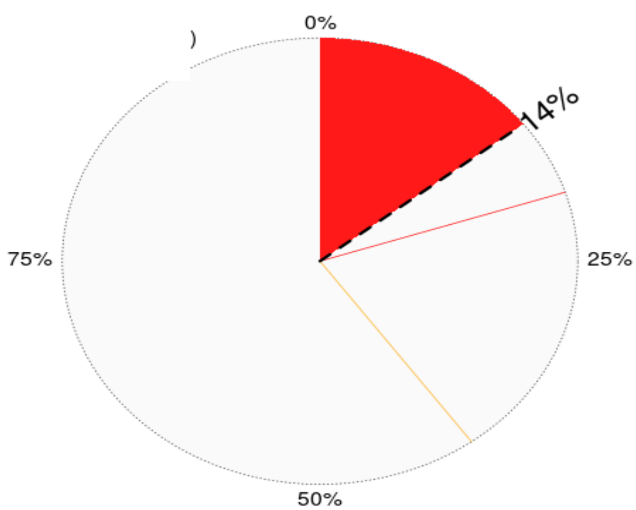


Figure 9: Spawning Potential ratio of E. heteroloba

Figure 9 shows the spawning potential ratio of *E. heteroloba* in the west coast of Sri Lanka. According to the results Spawning potential ratio is 14%. It means the stock status is in the state of over exploitation. It means the stock status is in the state of below reference point. The number of mature *E. heteroloba* in t ssary to generate optimum economic and social benefits now and in the future. Therefore, it is important to take management measures to increase the number of mature *E. heteroloba* in the fishery.

Anchovy fishery in the West coast of Sri Lanka

Anchovy fishery is widely operated in the western coastal region. Study was done in Negombo and Chilaw fishery districts to represent the west coast. According to the findings, anchovies were caught from drift gill nets with the different mesh sizes from 5 mm to 14 mm. Most common stretched mesh sizes were 12 mm (35%), 13 mm (28%) and 10 mm (12%). It was observed that, Motorized-Fiberglass Reinforced Plastic (FRP) boats are mostly operated for the anchovy fishing with few traditional non-motorized boats. Motorized boats are usually aided with engines of 25 and 40 Horsepower. Almost for all the boats 2 crew members were engaged in fishing activity, departing for fishing between 2.30 am to 5.00 am and arrival between 6.30 am to 9.00 am. True fishing time varied from 20 minutes to 2 hours. In addition, an average of 20±5 net pieces were used per operation of anchovy fishing. According to the information by the fishermen, fishing operations take place 1 km to 15 km away from the shore, depending on the weather condition and seasonality of the anchovy fishery.

Figure 10: Monthly effort variation

Figure 10 shows the monthly variation in the efforts used for the Anchovy fishery in the west coast of Sri Lanka during the period of January to December 2021. The highest effort was recorded in the month of November as 750 boats followed by October (525 boats). Whereas the month of June recorded 60 boats showed the least effort followed by March (90 boats).

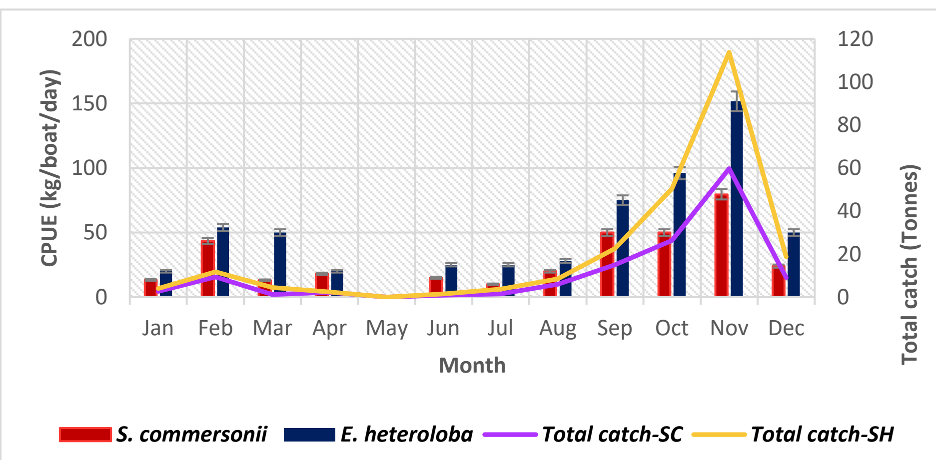


Figure 11: Monthly variation of catch rates (CPUE in Kg/boat/day)

Figure 11 shows the monthly variations in the catch rates (CPUE in Kg/boat/day) and total catch (Tones) for the *E. heterolob*a and *S. commersonii* recorded in the west coast of Sri Lanka. According to the figure, it's obvious that, CPUE of *E. heteroloba* is higher than the CPUE of *S. commersonii* during the study period. Also, *E. heteroloba* catch rate was increased from September to November, where the total catch also increased dramatically. However, the total catch and Catch rate of *S. commersonii* shows a gradual increase as well. After November, catch rate and total catch were drastically reduced for both the species. The highest CPUE was recorded as 152 Kg/boat/day and 80kg/boat/day for both *E. heteroloba* and *S. commersonii* respectively in the month of November. Whereas the least CPUE were recorded in January and March for *S. commersonii* and January and April for *E. heteroloba* as well. Graph shows the decline in the CPUE and total catch during the month of May and June. This is due to external factors to a certain extent, such as, the curfew restrictions due to the covid 19 outbreak and fishing ban imposed on Negombo area due to the Express pearl ship fire incident. As a result, fishing effort was decreased.

Conclusions and recommendations

Conclusions based on the study

This study reports the finding of population characteristics and reproductive biology of commonly caught Anchovy species in the west coastal waters of Sri Lanka.

According to the exponential relationship of present study, *E. heteroloba* in the studied area shows allometric growth. As such, it can grow faster in length than in weight. Whereas the results illustrate negative allometric growth ($b<3$) for *S. commersonii*. However, it concludes that, reproductive output of anchovy species studied in the west coast of Sri Lanka increases disproportionately with size increases.

The size at first maturity of *E. heteroloba* was determined as 74.4 mm total weight and size at 95% of the maturity was determined as 83.6 mm. Furtther, *S. commersonii* shows size at first maturity as 76.6 mm. This detects at which length the fish should be protected and *S. commersonii* is comparatively attains mature in considerably larger size. The study has added information on the present knowledge of size at first maturity of Anchovies species in west coast of the country.

According to the CPUE analysis, the highest CPUE was recorded as 152 Kg/boat/day and 80kg/boat/day for both *E. heteroloba* and *S. commersonii* respectively in the month of November.

The study states the stock status of *E. heteroloba* in the west coast of Sri Lanka. According to the stock assessment results, stock of *E. heteroloba* in the west coast of Sri Lanka is in below the limit reference point (spawning potential ratio was recorded as 14%).

This study reports the first findings on length-weight relationship and size at maturity of *S. commersonii* and first stock assessment report of E. heteroloba in Sri Lankan waters as well. These results will be useful for management of Anchovy population in the west coast of Sri Lanka.

Recommendations

According to the results, stock is over exploited. Therefore, stock rebuilding measures need to be taken as early as possible.

Proper mesh regulation and gear regulation need to be introduced in order to protect the capture of immature fish stock, which may possibly contribute for further growth overfishing.

However, this study was conducted only one-year period of time. To provide management recommendation, further studies should be carried on biology and population parameters of Anchovy species.

Progress:

Financial: Physical:

2.5 Study of biology, fisheries and population structure of common shark species of Sri Lanka and the status of shark fin trade.

Introduction

Sharks are highly migratory cartilaginous fishes which are often apex predators in marine ecosystems in which they play an important role in maintaining the balance between prey organisms. Sharks are an important fisheries resource supporting the local economy by producing not only the meat and fins, but also the skin and most of the body parts. This paramount importance and factors such as long life span, low fecundity and slow growth rate make sharks extremely vulnerable to overexploitation, declining the shark fishery resources.

According to the Joseph (1999), the fisheries sector of Sri Lanka changed significantly with the introduction of motorized fishing vessels, synthetic fiber fishing gears and establishment of Exclusive Economic Zone (EEZ) in the 1970s. Fishing activities expanded outwards, leading to a rapid development of the offshore fishery (Hasarangi & Maldeniya, 2012). The shark fishery, which is a substantial fishery, captures coastal and bottom living species in localized coastal areas. Previously, bottom trawl, large-mesh gill net and hook and line were the major fishing gears used for catching sharks in coastal areas. But after the introduction of synthetic gill nets in 1970, pelagic shark landings increased more rapidly than that of coastal and demersal sharks (Joseph.1999). In the 1990s, the major fishing gears used in the shark fishery became the drift longline and drift gill nets.

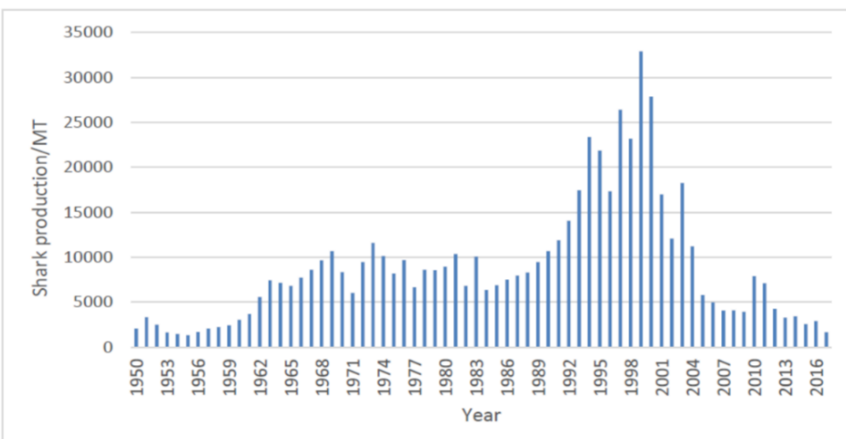


Figure 2: Trends in shark catch in Sri Lanka (1950-2016) Source: TOTC database

Shark landings in Sri Lanka declined drastically after the peak landings in 1999, probably as a result of the development of the more profitable tuna fishery. At the same time, several regulations taken by the government have contributed to this decline (Hasarangi et al., 2012). Despite the decline, in 2013, Sri Lanka was the top 16th in the world ranking of shark fishing countries (Lack & Sant, 2003). Shark catch was, however, reduced to 2% of the total pelagic shark production after 1999, and sharks were mostly caught and landed as bycatch production of the tuna fishery. According to catch statistics, silky shark was the dominant species until 2017, followed by Blue shark (Balawardhana et al., 2018).

Since 2018, the Blue shark has been the dominant species, followed by silky shark and hammerhead sharks (NARA, PELAGOS database). There is a dearth of information on the biology, stock status and fisheries aspects of common shark species in Sri Lanka. Studying about these aspects of dominant shark species are flag objective of National Plan of Action–sharks (2018-2022). In addition, in Sri Lanka there is no comprehensive study about the shark fin trade. Complete understanding of the current status of shark fin trade in Sri Lanka is important to determine whether shark landings are in a sustainable level or not. In addition, it helps to identify pitfalls in development in community management. Therefore, the main objective of this study is to address this gap of important information of dominant shark species in offshore waters of Sri Lanka.

Methodology

Figure 1: Study sites/ Fisheries harbours

According to the annual shark landing statistics which is submitted to IOTC Silky shark (*Carcharhinus falciformis*), Blue shark (*Prionace glauca*) and Scalloped Hammerhead (*Sphyraena zygaena*) sharks were selected for the study. Data and sample collection were carried out in Negombo, Beruwala, Mirissa and Valachchenei fisheries harbours. These harbours were selected based on the annual shark landings. At the field fisheries data including total fish catch, weight of each shark species, type of gear, fishing location, fishing duration were collected while morphometric data including total length, eye diameter, head length and biological data including sex, maturity was recorded on a monthly basis at each fisheries harbour. In addition, tissue samples were collected and stored in 100% alcohol for the genetic analysis to estimate the stock structure of common shark species. Shark fin export data during last 10 years was collected from major shark fin exporters, Sri Lanka customs and EDB. These data was validated and analyzed to estimate the catch trends using a suitable model.

Results and Discussion

During the study, 1731 silky sharks, 893 blue sharks and 321 scalloped hammerhead sharks were recorded and measured at the field. The maximum length recorded for silky, blue and scalloped hammerhead sharks was 298 cm 310 cm, and 279 cm respectively. A larger number of immature specimens of silky sharks were recorded recently in Negombo and Beruwala fisheries harbours. 36% of recorded Silky shark landings were in an immature stage while 3% of Blue sharks were immature. In addition, female scalloped Hammerhead was recorded with pups. According to the results, landing of immature sharks can directly affect the depletion of shark populations.

Among the multiday boats operated in the tuna fishery with longlines, the non-zero Catch Per Unit Effort (CPUE) of silky shark and blue shark were recorded as 21individuals per boat per trip and 6 individuals per boat per trip respectively. According to the IOTC data of fish production in Sri Lanka, shark production was 1.9% from the total catch while shark production was higher within EEZ than Beyond EEZ. Gill net and Longline combination were responsible for more than 80% of shark landings in Sri Lanka while Gill net is the main fishing gear responsible for shark catch within EEZ and Longline is for beyond EEZ. The sex ratio for silky shark was estimated at 1:1. However, sex ratio for blue shark was 1:4 (Female : Male).

Sri Lanka is one of the top countries which exports shark fins. There are two HS codes for export shark products (30381 and 30571). According to the statistics Hong Kong is the main destination country that imports shark fins from Sri Lanka followed by Maldives and Singapore. According to the statistics, the quantity and value of shark fin exports of Sri Lanka during 2000-2019 were 1315 mt and 3292 Mn LKR respectively. Silky shark (*Carcharhinus falciformis*), Blue sharks (*Prionace glauca*) were dominant species in the trade records.

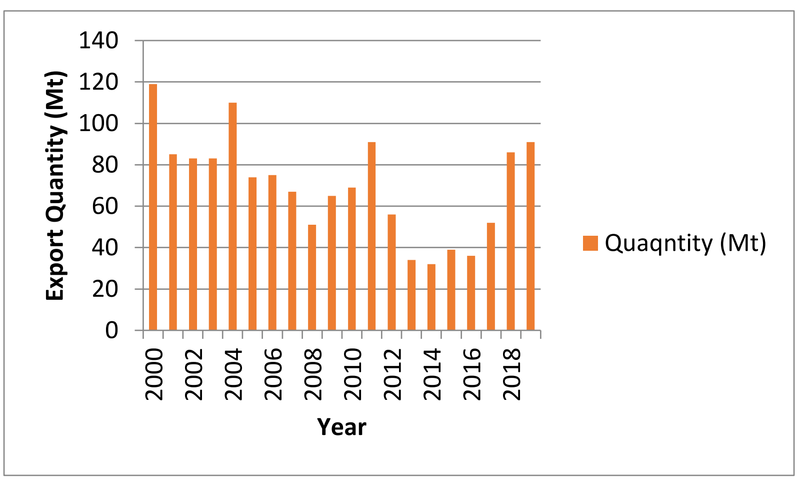


Figure 2: Trend of shark fin export quantity versus Year

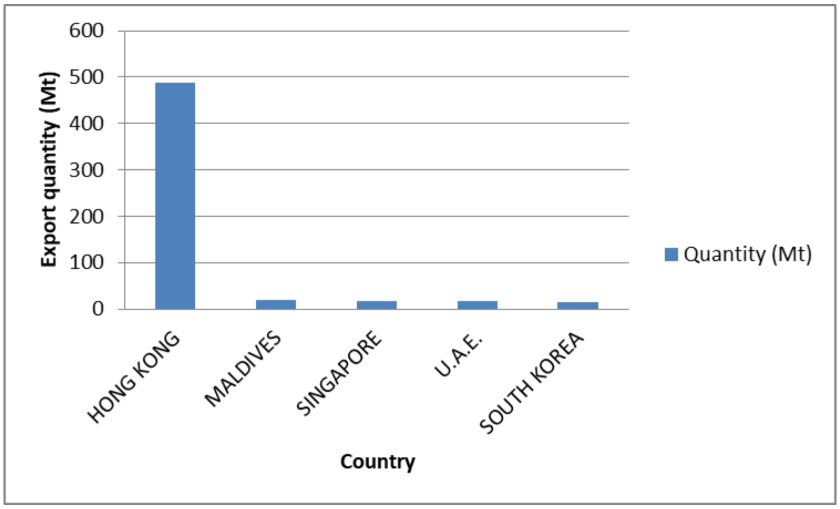


Figure 3:- Shark fin export quantity versus Country (2010-2019)

There is a derth of information on shark landing catch and effort data. Continuous monitoring and determining the Total Allowable Catch for shark species is essential for the management of shark resources. In addition, illegal landing of prohibited shark species could be observed during the unloading. Hence, management measures should be implemented for the conservation and management of sharks.

References

Andrade, I., Rosa, D., Muñoz-Lechuga, R., & Coelho, R. (2019b). Age and growth of the blue shark (Prionace glauca) in the Indian Ocean. *Fisheries Research*, *211*(March 2018), 238–246. https://doi.org/10.1016/j.fishres.2018.11.019

Fisheries Outlook , National Aquatic Resources Research and Development Agency, (2017). Fisheries Industry.

Balawardhana, D., Dalpathadu and, K, Haputhantri, S. (2018). Reviewing effectiveness of management measures on shark landings in Sri Lanka over past five years | IOTC. Retrieved from http://www.iotc.org/documents/WPEB/14/43

Baum, J. K., & Blanchard, W. (2010). Inferring shark population trends from generalized linear mixed models of pelagic longline catch and effort data. *Fisheries Research*, *102*(3), 229–239. https://doi.org/10.1016/j.fishres.2009.11.006

Biological, M., Division, R., Aquatic, N., Island, C., & Lanka, S. (2015). Iotc – 2015 – wpb13 – 22, (August 2014).

Hasarangi, D. G. N., Maldeniya, R., Aquatic, N., & Island, C. (2012). A Review on Shark Fishery Resources in Sri Lanka, *1999*(January).

Heard, M., Rogers, P. J., Bruce, B. D., Humphries, N. E., & Huveneers, C. (2018). Plasticity in the diel vertical movement of two pelagic predators (Prionace glauca and Alopias vulpinus) in the southeastern Indian Ocean. *Fisheries Oceanography*, *27*(3), 199–211. https://doi.org/10.1111/fog.12245

Jayasooriya, S. P. (1997). IN DIFFERENT SPECIES.

Jayathilaka, R. A. M., & Maldeniya, R. (2015). IOTC – 2015 – WPEB11 – 18 Rev _ 1 Impact of policies on the conservation of sharks in the large pelagic fishery IOTC – 2015 – WPEB11 – 18 Rev _ 1, (1768), 1–14.

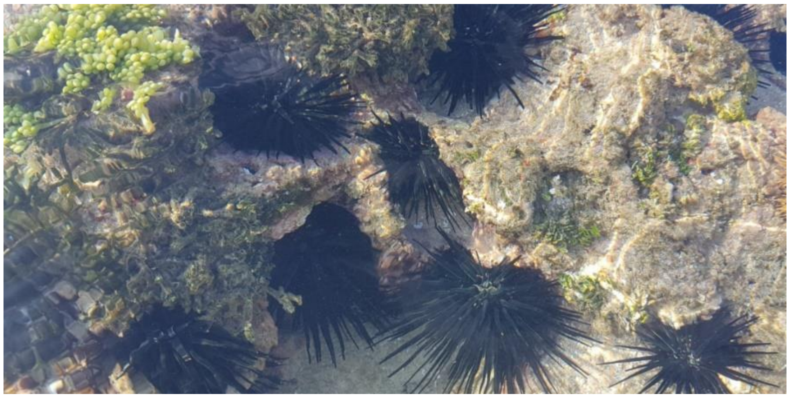
Jordaan, G. L., Santos, J., & Groeneveld, J. C. (2018). Effects of inconsistent reporting, regulation changes and market demand on abundance indices of sharks caught by pelagic longliners off southern Africa. *PeerJ*, *2018*(10). https://doi.org/10.7717/peerj.5726

Lack, B. M., & Sant, G. (2003). WORLD SHARK CATCH , PRODUCTION & TRADE 1990 – 2003.

Progress:

Financial : Physical :

2.6 Sea urchin fishery development in Sri Lanka.



Introduction

Sea urchins are marine benthic organisms that have a calcareous shell and movable spines, which belong to phylum Echinodermata, inhabit tropical and temperate ocean habitats and are distributed from intertidal to deep sea areas (Saravanan, 2017). Nearly 7000 species have been recorded worldwide. They primarily feed on macro-algae and are known as most common macro-grazers in rocky shore habitats (Cebrian and Uriz, 2006). Some sea urchins such as *Tripneustes gratilla*, play a key role by facilitating growth of coral by feeding on algae and controlling their growth (Yao et al, 2019). In addition, sea urchins respond so readily to environmental conditions making them ideal to act as bio indicators that are used to determine the health of an ecosystem (Parish et al, 2012). Sea urchins (Echinoidea) play an important role in ecological aspects, for example their spines act as shelters for the organisms such as ctenophorans, turbellarians, polychaetes, molluscs, copepods, shrimps, crabs, ophiuroids and fishes.

Edible sea urchins belong to a number of families and their reproductive system is made from five lobes ovary or testes which are referred to as “roe” (*uni* in the trade) are not only the eggs or sperms, but also serves as main nutrient storage organ in their body (Toha, 2012). Sea urchin gonads are considered as a good source of protein and it is consumed by the human from pre-historic time. Sea urchin gonads are found to be very rich in bioactive compounds which can be used as food supplements. In addition to that “roe” of about 20 species of sea urchins are consumed worldwide. It is a culinary delicacy prized in many European countries, Chile, North America, Asia, and especially Japan, which accounts for around 90% of worldwide demand. Japan is the world’s largest Sea urchin roe importer and consumer. In 2016 Japan has imported 11,000Mt of roe value of 183 million dollars. Russia is the top exporter of Sea urchin worth US$ 78.3M followed by Japan (https://www.tridge.com/intelligences/sea-urchin/export). The price of sea urchin gonads depend on colour; quality and nutritional value while season and the gonad yield determine the quality of wild catch. While free amino acids and fatty acids determine the nutritional value and the flavour of roe. Raw roe is the value-added product of sea urchin gonads in Japan and it costs ¥ 5000 for 20gm serve in top restaurants. While processed sea urchin gonads cost over US$ 100/Kg in wholesale markets (www.nmfs.gov/owstrade).

Sea urchins are highly abundance in shallow coastal waters in Sri Lanka. 28 species of sea urchins have been identified by Jayakody (2012) among them *Stomopneustes variolaris*, *Diadema* spp and *Tripneustes gratilla* are the common species while *Salmacis* spp are dominant in northern coastal region in Sri Lanka while no species is used for human consumption in Sri Lanka (Jinadasa, 2016). *Stomopneustes variolaris* (Black sea urchin) is the dominant sea urchin species mostly in south and western coastal region which is a warm water sea urchin species belong to Family stomopneustidae which inhabit rocky habitats in shallow coastal area. They are mostly prefer to live in shady areas aggregating in rock pools, crevices and bores (Kroh et al ,2014). They are one of the most edible sea urchin species which can be distinguished externally by their short thick, fragile spines and by absence of blue colour margin on test in Indian Ocean (De Zoysa, 2014). They have a wide distribution from East Africa, Madagaskar, Arabia, Maldives, Lakshadweep, Sri Lanka and Bay of Bengal, China , Japan and South Pacific Islands.

There is a high possibility of developing the sea urchin fishery in Sri Lanka as an export oriented fishery. But, developing the fishery without having a proper management scheme could easily lead to a stock depletion as experienced in other countries. In this study, an attempt was made to identify edible sea urchin species found in Sri Lanka and to find out the distribution of sea urchin in the North and West coasts of Sri Lanka. The main objectives of the study are to study the sea urchin density and the stock size with Total Allowable Catch in above areas.

Objectives

To identify distribution and reproductive cycle of the edible sea urchin in western and Northern coasts of Sri Lanka.

Mapping the edible sea urchin diversity and density of study area.

To identify the feeding behaviour of commonly found sea urchin species in Sri Lanka.

To identify the population genetics of the sea urchin in the study sites of Sri Lanka.

Materials and Method

Preliminary surveys for site selection were conducted in western coastal region starting from the Beruwala Fishery harbour to Negombo Pitipana fishery harbour. Maggona, Kudawa Beach (6° 30'N and 79° 58'E), Uswetakeiyawa (7° 4'N and 79° 50' E) and Morawala Beach (7° 12'N and 79° 49'E) coastal rocky shore areas from western region were selected for the study (Figure 1). Study was carried out in selected sites from January to December 2021.

The underwater survey was conducted using under water observation method by snorkeling to quantify the abundance of Black Sea urchin (*Stomopneustes variolaris*) inhabiting in selected locations. Three different habitats where sea urchins live were identified and surveys were carried out in each habitat separately. In each location, 20 m Belt Line Transects (BLT) were laid to quantify the abundance of sea urchin. All transects were parallel to the shoreline. At the time of data collection, a quadrate of 50cm x 50cm was laid along transects holding from the middle. All the sea urchins present within the quadrate area was counted and recorded for further analysis.

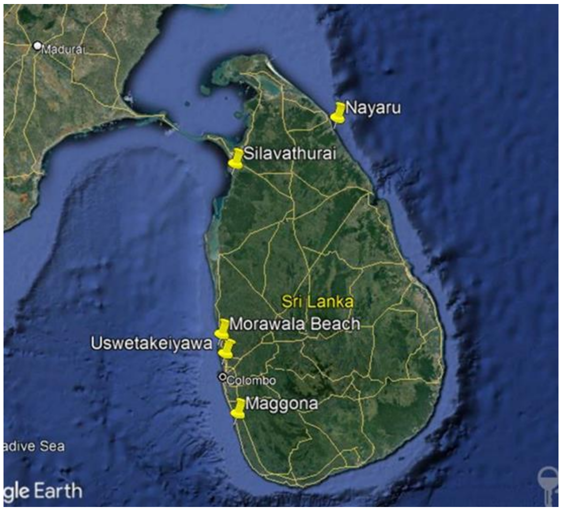


Figure 1: A map of the sea urchin sampling locations

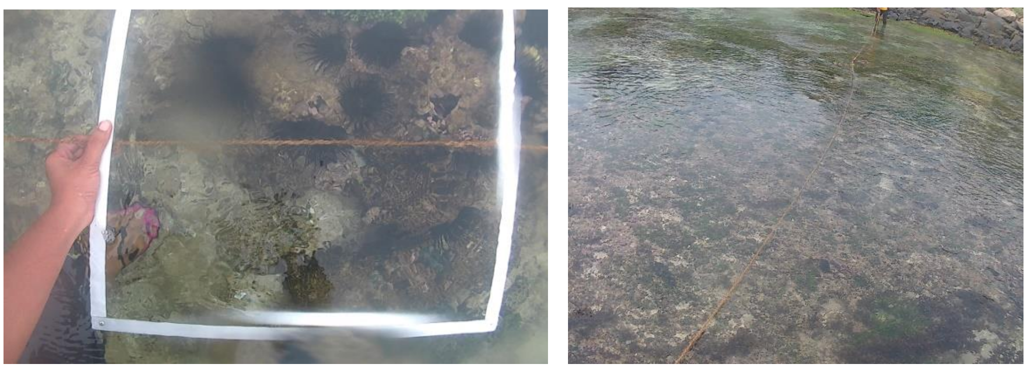


Figure 2: During the sea urchin abundance survey conducted using random transect sampling method

Figure 3: Dominant sea urchin species Black sea urchin (*Stomopneustes variolaris)*in west coast

Figure 4: *Salmacis virgulata* Sea urchin species recorded in Northern region

Results

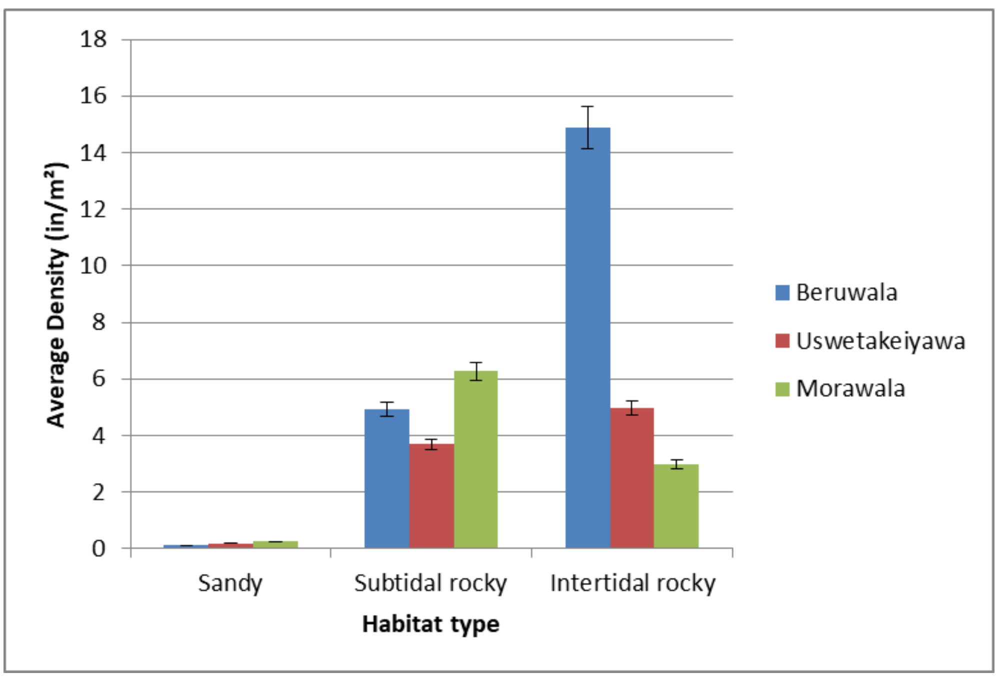


Figure 5: Density distribution of Black Sea urchin (*Stomopneustes variolaris)* in three different habitats of selected sites

Black sea urchin stock size was estimated for each sampling location. Morawala study site has a larger area covered with black sea urchins (Table 3). Also, Morawala has the highest stock size. The lowest population was recorded in Maggona (Beruwala) area.

Table 01: Estimated black sea urchin stock size in study area

Location	Estimated stock size (Individuals)
Morawala	217800
Uswetakeiyawa	123800
Maggona	80940

Discussion

Sea urchin fishery has not yet been established in Sir Lanka. But, there is a higher possibility of developing it as a new export oriented fishery. Due to the higher price, there is a high demand for sea urchin gonads. Therefore, there is a tendency in the depletion of the worldwide sea urchin stocks due to over harvesting. Also, the resource depletion directly affects the maintenance of the ecological balance in an ecosystem since sea urchin plays a key role in the marine food web. In fact, sea urchin has a vital ecological role. They maintain algal overgrowth of their habitats. If sea urchins were largely removed from the natural environment, algal growth cannot be controlled and the system will be covered with different algae species. This can turn in another way too, in some reported cases, removing sea urchin from the system increased sea urchin abundance due to lack of competition that will lead to algae overgraze in the system, finally making it barren. Sea urchins are prey for several organisms, like triggerfish, lobster and puffer fish. Another important ecological role of sea urchins is that they provide refugee for small fish, from their predators. This behaviour has been observed worldwide, mainly with long spine sea urchin species.

This invertebrate species cannot move rapidly from one location to another and they take around 2.5 years to mature. These facts make sea urchin recovery much slower than other species. Many countries are now experiencing sea urchin stock depletion in recent years. For example, the urchin fishery in maine faces many challenges. Dive surveys and port sampling conducted by the Maine DMR from 2007 through 2012 indicate that previously well abundant stocks are not recovering now due to over fishing. Therefore, they have to implement strict regulations to control the harvest.

The high value for sea urchins, strong demand, and dwindling supply from capture fisheries have encouraged interest in sea urchin aquaculture, or echiniculture. Echiniculture can make sure the existence of natural stock by ensuring a consistent supply for the fishery, providing seed for restocking, relieving pressure on the natural resource, and delivering a quality product. Worldwide, there has been enough confidence in the viability of echiniculture to motivate serious research effort and commercialization of hatcheries, feed manufacture, and grow-out operations. Strategies considered for grow-out include sea-based cage systems, sea ranching, and land-based tank systems.

According to University of Maine's Center for Cooperative Aquaculture Research (CCAR) echiniculture researchers, survival of the cultured animal has exceeded 95% and many of these urchins are nearing market size after 2.5 years of growth. Export quality of sea urchin gonads can be enhanced using modern culture methods. Therefore, it is appropriate to think about mariculture rather than wild stock harvest. Since Sri Lanka does not have previous experience regarding sea urchin culture, it is better to start with grow out methods using mariculture as a pilot project. Furthermore, new research is needed on echiniculture and gonad enhancing methods.

Recommendations

Exploiting wild catch in a small quantity could be allowed while ensuring the sustainability of resources. Accordingly, following management and controlling measures could be adopted:

Issuing a license for the exploitation of black sea urchin only.

40% is considered as total allowable catch from the standing stock.

Allocating quotas on area specific resource base for the exploitation of black sea urchin once per every two-year period based on NARA recommendation.

Implementation of minimum size regulations or maximum number of individuals per kilogram

Only the hand picked method should be allowed for the exploitation of sea urchin

Proper catch reporting system needs to be introduced.

Exploitation during the peak season(s) of spawning needs to be promoted in order to get maximum economic benefits (Note: it was not possible to determine the spawning season(s) due to the constraints in the sample collection during the COVID 19 outbreak)

References

ANDREW, N., AGATSUMA, Y., BALLESTEROS, E., BAZHIN, A., CREASER, E., BARNES, D., BOTSFORD, L., BRADBURY, A., CAMPBELL, A. & DIXON, J. 2003. Status and management of world sea urchin fisheries. *Oceanography and Marine Biology-an Annual Review*, 40, 343-425.

B.K.K.K. Jinadasa, H.K.S. De Zoysa, G.D.T.M. Jayasinghe & E.M.R.K.B. Edirisinghe | Fatih Yildiz (Reviewing Editor) (2016) Determination of the biometrical parameters, biochemical composition and essential trace metals of edible sea urchin (*Stomopneustes variolaris*) in Sri Lanka, Cogent Food & Agriculture, 2:1,

LAWRENCE, J. M. 2001. *Edible sea urchins: biology and ecology*, Elsevier.

LE CREN, E. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *The Journal of Animal Ecology*, 201-219.

PEARSE, J. S. 2006. Ecological role of purple sea urchins. *Science*, 314, 940-941.

RAHMAN, M., AMIN, S., YUSOFF, F. M., ARSHAD, A., KUPPAN, P. & NOR SHAMSUDIN, M. 2012. Length weight relationships and fecundity estimates of long-spined sea urchin, Diadema setosum, from the Pulau Pangkor, Peninsular Malaysia. *Aquatic ecosystem health & management*, 15, 311-315.

SONU, S. C. 2003. The Japanese sea urchin market. Long Beach, California National Marine Fisheries Service, NOAA

VAÏTILINGON, D., RASOLOFONIRINA, R., EECKHAUT, I. & JANGOUX, M. 2005. Reproductive cycle of edible echinoderms from the South-Western Indian Ocean: II. The sandfish Holothuria scabra (Jaëger, 1833).

Progress:

Financial : Physical :

2.7 Sea cucumber fishery assessment in Northern and Northwestern waters

Introduction

Sea cucumbers are locally known as *muhudu kekiri* or *attaya* is one of key export-oriented fishery resources in Sri Lanka. The fishery for sea cucumber had been introduced by the Chinese around the 18th century. Though there is a long history for sea cucumber fishery in Sri Lanka, sea cucumbers are not consumed locally and whole harvest is prepared for the export market. Beche–de–mer is the major commodity produced in Sri Lanka from sea cucumber, and the entire annual production is exported to Asian countries.

The fishing season in the North west coast starts in November and prevails till the end of March. Sea cucumber collection centers are located in Kalpitiya, Puttalam and Mannar districts. Mostly collectors and divers who engage in the sea cucumber fishery in the North coastal area migrate to the North west coast to initiate the fishery in the season.

The fishing season for Pawakkai attaya' (*Stichopus naso*) in the Jaffna district normally starts in March when the sea is calm and clear and it continues up to September. At present, divers who had involved in the sea cucumber fishery in the Mullaitivu waters are now carrying out fishing activities targeting Pawakkai attaya' (*Stichopus naso*) in the fishing ground located near Point Pedro in the Jaffna district. The aim of this study is to provide managers with information on the status of sea cucumber stocks in relation to current levels of exploitation.

Materials and methods

In order to achieve above objectives, a survey of fisheries records was carried out in 2021 in North coastal area and North West coastal area based on sea cucumber collection centers ('*Waadi*'). In 2021 fishing season, there were no fishery for sea cucumbers by SCUBA diving in the North western coast till the end of March due to the temporal ban declared by the Ministry of Fisheries.

Considering the North coast, fishers established themselves in 'Nagar Kovil' area in Jaffna district (Figure 1). The fishing season was initiated in May and continued till the end of October in 2021. 20 collectors were mainly responsible for conducting the fishery for sea cucumbers in North coastal areas in 2021.

Figure 1: Sea cucumber fishery in the Nargar Kovil area

Data collection.

Field visits were conducted during the fishing season of the respective regions. Thus 2 field visits were conducted to each collecting center at around the middle of the season and close to the end of the season. Data was extracted from the personal log book records of the collectors in the landing sites. Accordingly, the total landed catch per boat by species in terms of number of pieces was extracted from daily log book records of 20 collectors who agreed to share the logbook data for this study. Also, they provided information relevant to monthly fishing effort i.e., total number of boats operated from a collection center in a particular month. The species were identified using available published literature and guides.

Underwater survey

A preliminary underwater survey of line transect method was conducted in the fishing ground in the Point Pedro in order to identify the distribution and the density of the 'Pawakkai attaya' (*Stichopus naso*) (Figure 2). The low visibility of the water and the depth was not at an optimum level as per the human power band instrument had been available for a comprehensive survey. Thus, only two locations were investigated during this preliminary underwater survey.

Figure 2: The underwater survey at Point Pedro fishing ground

Data analysis.

With the available data following parameters were analysed: total production (species wise); effort and the CPUE. The results of the present study were compared with the results of the similar study conducted in 2021 inorder to undestand the prevailing trend in the sea cucumber fishery in the North coast.

Results and Discussion.

Current status of the sea cucumber fishery in North West coastal waters

In 2021, there were no fishery for sea cucumbers by SCUBA diving in the North western coast till the end of March due to the temporal ban declared by the Ministry of Fisheries. Few divers had engaged in collection of sea cucumbers by skin diving but had not been well established. Instead most of the divers had switched to the demersal fishery. Among them some had used spear guns (which is a prohibited fishing method) to catch high valued demersal fish species such as large size groupers, parrot fishes…etc. Some divers had engaged in capturing larger coastal skates using nylon traps (Figure 3).

As the season for the sea cucumbers prevailed till the end of October and due to the extreme weather condition that had been experienced in the North West coast, though the permission had been granted for the season from October to March, the sea cucumber fishery in the North west coastal region was not well established till the end of November when the field survey was conducted.

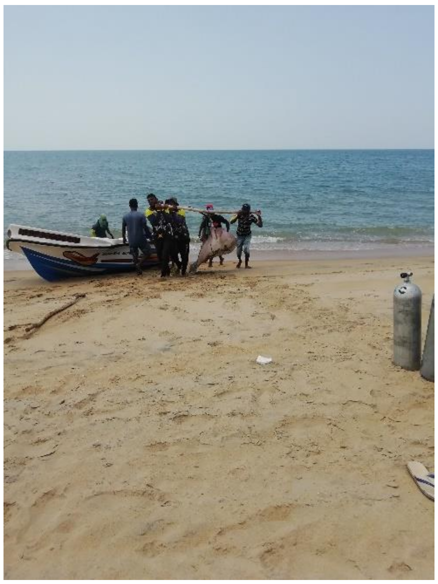


Figure 3: Skate fishery carried out by the divers as the sea cucumber fishery had been banned temporarily

Current status of the sea cucumber fishery in North coastal waters

The fishing season was initiated in mid May and continued till 3rd week of October in 2021. 18 collectors were mainly responsible for conducting the fishery for sea cucumbers in North coastal areas in 2021. The main target species was ‘Pawakkai attaya’ (*Stichopus naso*) for which the fishing ground located in the Point Pedro region in Jaffna district. ‘Disco attaya’ (*Holothuria spinifera*), Kiri Nool (*Bohadschia vitiensis*) and Sangu (*Turbinella* Spp.) were the other species recorded in the commercial catch. These species contributed 97.38%, 1.25%, 1.35% and 0.02% to the total catch respectively (Figure 4). In addition, *Stichopus herrmanni* and *Thelenota anax* contributed in insignificant amounts to the total catch.

The average CPUE for the ‘Pawakkai attaya’ (*Stichopus naso*) was estimated as 3094 individuals/boat/day respectively. The total production for *Stichopus naso* was estimated as 23,815,589 individuals at the end of the fishing season in 2022 (Table 1).

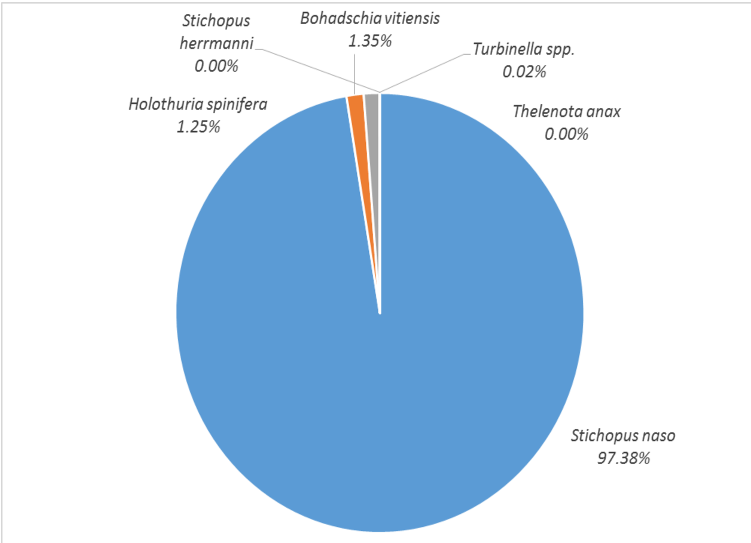


Figure 4: Species composition in the sea cucumber catch in 2021

Table 1: Comparison of the production in the North coast

Species	2020	2021
Stichopus naso	10,693,743	23,815,589
Bohadschia vitiensis	270,268	331,052
Holothuria spinifera	78,841	305,814
Turbinella spp.	2,319	4,088
Stichopus herrmanni	0	8
Thelenota anax	0	215

Considering the total production in 2021, it has been drastically increased than that in 2020 (Table 1). When analyzing the log book records of the sea cucumber collectors, it was obvious that all the collectors had involved in night time diving activities in several weeks of the fishing season. That could be the reason for increased production of *Bohadschia vitiensis* and *Holothuria spinifera* in 2021.The number of collectors had increased form 11 in 2020 to 20 in 2022. During the interview of the divers it was found that some of the divers who had been engaged in the marine ornamental fish collection had then joined the sea cucumber fishery for the first time. The average monthly fishing pressure had also increased than 2020 (Figure 5).

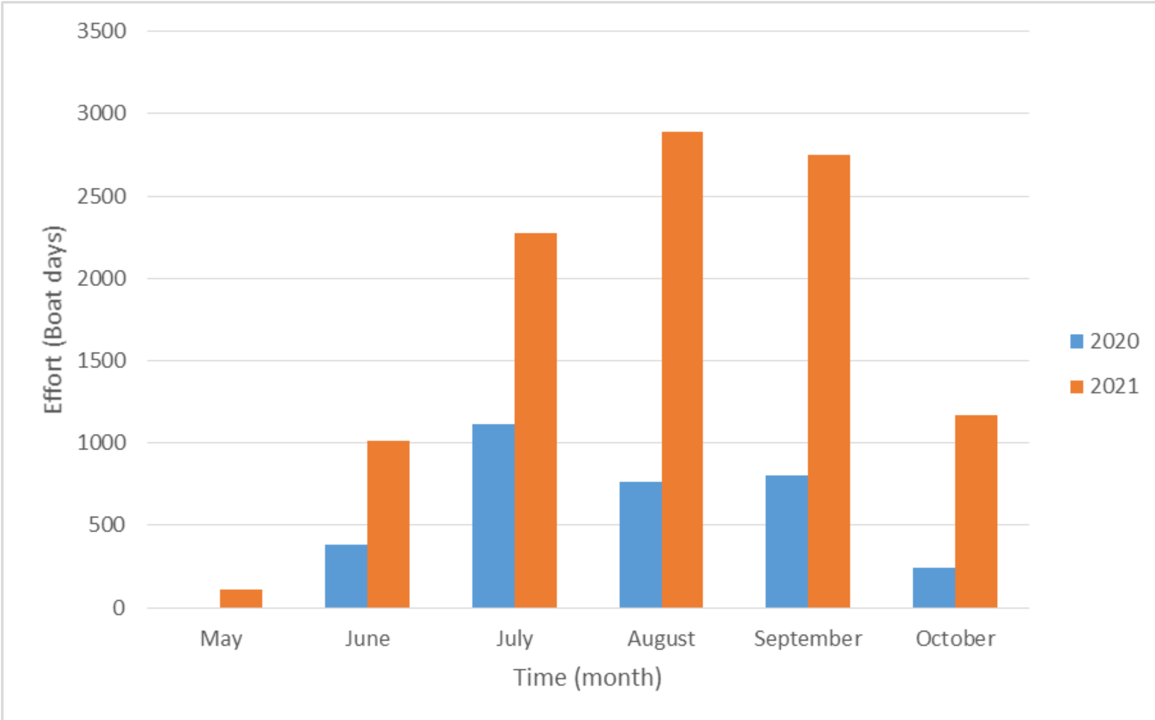


Figure 5: Compression of the average monthly fishing effort in 2020 and 2021.

The combined effect of all these factors may be the reason for the drastically increased production of the ‘Pawakkai attaya’ (*Stichopus naso*) in the North coastal region. Even though the production was increased, the average CPUE has been decreased from 3178 individuals/boat/day in 2020 to 3094 individuals/boat/day in 2021.

Considering all these facts, it is evident that there is more intense fishing pressure for the ‘Pawakkai attaya’ (*Stichopus naso*) in the North coastal region than that in the 2020.

<u>Underwater survey</u>

The fishing ground for ‘Pawakkai attaya’ (*Stichopus naso*) was located in the close proximity of Point Pedro, about 16 km away from the shore. The average depth of the fishing ground varied around 55ft. Based on the survey conducted in two locations in the fishing ground, the average density of the ‘Pawakkai attaya’ (*Stichopus naso*) was estimated at 8,000,000 individuals/km^2 (Figure 6). However a comprehensive survey should be conducted sampling in more number of locations, covering the entire fishing ground in order to conclude more accurately on the density and distribution of the species.

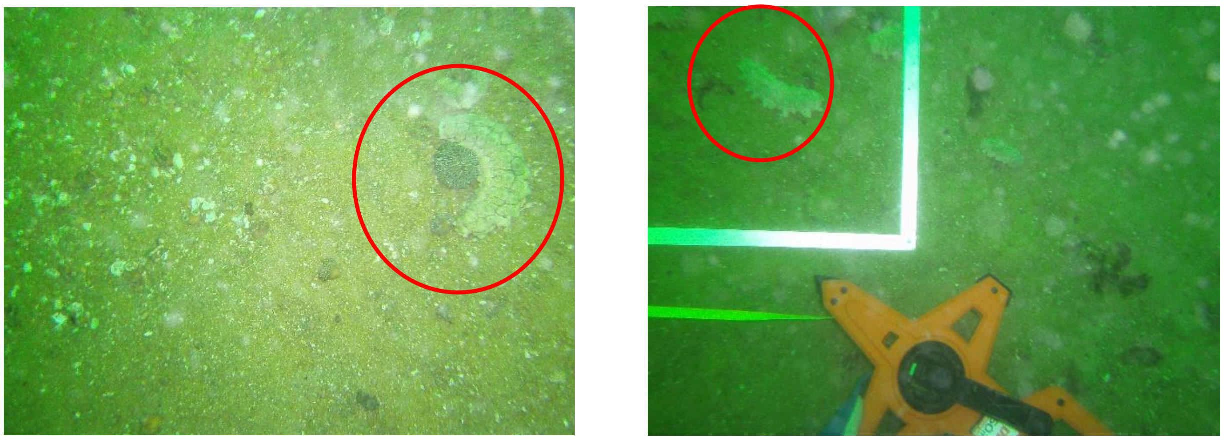


Figure 6: Distribution of the Pawakkai attaya' (*Stichopus naso*) in the North coast fishing ground

Conclusions

Based on the results gathered in both 2020 and 2021, it can be concluded that there is a intensively growing trend in the sea cucumber fishery for the 'Pawakkai attaya' (*Stichopus naso*) in the North coast fishing ground. If the fishing activities continues without proper monitoring, the resource can be depleted in very near future.

Recommendations

Thus, it is recommended to conduct comprehensive underwater survey as soon as possible in order to understand the distribution and biomass of the resource in the fishing ground. In addition, it is recommended to continue the data collection on the sea cucumber fishery in the North coast.

Progress:

Financial : Physical :

2.8 Spiny lobster fisheries management, in situ conservation of berried spiny lobsters and lobster fattening

Introduction

Lobsters are one of the most valuable and economically important crustacean species found in Sri Lankan coastal waters largely used for export. Major fishery of the country is located in the shallow waters of the south coast of Sri Lanka in Hambanthota district and adjacent coastal region of the Ampara district. This fishery is very popular among the small-scale artisanal fishers in the district and approximately 2000 people directly or indirectly depend on it. Mean annual lobster export of the country is around 225 MT and the Hambanthota district accounts for an average 60% to the national lobster production. Observations on the annual spiny lobster export volume and income after the year 1999 revealed that export volume has been slightly falling from 1999 to 2019, but income has fairly increased with time due to growing prices in the world market. The lobster fishery resources of the district have depleted due to violation of the existing management regulations and increasing fishing pressure, hence a new set of regulations has been introduced under the fisheries co management. This study focused on the current status of the spiny lobster fishery in the district to review the existing management regulations.

Methodology

Major lobster landing sites and collecting centers in the Hambanthota district (Tangalle, Hambanthota, Kirinda, Amaduwa) were visited twice a month for fisheries and biological sampling. Carapace length, total length, sex, species composition presence or absence of external eggs or spermatogonia, craft type, gear, catch volume were recorded.

Catching of berried females adversely impact of the resource health; hence for conservation of the berried lobsters 30 individuals were kept in the pen constructed at the Matara Polhena sea until they release their external eggs. This programme was continued in collaboration with the Polhena fisheries co-management committee.

For introduce lobster aquaculture, lobster fattening facility developed in the Kaisawella Dondra but trails couldn't be started due to Corona pandemic and lack of sufficient small lobsters available in the area for fattening.

Results

Species composition

It is observed that drastic change in the species composition of the spiny lobster catch during the year 2021 (Fig.1) compared to the past years. Among the five species of spiny lobsters recorded in the south coastal region, *P. homarus* is the most common species (65%) contributing to the catch; although, for more than two decades it has represented over 80%. Composition of *P. versicolor*, *P. penicillatus*, *P. longipes* and *P. ornatus* are respectively 19%, 13%, 3% and less than 1 percent.

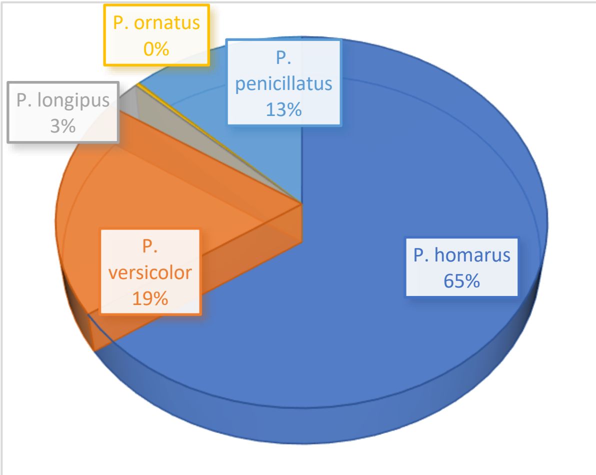


Figure 6: Species composition of the lobster catch

Monthly variation of the berried females

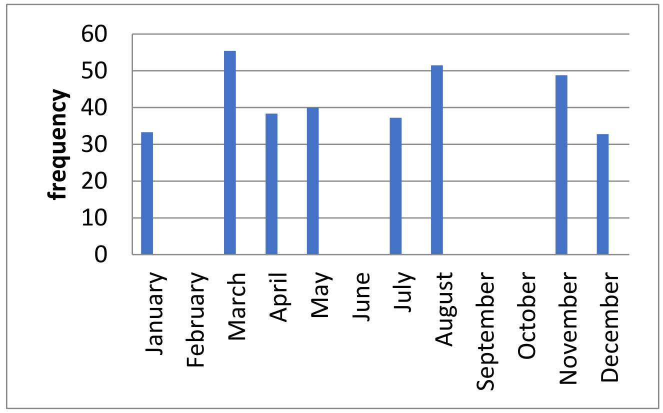


Figure 7: Monthly variation of the berried females present in the catch

Catching of the berried females have been identified as a major threat for the population growth of major species. Monthly variation of the berried females (% as total female to berried females) that were presence in the catch are presented in figure 2. Among the two peak breeding cycles, percentage of the berried females exceeded or was close to 50% in March, August and November months. Further, results revealed that implementation of the regulations related to the catching of berried females are inactive or poorly employed.

Length based Spawning potential ratio (LBSPR)

Length based-spawning potential ratio (LP-SPR) approach is a new management measure that can be applied in data poor fisheries. Spawning potential ratio (SPR) based on length data is well-established with a biological reference point for data-poor fisheries management. In this study LBSPR was calculated only for the major species *P. homarus* since there is a lack of sufficient data for other species found in the area.

The biological parameters used to estimate LBSPR are as follows

M/k= 1.74 , CL_{inf} = 117.0, CL_{m50}= 61.2, CL_{m95}= 67.3

Figure 3. indicates that current status of the LBSPR for the *P. homarus* during the year 2021. Further, it was revealed that current LBSPR value 28% is 2% below the target reference point (30%). However, within the past years it was far below the target reference point.

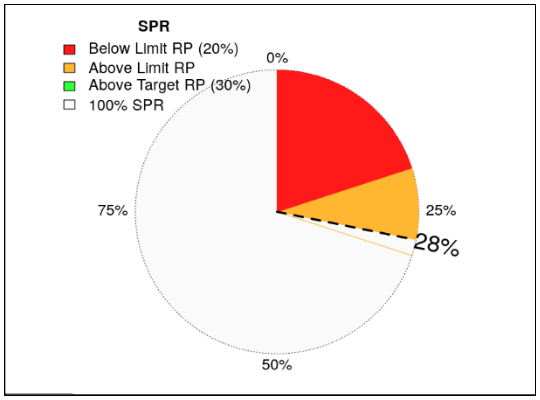


Figure 8: LBSPR value generated through Barefoot Ecologist's toolbox

Selectivity and maturity

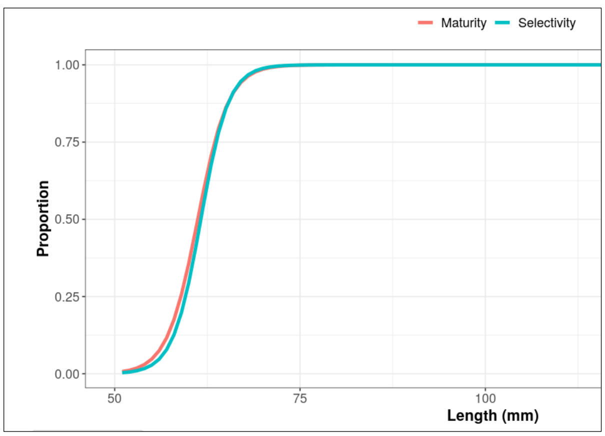


Figure 9: Selectivity and maturity curves for the P. homarus

Selectivity and maturity curves generated through the Barefoot Ecologist's tool box indicated in figure 4 revealed that both curves are overlapping for major part of the graph. This is an indication of the threat levels of the population for fisheries; when lobsters get matured, they are vulnerable to exploitation.

Length frequency distribution

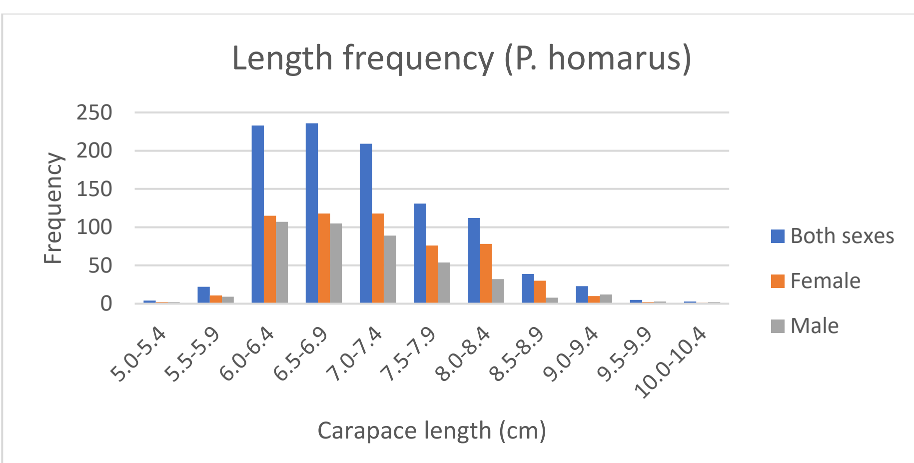


Figure 10. Length frequency distribution for the P. homarus

Length frequency distribution pattern of the major species, *P. homarus* is mentioned in the figure 5. According to this figure large portion of the catch consisted of small lobsters (6-6.9cm CL- 46% , n=469) but above the minimum legal size (CL 6 cm) and also 28 (2.56%) under size lobsters. Further, it was revealed that a number of large size lobsters represented in the catch is small and reflect the threat level to the stock. Length frequency distribution of male and females revealed that number of females in each length class is bigger than that of the males.

Lobster fattening trials

Facilities for the lobster fattening trials were developed at the Kaisawella, Dondra but trials were postponed due to corona pandemic and lack of required quantity of lobsters for fattening.

Figure 11. Construction of fattening cages

Conservation of the berried lobsters

Berried lobster conservation was carried out in the facility constructed at the sea in Polhena. This was done in collaboration with Polhena fisheries development committee. During one-year period 30 berried females were stocked and 7.5 million of larvae were released to the natural environment.

Figure 12: Lobster conservation facility constructed at Polhena, Matara

Conclusion.

Still *P. homarus* is the main species found in the catch, but species composition changed drastically.

Fishermen are not respecting the current regulations and they are catching berried females in large scale.

Large number of berried females are present in the catch during the months of March, August and November.

Bottom set gill net which is the main fishing gear used to catch lobster is a prohibited gear set on the coral and reef areas.

CPUE values have remained the same within the past year.

Community based berried female conservation programme is very successful and additionally fishing community earn money showing lobsters to foreigners.

Recommendations.

Strict enforcement of the regulations for egg removing.

Introduction of ecofriendly fishing gear instead of the bottom set gill net.

Amendment of the second closed season. (For the September and October month should be declared October and November).

Complete prohibition of catching females for at least one year or revision of the minimum legal size at least more 2 cm.

Progress:

Financial : Physical :

2.9 Assessment of ecosystem health using bio-indicators associated with nutrient enrichment and sedimentation on some targeted coral reefs in Sri Lanka.

Officers Responsible: M.P. Hendawitharana / Scientist

Dr. R.P.P.K. Jayasinghe / Principal Scientist

M.M.C. Karunarathne / Development Officer

1. Summary of the research:

The project, “Assessment of ecosystem health using bio-indicators associated with nutrient enrichment and sedimentation on some targeted coral reefs in Sri Lanka”, was designed to investigate the possibility of using time integrated bio-indicators to evaluate the impacts of nutrient enrichment and sedimentation impacts on coral reefs health in the vicinity of Sri Lankan coastal waters. For decades’ reef monitoring programs conducted in Sri Lankan coastal waters depended exclusively on direct measurement of water quality parameters to assess the ecosystem health. Such approaches are now considered as less effective as it only provides a snapshot of data at a given point of time. Further, given that the long-term reef monitoring programs are expensive and work intensive, identifying a few time-integrated bio-indicators to assess coral reef health at the local scale would simplify reef monitoring efforts and facilitate effective reef management actions. Hence it is a timely need to incorporate efficient and novel monitoring techniques to account for these limitations.

The general objective of the proposed study is to establish a baseline long-term reef monitoring program with a special focus on investigating nutrient enrichment and sedimentation impacts on coral reef health using time integrated bio-indicators. In addition, the specific objectives are as follows;

To establish a database to record long-term reef monitoring survey data on annual basis

To investigate the effect of nutrition loading (Nitrate, Nitrite, Phosphate, Silicate, Ammonium) on coral reef degradation.

To investigate the effect of sedimentation on coral reef degradation.

To identify suitable wild coral species which have the potential to be used as mother colonies in coral culture.

To map the existing coral reefs

To update the present status of reef fish community in selected study sites (abundance and diversity).

The proposed study was to be conducted as a two-year continuous monitoring program and will be extended to a five-year monitoring program after evaluating the success of the initial phase.

2. Study site

Below listed study sites were identified as potential for the proposed project;

Kayankerni Marine sanctuary (Figure 1a)

Silawathureai coral reef system (Figure 1b)

Rumassala marine sanctuary (Figure 1c)

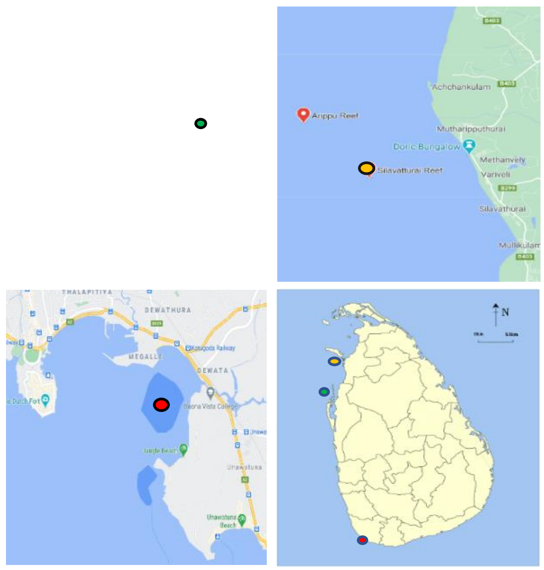


Figure 13: Maps indicating the preliminary survey locations a) Bar Reef Marine sanctuary b) Silawathurai Reef c) Rumassala Marine sanctuary

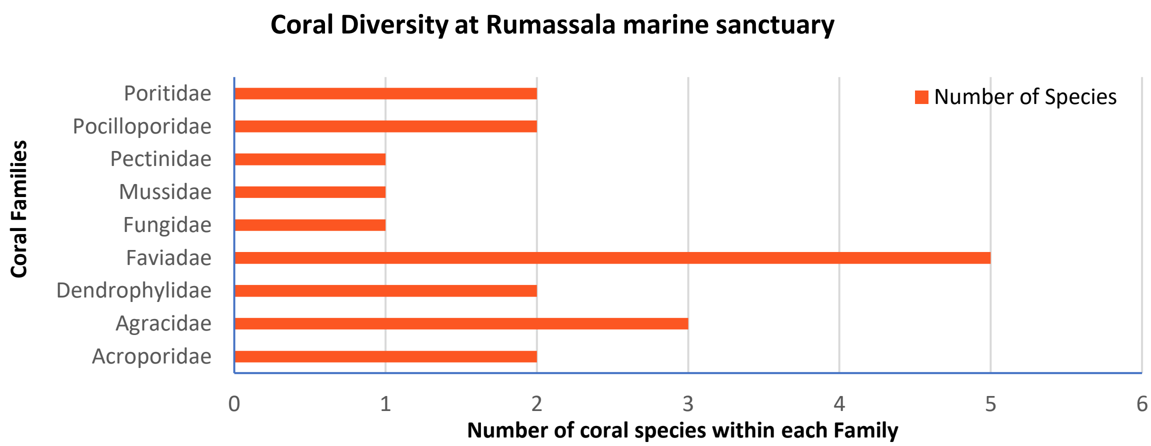
Data Collection

For the initial stage of the study, preliminary surveys were aimed primarily to investigate the species diversity of corals, reef fish and other marine invertebrates in the vicinity of the proposed study sites. The availability of desired bio-indicators with a potential to respond in a bimodal oscillation for the changes of environmental parameters were also planned to be investigated as the second stage of the study followed by the successful completion of the preliminary surveys. Each study site was surveyed using underwater line intersect transects (LIT) where diversity and the abundance of coral species were estimated along 50 m transect lines. To estimate the abundance of coral reef fish species, belt transects of 50 m long and 2 m wide from either side were surveyed. Line transects were deployed randomly between 3-5 m depth range and the number of transects were determined as a representative of the existing coral cover. In addition, type specimens were collected to identify the existing coral species to the lowest possible taxonomic level.

Data Analysis

Preliminary study at Rumassala marine sanctuary

During the preliminary survey, 19 coral species belonging to 9 families were recorded (Figure 2). The highest number of species were recorded from the family Merulinidae (5). Total live hard coral cover was recorded between 20% - 25%. Forty-six (46) species of reef fish belonging to 22 families were also recorded during the preliminary survey (Figure 3). The highest number of reef fish species were recorded from the family Acanthuridae (6), followed by family Pomacentridae (5) and Labridae (5) respectively.



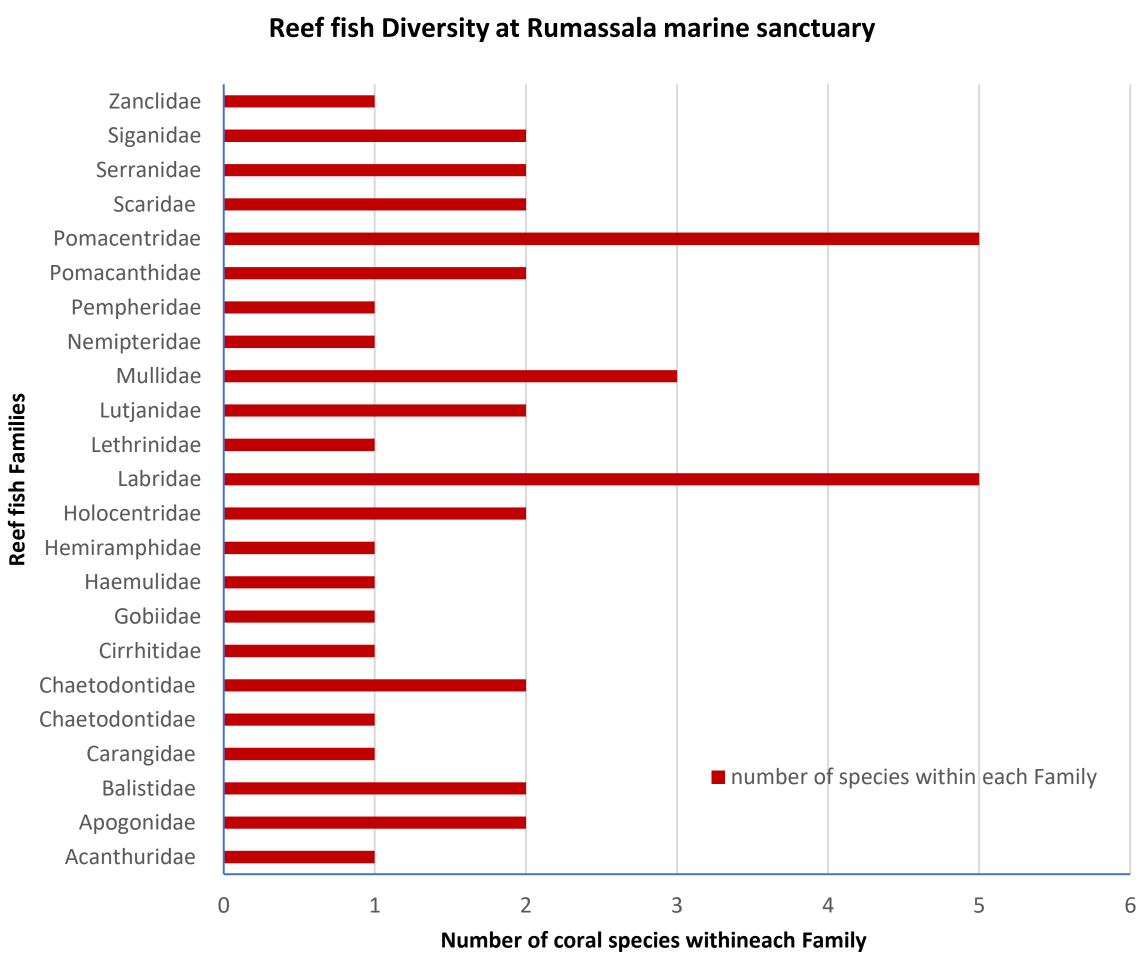


Figure 2: Reef fish species diversity at Rumassala marine sanctuary

3.2. Preliminary survey at Silawathurei reef

During the preliminary survey, 15 coral species belong to 9 families were recorded. The highest number of species were recorded from the family Merulinidae (5) followed by Acroporidae (4) and Poritidae (2). Total live hard coral cover was recorded as 59-60%. Forty-six (75) species of reef fish belonging to 22 families were also recorded during the preliminary survey. The highest number of reef fish species were recorded from the Family Cheatodontidae (11) and Pomacentridae (11).

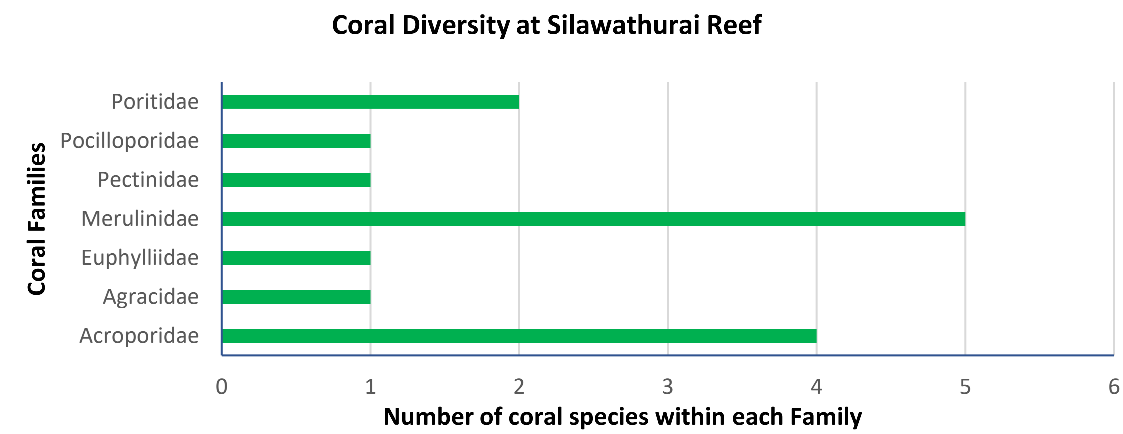


Figure 3: Coral species diversity at Silawathurai Reef

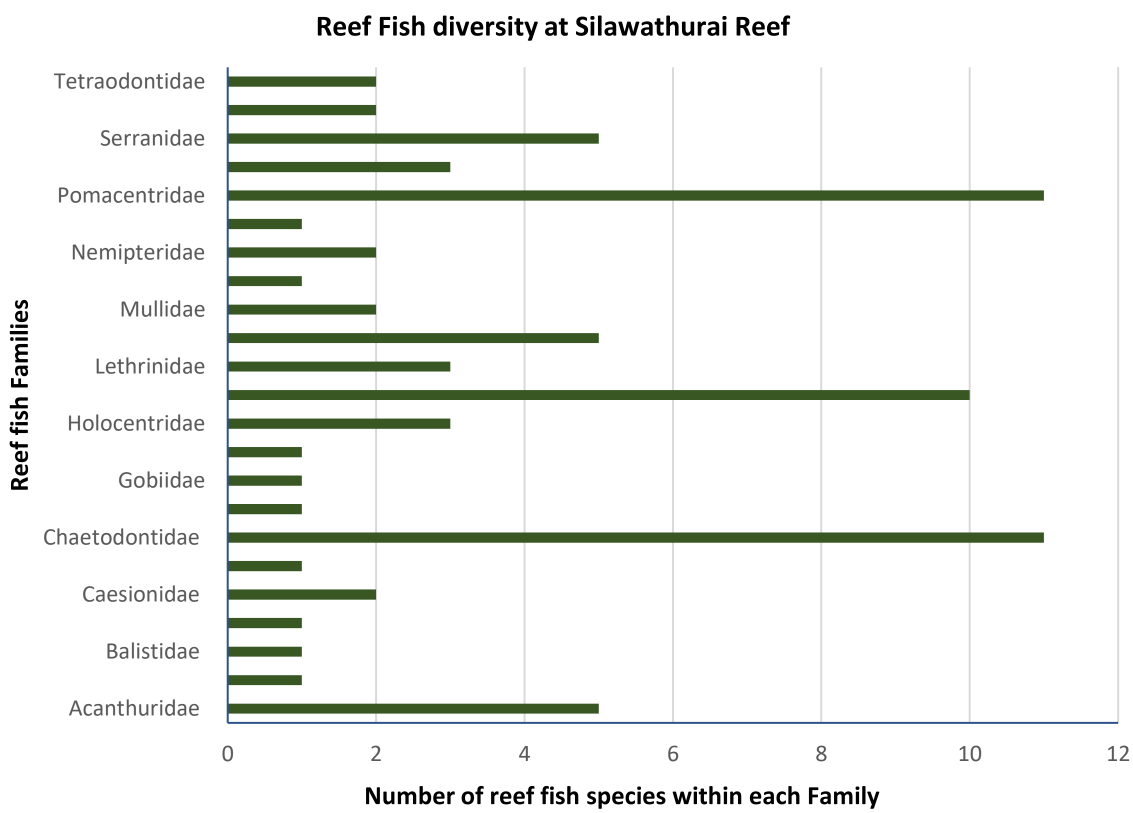


Figure 4: Reef fish species diversity at Silawathurai Reef

Preliminary survey at Kayankerni marine sanctuary

Kayankerni reef recorded a live hard coral cover of 15-17% including 31 coral species and 70 species of reef fish. Highest number of coral species 31 and highest number of reef fish species 70 was recorded at Kayankerni reef. But the observed coral cover was very low comparing with the other two sites.

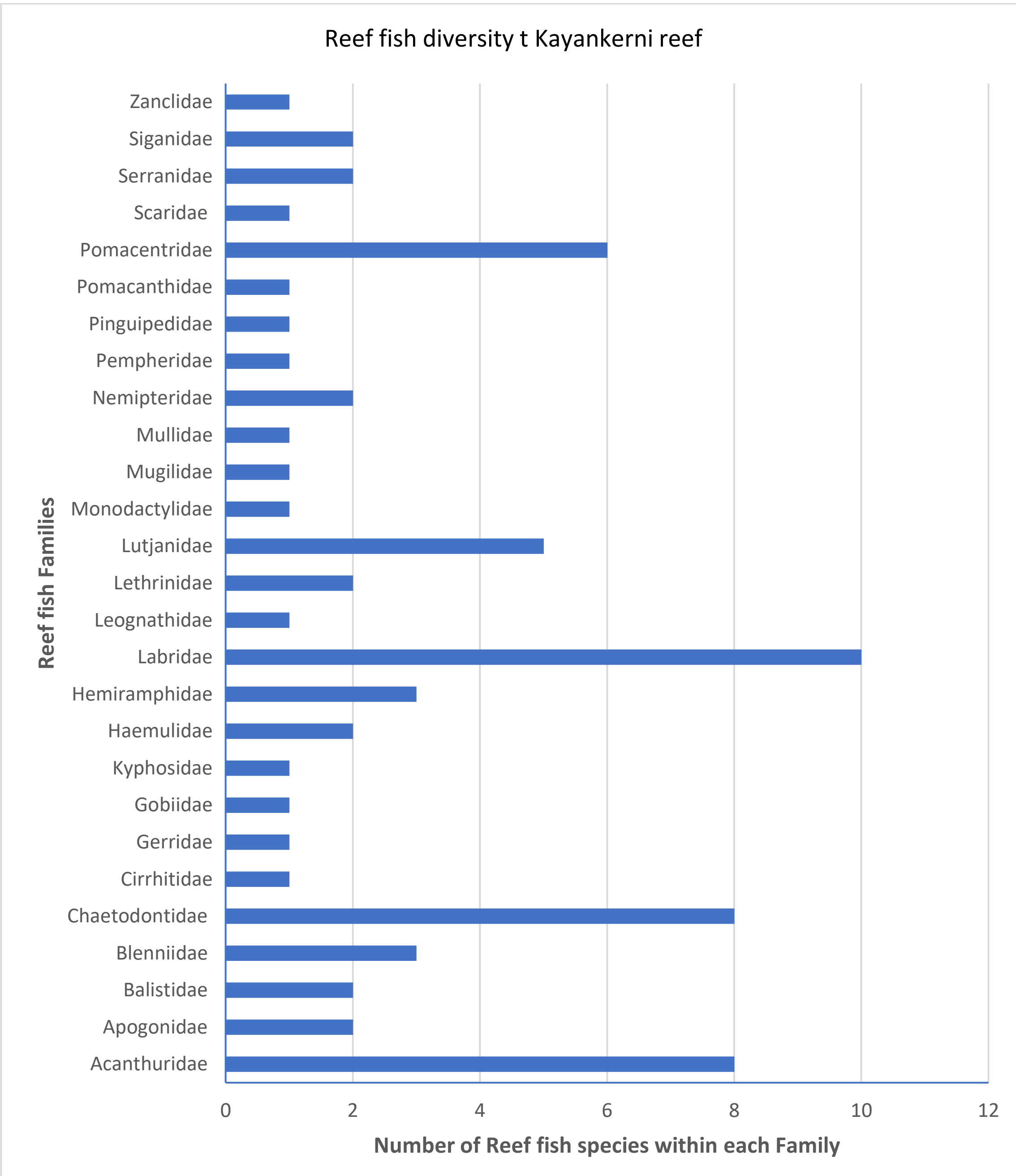


Figure 5: Reef fish diversity at Kayankerni reef

Remarks/ prospects/ Constrains

Constrains

During the preliminary survey at Bar reef, it was identified that the shallow reef flats are not suitable for the proposed study. Since the live hard coral cover is around 0 -1%, the site itself doesn't align with the main objective of the study which is the identification of suitable bio indicators that can account for environmental stressors. Hence, a request has made to change the study site from Bar reef to one of the below mentioned reef sites;

Vankalei Reef

Arippu Reef

Silawaturei Reef

In accordance with the above request, a preliminary survey was conducted at Silawathurai Reef area and it was identified as a well suitable study that meets the requirements of the proposed study

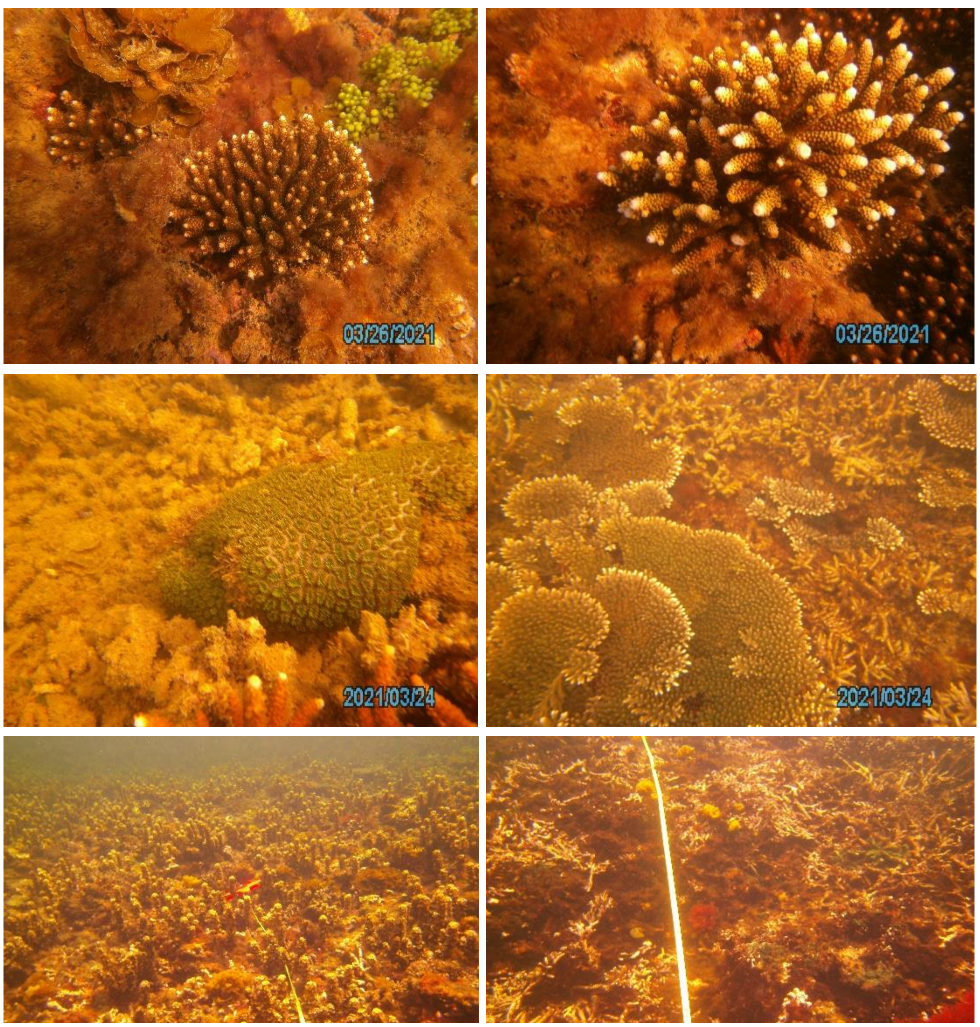


Figure 6: Underwater photographs of benthic habitats at Silawathurai reef site a/b) Acropora sp. (branching) c) Galaxia sp. c) Acropora sp. (table) e) macro algal overgrowth of Turbinaria ornata e) coral rubble

Preliminary survey at Bar reef marine sanctuary

Figure 7: a) NARA scientists conducting the underwater survey at Bar Reef marine sanctuary b/c) Abundant coral rubble substrate at the sampling sites d) new recruitment of Acropora sp. (highlighted in red).

A preliminary survey was conducted at the shallow reef flats of Bar Reef during February, 2021 to investigate the diversity and the abundance of existing corals species. Three sampling points were investigated to conduct underwater surveys between the depths of 1.5 m to 3 m.

A total mortality of hard coral (HC) species was observed during the preliminary survey at Bar reef marine sanctuary. No visible live HC cover was observed. A negligible proportion of new coral recruits (less than 1%) of *Acropora* sp. was present at the study site. An abundant overgrowth of seaweed *Stoechospermum polypodioides* was visible in all the 3 sampling sites. Occasional occurrence of *Halimida* sp. was also evident in small numbers.

4.2. Recommendations

Immediate conservation actions should be taken to restore the coral ecosystem at shallow reef flats of Bar reef marine sanctuary. In this regard, suitable conservation actions were also recommended in the submitted status report on the current status of the Bar reef marine sanctuary.

5. Conclusions

Rumassala marine sanctuary, Kayankerni marine sanctuary and Silawathurai reef areas were identified as suitable study sites that meet the objectives of the study.

Bar reef marine sanctuary was identified as not suitable to account for the long-term monitoring of bio indicators.

Progress:

Financial : Physical :

2.10 Studying the fisheries and marine mammal interactions and declaration of marine mammal protected areas in Sri Lanka

Introduction

Tuna long liners play a vital role in the export-oriented fisheries sector in Sri Lanka via providing quality fish for export market in order to earn substantial foreign exchange to the country. Fisheries and marine mammal interactions are becoming serious issues for the industry making huge economic losses and adverse impacts to the marine mammals as well. Depredating behaviour of the marine mammals can have serious consequences for fishermen, especially when they lose valuable catch and face other associated operational and regulatory challenges. The multiple measures taken by the fishermen are not sufficient to mitigate the depredation. The spatial distribution of the marine mammals, identification of marine mammal species that are responsible for depredation, and mitigatory measures already practiced by the fishermen are important factors when designing the new mechanism incorporated with depredation pingers.

Methodology

To study the fisheries and marine mammal interactions, questionnaire surveys were carried out in two major fisheries harbours (Dikovita and Gandara) used to fishing in high seas and EEZ. Boat owners or crew members of multiday fishing boats (IMUL) were interviewed monthly covering 20% of the boats. Several measures are taken by the long liners but have not been successful. Therefore, current study is aimed to understand

Species responsible for the depredation

Temporal and spatial changes

Severity of the damage

Mitigation measures

Damages to the marine mammals (entanglement or damages)

Information was collected regarding last fishing trip they have completed and the severity of depredation calculated following the method described below.

Result

Depredation Index (DPI)" (Romanov et al., 2007; Ramos-Cartelle & Mejuto, 2008)

$$DPI = \frac{\sum_{o}^{i} FD}{\sum_{o}^{i} H} \times 10000$$

Where, FD (fish damaged) is the pooled number of marketable fish individuals that were damaged; H is the total number of hooks deployed (pooled nominal fishing effort).

Attack interval (AI) (Nishida and Tanio 2001)

$$AI = \frac{\sum O}{\sum OD}$$

O is number of fishing operations and OD is operation with depredation.

Damage rate (DR) (Nishida & Tanio, 2001; Romanov et al., 2007)

$$DR = \frac{\sum OD}{\sum O}$$

O is total number of fishing operations (longline set), OD operations with depredation

Depredation rate (Donoghue et al., 2003, Romanov et al., 2007)

$$DPR = \frac{\sum_o^i FD}{\sum_o^i Fc}$$

FD (damaged catch) is number of fish damaged, FC (total catch) is number of fish caught, i – number of fishing operations.

Damaged intensity (DI) (Nishida, Tanio, 2001, Romanov et al., 2007)

$$DI = \frac{\sum_o^i FD}{\sum_o^i Oy}$$

F_D is fish damaged, O_Y – operations (either total, positive, affected, affected by specific predator);

Index	Value
Depredation Index (DPI)	15.60
Depredation ratio (DPR)	0.36
Attack interval	3.46
Damage rate	0.29
Damage intensity	2.31

Economic loss

The economic loss of depredation for two IMUL boat categories were calculated considering the direct loss of depredation.

Boat category	Number of hooks/boat	Number of days spent at sea pre trip	Number of fishing days per trip	No of days damaged	Loss per trip Rs
IMUL High seas	1532±415	36.3±11.0	11.86±3.53	3.83±3.25	1149671.00
IMUL EEZ	1132±504	19.23±13.61	9.62±5.64	2.08±2.77	348786.00

Through the questionnaire survey of IMUL boats, four marine mammal species have been identified that have been damaged due to the hooked yellow-fin tuna, skipjack tuna, marlin and sailfish. These species are

A. False killer whale -*Pseudorca crassidens* -

B. Pigmy killer whale -*Feresa attenuata*

C. Mellon headed whale - *Peponocephala electra*

D. Short finned pilot whale *Globicephala macrorynches.*

Types of damage

1. Depredation of entangled fish and/or bait

3. Dissolving the fish species.

4. Extra running cost and more time spent to find new fishing areas, therefore reducing the fishing time.

5. Damaged to fishing gears – Extra time to repair the fishing gears. Therefore, delaying the next fishing trip and extra repairing cost.

Recommendations

It is very important to launch research towards the use of dolphin pingers to repel the harmful cetacean species.

Training the crew members for cetacean identification and record keeping.

Continuous assessment to study the population level of black fish species and other cetaceans.

Introduction of potential forecasting method to avoid depredation.

Constraints

The trials with depredation pingers were postponed until completion of the importation process.

Marine mammal abundance surveys were also postponed due to unavailability of suitable boats in proposed survey areas, high boat hiring charges, Covid-19 pandemic and in 2022 plans for conducting survey covering the entire coastal belt (SL China joint survey).

Progress:

Financial : Physical :

2.11 Strengthening marine fisheries data collection in Sri Lanka: contribution for Norway-Sri Lanka bilateral project Improved management of the marine resources in Sri Lanka

Introduction

As a coastal nation in the Indian Ocean, Sri Lanka is blessed to own diverse marine resources. Among them, fisheries resources possess a remarkable place where thousands of people depend directly and indirectly. Hence, it is vital to monitor and improve marine fishery resources. Therefore, the bilateral project between Norway and Sri Lanka was started in 2016 to improve the management of the marine fish resources of Sri Lanka.

Phase I of the project ended in 2019 by laying the foundation for strengthening fisheries dependent data collection system in the marine fishery of Sri Lanka. The data collection system in the marine fishery is complex since the fishery is multi-species, multi-gear and multivessel. On the other hand, landing sites of smaller to larger in size are scattered over the island. The phase I of the project completed a baseline survey to classify all landing sites and harbours concerning vessel composition, gears, target species, seasonality etc. Also, during phase I, the project staff created the new standardized set of data collection sheets with a manual to be used in the fisheries data collection. Further, tabulated software was developed for data collection, data entry, validation, and use of a standardized set of codes to ensure that high-quality data are readily available, which was a part of a separate data infrastructure project within DFAR. Hence, landing data collected by DFAR and NARA enumerators are stored in the same system by DFAR as other related data like the fisher's registry, vessel registry and logbook data of the multiday fishing fleet.

Data collection under the new system was started in October 2020 at the major fishery harbours by the enumerators of NARA and DFAR, under the prepared new plan. They were encouraged to enter the data using the software on the provided tablets. The Norway experts provided the technical support to improve the fish landing data collection system of small pelagic and large pelagic and demersal fisheries in Sri Lanka.

Works carried out in 2021

Online workshop conducted for enumerators

At the beginning of the year 2021, a training workshop on data collection was conducted aiming 150 enumerators of NARA and DFAR. However, due to the prevailed covid pandemic situation, the workshop was conducted online. DFAR enumerators connected from the respective Fisheries Administrative Divisional offices whereas NARA enumerators connected from the MBRD division. The officers of the Statistics Unit of MoF and IT Unit of DFAR were the resource persons for the session which was about the new data collection sheet used for sampling and the data collection application software used for fisheries data collection. The Scientists of MBRD trained the participants on biological sampling and species identification etc.

Port Sampling

In 2021, the project was focused to on the implementation of the coastal fisheries data collection at the landing sites classified as high, medium and low according to the number and types of boats operated at the landing site. The fisheries data collection at major and smaller harbours were continued. A total of 946 landing sites were divided into seven different types: Harbour, Land, madel, lagoon, land and madel, harbour and madel, and the anchorage and those sites were included in the Sri Lanka landing sites registry and were selected for the sampling. The Norway team generated the sampling plan for fisheries data collection in 2021 following the randomized stratified sampling technique. The sampling frequency was determined according to the strata of the landing site, which means the most important landing sites and fisheries are allocated more sampling effort than less important sites. Accordingly, two sampling programs were prepared for sampling fishery harbours and coastal landing sites.

Program 1

LS-High – High sampling intensity: Ambalangoda, Devinuwara, Galle, Beruwala, Mirissa, Dikowita, Negombo, Kudawella, Cod Bay (Trinco Town ii), Cod Bay Fisheries Harbour (Trinco West).

LS-Low – Low sampling intensity: Point Paduru, Oluvil, Gandara, Kalpitiya, Hambanthota, Kirinda, Valaichchenai, Hikkaduwa, Nilwella, Suduwella and Tangalle,

Table 1. Sampling program and the strata of the WP1 of the project (Source: Initial report of WP1.3 – Sampling strategy development)

Stratum	Sampling program	Sampling effort
	Program 1 – Large scale fishery (LS) Like today's coverage (LPPS) but including all main harbours, and randomised sampling. Strata defined from registered catches in logbook data.	40% of total SL sampling capacity. At least the total effort used today.
LS-High	Large scale fishery in main harbours	
LS-Low	Large scale fishery in small harbours	
	Program 2 – Small scale fishery (SS) Coastal small-scale fishery (pelagic and demersal). Randomised sampling in all harbours and landing sites. Strata defined from baseline survey and number of vessels (IMUL excluded)	60% of the total SL sampling capacity.
SS-High	Small-scale fishery – large landing sites	
SS-Medium	Small-scale fishery – medium landing sites	
SS-Low	Small-scale fishery – small landing sites	

Program 2

The stratification of coastal fishery landing sites was based on the registered vessels, a proxy for landed biomass. The potential catch depends on the vessel type, which means that the index is a weighted sum of vessels per vessel type. Even though seasonality was not included in the index in 2021, this factor will be considered for the sampling plan of 2022.

SiteIndexMonth= (N_IMUL x Weight_IMUL + N_IDAY x Weight_IDAY +...) x Month_Adjustment

The monthly sampling plans for each fisheries district were generated using the prepared annual sampling plan. The sampling schedule was provided for the DFAR and NARA enumerators who visited the particular sites on particular dates and entered the data through tabulated software. Consequently, the data was stored at the data server located in the data unit of the DFAR.

Further, two workshops for the enumerators and data users of the DFAR and NARA were conducted to improve the data collection, usage of the CAPI system and data analysis.

Data analysis workshop for the data users

Three-day training workshop was conducted by the Norwegian experts in August 2021 via Microsoft Teams for the data users of DFAR and NARA. Generating a sampling plan using the R program was the workshop's main topic. Around 30 officers from NARA, DFAR and MoF participated for the workshop.

Fig.1. Data analysis workshop

Workshop conducted for the selected enumerators of DFAR on coastal fisheries data collection

Thirty DFAR officers, two from each Fisheries District were assigned for coastal fisheries data collection. Accordingly, a workshop for the coastal fisheries data collectors of DFAR was carried out in December, 2021 at Hector Kobbekaduwa Agrarian Research and Training Institute. The first day of the workshop focused on the following topics.

Strengthening coastal fishery data collection.

Biological data recording and identification of Sharks and Rays

Identification of tuna and tuna-like species

Identification of common small pelagic fish species

Identification of non-fin fish

Species identification of demersal fish species

Introduction of new data collection sheet

Data collection software

Fig.2. Data workshop on coastal data collection

On the following day the field training programme on data collection was conducted at Beruwala Fisheries harbour and Maggona coastal landing site to get hands-on experience on identification of fish species and data recording via the app and correct data entering to the data sheet. The sampling strategy and practical applications were discussed at the end of the day.

Data storage

The data entered through the app is stored in the DFAR server and this can be accessed via the MSDFAR.

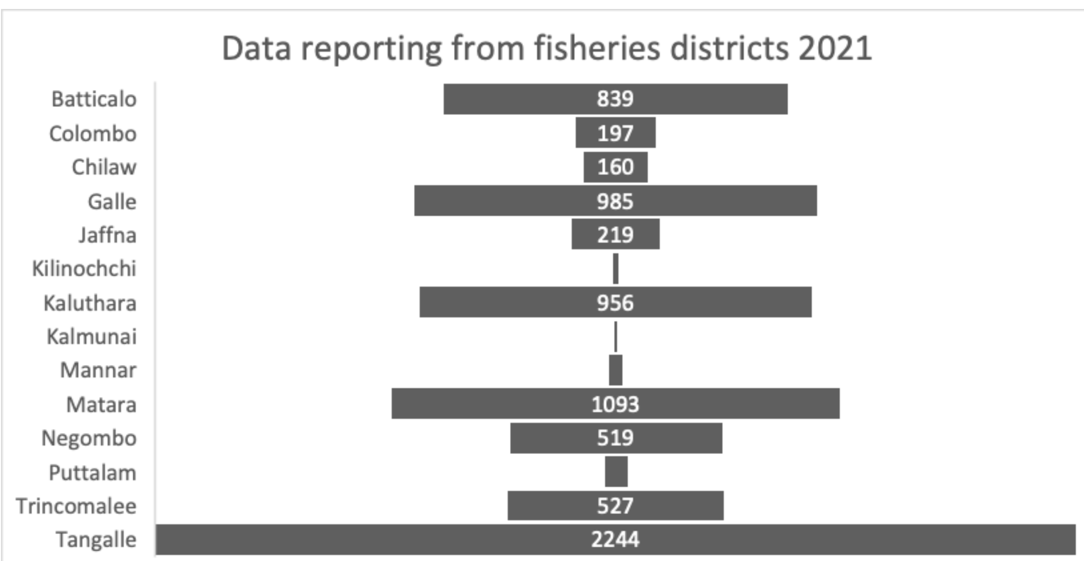
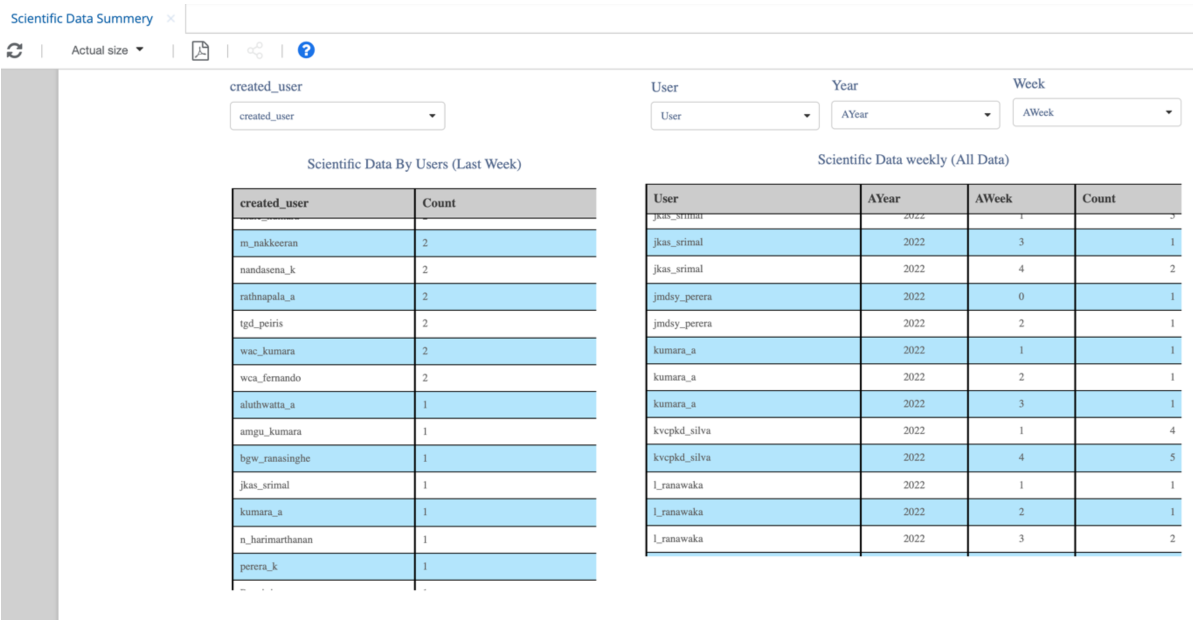


Figure 3: The number of data recordings according to the fisheries districts



Scientific Data By Users (Last Week)

created_user	Count
m_nakkeeran	2
nandasena_k	2
rathnapala_a	2
tgd_peiris	2
wac_kumara	2
wca_fernando	2
aluthwatta_a	1
amgu_kumara	1
bgw_ranasinghe	1
jkas_srimal	1
kumara_a	1
n_harimarthanan	1
perera_k	1

Scientific Data weekly (All Data)

User	AYear	AWeek	Count
jkas_srimal	2022	3	1
jkas_srimal	2022	4	2
jmdsy_perera	2022	0	1
jmdsy_perera	2022	2	1
kumara_a	2022	1	1
kumara_a	2022	2	1
kumara_a	2022	3	1
kvcpkd_silva	2022	1	4
kvcpkd_silva	2022	4	5
l_ranawaka	2022	1	1
l_ranawaka	2022	2	1
l_ranawaka	2022	3	2

Fig.4: The snapshot of the collection of scientific data summary

Discussion between the collaborators

Regular meetings between the NARA, MSDFAR, DFAR and the Norway team were conducted online. The issues and suggestions were discussed. The issues in sampling sites, and software applications were discussed at length to overcome the issues.

Limitations

Due to covid 19 outbreak sampling program could not be conducted for several months.

Few technical errors of the software were identified

Difficult to work with the tablet under bad weather conditions such as heavy rains.

Some fishers do not cooperate well for port sampling data collection

The complexity of the fisheries landing sites and still not considering the seasonality of fishing operations still not being considered have affected the quality of the data

Discussion

The fisheries data is vital for developing the industry and for the sustainable utilization of marine resources. As a nation considerably dependent on the fisheries industry, the data collection needs to be carried out in a well-organized manner and effectively. Through the project, this objective is being achieved successfully consequently with the excellent collaboration from the Norway government. The introduced new sampling strategy under the project is applied for every landing site at different levels subject to the sampling suitability and magnitude of the landings. Further, digitalization of the fisheries data will be beneficial to sharpen the marine fisheries data collection in Sri Lanka, enabling to make use of such data to provide management advice and policy decisions. The enumerators and data users are trained during the project period via conducting various training programmes for them and this has been identified as a mandatory process to improve their skills and knowledge on the fisheries data. The data are recorded via the CAPI computer assisted personnel interview system using tabulated software. The method is a convenient way but practicing the method takes time. The meetings between the collaborators are frequently held to discuss the errors/ issues of the software used and necessary updates for the software is done accordingly as much as possible. The unnecessary repetitions of some data being entered to the software were identified. For example, two species lists were prepared: the species list use for recording catch data and the species list use for recording biological data. This would save the time of the enumerators for data collection. Also, the frequency of data collection has been introduced to avoid repetition. The Landing site registry of Sri Lanka could vary annually for numerous reasons. Even though there are registered boats, the number of active boats could be more or less in the landing sites of the coastal fishery. Hence, it is crucial to update the landing sites registry annually.

Considering the data recordings, the highest data have been recorded by the enumerators of the Tangalle Fisheries District and the minor records are from the Kalmunai Fisheries District. Therefore, the variation of data recording among the fisheries districts needs to be reviewed periodically for carrying out the project successfully. Data reporting of enumerators can be assessed through the server, which is an excellent tool to monitor the data collection program. Further, the data collectors report no operation at several sites on days. This issue can be overcome by introducing the sites' seasonality and updating the site's registry annually. Moreover, discussion and the issues between the coordinating institutes are mandatory to carry out the data collection successfully.

Progress:

Financial : Physical :

2.12: Fisheries independent surveys in the coastal areas in Sri Lanka

Acoustic surveys are used to estimate distribution and biomass (total weight of fish in a given area) of species living in open waters (pelagic) and often aggregate in large fish schools. Even though it is a reasonably precise tool used in fish abundance estimates, it is largely underutilized for fisheries research in Sri Lanka. Notably, the 2021 survey was the first survey conducted in Sri Lanka with the aim of obtaining a time series abundance index for pelagic fish. The pelagic fish is one of the main sources of seafood in Sri Lanka, and several pelagic stocks are currently overfished or subject to overfishing. Therefore, the main objective of the acoustic survey was to establish time-series abundance indices for pelagic fish to assess the stock status. The acoustic survey was conducted on the West and Sothern coasts of Sri Lanka in February and March 2021 using NARA's research vessel S*amuddrika*.

A survey plan was made prior to the survey. The study area was divided into three strata (NW-Northwest, SW- Southwest and S-South) (Figure 7). A random, systematic zigzag transect design was chosen for each stratum (Figure 8). The StoX application was used to define the strata boundary definitions based on available previous depth strata from the RV Dr. Fridtjof Nansen survey conducted in 2018 covering the depth range of 10 – 100 meters. This range included the distribution of coastal small pelagic fish. Acoustic data were collected using the EK 15 echosounder of the RV *Samudrika* (Figure 9). Plankton samples were collected at the middle of each transect along the survey track using a WP2 plankton net.

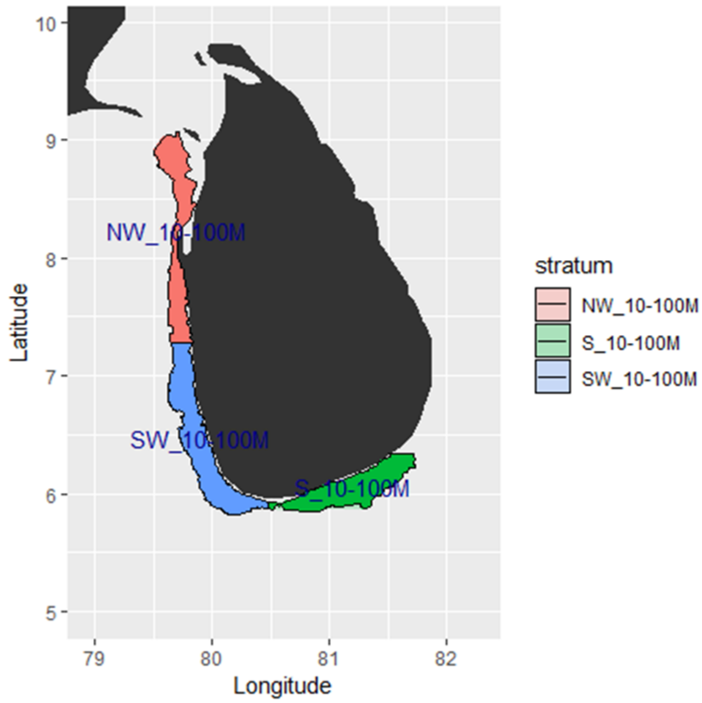


Figure 7. A map of survey strata selected for acoustic survey

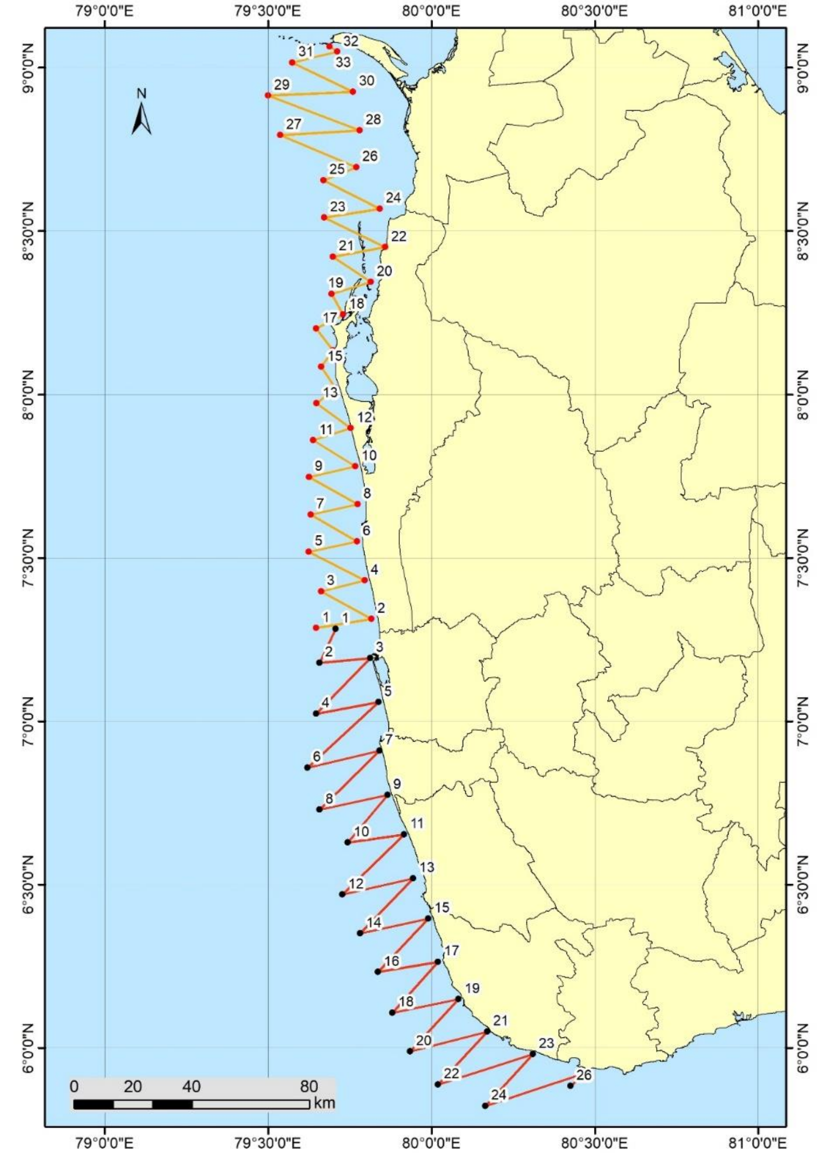


Figure 8. Zigzag transects used for the survey. Each stratum covers the depth range between 10 m and 100 m

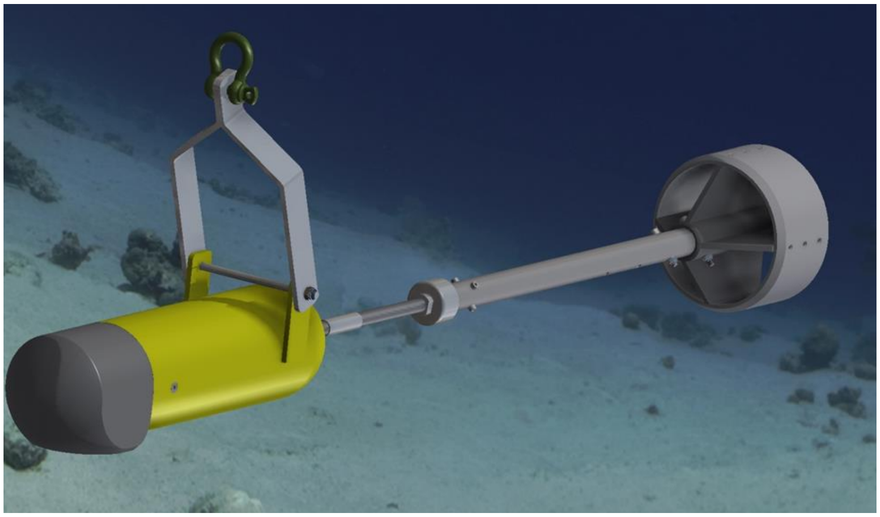


Figure 9: The towed body for echosounder transducer

The raw acoustics data from the EK15 echosounder was used for the post-processing in LSSS 2.6 application. Data were analyzed according to the predefined eight acoustic categories listed in Table 1.

Table 1. Acoustic groups used for the processing of raw data

Name	Priority	Species / Groups
PEL 1	1	Herring- like (e.g., *Amblygaster sirm*)
PEL 2	1	Mackerel-like (e.g., *Selar crumenophthalmus*)
PELAG	1	Squids (e.g., *Loligo* spp.)
PLANK	2	Plankton
BOTTOM	2	Bottom Fish
HERR	3	Possible- Herrings
MACKE	3	Possible- Mackerels
OTHER	3	Other Species

(1 – High, 2- Low, 3- useable)

Biological and fisheries survey at the commercial landings was conducted along the costal sketch on the same survey area and survey dates, focusing the landing sites located along the coast from Mannar to Tangalle. Accordingly, two enumerators were employed to collect the fisheries and biological data, emphasizing the species composition in the catch. More attention was paid for most abundant pelagic fish species, such as herrings (*Amblygaster sirm*) and sardines (*Sardinella* sp.), which are landed at the landing sites in the study area. In addition, the catch data of demersal fish and other species, which contribute in a considerable proportion to the total catch, were also obtained. Further, length and weight data of individual fish were also collected aiming density and biomass estimations.

Abundance estimates for acoustic categories PEL1 and PEL2 were calculated using StoX version 2.7 considering only one PEL1 and one PEL2 fish per stratum. These fish were given the average individual length and weight calculated from the biological samples from the nearby landing sites.

The density of fish larvae was higher than the fish eggs and most of the eggs were recorded from the NW coast (Figure 10).

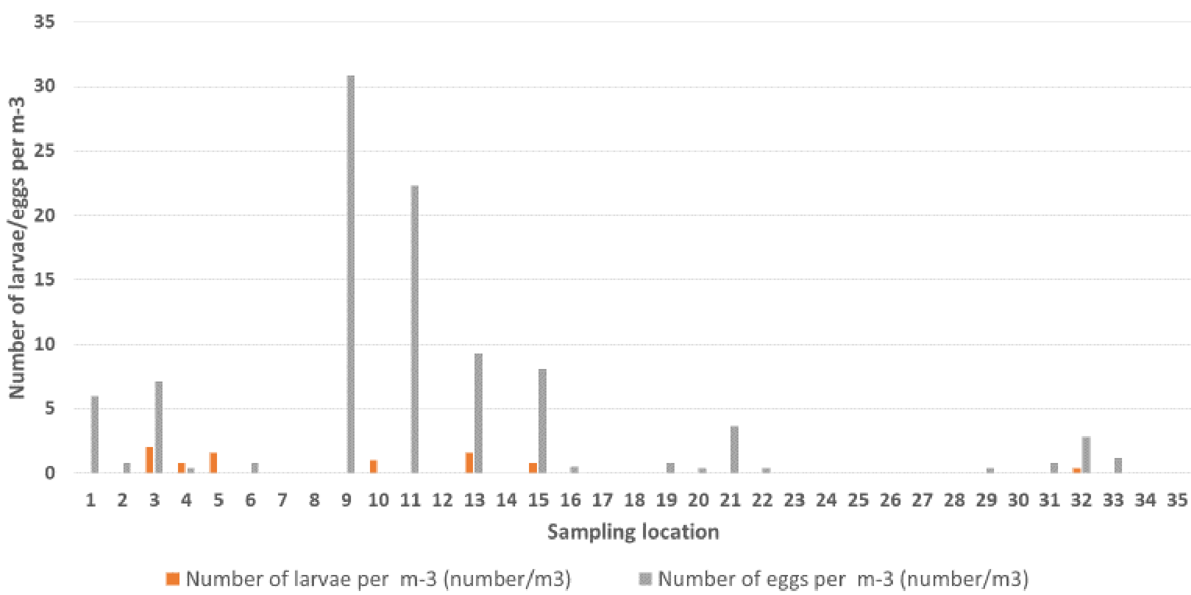


Figure 10: Density of fish larvae and eggs recorded during the survey

Progress:

Financial : Physical :

2.13 DNA barcoding of marine fish species found around Sri Lanka.

Officers responsible **:** D.R. Herath and Y.C. Aluwihare

Duration : 1 Year

Objectives of the project

To collect different species of commercially important fish from around the coast of Sri Lanka.

To develop a database including DNA barcodes of important marine fish species of Sri Lanka.

Rationale of the project:

DNA barcoding is a concept where a particular region of DNA is amplified and sequenced and is subsequently used for the identification of the species to which the organism belongs (Ward et al., 2005: Lakra et al., 2011). For this purpose, the mitochondrial cytochrome oxidase subunit 1 (COI) region of the DNA is universally used as this region is conserved within a species (Weigt et al., 2012). Though fish can be identified using morphological characteristics, sometimes the features are not clear enough for proper identification of the species (Zhanga and Hanner, 2011). Further, DNA barcoding of fish species in Sri Lankan water is really important as our country is rich in biodiversity. Therefore, carrying out barcoding for these fish will iron out any taxonomic ambiguities that can exist in the identification process. Further, development of sequence data base is important for future fisheries related scientific work and it is a part of conservation and management of the fish resource (Ardura et al., 2010).

The project is aimed at the molecular identification of the fish resources available around Sri Lanka. Samples were collected from different region around the country. The fish samples were barcoded and a database of the sequences of the identified fish were created. The generated DNA sequences can be used for future reference.

Methodology

Fish samples were collected from Negombo, Beruwela, Kalpitiya, Trincomalee, Batticaloa, Ampara and Hambanthota areas. The fish samples were collected and transported to the NARA laboratory. In addition, other samples of stranded marine mammals and turtles were also used to generate barcodes.

At the biotechnology laboratory of the National Aquatic Resources Research and Development Agency (NARA), the DNA of the collected samples was extracted by using Qiagen's DNeasy Blood and Tissue Kit, following the manufacturer's protocol. PCR was carried out with

Fish F1- 5'-TCAACCAACCACAAAGACATTGGCAC-3' and

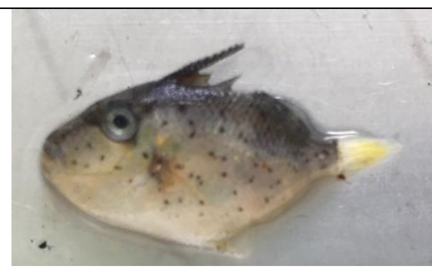
FishR1-5’ACTTCAGGGTGACCGAAGAATCAGAA-3’

primers (Ward et al., 2005) developed from mitochondrial cytochrome oxidase subunit I gene (cox *1*) with the length of 655 bp. PCR was performed in a final volume of 50 µl containing 5 µl 10× Taq Polymerase Buffer, 4 µl $MgCl_2$ (25 mM), 5 µl dNTPs (0.5 mM), 1-unit Taq polymerase and 0.5 µl each of 25 pmol/µl, Fish-F1 and Fish-R1 primers (Ward et al., 2005). The thermal regime consisted of (i) an initial denaturation step of 5 min at 94ºC, (ii) 35 cycles of, 30 s denaturation at 94ºC; 30 s annealing temperature at 55ºC and 1 min extension at 72ºC, (iii) 10 min final extension at 72ºC and then samples were held at 4ºC. The amplicons were sent to Macrogen, Inc. Korea for purification and bidirectional sequencing by Capillary Electrophoresis Sequencing (CES) method. Sequences were aligned with the Genbank sequences in the NCBI site using the BLAST method. The percentage identity, E value, and query cover values were considered in confirming the species of sequenced individuals. Sequences generated during the study were finally submitted to GenBank to obtain accession numbers. For each species, multiple sequence alignment was performed by using BioEdit 7.2 (Hall, 1999) and MEGA (Tamura et al., 2013) software.

Results

A total of 90 fish samples and 9 other samples (turtles and marine mammals and invertebrates) were sequenced and Barcodes were generated.

Nibea maculate



Balistoides viridescens

Scomberomorus guttatus

Figure 1: Some samples used to generate DNA barcodes

GenBank ▾ Send to: ▾

Decapterus russelli isolate DR11 cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial

GenBank: MT541836.1

FASTA Graphics

Go to:

```
LOCUS       MT541836                 663 bp    DNA     linear   VRT 01-JUN-2021
DEFINITION  Decapterus russelli isolate DR11 cytochrome c oxidase subunit I
            (COX1) gene, partial cds; mitochondrial.
ACCESSION   MT541836
VERSION     MT541836.1
KEYWORDS    .
SOURCE      mitochondrion Decapterus russelli (Indian scad)
  ORGANISM  Decapterus russelli
            Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi;
            Actinopterygii; Neopterygii; Teleostei; Neoteleostei;
            Acanthomorphata; Carangaria; Carangiformes; Carangidae; Decapterus.
REFERENCE   1  (bases 1 to 663)
  AUTHORS   Aluwihare,Y.C.
  TITLE     Decapterus species in Sri Lankan waters
  JOURNAL   Unpublished
REFERENCE   2  (bases 1 to 663)
  AUTHORS   Aluwihare,Y.C.
```

GenBank ▾ Send to: ▾

Nibea maculata isolate iso1 cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial

GenBank: OL444938.1

FASTA Graphics

Go to:

```
LOCUS       OL444938                 469 bp    DNA     linear   VRT 17-NOV-2021
DEFINITION  Nibea maculata isolate iso1 cytochrome c oxidase subunit I (COX1)
            gene, partial cds; mitochondrial.
ACCESSION   OL444938
VERSION     OL444938.1
KEYWORDS    .
SOURCE      mitochondrion Nibea maculata (blotched croaker)
  ORGANISM  Nibea maculata
            Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi;
            Actinopterygii; Neopterygii; Teleostei; Neoteleostei;
            Acanthomorphata; Eupercaria; Sciaenidae; Nibea.
REFERENCE   1  (bases 1 to 469)
  AUTHORS   Herath,D.R. and Ranasinghe,V.
  TITLE     Barcoding of Marine Fish of Sri Lanka
  JOURNAL   Unpublished
REFERENCE   2  (bases 1 to 469)
  AUTHORS   Herath,D.R. and Ranasinghe,V.
```

Figure 2: NCBI entries giving accession numbers

The sequences were submitted to the NCBI GenBank to obtain accession numbers (Figure 2). These entries are available in the web for comparison for any user to access.

Table 1: Summary of fish species collected and barcoded

	Common name	*Scientific name*	Family
1	Indo Pacific King mackerel	*Scomberomorus guttatus*	Scombridae
2	Frigate tuna	*Auxis thazard*	Scombridae
3	Kawakawa	*Euthynnus affinis*	Scombridae
4	Bullet tuna	*Auxis rochei*	Scombridae
5	Leaping blenny species	*Alticus monochrus*	Blenniidae
6	Leaping blenny species	*Entomacrodus striatus*	Blenniidae
7	Leaping blenny species	*Entomacrodus epalzeocheilos*	Blenniidae
8	Leaping blenny species	*Istiblennius dussumieri*	Blenniidae
9	Leaping blenny species	*Alticus saliens*	Blenniidae
10	Leaping blenny species	*Entomacrodus vermiculatus*	Blenniidae
11	Goby fish species	*Istigobius ornatus*	Gobiidae
12	Blotched croaker	*Nibea maculata*	Sciaenidae
13	Titan trigger fish	*Balistoides viridescens*	Balistidae
14	Moonfish	*Mene maculata*	Actinopterygii
15	Two spot Snapper	*Lutjanus biguttatus*	Lutjanidae
16	Bluestripe herring	*Herklotsichthys quadrimaculatus*	Clupeidae
17	wavy-lined grouper	*Epinephelus undulosus*	Serranidae
18	John's snapper	*Lutjanus johnii*	Lutjanidae
19	Tseiloni Puntius	*Puntius thermalis*	Cyprinidae
20	Pacific yellowtail emperor	*Lethrinus atkinsoni*	Lethrinidae
21	Blacktail snapper	*Lutjanus fulvus*	Lutjanidae
22	Barramundi or Asian sea bass	*Lates calcalifer*	Latidae
23	Elongate surgeonfish	*Acanthurus mata*	Acanthuridae

24	Yellow-stripe toadfish	*Torquigener brevipennis*	Tetraodontidae
25	Bristly catshark	*Bythaelurus hispidus*	Scyliorhinidae
26	Darwin's slimehead	*Gephyroberyx darwinii*	Trachichthyidae
27	Beach conger	*Conger japonicus*	Congridae
28	Pastel tilefish	*Hoplolatilus fronticinctus*	Malacanthidae
29	Oblique-barred monocle bream	*Scolopsis xenochroa*	Nemipteridae
30	Gelatinous cardinalfish	*Pseudamia gelatinosa*	Apogonidae
31	Oriental flying gurnard	*Dactyloptena orientalis*	Dactylopteridae
32	Red-spotted bandfish	*Acanthocepola indica*	Cepolidae
33	Sailfin armourhead	*Histiopterus typus*	Pentacerotidae
34	Smalleye squaretail	*Tetragonurus cuvieri*	Tetragonuridae
35	Onestick stingfish	*Minous coccineus*	Synanceiidae
36	Shadow driftfish	*Cubiceps squamiceps*	Nomeidae
37	Bigeye cigarfish	*Cubiceps pauciradiatus*	Nomeidae
38	Spinyjaw greeneye	*Chlorophthalmus corniger*	Chlorophthalmidae
39	Many-eyed snake-eel	*Ophichthus polyophthalmus*	Ophichthidae
40	Crimson jobfish, rosy snapper, bluespot jobfish, crimson snapper, king emperor, king snapper	*Pristipomoides filamentosus*	Lutjanidae
41	Round hatchet fish	*Polyipnus polli*	Sternoptychidae
42	Bignose unicornfish, scibbled unicornfish	*Naso vlamingii*	Acanthuridae
43	black snapper	*Apsilus dentatus*	Lutjanidae
44		*Physiculus microbarbata*	Moridae
45	Dussumier's surgeonfish	*Acanthurus dussumieri*	Acanthuridae
46	African spadefish	*Tripterodon orbis*	Ephippidae
47		*Ostracoberyx dorygenys*	Ostracoberycidae

48	Largehead hairtail	*Trichiurus lepturus*	Trichiuridae
49	Watases lanternfish	*Diaphus watasei*	Neoscopilidae
50	sharpsnout snake eel	*Apterichtus klazingai*	Ophichthidae
51	Brown-banded cusk-eel	*Sirembo jerdoni*	Ophidiidae
52	Mottled fusilier	*Dipterygonotus balteatus*	Caesionidae
53	Live sharksucker	*Echeneis naucrates*	Echeneidae
54	Silvery John dory	*Zenopsis conchifer*	Zeidae
55	Green jobfish	*Aprion virescens*	Lutjanidae
56	Longtail butterfly ray	*Gymnura poecilura*	Gymnuridae
57	African spadefish	*Tripterodon orbis*	Ephippidae
58	Eyestripe Surgeonfish	*Acanthurus dussumieri*	Acanthuridae
59	pangled emperor	*Lethrinus nebulosus*	Lethrinidae
60	Pink ear emperor	*Lethrinus lentjan*	Lethrinidae
61	Mackerel scad	*Decapterus macarellus*	Carangidae
62	Shortfin scad	*Decapterus macrosoma*	Carangidae
63	Indian scad	*Decapterus russelli*	Carangidae
64	Blackspot snapper	*Lutjanus fulviflamma*	Acanthuridae
65	Yellowfin snapper	*Lutjan xanthoponnis*	Lutjanidae
66	Japanese Rubyfish	*Erythrocles schlegelii*	Emmelichthyidae
67	spotted sardinella	*Ambligaster sirm*	Clupeidae
68	Tomato hind	*Cephalopholis sonnerati*	Serranidae
69	brine shrimp	*Artemia franciscana*	Artemiidae
70	Indian mackerel	*Rastrelliger kanagurta*	Scombridae
71	Giant oceanic manta ray	*Manta birostris*	Mobulidae
72	Taiwan pouched octopus	*Cistopus taiwanicus*	Octopodidae
73	Yellowtail scad	*Atule mate*	Carangidae

74	Shorthead anchovy	*Encrasicholina heteroloba*	Engraulidae.
75	Bigeye scad	*Selar crumenophthalmus*	Carangidae
76	Talang queenfish	*Scomberoides commersonianus*	Carangidae
77	splendid ponyfish	*Leiognathus splendens*	Leiognathidae
78	Goldstripe sardinella	*Sardinella gibbosa*	Clupeidae
79	White sardinella	*Sardinella albella*	Clupeidae
80	Black marlin	*Makaira indica*	Istiophoridae
81	Pickhandle barracuda	*Sphyraena jello*	Sphyraenidae
82	Black-barred halfbeak	*Hemiramphus far*	Hemiramphidae
83	Swallowtail dwarf monocle bream	*Parascolopsis eriomma*	Nemipteridae
84	Crescent grunter	*Terapon jarbua*	Terapontidae
85	Banded needlefish	*Strongylura leiura*	Belonidae
86	Silver sillago	*Sillago shiama*	Sciaenidae
87	Malabar grouper	*Epinephelus malabaricus*	Serranidae
88	Blue and gold fusilier	*Caesio caerulaurea*	Caesionidae
89	Goldbanded jobfish	*Pristipomoides multidens*	Lutjanidae
90	Mangrove red snapper	*Lutjanus argentimaculatus*	Lutjanidae
91	Shortfin mako shark	*Isurus oxyrinchus*	Lamnidae
92	Bigeye thresher	*Alopias superciliosus*	Alopiidae
93	Pelagic thresher	*Alopias pelagicus*	Alopiidae
94	Scalloped hammerhead	*Sphyrna lewini*	Sphyrnidae
95	Dusky shark	*Carcharhinus obscurus*	Carcharhinidae
96	Spinner dolphin	*Stenella longirostris*	Delphinidae
97	Spotted Dolphin, Pantropical Spotted Dolphin	*Stenella attenuata*	Delphinidae

98	Dwarf Sperm Whale	*Kogia sima*	Kogiidae
99	Narrow-barred Spanish mackerel	*Scomberomorus commerson*	Scombridae

Discussion

Different fish species in different families were recorded from Sri Lankan coastal zone. Further, this list will be updated based on the samples collect by NARA and it is planned to update the database with barcodes generated for samples sent to NARA for fish and other species identifications. All sequences will be submitted to NCBI for the accession numbers. This is the first step for a large database collection in the future.

References

Ward RD, Zemlak TS, Innes BH, Last PR, Hebert PD. DNA barcoding Australia's fish species. *Philos Trans R Soc Lond B Biol Sci*. 2005;360(1462):1847-1857. doi:10.1098/rstb.2005.1716

Lakra, W. S., Verma, M. S., Goswami, M., Lal, K. K., Mohindra, V., Punia, P., ... & Hebert, P. (2011). DNA barcoding Indian marine fishes. *Molecular Ecology Resources*, *11*(1), 60-71.

Ardura, A., Linde, A. R., Moreira, J. C., & Garcia-Vazquez, E. (2010). DNA barcoding for conservation and management of Amazonian commercial fish. *Biological Conservation*, *143*(6), 1438-1443.

Weigt, L. A., Driskell, A. C., Baldwin, C. C., & Ormos, A. (2012). DNA barcoding fishes. In *DNA barcodes* (pp. 109-126). Humana Press, Totowa, NJ.

Zhang, J. B., & Hanner, R. (2011). DNA barcoding is a useful tool for the identification of marine fishes from Japan. *Biochemical Systematics and Ecology*, *39*(1), 31-42.

Tamura, K., Stecher, G., Peterson, D., Filipski, A., Kumar, S., 2013. MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. Mol. Biol. Evol. 30(12), 2725–2729.

Hall, TA., 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Window 95/98/NT. Nucleic Acids Symposium Series. 41: 95–98.

Progress:

Financial : Physical :

3. Fishing Technology Division

3.1 Study of flotsam associated fishery in offshore to introduce management strategies for sustainable fishery

Introduction

Offshore surrounding net or ring nets are being operated around the floating objects in the deep-sea area Lanka using Ring net, a kind of small-scale encircling net. Normally fish species are associated around these kinds of floating objects for the foods. Normally these multiday boats travel for 15-45 days and bring or collect 10-12 metric tons per single trip. About 1500 of ring net boats are operated around Sri Lanka. It helps to consumer to buy rich protein sources in cheap price and maintain the fish price in the local market. Main target species of this fishing method is carangidae family fish species associated mainly floating objects and fisherman traditionally know about the behavior of this fish species. However, during the fishing gear operation fishermen collect all most all fish associate with that floating object, helping with scoop nets without selection. The collected fish are stored in fish hold with crushed ice. Fish catch comprises various types of fish species in different quantities. Main target species are Indian scad (*Decapterus russelli),* spotted trigger fish (*Canthidermis maculate*) and Rainbow runners (*Elagatis bipinnulata*). Same as large and small tuna also associated with floating objects for the feeding requirement. Specially skipjack tuna (*Katsuwonus pelamis)*, Yellowfin tuna (*Thunnus albacores)* and big eye tuna. These fish species the catch consists of immature under size fish. Currently policy makers do not have idea about present population structure of off shore fish stock. Therefore, catch data collect to determine the population structure as age structure, sex composition and maturity stage of fish. This fishing method is highly efficient method and fisherman are very attractive for this method day by day, they collect all fish who caught to the net. Some time there are high by catch or accidental catch. Therefore, to apply proper management strategies, knowledge of the current situation of fish stock and changes of fishing ground throughout a year are essential. Therefore, catch data, fishing location, on offshore ring net fishery are going to be collected. Data are going to be collected from selected fishery harbors in Western, Southern and Eastern coast.

Indian scads are belonged to carangidae family and are collected from ring nets in high quantities with various length classes. *Decapterus russelli* has an elongate, somewhat slender and slightly compressed body. *Decapterus russelli* occurs throughout the Indian Ocean, from the coasts of eastern Africa from the Gulf of Suez as far south as South Africa to Indonesia, eastwards into the western Pacific Ocean, from Japan in the north and south to Australia. Adult Decapterus *russelli* are benthic and form large schools in deeper water, although they may occasionally be found inshore in smaller groups where there are sheltered bays. It is the most common species of Decapterus in coastal waters and on open shallows of the Indian Ocean. *Decapterus russelli* is fished for wherever it occurs, normally using seine nets and trawls.

The rainbow runner (Elagatis *bipinnulata*), also known as the rainbow yellowtail, Spanish jack and Hawaiian salmon, is a common species of pelagic marine fish of the jack family, Carangidae. The species is widespread throughout the tropical and subtropical waters of the world, inhabiting both coastal and offshore areas. The rainbow runner's body is atypical of the jack family, which generally have deep, compressed bodies. The rainbow runner has a subcylindrical, elongated to almost fusiform body, with a long, pointed head and snout and a tapering rear end before the caudal fin emerges. The species is primarily pelagic, inhabiting the upper 164 m of the water column, sometimes close to land over rock and coral reef systems, as well as far offshore. Rainbow runners, like other carangids such as yellowtail kingfish, are easily attracted to special fish-attracting devices (FADs), floating buoy-type structures. The species has been shown to occupy a water zone outside of the FADs up to 12 m deep and 10 m wide, treating them as if they were stationary objects.

Spotted trigger fish can be found Around the Indian Ocean, it ranges from the Red Sea and eastern Africa to Seychelles, the Maldives, the Persian Gulf, India, Sri Lanka, the Andaman Sea, Australia, and Indonesia. The maximum length for this species is 50 centimetres (20 in) but usually grows up to 35 centimetres (14 in). Adults and juveniles have different coloration. Adults are blue grayish while juveniles are grayish black with white spots that fade over age. Adults may be seen with dark blotches appearing on the face and pectoral fins during mating. *Canthidermis maculata* are known to gather in large groups, hundreds and sometimes thousands (Taquet et al., 2007) and are frequently associated with FADs. This fish species shows some importance to commercial fishing. The spotted oceanic triggerfish, like other triggerfish, is sold at local markets in coastal Asian countries as a fish to be eaten

The **skipjack tuna** (*Katsuwonus pelamis*) is a medium-sized perciform fish in the tuna family, Scombridae. It is a streamlined, fast-swimming pelagic fish, common in tropical waters throughout the world, where it inhabits surface waters in large shoals It is an important

commercial and game fish, usually caught using purse seine nets, and is sold fresh, frozen, canned, dried, salted, and smoked. Countries recording large amounts of skipjack catches include the Maldives, France, Spain, Malaysia, Sri Lanka, and Indonesia.

The yellowfin tuna is among the larger tuna species, reaching weights over 180 kg. Yellowfin tuna are epipelagic fish that inhabit the mixed surface layer of the ocean above the thermocline. An individual tagged in the Indian Ocean with an archival tag spent 85% of its time in depths shallower than 75 m (246 ft), but was recorded as having made three dives to 578, 982, and 1,160 m (3,810 ft). Although mainly found in deep offshore waters, yellowfin tuna may approach shore when suitable conditions exist. Modern commercial fisheries catch yellowfin tuna with encircling nets (purse seines), and by industrial longlines

Therefore, objectives of the project were, Inquire the current situation of flotsam associated Ring net fishery and provide management strategies for future plans, disseminating the findings to the stakeholders, disseminating the findings to the Ministry of fisheries for policy making. This project was conducted based on catch data and boat log sheet data. Catch data were collected from Beruwala, Galle, and Tangalle and Kudawella fishery harbors.

Method

Length frequencies of Skipjack tune, Yellowfin tuna, Indian scads, Rainbow runner, rough triggerfish or spotted oceanic triggerfish were taken. Length data were collected from fishery harbors, Tangalle, Dondra and Kudawella. Fifty length data were recorded per one time for one species and measurements took for two times per month

As well as fishing location also collected using log sheets data and in person interviews. Collected length data were grouped into length classes. Length class interval is 1 cm and different fish species have different number of length classes. For the Indian scads minimum and maximum length was 17cm to 34 cm respectively. For the spotted trigger fish maximum and minimum was 38cm and 22cm respectively. For the yellowfin tuna, minimum length was 22 and maximum length was 40cm. Collected data were analyzed for further decisions. Total fish weight data were collected.

Results

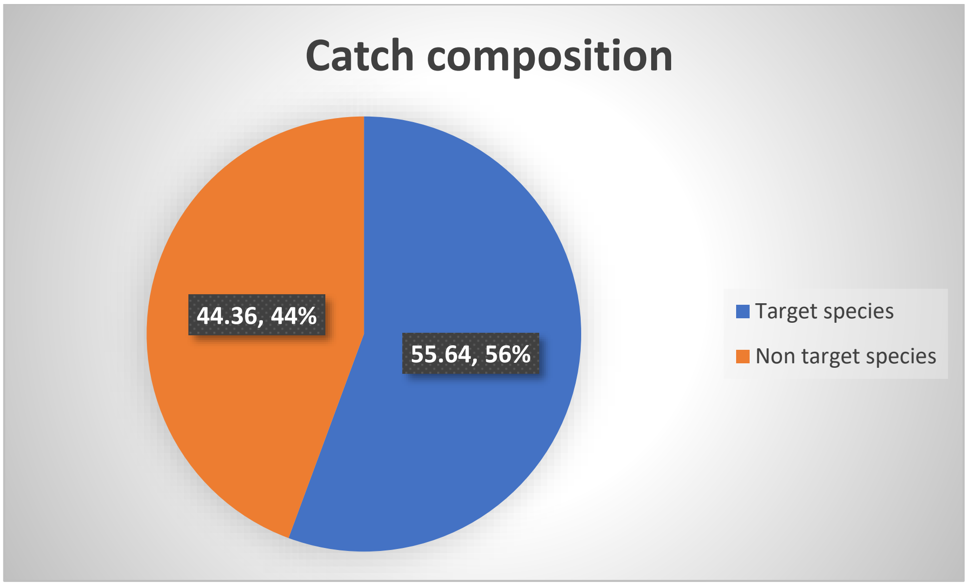
Fish weight data

Collected fish weight data during year 2021 summarized and tabulated in following table (Table 01).

Table 01: Weight of fish species collected using ring net fishing method.

Species	**Total weight(kg)**	**Percentage catch**
Indian Scad	354160	48.17
Spotted trigger fish	26340	3.58
Rainbow runner	28575	3.88
Bigeye tuna	250	0.034
Yellowfin tuna	25100	3.41
Skipjack tuna	277465	37.73
Kawakawa	1550	0.21
Frigate	10325	1.40
Bullet	5100	0.69
Marlin	2978	0.40
Sailfish	938	0.12
Dolphin Fish	1215	0.16
Carangid sp.	465	0.06
Skates	755	0.10

Main target species of ring net fishing method are Indian scads, trigger fish and rainbow runners. Other than the main target species some of tuna species are also collected. Among other species, Skipjack tuna, big eye tuna and yellow fin tuna have high demand and high economic value. Indian scads collect around 48% and skipjack tuna collect around 38% and yellowfin tuna collects around 3% of total weight. This skip jack tuna and yellow fin tuna have high economic value in export market.

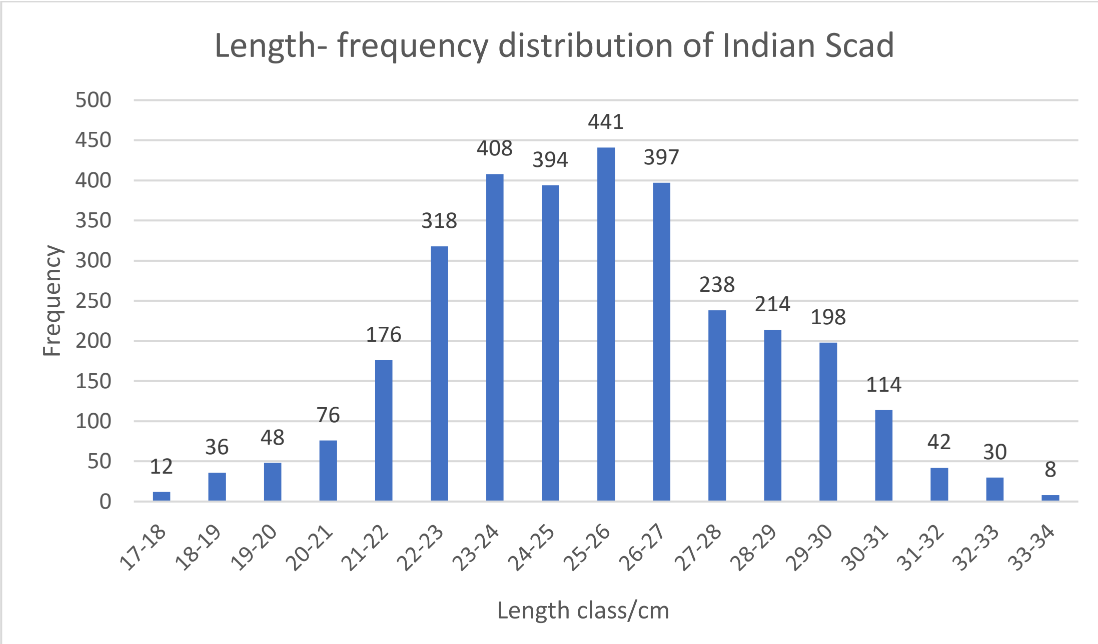


Length frequencies

Collected length data were arranged in to length groups and group interval was 1cm for all fish species. Minimum length recorded for the species of Indian scads and highest length was recorded for skipjack tuna.

Indian scads/ *Decapterus russelli*

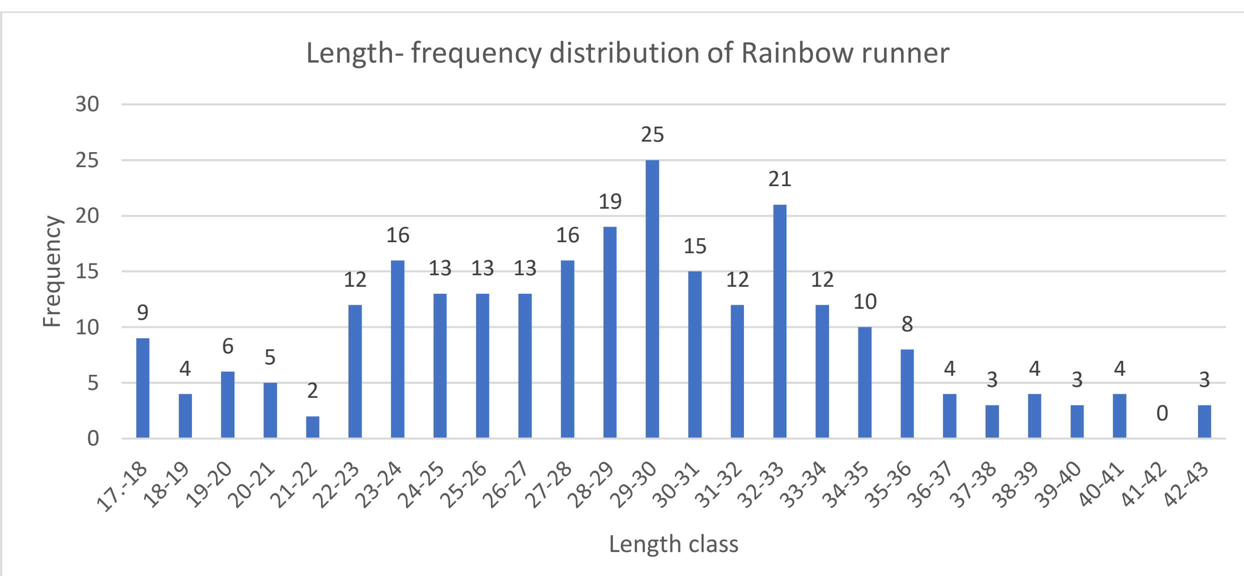
According to the collected data, minimum length was 17cm and maximum length was 34 cm. This is very popular and low-price fish species among the consumers. However, quality of fish is damage due to bad storage practices.



According to the length frequency distribution of Indian scads fish species, minimum length data recorded for both 17-18 and 33-34 length classes. Highest frequency recorded for the 25-26 length class. According to the fish base organization, length at first maturity of Indian scads is 14.5cm and length can be varying from 14.5-25cm. Hence, recorded all length classes are matured fish length classes. Harvesting of Indian scads fishing can be considered as sustainable utilization.

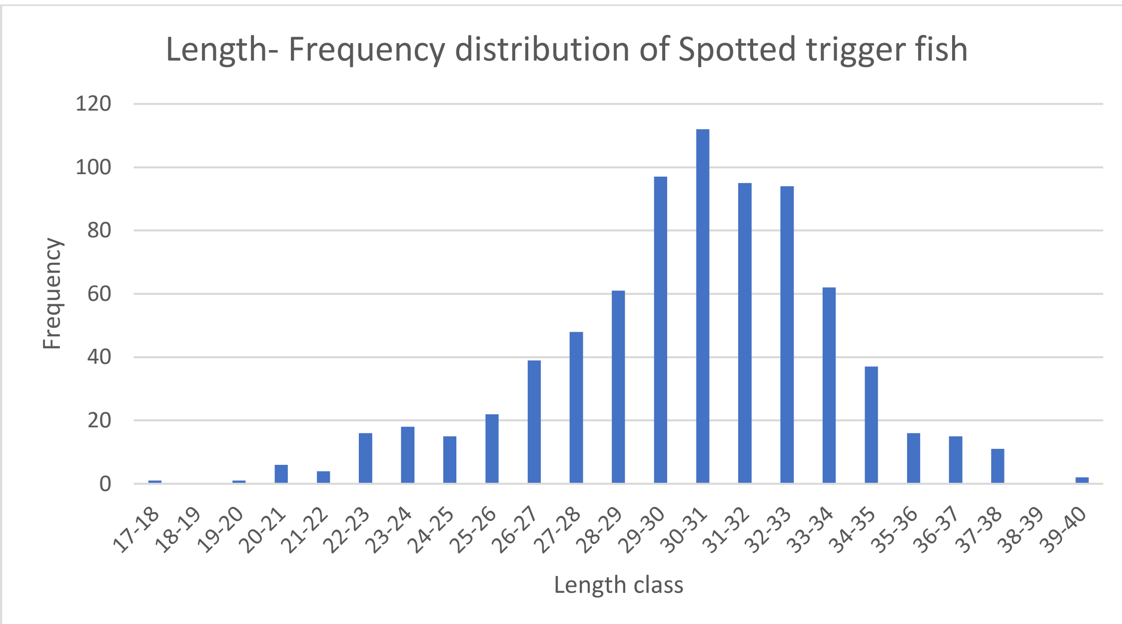
Rainbow runner/ *Elagatis bipinnulata*

For the Rainbow runners, recorded minimum length was 17cm and maximum length was 43cm. According to the length frequency distribution, highest frequency recorded for the 29-30cm length class while minimum frequency recorded for the 42-43cm length class. However, length at first maturity recorded as 65.7cm, in total length. But there is no any fish length data recorded above or equally to the length at first maturity. All individuals are below the first maturity length.



Spotted trigger fish/ *Canthidermis maculate*

For the spotted trigger fish, minimum and maximum length recorded 17cm and 40cm respectively. Highest frequency recorded length class was 30-31 cm length class. However, according to the fish base, common length is 35cm and maximum recorded length was 50 cm.

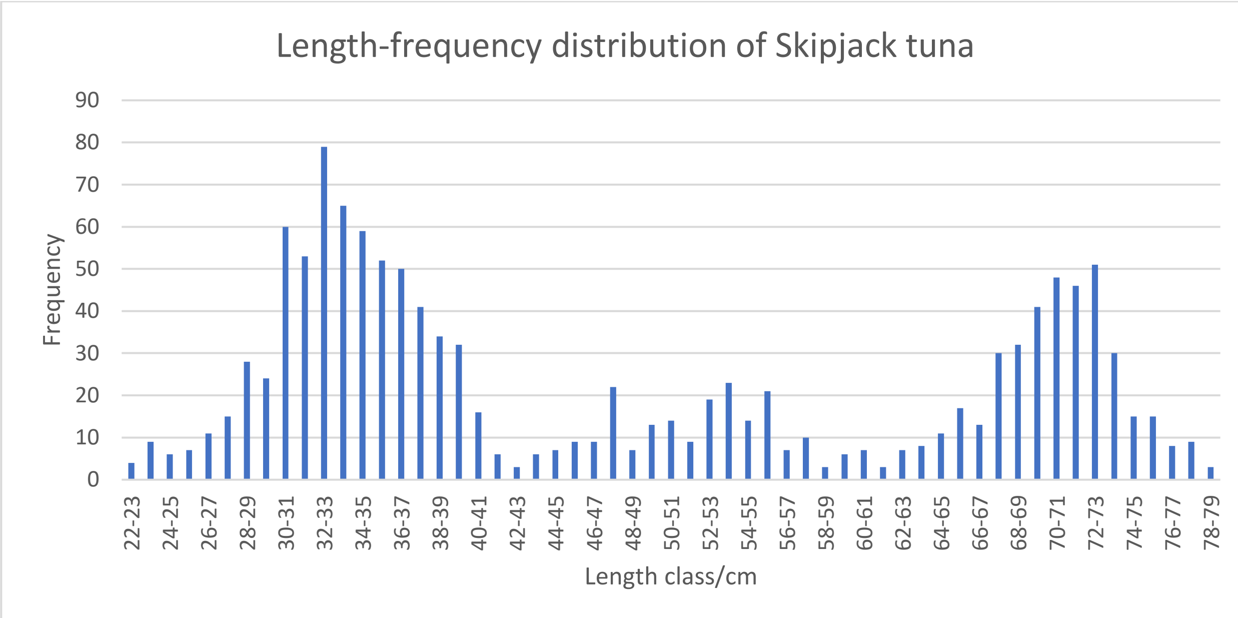


Same as the target fish species, skipjack tuna, yellowfin tuna, big eye tuna and other small tuna also collecting using the ring net.

Skipjack tuna/ *Katsuwonus pelamis*

When consider of story of skipjack tuna major two length groups can be observed.

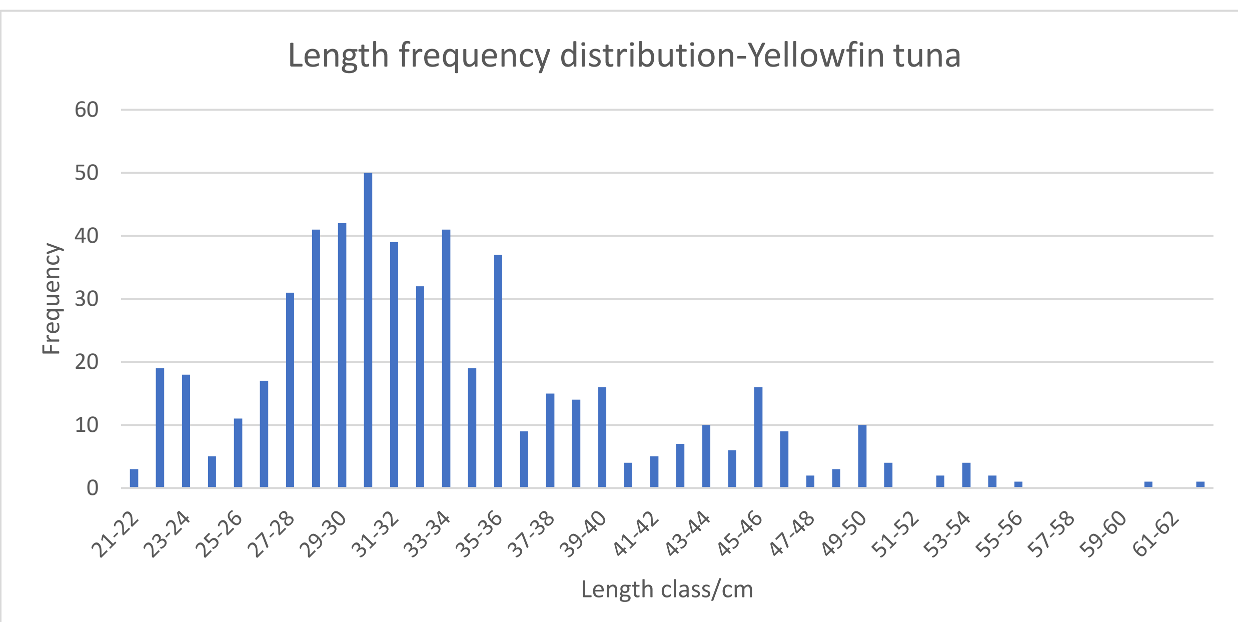
From 22cm-63cm and next group distribute from 64cm to 79cm. Among the small size tuna group, 32-33cm length group shows highest frequency and among the large size tuna group72-73cm length group shows the highest frequency.



Sexual maturity may occur as small as 15 inches (40 cm) length, however most fish appear to mature at larger sizes. Larger females produce significantly more eggs than smaller females, with the average adult producing 80,000 to 2 million eggs per year. According to the collected length frequency data, 50% of the fish are immature.

Big eye tuna collects very small quantity by the ring net fishery. However, these big eye tunas have high economic value in the export market.

Yellow fin tuna/ *Thunnus albacares*



Yellowfin tuna are also collected by the ring net fishing method. Various size of yellow fin tuan are also collected. Collected data are normally distributed. According to the collected data only one peak can be observed. And highest frequency shows the 2-30cm length group.

The size of Yellowfin tuna at maturity varies by region, and could also vary between individuals found near- and offshore. Yellowfin reach the status of mature by the time they reach a length of 120 cm in fork length at an age of about 2 to 3 years; however, there are some exceptions where fish become mature at the size of 50 to 60 cm in fork length at an age of about 12 to 15 months.

When consider about the data, all collected fish from the ring net are immature.

Conclusion and recommendations

When consider about the target catch or target species of the ring net, Rainbow runners are below the mature stages while Indian scads and Spotted trigger fish are within of above the matured length. Therefore, this ring net fishing method can be recommended for the catching of Target species except the rainbow runners. Especially this ring net is most suitable for the Indian scads and spotted trigger fish.

When consider about the non-target species especially, Skipjack tuna and Yellowfin tuna, 50% of skipjack tuna harvest is below the first mature length. All collected yellowfin tuna are below the first mature level. At the moment Indian ocean tuna stock is moderately of fully exploited. If fishing activities are conducting at current speed, the natural fish stock will be destroyed near future. Therefore, to minimize the tun catch from ring net, mesh size can be changed and depth of the net can be changed. As well as net operation time of the day can be change avoiding the feeding time of tuna species. Because fisherman collect small tuna individuals using ring net and if it fully grown fish, it has good economic value than the small individuals.

Data analyzing is in progress.

Progress:

Financial : Physical :

4 Institute of Post-Harvest Technology

4.1 Enhancement of quality of fish handled in multiday boats and monitoring of antimicrobial resistance in the aquatic environment

Officer/s responsible -:

Sujeewa Ariyawansa, Pavithra Ginigaddarage, K.G.S Nirbadha, M.G.C. Wijesinghe, Sudeepa Rasnasinghe, Mihirani Subasinghe, Kaumi Piyasiri

Component 1

Introduction

Introduction of a refrigeration system and improvements in the fish hold of the multi-day fishing boat

The spoilage of the fish in the multi-day fishing boats provides a loss for the fisherman and the country's economy. The quality of fish landings is generally poor and fish spoilage is high particularly in the landings of multi-day boats. Therefore, it is aimed to design a refrigeration system for fish hold of multi-day boats used for fishing in Sri Lanka and find solutions to reduce quality loss.

Component 2

Introduction

Combating antimicrobial resistance

Antimicrobials are a precious group of medicines that are used to treat infections caused by bacteria, viruses, fungi and parasites. Antimicrobial resistance (AMR) occurs when microorganisms such as bacteria, viruses, fungi and parasites change in ways that make treatments ineffective. Currently, there is a global effort in combating AMR. Sri Lanka has initiated combating AMR with multi sectoral collaboration, under one health concept. Recent years have seen an alarming increase in multidrug-resistant microorganisms causing infectious diseases, resulting in very high morbidity and mortality as well as increasing cost to the government, individuals and the society at large.

Bacterial, viral, fungal and parasitic diseases are the major causes of shrimp /ornamental farm mortality and production losses in hatcheries and culture systems. Antibiotics are commonly used to control the bacterial populations in hatcheries and farms. However, these antibiotics are applied in *ad hoc* manner with consequences leading to alteration of microbial communities and the generation of drug-resistance strains of bacteria. Antibiotics could leave residues in shrimps, the culture environment of shrimps which could have implications in human health. Hence it is important to be aware of the gravity of the situation in Sri Lanka and to take prompt action.

Main objectives

To modify fish hold and storage facility in multi-day boats in order to enhance the quality of fish

To implement antimicrobial resistance (AMR) in the fisheries sector through surveillance and research

Specific Objectives

To study the microbiological, chemical and sensory quality of fish landings of multiday boats

To study antimicrobial use and resistance prevail in shrimp culture systems in Northwestern province

Methodology (Study area, Field sampling, data collection, and analysis)

Component 1

Triparty collaboration of NARA, NERDC, and DFAR. Funds were obtained from FAO for the fishing boat modification

Selection of a multiday boat for fish hold modifications, signing of an agreement with the boat owner. Fresh Skipjack tuna samples collected from Mirissa fishery harbour were analyzed to assess fish quality (microbiological, chemical, and sensory quality) before the fishing boat modification to compare the impact after the modification

Fish samples (n=30) were collected from IMULs and those were categorized based on the storage period in IMULs as 0-20 days (T1), 21-40 days (T2), and 41-60 days (T3). Further, fish collected from single-day boats (n=10) were considered as fresh fish (C). At the reception, sensory evaluation was done by 6 trained panelists. The samples were analyzed for Total Coliform Count (TCC), Faecal Coliform Count (TFCC), *Escherichia coli (E. coli)* and *Salmonella* to assess the microbial quality and Total Volatile Base Nitrogen (TVB-N), Trimethylamine (TMA) and Histamine to assess biochemical quality. Parametric and sensory data were analyzed using Analysis of Variance and the Kruskal-Wallis test, respectively.

Facilitation of multiday fishing boat modification. The design of the boat modification has been completed by NERDC. Procurement of generator, compressor and other items necessary for the modification is in progress.

Organizing a virtual Inception workshop of FAO funded project on "Ensuring Food Security through Minimizing Post-Harvest Losses in Fisheries Industry"

Component 2

Information was gathered on the usage of antimicrobial agents (AMU/C) in certain shrimp farms and hatcheries in Northwestern Province and shrimp farms in the Eastern province of Sri Lanka using a structured questionnaire.

Information was collected from 68 shrimp farms of low, intermediate, and high-density farms in Northwestern Province (NWP), 11 farms in Eastern province, and 17 shrimp hatcheries in NWP

(Figure 1) using a questionnaire. Farms and hatcheries were visited, and information was gathered by interviewing farm/hatchery owners/managers or supervisors. This survey was conducted from July to December 2021.

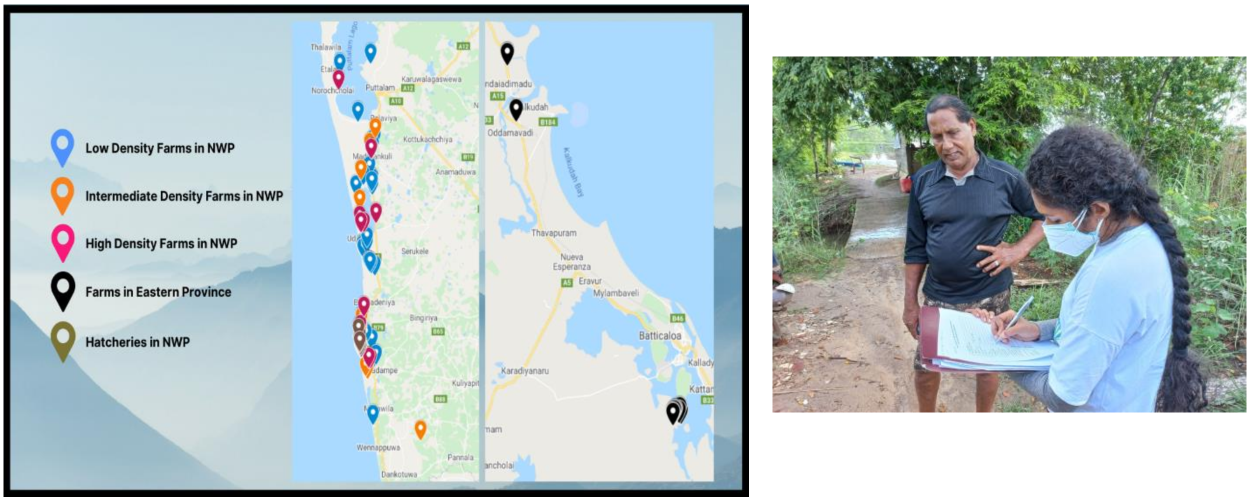


Figure 1: Locations of Shrimp farms and Hatcheries

Antibiotic Sensitivity Test (AST) was performed on 153 *E. coli* isolates from water (n= 93) and shrimp (n=60) samples collected from shrimp farms associated with North Western Province, Sri Lanka. Shrimp samples and water samples were collected from selected low density, intermediate and high-density shrimp farms. Collected samples were brought to the laboratory within 4-5 hours of sample collection under low temperature conditions.

E.coli was isolated from shrimps and water. Biochemically confirmed *E. coli* colonies were then subjected to AST.

Biochemically confirmed *E. coli* colonies were revived by transferring a loopful of *E. coli* bacterial culture to 10mL nutrient broth media. The broth medium was incubated for 24±2 hours at 37±1°C. The turbidity of the broth medium was adjusted to the turbidity equivalent to 0.5 Mac Farland reagent. A volume of 1 mL of the broth culture was then poured onto freshly prepared Mueller Hinton Agar (MHA) plates and spread evenly and plates were allowed to dry. After the plates were dried, 12 antibiotic discs were placed on the Petri dish in similar distances; Ampicillin 10µg (AP), Augmentin (amoxicillin 20µg/clavulanic acid 10µg- AUG), Amoxicillin 10µg (AX), Chloramphenicol 30µg (C), Erythromycin 15µg (E), Gentamycin 10µg (GM), Meropenem 10µg (MEM), Nalidixic acid 30µg (NA), Neomycin 30µg (NE), Oxytetracycline 30µg (OTC), Tetracycline 30µg (T), Trimethoprim 1.25µg/sulfamethoxazole 23.75µg (TS). MHA plates containing antibiotics were incubated for 24±2 hours at 37±1°C, and the inhibition zone diameters were measured. The average value of inhibition zone diameter was taken as the inhibition zone diameter for each antibiotic disc. Zone diameters were compared with CLSI guidelines for antibiotics to determine the level of sensitivity or resistance of the antibiotic to *E. coli*.

Results:

Component 1

Facilitation of multiday fishing boat modification process was completed and designing of existing boat modification has been completed by NERDC

Expenditure for boat modification is Funded by FAO and a virtual inception workshop of the project was organized and was held on 30th July 2021 with the participation of 33 stakeholders.

Selection of a multiday boat for fish hold modifications, signing of an agreement with the boat owner.

According to the sensory analysis, stale fish were observed in T3 ($p<0.05$). Further, T3 recorded significantly *(*$p<0.05$*)* higher chemical and microbiological average values as TVB-N (62.15 $mgN100g^{-1}$), TMA (30.83 $mgN100g^{-1}$), Histamine contents (38.35 ppm), TCC (0.36-93 $MPNg^{-1}$) and TFCC (0-9.3$MPNg^{-1}$), respectively. *E. coli* and *Salmonella* were shown an insignificant difference *(*$p>0.05$*)* between all categories. Further, all measured parameters of T1, T2 and C fishes have not exceeded the maximum permissible limits (MPL), except *E. coli*. However, TVB-N, TMA and *E. coli* values in T3 have exceeded the MPL, as well as the Histamine, TCC and TFCC values, were much closer to the MPL, thus, it is possible to exceed within the distribution channel.

Component 2

According to the data, there was no evidence of direct antibiotic usage in shrimps farms during the rearing periods, in culture ponds. However, some hatcheries are applying one or two antibiotics during the operation in 1-2 ppm concentrations.

Stocking densities are maintained not to stress the animals. Most of the farmers in NWP stock shrimp in the pond at low density (62%), while 19% each at intermediate and high densities. In Eastern province, out of 11 farms visited 9 farms (82%) maintain low densities in culture ponds while 18% maintain intermediate densities. Stocking density is an important parameter in shrimp culture operations since it has direct effects on the growth and survival and hence on production.

Forty-seven percent of the hatcheries surveyed used 1 or 2 antibiotics at the levels of 1-2 ppm as prophylactic measures (Figure 2).

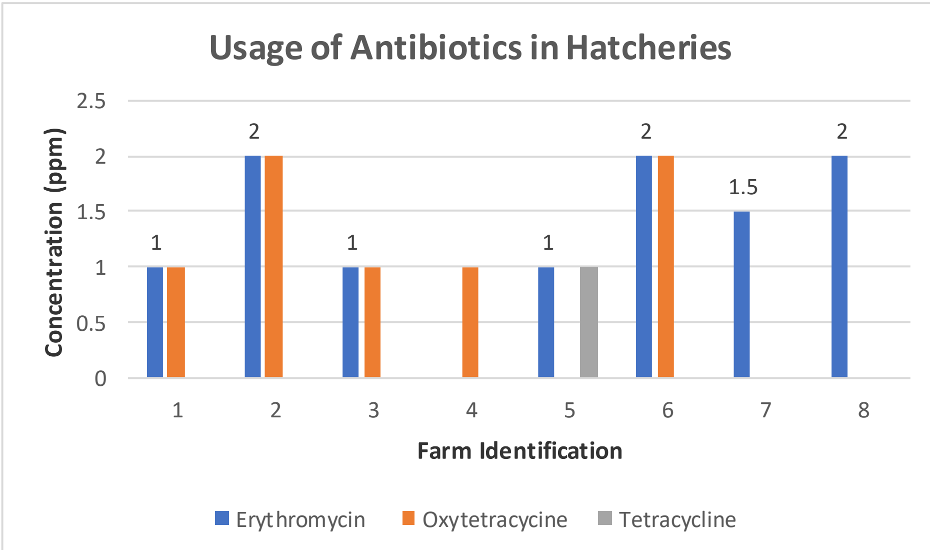
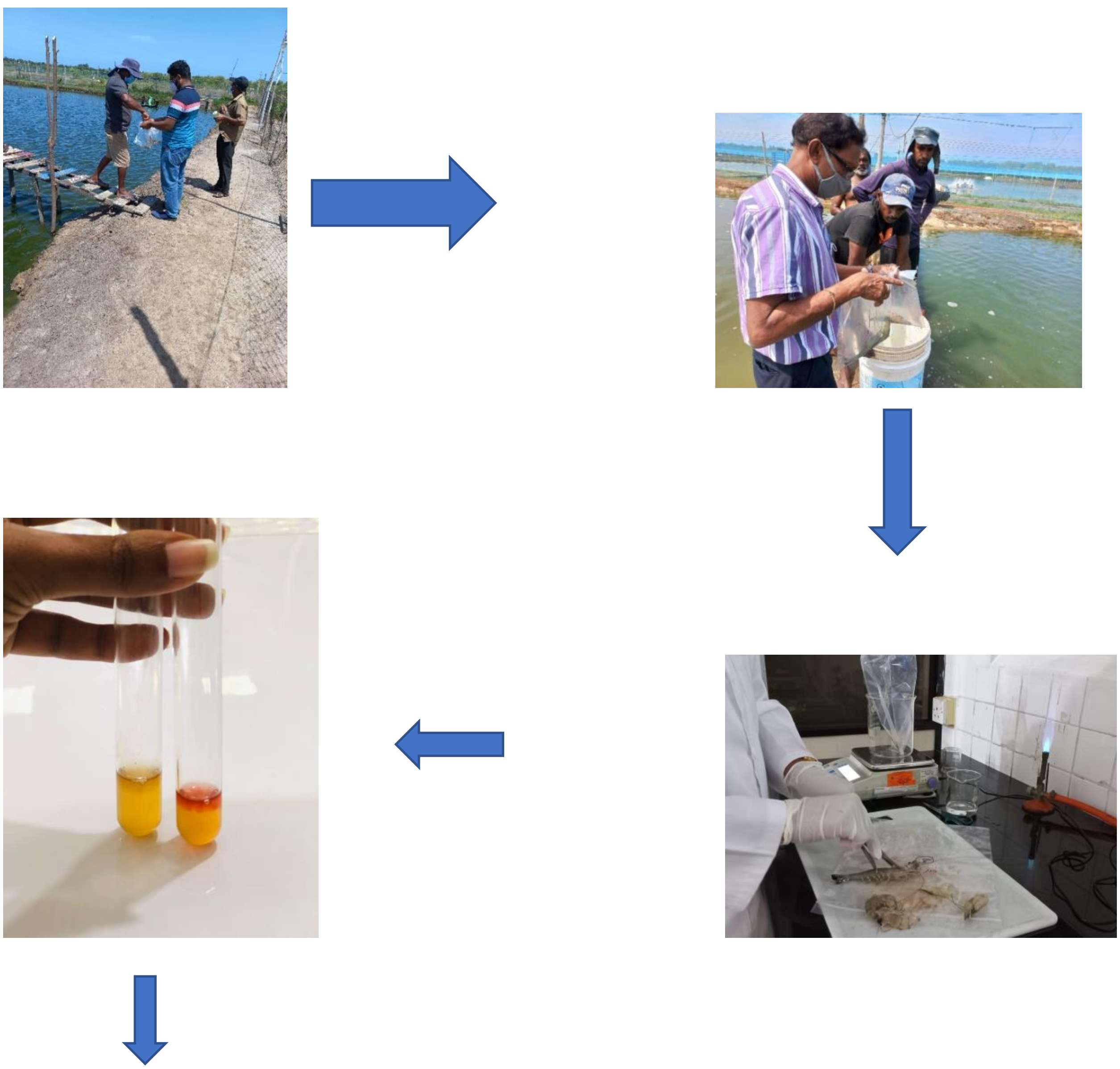


Figure 2: Usage of Antibiotics in Hatcheries



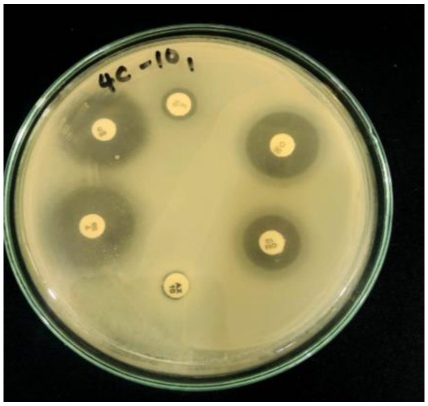


Figure 3: Collection of samples and testing of samples

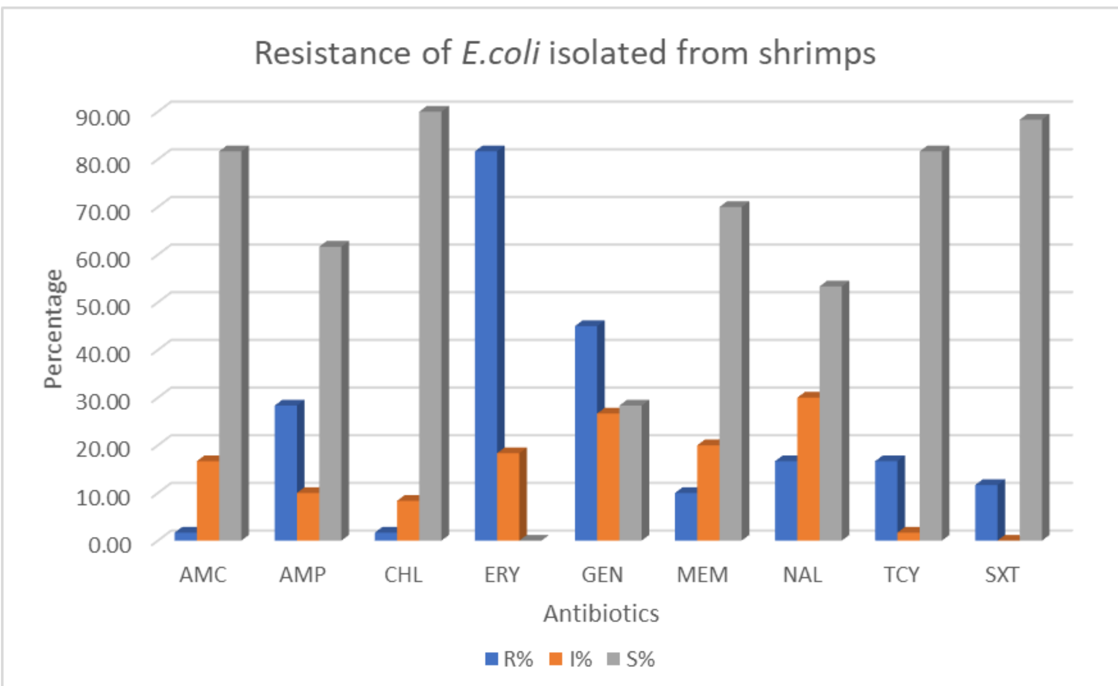


Figure 4: Susceptibility/ Resistance of *E.coli* isolated from Shrimps

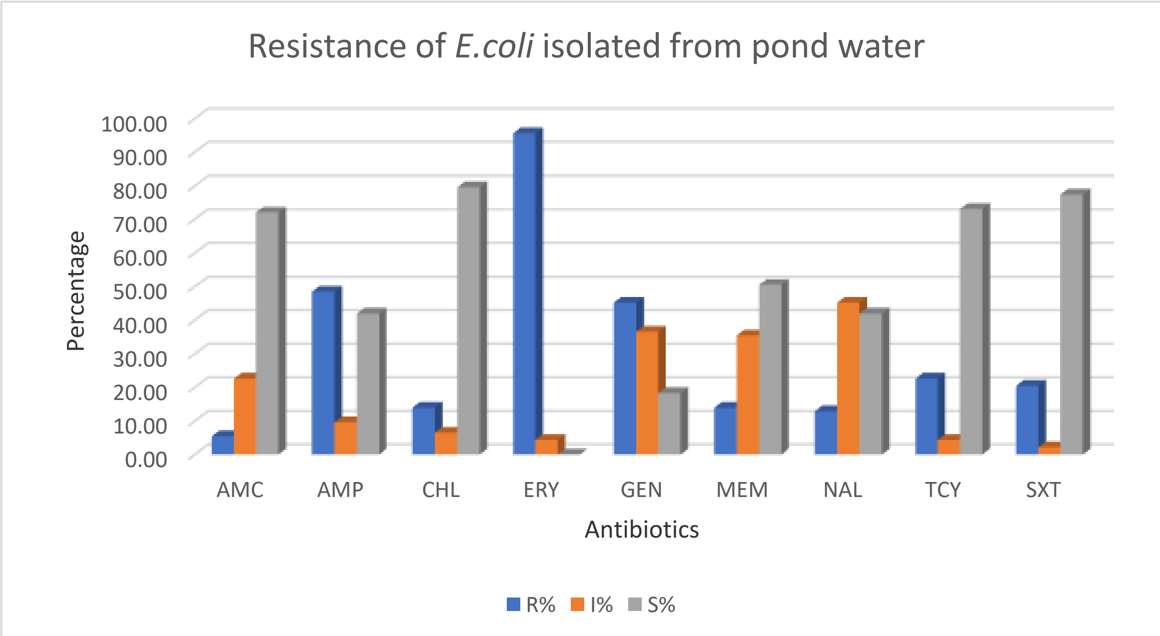


Figure 5: Susceptibility/ Resistance of *E.coli* isolated from Shrimp culture pond water

The antibiotic susceptibility of 153 *E.coli* isolates (60 isolates from shrimps and 93 isolates from culture pond water) was investigated against 12 antibiotics. As shown in Figures 4 and 5, a large number of isolates showed resistance to Erythromycin (81.67% for shrimps and 95.7% for water), Gentamycin(45% for shrimps and 45.16%for water), Ampicillin (28.33% for shrimps and 48.39% for water), Tetracycline (16.67% for shrimps and 22.58% for water), Nalidixic acid (16.67% for shrimps and 12.90% for water) and Chloramphenicol (1.67% for shrimps and 13.98% for water). However, CLSI epidemiological cut-off values are not available for Amoxicillin, Neomycin and Oxytetracycline for the interpretation. Multidrug resistance was observed in 28% and 44% of the resistant *E.coli* isolates from shrimps and water samples respectively. Though there was no evidence of usage of antibiotics in shrimp culture ponds the high prevalence of antibiotic resistance in shrimp culture environment is a matter of concern. The identification of antibiotic resistance among the isolates does rises a public health concern and permits continuous surveillance.

Outputs & outcomes

Out put

Enhanced awareness to improve fish quality

Fish quality assessment before the boat modification

Conclusions

Though AMR is observed in aquatic bacteria associated with shrimp farming systems, it is difficult to find a direct link between the resistance profile and the usage of antibiotics.

Recommendations

There is a need for appropriate management and control of the use of antibiotics in the shrimp culture industry. Efforts are needed to prevent the development and spread of antimicrobial resistance in aquaculture. These efforts should be focused on the improvement of management routines, regulatory control of the use of antimicrobial agents, implementation of prudent use guidelines and monitoring of the use of antimicrobial agents and antimicrobial resistance.

Constraints

Impact of COVID-19

Financial Allocation (Rs)

Financial progress (%)

Physical Progress (%) 90%

4.2 Control and assessment of risk associated with isolated histamine forming bacteria from yellowfin tuna industry in Sri Lanka

Officer/s responsible : Pavithra Ginigaddarage, K.W.S. Ariyawansa, G.J. Ganegama Arachchi

Introduction :

Histamine formation in fish is a common problem related to the fishery industry. This happens mainly due to poor handling practices and lack of temperature control. In the previous stages of this study histamine forming bacteria have been isolated from several points in the tuna supply chain due to cross contaminations and some isolated bacteria were able to form histamine in toxic amounts in laboratory conditions. Therefore it is important to give recommendations on controlling those bacteria (in fish and fish contacting surfaces) and assess the risk associated with these bacteria to reduce the histamine formation.

Main objective

To isolate and control histamine forming bacteria on fish contacting surfaces and assess the risk associated.

Specific Objective/s

To isolate histamine forming bacteria from chilled fish, ice in multiday boats landed at fishery harbours.

To detect the effective disinfectant and effective concentration of the disinfectant in controlling histamine forming bacteria on fish contacting surfaces.

Methodology (Study area, Field sampling, data collection and analysis)

Isolation of histamine forming bacteria

Ice samples and swab samples were collected from multiday boats landed at Trincomalee and Dondra fishery harbours and three samples were collected from each sampling point.

Ice from fish hold

Ice from factories

Swabs from fish holds

Swabs from boat decks

Swabs from skin of fish

The samples were analysed at Quality Control laboratory and Chemistry laboratories.

Control of bacteria on surfaces

In normal practice fishermen use Vim, Teepol, Sodium hypochlorite etc. to clean surfaces of multi Day boats (source: information gathered during this study).

Aim of this component was to evaluate the effectiveness of food grade cleaning agents available at the market and effective concentration in controlling bacteria by using standard quantitative suspension test (Rutala *et al*., 2000, Sheraba *et al*., 2014).

Activities proposed to be completed during the period

Isolation of histamine forming bacteria

Evaluation of the effectiveness of food-grade cleaning agents

Assessment of risk

Results: Activities carried out:

Bacterial isolate	**No. of isolates**	**Sampling location/Type**	**Amount of histamine formed (ppm)**
Pseudomonas sp.	07	Ice collected from chill transport vehicles, swabs from boat decks, swabs from fish skin, ice collected from fish hold, swabs from fish hold	05 - 35
Serratia sp.	01	Ice collected from fish hold	1600
H. alvei	01	Ice collected from chill transport vehicles	75
S. baltica	05	swabs from fish hold, ice collected from fish hold, Ice collected from chill transport vehicles	05-17

Controlling of histamine forming bacteria on direct fish contacting surfaces

Since both strong and weak histamine forming bacteria including spoilage bacteria are present on direct fish contacting surfaces cleaning those surfaces thoroughly using disinfectants to reduce the bacterial load is important.

Sampling location/Type	Fishery harbour	
	Trincomalee	Dondra
Swabs from fish skin (CFU/cm^2)	8.0×10^5	2.0×10^5
Swabs from boat decks (CFU/cm^2)	1.8×10^5	4.7×10^5
Swabs from fish holds (CFU/cm^2)	4.7×10^5	1.8×10^5
Ice samples from chill transport vehicles (CFU/mL)	4.8×10^3	1.2×10^5
Ice from fish holds (CFU/mL)	4.6×10^7	4.2×10^6

Data obtained from multiday boats during the study revealed that majority of the boats used only cleaning agents (detergents) to clean surfaces.

Anti microbial activity of food grade disinfectants and detergents used in the local fisheries industry was determined against *Klebsiella aerogens* and *Morganella morganii* using standard quantitative suspension test

From the laboratory trials conducted, it was seen that the disinfectant which contained triclosan (1:5,1:10,1:20,1:40) showed a weak bactericidal activity at different concentrations. Disinfectants with quaternary ammonium compounds (0.2:100, 0.1:100, 0.05:100, 0.025:100) hydrogen peroxide (0.2:100,0.5:100,1:100,2:100) and sodium hypochlorite (1:10,1:20,1:30,1:40) showed 100% inhibition of organisms at different concentrations at respective dilutions where the tests were carried out. Detergents also showed zero inhibition against the tested microorganisms.

9. Outputs & outcomes

Identification of cross-contamination points in the fish supply chain.

Conclusions

Ice, fish contacting surfaces (boat deck, fish hold) and fish skin were identified as sources of HFB

It is necessary to control the occurrence and growth of these bacteria by adopting proper handling and cleaning practices

Recommendations

Need to adopt better sanitation procedures on fish contacting surfaces of boats by using effective disinfectants.

Quality of ice should be improved

Constraints

There were some delays in sampling and sample analysis due to COVID 19 pandemic.

Financial Allocation (Rs)

Financial progress (%)

Physical Progress (%) - 90%

4.3 Aquatic products, process development and popularization

2. Officer/s responsible -: .S. Ariyawansa, D.S.Ariyarathna, M. Paththuwearachchi

Component-1

3. Introduction

This project was launched to ensure the hygienic conditions of the Maldive Fish and dried fish in the local market through introducing new technology to the people who are already engaged in the industry in terms of technology transformation. Expertise is provided by NARA and NERDC to introduce new set of utensils and equipment. The World Bank is the funding Organization for this project under agriculture modernization project. Interested applicants can joined the project based on their scale of production land space they have and the amount of money they can spend on this project since World Bank contribution is only 60% from the total budget.

4. Main objective

Introduction of new technology approach for the dried and Maldive fish industry in Sri Lanka.

5. Specific Objective/s

Introduction of a new drier and smoking unit for the dry fish and Maldive fish industry in Sri Lanka.

Training the relevant group of people in fish industry by awareness programmes.

6. Methodology (Study area, Field sampling, data collection and analysis)

Identifying the short comings of existing Maldive fish/ dried fish processing practices in Southern Province of Sri Lanka **-->** Development of innovative set of equipment for hygienic production**-->** Selecting of interested Maldive fish and dried fish producers for Agriculture Sector Modernization Project- Value Chain Development Programme**-->** Establishment of model dryers in a public property at Kottegoda.

7. Activities proposed to be completed during the period

Following tasks have been completed under the above project.

Identifying the short comings of existing Maldive fish/ dried fish processing practices in Southern Province of Sri Lanka and preparation of a report including the suggestions for improvement.

Development of innovative set of equipment for hygienic production of Maldive fish ensuring no impact on the traditional flavor and the quality of the final product using the expertise from National Aquatic Resources Research and Development Agency (NARA) and National Engineering Research and Development Centre (NERDC).

Conducting awareness programs for Maldive fish and dried fish producers (250) in Dondra, Dickwella and Kottegoda areas of Southern Province of Sri Lanka on importance of hygienic preparation of dried fish and Maldive fish and basic guidelines of Agriculture Sector Modernization Project- Value Chain Development Programme.

Preparation of initial screening guide and conducting initial screening of interested Maldive fish and dried fish producers for Agriculture Sector Modernization Project- Value Chain Development Programme. (184 Applications were received and 136 applicants got passed the initial screening).

Secondary screening has been conducted for 136 selected applications and 46 applicants were selected based on their experience, availability of land, financial ability for contribution etc.

Field inspection and Environmental impact assessment of working sites of selected 46 applicants.

Preparation and submitting of major proposal for Agriculture Sector Modernization Project- Value Chain Development Programme.

Finalizing and submitting the individual files of selected applicants.

Calling for quotations to construct the developed processing units.

Establishment of model dryer (Biomass dryer) in a public property at Kottegoda for use of a corporative society.

Introduction of smoking unit for the Maldive fish industry.

A trial has been carried out to evaluate the efficiency and the suitability of newly introduced smoking unit and Biomass dryer using 1000 kg of Skip jack tuna fish**.**

8. Results: Activities carried out:

Introduction of new set of utensils and equipment for the processing industry of Maldive fish and dried fish industry Sri Lanka.

9.Outputs & outcomes

Out put

Introduction of New smokimg unit that can be smoked about 1000kg of Skip jack tuna fish within 5 hours using 50-75 kg of fire wood.

Introduction of New biomass dryer that can be dried 1000kg of Skip jack tuna fish withing 48 hours**.**(Cost of fire wood was about Rs.1800.00)

Improvement of safety and efficiency of Maldive fish and dried fish processing process while improving quality and value of products**.**

10. Conclusions

Activities of this project were led to introduction of enovative Smokig unit and Biomass dryer for the dried and maldive fish industry in Sri Lanka

11. Recommendations

It is required to popularize the smoking unit and biomass dryer among the dried and maldive fish producers around Sri Lanka.

12. Constraints

Management of resistance of fisherfolk during the introduction of new ideas against the traditional practices.

Financial Allocation (Rs)

Financial progress (%)

Physical Progress (%) - 85

4.4 Aquatic products, process development and popularization

1. **Officer/s responsible -:** S. Ariyawansa , D.S.Ariyarathna, M.Paththuwearachchi

Component-2

3. Introduction

Aquatic products (fish/ fish products/seaweed /seaweed-based products) are playing a very important role in the human nutrition supply as well as the national economy. However, the prices of products are relatively high due to the demand increase with the population growth and health benefits associated with the aquatic products. As a solution for the problem, it is possible to promote new product development and value addition for the underutilized and low trendy aquatic recourses and high-quality fish waste.

4. Main objective

Optimum utilization of underutilized aquatic resources (Ex: High-quality waste and underutilized fish varieties**)**

5. Specific Objective/s

- Production of fish burgers using fish minces and introduce to the market.
- Conduct market trials and surveys for the above products.

We have arranged to conduct fish burger processing trials with Nor-fork (Pvt) Ltd located in Pitipana, Homagama due to lack of facility in our fish processing unit, IPHT and could not complete due to the high workload carried out under component -1 (dealing with 40 number of document files of individuals and field visits).

4.5 Development of value-added products using aquatic Resources

1. **Officer/s responsible:** Pradeepa Jayasinghe

2. **Introduction:**

Value addition of existing foods with incorporation seaweed-based ingredients and hydrocolloid is a simple and feasible way of enhancing nutritional values of foods. Research has attempted to make more healthy products by incorporating new ingredients into mixture in order to increase their nutritional and textural qualities. Seaweeds are considered healthy food owing to their richness in protein, antioxidant, essential amino acid, vitamins, phytochemicals, polyunsaturated fatty acids, minerals and bioactive compounds, at the same time having relatively lower calorie content. relatively higher carbohydrate content in red and green seaweeds and higher content of soluble fiber and iodine in brown seaweeds. Seaweeds are also a good source of dietary fiber, which includes soluble as well as insoluble dietary fibers (based on solubility in water). Soluble dietary fiber helps to increase viscosity and reduce glycemic response and plasma cholesterol in humans. Many studies have evaluated the gelling, thickening and therapeutic properties of seaweeds when they are used individually. The effect of seaweeds incorporation on properties of meat, fish, bakery, and other food products were highlighted in depth. Moreover, the positive effects of foods enriched with seaweeds and seaweed extracts on different lifestyle diseases such as obesity, dyslipidemia, hypertension, and diabetes were also discussed. The results of the studies demonstrated that the addition of seaweeds, in powder or extract form, can improve the nutritional and textural properties of food products. Moreover, the addition of seaweeds also affected the health properties of food products.

Seaweed is found in many products than thought commonly. It can be consumed either directly or processed into food products. It is a sensible decision to combine seaweed with another type of food product found in the market that's much sought – after and preferred over many other types of food. Edible and commercially important seaweeds species will be used for the study. The seaweed and rice flour incorporated healthy biscuit formulation can offer a diversified, enhanced and a quality product to the market.

3. **Main objective**

To prepare seaweeds powder from the dried seaweeds and to develop seaweeds and rice flour incorporated healthy biscuits formulation from locally available species.

Commercialization of the seaweed based products

5. Specific objectives

- To prepare seaweed powder from the dried seaweeds.
- To add value for damaged or broken rice grains from grinding of broken rice grains into flour.
- To develop a rice flour-based seaweed product.

- To identify the proper ratio of seaweed and rice flour to develop the healthy biscuit formulation.

- To evaluate the taste, odor, palatability of the developed product through a sensory evaluation.

- To evaluate proximate composition, physicochemical properties and microbiological quality of the developed seaweed and rice flour incorporated healthy biscuit formulation.

6. Methodology (Study area, Field sampling, data collection and analysis)

6.1. Location

All the laboratory experiments were carried out in the Aquatic quality control Laboratory, product development laboratory and Analytical chemistry laboratory of NARA.

6.2. Raw Materials

- Fresh seaweeds species were collected from Kalpitiya,Jaffna and Mannar areas and transported in chilled conditions (0 ^{0}C) using ice. Other raw materials were purchased from supermarkets.

6.3. Equipment for testing

Homogenizer, thermometers, blenders, sieves and other apparats such as Kjeldahl unit, oven, Soxhlet apparatus, electronic balance, analytical balance, pH meter, pulverizers, cutting boards, rollers were used as the main equipment in this study.

6.4. Biscuits Making process

Rice flour + Seaweed powder

Weight and measuring

Mix with baking powder

Sieving

Blend with egg, margarine and sugar (make cream)

Add flour mixture to the cream and mix well

Make the dough

Cut into shapes

Baked in 165^0C for 15 min

Cool

Packed in polythene bags

Figure 1 : Unit operations in Biscuit making

6.5. Preparation of Seaweed Powder

Sand, dust, mud, unwanted seaweed and other debris removed in fresh seaweed by thoroughly washing for 5-6 times with running tap water. Washed seaweed was kept for several minutes to drain out excess water. Then cleaned seaweed was dried using solar dryer and pulverize to take white color seaweed dust. After it was packed in zip lock bags and stored in a dry place until used for the product development process.

6.6. Preparation of the biscuit formulation

Trials with different ratios of seaweeds and rice flour mix were carried out to find the formulation with the highest nutritional content which gives the optimum palatability.

The selected raw materials are rice, seaweeds. Rice was milled and made rice flour. Seaweeds were cleaned, dried and pulverized to make powder form. These two were mixed in 1:1 ratio to make the mix.

6.7.1 Laboratory Analysis of Seaweeds and prepared product

Analysis of nutritional and physicochemical properties of seaweed (table 1).

Parameter	Method
pH	AOAC method, 2000
Moisture content	AOAC 934.01 (2010)
Ash content	AOAC 923.03 (2010)
Crude fat content	AOAC (2010)

Crude fiber	AOAC 962.09 (2010)
Crude protein content	AOAC 981.10 (2010)
Carbohydrate content	AOAC (2010)
Energy value	AOAC (2010)

6.7.2 Statistical Analysis

The collected data from selected six treatments were subjected to analysis of variance (ANOVA) at the significance level of α=0.05 and whenever appropriate, the mean separation procedure of Least Significance Difference (LSD) was employed. The Statistical Analysis System (SAS) software system (version 9.0, SAS Institute Inc, 2004) was used to perform the analysis. Data from the sensory evaluation was analyzed by using Minitab 17 software at a 95% confidence interval adapting the Friedman Test.

6.7.3 Microbial Analysis

Total Plate Count (TPC) and yeast and mould count of prepared biscuit formulation were tested in 25 days intervals up to 50 days of storage period. Analyses were carried out according to the SLS (2013) guidelines.

6.7.4 Sensory analysis

Sensory analysis for prepared seaweeds incorporated cereal formulation was carried out using 30 untrained panelists. The panelists were asked to give scores for the color, flavor, appearance, texture and overall acceptability according to a five-point hedonic scale

7. Activities completed

The sensory results revealed that 20% SW + 15% RF treatment had the highest scores for all sensory attributes. It had 2.3±0.16 % moisture,5.1±0.11 % Ash, 23.3±0.43 % crude fat, 3.7±0.04 % crude protein, 63.5±0.13 % carbohydrate, 484.60±0.17 % kcal/100 g energy and 25.3±0.03 % total dietary fiber content. According to the mineral results there were 12703.989±6.02413 % Na, 657.2047±1.20389 % Mg, 250.69±0.24591 % Fe, 4810.944±2.42899 % K, 3634.5185±.58235 % Ca, 0.3775±0.00875 % Cu, 3.7585±.29006 % Cr, 3.7585±0.29006 % Zn, and 20.672±1.04728 % Mn content. The yeast and mould count were not detected and total plate count was 530 CFUg-1 initially and further decreased in accordance with the Sri Lanka standards (<1×104 CFUg-1) for 21 days at room temperature was significantly increment ($p<0.05$) recorded in these storage period and water activity pH value was significantly increase ($p<0.05$) 21 days of storage period. However, it was within the acceptable limit. Accordingly, it can be concluded that seaweed biscuit supplement incorporated 20% seaweeds with 15% rice flour (w/w) has better organoleptic and nutritional properties and can be stored at room temperature conditions for 21 days without any quality deterioration.

7. Outcome and Output

- Introduction of a seaweed mixed different value-added product to producers and specific consumer groups in food industry in Sri Lanka.

- Motivate the relevant groups for the production and consumption of healthy and functional food and food supplements.
- Ensure the health and safety of the final product for the consumers through out the production process.
- Creating several small-scale employment opportunities

8. Conclusions

Seaweed with rice flour was a good combination to produce biscuit supplement as a novel food product. Biscuit supplement prepared with 20% seaweed and 15% seaweed (w/w) was achieved the highest scores for all sensory attributes than other biscuit samples in different levels of seaweed. **Recommendations**

Accordingly, to the results, it can be recommended that seaweed biscuit supplements incorporated 20% seaweeds with 15% rice flour (w/w) are suitable to introduce to the commercial market. This product is recommended storing at room temperature conditions for 21 days without any quality deterioration.

9. Constraints

The major constraints are the unavailability of enough raw seaweed in the country. Apart from that seaweed doesn't show high sensory properties. Therefore, it is essential to product incorporate with other flavour enhancers to improve the sensory properties

- **Financial Allocation (Rs) : 17,2200.00**
- **Financial progress (%) : 1641921.00**

Physical Progress (%) : 85%

4.6 Contamination and bioaccumulation of Heavy metals PAH and pesticide residues in fish during post-harvest handling and landing stage of fishery in selected harbours, inland reservoirs, and lagoons in Sri Lanka

1. **Officer/s responsible:** K.G.S Nirbadha, K.W.S. Ariyawansa, M.G.C.R Wijesinghe

2. **Introduction :**

The contamination of the aquatic environment with a wide range of pollutants has become a matter of concern over the last few decades. The natural aquatic systems may extensively be contaminated with heavy metals and other toxic pollutants including PAHs, pesticide residues released from domestic, industrial and other anthropogenic activities. Heavy metals have a great ecological consideration due to their toxicity and accumulation. Heavy metals are non-biodegradable and once discharged into water bodies, they can either be adsorbed on sediment particles or accumulated in aquatic organisms. Fish may absorb dissolved elements and heavy metals from surrounding water and food, which may accumulate in various tissues in significant amounts and are stimulating toxicological effects at critical targets.

Polycyclic aromatic hydrocarbons (PAHs) are a group of common environmental contaminants. PAHs originate from anthropogenic sources such as waste incineration, coal gasification, as well as natural processes such as fossil fuel and wood combustion (Asikainen et al., 2002;). Because of their hydrophobicity, low water solubility, and vapor pressures, PAHs tend to accumulate in sediment and various organic components (Savinov et al., 2000). The presence of pesticide residues in water and sediments has been extensively studied in last decades. Monitoring of fish and shellfish serves as an important indicator of the water ecosystem (Fairey et al., 1997) where there is a vertical transport of pesticide residues leading to accumulation in the benthic organisms. Reports are available in plenty indicating the presence of Organochlorine pesticides in a variety of commercial fish species in many countries (Itawa et al., 1993; Kannan et al., 1995; Grobler et al., 1996; Pastor et al., 1996; Fairey et al., 1997; Anon, 1998; Spiric and Saisic, 1998; Chan et al., 1999; Monirith et al., 1999; Cleeman et al., 2000; Zhulidov et al., 2000; Jabbar et al.,2001) In general , persistent organic compounds all have the following characteristics: they are stable and toxic, and share a similar structure. It has emerged that some highly stable organic compounds, chiefly halogenated hydrocarbons can have serious environmental effects in aquatic ecosystems.

In recent years, world consumption of fish has increased simultaneously with the growing concern of their nutritional and therapeutic benefits. In addition to its important source of protein, fish typically have rich contents of essential minerals, vitamins and unsaturated fatty acids. However, fish have the ability to accumulate heavy metals and other organic substances in their tissues by absorption along the gill surfaces and kidney, liver and gut tract wall to higher levels than environmental concentration known as bioaccumulation. Furthermore, the fish was contaminated with heavy metals and organic substances during the post-harvest handling and while landings. This research was carried out as a comprehensive investigation of heavy metals, polycyclic aromatic hydrocarbons (PAHs) and pesticide residual in fish tissues in commercially important fishery harbours, inland fishery and lagoons in Sri Lanka. However, analysis of polycyclic aromatic hydrocarbons (PAHs) and pesticide residuals in fish tissues were not able to carry out due to a deficit of standard chemicals and consumables.

4. Specific Objective/s:

- To determination of levels of contamination of heavy metals, PAH and pesticides contaminants in fish tissue, water and sediments in selected fishery harbours, inland reservoirs and lagoon

5. Methodology:

Water, sediment and selected fish specie's tissues samples were collected from Chilaw, Negombo and Rekawa lagoons. All the laboratory analyses were carried out using Atomic absorption spectrophotometer (AAS) in ACL, IPHT, NARA, and Inductively Coupled Plasma Mass spectrometer (ICPMS) in Industrial Technology Institute (ITI). The 12 number of heavy metals of Aluminium (Al), Arsenic (As), Lead (Pb), Cadmium (Cd), Mercury (Hg), Copper (Cu), Chromium (Cr), Iron (Fe), Lithium (Li), Zinc (Zn), Manganese (Mn) and Molybdenum (Mo) were determined in water, sediment and fish tissues.

6. Results

Heavy metals contents of fish from Chilaw, Negombo and Rekawa lagoons as follows.

Lagoons	Fish species	Heavy metals (mg/kg = ppm)					
		Pb	Hg	Cd	As	Cu	Fe
Negombo	Liza parsia Godaya	0.05 ±0.01	0.11 ±0.03	nd	1.05 ±0.06	0.57 ±0.22	163 ±33.04

	Etroplus suratensis Korali	0.05 ±0.01	0.17 ±0.01	nd	10.79 ±1.56	0.46 ±0.11	171.33 ±20.50
	Lutjanus fulviflamma Ranna	0.04 ±0.01	0.29 ±0.04	nd	0.19 ±0.04	0.57 ±0.21	156.39 ±9.48
	Caranx ignobilis Parawa	0.04 ±0.01	0.13 ±0.01	nd	0.44 ±0.10	0.68 ±0.31	95.83 ±7.93
	Leiognathus berbis Karalla	0.05 ±0.01	0.04 ±0.02	nd	1.68 ±0.15	0.43 ±0.09	152.54 ±19.54
	Scylla serrate Mud crab	0.14 ±0.02	0.10 ±0.01	nd	4.30 ±0.43	2.69 ±1.17	142.53 ±11.83
Chilaw	Liza parsia Godaya	0.20 ±0.21	0.04 ±0.03	0.61 ±0.52			
	Etroplus suratensis Korali	0.26 ±0.26	0.042 ± 0.03	0.260 ±0.24			
Rekawa	Liza parsia Godaya	0.04 ±0.01	0.15 ±0.03	nd	1.2 ±0.06		
	Etroplus suratensis Korali	0.06 ±0.01	0.19 ±0.01	nd	5.89 ±1.56		
	Scylla serrate Mud Crab	0.18 ±0.02	0.15 ±0.01	nd	3.81 ±0.43		

ND-Not detected

The heavy metal levels in selected fish species tissues (Edible parts) were not exceeded the food safety limits specified by international authorities (WHO and EU/EC 1881/2006 legislations) except Arsenic. Sediment and water samples will be analyzed in due course.

7. Outcome and Output

The heavy metal levels in selected fish species tissues (Edible parts) were not exceeded the food safety limits specified by international authorities (WHO and EU/EC 1881/2006 legislations).

8. Constraints

Due to the Covid 19 pandemic situation unable to achieve objectives and hence, the project will be continued for the year of 2022.

Financial Allocation (Rs) :

Financial progress (%) :

Physical Progress (%) : 50%

4.7 Application of Bio-Nanotechnology in Value Addition to Aquatic Resources: Preliminary study on analysis of bioactive compounds from selective marine sponges (Marine fauna) and seaweeds (Marine flora)

2. Officer/s responsible: K.G.S Nirbadha, K.W.S. Ariyawansa, M.G.C.R Wijesinghe

3. Introduction:

Bioactive compounds are basically obtained from two types of sources. Firstly, the terrestrial sources like plants, animals and microorganisms and secondly, the marine source, which comprises invertebrates and marine microorganisms. This is further to mention that, the diversity of marine animals is more compared to terrestrial organisms and rich source of natural products. The Ocean, which is called the 'mother of origin of life', is also the source of structurally unique natural products that are mainly accumulated in living organisms. Several of these compounds show pharmacological activities and are helpful for the invention and discovery of bioactive compounds, primarily for deadly diseases like cancer, acquired immunodeficiency syndrome (AIDS) etc., while other compounds have been developed as analgesics or to treat inflammation, etc. The lifesaving drugs are mainly found abundantly in microorganisms, algae and invertebrates, while they are scarce in vertebrates. Modern technologies have opened vast areas of research for the extraction of bioactive, biomedical compounds from oceans and seas. Many bioactive compounds have been extracted from various marine invertebrate animals like sponges, soft corals, echinoderms, sea hares, nudibranchs, bryozoans, sea slugs and a few others (Harvey, 2000). Among these, the sessile invertebrates like sponges, bryozoans and tunicates are better candidate species for extraction of marine-derived secondary metabolites with drug leads (Falukner, 2002). Seaweeds are abundant in the intertidal zones and in clear tropical waters. Marine algae have received comparatively less bio-assay attention. In addition, there are a number of seaweeds with economic potential. It will be of great significance if these species could be the major role players in drug development. The marine pharmacy currently holds more than 35000 marine-derived biological samples, with approximately 150 compounds to be cytotoxic against the tumour cells. Some of the prominent anticancer compounds in clinical trials include yondelis, bryostatin-1, squalamine, aplidin, dolastatin-10 (Joseph and Sujatha, 2011). In general. Natural Products have long been used as food, fragrances, pigments, insecticides, medicines, etc. Marine organisms comprising approximately half of the total biodiversity on the earth and the marine ecosystem are considered as the greatest source to discover useful therapeutics (Blunt et al., 2005). Marine biotechnology is the science in which marine organisms are used in full or partially to make or modify products, to improve plants or animals or to develop microorganisms for specific uses.

4. Specific Objective/s:

- To identify bio active natural compounds and nanoparticles from marine sponge, seaweeds and biotic/abiotic wastes
- To specify natural biomedical compounds from marine sponge, seaweeds and biotic/abiotic parts
- To identify feasibility of marine sponge culture

5. Methodology:

The project of a preliminary study on analysis of bioactive compounds from selective marine sponges (Marine fauna) and seaweeds (Marine flora) was carried out to identify specific bioactive compounds in seaweeds and marine sponges around Sri Lanka. During the study, 10 species of seaweeds (*Kappaphycus alverezii*, *Glacilaria verrucosa*, *Caulerpa racemosa*, *Padina boergesenii*, *Actinotrichia fragilis*, *Sargassum turbinatifolium*, *Anphiroa anceps*, *Avrainvillea amadelpha*, *Halimeda opuntia*, *Turbinaria ornata*) and nearly one hundred of specimens/samples of marine sponges were collected from several locations in Sri Lankan waters. Seaweed samples were identified locally using specific keys and the marine sponges samples were identified with assistance of Naturalis bio diversity centre, Leiden, Netherlands. Phytochemical profiles of seaweeds and zoochemical profile of marine sponge of *Xestospongia testudinaria* (Barrel sponge), *Gelliodes* sp., *Heliclona* sp. and *Clathria* sp. were carried out in analytical chemistry laboratory, IPHT, NARA.

6. Results: Activities carried out:

The basic chemical groups of bioactive compounds (Terpenoids, Flavonoids, Steroids, Glycosides, Phlobatannins, Proteins) were identified using appropriate testing methods (Salkowski test, Alkaline Regent test, Libermann test, Precipitate test, Xanthoprotein test). Ethanol was used as a solvent system for the preparation of the extract of seaweeds. The ethanolic extracts of seaweeds were undergone to the qualitatively phytochemical test by means of typical measures.

7. Outcome and Output

Phytochemical analysis shows the presence of alkaloids, tannins, steroids, flavonoids, and carbohydrates, whereas proteins, free amino acids and saponins were found to be absent. The results of the study may lead a foundation for the further studies on those seaweeds and sponges.

8. Recommendations

The Gas Chromatography Mass Spectroscopy (GC-MS) analysis will be done for the next year due to continuity of project. Bioactive compounds interpretation of the spectrum obtaining using GC-MS analysis will be performed by comparing with data base and using phytochemical standards.

9. Constraints

Due to the Covid 19 pandemic situation unable to achieve objectives

- **Financial Allocation (Rs) :**
- **Financial progress (%) :**
- **Physical Progress (%) : 50%**

5 Environmental Studies Division

5.1 Development of Coastal Water Quality Index (WQI) for Southern Beaches: A road to the Blue Flag Certification

Objectives:

To rank the current status of water quality of the southern beaches (Unawatuna, Mirissa and Polhena) using Water Quality Index (WQI) to facilitate economic development of the country through tourism attraction.

To study the feasibility of obtaining "Blue Flag Certification" to the selected beaches.

To identify the water pollution sources to selected beach areas.

Description of the project

The coast is a unique habitat in which land, sea, and atmosphere constantly interact and interplay, impacting a strip of space known as the coastal zone. In other words, coastal zones are the areas having the influence of both marine and terrestrial processes. Sri Lanka's coastal zone has served as a focal point for the social, cultural, environmental and economic development of the country for centuries. Sri Lankan coastal zones are continually changing because of the dynamic interaction between the oceans and the land. Environmental degradation, habitat loss, climate change, over-population, unsustainable socioeconomic conditions, and civil unrest all potentially threaten the sustainability and quality of life in the coastal regions of Sri Lanka (Powell *et al.*, 2009). Currently, a majority of Sri Lanka's population lives within the coastal zone. In developing countries, such as Sri Lanka, this coastal population primarily relies on the coastal zone's ecological health and attractiveness for their livelihood through fisheries, coastal tourism, and other coastal-related services and industries (Powell *et al.*, 2009). Because of the increasing use of coastal zones, there is a considerable risk of coastal zones becoming polluted.

With upsurge to the high demand by the both local and foreign visitors, infrastructures have been developed along the coastal belt. Hence, the beaches are susceptible to degrade and pollute due to the anthropogenic activities in long run. So a proper identification of current water quality and pollutant sources (if any) is crucial. As per the objectives defined in this project, development of a water quality index was the main assignment. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits (Tyagi *et al.*, 2013). Therefore, the suitability of water sources for human consumption has been described in terms of Water quality index (WQI), which is one of the most effective ways to describe the quality of water. The other objective was to study the feasibility of getting blue flag certification to the beaches selected. The Blue Flag Programme is a voluntary certification scheme for beaches and marinas, owned and run by the independent non-profit organization, the Foundation for Environmental Education (FEE) formerly known as FEEE – Foundation for Environmental Education in Europe. Since 1991 the organization has become international, now with member organizations from around the World. As of 2006 FEE has member organizations in 44 countries. Getting blue flag certification to Sri Lankan beaches will definitely increase the attraction of foreign tourists, thus an increase in foreign exchange.

Unawatuna, Mirissa and Polhena were selected for the project and 19 locations were selected (Unawatuna – 7, Mirissa – 6 and Polhena – 6) along the beaches. Although the monthly sampling was proposed, sampling was done in March, April, October, November and December. The sampling was negated in other months due to the Covid 19 outbreak and the Xpress Pearl ship burn incident, as all the resources have to be allocated for it.

Study has recommended continuing the development of water quality index for all the beaches in Sri Lanka, ultimately which will be useful to improve the marine water quality guideline for Sri Lanka. Additionally it is recommended to continue the studying of feasibility of getting blue flag certification to Sri Lankan beaches. In order to accomplish this aim, an extensive collaboration with other government and non-government agencies is needed.

Remarks

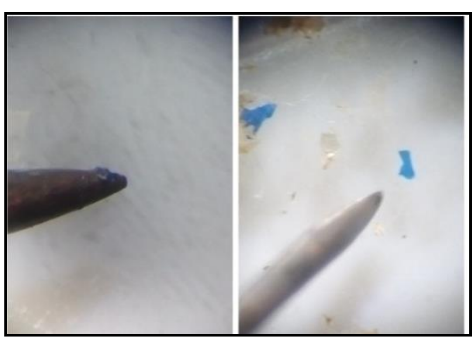
Heavy metal analysis was handed over to the Joint Research and Demonstration Center for Water Technology – Ministry of Water Supply and the results are being delayed with the pandemic situation. Once the heavy metals data are received, the water quality index will be determined.

5.2 Study on marine litter and microplastic abundance in the sediments, fish & other aquatic species in the coastal area of Sri Lanka

Description of the project

Marine litter is one of the major problems in the world in recently. Mostly these are containing macro and micro plastic. Plastics are man-made and non-biodegradable material. There are many plastics families in production including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC) and polyethylene terephthalate (PET) (Regoli, 2016). In Sri Lanka, a survey was conducted according to the ocean conservancy guideline and it has quantified the quantity of marine litter collected within the coastal zone (Mean High Water Line to 50m landward) of Sri Lanka as 103.38 kg/km in 2017. However plastic waste can be divided in two groups such as large plastics waste and small plastics particles below 5mm size named as microplastics. Marine litter is consisting all below 5mm litter as well as >5mm litter in the coastal area. This study is focused to evaluate micro-plastic abundance in the different flora/fauna species in the coastal areas and to assess the marine litter and micro-plastic contamination in the beach sediment.

Initially, study was focused to quantify and characterize the MPs in the edible dry seaweed Kappaphycus alvarezii collected from eight cultivated. Dry seaweed samples were collected in each sampling site during 17th September and 22nd of December 2020 in North and Northwest coasts of Sri Lanka. Seaweed samples were analyzed for tow size classes (300µm - 1mm and <300µm). Total of 24 seaweed samples were analyzed and found that mean (±SE) total MPs abundance is 0.247±0.022 items/g and abundance varied significantly among the study sites (One-way ANOVA $p<0.05$). Significantly high abundance of total MPs (0.3937±0.096 items/g) were reported in Pallikuda cultured site and significantly low abundance was observed in Vankalai (0.166±0.007 items/g) than other cultured sites. Composition Analysis of five types of shape categories in MPs revealed that studied seaweed cultured sites are dominated by fibers (69.93%) and sphere (0.34%) was the lowest shape of composition within the studied sites, Suggesting contamination of microplastics in dry seaweed and potential for accumulation from the seawater and beach through the cultured and dried processes.



Also, beach-seine fish samples were collected from western and southern coastal regions and it was recorded that, there are micro plastic abundance in the fish gut. Also, sand samples were collected from different beaches in the western province and it was noted that, there are high abundance of pellets in the beaches as following.

The present study was badly interrupted due to lockdown of the country and also inter provincial travel band due to Covid-19 pandemic. In addition, analysis of water and sediment samples capabilities were hinders due to malfunction of instrument.

5.3 Nutrient dynamics and agrochemical impacts to inland fish and aquatic resources in Walawe River Basin

Description of the project

Walawe River is the seven largest of the 103 river basins found in Sri Lanka. The Walawe River originates in the central highland of Sri Lanka and parts of the upper catchment fall within the wet zone of Sri Lanka with average annual rainfall of more than 3,000 mm. But, the largest part of the basin is in fact in the dry zone and finally end-up from Godawaya area in the Amabalanthota. Uplands are land-use pattern comprise with thinly populated with sub-montane wet evergreen forests, agricultural lands, grasslands, tea estates etc.

The main land use in the lower basin is irrigated agriculture with paddy cultivation, but irrigated area has non-rice field crops. There are several reservoirs connected with this river from upstream to downstream. This project aim is to identify the sources of point and non-point sources of pollutants (including agrochemical inputs) and to estimate pollutant load to coastal area.

Eighteen sampling locations were selected from upper catchment, middle catchment and lower catchment of the river basin based on the point sources pollution and non-point sources pollution. Water quality parameters were study in all sampling location and selected sampling locations were subjected to microbiological study. When consider the pH and dissolve oxygen (DO) in the river, mean pH was 6.33 ± 0.33 and DO was 6.90 ± 0.73 mg/l which is favorable for fish and aquatic life. The results reveal that, there are elevated level of turbidity was detected in lower catchment with over 600 NTU. In addition, dissolve phosphate was recorded slightly higher level when compare with previous studies. Also, aquatic invertebrate study shows that, most dominant species is Mayfly (Ephemeroptera). Microbiological study reveals that all sampling locations were positive with fecal coliform and E-coli. The highest fecal and E-coli content were recorded in Mau ara/Kiriebban Ara sampling location with more than 1800/100 ml.



The present study was interrupted due to lockdown of the country and also inter provincial travel band due to Covid-19 pandemic. In addition, analysis of water and sediment samples capabilities were hinders due to malfunction of instrument.

5.4 Study on current status of water pollution levels in Daduru Oya river basin in Sri Lanka basin for Environmental Pollution Assessment (Continuous Project)

Objectives:

To determine the levels of Physico - chemical parameters of water in the rainy and non-rainy periods.

To determine the concentrations of the heavy metals in water and edible muscle tissues of selected fish species.

To assess the toxicological impact from agrochemicals (pesticides) to aquatic resources.

To assess associations between contaminant load and health status of the selected fish in the Daduru oya

Description of the project

This study mainly aims to investigate the accumulation of certain heavy metals (lead, mercury, cadmium, and Arsenic) in edible muscle tissues of selected fish (*Oreochromis niloticus*) species relative to heavy metal concentration in water samples of Daduru Oya basin during the rainy season (Wet Season) and non-rainy season (Dry Season). This research study has been drawn from constructive research questions to check if the water quality of Daduru oya basin is favorable for the selected fish species (*Oreochromis niloticus*), the concentrations of the heavy metals and their possibility of bioaccumulation in selected fish species, if the heavy metal concentration is within the recommended levels and their presence in the muscle tissues of selected fish species.

Further, the major objectives of the study are to determine the levels of Physico-chemical parameters of water samples and whether those levels are favorable for selected fish species during both rainy and non-rainy seasons, to determine the concentrations of the heavy metals in water samples and edible muscle tissues of selected fish in the rainy and non-rainy periods, to assess the toxicological impact from agrochemicals to aquatic resources and to assess associations between contaminant load and health status of the selected fish in theDaduru Oya basin.

Initially, twelve sampling locations were chosen from upper catchment, middle catchment and lower catchment, representing the wider area of Northwestern province, starting from Kurunegala to river mouth in Chilaw. Sampling locations were selected on the basis of wastewater disposal points, irrigation channels, shrimp farm outlets and sewage discharge points. Sampling points in upper catchment includes Kurunegala, Mawathagama, Panagamuwa, Mahaliyawa, and Subhasinghapura. The middle catchment sampling points include Nikawaratiya, Rasnayakapura, Wilpotuwewa and Pallama. And the lower catchment sampling points include Bingiriya, Bangadeniya, and Chilaw.

Both in-situ and laboratory Physico-chemical parameters and heavy metal levels of water samples were analyzed according to the standard methods by American Public Health Association (APHA, 22nd Edition 2012). Fish samples were send to Institute of industrial technology (ITI) for the aforementioned heavy metal analysis.

5.5 Assessment of Environmental Pollution Impacts of coastal fishery at selected landing sites in Southern Province, Sri Lanka. Project

Objectives:

To study pollution impacts of abandoned or discarded fishing gears and fishing vessels, waste oil, solid waste and fish discards generated from coastal fishery activities to land and coastal water at selected landing sites in Southern Province

To provide recommendations for appropriate management of the above waste and to mitigate negative impacts to ensure the environmental sustainability

Coastal fishery is the major contributing sub-sector to the marine fisheries that contributed around 58% (242,580 MT) to the total marine fish production in 2019 (Fisheries Statistics 2020, Ministry of Fisheries). It is broadly defined as fishing activities taking place in the continental shelf and has diverse range of fish species and activities. Coastal habitats are critical for sustained fish production, maintenance of good water quality and provide rich bio-diversity reserves including coral reefs, seagrass beds and mangroves.

Most of the coastal fishing vessels land at fishery landing site and disposing their products into markets in a less formal structure. Although many studies have been conducted on harbor pollution, limited information is available on the pollution impact of coastal fisheries at landing sites. Therefore, this study was intended to conduct an environmental monitoring survey at major fishery landing sites in Southern province to study pollution impacts of coastal fishery activities to land and coastal water and provide recommendations to mitigate any negative impacts to ensure the environmental sustainability.

Thirteen (13) fishery landing sites which receive more than 30 motorized boats in Galle, Matara, and Tangalle fisheries districts in the Southern province were selected for the study. Methodology involved two questionnaire surveys for Fisheries inspectors and fisherman/boat owners/skippers at selected landing sites along with analysis of physiochemical parameters of coastal water. Nevertheless, a part of the study from May to September could not be carried out due to Covid 19 pandemic.

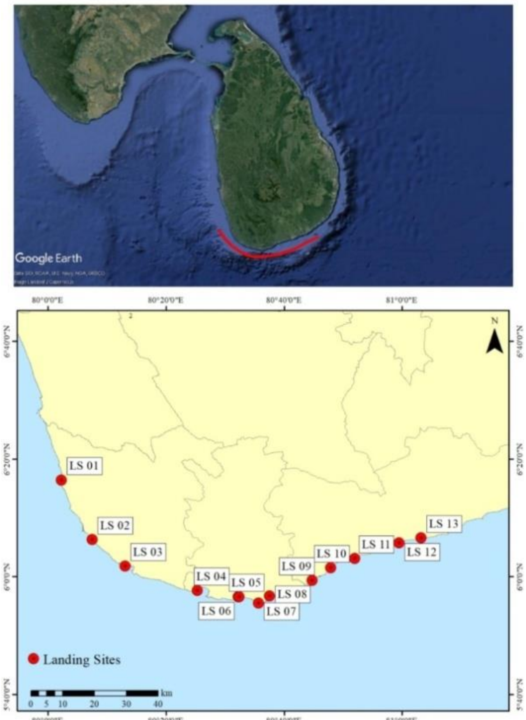


Figure: Location map of the landing sites selected for the study

Results of the questionnaire survey indicated that, Fishery landing sites were moderately polluted by plastic waste (bottles/cans), discarded fishing nets, abandoned fishing boats and fibreglass scrap. Discarded Fiberglass waste from boat repairing can harm the coastal marine life releasing toxins and micro plastics. Abandoned boats are a source of pollution (plastics, heavy metals, oil-related hydrocarbons) and represent a hazard to humans and wildlife (Turner and Rees, 2016). Increasing number of abandoned fiberglass fishing vessels in future may be problematic to coastal environmental health. Several infrastructure facilities for fishermen including electricity, drinking water, toilets and sanitary facilities, hall for net mending had not been developed or properly maintained in several landing sites surveyed. However, overall coastal water quality of the selected landing sites was favourable for fish and aquatic life.

Study has recommended providing separate waste disposal bins to collect different types of non-biodegradable waste (plastic bottles/cans, polythene, Rigifoam, glass) at landing sites. Environmental friendly alternatives should be proposed for discarded fishing gears/nets and abandoned fishing boats. Essential infrastructure facilities for fishery landing sites should be developed and maintained. Further studies should be carried to quantify the waste on fishery landing sites in order to measure their impact on the environment.

Figure: Abandoned fishing boats, discarded fishing nets and discarded fiber glass waste on landing sites

5.6 Identification of most appropriate freshwater fish species as a biological indicator for Environmental pollution assessment in Kelani river basin Sri Lanka

Objectives:

Discover the most suitable freshwater fish species that can serve as a bio-indicators in upper and lower catchment of Kelani river basin.

To elucidate the tolerance capacity of selected freshwater fish species on selected pollution pressures under laboratory conditions.

Description of the project

The Kelani River is the principle consumable water source for 80% (over 6 million) of the human population of the Colombo district (Surasinghe *et al*. 2020). Further, it is an important ecosystem complex for the freshwater fish biota of Sri Lanka. Therefore, it is important that the water quality parameters of the river be monitored regularly and effectively using accurate pollution predictability features of importance. Studies have revealed pollution evident in the Kelani river basin and its effects on quality of source water for drinking, ecosystem health, agricultural production and aesthetic value of landscapes. However, a methodical study assessing the water quality parameters targeting the lower and upper catchments separately and suitable freshwater fish bio-indicators for both catchment separately has not been conducted.

Further, the vector features/ parameters that can predict the pollution of the catchments more effectively have not been extracted. Therefore, the present study was conducted to assess the pollution of the lower and upper catchments of Kelani River and extract the important water quality features that predict the pollution of each catchment. The study intends to compare the pollution of the catchments with previous recordings, fish diversity and evaluate whether the trend of pollution in the river basin has accelerated, leveled out or decreased over the past few years with the findings of suitable fish bio-indicators.

This is a three-year research project consisted with two main phases and phase one consists of discovering the fish diversity, abundance and biology and some other bio indicatory characteristics of the fish species found along the lower and upper catchments of Kelani river basin. And, pollution assessment also was carried out in the same locations which were used to identify the fish species to compare with their diversity. Twenty-six sampling locations were selected for both upper and lower catchment including 13 locations from each catchment. Water samples were collected once in three months during year 2019, 2020 and 2021 from the 26 upper and lower catchment locations. The physical and chemical parameters of the collected water samples were analyzed using standard methods (APHA, 2012) with triplicates.

Considering the lower catchment, with the exception of location L8, Nawagamuwa, all the other selected locations of the lower catchment had at least one water quality parameter that was not within the permissible levels suitable for aquatic life. Waters near Mattakkuliya (L1), Kolonnawa (L4) and Kaduwela (L7) were the most polluted with regard to many parameters, and all three locations had high levels of phosphates. High phosphate concentrations in L1 and L7 can be attributed to urban and industrial wastes and that of L4 to fertilizers used in paddy cultivations and phosphates used in crude oils in the refinery industry. The total suspended solids (TSS) were also high in L1 and L4 and the waters of L7 had high levels of nitrogen in the form of nitrites and ammonia. The lower catchment of the river housed an important community of freshwater fishes consisting of 34 species of which the majorities were of family Cyprinidae. Three of these fishes, *Dawkinsia singhala*, *Pethia reval and Rasbora daniconius* were widely distributed in the river, irrespective of the polluted condition, and were more abundant in most locations with respect to the other fish species. The study revealed that these three species can be found in locations with poor water quality whereas species of genus Puntius are unable to tolerate unfavourable water quality conditions. *Dawkinsia singhala* was particularly tolerant to the nutrient fluctuations of the water, especially the ammonia and phosphate contents, while *Rasbora daniconius* and *Pethia reval* were unaffected by the changes in the physical parameters of the water. *Rasbora daniconius* was unaffected by turbidity fluctuations while *Pethia reval* displayed tolerance to pH changes. Thus the study revealed the possibility of using the presence and absence of individual fish species data to predict the quality of water.

The majority of the water quality parameters of the upper catchment of the Kelani River were within the permissible levels for drinking purposes and aquatic life. However, U2 Kotiyakumbura had high electrical conductivity values that were not suitable for drinking purposes, and U4 (Parussalla), U6 (Panakoora) and U8 (Kithulgala) had high COD levels. The Principal Component Analysis conducted for the selected locations of the upper catchment revealed nitrate concentration and chemical oxygen demand as the most suitable water quality parameters to predict the water quality of the upper catchment of the river. Therefore, the study reveals that the COD concentration can be used to predict the quality of water in the upper catchment. COD levels of the upper catchment are comparatively low when compared with that of the lower catchment.

Remarks

Due to the COVID 19 pandemic and MV X Press Pearl ship accident many of the project activities were delayed and field sampling also were cancelled.

5.7 Investigation of causes for emergency incidents such as oil spills algal blooms and fish kills (emergency studies)

Objectives:

To assess and monitor the emergency environmental incidents such as oil spills, chemical spills, algal blooms, fish kills etc and provide necessary recommendations to stakeholder agencies.

Description of the project

Environmental emergency incidents including sudden occurrence of fish kills, oil spills, pollution of water bodies with toxic substances, fish and turtle strandings, and algal blooms are very prevalent in the aquatic environments of Sri Lanka. These kinds of incidents were reported mostly with sensational media headlines and mass public protests. Their impacts can be inevitable and long lasting, and it is our utmost responsibility to prevent them from reoccurring and deal with them effectively when they occur.

NARA receives information regarding emergency incidents through different source of information such as public, media, and relevant authorities. NARA receives many requests from the public, different parties including government institutions to investigate and provide scientific reports based on the site inspection, field investigation, and laboratory analysis to reduce the negative impacts. Officers belong to other divisions of NARA such as IARAD, IPHT, MBRD and FTD also collaborate with ESD during the field investigations and reporting depending on relevancy.

These emergency studies are conducted to identify and investigate the major causes for environmental emergencies and provide recommendation in the form of report, media release, and executive summaries to the relevant authorities. Total of nine emergency studies were carried out throughout the year, 2021 and the most significant emergency project carried out by the ESD is the “Damage assessment studies conducted in relation to MV X press pearl maritime disaster”.

ESD official, together with other technical divisions of NARA is actively engaged in assessing the environmental impacts of this maritime disaster and monitoring the environmental aspects for post impacts since May 2021. Environmental Studies Division (ESD) had formed 3 separate research teams to investigate the environmental issues related to emergency fire incident occurred at MV X press pearl container ship. The research teams and conducting surveys in the coastal area from Kalutara to Kalpitiya and collect water and sediment samples to determine the changes in coastal water quality. In addition, coastal area from Galle to Kalpitiya is being survey for the plastic contamination and plastic pellet samples are being collected for further analysis in the laboratory. Sediment core samples are also being collected from the selected locations of the coastal area to observe the soil profile and impacts on it and temperature changes of the sediments. Separate assessments are carries out in the Negombo lagoon and water and plankton samples are collected to determine the water quality of the lagoon and impacts on it. Short-term monitoring plan was implemented to assess the immediate impacts on the marine environmental and its resources and medium term damage assessment studies are currently being conducted.

The summary of each incident is provided in the below mentioned table.

No	Date of Investigation	Incident	Causes of the emergency situation	Output
1	22nd February 2021	Colour change of Lunawa Lagoon water	Water colour change might have occurred due to the *Microcystis aeruginosa* and *Spirulina spp* as they were reported in high density in the water samples.	Field investigation was done and the report with recommendations was submitted to Central Environment Authority
2	March 2021	Fish Kill at Water's edge	Cause of the situation was not identified and continuous monitoring was recommended.	Field investigation was done and the report was submitted to relevant authority
3	3rd April 2021	Black color solid patches found along the Galle Face Beach	Causes of the situation was not found. It was suspected to be oil patches	Field investigation was done and the report with recommendations was submitted to relevant authority
4	16th April 2021	Fish Kill and color change in waters of Diyawanna Lake/ Parliament area	Dumping of waste water after the clean-up of inbuilt pond od Parliament complex (continuous monitoring was needed to identify the source of pollution)	Field investigation was done and the report with recommendations was submitted to relevant authority
5	April 2021	Colour change of sea-water Kankesanthurai	Cause of the situation was found to be algal bloom due, specific identification could not be done due to delay in sample collection	Sample analysis was done and a news report was submitted to Oruwalla magazine on behalf of NARA.
6	23rd May 2021	Emergency situation of fire and Oil spill happened due to X-Press Pearl Ship fire incident	Ship fire and oil spill	Information and initial reports were submitted to the Marine Environment Protection Authority (MEPA) for assessing the economic cost due to environmental damage for necessary legal actions. Further, research and laboratory analysis are ongoing with the collaboration of all the divisions of NARA
7	July 2021	Oil leak incident in Hambantota	Oil leakage from a ship at the harbour	Field investigation and laboratory analysis were done and the final report was

		commercial harbour		submitted to Hambantota Police Station.
8	September 2021	Fish kill in Kurunegala tank (Ranthali wewa)	The reason for fish kill could be due to the increased density of *Microcystis aeruginosa* found in the water samples that produces neurotoxins and hepatotoxins.	As per request from the state ministry of fisheries, field investigation and laboratory analysis were done by ESD and IARAD and the final report was submitted to the state ministry and other relevant authorities.
9	12th October 2021	Shrimp mortality incident near Amaluana Resort, Kapungoda, Negombo	The shrimp mortality might have occurred due to waste discharge done from the close proximity.	Filed investigation, laboratory analysis were done by both ESD and IARAD and the final report was submitted to the director general of department of fisheries.

5.8 Assessment of Water Pollution Status of Selected Fishery Harbours in the Southern Province of Sri Lanka

A fishery harbour is a complex center of activities which are potential waste generators and thus considered as coastal pollution hotspots. Discharge of burned oil and bilge water from fishing vessels to harbor waters, production of load of organic wastes which derived from fish degutting, market floor runoff, cleaning and garbage dumping are main causes for the water pollution in fishery harbours (Holmgren, 1994). In addition, improper dumping of fish offal and other garbage into harbour waters, dumping of untreated sewage from toilets and defecation inside the harbour premises are the other pollution sources in a fishery harbor. The use of contaminated water for fish may cause for the post-harvest losses due to spoilage from bacteria and chemical reactions. Therefore, to improve the water safety and quality of a fishery harbour, its pollution level should be thoroughly assessed. Therefore, objectives of the research are to determine the current status of water quality in five selected fishery harbours and collect information on the present status of anthropogenic activities which pollute the harbour.

The study was carried out in five selected harbours from 2020 to 2021 and physical, chemical and biological parameters of water quality of harbours were measured. In-situ parameters such as water temperature, pH, salinity, electrical conductivity, dissolved oxygen, turbidity were measured. Ammonia, Ortho-phosphorus, Nitrate and Nitrite concentrations (ppm), Total suspended solids, Biochemical Oxygen Demand (BOD), chemical Oxygen Demand (COD), coliform content and plankton diversity were the tests carried out in the laboratory. All the tests were performed according to the standard methods for Water and Waste Water Analysis given by American Public Health Association (APHA, 2012). All the input canals were identified. Social survey was conducted to assess about solid waste within the harbor premises.

According to our studies we found that the water quality of the harbours has been degraded and they are subjected to severe oil pollution, organic pollution and microbial contamination in terms of fecal contamination. When compare with other harbours, higher level of turbidity and oil & grease concentration were recorded in Galle harbour with 19.94 NTU and Kudawella harbour with 76 mg/l respectively. Higher level of turbidity levels was recorded in the Galle and Beruwala harbours due to major stream opening to harbour basin. Also, higher chemical oxygen demand was recorded in Galle harbour. Microbiological study reveal that all the harbours were positive with fecal coliform and E-coli. The highest fecal and E-coli content were recorded in Galle harbour with more than 1800/100 ml. In addition, analysis of plankton reveals that, *Tropidoneis* sp and *Protoperidium* sp. are the most abundance plankton species among all harbours. Based on the sample analysis, and questionnaire survey, it was reveal that, discharge of burned oil and bilge water from fishing vessels, production of load of organic wastes derived from fish degutting, market floor runoff, cleaning and garbage dumping, accidental oil spillage during refueling, solid waste derived from boat repairing, untreated sewage from toilets and defecation inside the harbour premises were the identified main sources and activities which increase the pollution in the harbor. In the same way PET bottles and polysac bags become severe threaten in some harbours specially Kudawella. Abundant and broken boats can be seen in every harbor and it may cause to severe problem as the fiber is non-degradable. Some field visits cancelled and also some analysis not yet completed due to COVID 19 pandemic situation.

Sustainable Development Goal (SDG) 14 is exclusively dedicated to “conserve and sustainably use the oceans, seas and marine resources for sustainable development. Directly relates to SDG target 14.1 and 14.2 as the data and information gathered during this study helps to reduce marine pollution particularly from land-based activities.

The present study was badly interrupted due to lockdown of the country and also inter provincial travel banned due to Covid-19 pandemic. In addition, analysis of water and sediment samples capabilities were hindering due to malfunction of instrument.

6 Socio Economics and Marketing Division

6.1 Assessment of socioeconomic adaptations taken by fishers on climate change scenarios

Project Leader: KHML Amaralal Officer/s responsible, KPGL. Sadaruwan and MMAS. Maheepala

Introduction

The marine capture fishery contributes 85% to the total fish production of the country (MFARD, 2018). The fishers and coastal inhabitants need to bear forces of climate change scenarios and impacts that threatened their livelihoods, changes in food security and health and physical assets. Fisher communities live in precarious and vulnerable existence due to poverty, lack of social services, and essential infrastructure. The fragility of these communities further intensify by lower productivity of resources and ecosystems due to climate change scenarios. These situation further triggered with knowledge gap to understand the vulnerability of fishing communities to climate change across the country. The lack of knowledge is a big problem to prepare a sound policy framework to improve the resilience and adaptation of fishing communities to face climate change.

Main objective

This research focuses to assess the vulnerability of the fishing community for climate changes and understand possible adaptation strategies to mitigate the negative impact of climate change.

Methodology

The stratified random sampling technique used to collect primary data from fishermen in coastal fisheries in Trincomalee, Baticloa, Jaffna, Puttlam, Galle, Matara, Negambo and Hambanthota districts. The population frames of registered boats prepared for each district and the 100 of boats were selected randomly to the study. Eight focus group discussions, one each, were conducted for fishers in eight districts. Twelve in-depth interviews were conducted for government officials, scholars who work related to climate change and community leaders. Data were collected during the time period of January to November 2021.

Activities proposed to be completed during the period

The research proposed to complete 100 questionnaires for fishers and 8 focus group discussions for officials and key informants. The targets were achieved successfully.

Result and discussions

The highest percentage of fishermen had first-hand experienced on coastal erosion and sea level inclined (86%). There were 43% of fishermen who suffered from seawater intrusion. The fishermen who lived near the lagoon mentioned that lagoon siltation was one of the major problems for navigational and fishing operations of the lagoon. 55% of the fishermen observed that lagoon siltation rate has risen in the recent past. As vulnerability index and wellbeing index were measured on categorical variables a Chi-square was performed to identify association and correlation between vulnerability and wellbeing. The results depicted that, there was a reciprocal significant relationship existed between vulnerability and wellbeing (person correlation coefficient was -.634 at P=0.000). It means that well-being of fishermen who lived in climate hazard high areas was lower than the well-being of fishermen who lived climate hazards relatively low areas. The vulnerability index found that Jaffna and islands near Jaffna are the highly vulnerable area to the climate change scenarios. Jaffna district has faced cyclones, coastal erosion, and saltwater intrusion than other districts. Puttlam district experienced high level of lagoon siltation and sea-level rise. Galle had faced with flood, lightning and thundering threat than other districts. Hambanthota and Negombo had experienced low level of climate change vulnerability than other districts. The highest annual per-capita lost Rs. 48,356.00 incurred with Jaffna fisher while the lowest with Negambo (Rs. 25,436.00). The country average value of the damage per fisherman was Rs 34,498.00.

Conclusion

The majority of the fishermen suffered from climate change-related environmental hazardous. The well-being of highly vulnerable fishing communities was significantly lower than lesser vulnerable fishing communities. There were smaller number of fishermen aware of climate change and the consequences of climate change scenarios on their economic activities and livelihoods. They have been implementing reactive measures to minimize damages of hazardous but not proactive measures to minimize the damages of hazardous.

Recommendation

It is recommended that identification of gaps in regulations and policies related to the climate change and adaptation, strengthening of coordination among governmental, non-governmental organizations and research institutions for collection, analysis, and sharing of climate change-related information to the public. Reformulate policies to tackle the harmful damages of vulnerable communities to climate change scenarios.

Constraints

Difficulties in data collection phase due to COVID19 pandemic of the country

11.) Financial Allocation (Rs) 500,000.00 (according to revised budget)
12.) Financial progress (%) 100%
13.) Physical Progress (%) 100%

6.2 Value Chain Analysis of Export Oriented Marine Fin Fish in Sri Lanka

Project Leader: KHML Amaralal, Officers responsible - N. Abeykoon and T.N.Thilakaratne

Introduction

The marine fin-fish fisheries in Sri Lanka have emerged as an export-oriented sub-sector contributing in foreign exchange earnings in recent past. Among Fin – fish varieties, tuna species mainly yellow fin, big eye and skipjack are fetched a higher value and demand in international markets. The policy statement of the Ministry of fisheries has highlighted the importance of conducting a research on export oriented fin-fish under the value chain concept for the sustainable development of the sub-sector. Through the value chain concept, the study tries to find out key players and their roles, issues, opportunities and governance structures for policy analysis.

Main objective

The main objective of this study is to evaluate the export oriented marine fin fish fisheries value chain in Sri Lanka under the concept of value chain development. To fulfil it the following specific objectives were developed.

1) To identify and assess the value chain players in export oriented marine Fin-fish in Sri Lanka.

2) To identify the issues in export oriented marine Fin-fish fisheries and calculate the corresponding costs and earnings of those activities, and evaluate the performance of the value chain players.

Methodology

The study was a questionnaire survey and data were collected through direct interviews with randomly selected boat owners/skippers, fish agents/wholesalers & processors/export companies in Negombo, Dikkovita, Beruwala and Nilwella. The total sample was 60, comprised of 40 boat owners/ skippers, 15 middlemen and 5 exporters. In addition two focus group discussions, one for owners/skippers and the other for middlemen were conducted. 2 in-depth interviews for fish processors and exporters were also conducted. Data were collected during the time period of Feb to October in 2021.

Activities proposed to be completed during the period

Initially planned to collect data from 120 samples but due to the Covid-19 pandemic sample number was reduced to 60. The revised target was successfully achieved at the end of the year 2021.

Result and discussions

The value chain comprised of fishers, fish assembler or argent at the landing site and exporter cum processer. Local consumers buy fish from the retail traders/ supermarkets and restaurants. Tuna, Sward fish and Marlin were main varieties exported. The present study found that 25% of fishermen paid a 3% or 5% commission to assembler in their marketing process. Only 10% of skippers/owners were aware of export market and its dynamics. 53.3% of middlemen were part-timers who engaged in fisheries as well while the rest were full-timers. High input cost, price volatility, weak bargaining power, lack of skilled labour, imperial quality of fish, lack of equipment and insufficient supply of fish were major constraints faced by players.

Conclusion

Boat owners, middlemen and exporters were the key value chain players in fin fish value chain of Sri Lanka. An array of constraints hinders the activities of value chain actors that need to be given concern. The sector has full potential to further develop and therefore need necessary actions to overcome the constraints faced by the value chain players.

Recommendations

It is recommended that government intervention in regulating fish prices among all players in the value chain and financial support through formal institutions. Providing of trainings to improve skills in processing and value addition, in modern high tech equipment are also recommended to the sustainability of the value chain of export oriented fin fish fisheries in Sri Lanka.

Constraints

Covid 19 pandemic situation affected some of field trips planned

Financial Allocation (Rs) 675,000.00 (revised budget)

Financial progress - 99%

Physical Progress - 100%

6.3 Assessment of Socio-economic status and Benefit - cost of farming systems of Penaeus monodon and *Litopenaeus vannamei* in Sri Lanka

Project Leader: KHML Amaralal, Officer/s responsible-W.A.A.M.Bandara and K.P.G.L. Sandaruwan

Introduction

Growing interest towards sustainable shrimp farming needs to find out influential internal and external driving forces for higher productivity of culture systems. India and Thailand have proved 2 to 4 time higher productivity of Vannamei than Monodon. Further, previous studies found that Vannamei is high in resistance for white-spot disease than Monodon but high effluent accumulation that require strict biosecurity measures and lowering the growth rate after 20g of weight. Although most of the researchers have looked into the biological and environmental aspects of *Penaeus monodon* and *Litopenaeus vannamei* farming systems, while little attention has been paid on socioeconomic aspect. An investigation of socioeconomic parameters with benefit-cost analysis would be beneficial for the sustainable development of shrimp farming systems in Sri Lanka.

Specific Objectives

1. To assess the socio-economic parameters and feasibility of farming systems of *Penaeus monodon* and *Litopenaeus vannamei*.
2. To undertake benefit-cost analysis of *Penaeus monodon* and *Litopenaeus vannamei* farming systems.

Methodology

The purposive sampling technique was used to collect primary data from shrimp farms which are located in, Chilaw within the Puttalam district in North-Western province in Sri Lanka and data were collected from Jan to Oct 2021. Economic analysis was done and a database was created after eliciting the data through 45 questionnaire-based interviews and 3 focus group discussions. The assessment was done and test the economic viability of two shrimp farming systems.

Activities proposed to be completed during the period:

1. Develop a questionnaire and conduct a preliminary study
2. Collect data via questionnaire-based survey for a sample of 45 shrimp farmers
3. Conduct in-depth interviews and 3 focus group discussions
4. Data tabulation and analysis
5. Asses economic viability of two shrimp farming systems
6. Conduct awareness programs and development activities

Results and Discussion

All most all shrimp farmers were male and the majority (42%) belonged to 40-49 age category. Fifty six percent of farmers had more than 10 years of experience while 87% had ordinary level education but only 9% of them had received training skills on shrimp farming. Economic analysis revealed that for one hectare of land with one acre of a pond in type C farms recorded 4.47% higher initial investment in vannamei than monodon. This is basically due to higher requirement of equipment such as paddle wheels. The operational cost of production per year was higher 5720357 for vannmei than Rs 5475357 for monodon. Net present Value (NPV) used to assess the profitability of each investment by calculating the present value of a future stream of cash flow generated through two framing systems. Net Present Value (NPV) at the end 10 years was found to be 2 times higher for monodon than vannamei for the total capital invested. Higher NPV of mondon reflects it is financially worthwhile and attractive investment. Internal Rate of Return (IRR) for mondon is 23% which was higher than vannamei of 16%. The higher IRR for monodon indicated that investment is attractive and profitable. The payback period for the total capital investment were approximately 3 years for monodon while it was 4 years for vannamei. Shorter the payback period fewer years required to recover the amount of the initial investment from the net cash. Benefit-Cost Ratio (BCR) is an investment summarize the overall value for money of an investment. Results of the cost benefit analysis depicts that BCR was greater than 1.0 for both farming systems which delivered a positive net present value to both monodon and vannamei shrimp growers.

.

Table 1.2: Cost structure and economic indicators for one culture cycle

	Monodon	**Vannamei**
Total Capital Cost	5475357	5720357
Operation cost	4444856.3	5355405.7
Overhead / Administration	4100	4100
Depreciation Cost		
Building	4%	4%
Equipment	10%	10%
Other	20%	20%
NPV	3176402	1465445
Pay Back	3.6	4.6
Discounted Payback Period	4.8	7.4
IRR	23.25%	16.13%
Benefit Cost Ratio	1.1	1.0

Conclusions

Shrimp farming is a male-dominated industry where women are not directly involved in farming activities. The cost of initial investment vary depending on value of farm site where vannamei recorded highest initial investment all thetime. Operating a 1-ha shrimp farm with 1 acre of pond (type C farm) area gives positive net present values for both farming systems revealed that the value of revenues or cash inflows are greater than cash outflows, which conclude both monodon and vannamei systems are profitable. Further, comparing two farming system, due to the higher NPV value, IRR and relatively short pay-back period indicated that invest in monodon farming is highly profitable than vannamei. Moreover, shrimp farming is most sensitive to changes in the sales price and monodon recorded comparatively higher selling price than vannamei due to higher demand. Shrimp farming in Sri Lanka is facing few key challenges such as disease outbreaks, limitation of resources and increasing production costs. Farming specific pathogen free (SPF) strains of white shrimp (Litopenaeus vannamei), with higher disease resistant and higher growth rate would overcome the risk and uncertaninty of cash flow. But, at the same time involves high inititail cost comaire to monodon farming. Further, unless following appropriate hygienic practices Vannamei is also susceptible to white spot disease. Therefore, high quality pond management and maintaining ambient environment for acceptable ranges through adopting the best management practices (BMP) ensure the economic sustainability of both farming systems and sustainable development of shrimp industry in Sri Lanka.

Recommendations

It is recommended that farming of *P monodon* need to be popularize using SPF monodon due to economic feasibility along with *L vannamei.*

Constraints

As lock down of country after 17th March 2020 all the field works had to stop. When the country re-opened in June there wasn't enough time to complete the project within expected timeline. So had to extend the project timeline till October. Industry was undergo significant frequent changes (ban the culturing of wild monodon) during the project life-cycle, affect the consistency of collected data.

Financial Allocation (Rs): 300,000.00 (revised budget)

Financial progress (%): 99%

Physical Progress (%): 100%

7 National Institute of Oceanography and Marine Sciences

7.1 Potential fishing ground forecasting

Potential fishing ground forecasting (Tuna Fishing Ground Advisory and Fisheries Information Service)

Officer/s responsible

H.B.U.G.M. Wimalasiri (January – July 2021), S.S. Gunasekara (July – December 2021)

Introduction

The potential fishing zone forecasting is an application of satellite remote sensing data, in turn, calculates the physical properties of seawater used to forecast the fish abundance areas. Fishery forecasting involves understanding the oceanic processes and interactions ofphysical, biological, and chemical parameters. Remote sensing data can provide a significant part of the information needed to assess and improve the potential fishing grounds and assist judicious exploration, conservation and management of marine resources. Timely forecasting of potential fishing grounds information can help an optimizing the scheduling of fishing operations. Fish tend to aggregate in ocean areas that exhibit conditions favoured by specific fish species. Relevant oceanographic conditions, such as sea surface temperature, ocean colour (productivity), upwelling, thermal fronts gyres and eddies favouring the fish school, can be monitored and measured by remote sensing sensors. Development of fishing ground forecasting system for offshore tuna fishery in Sri Lanka was started in 2007 and implemented in 2008 on an experimental basis.Since 2016, the fishing ground forecast provided three times a week.

Main objective

To enhance the economic and time efficiency of offshore/high seas fishery by providing information on potential tuna fishing ground advisory to multi-day fishing vessels

Specific Objective/s

To provide potential fishing zone advisories for tuna multi-day fishing vessels of Sri Lanka

Methodology

Sea surface temperature, sea surface height and sea surface chlorophyll data obtained fromsatellite remote sensing, fisheries catch information, and global ocean physical models areused to obtain preferable areas for yellowfin tuna (Figure1). This information is disseminated to fishers via email, fax and telephone. Fishers are expected to use advisoriesto improve their fishing operation.

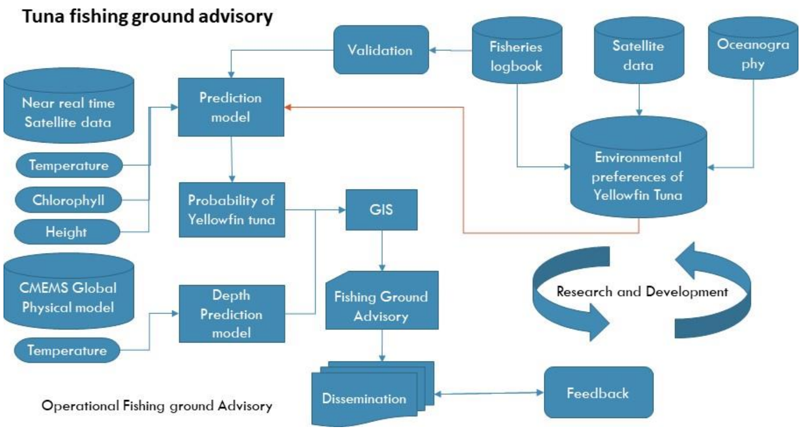


Figure.1 Flowchart of the Methodology

Activities proposed to be completed during the period

Generating fishing ground advisory maps

Fishery data collection: VMS data fisheries data

In-situ data collection (TDR)

Model development

Validation of results

Disseminate information by telephone, fax, radio, email and web to the users

Awareness programs for fishermen, vessel owners and other stakeholders

Results:

Activities carried out:

Timely forecasting of potential fishing grounds information can help an optimizing the scheduling of fishing operations. Even under COVID-19 restrictions, technical failures, limited research staff, 132 fishing ground advisories (target 144) were produced three timesa week and disseminated to high sea fishermen via email, telephone and WhatsApp.

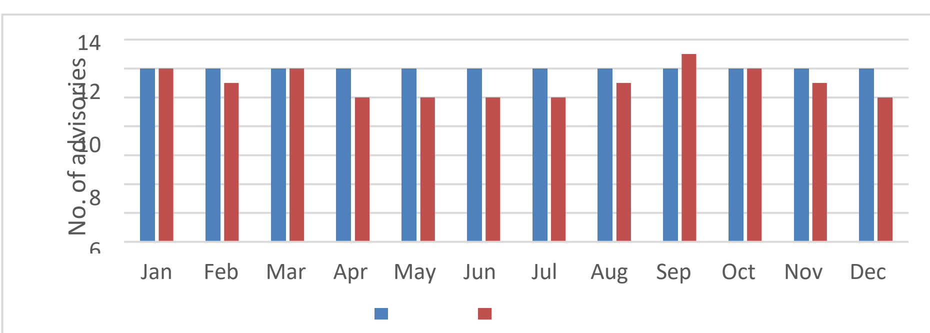


Figure 1: Fishing ground advisories issued in 2021

Awareness of Skippers and owners of multi-day fishing boats about potential fishing ground forecasts of Nara will be a crucial factor in the project's success. Therefore, awareness programs should conduct frequently. Awareness programs and fisheries data collection were conducted in Dikowita, Beruwala, Ambalangoda, Hikkaduwa, Galle, Mirissa, Devinuwara, Suduwella, Nilwella, Kudawella and Tangalle fisheries harbours.

The number of email subscribers has been increased up to 350. Fishing ground advisorieswere started to disseminate via WhatsApp, and 220 longline vessel owners and DFAR officers have received the advisories. Projects Facebook page (www.facebook.com/tuna.forecast) and Department of fisheries registered skippers Facebook group (ධීවරදෙපාර්තමේන්තුවේලියාපදිංචිනියමුඑකතුව, https://www.facebook.com/groups/1007014279736528) were used to disseminate advisories effectively. Emails of all multi-day vessel owners (about 1800) were collected

from DFAR, and an online questionnaire survey was conducted. Eighty-two vessel ownersresponded to the survey.

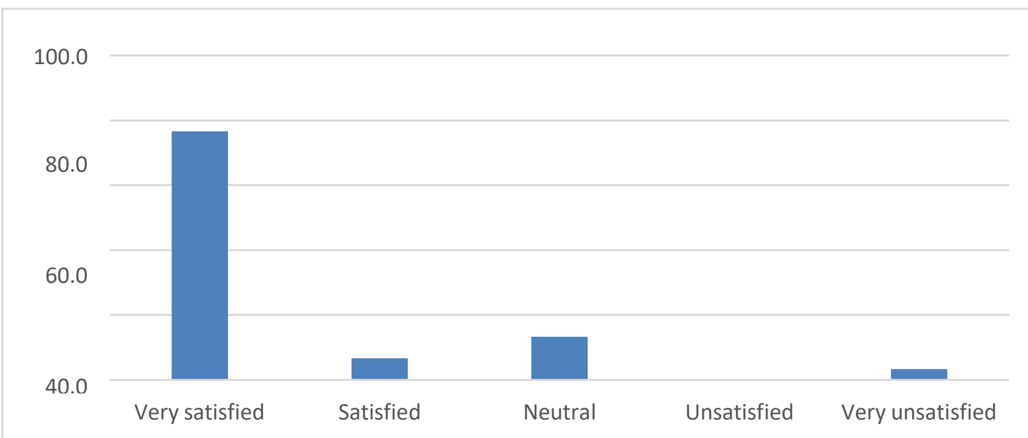


Figure 2: Existing users satisfaction (30 responses) based on the online questioner survey

Remote sensing and fisheries logbook data analysis has been continued with limited resources but unable to launch the improved prediction model as planned for the 4th quarterof the year.

Awareness programs and fisheries data collection were conducted in Dikowita, Beruwala, Ambalangoda, Hikkaduwa, Galle, Mirissa, Devinuwara, Suduwella, Nilwella, Kudawella and Tangalle fisheries harbours. Several awareness programs were cancelled due to the prevailing COVID-19 situation.

Awareness materials (Leaflets and banners) were designed, and 4000 leaflets were printedwith funds from the Ministry of fisheries development project 01: Software for fishing ground (V5139). SSB radio was reinstalled to establish direct communication with multi-day vessels. In-situ data collection using temperature-depth recorders (TDR) was unable to conduct. However, TDR sensors were able to procure with funds from the Ministry of fisheries development project 01 in December 2021.

Outputs & outcomesOutputs

Improved the predictability of potential fishing grounds

The model was updated for the latest satellite and oceanographic modal datasources

Increasing the number of recipients

the number of email recipients were increased upto 350

WhatsApp 220 recipients

Facebook page and groups

Increase the awareness on the usage of fishing ground advisoriesOutcome

Improve the efficiency of tuna multi-day fishery of Sri Lanka

Conclusions

Even under COVID-19 restrictions, technical failures, limited research staff, 132 fishing ground advisories (target 144) were produced three times a week and disseminated to highsea fishermen via email, telephone and WhatsApp.

Recommendations

It is crucial to allocate the necessary staff and support of supporting divisions to achieve the targets.

Constraints

Two scientists were allocated for the project have been left Nara, and no replacements weredone. The forecasting model was planned for a significant upgrade during Q4 of 2021, andwas unable to complete the activity due to the unavailability of required staff.

Validating the forecast with logbook data was planned for the 1st quarter but did not be completed due to lack of competence.

Hardware failures of satellites and data delays caused interruption of the advisories. Therefore, the development of methods to get alternative satellite data is recommended.

Extreme delays of supporting divisions hinder the project activities.E.g.Internet package was requested to update on 17/09/2021, chairman’s authorisation was received on 22/09/2021, but the package was changed on 28/12/2021. Even funds were available, purchases were not made due to delays.

Financial Allocation (Rs) 0.6 million, 0.39 after budget revisionFinancial progress (%)

Physical Progress (%)92

Climate change impact on ocean environment

7.2 Geological and Geophysical investigation in Continental shelf of Southwestern and Eastern coast of Sri Lanka

Geological and geophysical investigations in continental shelf of Southwestern andEastern coast of Sri Lanka

Officer/s responsible

T.B.D.T Samaranayake , H.A.S.D Perera

Introduction

Sand is considered as one of the main raw material in construction industry. Despite it is used as a filling material in land reclamation and beach nourishment projects. However, due to rapid development in construction industry since 2009 the demand for the construction materials including sand has grown up enormously resulting shortage of the supply. More on,development projects such as Port City project and beach nourishment projects further increase the demand for sand. The crisis led to illicit sand mining in majorriver banks which arise many environmental issues. Therefore there is an urgent need for an alternative for river sand. Offshore sand consider as a promising alternative for river sand (Ratnayake and Chaminda,2014).

Further, Sri Lanka exploiting mineral sand from Pulmuddai since 1956 and as the replenishment rate is lower than the extraction rate it is better to prospect additional mineralsand reserves to strengthen the export economy.

The project aimed to study two sites of Southwestern and Eastern coastal stretches for construction sand and mineral sand. The two sites were selected based on comprehensive literature survey. Besides the resource survey, side scan sonar survey was done for get better image on the sea floor which will be important for the extraction phase.

Since the extraction process in deep ocean is not economically feasible, this study intendedto study the construction sand and mineral sand reserves in the continental shelf of selectedlocations .

Main objective

To identify offshore sand reserve to be utilized for construction industry as an alternative for river sand

Specific Objective/s

To prospect the Mineral sand reserve in selected sitesTo study the offshore -surface geology of the area

Methodology (Study area, Field sampling, data collection and analysis)

The study of consisted of three major components; Sedimentological study, Sub bottom profiling survey and Side scan profiling survey. The data and sample collection planned in following monthsbased on the monsoon and the availability of the R/V Samuddrika .

Survey in Southwestern coast: During February – March (One visit during the season)Survey in Eastern coast: During May –September (One visit during the season)

Sediment Sampling

Fifty samples were collected from pre -determined locations, using the Van-Veen grab sampler

Sub bottom profiling

The sub bottom profiler “Innomar SES-2000” Sediment parametric echo sounder was used to differentiate strataand data was used to measure the layer thickness and sand volume in the proposed sites.

Side scan survey

The Side scan profiler was used to identify geological features to get better image of the sea floor which will be important in extraction of sand.

Sample and data analysis

Laboratory analysis for sediment samples

Sieve analysis

Granulometric analysis was done to study the sand size distribution in the area.

Chloride content and shell content

Chloride and shell content directly affects to the reinforcement of the concrete as they react with several chemical compounds. Therefore it is crucial to study them before recommending dredged sand as an alternative to river sand.

Standard laboratory procedures were employed.

Heavy mineral content

Heavy minerals was concentrated by employing gravity method and the concentratewas observed under microscope and the approximate abundance will be calculated.

Data analysis

ISE 1.2 software andSonarWiz software were employed to process sub bottom and side scan survey data respectively.

Activities proposed to be completed during the period

Literature survey

Field works for sample and data collection (For both sites)Grab samples

Sub bottom surveySide scan survey

Laboratory sample analysis

Data processing for side scan and sub bottom surveyData analysis and map preparation

Report writing

Results: Activities carried out:

Literature survey was carried out through -out the year and was completed as proposed. Though the field works planned to be done using the research vessel Samuddrika some ofthe planned activities such as sub bottom survey could not be done due to technicalproblems. Therefore, the survey re- scheduled to conduct using fishery boats.

Two sites from southwestern and Eastern offshore area (Weligama and Trincomalee) wereselected and following activities were conducted (Table 01). Apart from the selected sitesanother two sites of off-southwestern coast were studied. The site at off-Galle was studiedfor sub bottom survey and side scan survey as they were could not be completed during thelast year (2020) due to Covid pandemic. The site Dodandoowa was studied for grain size as an extra work.

However, could not complete the activities as proposed due to Covid pandemic and unfavorable weather conditions.

Table 01 : Activities carried out

Activity	Progress			
	Weligama	Trinco	Galle	Dodandoowa
Grab samples	Completed	Completed	Completed (2020)	Completed
Sub bottom survey	Completed	Unfinished	Completed	Unfinished
Side scan survey	Unfinished	Unfinished	Completed	Unfinished
Sample analysis	Completed	Completed	Completed (2020)	Completed
Data Processing	Completed	NA	Completed	NA

Data analysis	Complete d	Complete d	Completed	Completed

Outputs & outcomes

a. Grab samples

Grain size and distribution characterization

All the parameters related to grain size were calculated based on Falk and Ward (1957) classifications.

Weligama

Total of 25 samples, the mean grain size of the samples varied from 0.09 to 0.95 mm whilethe D50 of the samples varied from 0.09 to 0.92 mm. Both the mean grain size and the D50of the samples were in the recommended range defined by engineering standards. All the samples are in the range of poorly to moderately sorted range(Figure 01 (a).

Dodandoowa

The mean grain size varied from 0.07 to 0.79mm. However, the majority of the samples contain very fine to silt grains and hence the sand in surveyed area cannot be used as construction sands. Further, the samples collected from the northern part of the surveyed area fully consisted of coral and shell debrisFigure 01 (b).

Trincomalee

This area surveyed to prospect mineral sand. The mean grain size varied from 0.1 to 1.5 mm. Majority of the collected sand samples consisted of coral and shell debris. Though 23% mineral percentage found from samples it is not a considerable value and the depositis not continuous Figure 01 (c) .

Shell and coral percentage

The shell and coral percentage for the size (mm)>10 was less than 5% at both Weligamaand Dodandoowa sites . The coral and shell percentage for the size 5mm to 12mm is around10% at Weligama ,which is at the standard limits while the same is higher than the standards at Dodandoowa.

Chloride percentage

The chloride percentage was 2.8 %, 2.6% by the weight of the sand at Weligama and Dodandoowa area respectively while the recommended range is 0.075%(Dias et al.,2008).However, appropriate remedies such as piling up and artificial washing could reducethe chloride content.

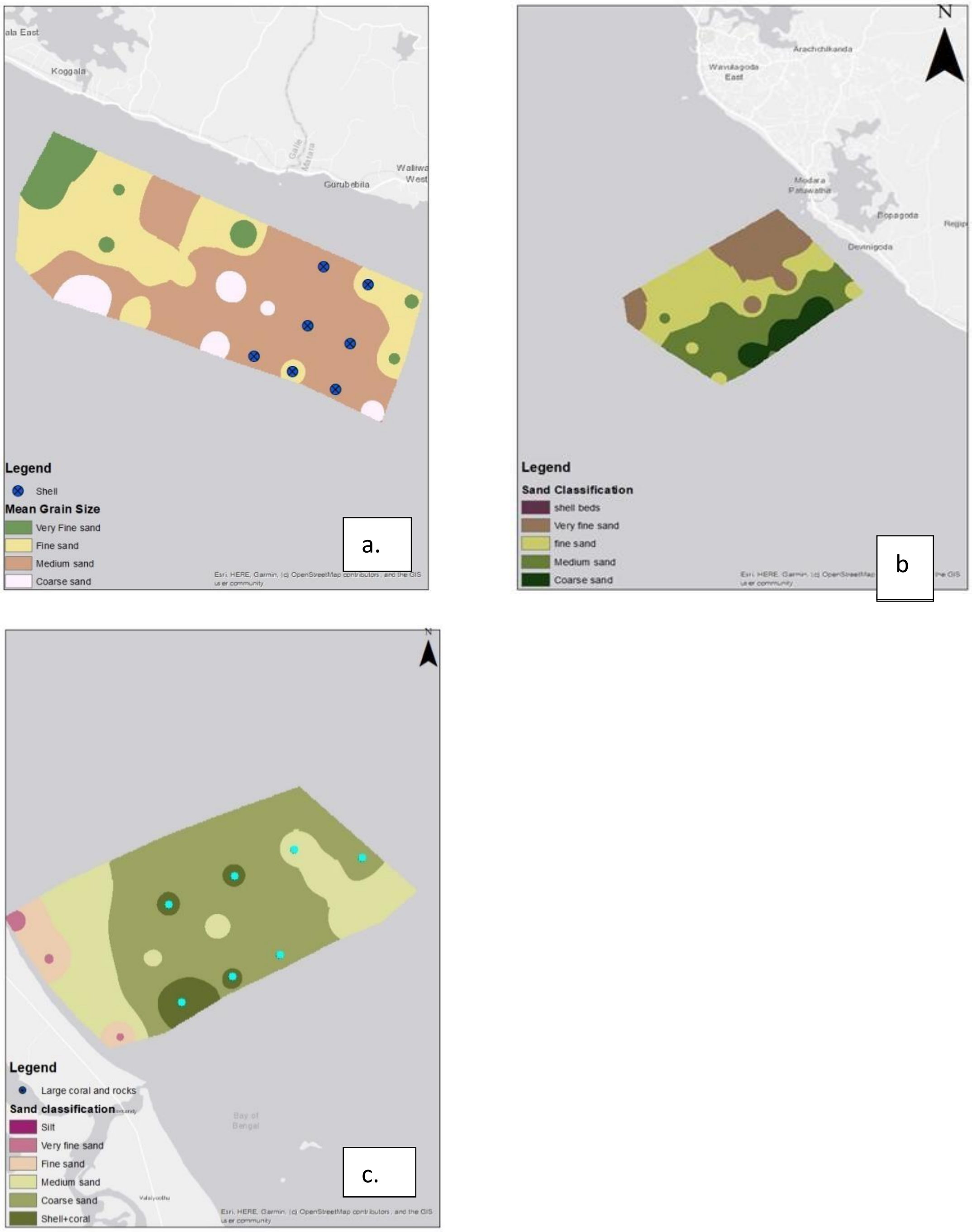
Heavy Mineral content

The heavy mineral content varied from 0.12 to 12% by weight at Weligama area. The minerals identified were Ilmanite and Garnet and the process is not completed yet. The heavy mineral content of off Trincomaleewas 23% at two sampling points but there were no particles could be identified from the other sampling points.

b. Sub bottom profiling

The total surveyed area of the off-Weligama is 40km^2 and the average thickness of the sediment varied from 1m-2.5m while the total estimated sand volume is 24Mm^3.

The average sediment thickness of off -Galle is 0.2-1.5 m and the total estimated sand volume is 12.6Mm^3 . However, the sand deposit in in Galle area confined to a narrow stretch and hence the mining will be not economically feasible.



b

Figure 01 : Mean Grain Size Distribution

Conclusions

Considering the two sites surveyed for offshore sand off_Weligama site is the most suitablesite for sand extraction beacuse the the sand deposit at Galle area confined to a narrow stretch and hence the mining will be not economically feasible**.**

The site selected(Trincomalee) for mineral sand prospecting is not suitable due to excess shell and coral fragments .

Recommendations

Another site near Weligma should be surveyed further.

The site selected (Trincomalee) for mineral sand prospecting is not suitable due to excess shell and coral fragments. More on the survey could not completed due to covid pandemic and unfavourable wether conditions. Therefore, survey shouldbe conducted again in a new site.

Constraints

Covid Pandemic

Unfavorable weather conditions

Financial Allocation (Rs) 15M

Financial progress (%)

Physical Progress (%) 72%

7.3 Hydrodynamic studies for sustainable management of Lagoons

Officer/s responsible: W.N.D.S Jayarathna, H.A.S.D Perera

Introduction

Lagoon is a highly dynamic environment and Natural phenomena changing with human intervention is highly impact not only environment but also on livelihood activities. Puttalam Lagoon, which covers 226 km^2 on Sri Lanka's northwest coast, plays an important role in aquaculture and lagoon capture fisheries. Aim of this project are to build strong awareness to the stakeholders about the hydrology, hydrodynamic for control lagoon pollution, improve the feasibility for lagoon management projects and sustainable usage of lagoon-based fisheries and aquaculture.

In recent years, most of the coastal lagoons in Sri Lanka have been affected by natural and mostly anthropogenic influences, including environmental degradation from hydrological alterations (Tsunami in 2004) and point and non-point source of pollutions such as effluent discharge and garbage dumping (Miller et al., 1990). As a result of that, alteration in physical, chemical and biochemical parameters in a coastal lagoon have direct impact on the fish production and ecosystem dynamics (Pérez-Ruzafa et al., 2006). The Puttalam Lagoon is both economically and ecologically important which located in the North Western Province of Sri Lanka at 70 44’46-80 35’60 North and 790 48’25-790 49’17 East and area around the Lagoon comprises only four Divisional Secretariats: Kalpitiya, Puttalam, Vanathavillu and Mundel. The Lagoon system is very shallow and surface area of 226 km2 and a mean depth at mean sea level (MSL) of about 1.5 m. The largest depths, 6-7 m are found in two narrow channels at Kalpitiya. The lagoon environment has deteriorated over the last two decades due to the impact of pollution from point sources, such as sewage, solid waste, agriculture runoff and prawn farms.

There are many researches were conducted the based on Puttalam lagoon, but still not the proper conservation and management actions to express the complications around this system. This project is planned to carry out surveys over selected commercially, and ecologically important lagoons in Sri Lanka. A monitoring program will be undertaken in each lagoon that include the continuous recording of flow and various environmental parameters, during typical tidal cycles, at the inlet channel close to the mouth and in the upstream end of the lagoon. This monitoring will be conducted to measure water depth, velocity and flow, temperature, conductivity, salinity, nitrate, ammonia, phosphorus, and chlorophyll concentrations, during specific tidal cycles and seasons of the year.

Wetlands such as Lagoons which required the monitoring under some major variables for effective management (Devendra, 2002) described as follows.

Key variables

Water balance: The water balance, monthly or daily basis, is a crucial component in wetland hydrology. It requires attention to the full range of hydro meteorological variables including precipitation, input from rivers and surface runoff, groundwater input or/and outputs, evaporation and transpiration, river outflow, any tidal exchanges of water, and abstraction of water or returns of effluent.

Water quality: Plays a dominant role in determining the composition of wetland flora and fauna.

Turnover rate:(the ratio of throughput to storage) defines the flushing rate of a wetland and is the inverse of the retention period. This has vital ecological significance because it influences chemical and biotic wetland properties such as nutrient accumulation, salinity, and the flushing of pollutants.

Therefore, this project will be a new approach for evaluating present status of the main physical process of the particular lagoons and generating hydrodynamic models to quantify water and predict hydraulic parameters such as water mass movement, and transportation properties in the lagoon. At the same time, biochemical in the lagoon water also will be inspected, aiming at reaching better decisions with regards to lagoon restoration design, water quality control and management actions for improvement of associated environmental conditions and fishery exploitation.

Main objective

Evaluate the hydrology of the lagoon, including quantity, distribution and flow pattern,and quality of the water.

Simulate the hydrologic, hydraulic and water quality in the lagoon to overcome theexisting and upcoming scenarios

Specific Objective/s

Identify seasonal and temporal salinity variation

Identify lagoon water circulation including water balance and residence time

Identify seasonal and temporal variation of Nutrients

Methodology (Study area, Field sampling, data collection and analysis)

a. Study Site

The Puttalam Lagoon is located 7^0 44’46-80 35’60 North and 79^0 48’25-790 49’17 East and area around the Lagoon comprises only four Divisional Secretariats: Kalpitiya, Puttalam, Vanathavillu and Mundel. Lagoon area which surrounded by mainland of east and southern end. Lagoon is connected to open ocean by lagoon mouth through Dutch bay. The length of the lagoon isalmost 35 km with a width various from 2.5 to 12 km and it has surface area of 220 km^2 and a mean depth of approximately 1.25 m (Wijeratne, Rydberg, Arulananthan and Cederlöf, 1995). Technically it’s considered as barrier-built estuary. It’s feeding fresh water from Kala Oya and Mee Oya empties to Dutch bay and Etalai basin respectively.

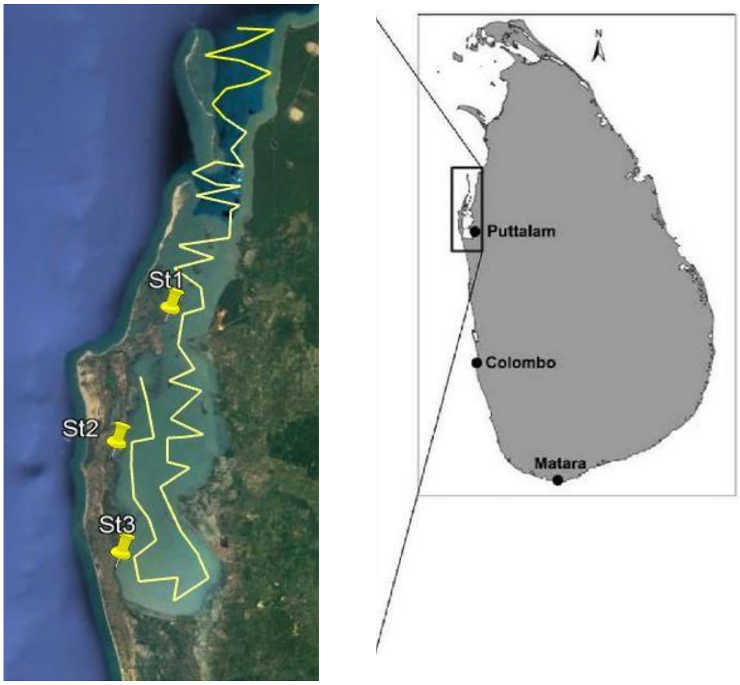


Figure 1: Map of Puttalam lagoon including cruise track

Main activities

Water balance

Hydrology, Hydrodynamic and circulation

Bio-Chemical properties

Collection of samples

This research work was started with a comprehensive literature survey.

Pre available data sources in the lagoon environment were used as the references for the comparatively study the present status of the lagoon.

In order to study the water balance and bio-geochemical properties, major 7 stations, including outside stations and major stations were selected with close to stream outflows were selected for sampling in the lagoon. Cross section of Lagoon mouth was selected for analyze water exchange and Tidal prism width of 2216.17m and average depth of 1.5m. These in-situ measurements were employed on a seasonal basis to understand the seasonal variability.

To investigated the water balance, and Water exchange in the lagoon water level (tide pole), flow rate (flow meter), salinity (mini CTD and SBE 19plus CTD), evaporation and precipitation (met. department data) data was collected during the field visit under the activity 1.

Under the activity 2, Biological conditions (Chlorophyll), and Chemical properties (Nutrients, TSS) will be employed in the field.

Under the activity 3, The hydrological budget models which called Water balance was estimated. Therefore, the net water balance can be written as follow,

(Gu $\frac{\Delta V}{\Delta t} = Q_P + Q_E + Q_G + Q_R + Q_O$

V= lagoon water volume (m^3)

Q_P= mean monthly precipitation (m^3s^{-1})

Q_E =mean monthly evaporation rate (m^3s^{-1}) Q_G=groundwater inflow into the lagoon (m^3s^{-1})Q_R= surface runoff discharge rate (m^3s^{-1}) Q_O=advection gain/lost (tidal flow) (m^3s^{-1})

This methodology has been described in detail by LOICZ biogeochemical Modelling guidelines for the uses of simple budget models in coastal water bodies, such as lagoons (Gorden et al.,1996). Hydrodynamic modelling of the lagoon will be complex, due to the various conditions and alternatives.

Analysis of sample and Data

Samples was analyzed for both quantitative and qualitative parameters. As on site parameters Salinity Temperature, and Conductivity parameters were measured by SBE 19 plus v2 CTD. Nutrient, Chlorophyll-a, Sediment analysis were conducted as Laboratory analysis. Tidal prism, Residence time and phase lag were measured by using tidal variation and velocity data. In addition, the descriptive and inferential statistical techniques was employed in the study. Software packages: MATHLAB and SPSS were used to analyze data.

Activities proposed to be completed during the period

Spatial and Temporal variations of Salinity, Nutrients, Sediments

Analysis of Water Circulation

Results: Activities carried out:

Water Balance

Tidal Fluctuation

As tidal waves propagate from the ocean through an inlet and into the Back Bay (lagoon), amplitudes decrease, and phase lags develop relative to the oceanic sea-surface elevation fluctuations. If the amplitude reduction is large, the system is considered tidally choked. Tidal choking influences the amount of flushing from the lagoon to the ocean, which is important to coastal ecology, water quality, and sedimentation. Coastal lagoons have been divided into three categories (choked, restricted, and leaky) based on the ability of the lagoon to flush water. In Puttalam Lagoon under study periods Semi diurnal tidal pattern was observed during the field visit at the lagoon. Average tidal range is about 31-52 cm.

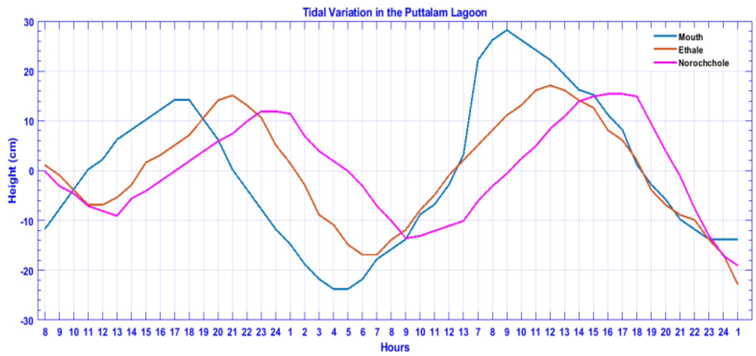


Figure 2: Comparison of sea level measurements in the lagoon (November)

Blue line is tidal fluctuation in the lagoon mouth.

Orange line represents the water level at Etahale (15 km from mouth)

Pink line is tidal fluctuation at Norochchole of the lagoon (27 km from the mouth)

According to the observation of Trincomalee permanent sea level station, the tidal range between highest high tide and lowest low tide is nearly 60 cm and between low tide and high tide nearly 38 cm. The recorded tidal range is 52 cm in the channel of the lagoon while the open sea is 60 cm with a 8 cm of reduction of tidal amplitude in the lagoon. At that time heavy rainfall and expected the considerable discharge from river runoff. Ethalai tidal value show the 34 cm and Norochcholai 29 cm. Incoming tidal wave loses range due to bottom friction as it travels towards the head. The observed ranges and phase lags result from the combined effects of the incident and reflected waves. Phase lag from Kalpitiya to Eththalai nearly 1.5 hrs and up to Puttalam it shown as nearly

2.5 - 3hr.

The tidal amplitude in the lagoon is lower 50% than the open sea indicating the chocking effect in the system and tidal choking coefficient in the lagoon is 0.86 where η_l is tidal amplitude in the lagoon and ηo is in the ocean.

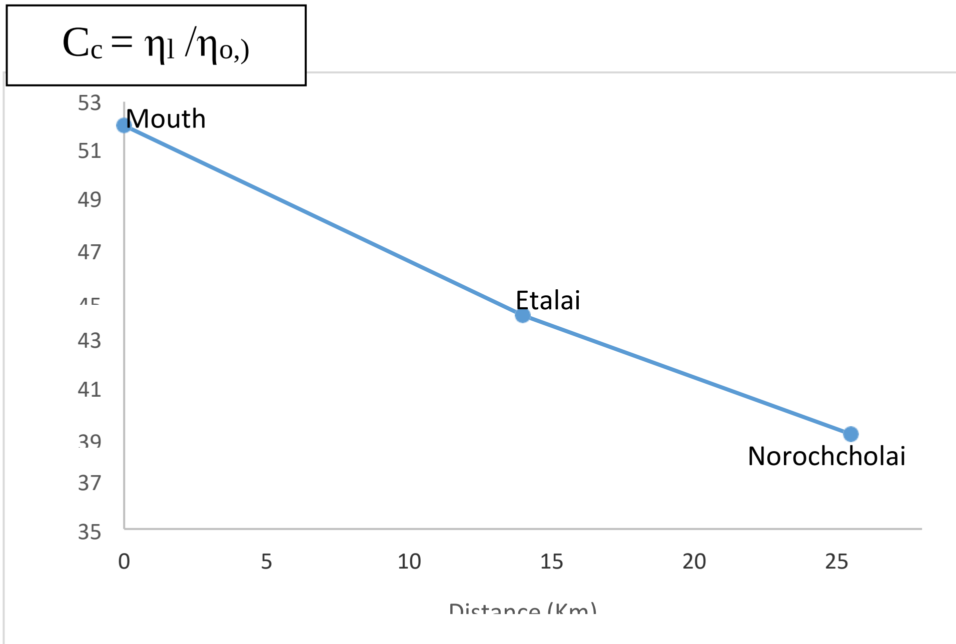


Figure 3: Tidal amplitude versus along-Horizontal distance from the Lagoon Mouth to the Lagoon head (November)

In this lagoon, total extinction of the tide occurs before the tidal wave reaches the head (Wijeratne and Rydberg, 2007). This was clearly explained figure 3, which tidal wave decreased gradually when it reached to mouth to head.

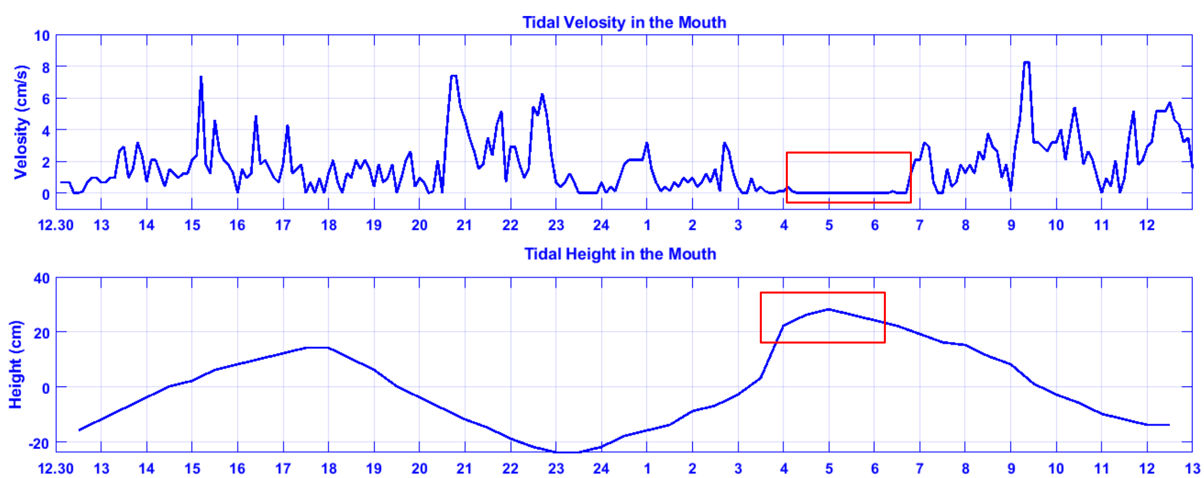


Figure 4: Tidal velocity and Tidal height of the Lagoon mouth (kalpitiya-November)

Maximum velocity was observed during low tide period and specific slack time period identified with high tide in 2nd cycle. At that time heavy rainfall and river runoff caused to result the abnoramal tidal improvement with longer slach period.

January - 31cm, March -34 cm and July - 31 cm are the observed tidal ranged on Lagoon Mouth section. So camparatively November tidal range get dominant with maximum tidal fluctuation among study periods.

Precipitation and Evaporation

Meteorological Data was obtained through Department of Meteorology and Agrarian Research Institute of Kandakuliya. Monthly average values are calculated and tabulated.

Table 1: Monthly average Evaporation and Precipitation in Puttalam (mm)

Month	January	February	March	April	May	June	July	August	September	October	November
Average Evaporation (mm)	3.2178	4.2037	4.3677	4.7709	3.3400	4.2093	4.8832	4.7115	4.9480	3.2752	2.1277
Average Precipitation (mm)	3.1258	0.3535	2.2612	2.21	9.7935	4.3366	0.1032	0.2000	0.4034	11.2613	13.0967

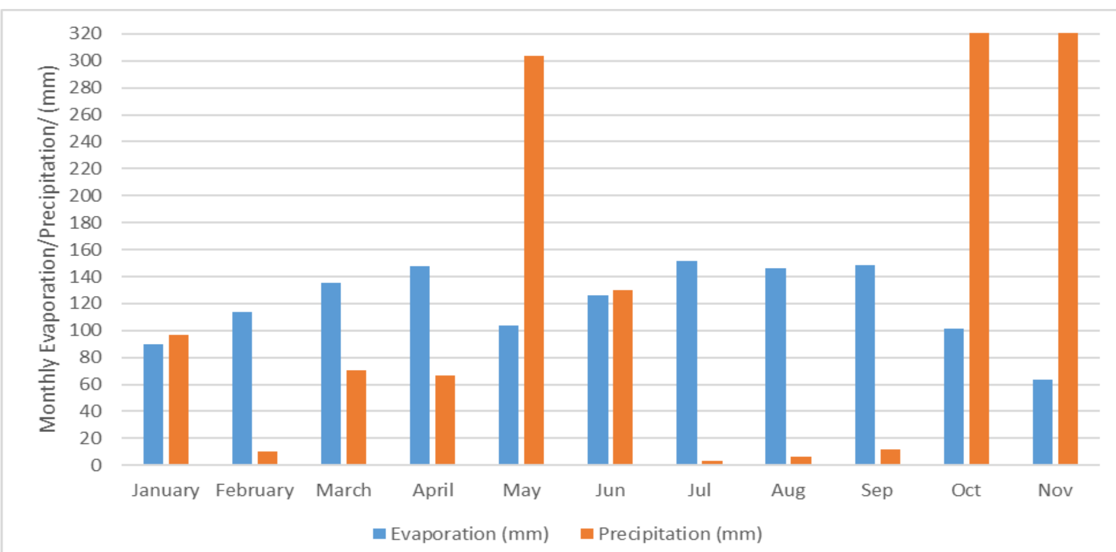


Figure 5: Monthly Evaporation and Precipitation in Puttalam (mm)

January to December total rainfall was 1440 mm which exceed annual rainfall values in previous years and evaporation was 1328 mm. February to April and July to September are evaporation dominant periods.

Fresh-water inputs

Three river basins, Mee Oya, Kala Oya and the very small Moongil Ara discharge into the Puttalam lagoon. Their catchment areas are: Kala Oya 2772 sq km and Mee Oya 1516 sq km. Kala Oya discharges the highest quantity of water (587 Cu M x 10^6) followed by Mee Oya (387 Cu M x 10^6). Two ground water basins, Vanathaviluwa and Madurankuliya are also located close to the Puttalam lagoon system (Dayaratne et al 1997). So average river flux from both Kala oya (18.61 ms^{-1}) and Mee oya (12.27 ms^{-1}) is 30.88ms^{-1}(Ecological and Socio-Economic Assessments of Selected Sites of the Puttalam Lagoon Area, 2008).

Table 2: illustrates the summary of the estimated average monthly Net freshwater flux contributors for Puttalam Lagoon based on rainfall and evaporation data Study Period (from 2021 January to 2021 November).

Month	Precipitation rate (Q_p)/ m^3s^{-1})	Evaporation rate (Q_E)/ m^3s^{-1})	Q_p-Q_E	Net freshwaterflux (River flux+ Q_p-Q_E)/ (m^3s^{-1})
January	8.17	7.60	0.57	31.45
February	0.83	9.58	-8.75	22.13
March	5.91	11.42	-5.51	25.37
April	5.59	12.48	-6.89	23.99
May	25.61	8.74	16.87	47.75
June	10.98	10.66	0.32	31.20
July	0.27	12.77	-12.5	18.38
August	0.52	12.32	-11.8	19.08
September	0.98	12.53	-11.55	19.33
October	29.45	8.57	20.88	51.76
November	34.25	5.56	28.69	59.57

The precipitation measured at Vanathu Villu from June 1960 to May 1961was 1220 mm/yr, and 1990-1992 an average of 1181 mm/yr according to (Arulananthan, Rydberg, Cederlöf and

Wiyeratne, 1995) study. Only for the 11 months in 2021 it's calculated 1440 mm. Thus, even if the evaporation climate may have changed, the river runoff must also have decreased considerably. Precipitation and Evaporation explain respectively positive (Figure 6) and negative (Figure 7) correlation with net freshwater discharge.

Figure 6: Correlation between precipitation rate Net freshwater discharge

Figure 7: Correlation of Evaporation rate and freshwater discharge

According to the Table 2 tidal net water discharge (Q_O) throughout the year was negative and that means the total outflow runs towards the sea.

Evaporation loss

$E_t=A_t*E_L$

E_t – Evaporation loss in each time step

A_t – Water Surface area at the beginning of each time stepE_L – Adjusted Pan evaporation

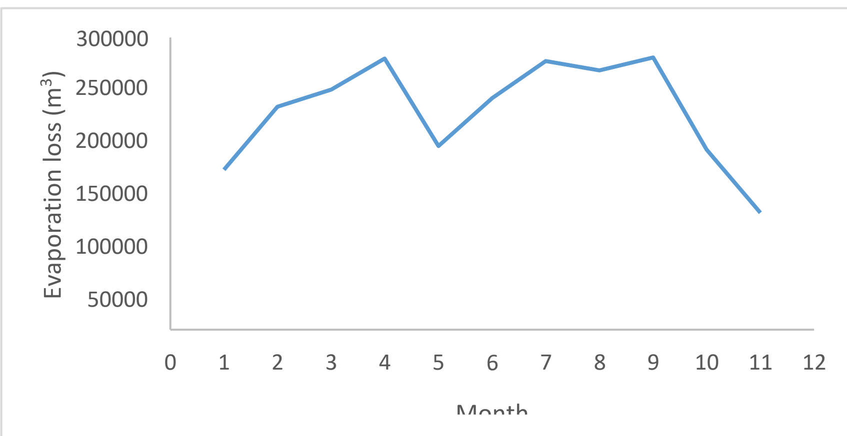


Figure 8: Evaporation loss of January to November in Puttalam Lagoon

This is explain loss of a stored volatile liquid component or mixture by evaporation which controlled by temperature, pressure, and the presence or absence of vapor-recovery systems. Figure 8 explained April, July, and September are dominant for losses and less effected in January and November.

Tidal prism Residence time and Water exchange:

The tidal prism is the amount of water that flows into and out of an estuary or bay with the flood and ebb of the tide, excluding any contribution from freshwater inflows (Mustoe et al., 2005).

The residence time may be defined as the time it takes for a particular water parcel to leave a water body through its inlet (Wijeratne and Rydberg, 2007). Below mentioned equation was used to measured residence time in Puttalam lagoon (March, July and November) figured in Table 3.

Residence time = Lagoon volume/Tidal prismTable 3: Puttala Lagoon Residence time

Month	March	July	November
Residence time	43.6 days	43.06 days	44.98 days

Water exchanged between Lagoon inflow and outflow was calculated during July (dry period). According to (Arulananthan, Rydberg, Cederlöf and Wiyeratne, 1995) studies residence times for the lagoon water vs the ocean of 33 and 47 days, respectively, corresponding to an average water exchange is 100 ms^{-1}. Current studies observed residence time 43-45 days and water exchange in Dry period (July) 98.31 ms^{-1}.

In an estuary, time scales of flushing rate and residence time, which are usually used to measure the rate of water exchange between estuary and the adjacent ocean have a major impact on the ecological processes and functions including water chemistry and sedimentation and in turn biophysical environment. The water exchange and residence time in the lagoon is mainly driven by river input (Wijeratne, 2003).

Results of this study explained of residence time somewhat increase 2 days when climate goes with dry to wet period. Wijeratne, Rydberg, Arulananthan and Cederlöf, 1995, studies revealed freshwater supplies cause to residence time up to 50% greater.

In November maximum precipitation recorded and net fresh water discharge caused to extend the residence time in Puttalam lagoon. However, there is a no significant variation between all other study periods.

Tidal prism is responded to a function of area of open water and tidal range, it can be changed by alterations of the basin area of estuaries and inlets as in dredging. If lagoon morphology or hydrology changed (estuary or inlet is dredged, or the size changed) the channel will fill in with sediment until it has returned to tidal prism equilibrium.

Bio-Chemical properties

Salinity

Selected Puttalam lagoon was higher sea water influence Lagoon which explained by Figure 10 which using Lagoon morphological characters. Salinity in Puttalam lagoon strongly related with the Meteorological conditions (Precipitation & Evaporation) and fresh water discharges. Both Kala oya and Mee oya discharges which make significantly changes on Salinity. During dry season (July) less freshwater discharge reason for increase the salinity level close to river mouth areas (Figure 12) with highest saltwater intrusion. Saltwater intrusion got dominant in July which river discharging reduced drastically explained table 2.

Outside the of the salinity front in the lagoon mouth has normal oceanic salinity 35 psu. In January (northeast monsoon) near to the freshwater inlets such as Kala oya and Mee oya salinity reduce upto 19-23 psu (figure 11). But it is comparatively high salinity in the south near to Puttalam region due to the less mixing and excess evaporation same scenario happen in October as well. The water is of normal oceanic salinity in the north, whilst high evaporation makes it generally hypersaline in the south (Wijeratne, Rydberg, Arulananthan and Cederlöf, 1995).

Durairatnam, 1963 studies revealed that highest salinity in Puttalam lagoon may (29.9%) – October (36.4%) which confirmed recent studies shown highest (figure 13) value in October (36.41 psu). During these period central Indian ocean and Arabian sea currents from south to north which brings the higher salinity water to lagoon and during north-east monsoon currents are reverse back.

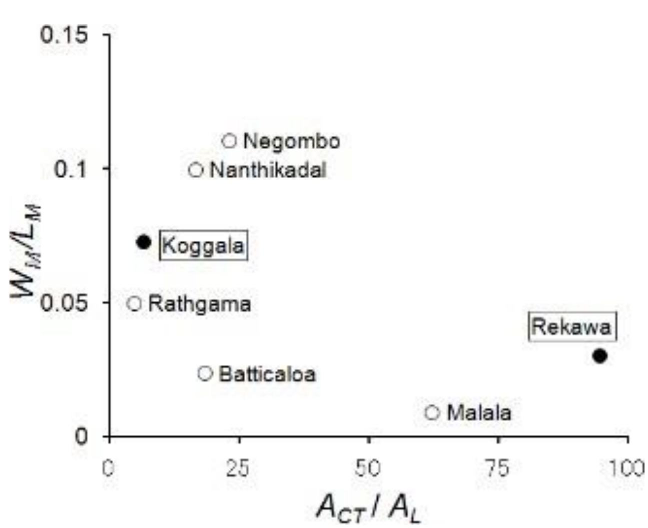


Figure 9: Representative assessment based on accessibility of sea water into selected lagoons and

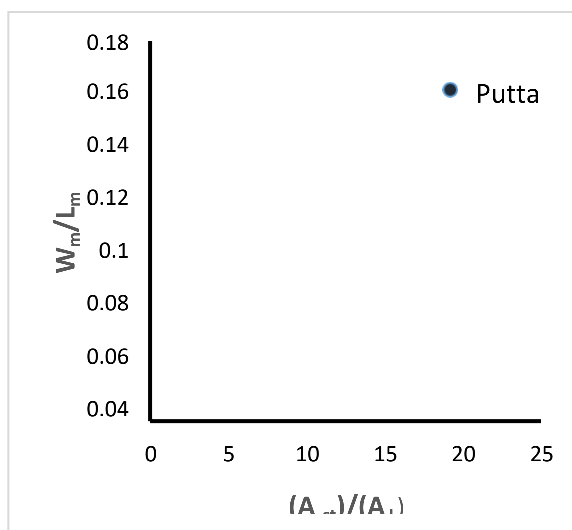


Figure 10: Representative assessment based on accessibility of sea water into Puttalam lagoon and Probable freshwater

Probable freshwater discharge.

(Perera, Furusato, Tanaka and Priyadarshana, 2015)

(W_m)- Width of Mouth (L_m)- Length of Mouth

(A_{ct})- Catchment area (A_L)- Lagoon area

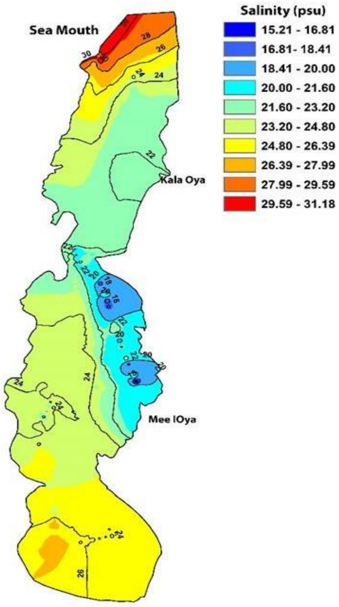


Figure 11. Spatial surface salinity of Kalpitiya Lagoon during January 2021

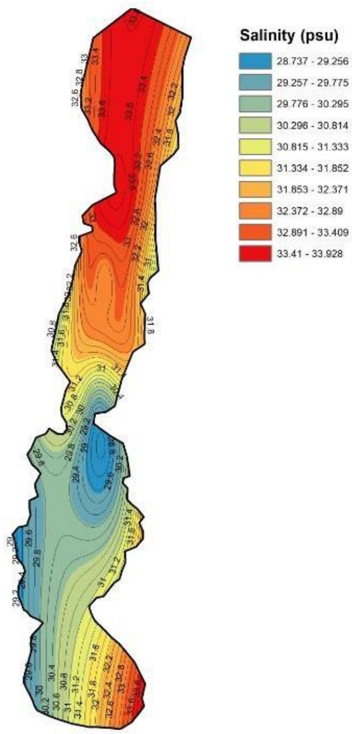


Figure 12. Spatial surface salinity of Kalpitiya Lagoon during July 2021

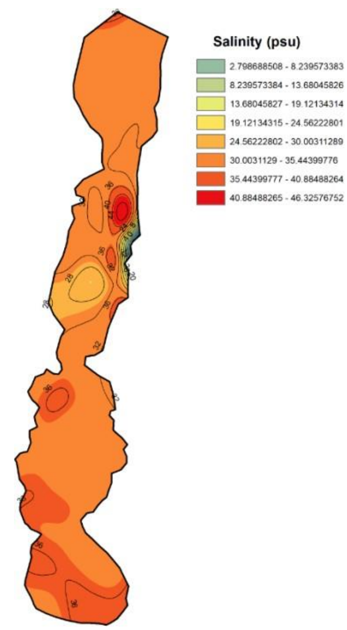


Figure 13. Spatial surface salinity of Kalpitiya Lagoon during October 2021

In dry season (July) salinity level increased drastically in Dutch and Portugal basins (upper half) due to reduction of Net freshwater flux.

CTD profiling was conducted across the selected locations of the Kalpitiya lagoon. The vertical cross section of the lagoon indicates the significant salinity variability, and different water masses.High dense, salt water is laid at the bottom of the deepest point of the western boundary (figure 14). The high salinity water advection along the deepen western boundary of the lagoon. At the western boundary, the bottom water looks saltier than the surface. Low salinity in the Eastern boundary of the lagoon indicates, the freshwater inputs from the marginal river (Kala oya).

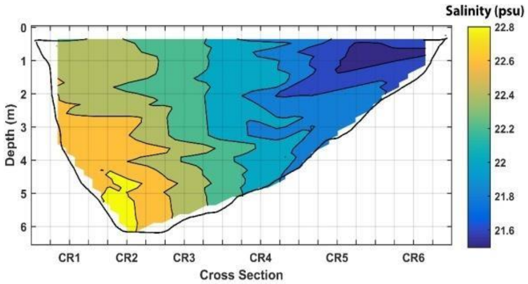
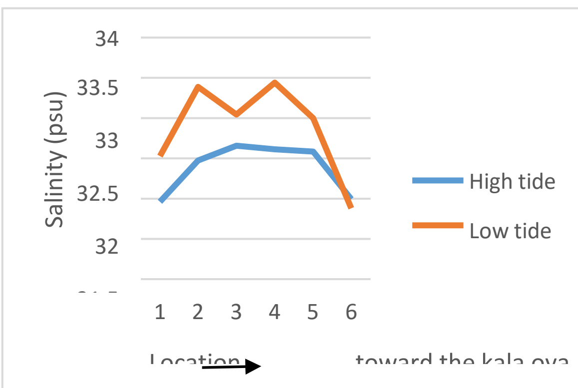


Figure 16 : Salinity changes in cross section (Kalpitiya) in Low and High tide - July

Figure 14. Vertical salinity profiles of the cross section of the Kalpitiya lagoon – January



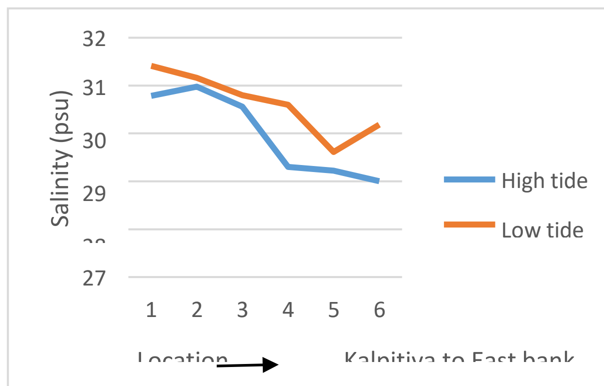


Figure 15 : Salinity changes in cross section (Kala oya) in Low and High tide - July

Cross section in western bank to kala oya mouth area which explained salinity level decreased in both marginal areas. But it's drastically dropped in high tide than low tide salinity level. Same scenario which happened in Kalpitiya cross section except the eastern bank indicate highest level of salinity. These scenarios clearly built the combination of freshwater discharge get dominant especially in eastern bank. Physically observed margin was created surrounded the kala oya mouth by density difference between Freshwater discharge and sea water.

Figure 17: Fresh water and sea water mixing area close to kala oya mouth

Nutrients

Nitrate

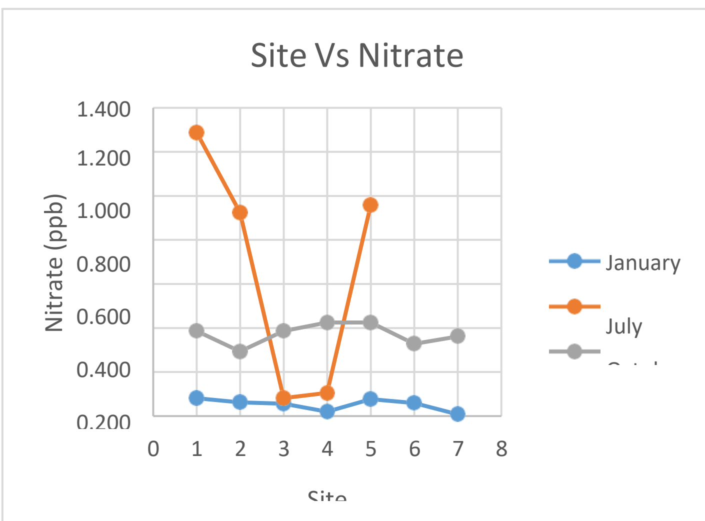
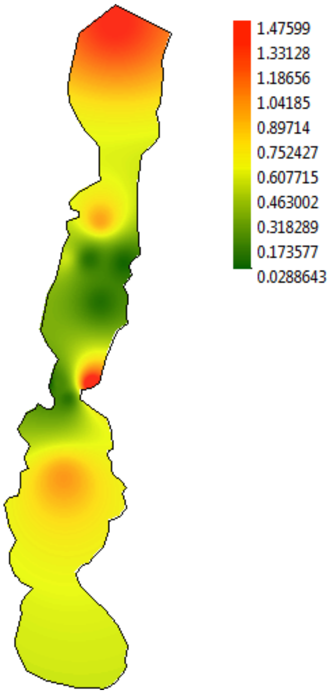


Figure 18: Temporal and Spatial variations of Nitrate concentration (ppb)

Nitrate concentration was some significant in July (dry period) in both site 1 (close to open ocean) and site 5 (close to mee oya mouth) showing figure 18. Other periods were not explained significant variations of above mentioned, but also site 5 nitrate concentration deviate with given the maximum concentration.



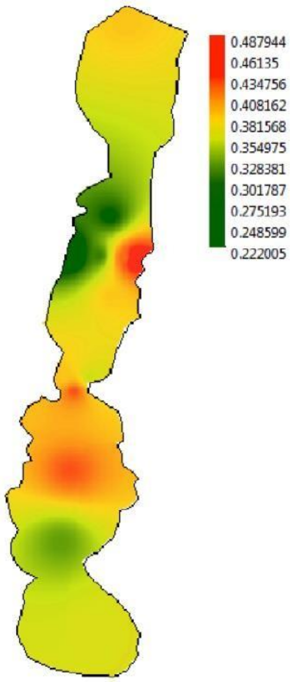


Figure 19: Nitrate (ppb) in July   Figure 20: Nitrate (ppb) in October

Nitrite

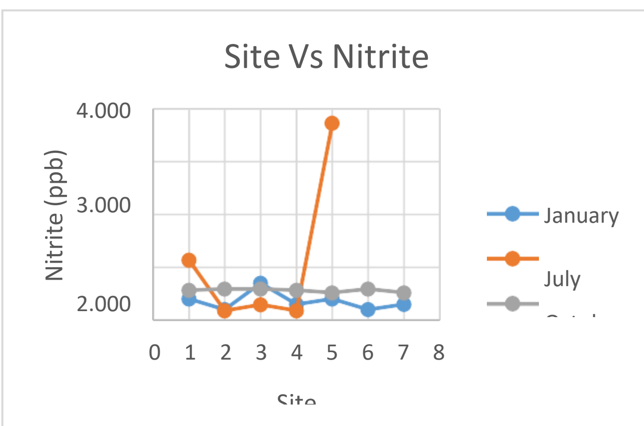


Figure 21: Temporal and Spatial variations of Nitrite concentration (ppb)

Nitrite concentrations was behaved as same as nitrate which was given. In dry period (July) explained maximum concentration.

Phosphate

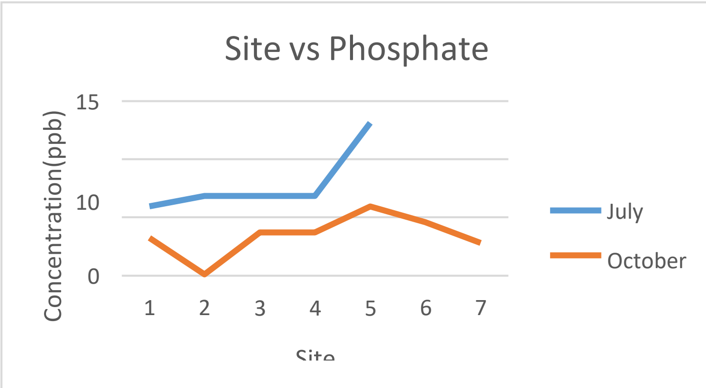


Figure 22: Temporal and Spatial variations of Phosphate concentration (ppb)

Phosphate concentration indicated maximum level in site 5 (close to Ma oya mouth). Also, some considerable concentration exceeded in July (dry period).

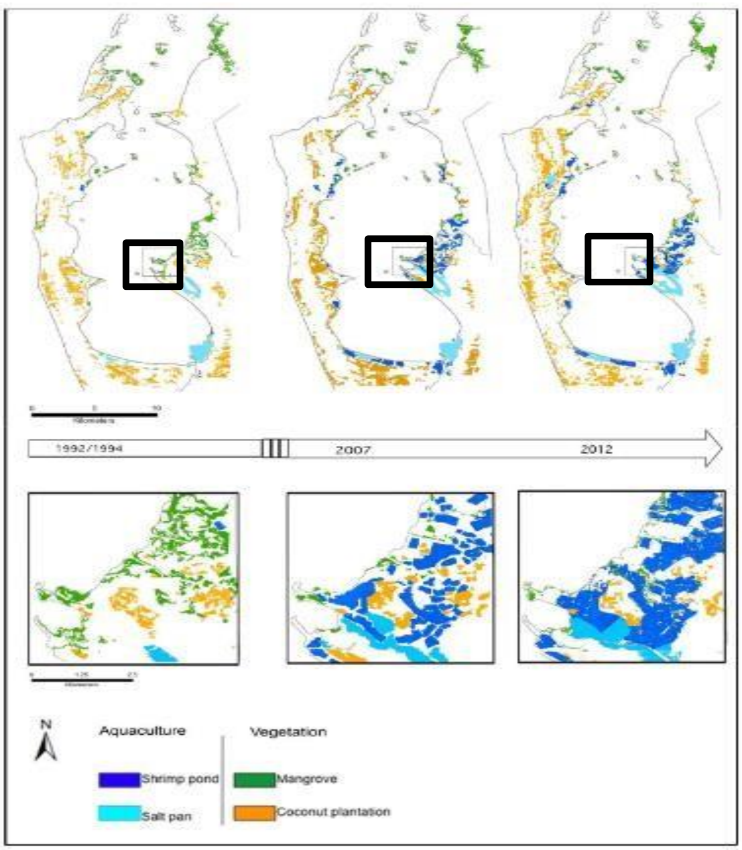


Figure 23: Time series for the four land uses classified in Puttalam lagoon, with a zoom in the Mee-Oya estuary, clearly showing expansion of shrimp farms and salt pans and loss of the coastal mangrove ecosystem between 1992/4 and 2012 (Bournazel et al., 2015).

Nutrients are significantly trending towards the mee oya discharging area due to anthropogenic activities specially expansion of shrimp farms and salt pans with losing coastal mangrove patch clearly mentioned figure 23. As well as evaporation in dry season contributed the increase the nutrient concentration significantly.

Sediments

Fine Sand are the dominant sediment types in here not specific variations along the open ocean area to Lagoon head. There are some shell particles dominant in both Lagoon banks with observing two cross sectional areas. It's seems to be a favorable condition for molluscans in Eastern bank. Also grain sizes of sand increased in eastern bank of both cross section which carried by river discharge. Nutrients which carried by river discharge was caused the improve algae, bacteria and small organic particles to mussels and bivalves favorable for eastern lagoon bank.

Figure 24: Cross 1-West bank to Kala oya mouth

Figure 25: Cross 2- Kalpitiya West bank to East bank

Outputs

Temporal variability of water balance, Tidal fluctuations and Residence time identificationin the lagoon

Seasonal and spatial variation of nutrients, Salinity and Sediments dynamics.

Identification of some anthropogenic scenarios affect on lagoon quality.

Outcomes

Identified spatial usage of shrimp culture and effects on lagoon water.

Temporal and spatial usage of lagoon water for aquaculture development.

Improved the ability to provide better awareness to the stakeholders about the hydrology, hydrodynamic of the lagoon

Created the path to Management strategies for land based pollution runoff

Conclusions

Puttalam lagoon, one of the most significant lagoonal systems in Puttalam district Sri Lanka. Less mixing and high evaporation impact on Puttalam basin which indicated with high salinity values throughout the seasons. Also highly affected from freshwater inflows by both Kala & Mee oya which caused to reduce salinity drastically and saltwater intrusion get dominant with reducing freshwater discharge. Net freshwater flux, evaporation, and Tidal fluctuation highly impact on lagoon salinity changes by temporal as well as spatially. Net water exchange towards the ocean (Lagoon outflow) which explain net lagoon water discharge get dominant in here. Residence time in here which allowed to settle the sediments and it‘s physically observed developing sand deposits in middle of lagoon.

All Nutrients dominant which closes to Mee oya is confirm the nutrient concentration alteration with human intervention (Shrimp farming, Salt pans) on the Lagoon water and seasonal climate. Also mixing and water exchange are the other physical process which affected to biochemical balance. Sediments in marginal areas (Kala oya to Kalpitiya) and Water quality factors favorable for molluscans. Fishermen are tending towards the cage culture and shrimp harvesting by using areas of lagoon bed filling with sediments.

Fresh water inputs, Tidal flushing and wind stress are the some forces alteration of hydrodynamic patterns in here. However salinity values and other factors are still favorable for fisheries which depend on shrimps and further analysis shall be consist with bottom dwellers to improve aquaculture practices. So there is a potential to maximize national GDP and to achive SDG goals in future.

Recommendations

To the confirmation of Natural flow which affecting by natural or anthropogenic activities, continues water budget estimation is highly recommended. Because sedimentation factors also depending on that. Continues further studies in similar seasons which studied shall be recommended to continue.

Constraints

Boat availability and unhealthy weather was the major concerns which faced as the challenges. As well as COVID-19 pandemic situation effected on sample analysis process.

Financial Allocation (Rs): 475,000/-

Financial progress (%) : 105.43%

Physical Progress (%): 85%

References

Pathirana, K., Kamal, R., & Riyas, M. (2008). MANAGEMENT OF COASTAL RESOURCES IN PUTTALAM LAGOON, SRI LANKA.

Wijeratne, E., Rydberg, L., Arulananthan, K. and Cederlöf, U., 1995. The Tidal Response of Puttalam Lagoon, Sri Lanka: A Large Shallow Tropical Lagoon. *AMBIO A Journal of the Human Environment*, 24(7/8), p.444.

Devendra, A., 2002. *Hydrodynamics of Muthurajawela Marsh & Negombo Lagoon Coastal Wetland Ecosystem*. Effective Management for Biodiversity Conservation in Sri Lankan Coastal Wetlands. Project EMBioC, pp.3-25.

2008. *Ecological and Socio-Economic Assessments of Selected Sites of the Puttalam Lagoon Area*. IUCN, pp.1-4.

Gunaratne, G., Priyadarshana, T., Manatunge, J., Tanaka, N. and Yasuda, S., 2010. *Water balance and renewal time of rekawa lagoon, Sri Lanka; a restorative approach*. [online] Dl.lib.uom.lk. Available at: <http://dl.lib.uom.lk/handle/123/9253> [Accessed 26 December 2021].

Perera, G., Furusato, E., Tanaka, N. and Priyadarshana, T., 2015. *THE APPLICABILITY OF CLASSICAL BULK MODEL FOR ESTIMATING SALINITY STRATIFICATION OF CHOKED COASTAL LAGOONS IN SRI LANKA*. [online] Library.jsce.or.jp. Available at: <http://library.jsce.or.jp/jsce/open/00035/2014/69-cs/69-cs02-0031.pdf> [Accessed 3 January 2022].

Bournazel, J., Kumara, M., Jayatissa, L., Viergever, K., Morel, V. and Huxham, M., 2015. The impacts of shrimp farming on land-use and carbon storage around Puttalam lagoon, Sri Lanka. *Ocean & Coastal Management*, 113, pp.18-28.

Durairatnam, M., 1963. Studies on the seasonal cycle of sea surface temperatures, salinities and phytoplankton in Puttalam Lagoon, Dutch Bay and Portugal Bay along the west coast of Ceylon. .*Bull. Fish. Res. Stn., Ceylon*, 16(1), pp.9-24.

Wijeratne, E. and Rydberg, L., 2007. Modelling and observations of tidal wave propagation, circulation and residence times in Puttalam Lagoon, Sri Lanka. *Estuarine, Coastal and Shelf Science*, 74(4), pp.697-708.

Arulananthan, K., Rydberg, L., Cederlöf, U. and Wiyeratne, L., 1995. Water Exchange in a Hypersaline Tropical Estuary, the Puttalam Lagoon, Sri Lank. *AMBIO A Journal of the Human Environment*, 27(7/8), pp.438-43.

Mustoe, G., Pirazzoli, P., Fairbridge, R., Healy, T., Hands, E., Flemming, B., M., D., Semeniuk, V., Li, C., Wang, P., Fan, D., Charlier, R., Hume, T., Hayes, M., Woppelmann, G., Pirazzoli, P., Charlier, R., Parker, B., Lakhan, V., Schwartz, M., Miller, M., Hadley, N., Wong, P., Ciavola, P., Hopley, D. and Dawson, A., 2005. Tidal Prism. *Encyclopedia of Coastal Science*, pp.981-982.

7.4 Coastal Stability and Protection Measures in the Western Coast of Sri Lanka. Research Component: The Sand engine nourishment: A solution to beach erosionmanagement of Marawila Beach, Sri Lanka

Officer/s responsible

R.M.R.M. Jayathilaka, Scientist, Oceanography Division, NARA

Introduction

Coastal erosion is a long-term problem in Sri Lanka, subjected to a series of socio-economic and environmental impacts due to this problem. This includes the loss of natural beaches and leisure and livelihood-related activities like the fisheries (CC&CRMD, 2015). Approximately two billion Sri Lankan rupees (approximately 13 million US dollars) have been invested in erosion management up to 2017 (Samarasekara, 2018). Most of the erosion prone areas between the coastal stretches of Matara to Puttalam were identified under NARA project in 2016. Wedikanda (Between Agulana and Mount Lavinea), Pitipana (South of Negombo) and Marawila (between Maha oya and Chilaw) are identified as severely eroding coastal stretches in the Western Coast of Sri Lanka (Jayathilaka, 2019).In addition, Colombo, as the capital of Sri Lanka, has experienced strong anthropogenic interventions and alterations of the coastal zone due to the expansion and development of the city, combined with the Colombo south harbor project, was the major development activity causing physical alterations of the shoreline in Colombo (Abeykoon, 2021). In Sri Lanka, the coastal zone management plans has started traditional coastal protection works (hard measures) such as series of groins, revetments, jetties and offshore breakwater. Also regulations were reinforced and use of setback lines was introduced. Therefore, a long-term sustainable solution requires the integration of these measures into the local socio-economic and environmental aspects. A traditional beach nourishment project for Marawila was carried out in 2013 by President Gotabaya Rajapaksa when he was the secretary of the Ministry of Defense and Urban Development and then second nourishment in 2017. The shoreline analysis was revealed that the beach recovery from the traditional beach nourishment in Marawilawas short-lived (Samarasekara, 2018). This could be due to the sand nourishing method used, the amount of sand used, or the particle size used. Continuous beach nourishment or sand engine nourishment is therefore essential in such a setting (Stive, 2013).

This study investigate the applicability of sand engine nourishment known as the Sand motor, has recently been implemented in the Netherlands. According to this method, the sand is carried by alongshore transportation to the adjacent coasts following the principle of building with nature (Van Slobbe, 2013). This method is expected to be more efficient and effective in the long term than traditional beach and shore-face nourishments. Figure 1 shows the evaluation of sand nourishment strategies from 1970's onwards.

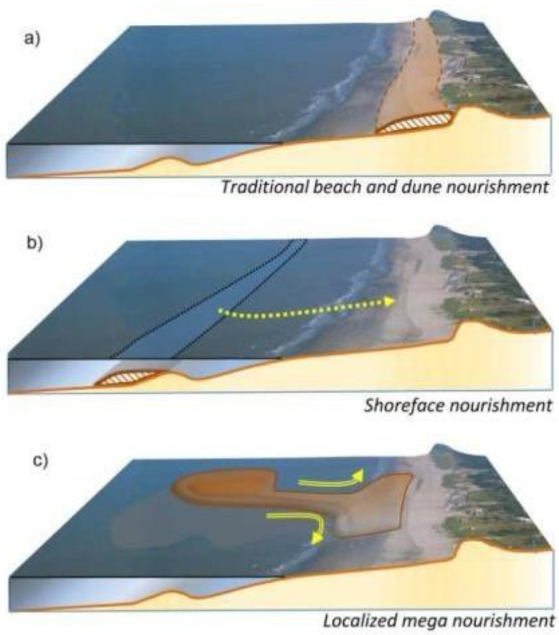


Figure 1. Conceptual diagram of the different nourishment strategies. (a) Traditional beach and dune nourishments used frequently from the 70's onwards, place sand directly on the beach and dunes (b). Shore-face nourishments, initiated in the 90's, make use of natural marineprocesses to redistribute the sand that is placed under water in the cross-shore direction and gradually create a wider coastal defence over time

(c). Concentrated mega-nourishments, as introduced here (see fig 2), exploit both marine and Aeolian processes, to redistribute the sand both in cross and alongshore directions (after Stive et al, 2013)

The main advantages of the Sand Engine concept are:

A nourishment will only be required approximately every 10-20 years as opposed to the 2-5 year cycle of present day beach and shore-face nourishments;

The nourishment will slowly diffuse and advance the shoreline over a larger stretch of thecoastline in a more natural fashion;

The large initial local perturbation will result in a short to medium term increase of locally available space for recreation and the environment, and

The ecological stress, while considerable at the initial nourishment location, does notdisturb adjacent areas, thereby containing it to a small area.

Figure 2: An example of mega sand nourishment in progress in the South Holland in the Netherlands

Main objective

The primary objective of this study to explore the suitability and feasibility of Sand engine nourishment for the Marawila beach, Sri Lanka.

Specific Objective/s

To determine hydrodynamic and sedimentary conditions, locations, dimensions and shape, expected evolution across multiple timescales and impact on adjacent coast in the construction of Sand engine nourishments.

To understand and assess the impact of offshore dredging and reclamation of CIFC onthe adjacent coastal environment via a numerical modeling approach.

To identify the spatial variation of Littoral Cutoff Diameter of sand and its relation to the wave energy in the western coast of Sri Lanka.

Methodology (Study area, Field sampling, data collection and analysis)

The methodology consists of three levels, i.e.

Understanding the problem and source: Correlation between the pattern of coastal retreat and the related natural and anthropogenic factors will be evaluated for a better understanding of the causes of coastline retreat. A new, open-source global shoreline mapping python toolbox called CoastSat (https://github.com/kvos/CoastSat) was used to obtain time-series of shoreline positions on the coastline. Landsat-5, Landsat-8 and Sentinel-2 images were used for different stage of the tide. Using the Global Inverse TideModel TPXO 7.2 and the measured intertidal beach slope the tidally correct time-series ofshoreline was taken for investigating coastline retreat (risk spots).

Field data collection Phase: A comprehensive literature survey was conducted. Measured sediment transport data in the coastal and river systems have been highlighted as a major gap in the study area. Two Sediment traps were installed at Maha Oya river mouth to measure fluvial sediment input into the coast. In addition, another sediment trap was deployed at 5m depth contour of Marawila coast to understand the alongshore sediment characteristics. For sediment characteristic investigation on Sri Lanka's western coast, thefollowing sediment sampling plan is formulated. The sampling map is shown in the appendixes.

Alongshore sand sampling survey

Location : Beruwela to Chilaw (30 locations) Sample Period: Seasonal (March/October) Methodology : Swash & berm crest samples

Expected Output : Spatial variability of sand sorting, skewness, kurtosis, D50 & LCD, wave climate impact, sediment source distance.

Cross-shore Profiling Survey Location : Marawila (S4-5)

Sample Period: Seasonal (March/October)

Methodology : Sounding data (bathy), Grab sampling using one-day fishing boat. Expected Output : Summer- winter (seasonal) profile change, Cross-shore Sand grading /characteristics & LCD.

Bathymetric survey in the 10 km span of Marawila coast is conducted by NHO.

Modelling and Scenario analysis Phase: The process-based numerical model Delft3D issetup to develop a multi-domain (nested) cascade of models on the West Coast of Sri Lanka. Model forcings applied included tide, waves and local winds. Wave conditions were derived from a series of nested SWAN wave models forced with ERA-5 wave and wind data (Appendix A). Following standard practice to reduce computational times of numerical flow-wave coupled sediment transport models, the full wave climate wasreduced to 16 representative wave and wind conditions (4 wave directional classes and 4 wave height classes) using the energyflux method (Benedet et al., 2016). Tidal boundary conditions were derived from an overall tidal model of Western Sri Lanka that was forcedusing Global Inverse Tide Model TPXO 7.2. The model was used to understand the impactof offshore dredging, Colombo south breakwater and reclamation of CIFC on the adjacentcoastal environment.

The model will finally then be used for an exploratory study on the evolution of schematized mega nourishments and also to perform sensitivity analyses on potential locations, dimensions (volume, alongshore and cross-shore extent) and shapes (hook, bell,shore-face) of such a possible Sand engine along the Marawila coast. The economically feasible and socially and environmentally acceptable measures will be introduced for coastal risk spots.

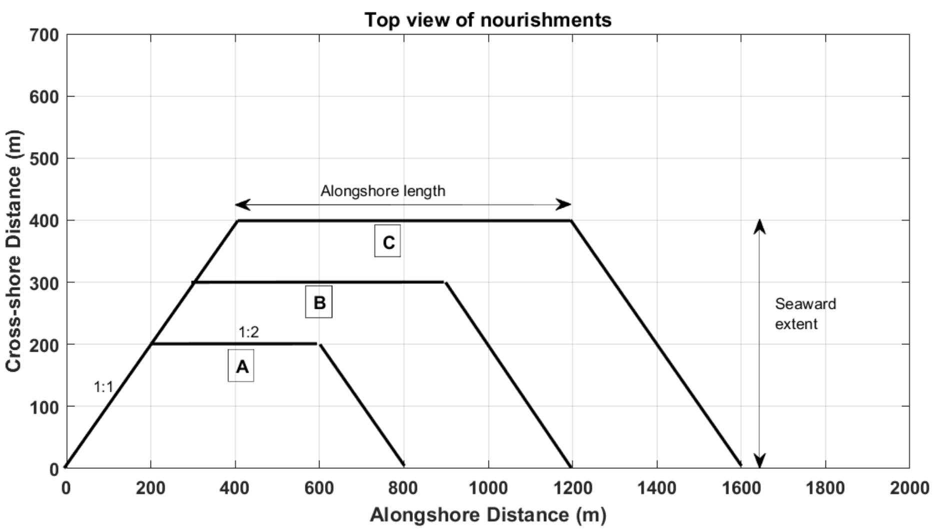


Figure 3: Top view of nourishments scenarios (note that the x- and y-axis do not have the same scale)

Three different idealized nourishment configurations were tested (Figure 3) for the Marawila coast. Most relevant parameters are set: the seaward extent (200m; 400m; 600m),the width over length ratio (1:2). Note that the nourishment with a cross-shore width of 300m and a W/L ratio of 1:2 is referred to as the reference nourishment. The cross-shore slope of the sand engine is set as 1:50, such that the toe of the nourishment is positioned at6 m (MSL)for the reference case. The table 1 shows the approximate cost of each nourishment configuration based on an engineering estimate. In 2020, CCD would spend a total of 890 million rupees to nourish 800,000 m3 of sand in the Calido, Agulana, and M'Lavinea beach nourishment projects (https://www.defence.lk/Article/view_article/1679).

Table 1: Overview of nourishment dimensions, initial volumes and estimated dredging cost.

Nourishments[#]	Seaward extent [m]	Alongshore length [m]	Volume in Delft3D [million cubic meter]	Approxi.Cost (Million Rs)*
A	200	800	0.540	600
B	300	1200	1.575	1750
C	400	1600	3.000	3337

* The cost is based on M' Lavinea beach nourishment projects in 2020

Activities proposed to be completed during the period

During each project phase, the following activities were proposed to be completed.

Table 2: Overview of proposed project activities for corresponding project phase. .

Project phase	Activity
Understanding the problem and source	Literature review and stake holder discussions.
	Understanding the al retreat in Marawila (using CoastSat: python coasttoolbox)
Field data collection Phase	Conducting Cross-shore transects surveyed (Bathymetry) in Marawila. (March/October)
	Alongshore sediment sampling between Beruwela to Chilaw (March/October)
	Cross-shore sediment sampling in a seaward transect of Marawila (March/October)
	Sediment trap deployment and recovery (Marawila and Maha oya River)
Modelling and Scenario analysis Phase	Wave climate assessment and wave model setup (SWAN)
	Determining the spatial variation of Littoral Cut-off Diameter of sand and its relation to the wave energy in the western coast.
	Assessing the Impacts of CIFC reclamation and mega sand mining on the prevailing coastal environment (numerical modelling)
	Sensitivity analyses & expected evolution for given sand engine nourishment scenarios (numerical modelling)

Results: Activities carried out:

This section details the activities undertaken to better understand Marawila's coastal retreat, including field data analysis and numerical model setup for sand engine nourishment, as well as the impacts of CIFC reclamation and mega sand mining.

The coastal retreat in Marawila

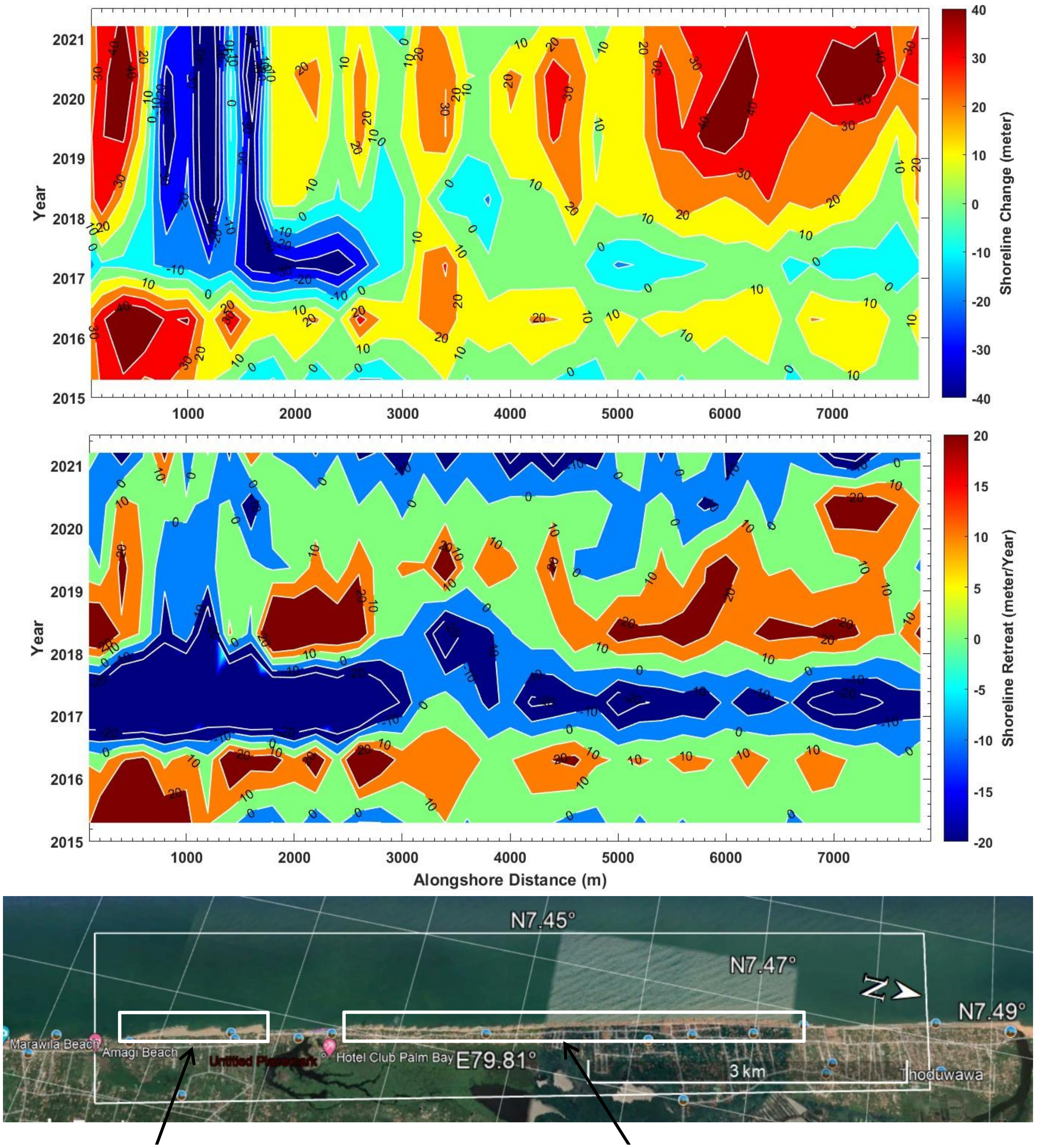
This study aimed to determine the chronological changes in coastal erosion/accretion in north of Marawila between 2014 and 2021 using Coast-Sat is an open-source software toolkit written in Python.

Most of the erosion prone areas between the coastal stretches of Matara to Puttalam were identified under NARA project in 2016. Coastal cell between Maha oya and Chilaw is identified the most severely eroding coastal stretches in the Western Coast of Sri Lanka (Jayathilaka, 2015). The whole beach stretch up to Marawila from Maha river mouth was protected from detached breakwaters and revetments and the propagated erosion reached Marawila area in 2005 (Wickramaarachchi, 2011). A maximum erosion rate of 5-8 m/yr was recorded most of the places during 2005 – 2014 (Jayathilaka, 2015).

Between 2011 and 2017, about 1 billion SLR was spent on coastline management in Marawila, which includes the construction of 2 km of revetments, six detached breakwaters (DB), four submerged breakwaters (SB), six groins, and 800,000 m3 of beach replenishment (Samarasekara, 2018). After 2017, a total of 40 groins, each separated by 100 meters, were installed north of Marawila up to Thoduwawa beach.

Figure 4 shows the results of coastline retreat between Marawila to Thoduwawa from 2014 to 2021. The 2017 beach replenishment and the effect of five DB in the nourishment region were clearly seen, retaining the nourish sand that was transported northward. A year after nourishment, the tombolos (or salients) formed by DB began to erode (probably SW monsoon of 2018).

(a)



Year
Shoreline Change (meter)
Shoreline Retreat (meter/Year)
Alongshore Distance (m)
N7.45°
N7.47°
N7.49°
N
Marawila Beach
Amagi Beach
Hotel Club Palm Bay
E79.81°
3 km
Thoduwawa

(b)

(c)

Figure 4: Overview of coastline retreat between Marawila to Thoduwawa from 2014 to 2021, (a) overall

Sand Nourishment in 2017 & three DB

Groin field introduced in 2018-2019

coastline change relative to 2014 coastline (Red: erosion / Blue: accretion) (b) relative coastline change per year consecutive years (c) Google-earth map showing the sand nourishments, detached breakwaters and groin field installed during 2014-2021.

Further north, in Thoduwawa, erosion is considerable after 2019, and the erosion signal appears to be propagating even after the sand nourishment in 2017. However, with the construction of groin series, the erosion signal is partly controlled to some extent. As a result, it is expected that the erosion signal will be bypassed in the future to the north (north of Thoduwawa).

<u>Wave climate assessment and wave model setup (SWAN)</u>

The Delft3D-Wave module is used in this study to execute behind the open source model SWAN, which was developed by Delft University of Technology in the Netherlands. In Deldt3D model set up, three offshore locations have been defined for offshore wave boundary condition as input for SWAN numerical wave modeling. The Model domain and bathymetry are shown in the figure 5.

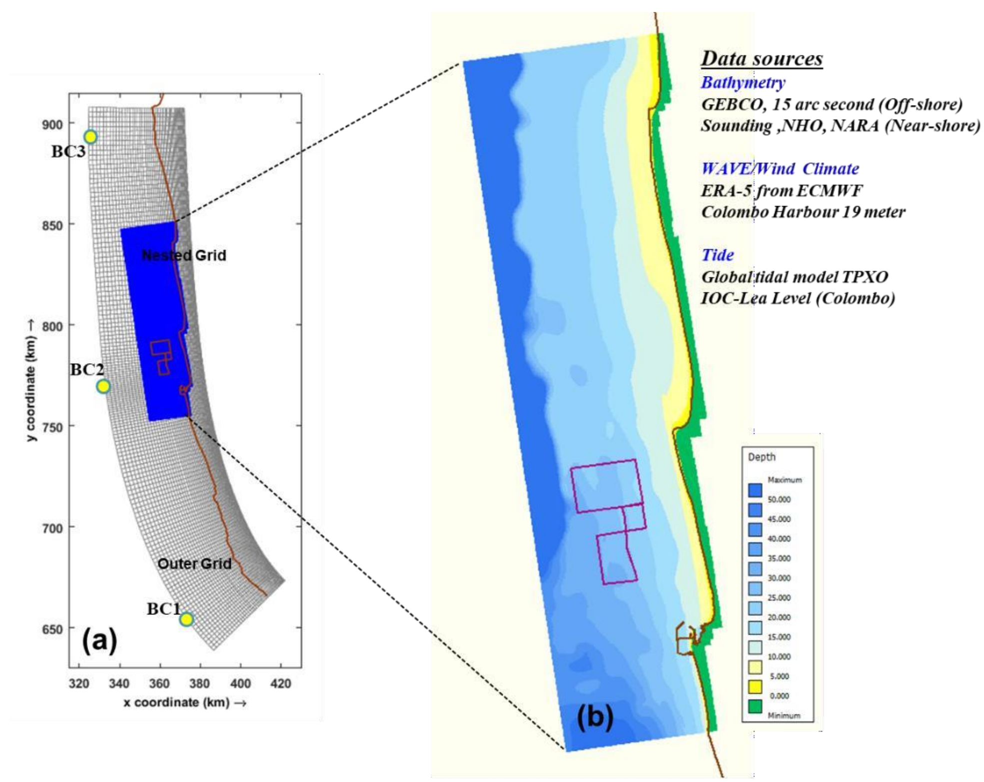


Figure5: Description of Model domain and bathymetry(a) Structured girds of M' Lavinea to Chilaw (Ash colour is overall grid and Blue colour is nested detail grid and yellow dots are used to derive boundary conditions for offshore (b) Bed elevations of detail wave model (in meters w.r.t. MSL).

Delft3D wave parameter settings closely followed those that were successfully used in a comprehensive modeling study undertaken for the West coast of Sri Lanka (Jayathilaka, 2019) and are summarized in Table 3 below.

Table 3: Delft3d-WAVE parameters

Diffraction	Activated	**Wave setup**	Activated
Wind growth	Activated	**Forces**	Radiation stress
Whitecapping	Activated	**Depth induced breaking**	Activated
			Alpha: 1
			Gamma 0.73
Quadruplets	Activated	**Non-linear triad interactions**	Activated
			Alpha: 0.1
			Beta: 2.2
Refraction	Activated	**Bottom friction**	Activated
			Type: JONSWAP
			Coefficient: 0.067

ERA-5 data from the European centre for medium range weather forecast (ECMWF)were used for the off-shore wave climate analysis. The ERA5gives the resolution of 0.1x 0.1reanalysis data drives from the third generation WAM model, which is coupled with the atmospheric model.

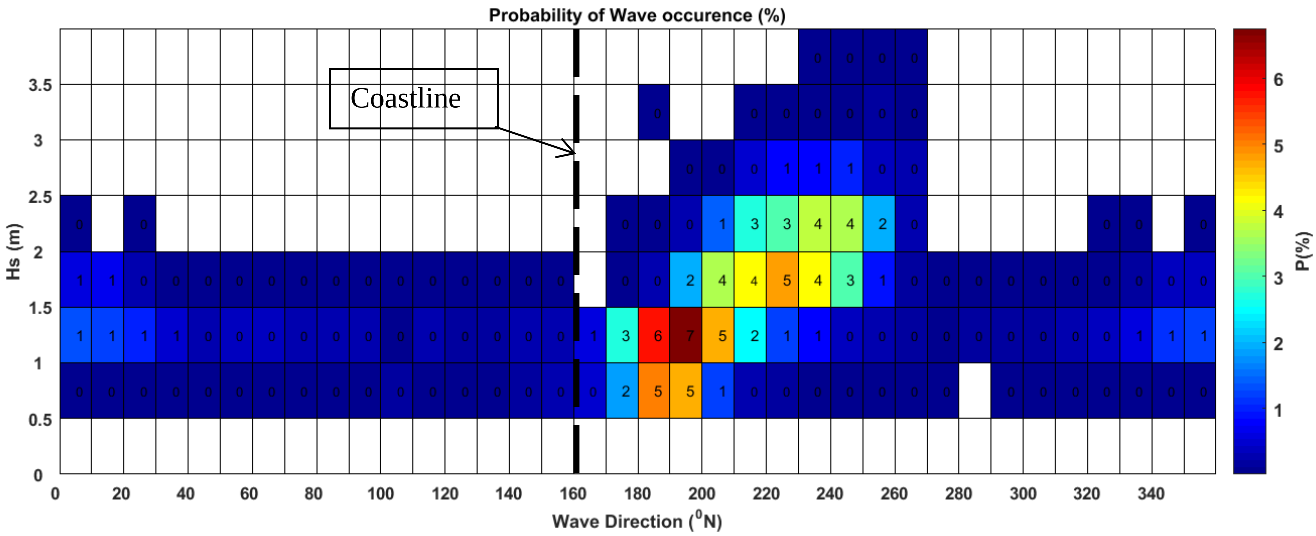
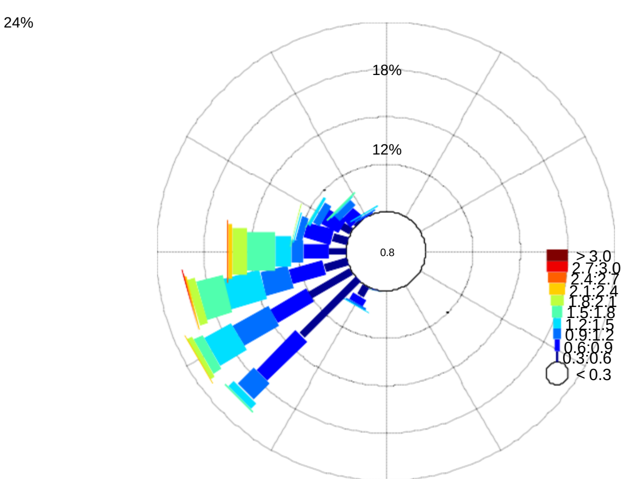


Figure 6: Overview of offshore wave climate at reference location (BC2) off Colombo

Mean wave direction and significant wave height are divided into 36 and 8 bins respectively (see fig, 6). Probability of wave occurrence for each bins were calculated. 93 scenarios have been selected covering 5 years wave data set (2017-2021) consists of 14600 wave records for each boundary points. The schematized offshore wave scenarios are similar to the durations of the wave scenarios that have been transformed towards the coast with the SWAN wave model.

Measured data **Model data**



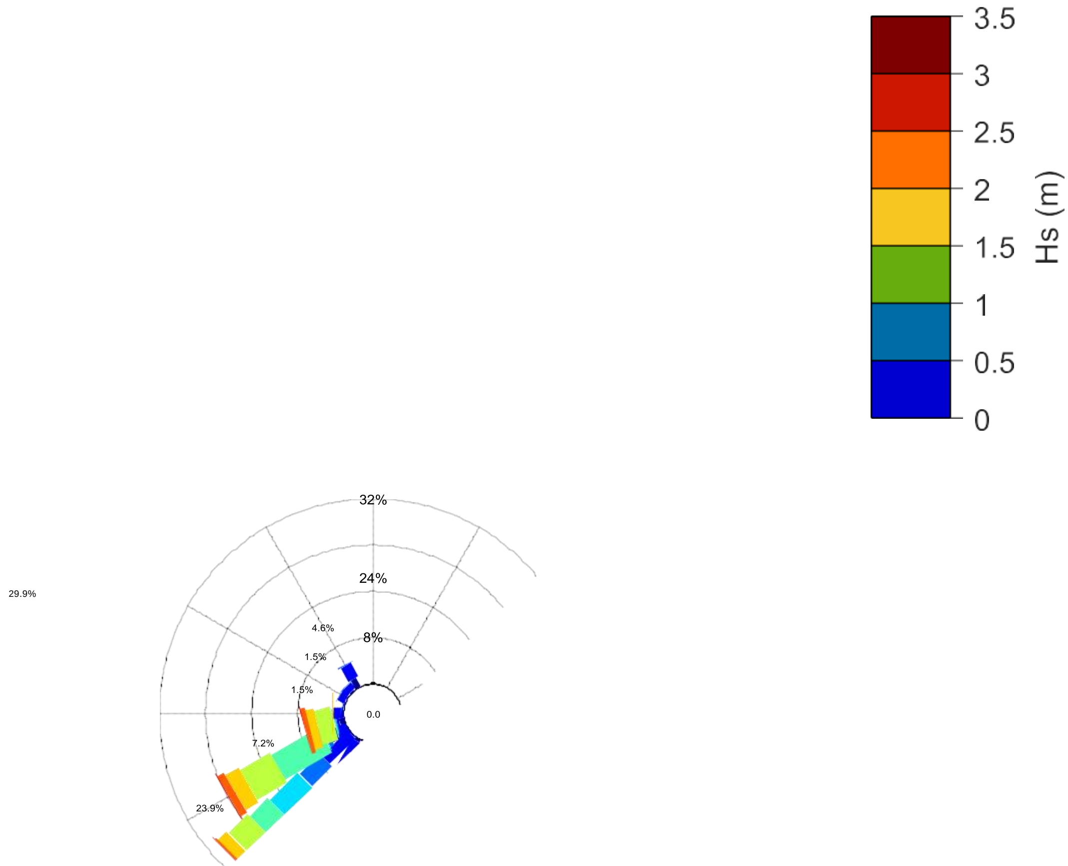


Figure 7:Comparison of Wave roses of significant wave height at Colombo 19m depth a) buoy measurements b) Delft3D wave transformed.

The output of near shore wave scenarios is used to calculate near shore wave energy, which is then employed in a hydrodynamic model of sediment transport and a scenario analysis of the effects of CIFC reclamation and mega sand mining. In this study, 30 near shore locations covering all 4 littoral coastal cells have extracted at 15 m depth shown in the figure 8.The output of Delft3D-WAVE model has been used to extract wave condition over the computational grid. Near shore wave climate which is used as input for sediment transport is considered as most important factor in the study.

The figure 7 compares and illustrates near-shore wave conditions at the location where Colombo wave buoy was installed. The transformed wave, as shown in Figure 7, has a pattern that is similar to the measured buoy data in terms of direction and magnitude, with the exception of a few bins particularly in higher wave height. Also, it Important to notice that wave heights are getting weaker towards the north.Furthermore, waves approaching the coast are more or less regular and converge into a narrower band, which is refracted when propagating in the nearshore zone.

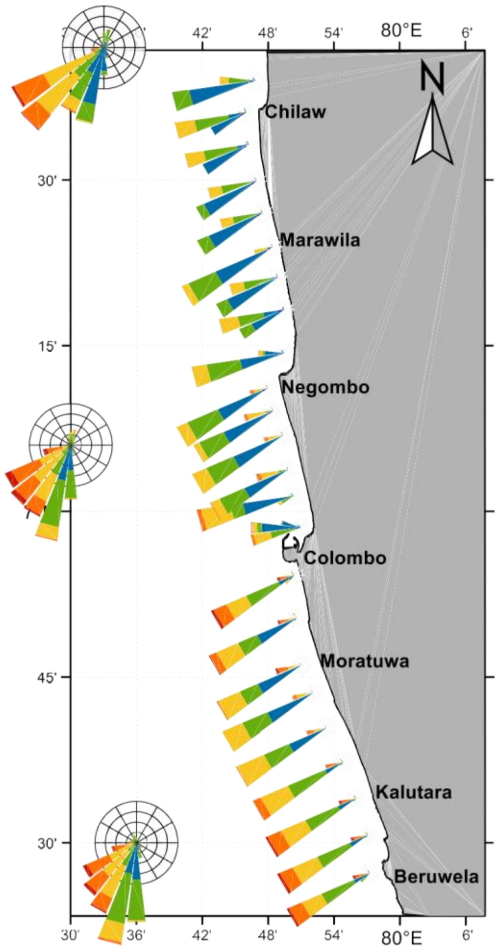


Figure 8: Extracted near shore wave climate in the defined coastal cells at 15 m depth.

Furthermore, the model appears to overestimate wave heights at Colombo. This may have something to do with bathymetry. However, significant wave height and wave direction for a specific time period are compared with measured data to have a thorough grasp of these changes.

Determining the spatial variation of Littoral Cutoff Diameter of sand and its relation to the wave energy in the western coast.

Alongshore sediment sampling between Beruwela to Chilaw was collected as shown in the sampling map (Fig A.1). Sand samples were gathered at each of 30 transects at specific locations of berm crest and swash zone (Fig 9).

Figure 9: Sampling location of Swash zone and berm Crest in Kaluthra Beach.

All the samples were collected in October 2021, during the neap tide period and. Riffle Sample Divider was used to select 100 g of each sample, which were sieved using a standard set of Sieves with sieve sizes ranging from 4000 to 63 microns. The mean grain size (D50), D10, D90, sorting, Skewness, and Kurtosis were calculated and extracted for further analysis (Folk and Ward method).

The study compares the median grain size values of samples collected in swash beach and berm crest. The corresponding wave power (KW/m) at 15 m depth were calculated using wave schematization method describe in previous section.

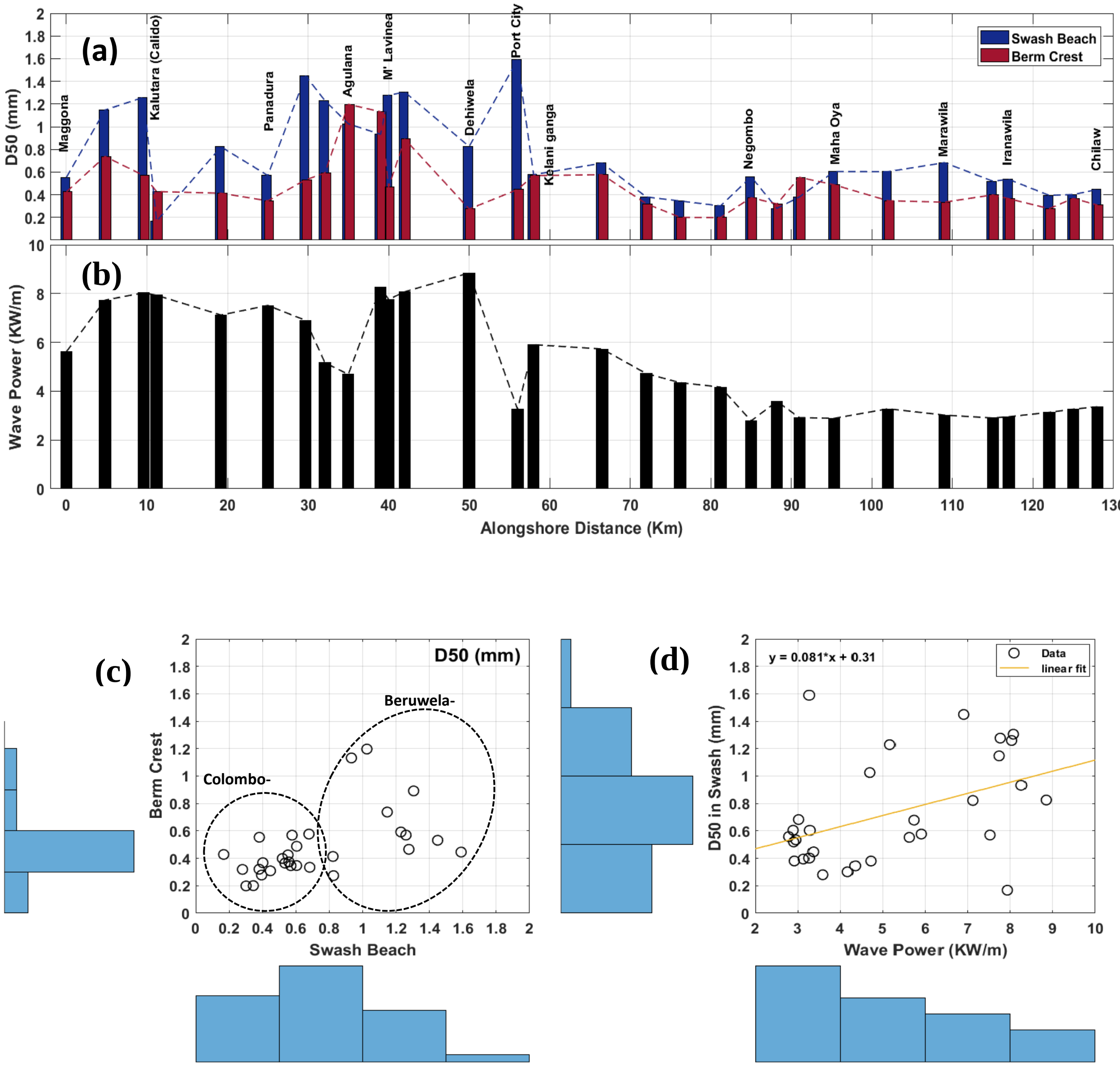


Figure 10: Comparison of median grain sizes (D50) of Swash beach and berm crest (a) Wave power calculated at 15 m water depth of sampled transect (b) correlation graph of D50 values of Berm crest and Swash beach (c) and correlation graph of D50 value of Swash beach and wave energy.

The wave energy (E) transportation per meter of wave breadth quantifies the amount of mechanical energy available in waves can be estimated as described in equation,

$$E = \rho . g^2 . T . \frac{H^2}{(32.\pi)}$$

ρ - density, g - gravitational acceleration, H - significant wave height , T- Wave period

The wave power is directly proportional to square of significant wave height where the wave height decrease northward along the western coast of Sri Lanka as observed from the results of SWAN wave model.

Except for transects at Kalu River (Calido beach) and Kelani River (Mattakuliya beach), the berm crest is finer than the swash beach Due to wave action, fine particles are washed away by stormy conditions, the Swash and near shore sand are often coarser than the dry visible beach. In our studies, this feature is clearly visible. Swash and berm samples have median grain sizes ranging from 0.6 to 1.0 mm and 0.2 to 0.6 mm, respectively. In addition, we noticed a considerable difference in D50 values in the coastal segments Beruwela-Colombo and Colomo-Chilaw, where we detected that sand is coarser in south Colombo than in north Colombo (fig 10). This feature is strongly correlate with the spatial variance of wave energy in the western coast of Sri Lanka. Coastal segments of Beruwela-Colombo and Colomo-Chilaw, have median grain sizes ranging from 0.8 to 1.6 mm (coarse-very coarse) and 0.2 to 0.8 mm(medium-coarse), respectively. It is generally accepted that the nourishing sand should be approximately equal to or coarser than that of the native beach (Azoor, 2015).

Beruwela-Colombo has the greatest average wave heights of the entire studied zone, as this sector is exposed to all wave directions. Except for the coastline stretch between Panadura and Agulana, the wave strength in this area ranges from 6 to 8 KW/m. Colombo-Negombo section is sheltered against the southern wave directions by a 2 km long breakwater arm of the Colombo port, which would increase the wave shadow, extending it northwards. As a result, wave conditions in this area (likely up to Uswatakeiyawa) would calm down. The average wave energy in Uswatakeiyawa is 6 KW/m, gradually decreased to 3 KW/m up to Negombo. The typical wave energy in the Negombo-Chilaw region is rather modest, averaging around 3 KW/m.

The littoral cutoff diameter (LCD) on Sri Lanka's western coast is calculated using data from sieving analysis. GLOGOCZOWSKI and WILDE (1971) and HICKS and INMAN (1987) were the first to recognize the notion of LCD along the wave-dominated California coast. The LCD is agrain size threshold below which no significant amount of sand will stay on a particular beach (HICKS, 1985). Sediment finer than the LCD supplied to a beach will likely be easily entrained, suspended, and deposited offshore as a permanent loss to the beach system (EITTREIM et al., 2002).

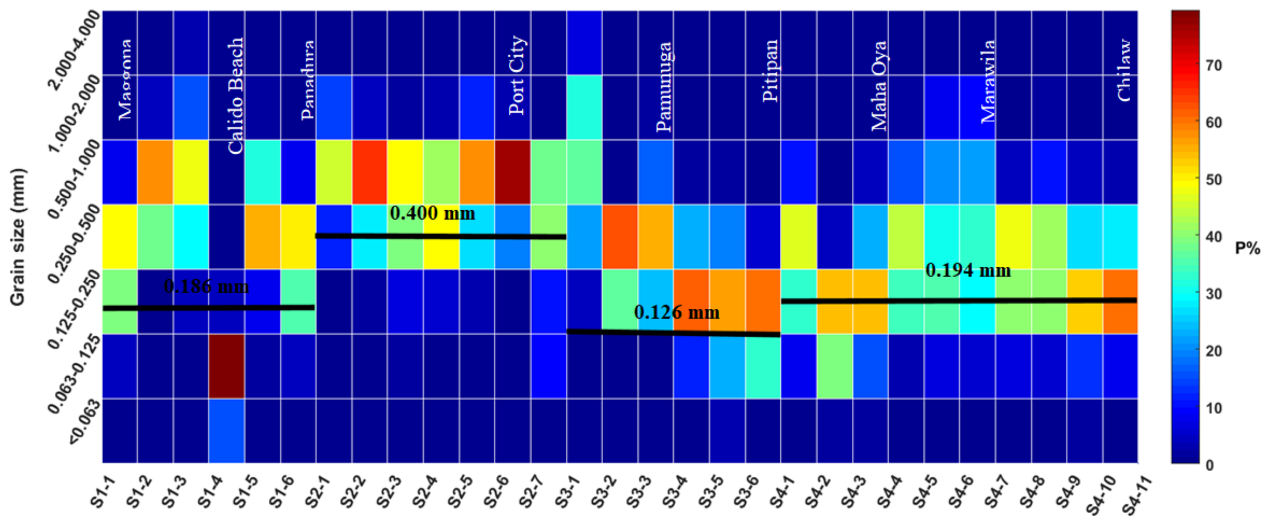


Figure 11: Map of spatial variance of grain size passing along the coastal stretch between Beruwela to Chilaw.

The LCD values are calculated for four coastal littoral cell using the method of HICKS (1985). The LCT is determine by taking the average D10 value(the grain size for which 90% of a sample is coarser and 10% is finer based on sieve analysis) of four defined littoral cells and then subtracting one standard deviation from that number to arrive at an LCD. The map of spatial variance the LCD values are shown in figure 11.

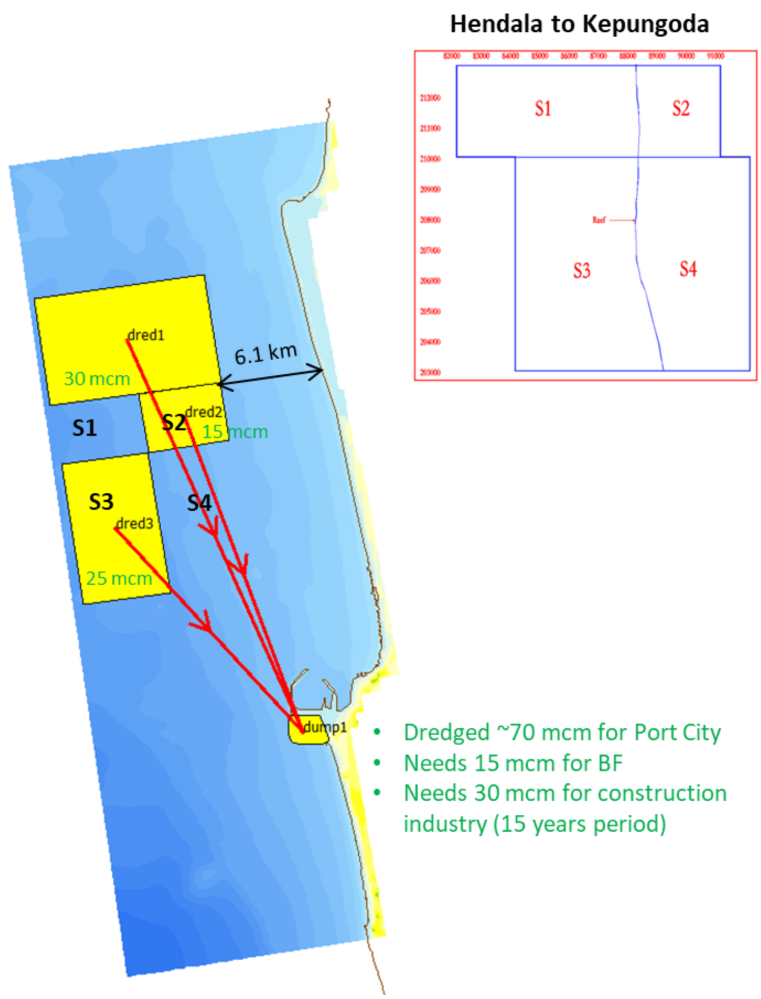
<u>Assessing the Impacts of CIFC reclamation and mega sand mining on the prevailing coastal environment (numerical modelling)</u>

Coastal erosion has been a long-term problem in the West Coast of Sri Lanka that has led to a series of socio-economic and environmental impacts. Recently, the development of the Colombo

International Financial City (CIFC) reclaimed 269 hectares of land from the sea, and 65 million cubic meters of sand is being used to land reclamation works in the vicinity of CIFC. The impacts of this intense reclamation, mega sand mining, and other coastal development activities such as 2Km long Colombo south breakwater on the prevailing coastal environment are poorly known.

In this section, impacts of CIFC reclamation, mega sand mining and Colombo South Break Water(CSBW)on the prevailing coastal environment will be assessed. The schematized wave condition explained in wave model setup (SWAN) and same hydrodynamic grid and settings were applied (see table 3). Bathymetric data during the post- dredging period in the study area are hardly found in the literature or may not be published by the relevant authorities. Therefore, we calculated an average dredging thickness based on the sand extraction volume used for reclamation works for port city project (Fig 12).

Figure 12: Configurations - Sand Extraction Trench



The SWAN model has been used to simulate the impact of three different configurations as given in the table 5.

Table 5.Details of models configurations.

Scenario No.	CSBW	CIFC	Offshore Dredging
01 (reference case)	NO	NO	NO
02	YES	NO	NO
03	YES	YES	YES

Wave energies at 15 m sea depths along the shoreline between M' Lavinea and Chilaw were determined using separate wave simulations for each scenario. Figure 13 shows the change in wave energy (percentage) in configurations 2 and 3 compared to the reference case.

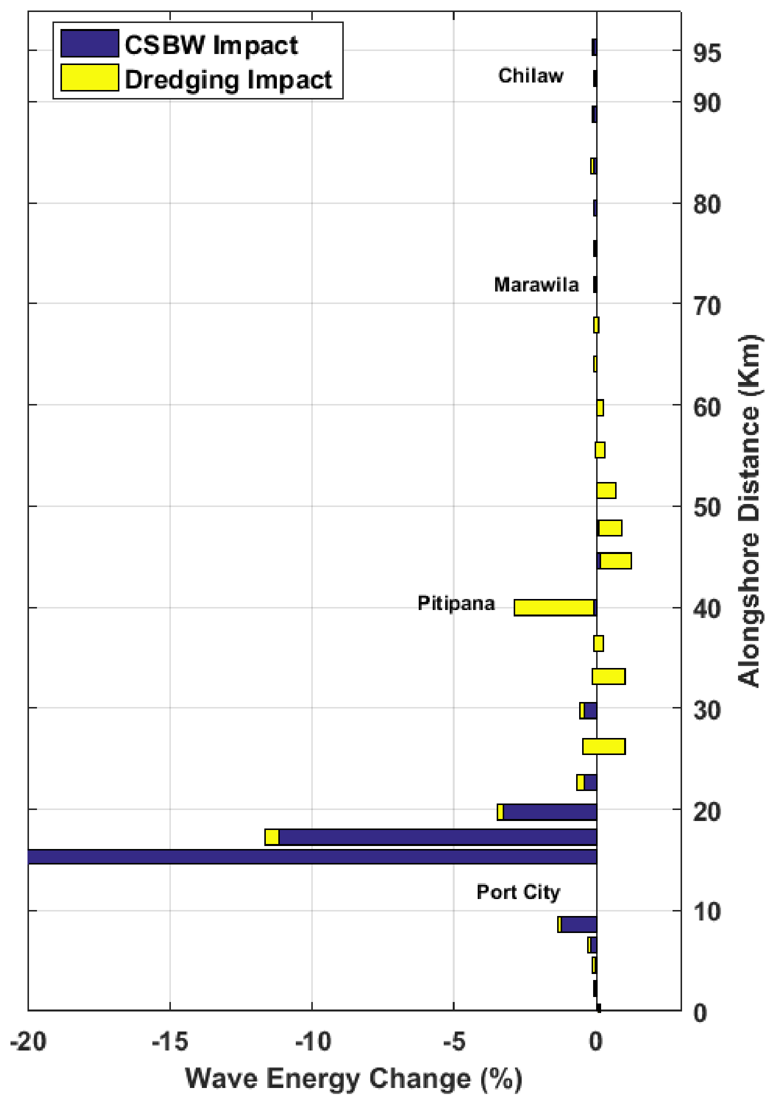


Figure 13: Difference in wave energy power in scenario 2 and 3 with reference to the scenario 1. The blue and yellow bars represents wave energy changes for scenario 2 and 3.

The impact of Colombo's south breakwater arm is significant all the way up to Uswatakeiyawa. Just north of Colombo harbor, the relative wave energy change is greater than 20% and decreased to 4 % near Kelaniriver. This is due to the wave shielding of 2 Km long breakwater arm of Colombo port. Many studies have highlighted this coastal stretch (between Colombo and Dikkoviata) as an erosion prone area (Jayathilaka 2019, Illamgakoon 2021, CC&CRMD, 2008). The downstream, notably the coastal stretch between Negombo and Chilaw, is not significantly affected by CSBW. Offshore dredging has a variety of effects, with the greatest impact being seen in the Pitipana area, which is located on the seaward side of the dredged pit.The impact of offshore dredging can be seen for up to 20 kilometers on both sides of Pitipana. However, in the Marawila area, the effect is insignificant. As a result, neither the CSBW nor offshore dredging has a significant impact on the Marawila area.

Outputs & outcomes

Output	**Outcome**
Field measurements: High resolution Cross-shore profile survey for Marawila Cross-shore profile sediment sampling data (Marawila) Along shore sediment sampling (berm/swash) between Beruwela and Chilaw Monitoring of Fluvial sediment of Maha oya	- Increasing the strength of research quality baseline data for Oceanographicdatabase, research and model validation.
Mapping coastline retreat, evolution and current statusof sand nourishment in Marawila.	- Information required for coastal defence re-alignment, modification, planning and implementation of currentand future coastal defences. Increasing the awareness amongst stakeholders (CCD/ Fisheries/Urban communities, tourism)
Wave climate assessment and wave model setup (SWAN) for Near-shore area of Western coast.	- Information/data required for coastaldevelopment projects such as sand nourishment, beach front and ports.

Littoral Cutoff Diameter data/map in the western coastof Sri Lanka	- Information/data required for conducting EIA's for planning and implementing coastal development projects such as sand nourishment, beach front.
Map of impacts of CIFC reclamation and mega sand mining on the prevailing coastal environment (numerical modelling)	- Information required for coastal defence, planning and implementation of current and future coastal defences.

Conclusions

The primary purpose of this research is to determine the suitability and practicality of sand engine nourishment as a strategy for preventing coastal erosion on the Marawila beach in Sri Lanka. To better understand the oceanographic setting in the area, field surveys, coastal erosion/accretion trends, and numerical modeling were carried out. The sediment data obtained along a 130-kilometer stretch of coastline from Beruwela to Chilaw was studied to learn more about the spatial variation of sediment distribution, littoral cutoff diameter, and its relationship to near-shore wave climate.

Except for the area where initial sand nourishment was collected in 2017, the Marawila-Thoduwawa coastline is still deemed to be erosion prone. From Marawila (Palm Bay hotel) to Thoduwawa(Wella Para Rd), a series of groins covering 4.6 kilometers were built. As a result, these sequence of groins will control erosion along the Marawila-Thoduwawa coastline region, even if it affects the beach's scenery. Further north, in Thoduwawa, it is expected that the erosion signal will be bypassed in the future. Furthermore, the median grain size in Marawila-Thoduwawa beach is 0.5-0.7 mm, and future nourishment should be the same or coarser. It is recommended that future nourishment be done on the leeward side of the groin field.

The numerical modeling study assesses the impact of Colombo's south breakwater arm and offshore sand mining for CIFC on the Western Coast. The impact of CSBW and offshore sand mining on Marawila beach was found to be insignificant (based on wave energy change). The impact of offshore dredging is greatest in the Pitipana area, and the impact of CSBW is greatest up to Uswatakeiyawa. Furthermore, a separate study on the coastal sediment budget for defined littoral cells should be conducted, including all sediment sources and sinks, to understand the overall impact on the western coastline.

Recommendations

We discovered a significant variation in D50 values in the coastal segments Beruwela- Colombo and Colomo-Chilaw in this investigation. The Beruwela-Colombo segment (0.8to 1.6 mm) is coarser than the Colomo-Chilaw segment (0.2 to 0.8 mm). It is generally accepted that the nourishing sand should be approximately equal to or coarser than that ofthe native beach. Therefore it is strongly recommended to study the D50 and LCD values of native beach and nourishing sand.

In Marawila, beach sand nourishment was completed in 2017, and the erosion signal appears to have continued even after the sand nourishment. Hard structure (groyn series) controls erosion in this area, although it is expected that the erosion signal will be bypassedin the future to the north (north of Thoduwawa). As a result, it is recommended that the sand engine nourishing method be considered, in which the sand is transported alongshoreto the nearby shores in accordance with the philosophy of building with nature.

This study collected sediment samples at the end of the SW monsoon period. Analysis of D50 and LCD are based on those data. It is recommend collecting sediment samples at theend of NE monsoon period and repeating the calculation to see the seasonal changes in thecoastline.

The sediment transport model is setup based on the validation of wave and current measurements. The sediment transport measurements in the surf zone are challenging andwe found no data in this coastline in literature. Therefore, it is recommended collecting sediment transport measurements together with the wave and current in order to validate the transport model.

The hydrodynamic model for the SM configuration should be modified to reflect the mostrecent bathymetry.

Constraints

Measurement of Near-shore sediment transport and fluvial sediment data are challengingdue to practical issues (technical) and vandalism by fishermen (social issue).

Financial Allocation : 650,000 Rs

Financial progress : 85 %

Physical Progress: 70 %

References:

Abeykoon, L. C. K., et al. "Are Coastal Protective Hard Structures Still Applicable with Respect to Shoreline Changes in Sri Lanka?." (2021).

Azoor, R. M., et al. "Performance Forecasting for the Beach Nourishment Project at Palliyawatta-Uswetakeiyawa Sri Lanka." (2015)

Benedet, L., et al. "A morphological modeling study to compare different methods of wave climate schematization and evaluate strategies to reduce erosion losses from a beach nourishment project." Coastal engineering 112 (2016): 69-86.

CC&CRMD, 2015.Overview Coast Conservation and Coastal Resource Management Department [WWW Document].Coast Conserv.Coast.Resour. Manag. Dep. Sri Lanka Web Page. (URLhttp://www.coastal.gov.lk/index.php?option=com_content&view=article&id=109&Itemid=57&lang

=en.)

EITTREIM, S.L.; XU, J.P.; NOBLE, M., and EDWARDS, B.D., 2002.Towardsa sediment budget for the Santa Cruz shelf. Marine Geology, 181, 235–248.

GLOGOCZOWSKI, M. and WILDE, P., 1971. River Mouth and Beach Sediments, Russian River, California to Rogue River, Oregon, Part A: Introduction and Grain Size Analysis. Berkeley, California: University of California Hydraulic Engineering Laboratory, Report HEL 2-36, 73p

HICKS, D.M., 1985. Sand Dispersion from an Ephemeral Delta on a Wave Dominated Coast. Santa Cruz, California: University of California, Santa Cruz, Ph.D. thesis, 210p.

HICKS, D.M. and INMAN, D.L., 1987.Sand dispersion from an ephemeral river delta on the central California coast.Marine Geology, 77, 305–318.

Jayathilaka, R. M. R. M. Large Scale Sediment Budgets in Data Poor Environments Via Numerical Modelling: A Case Study of Sri Lanka's South-West Coast. Diss. Unesco-IHE Institute, 2015.

Jayathilaka, R. M. R. M., & Fernando, M. C. S. (2019). Numerical modelling of the spatial variation of sediment transport using wave climate schematization method-a case study of west coast of Sri Lanka. Journal of the National Science Foundation of Sri Lanka, 47(4).

Samarasekara, R. S. M., Sasaki, J., Jayaratne, R., Suzuki, T., Ranawaka, R. A. S., &Pathmasiri, S. D. (2018). Historical changes in the shoreline and management of Marawila Beach, Sri Lanka, from 1980 to2017. Ocean & Coastal Management, 165, 370-384.

Stive, M. J. F., De Schipper, M. A., Luijendijk, A. P., Ranasinghe, R. W. M. R. J. B., Van Thiel De Vries,

J. S. M., Aarninkhof, S., ... & Marx, S. (2013). The sand engine: A solution for vulnerable deltas in the 21st century?. In Coastal Dynamics 2013: 7th International Conference on Coastal Dynamics, Arcachon, France, 24-28 June 2013. Bordeaux University.

Wickramaarachchi B (2011) Spatial Analysis & Mapping, Maha Oya Lowland Corridor.Colombo,Sri 655 Lanka, pp 16-17

Van Slobbe, E., de Vriend, H. J., Aarninkhof, S., Lulofs, K., de Vries, M., &Dircke, P. (2013). Building with Nature: in search of resilient storm surge protection strategies. Natural hazards, 66(3), 1461-1480.

Appendix A:

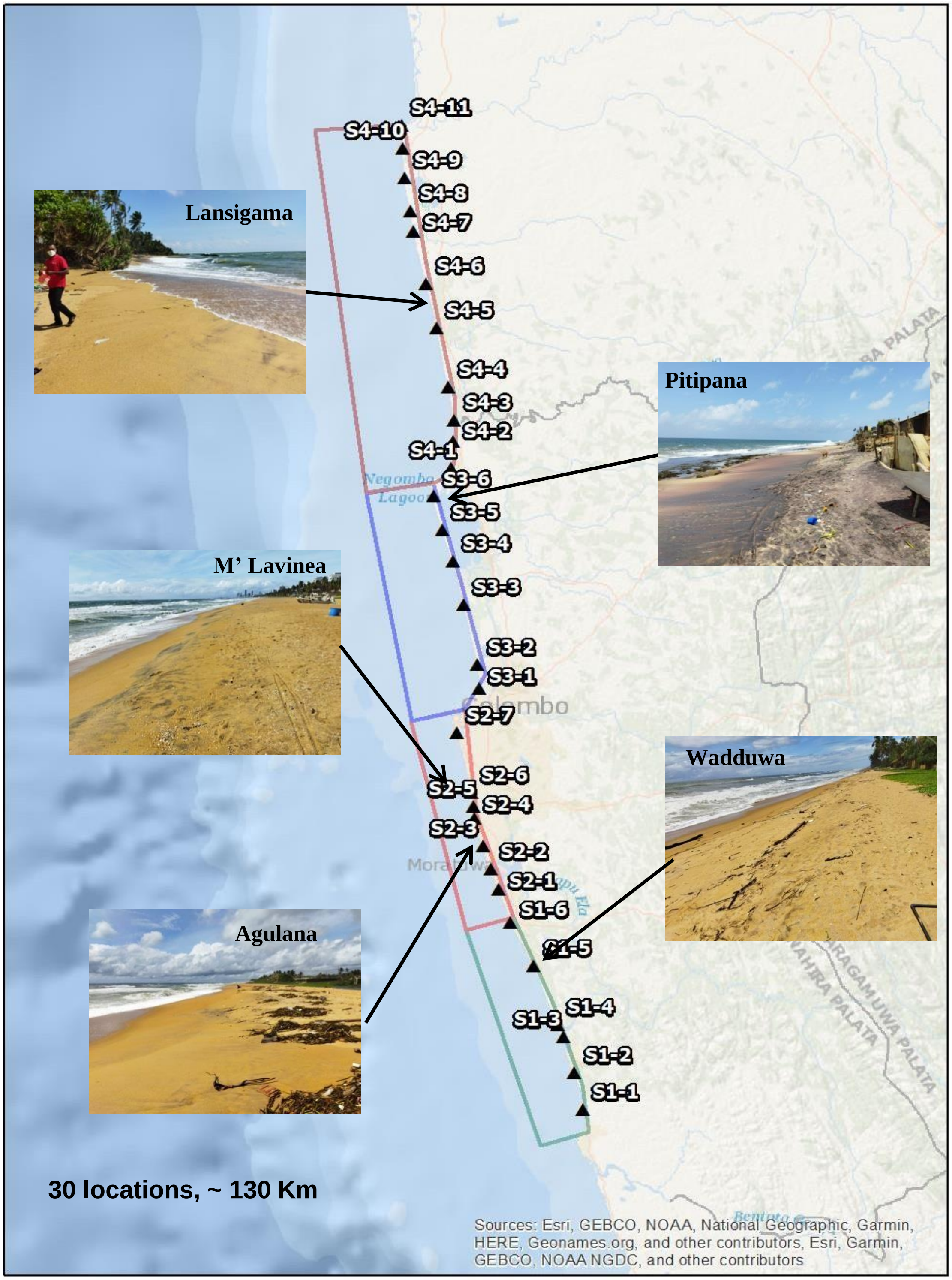
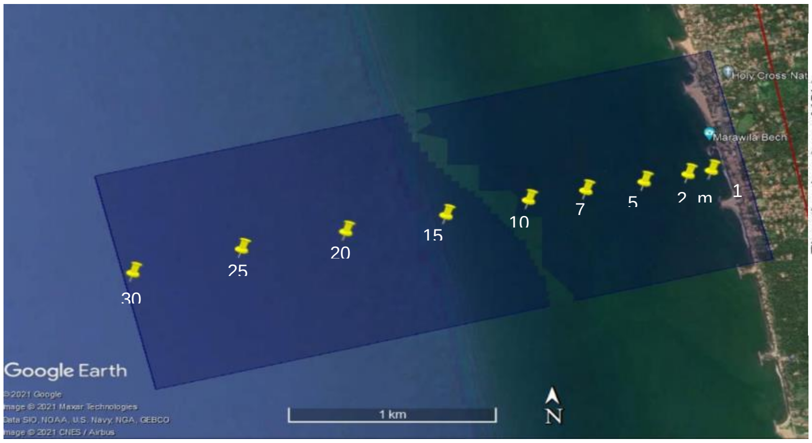
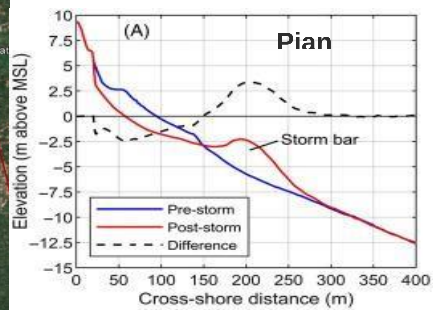


Fig A.1: Alongshore sand sampling points along the coastal stretch between Beruwela to Chilaw





Example of beach erosion resulting from

Fig A.2: Cross-shore profile survey/ Grab sampling for the transects of Marawila.

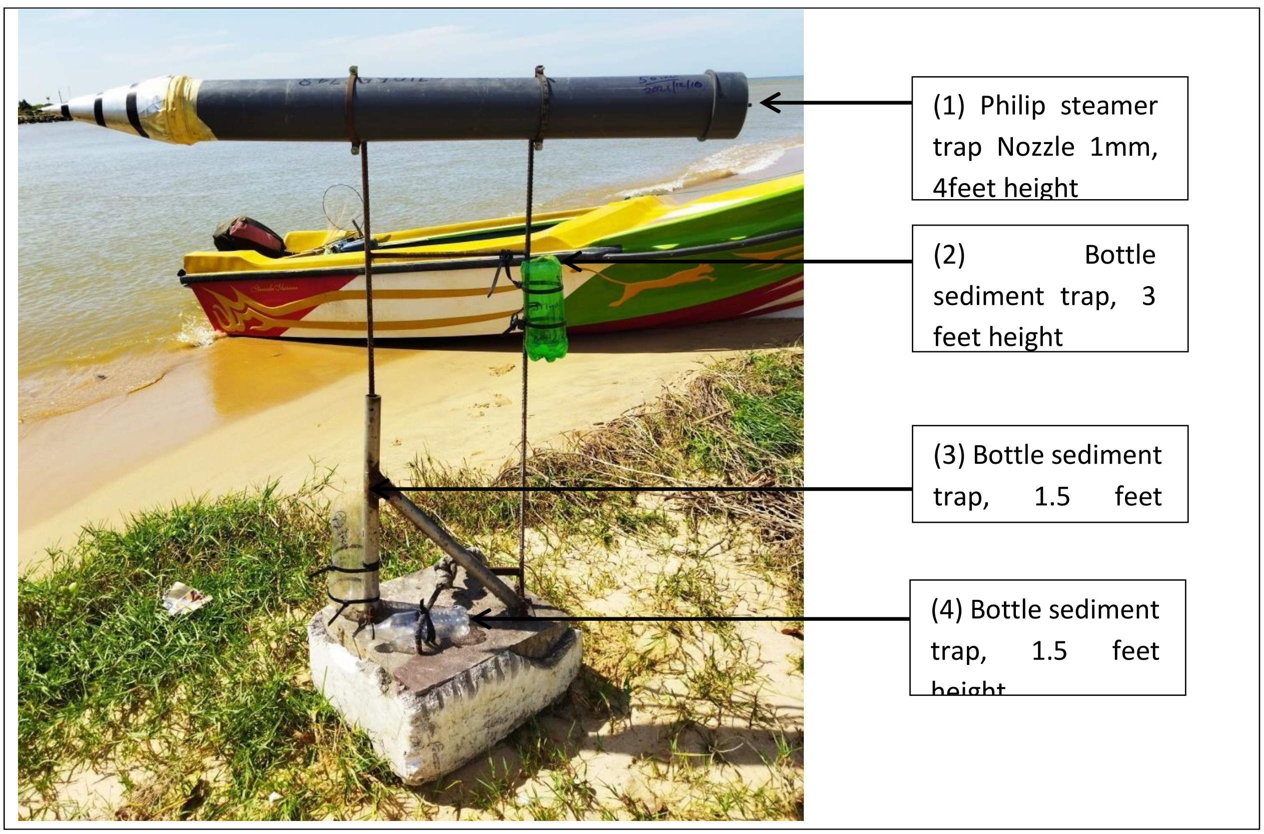


Fig A.3: A close up picture of sediment trap installed in Maha Oya River.

Re-establishing the offshore oceanographic survey capability

7.5 Re-establishing the offshore oceanographic survey capability

Officer/s responsible : Dr. K. Arulananthan, K.W. Indika

Introduction

Research Vessel Samuddrikka is a multidisciplinary research vessel with capability of simultaneously conducting oceanography, hydrography and fisheries research. However, currently the above surveys are conducted independently, which is not cost effective. The basic oceanographic instruments, such as water sampler, ship CTD and hull mounted current meter are not in working condition, need of repair and reinstalled to conduct successful oceanographic surveys.

The oceanographic instrumentuse to works salt water environment. Therefore the weathering, decaying, degrading process is common and speed more than general environment. Most of instruments consisted electronics and highly sensitive sensors covered by water resistive housing with sealed O rings by lubricating materials. That's the reason for the malfunctioning of instrument by making the necessity of replacinglatex rubber tubes, valves, springs, renewing of underwater connectors, mounts and brackets, updating of software, changing configuration, calibration and adjust the alignment.

Main objective

Re-establishing of function of CTD 9plus with Rosset water sampler

Re-establishing of hull mounted Acoustic Doppler Current Profiler (ADCP)

Re-establishing functionality of Autosal instrument

Specific Objective/s

Identification of replaceable spire parts for Autosal, CTD 9 Plus and ADCP

Identification of errors and configuration settings

Purchasing or of spare parts

Fabrication of unavailable spire parts or purchase in the market (or import)

Conduct test run and collect samples and readings

Methodology (Study area, Field sampling, data collection and analysis)

Study area:Research VesselMethodology:

As the first step of re-establishing of malfunctioned oceanographic instrument need to identify replaceable spare and the errors based on the status of instruments. Therefore, need to complete following main steps.

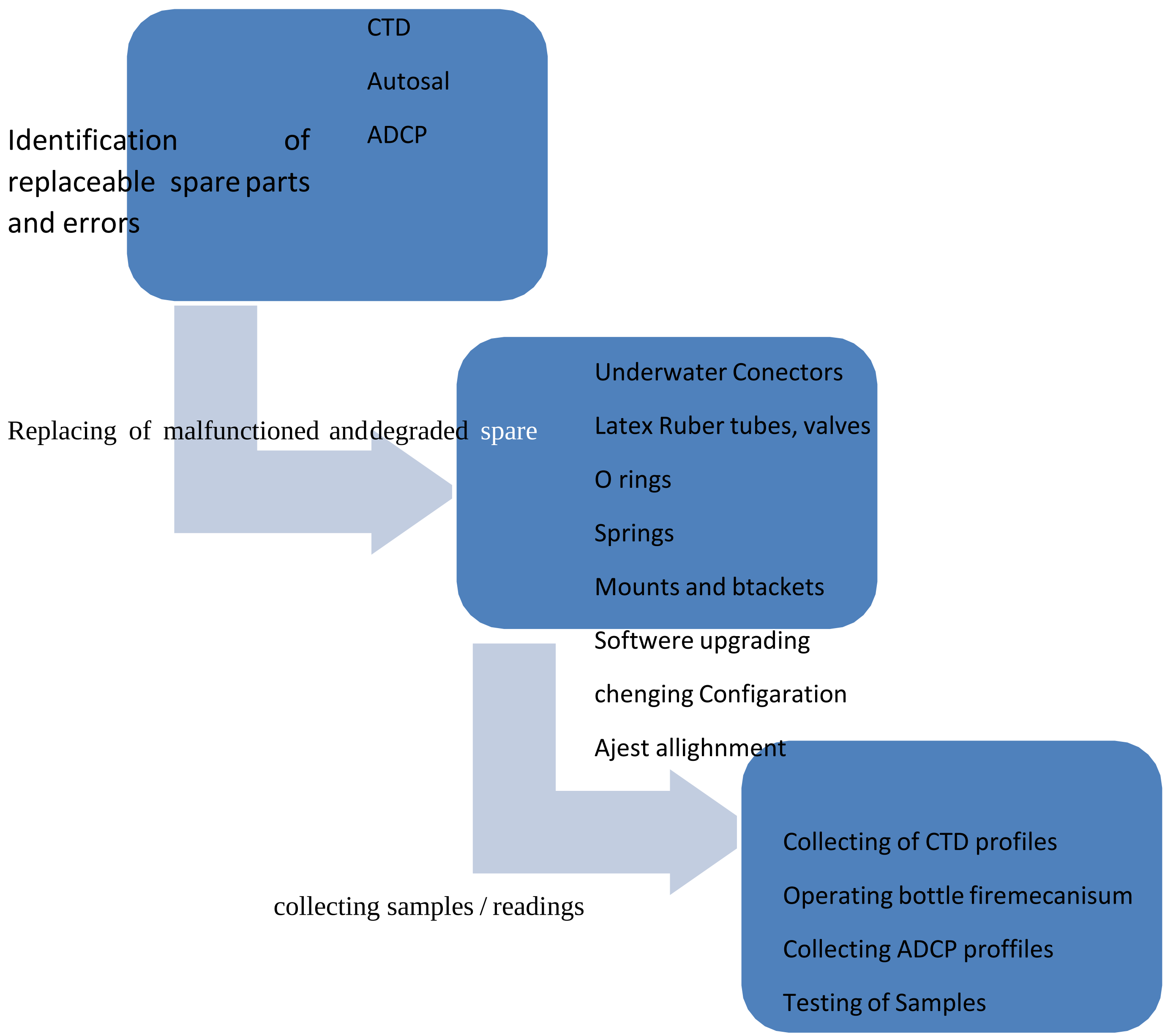

CTD
Autosal
ADCP
Identification of replaceable spare parts and errors
Replacing of malfunctioned and degraded spare
Underwater Conectors
Latex Ruber tubes, valves
O rings
Springs
Mounts and btackets
Softwere upgrading
chenging Configaration
Ajest allighnment
collecting samples / readings
Collecting of CTD profiles
Operating bottle firemecanisum
Collecting ADCP proffiles
Testing of Samples

Figure 01: Methodology for the re-establishing functionality of oceanographicinstrument

Activities proposed to be completed during the period

Making of underwater cable connection between CTD and winch cable

Fabricating of weight baring connector (Guy grip dead end) of CTD and Rosset

Load bearing test of CTD cable.

Establishment of functionality of automated Nisking bottle operating (firing)system

Establishment of functionality of Hull mounted ADCP

Synchronization of navigation track with ADCP data

Establishment of functionality of Autosal instrument

Purchasing of replaceable spare parts

Fabricating of suitablestain steel spring for Nisking bottles

Cleaning of hull mounted ADCP

Results: Activities carried out:

Completed making of underwater CTD cable connector: CTD 19 plus instrument and winch cable need to connect for power supply, transmit the data to the deck unit and issuethe command to close the lid of Nisking bottle based on the sampling requirement. Therefore this connector need to make without trapping air bubbles to secure the connectivity in the deep water under the high hydrostatic pressure.

Fabricated load baring connector (Guy grip dead end) between CTD and winch:The CTD19 plus instrument not included battery pack in itself. Therefore we have to supply powerthought the same cable (2000m)while bearing 600 kg of weight without damaging the physical structure of the cable during the deep sea profiling. There is no Sri Lankan marketto purchase this connector.

Figure 02: Fabricatedload baring connector (Guy grip dead end), between CTD and winch

Conducted load bearing test of the CTD cable: The CTD cable is 2000m deep and it's nearly 10 years old. Therefore we have to ensure the strength of cable before use deep seaprofiling.

Figure 03: testing of load baring capacity using weight know concrete slices

Cleaned the hull mounted ADCP transducer surface: The protective window of theADCP,cleaned by the assistance of Sri Lanka NAVY and RV Samuddrika crew. The transducer covered Polyurethane layer can be damaged by sand blast, hammering and chiseling during the cleaning of deposited barnacles/ ($CaCo_3$), therefor need to prevent mechanical damage during the cleaning process.

Figure 04: Cleaning and checking ofADCP connections

Setting of ADCP configuration: After established the connectivity need to check the functionality of each beams by test running of BBTalk software. After that VmDas used for the data acquisition and Wnadcp used for processing of the collected data.

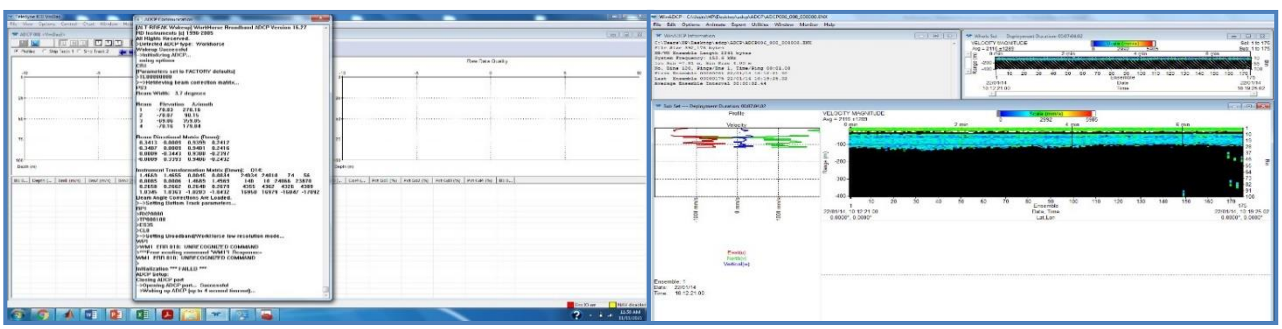


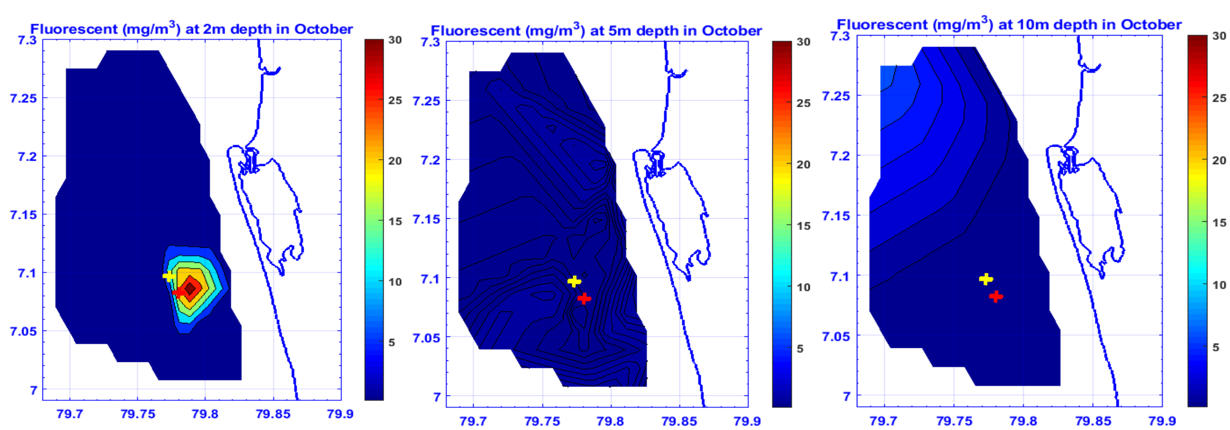
Figure 05: Setting of ADCP configuration

Completed synchronization of navigation track with ADCP data: During moving the ship need to match with ship track and ADCP observations to an exact time. Therefore output of ship navigation (GPS) coupled with the ADCP data profiled by the assistance of Sri Lanka NAVY and ship crew.

Established the functionality of automated Nisking bottle operating (firing) mechanisms: Nisking bottes are operate for collecting of water samples in specific depth by the signals send from the deck of the ship during the deep sea mooring.

Figure 06: Testing of automated Nicking bottle operating mechanism

Re-Establishment of functionality CTD 9 Plus instrument and analyzing of Fluorescent concentration of water column in 2m, 5m and 10m depth for the assessment of Xpress Perl ship crash.The concentration of Fluorescent higher in the 2m depth than to the 5m and 10 m around the



Xpress Perl ship.

Establishment of functionality of Autosalinstrument: The Autosalinstrument is salinity measuring instrument with accuracy of four decimal places (0.0001).This instrument needto maintenance in an air conditioned environment.

Figure 08:Autosal instrument

Developed Matlab cord for converting of Autosal reading to the salinity (PSU)

rt=1.955465;

rt=rt/2; a0=0.0080; a1=-0.1692;a2=25.3851; a3=14.0941; a4=-7.0261;a5=2.7081; b0=0.0005; b1=-0.0056;b2=-0.0066;b3=-0.0375;b4=0.0636; b5=-0.0144;

t=24; % bath temperature in Celsiusk=0.0162;

% onlyvalid the salinity range from 2 to 42

s=(t-15)*(b0+b1*rt^(1/2)+b2*rt+b3*rt^(3/2)+b4*rt^2+b5*rt^(5/2))/(1+k*(t-15));
psu=a0+a1*rt^(1/2)+a2*rt+a3*rt^(3/2)+a4*rt^2+a5*rt^(5/2)+s;

Calibration of CTD data using Autosal instrument.

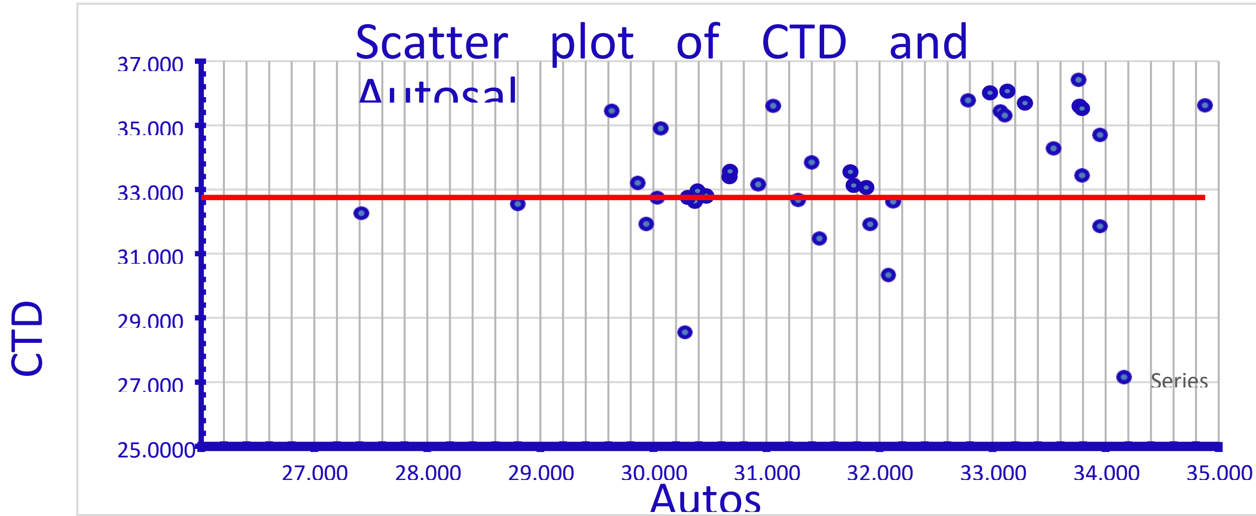


Figure 09: Comparison of CTD reading with Autosal instrument

Outputs & outcomesExpected Output

Research vessel Samuddrikka well equipped to collect water samples, CTD operation andcurrent measurements

Capacity to calibrate on board oceanographic instruments

Expected Outcome

Research Vessel RV Samuddrikka capable of conducting oceanographic expeditions, secure data and producing survey reports

Conclusions

The oceanographic instruments use to works salt water environment. Therefore the weathering, decaying, degrading process is common and speed more than general environment. Most of instruments consisted electronics and highly sensitive sensorscovered by water resistive housing with sealed O rings by lubricating materials. Those are the reasons for the malfunctioning of instrument by making the necessity of replacing latexrubber tubes, valves, springs, O rings renewing of underwater connectors, mounts and brackets, updating of software, changing configuration, calibration and adjust the alignment.

Recommendations

Continues maintenance required to smooth function of the instrument.

The instruments use to need send to the manufacturer to calibrate once two years.

Autosal instrument need to operate under air conditioned environment

Responsibility of the maintenance and operation need to give a trained staff person.

CTD, Rosset and ADCP and cables need to wash using fresh water after every deployment.

Constraints :

Most of spare parts not available in Sri Lankan market. Therefore we had to fabricate. Such as Guy grip dead end, suitable spring for Latex rubber tubes for Niskinbottles, suchas Silicone grease, standard O rings suitable for salt water.

Financial Allocation (Rs)

Financial progress (%)

Physical Progress (%)

7.6 Monsoonal Influence on Microplastic Dispersion in Sub-Surface Marine Waters aroundSri Lanka.

Monsoonal Influence on the Dispersion of Microplastics and Marine Debris in Sub-Surface Marine Waters around Sri Lanka (Phase – I)

Officer/s Responsible: W.R.W.M.A.P. Weerakoon

Introduction: Marine pollution by microplastics and marine litter has been increased over the world, where recent incidents such as the pollutant spill from the collapsed X-press pearl ship demands the continuous assessment of the ocean around Sri Lanka, in order to assess both short- and long-term impact of contaminants. All recent studies in Sri Lanka have been limited to either surface waters or beach sand, and none has focused on subsurface waters, which is why this studyis important for the country. Therefore, in the initial phase, this study has focused on (i) assessmentof plastic and polythene content in subsurface marine waters around Sri Lanka, (ii) assessment of distribution patterns pertaining to seasonal variations, (iii) identifying potential sources of pollution, (iv) assessing physical and chemical properties, and (v) assessment of aging andweathering of plastic and polythene debris found in sea water.

Main Objective: The main objective of this study is to assess microplastics pollution in subsurface Sri Lankan marine waters concerning monsoonal influence, to understand the seasonal and monsoon-influenced variation of pollutants that could be useful to facilitate (i) future research, (ii) impact assessments in case of an cargo spill, and (iii) planning and reformingof national policies.

Specific Objective/s:

To identify and trace microplastics and marine debris released by the collapsed ship, andidentify their existence in the water column, and their distribution around the Island.

To assess the physical and chemical characteristics and thereby to assess the aging andweathering of plastic and polythene debris in subsurface water (deep sea) water.

To study distribution patterns of plastic/ polythene debris with regard to monsoonal effectsand seasonal variations.

To conduct an in-depth analysis on sources of pollution, and chemical composition ofplastic/ polythene debris in sea water.

To construct a time series data set of the pollution level through continuous monitoring.

To develop more effective analytical methods and protocols through experimentation and research collaboration.

Methodology (Study area, Field sampling, data collection and analysis): The western coast (from Colombo to Negombo) was selected as the initial study area during phase - I. Off-shoreandcoastal surveys were conducted to study sea surface and subsurface water (from at least three depths: from 5-20m) at 16 sampling stations. Sampling was done on RV Samudrika, on a seasonal basis. Surface water samples were collected using a manta trawl net (mesh size = 330 µm), whereas subsurface water samples were collected using a Ratner water sampler. A total of320 water sampleswere assessed for microplastics (in the size of 0.3-5 mm).Occurrence of microplastics (in the range of 0.3 – 5 mm) was estimated in terms of number of particles per cubic meter (PCM). Time series data has been collected for the major seasons, while wind speedand current speed data have been collected from secondary data sources.

Activities proposed to be completed during the period

Off-shore and coastal surveys have been planned to assess surface and subsurface waters where the occurrence and the composition of microplastics can be revealed. Obtaining secondary has been scheduled to collect additional supportive information. Preliminary assessments, downloadsatellite data, preliminary field surveys, collection of secondary data, field work for sampling, data preparation/ quality control, analysis of data, formal & informal meetings, dissemination ofknowledge, and project documentation were the proposed activities.

Results: Activities carried out: Deep water sampling was commenced, and the analysis of small sized microplastics in the water column was initiated.Preliminary assessments were done at thestudy sites at a minimum level, while information gathered from literature was used for pre- assessments and planning. Preliminary field surveys were conducted from Dikowita to Negombo. Collection of secondary data was done from satellite/ online data sources, as well as from local survey reports. Field work for sampling was done by conducting 8 cruises in the studyarea. Data preparation/ quality control and analysis of data were done majorly at NARA laboratory. Formal & informal meetings were held with local/ international research institutions.Dissemination of knowledge were made bin terms of two conferences, meetings and scientific papers. Project documentation as at 2022.12.31 was >70%. Results from the Phase – I indicatesthat the surface waters are more polluted compared to all depth levels: 5m, 10m, 15m and 20m.The vertical of distribution showed a relationship to monsoonal weather; wind and current speedswhich should be further studied. Vertical distribution of particulate pollutants were enormous inthe study area during the Southwest monsoon where higher pollutant concentrations were observed throughout the water column. The stratification was less during the Northeast monsoonas a result of low vertical mixing. In addition to the pollutants from the packaging, textiles and fisheries industry, several other industrial particulate pollutants have been found during the study.

Outputs & outcomes:Outputs

Time series data (depth-wise) on microplastic pollution were produced.

Seasonal/ monsoonal based vertical profiles were produced on the abundance and distribution of plastic debris. Maps on spatial and temporal distribution of microplastics were produced.

Physical and chemical properties of buoyant and submersed plastic debris.

Outcomes

Knowledge was created on the occurrence of microplastics in subsurface ocean waters around Sri Lanka. Sharing of knowledge was done through making awareness in conferences, meetings with stakeholders, and scientific publications.

Capacity building on working onboard for the assessment of deep water microplastics is inprogress.

Useful data and information are getting readily available to cater the needs of future research, policy implications, development and conservation pertaining to fisheries and aquatic resources.

Conclusions: The surface layer of the ocean is polluted with more varieties of plastics, and suspended pollutants are found in large quantities even upto 15-20 m depths. Monsoon weatherposes a large impact and influence on the distribution of microplastics.

Recommendations: Further monitoring with time series data is suggested to analyze the vertical distribution patterns of microplastics in the long-run whereasmore research on sources of pollution is required to provide information for decision making.

Constraints: The occurrence in the study region has been altered due to the spill caused by the collapsed cargo Bessel, X-press pearl. Thus, further studies are suggested to assess the occurrence of microplastics in the ocean.Some in-situ data couldn't be obtained due to the malfunctioning of a few field equipment.Influence of monsoonal weather on the degradation of microplastics was hard to study due to the contamination of water by the cargo spill. Thecatastrophe has changed the milieu which needs long-term studies to understand.

Financial Allocation (Rs): 0.6 Mn

Financial Progress (%):

Physical Progress (%): 93

7.7 Ocean status forecasting and oceanographic data base

Officer/s responsible : K.W. Indika, N.G.L. Uthpala

Introduction

Sea level variability and change are manifestations of climate variability and changes by the circumstances of natural and manmade. Continues sea level monitoring, recording andreporting are importance for the study of threatening coastal life and limiting coastal land as an Island state country with the higher potential of ocean based disaster.

According to the record of Intergovernmental Panel on Climate Change (IPCC) the GlobalMean Sea Level Rising (GMSLR) rate during 1901-1990 was 1.5 (1.3 to 1.7) mm per yearwhile during 1993-2010 was 3.2 (2.8 to 3.6) mm per year with greater rate since the end of 19th century. The latest measurement of annual average global sea level trend is 3.3 mmper year according to climate change research center of NASA in July 2021. Rising of sealevel caused by the absorption of atmospheric temperature, expending of oceanic volume and adding of excess water to the ocean by melting of glaciers and ice sheet with reductionof solid water storage on land. The individual contribution of thermal expansion explained50% of sea level rise during 1971– 2018, while ice loss from glaciers contributed 22%, icesheets 20% and changes in land water storage 8% (IPCC AR6 2021).The stored more than90% of excess energy associated by the anthropogenic climate change as the leading contributor for the global thermos-steric sea level rise (J. Climate (2015). Historical recordsof earth surface temperature shows 2010 -2019 is warmest decade ever record as finding of NASA.

Main objective

Establishment of sea level monitoring network

Study of sea level variation around Sri Lanka

Development of national oceanographic database

Specific objective/s

Quantification of sea level trend around Sri Lanka

Study of seasonal and Inter annual sea level change

Study of extreme sea level events (Storm Surge, meteotsunami, El Niña, LaNiña)

Maintenance of existing sea level monitoring network

Renovation of Kirinda sea level monitoring station

Installation of instrument to Point Pedro sea level station.

Development of "Sea Level" web page to sharing data and data product withcommunity

Methodology (study area, field sampling, data collection and analysis)

Study Area

Study area is all the shoreline of the country. Study depend on the receiving data from automated sea level monitoring stations around the country. The present sea level monitoring network consisted five stations at Trincomalee, Point Pedro, Colombo, Mirissa, Kirinda.Siteselection and land clearance were completed for the proposed new tide station at Dondra fishery harbor but procurement processes for construction incomplete due to not recovering of bids.

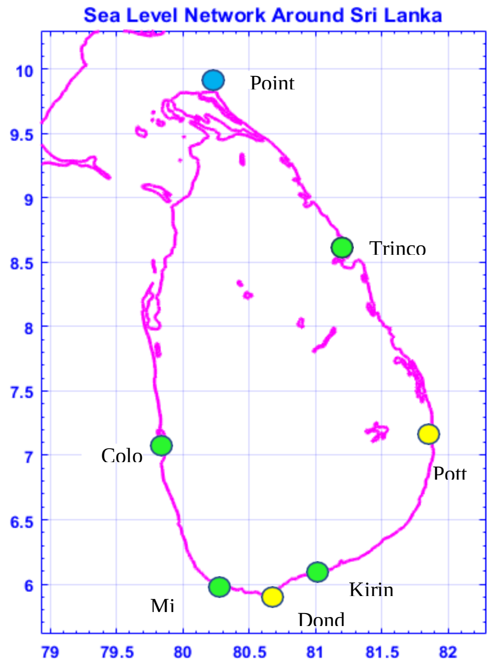


Figure 01: Sea level monitoring network around the country

Table 01: Description of the sea level stations and data collection.

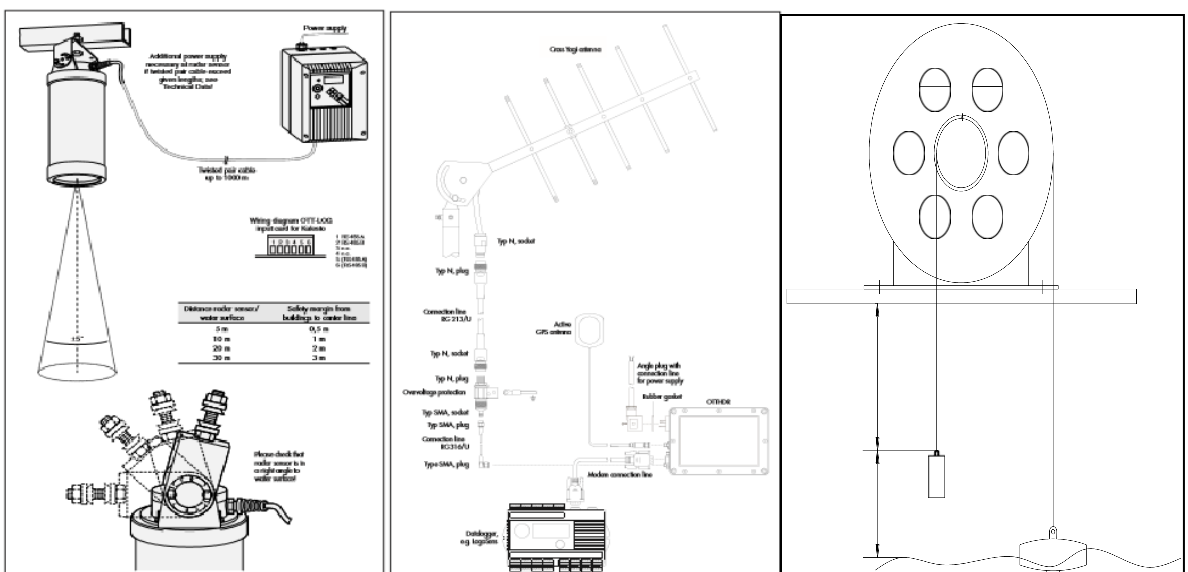
	Location	Status	Parameters	Transmission	Collaboration

01	Trincomalee	Functioning	Water height :Radar and Hydrostatics pressure sensor	Satellite : communication	University of Hawaii, Hawaii
02	Point Pedro	Completed constructions and procurement	Water height :Radar and Hydrostatics pressure sensor	General Packet Radio Service (GPRS) : local communication via Mobitel	First Institute of Oceanography (FIO), China
03	Colombo	Functioning	Water height :Radar and Hydrostatics pressure sensor	Satellite : communication	University of Hawaii, Hawaii
04	Mirissa	Functioning	Hydrological and meteorological :Wind, rain fall, water temperature,tide, pressure,Humidit	General Packet Radio Service (GPRS) : local communication via Mobitel	First Institute of Oceanography (FIO) , Chi
05	Dondra	Completed land clearance, Quotation calledfor constructionbut not received bids	Water height :Radar and Hydrostatics pressure sensor	General Packet Radio Service (GPRS) : local communication	South China Institute of Oceanography (SIO) , China
06	Kirinda	Renovation completed, Instrument received, Completed test run	Water height :Radar and Hydrostatics pressure sensor	Satellite : communication	Hawaii University, Hawaii
07	Pottuvil	Completed Site selection	Hydrological and meteorological parameters	GPRS	FIO, Hawaii

Methodology

The methodology consisted data acquisition, temporary saving and transmission to the data server at head office. The received data to the server need to be completed following main steps in order before use the data product development, downloading, processing, quality controlling and analyzing.

The data process and analysis were conducted by using Matlab R2018a, Panoplyand Microsoft excel. The long term sea level variation was derived using ECMWE reanalyzed data using Panoply software.The tidal range was calculated according to the equations of Understanding of Tide by NOAA (Hicks., 2006). The parameters we use to collect under main two category. They are meteorological parameters such as wind speed and direction, atmospheric pressure, atmospheric temperature, humidity, precipitation and hydrological parameters such as water temperature and sea level height. The data acquisition, temporary saving and transition conduct automatically by pre-defined time interval via satellite and General Packet Radio Service (GPRS). The Mirissa data transmits every one minutes to the NARA data server at the head office via the local communication network (Mobitel). The satellite data transmission conduct every 15 minutes via the Metosat to the server of University of Hawaii and update on the web page of Global sea level monitoring facility of Intergovernmental Oceanographic Commission (IOC) with a delay of few minutes.



A). Radar sensor B). Satellite Transmitter and data logger C). Floating tide gauge

Figure 02: Sensors and transmitters of a sea level measuring station.

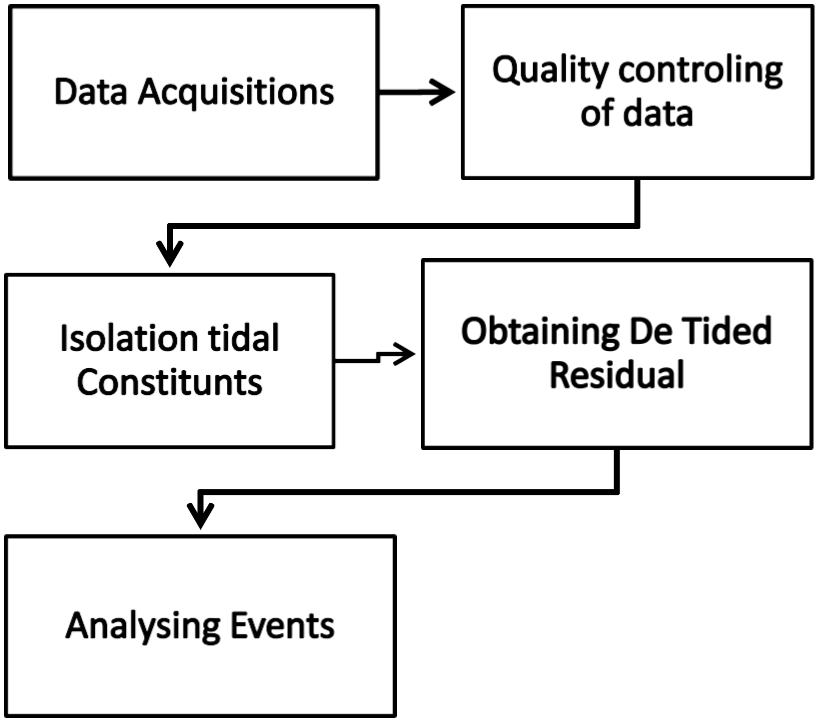


Figure 03: Major step of sea level data processing before identification of events.

The quality controlled data were used to obtain de-tided residual sea level signals and analyze the events such as storm surge, meteotsunami, Tsunami. The analysis conducted using Harmonic analyzing and mathematical function developed by Matlab software, high frequency detection functions, moving average, analyzing of energy density spectrum and fillingof missing time column functions.

Activities proposed to be completed during the period

Quantification of Sea level rise around Sri Lanka

Study of seasonal and Inter annual sea level change

Study of extreme sea level events (Storm Surge, meteotsunami, El Niña, La Niña)

Data downloading, preparation & quality controlling

Data Product development/ web publishing

Purchasing or Develop of Instrument and transmitter to Point Pedro Station

Installation of instrument to point Pedro Sea level station

Maintenance of existing sea level monitoring network

Renovation of Kirinda Sea Level Station

Establishment of sea level station at Dondra fisheries Haber

Issuing of monthly sea level related destructive event report to the Disaster ManagementCenter. (DMC)

Issuing of sea level data and data product for the development work of the country as the consultancy service

Training of university students (Master and Undergraduate)

Results: Activities carried out:

The sea level variation was studied around Sri Lanka using the Mirissa, Colombo and Trincomalee tide gauge observations by segmented time period of a solar day, fortnight, monthly, seasonal and long term. The results were compared with the western coast, southern coast and the eastern coast of the Sri Lanka. The Stellate data was used fromEuropean Centre for Medium-Range Weather Forecasts (ECMWE) reanalyzed data.The tidal related calculation was done according to the equations of Understanding of Tide by NOAA (Hicks., 2006).

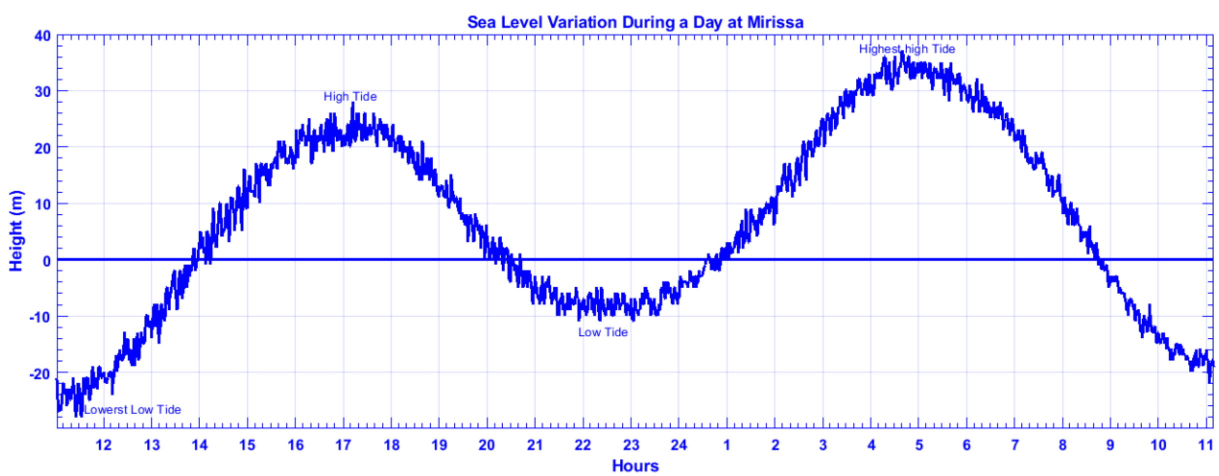


Figure 04: Tidal variation within a day.

The blue line shows the tidal variation in a solar day including two cycle of unequal high tide and low tide. According to the tidal classification it is mixed Semidiurnal (F = 0.2745, F Range: 0.25 to 1.5) which is included two high tide and two low tide per day with different strength within the micro tidal category in the southern coast of Sri Lanka (Hicks., 2006).

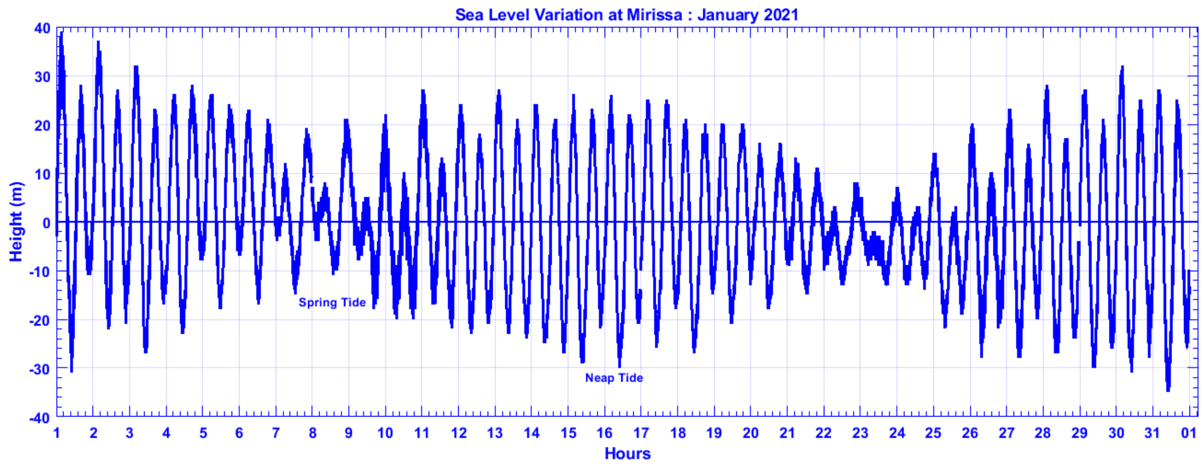


Figure 05: Tidal variation within a month period at Mirissa Tide gauge.

The tidal signal within a month period indicates two fortnight cycles including spring tidal and neap tidal. The spring tides occur during the new Moon and full Moon when the Earth, Moon, and Sun are aligned. Neap tides occur during the first quarter Moon in the middle of the month and again during the last quarter Moon late in the month (Ucar, 2016).

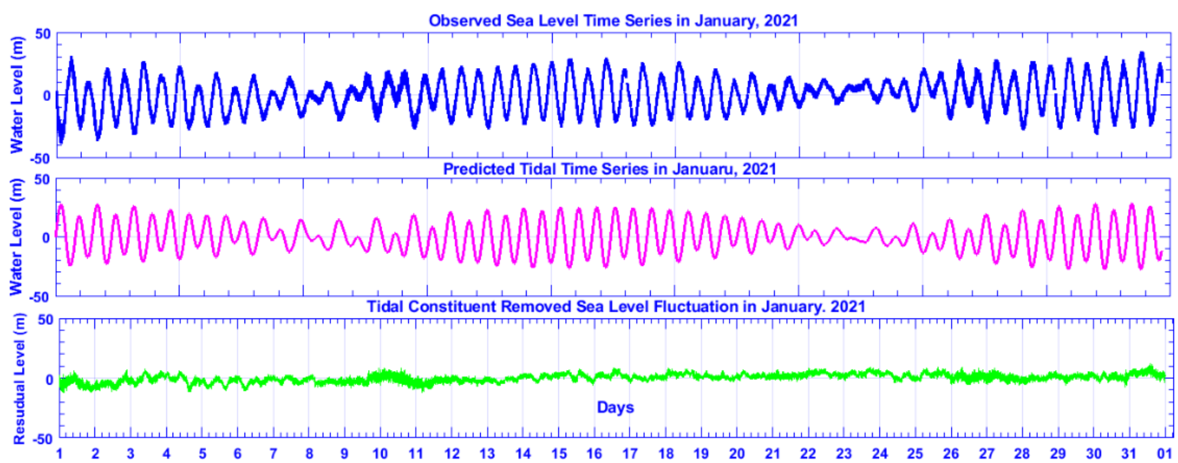


Figure 06: Obtaining of residual sea level variation by removing tidal component

The blue line is the observed tidal time series at the Mirissa tide gauge and the purple line is the predicted tidal time series for the same location and the green line is the residual sea level fluctuation during the same period. The tidal signal removed sea level variation was obtained subtraction of predicted tidal time series from observed water elevation time series.The tidal range was derived using resulted tidal constituents. The spring tidal range is 50 cm while neap tidal range is 11cm in the Mirissa harbor.

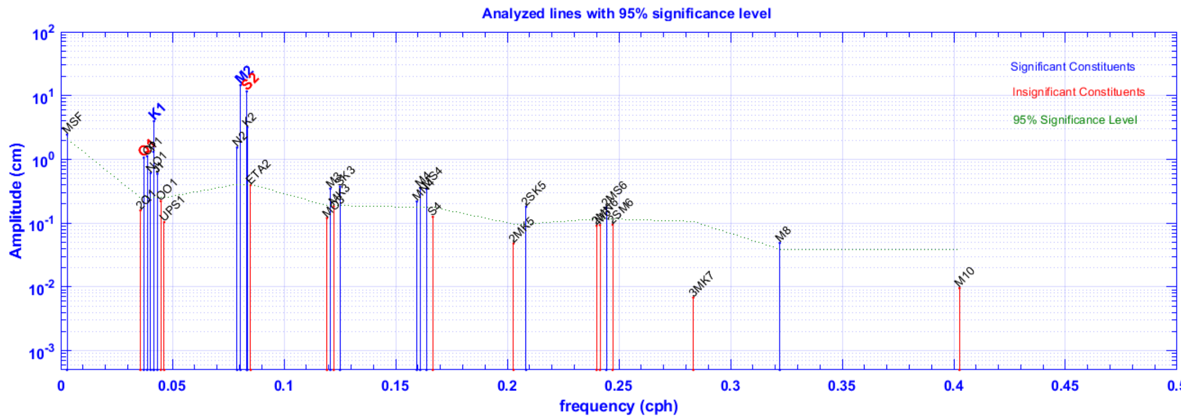


Figure 07: The significat constitutes with tidal amplitude in the suthern coast

The red lines indicate the insignificat tidal constituents while the blue line indicates the insignificant tidal constituents with 95% of confidence level. The amplitude of the K1 and O1 is lower than to the M2 and S2 as shown by the graph. The Semidiurnal lunar (M2) is the highest apmplitude than other constitunets with frequency of 0.082 cph.

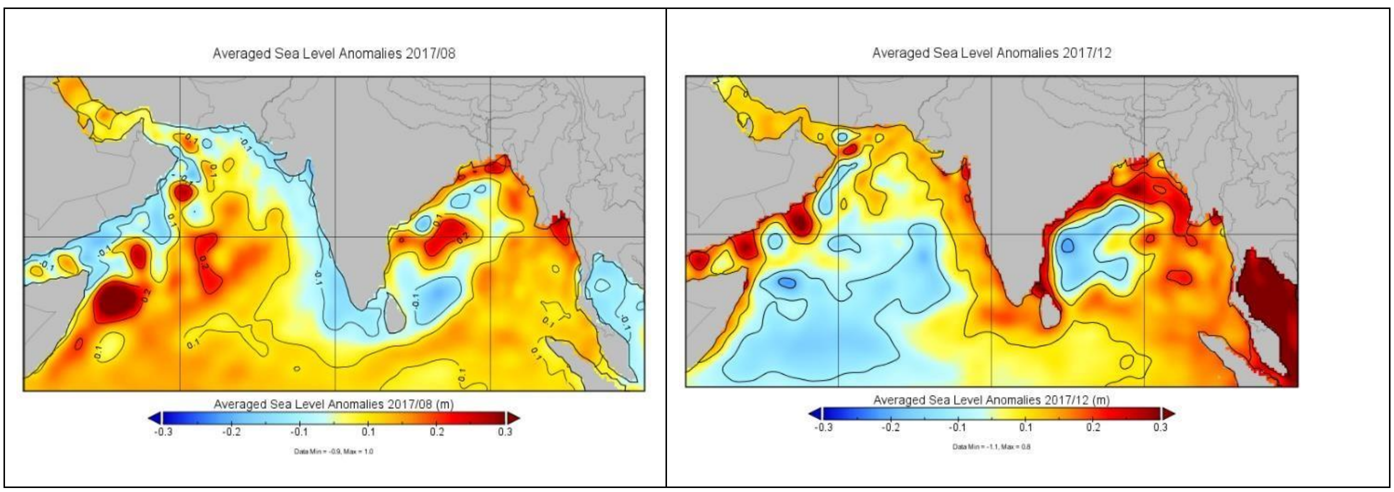


Figure 08 : Seaonanal sea level variation around Sri Lanka.

The sea surface height above the sea level was records in maximum during December while the minumun anomaly in August in the suthern coast of Sri Lanka. The change of salinity & temperature (Steric height), atmospheric pressure, wind and current are the major factors for the seasonal sea level signals in the Sri Lankan coast (Wijerathne., 2004).The sea level anomaly is lower in the south-westward than to the south-eastward by the deflection of the higher water mass toward the east coast than to the west coast through the southern tip of the country

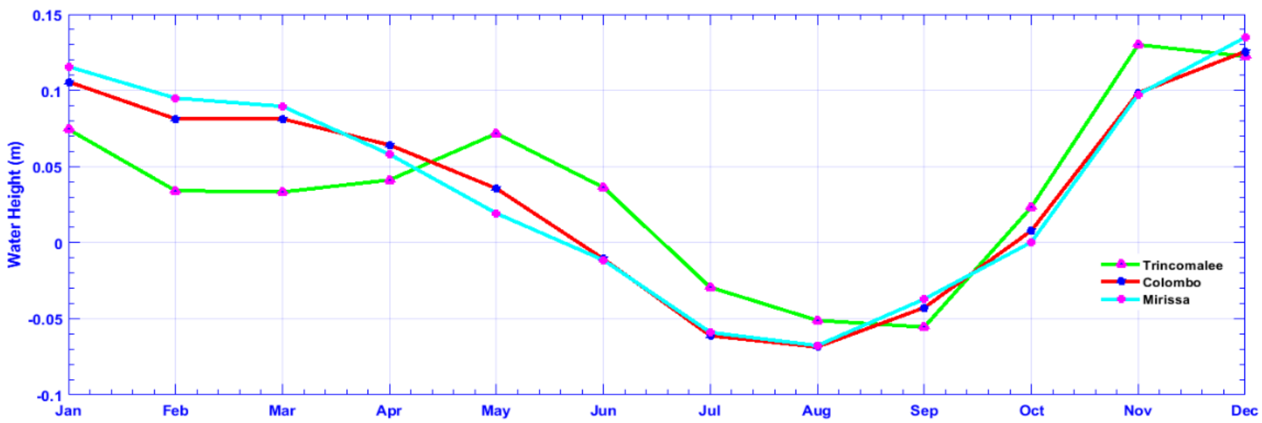


Figure 09 : Comparision of seasonal sea level variation.

The graph shows comparisaion of seasonal sea level variation amang the East coast, the West coast and Southern coast. The red line is monthly sea level variation in Trincomalee. The green line is the monthly average sea lea level variation in Colombo and light blue line is the Mirissa monthly average sea level variation. The maximum seasonal sea level variation was recorded during December to January while the minimum during July to August. The peak month of the southern coast (Mirissa) is slightly later than east coast (Trincomalee) as well as little lower than west coast. The seasonal sea level signal in the Southern coast is comparable with the west coast of Sri Lanka. The peak month of the east coast (Trincomalee) is slightly earlier than west coast (Colombo) as well as little lower than west coast (wijeratne, 2009).

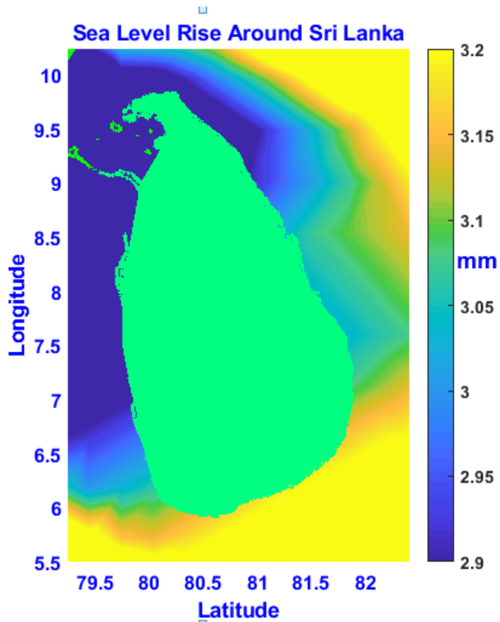


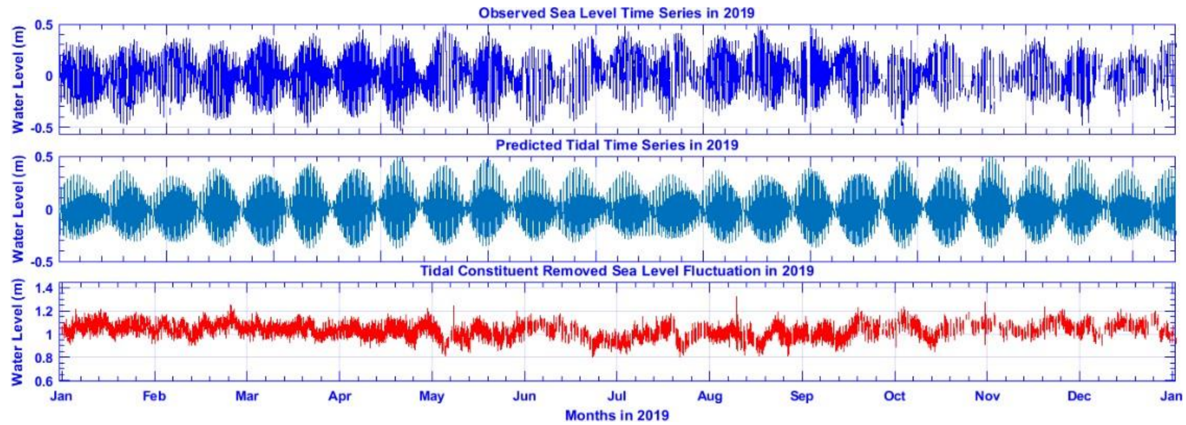
Figure 10: Sea level trend around the Sri Lanka.

The map shows the long term sea level variation from 1992 to 2018 around the Sri Lanka. The sea level trend around the country is unevenly positive. The annual sea level rise in the southern coast of Sri Lanka is 3.1 mm/yr .The resulted sea level trend in the west coast is little lower (2.9 mm/yr) than to the Southern coast. The Global warming is the main causative factor for the increasing the oceanic volume by the absorption of excess atmospheric heat and expansion, as well as adding of excess water to the ocean by melting of glaciers and ice sheet (IPCC 5th AR., 2014)

Study of extreme sea level events (Storm Surge, meteotsunami, El Niña, La Niña)

The annual sea level variation were plotted separately to determine the height of the non-tidal sea level fluctuations in the west coast of the Sri Lanka. The water level not exceeded higher than 50 cm in addition to the tidal fluctuation in the west coast. There were not observed destructive amplitude of storm surge. Tsunami or meteo tsunami during last 5 years.

Figure 11: The tidal effect removed sea level variation in the west coast in 2020.



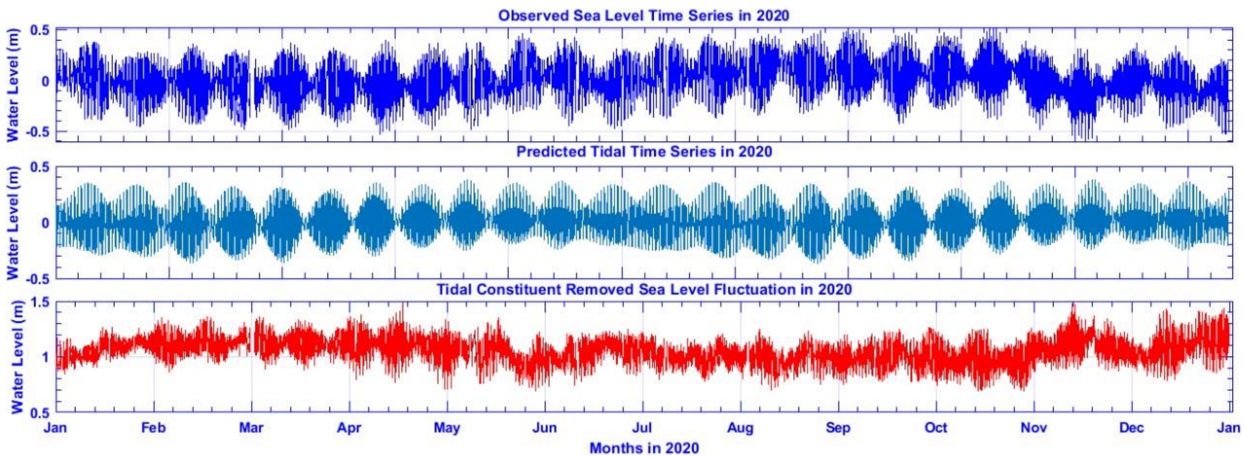


Figure 12: The tidal effect removed sea level variation in the west coast in 2019.

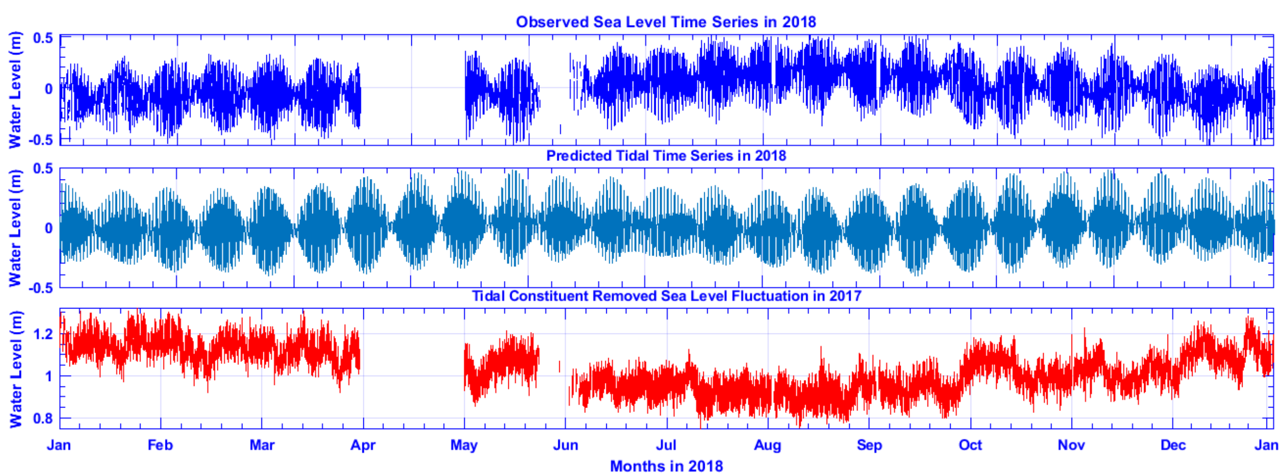


Figure 13: The tidal effect removed sea level variation in the west coast in 2018

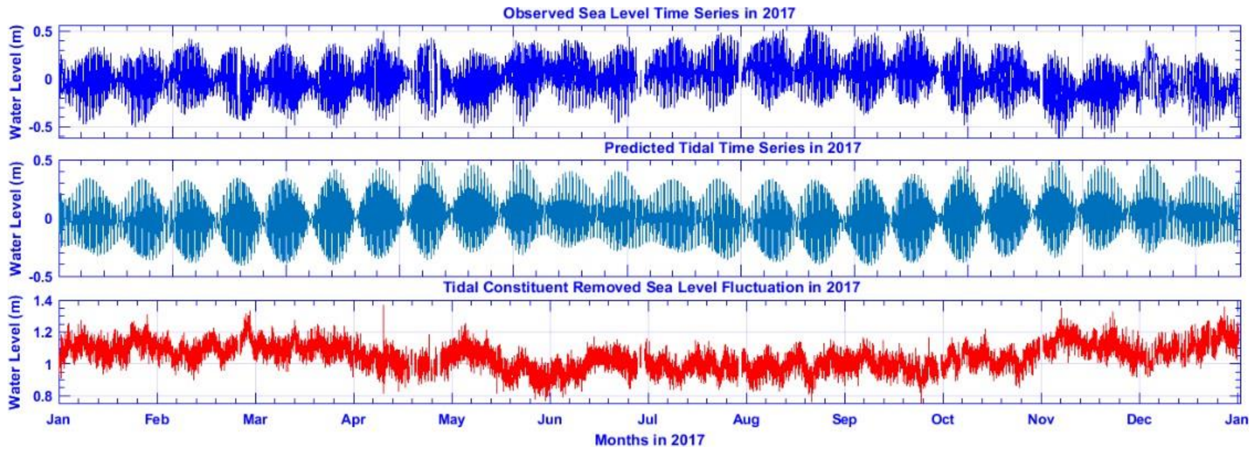


Figure 14: The tidal effect removed sea level variation in the west coast in 2017

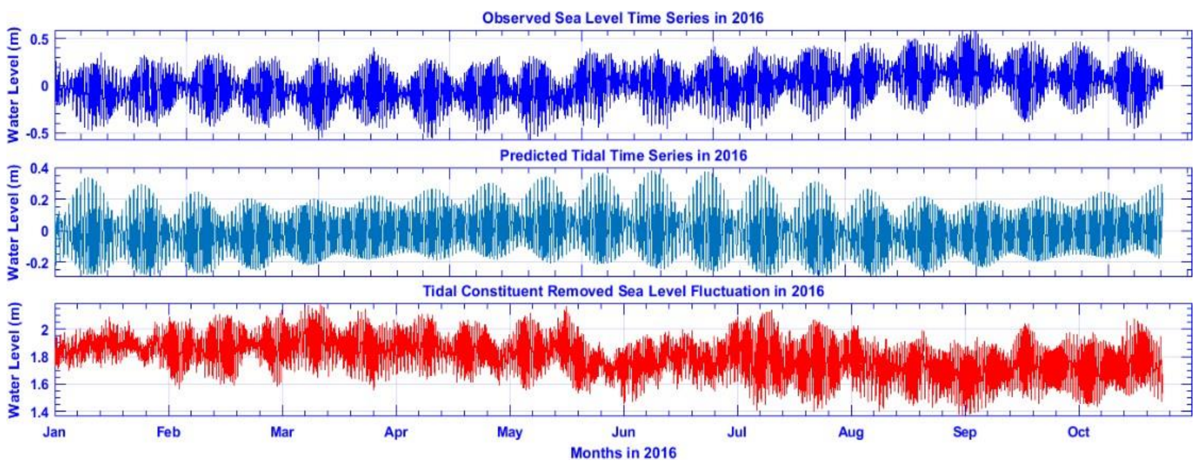


Figure 15: The tidal effect removed sea level variation in the west coast in 2016.

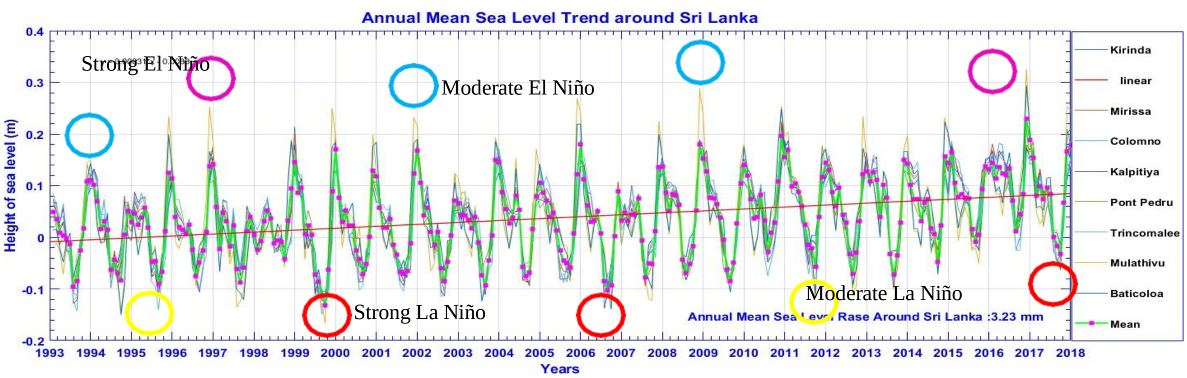
The figurenumbers from 11 to 15shows the isolation of the sea level signal by the tidal signal.

The Dark blue line is the observed sea level time series

The light blue line is the predicted tidal signal for the same period

The red line is residual sea level obtained by the subtraction the observed by predictedaviation

Study of extreme sea level events: El Niña and La Niña



Green line shows mean variation of eight (Kirinda, Mirissa, Colombo, Kalpitiya, Point Pedro, Trincomalee, Mulathivu, Batticoloa) different sampling locations from 1993 to 2018 around Sri Lanka.

Red line is long term sea level trend curve generated.

Colored ovals are indicate El Niño and La Niña events. Light blue: Moderately El Niño, Purple: Strong El Niño, Yellow: Moderately La Niña event, red: Strong La Niña.

The Niño events were determined based on at least 3 consecutive overlapping 3 month period of running mean Sea Surface Temperature (SST) anomaly above the +0.5 C^0 as warm (El Niño) eventand at or below the -0.5 C^0 anomaly for cold (La Niño) events. The amplitude of the Niña event wasranked based on the SST anomaly, as very strong (≥Strong (1.5 to 1.9), moderate (1.0 to1.4) and week (0.5 to 0.9) according to De-facto standers of NOAA.

Total number of 5 positive peak during El Niño (1994:1995,1997:1998,2002:2003,2009:2010,2015:2016) and 5 negative peak during La

Niña (1995:1996,1999:2000,2006:2007,2011:2012,2017:2018) signals were compared on the sea level time series. Some of weak Niño event was not indicated on sea level time series. Gradual increase of irreversible SST and mean sea level are manifestation of climate change and their variability.

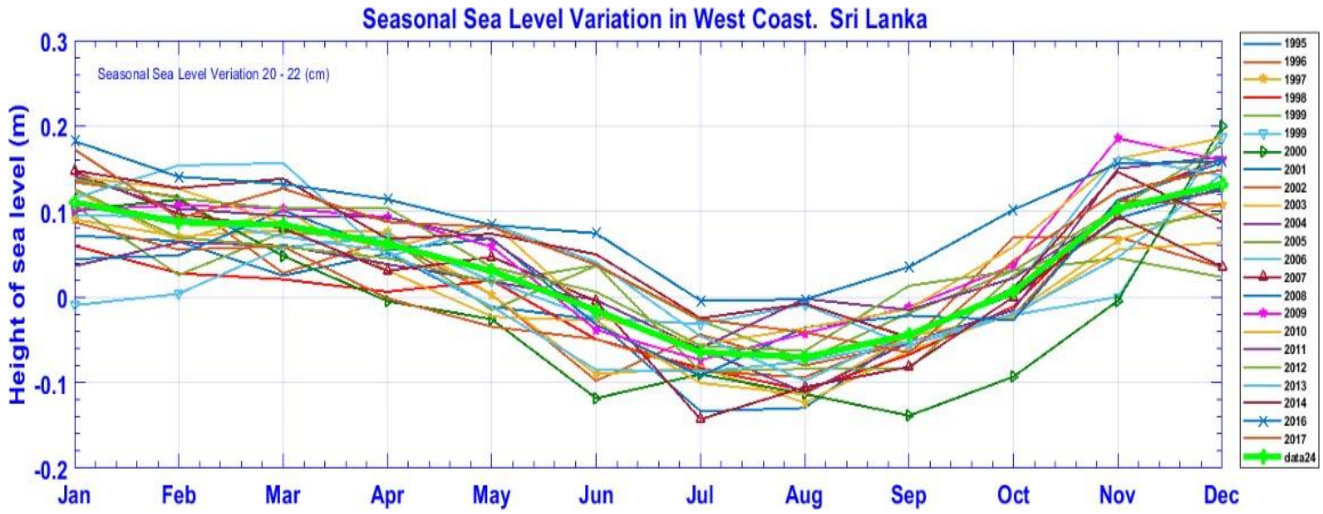


Figure 17: Seasonal Sea Level variation in the west coast in Sri Lanka

The graph shows monthly average sea level variation. The light green line indicate the average seasonal sea level fluctuation during last 25 years of historical data.

Issued of monthly sea level related destructive event report to the Disaster Management Center. (DMC)

Eight monthly reports were issued for 2021. Sri Lanka is highlyprone for the ocean based hazards due to located in the Indian Ocean as an Island state country. Therefore, DMC have to pay insurance claim to the fisheries and coastal community based on the scientific evidence. As the technical advisory institute for ocean based hazards NARA have to provide scientific evidence of destructive sea level variations (Storm surge, Tsunami, Meteotsunami) to the DMC for recovering process of fisheries and coastal community as well as prevention, mitigation and management fromocean based hazards.

Issued of sea level data and data product for the coastal development work of the country asthe consultancy service

During the last year sea level data and data product issued to threecoastal development work of the country.

Colombo sea level data issued to Wallawattha, Wastewater management project, Colombo municipal council.

Trincomalee sea level data issued to the Heyleys (PVT) Ltd

Colombo sea level data and data product issued to the Heyleys(PVT) Ltd

Training of university students (Master and Undergraduate)

Four students were trained during last years.

Trained two undergraduate students from university of Ruhuna

One undergraduate student university of Wayamba

One MSc student university of Colombo

Oceanographic data repository

The historical oceanographic data was organized typical hierarchical folders structure preparing the way to help access to the user. Data was arranged cruise, mooring, meteorology, sea level, sea glider in deferent folders based on the year of the research conducted. Each folders were consisted separate folders named as row data, processed data and data products. Further, reports and publications were saved deferent folders in each years of issued.

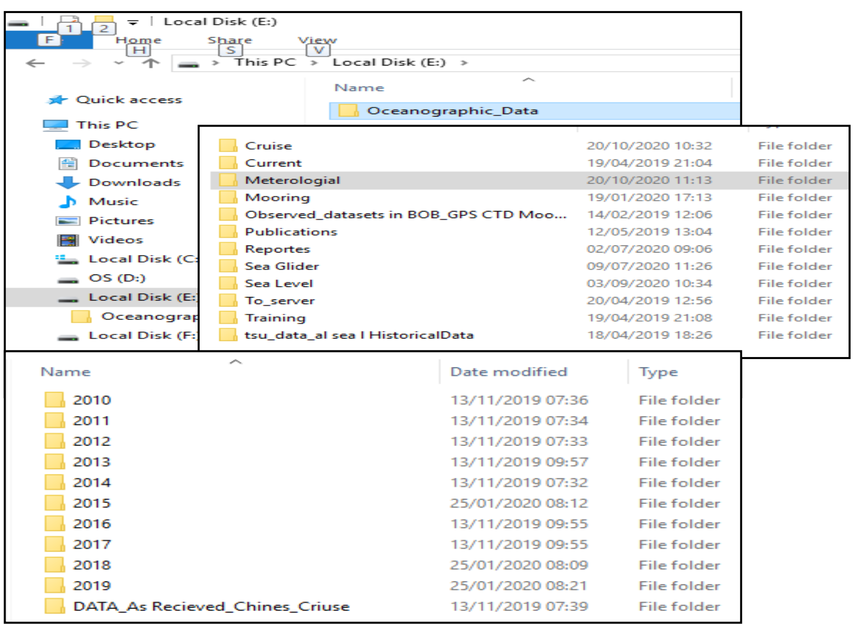


Figure 18: Historical data organized typical hierarchical folders structure

Table 02: Folder structure of the Oceanographic database

No	Folder Name	Description
01	Sea Level Data	Data saved based on the station and data availability as monthly data files in one minute's frequency. Data was saved by the permanent sea level monitoring stations as well as temporary installed tide gauge measurements. The processed data, row dataand data product saved in different folders in each years. Sea level data processing takes few steps those are removing of unwanted data column like battery voltage, program generated symbols, comma and text. After that removed negative and positive outliers/spikes, find missing time field and fill with Nan.
02	Cruises Data	Cruse data was saved in yearly basics conducted international collaborative cruises. Oceanographic data based on Physical, Chemical, and Biological Oceanographic parameters in a different folder structure.
03	Mooring Data	Mooring data was saved based on the mini mooring deployed on the surface and subsurface mooring deployed subsurface in different folder.
04	Meteorological Data	Meteorological data was saved as location of the station, year of data available and parameters in one month of data files. The meteorological data folders are Wind speed, Wind Direction, Rain fall, Atmospheric pressure, Atmospheric Temperature. The frequency of data files are change according to the data retrieved interval by the sensors. Ex: Mirissa, Kirinda, Beruwala,
05	Sea Glider	Sea glider data saved based on the glider number
06	Reports	Reports issued by the division stored under yearly based.
07	Publications	Publications saved based on published years

Development of sea level data base

The processed annual data files were used to create sea level data base. The oceanographic data base developed by using Structured Query Language (SQL), Server Management Studio 2018.3.1 (Express). The visualization of saved data using Graphical User Interface (GUI) was developed using Visual Studio. Net. 2018 version.

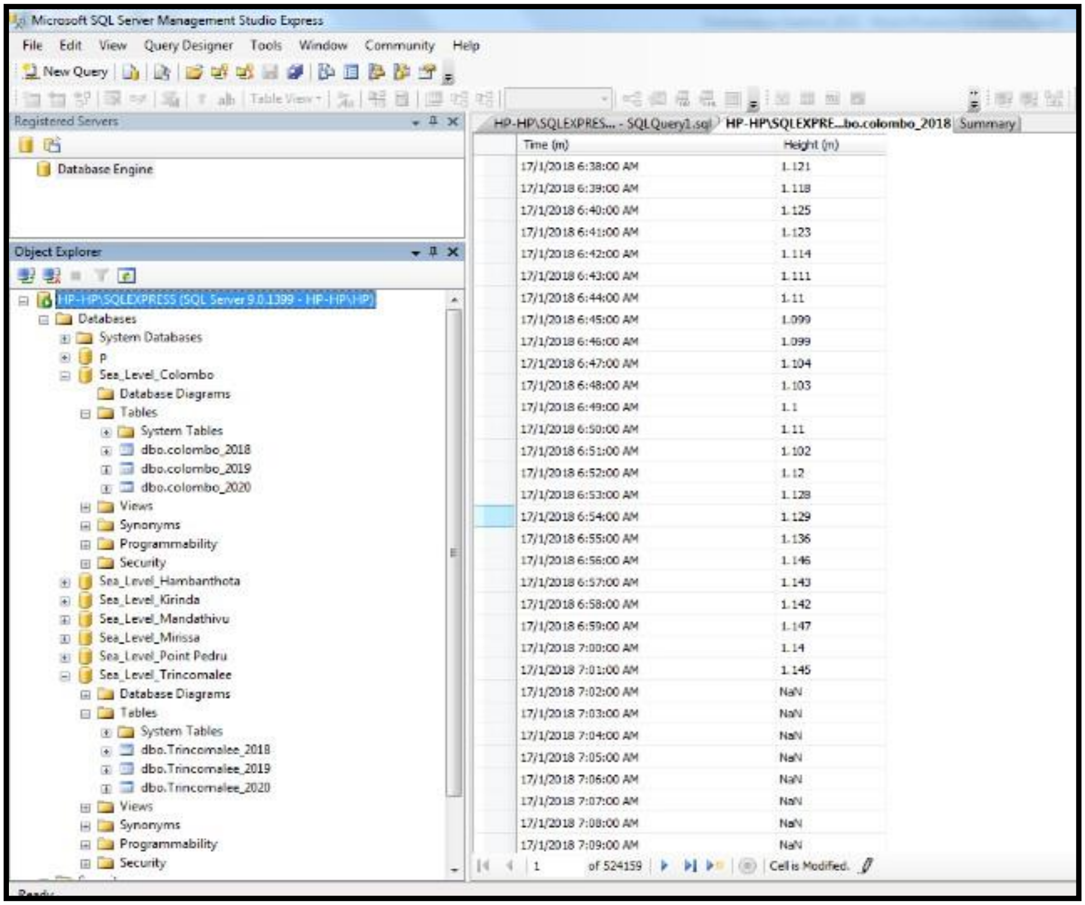


Figure 19**:** Interface of Sea level database developed by Microsoft SQL servermanagement studio version 2018.3.1

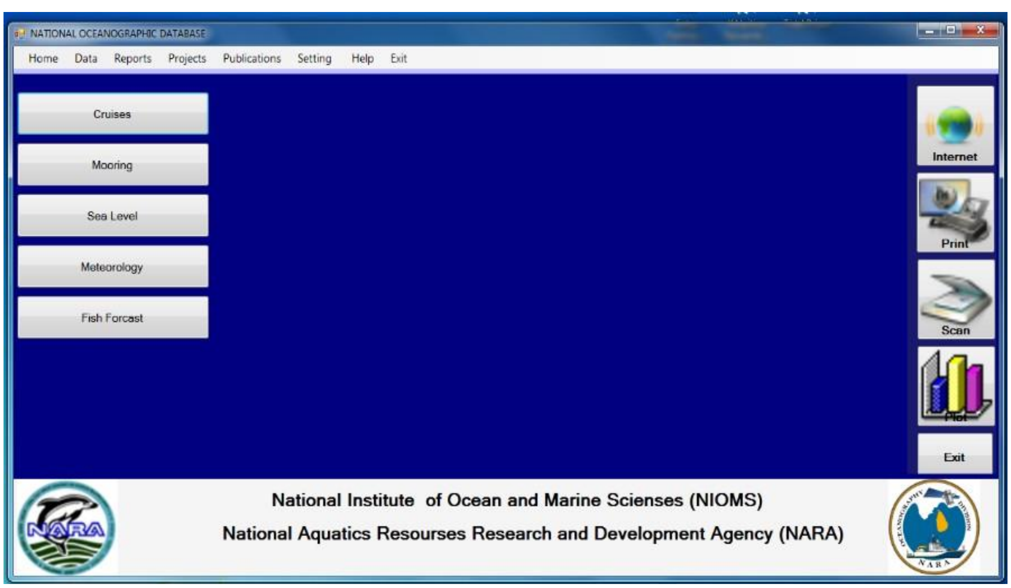


Figure 20**:** The Graphical User Interface (GUI) developed using Visual Studio. Net. 2018version to visualization of the data.

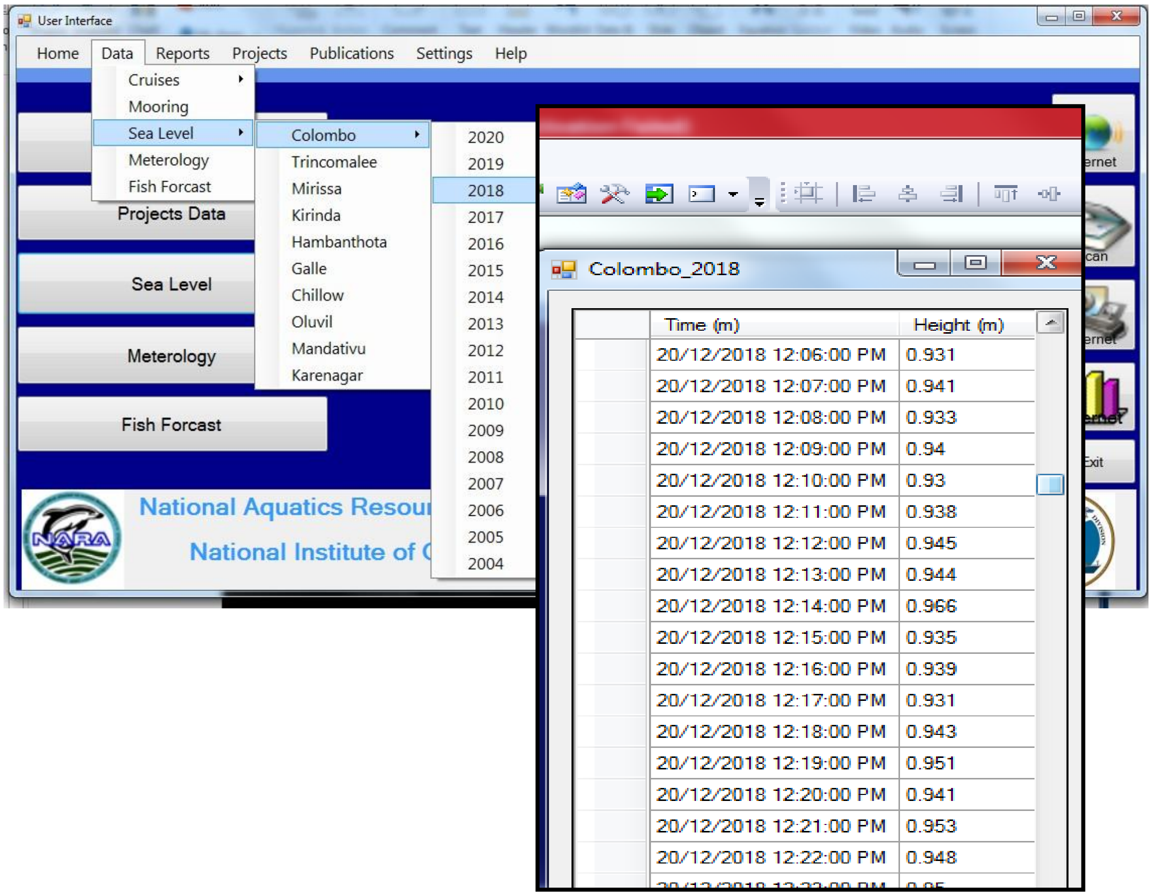


Figure 21: visualization of the data using Graphical User Interface (GUI) developed by Visual Studio. Net. 2018 version

Table 03: List of processed hydrological and meteorological data

	Station	Parameter	Period of data avilable
01	Mirissa	Wind speed and Direction	2017,2018.2019,2020,2021
		Sea Level	2017,2018.2019,2020,2021
		Atmospheric Temperature	2018.2019,2020,2021
		Sea level height	2017,2018.2019,2020,2021
		Water Temperature	2018.2019,2020,2021

		Rainfall	2017,2018,2019
02	Colombo	Sea level height	From 2005 to 2016 and from 2017 to 2021 (Relocated)
03	Trincomalee	Sea level height	2017,2018,2019,2020,2021
04	Hambanthota	Sea level height	2009,2010 (Only few month available)
05	Kirinda	Sea level height	2008,2009,2010,2011 (No continues data available)
06	Point Pedro	Sea Level height	2019 (Few months)

The table shows the processeddata and their periods. There are missing data period every parameter of the data due to the malfunction of the instrument and break down of the powers supply. The Mirissa station is working by the main power supply and external battery backup. Trincomalee and Colombo Stations are working solar power system.

Dissemination data and data product

NARA webpage provide link to access data and data product according to the requirement of policy planers and environmental managers of coastal resource development, researchers and student. The web page consisted contact form and monthly sea level product based on availability of data in sea level stations around the country. Ready to upload monthly sea level products of Mirissa, Trincomalee, Colombo up to end of December 2021.

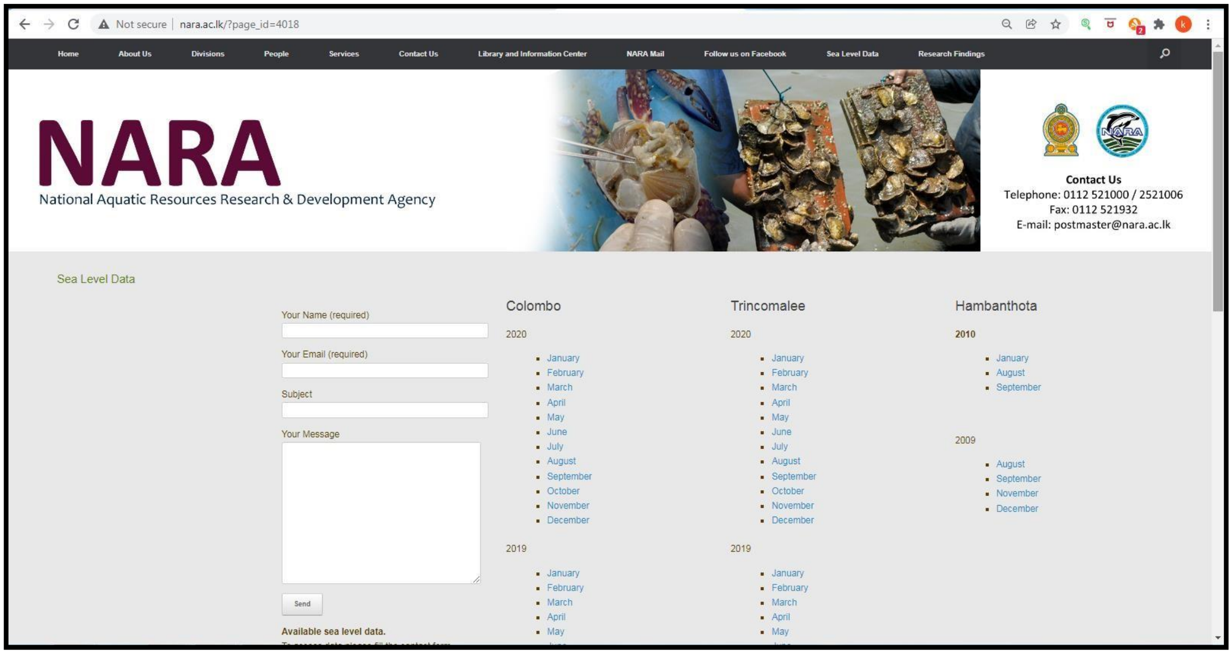


Figure 21**:** Sea level web page interconnected with NARA web page

The contact form can be used for interested web user to send their request relevant to the sea level data and data product. NARA has provided facilitate and directed approximately 78users through the contact form of the web page. Total number 593 of mails received through contact form increasing the number of users of NARA webpage. The 'Sea Level Data' link of NARA web page is http://www.nara.ac.lk/?page_id=4018. The monitoring and evaluation division of the NARA contributes for the updating and developing of sea level web link. Monthly sea level data imagers were uploaded Trincomalee (2017 to 2021), Colombo (2016 to 2021) and Hambanthota (2009, 2010) stations

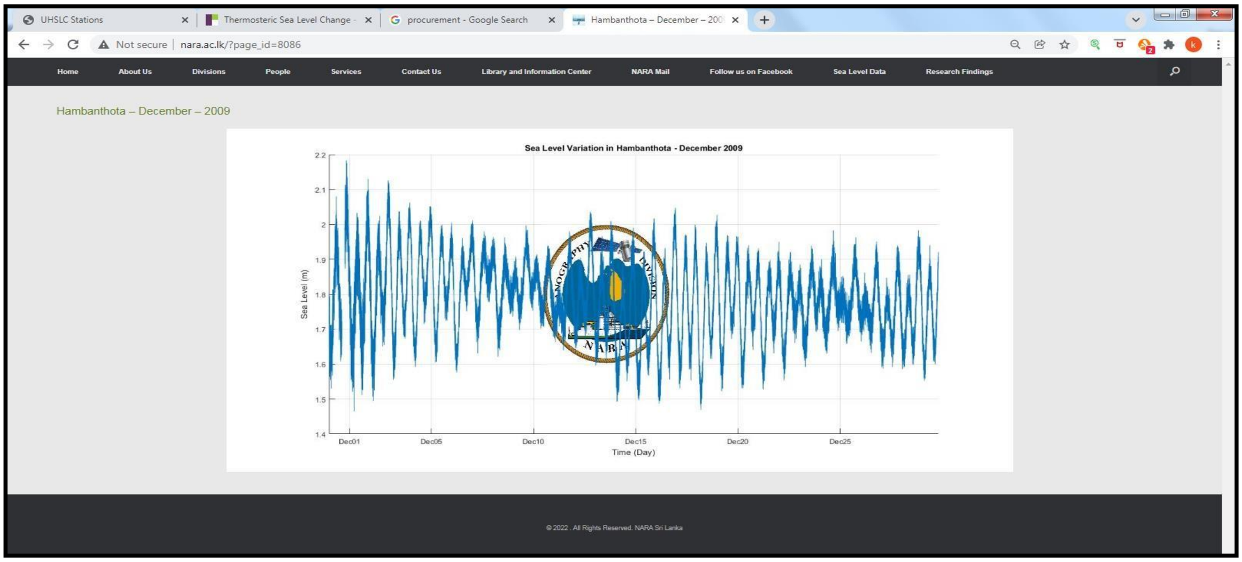


Figure 22 :Monthly sea level Product Available in the NARA web page

Renovation of Kirinda Sea Level Station

The Kirinda sea level station was not functioning due to end of the life time of the instrument and speed weathering process of the building with the location of situated. The station now renovated and completed test running.

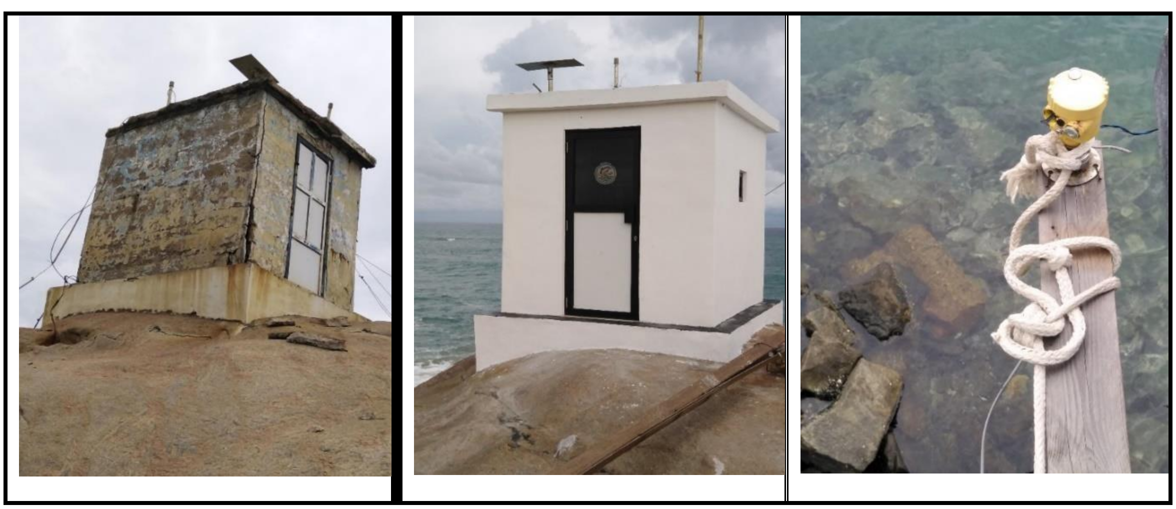


Figure 23: Sea level station before renovation and after renovation and testing of radar sensor

9. Outputs & outcomesExpected Output

Research Component 01: Study of Sea level variability around Sri Lanka.

Recording and reporting of long term sea level.

Estimation of seasonal and Inter annual variability

Identification of extreme sea level event and ranges (Strom Surge, Meteotsunami,El Niña, La Niña)

Data to re-establish sea-level datum.

Development Component 02: Development of sea level observation network

Establish Sea level and Meteorological observations network around the Sri Lanka

Identification of real time /near real time destructive regional oceanic event.

Data for the research and national development

Development Component 03: Development of oceanographic data base

Development of oceanographic data base for research and national developments.

Conservation of historical data

Establishing a common platform to archive, quality-controlled data and mete data

Establishing an efficient dissemination of data in required location, period and measurement intervals.

Providing of data and data product according to the request

Expected Outcome

Quantification of long term sea level rise around Sri Lanka

Minimizing the damages from ocean based destructive disasters

Knowledge and evidences for the policy planning of coastal land use management

Scientific inputs for coastal infrastructure development (harbors, wastewatermanagement, water breaks), and national policy planning.

Long term archive of sea level data and information

Contribution (vulnerability maps of sea level and inundation maps) to assess the potential impacts on the coastal zone.

Platform for efficient access of sea level data and information to stakeholders

Conclusions

The map shows the long term sea level variation from 1992 to 2018 around Sri Lanka. The sea level trend around the country is unequally positive. The recorded maximum annual

sea level trend is 3.1 mm/yr., on the southern coast while the lowest sea level rising trend is 2.9 mm/yr., on the west coast of Sri Lanka.

The maximum seasonal sea level variation was recorded during December to January andthe minimum during July to August. The peak month of the southern coast (Mirissa) is slightly later than east coast (Trincomalee) as well as little lower than west coast. The seasonal sea level signal in the Southern coast is comparable with the west coast of Sri Lanka. The peak month of the east coast (Trincomalee) is slightly earlier than west coast (Colombo) as well as little lower than west coast (wijeratne, 2009). The seasonal sea levelvariation around the country is between 20:23 cm.

Recommendations

Policy planning and coastal resources managers need to concern on the sea level rise and related oceanic hazardous.

The community living along the coastal belt need to well aware and preparedness Ocean based hazardous can be taken in the future.

Environmentalist need to concern on highly sensitive low laying coastal habitats can be effected by gradual increasing of sea level in the future with limiting coastal land and threatening coastal life.

Low laying agricultural coastal land need to find adaptation plan for the impact of coastal flood and salt water intrusion.

The river mouth management plan of the country need to adapt prevent saltwater intrusionand contamination of drinking water sources with the seasonal sea level variation.

Continuationof recording and reporting of sea level status in updated status.

Constraints

Procurement process were not completed duo to not receiving of bids for purchasing of underwater pressure sensor, Construction of Sea level monitoring station at Dondra fishery harbor, Purchasing of data logger,Purchasing of aluminum door to Kirinda station

---

Financial Allocation (Rs) 2.6

Financial progress (%)

Physical Progress (%)

National Hydrographic Office

8.1 National Charting Programme

Responsible Officers: S.R.C. Ranaweera

Introduction

The prime objective of National Hydrographic Office (NHO) is to provide Hydrographic services to ensure safe and efficient navigation in Sri Lankan waters. This is a mandatory requirement of full filling the obligation of the International Convention for the Safety of Life at Sea (SOLAS). Accordingly charting areas are selected to ensure that hydrographic surveys are being carried out, as far as possible, adequate to the requirements of safe navigation where stakeholders and also being to prioritized. The other principal services are the provision of up dated and accurate bathymetric and topographic data for coastal zone management, environmental protection and maritime delimitation. The up-to-date hydrographic information coverage offers significant economic and commercial benefits through facilitating maritime trade and other marine activities.

It has been realized that hydrographic data is underpinning the blue economy activities, accordingly NHO has carried out new surveys for Lankapatuna lagoon to develop a master plan. Here the hydrographic information perform a vital and valuable part of calculating carrying capacity to quantify the optimal economic and commercial benefit of each lagoon.

Following surveys and activities were conducted for the year 2021,

National Charting Program

3.1.1. Bathymetric data acquisition for Coastal Chart from Trincomalee to Kudremalai Point – Mannar Island

3.1.2. Bathymetric data acquisition for Coastal Chart from Trincomalee to Kudremalai Point-Trincomalee to Point Pedro

3.1.3. Bathymetric data acquisition for Coastal Chart Little Basses reef to Pulmoddai Roads

3.1.4 .Bathymetric data acquisition for Coastal Chart Weligama to Colombo.

3.1.5. Upgrading existing charts

Methodology

Project 1.1: Data Acquisition for Coastal Chart “Trincomalee to Kudremalai Point”

NHO has planned to produce a coastal chart from Trincomalee to Kudremalai Point (Scale-1:300,000) covering about 550 km coastal stretch from East to West of Sri Lanka. Total sea area covering from this chart is about 30,000 km2.Necessary surveys were planned in two phases. 40% of the total area was already covered and could not continue Offshore surveys (beyond 200m contour) due to unavailability of RV "Samuddrika". Anyhow northern island area was surveyed using small boat and fair sheet of the Northern Islands was completed.

During the year 2020 NHO has planned to complete the 98% of the Nautical Chart for Mannar Island as a separate chart. The total area surveyed 27 sqkm for the Nautical Chart Mannar Island. This chart will be facilitated for aquaculture development and other ocean based researches.

Due to the COVID-19 pandemic situation, the surveys couldn't carry out as planned within the year. Thus, the Harbor Master and the Ceylon Shipping Corporation emphasized the impotency of having the Nautical chart of Norochcholai and RV "Sammudirka" used for collecting the bathymetirc data as an urgent basis. Further, RV "Sammudirka" is used for the investigations of the Pearl X-press ship burning incident activities and the survey team was working with Side Scan Sonar to identify the debris. Furthermore, the surveys were carried out for the demarcation of areas in the sea cucumber export village in Northern Province and Dutch canal survey for the dredging purposes.

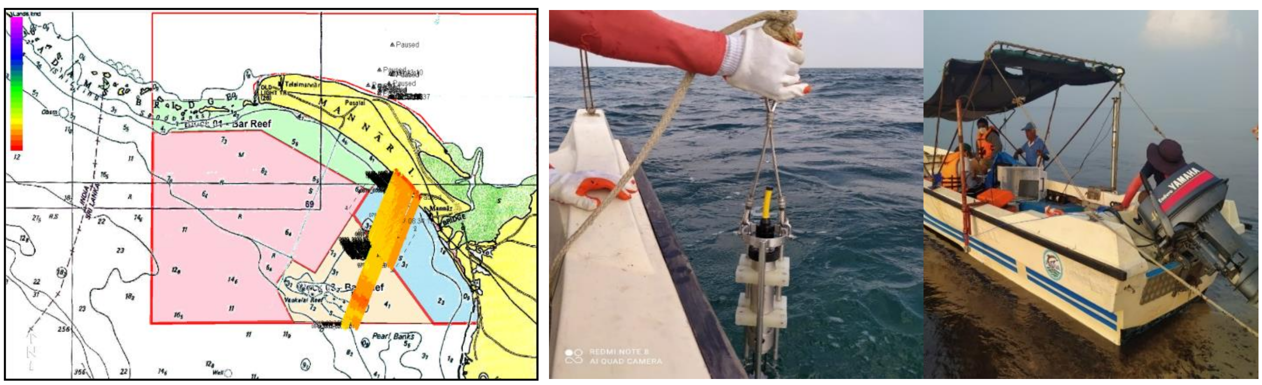


Figure 1:1 Bathymetry coverage for the Nautical Chart of Mannar Isalnd

Project 1.2: Data Acquisition for Coastal Chart "Little Basses Reef to Pulmoddai Roads".

According to the National Nautical Chart Index, the total coastal belt of Sri Lanka intended to cover with five small scale charts. Nautical Chart "Little Basses Reef to Pulmodai Roads" is one of those. This covers 250 km long coastal stretch from South to East of the island. The total area intended to survey in two phases.

Due to the COVID-19 pandemic situation, the surveys couldn't carry out as planned within the year. Further, RV "Samuddrika" is used for the investigations of the Pearl X-press ship burning incident activities and the survey team was working with Side Scan Sonar to identify the debris. Furthermore, the surveys were carried out for the demarcation of areas in the sea cucumber export village in Northern Province.

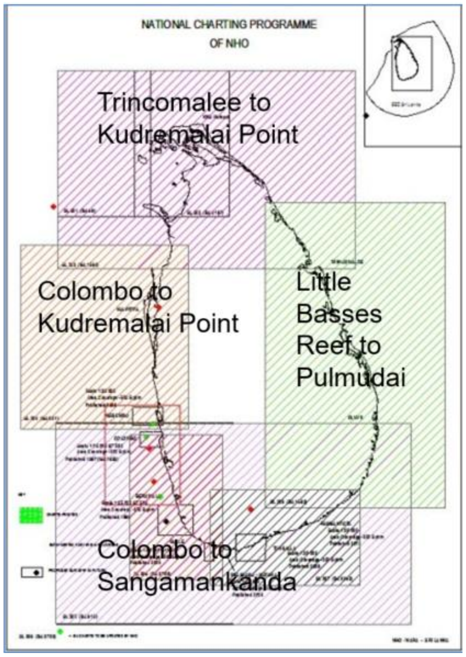


Figure 1:2 Nautical Charts covering the entire coastal belt

Project 1.3: Bathymetric data acquisition for Coastal Chart "Weligama to Colombo"

60% of the chart was completed at the end of year 2018 and NHO /NARA has intended to complete surveys up to 200m contour .Only 10% of the planned area could completed during the year 2019 since unavailability of RV "Samuddrika" for a considerable time period. Sri Lanka Navy hydrographic unit assure to provide bathymetric data beyond the 200m contour up to the chart limit. Due to the COVID-19 pandemic situation the gap surveys couldn't carry out as planned within this year due to the COVID 19- pandemic situation of the country and survey teams were allocated for the X-press pearl incident, data collection for the Nautical chart of Norochcholai and demarcation of areas in the sea cucumber export village in Northern province.

Project 1.4: Upgrading the published Nautical Charts

The published charts should be maintained to ensure the validity of existing data as the sea bed is subjected to change due to natural phenomena such as Tsunamis, storms or any other extreme weather condition or by other manmade hazard. Any changes of bathymetry are needed to be applied timely. Necessary communication links has been maintained with the relevant authorities, Harbor Master of Sri Lanka Port Authority and Director General of Merchant Shipping Secretariat.

Project 1.5: Data Processing and Cartographic Works

Data processing for the acquired bathymetry (phase I and phase II) of the Nautical chart Trincomalee to Kudremalai Point was completed.

Data processing , mapping and cartographic work completed for producing the Nautical Chart of Puttalam harbour for Ceylon Electricity Board and the chart is available print on demand.

Data processing completed of the collected data in Mannar.

Outcomes:

Ensure safety of navigation in Sri Lankan waters by providing nautical chart of Trincomalee to Kudremalai Point, Nautical Chart of Little Basses to Pulmudai Roads, and Nautical chart of Mannar Island and Nautical Chart of Colombo to Weligama.

Expected Outputs:

1. Fair Sheet of Trincomalee to Kudremalai point with the scale of 1:300,000 by 2021

2. Fair sheet for covering 50% of Coastal Nautical Chart from little Basses Reef to Pulmoddai Roads by 2021 with the scale of 1: 300,000

3. Fair Sheet of Coastal Nautical Chart of Weligama to Colombo with the scale of 1: 150,000 by 2021

4. Fair Sheet of Nautical Chart of Mannar Island with the scale of 1: 75,000 by 2021

Constraints

Due to the Covid 19 Pandemic situation of the country, the surveys couldn’t conduct as scheduled. Additionally, the staff of NHO was self-quarantined 14 days at late February and the early March and another 14 days in the month of May, because of the two members of the staff was infected from Covid 19.
Further, at early April, the priority was given for the demarcation of areas in the sea cucumber export village in Northern Province as per the instruction of Chairman/NARA by terminating the field programm in Mannar. Thus, the Harbour Master and the Ceylon Shipping Corporation emphasized the importance of having the Nautical chart of Norochcholai and RV “Samuddrika” used for collecting the bathymetric data as an urgent basis. Further, RV “Sammudirka” is used for the investigations of the X-Press Pearl ship burning incident activities and the survey team is working with Side Scan Sonar.

Additionally, the following services were done during this quarter.
1. The relevant maps and data provided for the team who were working with the biological and environmental impact assessment of the X-Press Pearl ship burning incident.
2. Mapping for proposed site for Mari culture development in selected areas in Northern Province.

3. Demarcation of areas in the sea cucumber export village in Northern Province.
4. Preparation of maps for "Continental shelf submission of Sri Lanka" in respect of the area

around Comorin Ridge for National Ocean Affairs Committee (NOAC) , Ministry of Foreign Affairs.

5. Bathymetric data collection for the Volume Calculation – Upper Kotmale Reservoir, Client: Ceylon Electricity Board and contouring and mapping.

5. Data processing, mapping and cartographic work for producing the Nautical Chart of Puttalam harbour for Ceylon Electricity Board

6. Volumetric calculation of Nandikadal and Arugambay lagoons

7. Dredge volume calculation at Vakarai River Mouth Area

8. Mapping propose100 Acre Sea Cucumber Farm Clusters in Northern Province
9. Mapping proposed sites for Mari culture Development in Selected areas in Northernrovince
10. Mapping potential areas and proposed culture species in Jaffna lagoon

11. Bathymetric survey in Lankapatuna lagoon

Financial Allocation :- Rs.10.109 Mn

Financial Progress :- 55.3%

Physical Progress : - 2.3%

8.2 An assessment of Tidal asymmetry around the Sri Lankan coastline

Responsible Officers: R.M.D.I Rathnayake, S.R.C. Ranaweera, Y.M.R.N. Kumari, B.Y.T. Dhanushka

Introduction

Sri Lanka is an island situated in the northern part of the Indian Ocean and is separated by a shallow and narrow Palk Strait. Higher salinity Arabian Sea is located on its western side and the low salinity Bay of Bengal on its eastern side. The continental shelf in Sri Lanka is narrow and is shallower than the average depth of the shelves around the world. It is narrowest around the southern part of Sri Lanka, but it broadens to merge with the Indian continental shelf towards north and northeast. The tide around Sri Lanka is mixed semidiurnal with a spring tidal range of between 0.40 and 0.60 m. The range is less in the northern part of the island. The east coast features different phases from west coast with a rapid change in southeast. The waters around the Island are subjected to seasonal reversals of currents forced by the monsoons.

One of the significant aspect in the tide around the Island is, there exhibits a complete opposite tidal phase difference between Western to South region and East to North region. For an example, when Colombo experiencing high tides, Trincomalee experiencing low tides and vice versa.

This indicates, the tide around Sri Lanka is generated from two different amphidroms in the Indian Ocean. Therefore, the aim of the study identifies these amphidromic points and their influence to the tidal phenomenon around the coast line. A comprehensive regional tidal modelling is expected to carry out encompassing Sri Lanka using existing tidal data. The interaction boundaries of these two amphidroms at the coast line are also expected to be carried out. Several new tidal stations will be set-up to validate the model results. Finally, with these results, it is possible to make a comprehensive study on tidal behaviour around Sri Lanka.

Further, this information is very useful in tidal datum establishment for hydrographic applications such as national charting as well as further densification of the tidal network around

Sri Lanka. Further investigations can be carried out regarding the MSL variation and the geoid undulation determination.

2.1 Objectives

- To identify the influence to the tidal phenomenon around the coast line caused by the two amphidromic points located in the Indian Ocean.
- To identify the interaction boundaries of these two amphidroms at the coast line along the coast.
- To develop a comprehensive regional tidal model for Sri Lankan coastline.

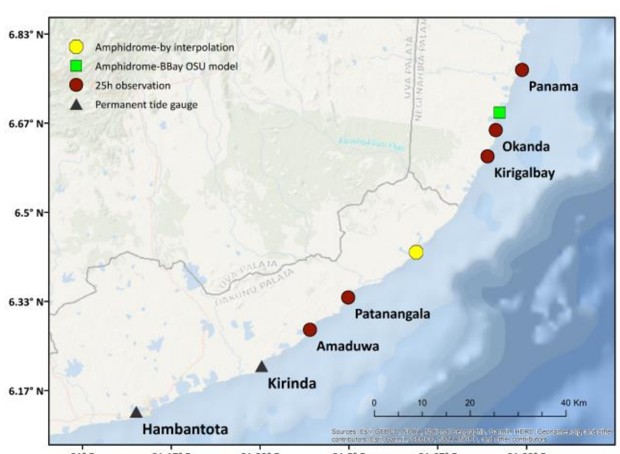
2.2 Data Collection & Analysis

Southeast Amphidrome

Tidal data from Trincomalee, Hambantota and Kirinda tide gauges were analyzed for identifying approximate location of the amphidromic point of Southeast coastline. Additionally 25h tidal observations were carried out at Amaduwa, Patanangala, Kirigalbay, Okanda and Panama which are located along the southeastern coastline. According to the regional tidal model BBay (Bay of Bengal) of Oregon State University (OSU) that has spatial resolution of 1/30°, the amphidromic point for M2 constituent is located between Panama and Kirigalbay (Figure 2:1).

Interpolation of observed 25h and archived tidal data reveals that the amphidromic point of M2 constituent is located near Potthana bay where phase of M2 tidal constituent becomes zero. This location is also confirmed by the interpolation of tidal constituent M2 which was derived from Sea Level Anomalies (SLA) data observed by Satellite altimeters (Figure 2:2 & 2:3).

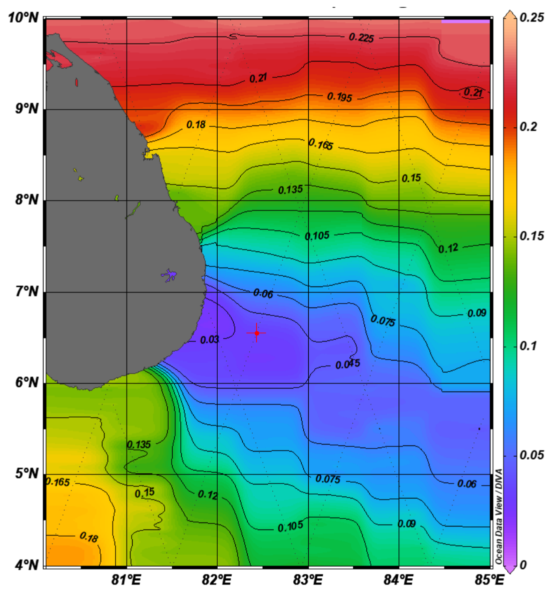
The amphidrome may also be considered as a time-dependent position of zero tidal range for a complete tidal band. Therefore daily and seasonal movements of amphidromic points needs to be tracked



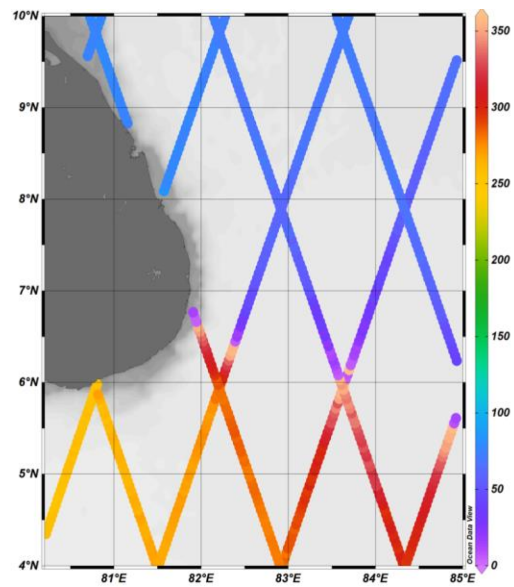
Location	Phase (Degree)
Trincomalee (1 year data)	65.50
Panama	34.89
Okanda	31.50
Kirigalbay	31.20
Patanangala	293
Amaduwa	320

Figure 2.1: Tide gauge locations along Southeast coastline

Table 2.1: Phase values of M2 along southeastern coastline



(a)



(b)

Target of the project of 2021 was to monitoring the positions of amphidromic points using permanent tide gauge. But project couldn't be implemented due to the delay of purchasing tide gauges.

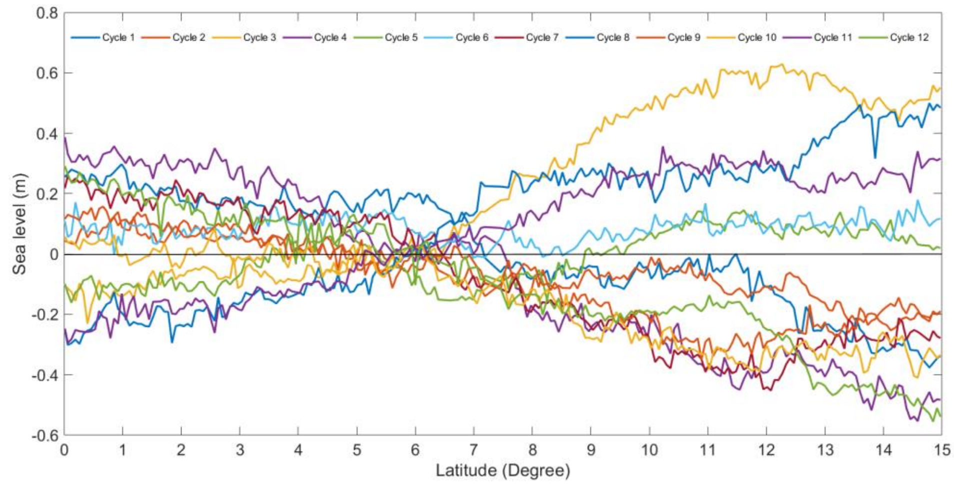


Figure 2.3: Sea surface height around amphidrome from SSH (SLA + Tide) along track data of SARAL/ALtiKa track 0023 for 12 cycles

North Amphidrome

Permanent tide gauge and 25h tide gauge observations were harmonically analyzed to identify the amphidromic point. According to the phase distribution, tidal wave propagates into northwest ward (Kalundai Bay), southward (Palk Bay) and southeastward (Ariyalai Bay) from Mandativu.

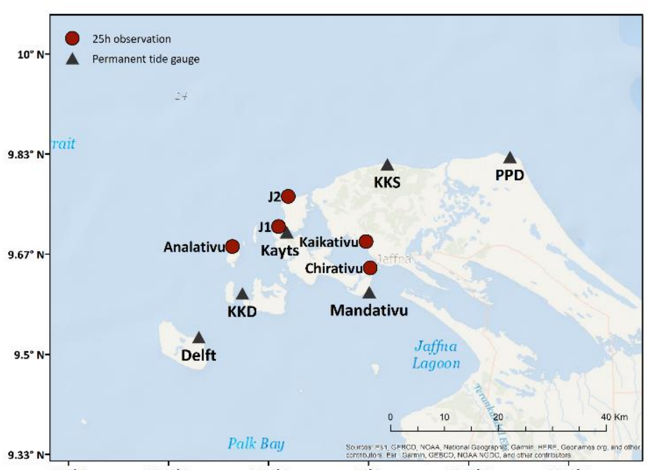


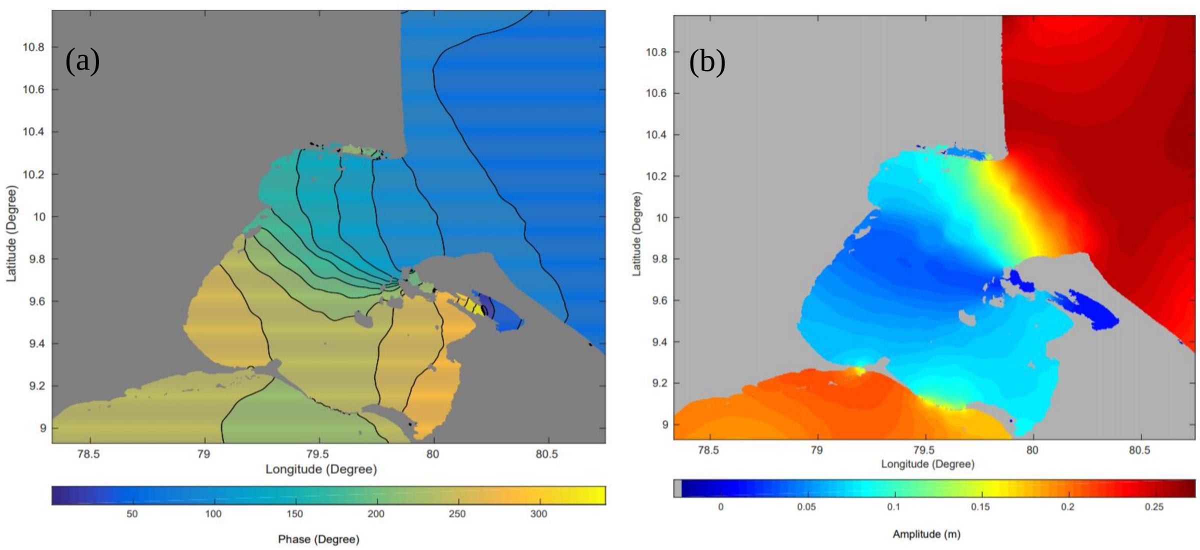
Figure 2.4 : Tide gauge locations at Jaffna Archipelago

Location	Phase (Degree)
Point Pedro (1 year data)	78.00
J2	104.00
J1	112.00
Kayts	110
Analativu	239.00
Kurikadduwan	251
Delft	245
Mandativu (1 year data)	254.00
Chirativu	280.00

Figure 2.5: Installation of tide gauges in Jaffna

Table 2: Phase values of M2 of Jaffna archipelago

A tidal model of 8 major tidal constituents was developed assimilating tide gauge observations and satellite altimetry derived tidal constituents for Jaffna archipelago.



The m Figure 2.6: a) Phase distribution of M2 constituent b) Amplitude variations of M2

Other semi-diurnal constituents S2, N2, K2, show the amphidromic system clearly. From diurnal constituents, except Q1, other constituents show the amphidromic system but with a northwest ward shift relative to the semidiurnal constituents.

Further tidal observations needs to be carried out within Ariyalai Bay and Kalundai Bay in order to observe the movements of amphidromic point and validate the tidal model results.

<u>Conclusion</u>:

The model simulates the amphidromic point of M2 constituent around Ariyalai Bay (Figure 5a). Other semi-diurnal constituents S2, N2, K2, show the amphidromic system clearly. From diurnal constituents, except Q1, other constituents show the amphidromic system but with a northwest ward shift relative to the semidiurnal constituents.

Further tidal observations needs to be carried out within Ariyalai Bay and Kalundai Bay in order to observe the movements of amphidromic point and validate the tidal model results.

<u>Outputs:</u>

1. Regional tidal model
2. Tidal datum variability map around the coastline

Financial Allocation: - Rs.0.816 Mn

Financial Progress: - 3.8%

Physical Progress : - 60%

8.3 Establishment of Database and online data processing unit for crowd sourced bathymetry parallel with the “Sea Bed 2030” global mapping project of General Bathymetric Chart of the Oceans (GEBCO)/ Nippon foundation

Responsible Officers: Y.M.R.Nilupa Kumari, R.K.A.Ariyarathna, R.M.D.I.Rathnayake, B.Y.T.Dhanushka, Darshana Wickramasinghe, Rajitha Harshana

Introduction

Bathymetric coverage of the sea around our country is very little and need to be done vast area and it needs years and years to fulfil this with the systematic bathymetric surveys. The world contest is very similar and hence the GEBCO Nippon Foundation has started a project called Seabed 2030 and member states of International Hydrographic Organization been invited to collaborate this project covering their own seas from the bathymetry.About 71% of the earth is covered by the ocean for which the bottom topography (Bathymetry) far less known than the surfaces of Mercury, Venus, Mars and several planets’ moons including our own.It is noted that considering the world oceans sparsest data gathering is in Indian Ocean. Hence the morphology, special features are not revealed successfully. This project is a small effort to gather crowd sourcing data and mapping the Indian Ocean as possible as to identify the morphology and increase the data coverage for future ocean base projects around Sri Lanka while doing the systematic surveys through National charting Program for most important areas.

Goal of the 2030 Sea Bed mapping project is “Leave no features of the accessible part of the world ocean floor larger than 100m unmapped by the year 2030 and this will be accomplished new field mapping projects initiate by many parties using many vessels. As a member of International Hydrographic Organisation and also as a coastal country and the focal point of hydrography in Sri Lanka the NHO has privilege to contribute this project to make success through increasing the data coverage.

Objective

The objective of this project is to map the Indian Ocean using crowd sources bathymetry and maintain and updating the data base and disseminate data for marine management, spatial planning and research in marine geology, ecology and oceanography. This will be a continuation project until 2030.

i. Gather crowd sourced bathymetry from all the possible means (research vessels, commercial ship cruises, fishing vessels, satellite derived bathymetry)

ii.Establish a Unit for create a bathymetric database with the metadata information and online data processing

iii. Mapping the sea bed, identify the geomorphological features and provide information to utilise the marine sector applications

iv. Contribute to Seabed 2030 global mapping project by showing the available bathymetric data coverage in Indian Ocean

Methodology

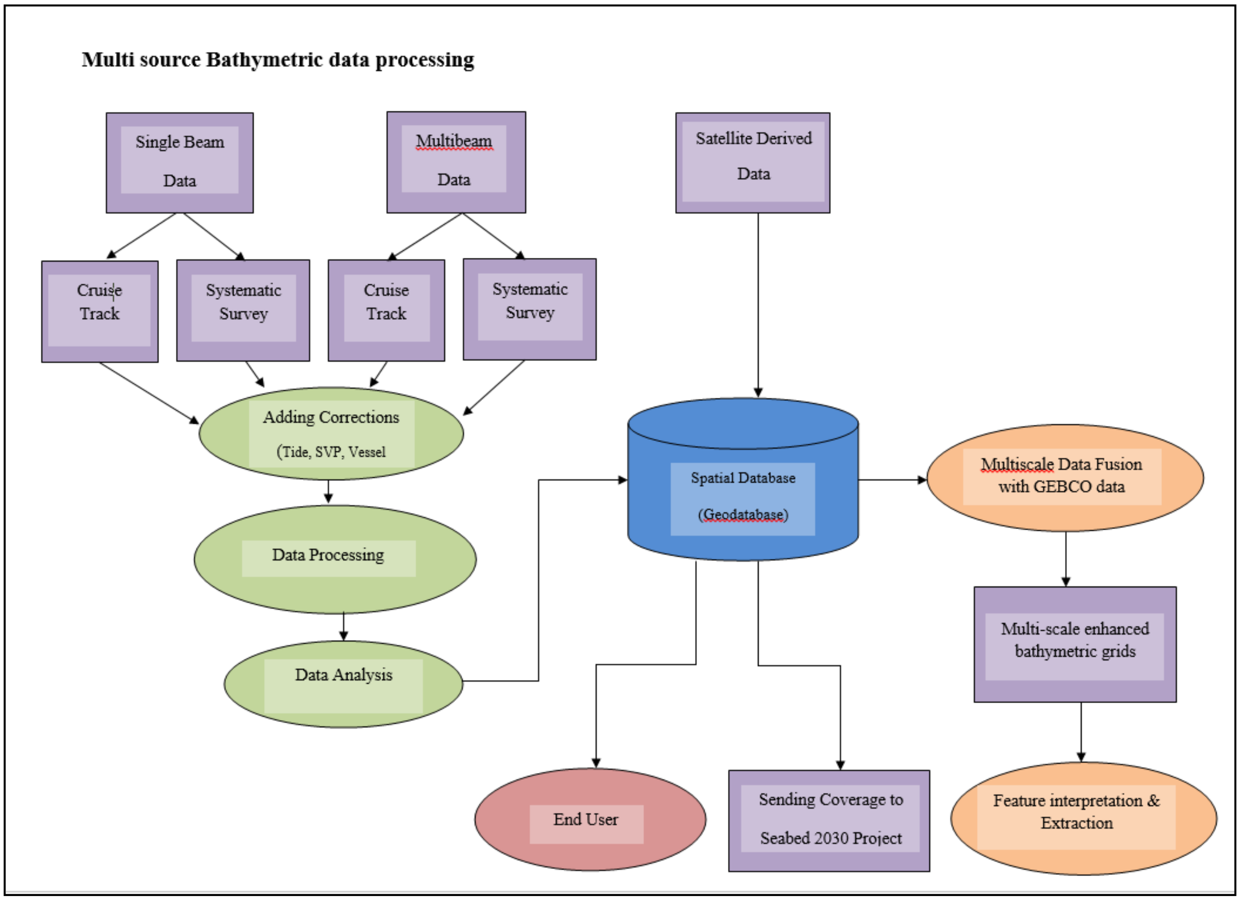


Figure 3:1 Working procedure

Results

The spatial database interface was generated using ArcGIS platform and model of the surface was created. Crowd sourced bathymetry from the Fridgetof Nanson Survey, Zhen He project, RV “Samuddrika” cruise track data and the bathymetric data from systematic surveys of NHO, bathymetric data from the admiralty charts were associated to the database. The overall progress of the project is 37% for the year 2021.

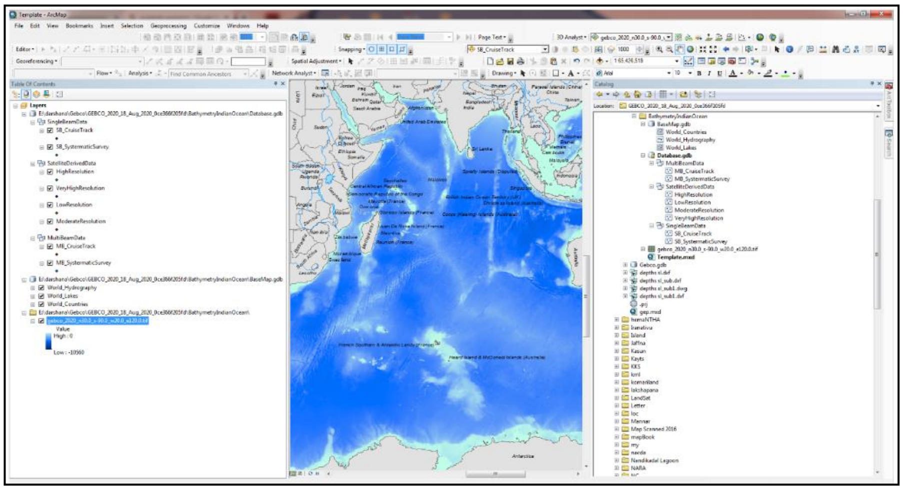
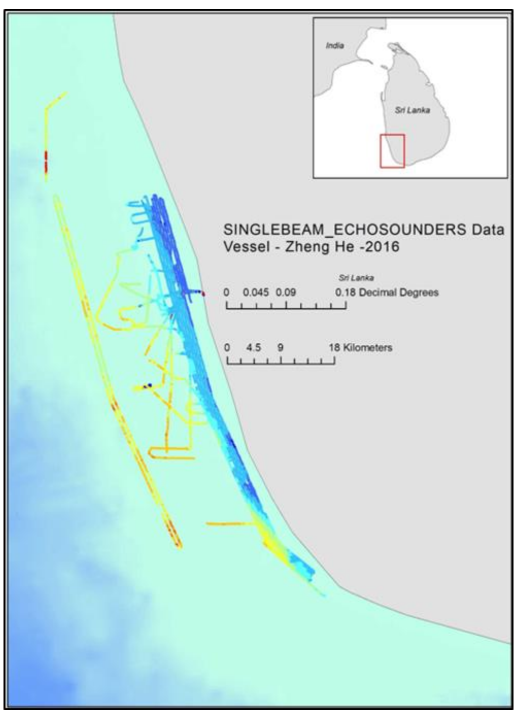


Figure 3.2: Spatial Database Interface



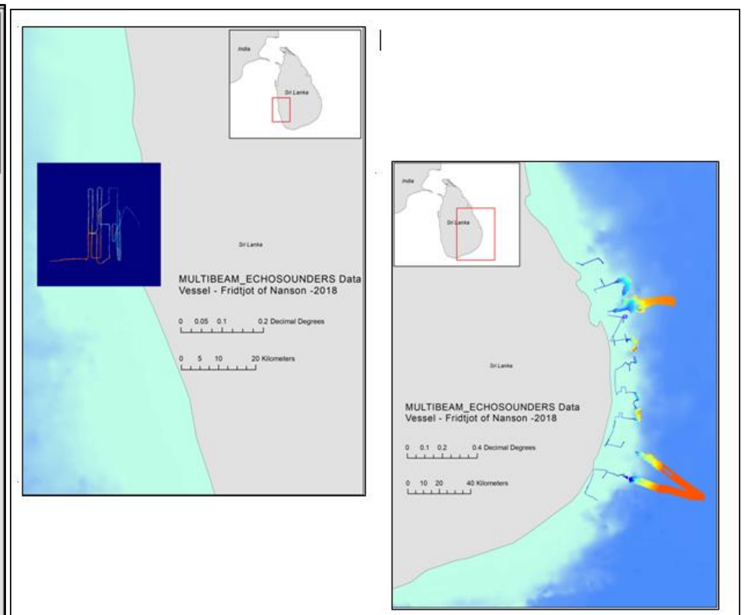


Figure 3.3: Bathymetry from the Sheng he project

Figure 3.4: Bathymetry from the Fridgetof Nanson Survey

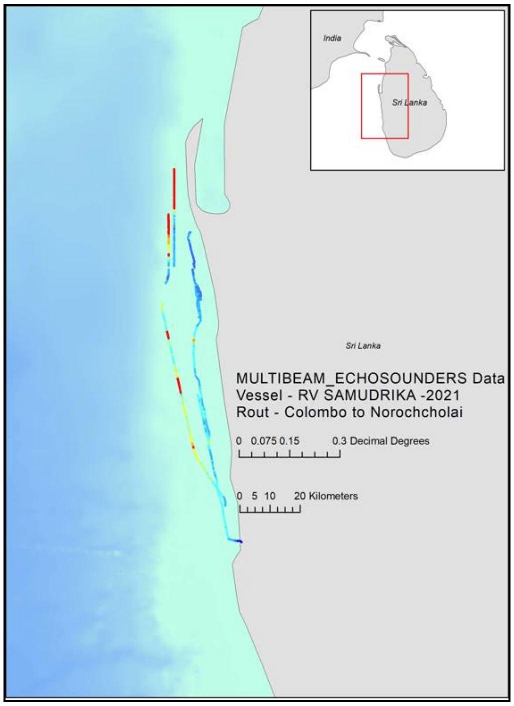


Figure 3.5: Bathymetry from RV"Samuddrika" Cruise track

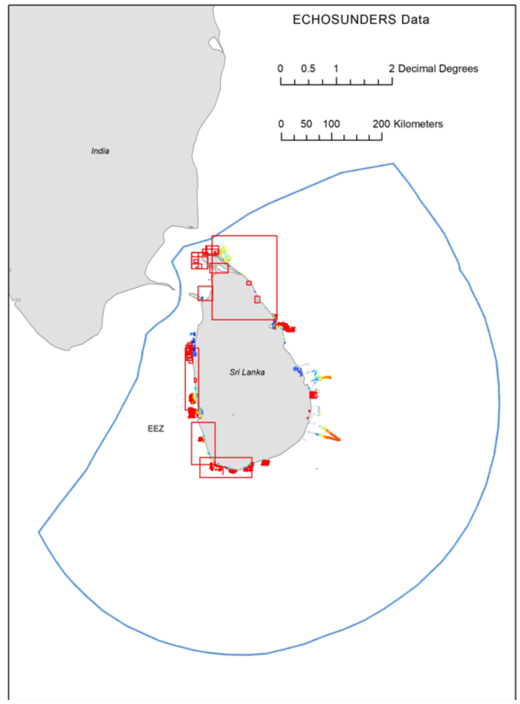


Figure 3.6: Bathymetry from NHO Nautical Charts

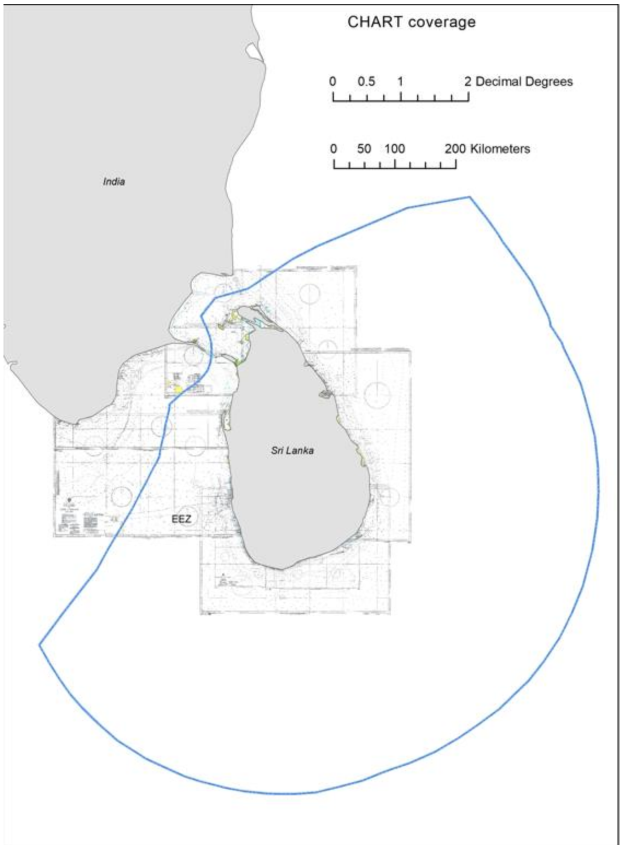


Figure 3:7 Bathymetry from Admiralty charts

Outcomes and Key performance indicators– Bathymetry coverage by area

Expected Outputs: Bathymetry database around Sri Lanka, Map, Research Paper

Constraints:

Because of the COVID 19 pandemic situation purchasing was delayed of necessary items of infrastructure facilities to establish Unit and the networking system as planned for this year. Fish finders purchasing is ongoing.

Financial Allocation: - Rs.0.420 Mn

Financial Progress: - 5.6%

Physical Progress : - 37%

8.4 Investigating Vulnerability of Coastal Erosion in Kalutara

Responsible Officers: N. Malarathne, P.V.D. Tharanga

Introduction

Coastal erosion is becoming a serious environmental issue worldwide due to sea level rise along with climate changes caused by global warming. This study will be focused on Kalutara which is a significant coastal area as the river mouth of Kalu Ganga is located. The sand dune was an important geographical feature in the area because it protected Kalutara town from sea waves.

Objective

1. To find out the vulnerability of coastal erosion in Kalutara coast using GIS
2. To find out whether offshore sand mining in nearby areas is related with coastal erosion
3. To create a prediction model for coastal erosion by considering the outcome of GIS analysis

Data Collection and Analysis

The literature review part is completed and due to the COVID 19 pandemic of the country, the process of the purchasing of satellite images and field work were hindered on time and couldn't continue the project within the year 2020. Further, purchasing of satellite images is in progress.

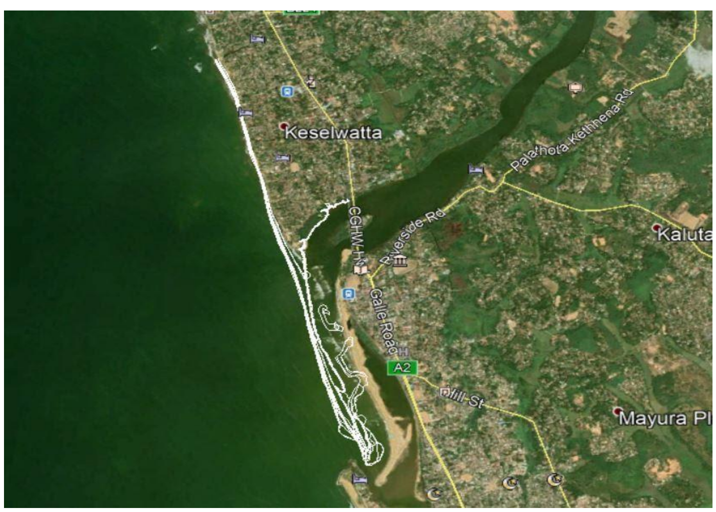


Figure 4.1: Digitized outlines from 2005 to 2018 - Google Earth

First the coastlines were digitized using freely downloaded Landsat images. The 30m resolution was not enough to estimate the coastline variations in these images. Therefore coastlines were extracted from historical satellite imagery in Google Earth using time-lapse tool. The main constraint with extracting data from Google Earth is that images are not available for the required dates and the given historical images shall be used then, which may be different in terms of resolution and particular month of the year. Following table includes the dates that were available for historical satellite images.

Table 1: Satellite imagery dates

2005 July 1	2006 January 31
2009 October 11	2010 November 16
2012 May 9	2013 January 22
2013 November 23	2014 February 6
2015 January 7	2015 November 25
2016 January 4	2016 December 24
2017 January 7	2017 December 17
2017 December 28	2018 January 8

The digitized outlines were opened in ArcGIS. The spatial variation among each outline indicated seasonal variation. This seasonal variation has to be observed along with inter-monsoonal periods. Also, use of geo-processing tools in ArcGIS should be discovered further to get more comprehensive result considering tide corrections.

Figure 4.2: Sandbar in 2005 (blue), 2010 (orange) and 2015 (red)

Seasonal variations of the sandbar were observed for the period 2005-2017. This is mainly happening during the southwest monsoon period prevailing from May to September. However the results have to be displayed in an appropriate graphical method. Also both the erosion and accretion have to be measured in GIS environment in order to get the relationship with monsoonal periods.

Until 2017, the coastal area was fairly stable but after 2017 May, the sand barrier had been collapsed due to the floods (Gunasinghe et al, 2019) making the town area more vulnerable to erosion. In 2018 the construction of an artificial sand barrier was started and completed in April 2020 by Coastal Conservation Department according to the information gathered.

Figure4. 14: Sand barrier collapse (Blue - January 2017 & red - December 2017)

Outcomes

1. Comprehensive scientific report on "Investigating Vulnerability of coastal erosion in Kalutara"
2. GIS based model indicating coastal erosion patterns in Kalutara

Recommendation:

The final output of the project will contribute to fulfil the existing gap by contributing for decision making relevant to coastal environmental protection and policy planning.

Constraints:

The purchasing of satellite images were delayed and the process is still on going. Further, the field visit couldn't conduct as scheduled due to the COVD -19 pandemic of the country.

Financial Allocation: - Rs.1.50 Mn

Financial Progress: - 2.6%

Physical Progress : - 69%

10.1: Feasibility study on pond culture of Asian Seabass (*Lates calcarifer* (Bloch)) with cost effective formulated feed (Kalpitiya).

Sea bass is an economically important food fish in the tropical and sub-tropical regions of Asia and the Pacific. It is highly carnivorous fish but can be trained to feed formulated diet. It can tolerate wide range of salinity levels. *Lates Calcarifer*, known as sea bass in Asia and barramundi in Australia, is a large eurihaline member of family Centropomidae that is widely distributed in Indo West Pacific region from the Arabian Gulf to China, Taiwan province of China, Papua New Guinea and northern Australia. Sea bass aquaculture commenced in the 1970s in Thailand and rapidly spread throughout South East Asia. Among the various species of finfishes, Asian sea bass *Lates Calcarifer* is considered as one of the most potential candidate species suitable for culture in marine eco systems, freshwater and brackish water ponds and cages. Sea bass possesses fast growth rate, open and responsive for artificial feed or trash fish and can be bread captivity, make it candidate species for aquaculture. Sea bass is generally cultured in sea cages located in river mouth or estuaries. Normally farmed seabass is usually marketed at around 500-800g while wild caught ones usually weigh 4Kg or more.

Ministry of Fisheries and Aquatic Resources of Sri Lanka made efforts in recent years to promote other coastal aquaculture activities involving seabass, sea weed sea cucumber and oyster culture with the objective of promoting exports and also provide livelihoods for coastal communities. First attempt at introducing sea bass farming in the country has been made in 2006 under the Asian Development Bank assisted Coastal Resource Management Project implemented by Ministry of Fisheries and Aquatic Resources.

Sea bass pond culture still not practices and priority was given mainly for cage culture system. Pond culture system easy to adopt in Sri Lankan condition where abandoned shrimp farming ponds can be converted to sea bass culture ponds. Due to the ability to withstand wide salinity range and low depth of water, sea bass pond culture can be started in intertidal zones.

The specific objectives of the project were to test the feasibility of culture Asian seabass in ponds, to test the cost-effective feed formulae prepared by NARA and to use locally available underutilized trash fish to make feed for seabass.

The planned total acclimatization period was one month, but due to constant power failure aeration system was failed at least 5 to 7 times average day. During power failure generator was used to run aerators. 15th of May 2021 power was disconnected and generator also broken down which made 960 dead of advanced fingerlings during acclimatization period.

	Mean weight (g)		
Days	T1	T2	T3
30 days	34.34±2.80	32.97±3.80	33.61±3.74
60 days	85.4±10.64	69.33±15.23	82.52±20.41
120 days	190.34±28.62	170.13±32.56	170.56±24.56
150 days	269.94±34.52	217.29 ±40.23	272.48± 42.54
180 days	342.47± 48.56	297.27± 54.63	347.38± 56.98
210 days	368.36± 56.64	311.33± 45.69	499.97± 60.34

Table 01: Mean weight gain of *Lates calcarifer* in monthly intervals

Amid this worst situation all other remained fish randomly distributed among prepared replicates. Stocking density in mud ponds adjusted 2 fingerlings /m2. Size of each replicate 125 m2 and number of fish 250 per replicate Rest of fifteen days until 1st of June commercial feed was given according to bodyweight of fish.

Water exchange to an extent of 70-80% of the total volume should be done daily. A flow through arrangement for water exchange is desirable. Important parameters of water quality to be maintained are as follows: water temperature: 28-32°C; salinity: 29-32 ppt; alkalinity (CO3): 80-120 ppm; pH: 6.8-8.0; dissolved oxygen: above 5 ppm; phosphate: less than 10 ppm; unionised ammonia: less than 5 ppm; ionised ammonia: less than 1.5 ppm;

Feed ingredients of formulated feed – Fish meal, meat and bone meal, Shrimp head meal, soybean meal, maize, wheat flour, rice polish, vitamin mineral premix, fish oil, methionine, lysine.

Feed ratio needed to maintain 2.5 1

(Trash Fish: Formulated Feed)

Results

Weight gain of cultured fish under three replicates

Table 02: Average daily growth rate and specific growth rate of *Lates calcarifer* in monthly interval

	Average daily growth rate (g day-1)			Specific growth rate (%)		
Days	T1	T2	T3	T1	T2	T3
30 days	0.44	0.51	0.41	27.06	30.36	23.4
60 days	1.7	1.12	2.83	32.93	69.66	95.16
120 days	3.29	3.36	3.53	32.94	44.8	37.1
150 days	2.65	2.33	3.18	62.2	67.8	74.46
180 days	2.41	2.66	2.49	49.76	32.73	34.76
210 days	2.84	2.68	3.01	16.06	15.2	51.9

Mean weight, ADGR and SGR of the seabass reared in ponds at three replicates, at 30 days interval are shown in Table 1 and Table 2. ADGR and SGR on termination of the experimental period were 2.84 g, 2.68g and 3.01g and 16.06, 15.2 and 51.6, respectively. SR and BI at the end of the culture period were 68.8% and 1t, respectively. Fish were fed with approximately 1.5t of trash fish, 500kg feed formulated feed and (700 kg trash fish + 350 Kg of formulated feed) respectively T1, T2 and T3 during the culture period.

The expected weight gain was not achieved at Kalpitiya sea bass ponds due to several reasons. This project was planned to start in month of March but due to unavailability of seabass fingerlings in Ambakandavila hatchery. It was observed that relatively low feed consumption rate of seabass cultured in brackish water ponds at Regional Research Centre. Due to heavy rain received during the month of October to December, feed consumption of fish reduced and mortality of fish observed. According to research findings feeding of 50% of trash fish + 50% formulated feed seems to be economically viable as well as for expected weight gain.

Constraints

Covid -2019 Pandemic acted as the major killing factor of this year because due to prolong curfew from mid of June to August and RRC kalpitiya also closed due to staff members had been quarantined due to positive results. Then North Western province of Sri Lanka received huge rain from inter monsoonal conditions and North-East monsoon. Therefore, salinity level had been dropped to 1-2ppt within one week period in the month of November which caused fish mortality. Due to both effects supply of trash fish had been dropped and the cost per kilo increased from Rs 20/=.

Output

1. Built up awareness among fishing communities, and NARA on sea bass pond culture in intertidal zone of Puttalam estuary.
2. Identified of trash fish: NARA formulated feed ration for proper growth of pond cultured sea bass.
3. Preparation of abandoned prawn ponds for effective sea bass aquaculture at North Western province.

Recommendation

To obtain the maximum growth of sea bass cultured at ponds in North Western province, formulated feed and trash fish combination will give the required results within period of one year and cost wise combination, is the most profitable option.

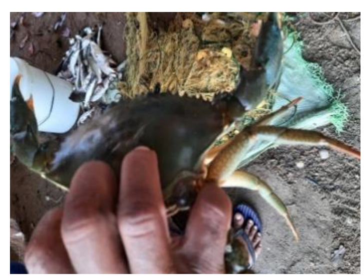
10.2 Monitoring of water quality parameters, fisheries, mangrove and seagrass ecosystems at the Puttalam lagoon

The main objective of this study was to establish continuous monitoring program in the Puttalam lagoon, to gather data about mangrove coverage, sea grass coverage, and monthly fish catch and water quality variation. The aquatic habitats of Puttalam lagoon area are occupied by marine and brackish water species of fish and shellfish which are important resources for the people living in the area, as the main livelihood in the area is fishing. As fish breeding and nursery grounds mangroves and seagrass ecosystems directly influence to enhance the fish catch. In the other hand water quality variation of the lagoon influence the ecosystem health and distribution of fish species. Present study aimed to consider all those aspects of the lagoon to provide proper management recommendation regarding the lagoon in the future. To fulfill the above objective monthly fish catch was collected from 7 landing sites (Gangewadiya, Serakkuliya, Puttalam, Anawasala, Palliyawatta, Uchchamune and Ippantivu) and water samples were collected from 20 locations (Figure 2) in the lagoon. Mangrove and seagrass species were identified and quantified in selected locations. However, due to the COVID-19 situation in the country, monthly field visits could not be conducted regularly as expected.

Gill nets, trammel nets and bottom-set gill nets were the most commonly used gears to catch both finfish and shellfish. Monofilament nets (Tangus nets) were observed rarely. Non- motorized traditional crafts, motorized traditional crafts and OFRP were used as fishing fleets. Several fin fish species were recorded during the survey as main catch and by catch. Most common fin fish species were *Silago sihama*, *Mugil cephalus*, *Arius* sp., *Leiognathus* sp., *Lutjanus* sp., *Epinephelus* sp., *Rastrelliger kanagurta*, *Gerres abbreviatus*, *Alectis ciliaris*, *Siganus* sp., *Terapon* sp., *Letrinus* sp. *Escuolosa thoracata* were recorded only from the Serakkuliya landing site. Shell fish catch of the lagoon dominated by crabs and shrimps. *Portunas pelagicus*, P. *sanguinolentus* and *Scylla serrata* were the main edible three crab species found during the survey. P s*anguinolentus* were limited to high saline areas. *Penaeus indicus*. P *monodon* and P. *semisulcatus* were the major shrimp species found during the survey. After the flooding in Puttalam area during November *Penaeus vannamei* was recorded from Puttalam landing site.

Portunas pelagicus

Portunas sanguinolentus



Scylla serrata

Penaeus monodon

Penaeus indicus

Penaeus semisulcatus

Arius sp.

Sillago sihama

Lutjanus fulvus

Rastrelliger kanagurta

Siganus sp.

Sacatophagus argus

Figure 1: Some fish species identified during the survey

pH, Salinity, Dissolved Oxygen, Turbidity, TDS and EC were measured in collected water samples at the laboratory of the NARA's Environmental Science Division. Water samples were collected only during February, March, April, October, November and December. As shown in the Figure 3 salinity level were higher in station 14, 15 and 16 which are located at the lagoon mouth. Average turbidity levels were shown in Figure 4. Accordingly, turbidity level was highest in station 2 which is situated near the urban area of Puttalam. However, due to the inconsistency of samples, an accurate conclusion cannot be made regarding the temporal and spatial variation of water quality parameters.

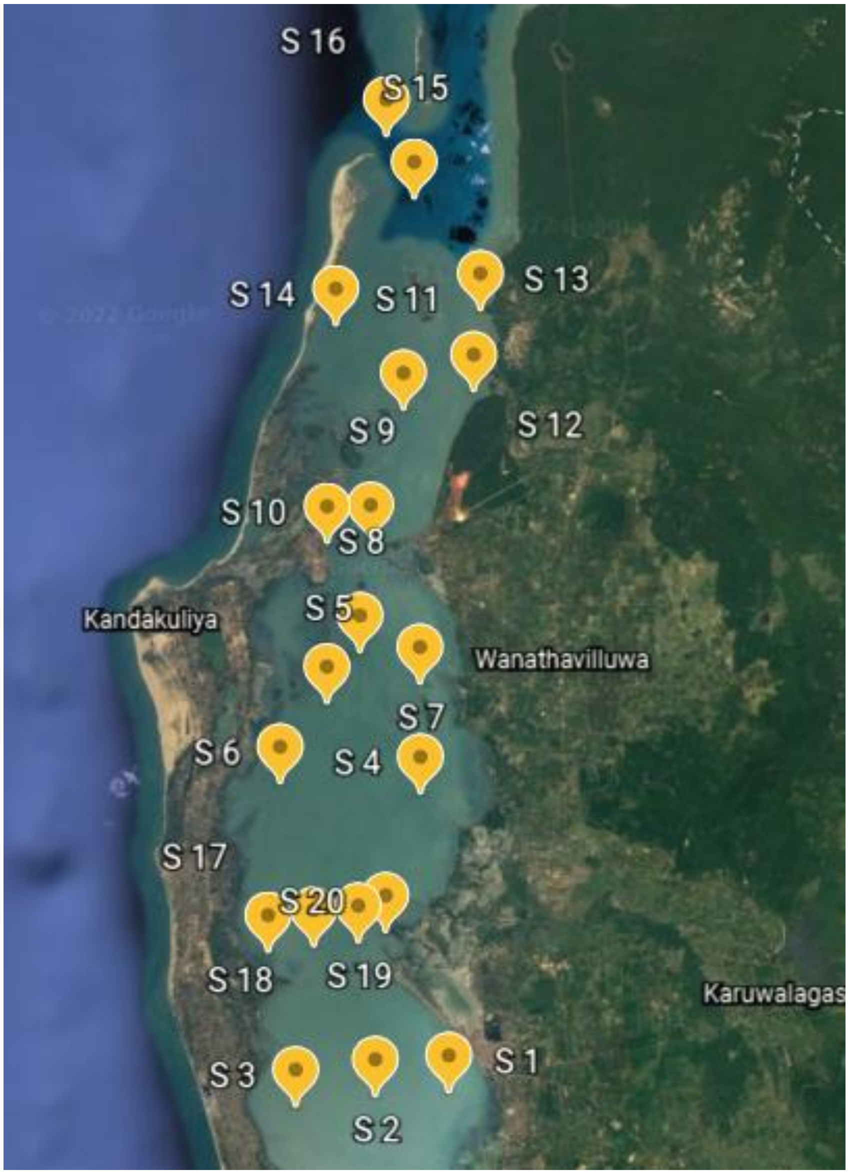


Figure 2: Sampling locations of the water quality monitoring

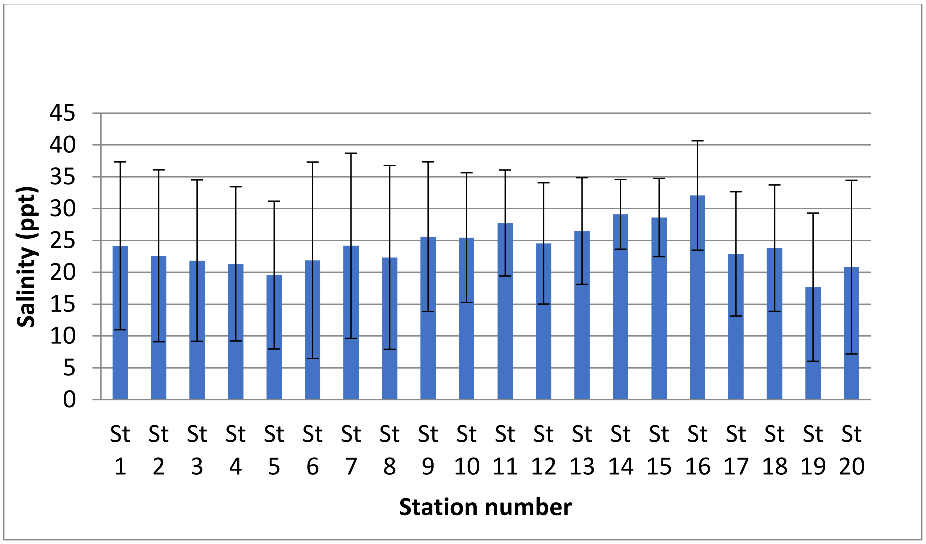


Figure 3: Average salinity level in each station

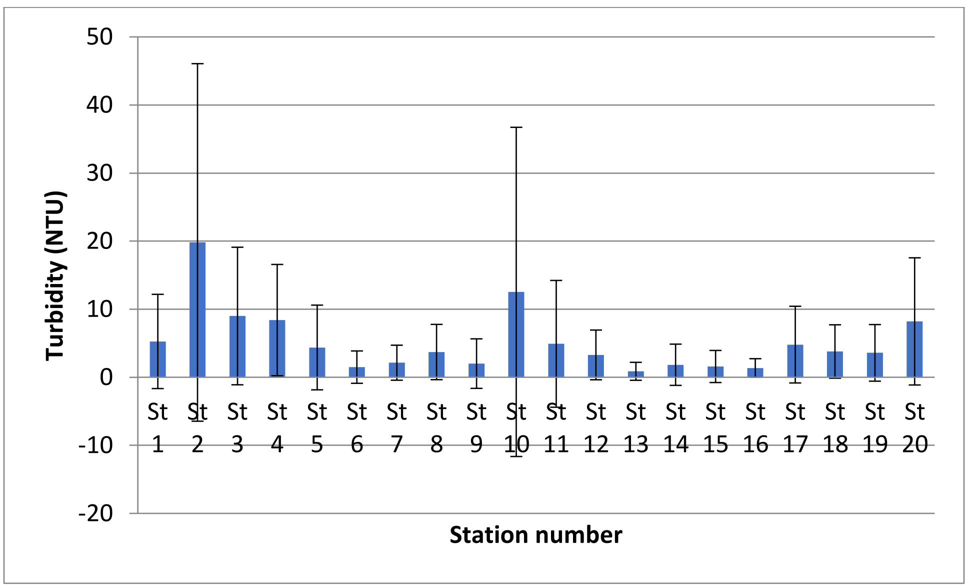


Figure 4: Average turbidity level in each station

During the 2021 mangrove survey was conducted from Uchchamune to Dutch bay and in Ippantivu, Periya arichchale, Sinna arichchale, Oddakarativu, Eramativu, Sinna Eramativu and Neduntivu islands. Recorded species with the location were shown in table 3.

Figure 5: Deploying transect for mangrove survey

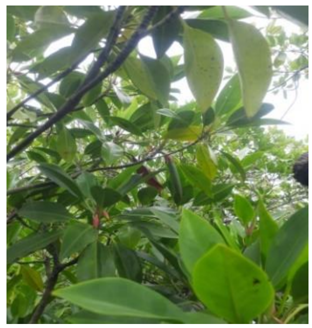
Table 3: Mangrove species distribution in studied sites

Species	Uchchamune	Mohottuwaram	Dutchbay	Ippantivu	Periya arichchale	Sinna arichchale	Oddakarativu	Eramativu	Sinna Eramativu	Neduntivu
Rhizophora mucronata	x	x	x	x	x	x	x	x	x	x
Rhizophora apiculata				x	x	x				
Avicennia marina	x	x	x	x	x	x	x	x	x	x
Bruguiera gymnorrhiza								x		
Bruguiera cylindrica				x	x	x	x	x		x
Ceriops tagal	x	x	x	x	x		x	x	x	x
Excoecaria agallocha	x	x	x	x	x	x	x	x	x	x
Lumnitzera racemosa	x		x	x	x	x	x	x	x	x
Pemphis acidula	x	x	x	x	x	x	x	x	x	x

Sonneratia alba	x	x	x			x	x			

Rhizophora mucronata and *Avicennia marina* were the major constituent species in the lagoon. Zonation of species was observed, *Rhizophora mucronata*, *Rhizophora apiculata* and *Sonneratia alba* were at the water front and mixed mangrove communities of *Ceriops tagal*, *Pemphis acidula* and *Lumnitzera racemosa* were on the landward side. Although previous studies found 13 mangrove species in lagoon present study found only 10 mangrove species since study did not cover the Kala oya and Mee oya mouth areas during this year.

Excoecaria agallocha



Bruguiera gymnorrhiza

Bruguiera cylindrica

Avicennia marina

Sonneratia alba

Ceriops tagal

Rhizophora mucronata

Lumnitzera racemosa

Rhizophora apiculata

Figure 6: Some mangrove species found during the survey

Figure 7: Dead mangroves

The Puttalam lagoon's seagrass ecosystem provides habitat for the organisms and acts as a breeding ground for commercially viable fish shrimp species. The seagrass coverage and species composition were measured using the quadrate and transect method. Every main site of the lagoon was studied for the seagrass composition, and the Dutch bay area was completed during 2021. *Thalassia hemprichii*, *Enhalus acoroides*, *Oceana serrulata*, *Cymodocea rotundata* and *Halodule uninervis* were identified as the common seagrass species that can be seen in the dutch bay area. Among them, *Enhalus acoroides* and *Oceana serrulata* obtain the highest coverage. *Halophila decipiens* and *Halophila ovalis* species are rarely observed in the studies sites. *Syringodium isoetifolium*, which was recorded in the previous research, was not recorded during the monitoring period. Hence, the species can be identified as the threatened seagrass species in the Puttalam lagoon.

Table 4: Seagrass species distribution in sampled sites

Species / Site	EN	CR	OS	HU	TH	HD	HO
Periyaarchilai	+	+	+	+	+		
Sinnaarchchilai	+	+	+	+	+		
Muttikalan	+	+	+	+			
Mattaithivu	+	+	+	+	+		
Illupanthivu	+		+	+	+	+	+
Vellamundel	+	+	+	+	+	+	
Gangewadiya	+	+	+	+	+		
Kilithivu	+		+		+		
Off Kalpitiya Harbour	+		+	+	+		
Krimundal	+	+	+	+	+	+	
Mohottupara	+	+	+	+	+		
Ucchimune	+	+	+	+	+		+
Boatuvadiya	+	+	+	+	+		

(EN: *Enhalus acoroides*, CR: *Cymodocea rotundata*, OS: *Oceana serrulata*, HU: *Halodule uninervis*, TH: *Thalassia hemprichii*, HD: *Halophila decipiens*, HO: *Halophila ovalis*)

Further, several anthropogenic and natural impacts on the seagrass beds could be observed during the study.

Table 5: Observed impacts on seagrass ecosystem in Puttalam lagoon

Natural	Anthropogenic
Due to the tide variation die back and die off of seagrass	Boat propelling
Grazing and epiphytes	Trampling
Interspecies and intraspecies composition	Distructive fishing gears
Due to the tide variation die back and die off of seagrass	Effluents
High turbidity due to wind and wave action	Aquaculture activities

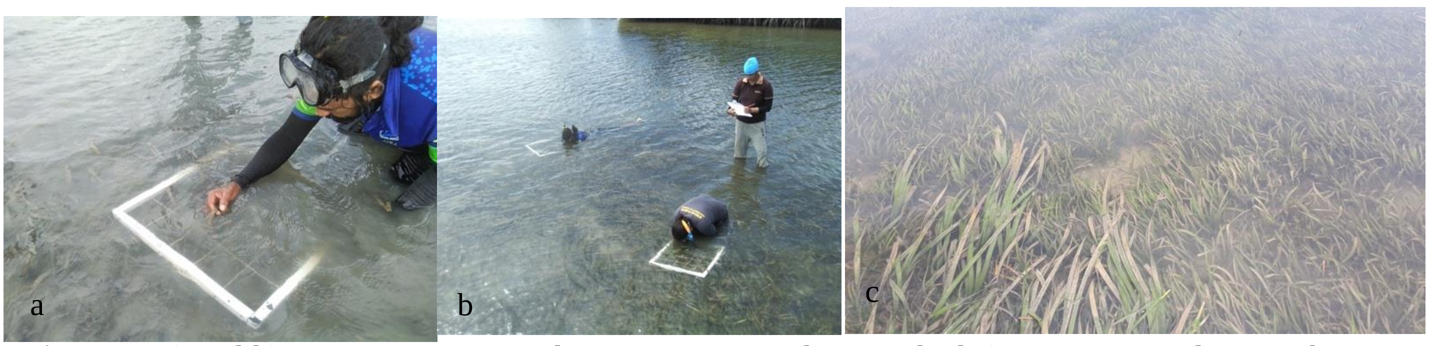


Figure 8: a) and b) Assessing seagrass diversity using quadrate method c) Seagrass meadows in the Puttalam lagoon

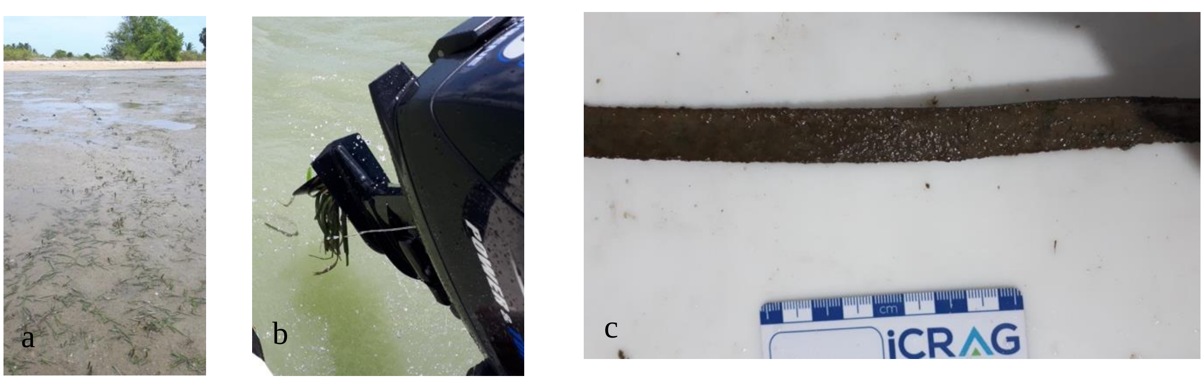


Figure 9: Impacts a) Exposure to the direct sunlight due to tidal fluctuation b) Damaged seagrass due to boat propelling c) Excessive epiphytes coverage due to high sediment loadings

10.3. Estimation of abundance and biomass of shrimp/ bycatch in trawl fisheries (Kalpitiya and Mannar): using fisheries dependent and independent methods

In Sri Lanka, the main wild shrimp fishing technique is bottom trawling. At present, demarcation of existing trawl grounds (Handala, Negombo, Kalpitiya, Mannar and Jaffna) is being NARA and DFAR as one of the steps for the management of these fisheries. Behind the trawl fishery there is an environmental sensitive concern through the degradation of natural resources by destruction of bottom ecosystem as well as bycatch of non-targeted marine bio resources. Meanwhile, mechanised trawl nets are indiscriminate and result in high levels of 'by-catch' in which wide variety of commercially important/less valuable matured/juvenile species are trapped in these nets, and often perish. The trawling activities conducted in particular regions almost all over the year without off season owing to that major part of resources exploited by trawl in unsustainable manner. So proper scientific management is much needed to ensure sustainability of fishery resources. Obtaining of time series data related to the abundance and biomass of shrimp as well as other marine bio resources in selected trawling site is essential to assess the current status of resource availability. In order to fulfill the existing gap in research site in shrimp trawl fishery the project was conducted through the survey in selected trawling sites (Kalpitiya and Mannar). The objectives of the research were to Monitor and update the information about trawl fishery, estimate the abundance and biomass of shrimps and by-catch and to provide the recommendations on shrimp trawl fisheries management

The study was conducted from January 2021 to December 2021 (due to Co-vid 19 pandemic the monthly visits were not in a continuous manner) based on in Kalpitiya and Mannar shrimp trawl fisheries. Data collections obtained through different sources:

(I) Fishery dependent survey:

Data collections were conducted in monthly basis in trawl landing sites of each location. Where catch data entry log books and bills of fishermen were collected and daily catch weight data of shrimp, number of boats operated and total monthly catch data were recorded. Details about vessel operation and gear type and fishing periods also collected. Using above information, Monthly variation of Catch Per Unit Effort (CPUE) per trip was calculated. Monthly biomass estimates also predicted with aid of dependent data and CPUE.

Plate 1: Trawl landing site-Kalpitiya

Plate 2: Trawl landing site-Mannar

(II) Biological sample analyses:

Sub samples of shrimp trawl catch from randomly selected trawler boat were collected during each field visits at both sites. The monthly analyses were planned, but due to the Co-vid 19 situations, vehicle unavailability the sampling was not conducted in a regular basis (field visits were not carried out in January, March & from June to September). Biological parameters such as total length, carapace length, individual weight, sex and maturity were examined foe collected sub sample.

Plate 3: Biological sample analyses

(III) Fishery independent survey:

Single survey at Kalpitiya trawling ground was successfully conducted from 29th November – 03rd December 2021, that includes 25 randomly selected sampling stations (covering whole trawl ground). Species composition in whole trawl catches from each sampling stations were recorded and biological survey also carried out. All the independent survey related data were entered to the Biotic Editor Software package and further analyses were carried out using StoX 3.3.0 software.

(I) Fishery de

Plate 4: Independent trawl survey at Kalpitiya trawling ground

Location	Vessel type	Gear type	Fishing effort	Catch species
Kalpitiya	Vessel: **11 tonne** trawler boat Power: 90 - 110 HP inboard engine Fuel: Diesel Total number of available vessels: 23 Total number of	Gear: Trawl net Width of mouth: 9.4 m Body mesh size: 1 ½ ″ (3.8 cm) Cod end mesh size: 1″ (2.5 cm)	Number of fishing days: **06 days** (departure: Mondays and landing: Friday or Saturday) Fishing time period: 6.00 a.m to 5.00 p.m (trawling in **day time only**) Number of hauls per trip per boat: 12 hauls Time duration taken for one haul: 4-5 hour	Major shrimp species caught: - ***Penaeus semisulcatus*** Other shrimp species: - *Penaeus indicus* - *Penaeus merguiensis* - *Metapenaeus moyebi* Major by-catch species:

	active vessels: 15 - 20 per week			- ***Leiognathus* sp**
Mannar	Vessel: **3.5 tonne** trawler boat Power: 30 HP inboard engine Fuel: Diesel Total number of available vessels: 230 Total number of active vessels: 150- 170 per single day	Gear: Trawl net Width of mouth: 3.6m (12 feet) Body mesh size: 1 ½ ″ (3.8 cm) Cod end mesh size: 1″ (2.5 cm)	Number of fishing days: **01 day** (trawling at **night time only**) Fishing time period: Monday 06.00p.m to Tuesday 6.00a.m Wednesday 06.00p.m to Thursday 6.00a.m Saturday 06.00p.m to Sunday 06.00a.m Number of hauls per trip per boat: 03 hauls Time duration taken for one haul: 03 hours	Major shrimp species caught: - ***Penaeus semisulcatus*** Other shrimp species: - *Metapenaeus moyebi* - *Metapenaeus dobsoni* Major by-catch species: - ***Leiognathus* sp**

Plate 5: Trawler boat (A) and Landing process (B) in Mannar

Pl ... alpitiya

Figure 9: Shrimp ... ya; *Penaeus indicus* (A), *Penaeus semisulcatus* (B), *Penaeus merguiensis* (C), *Metapenaeus moyebi*

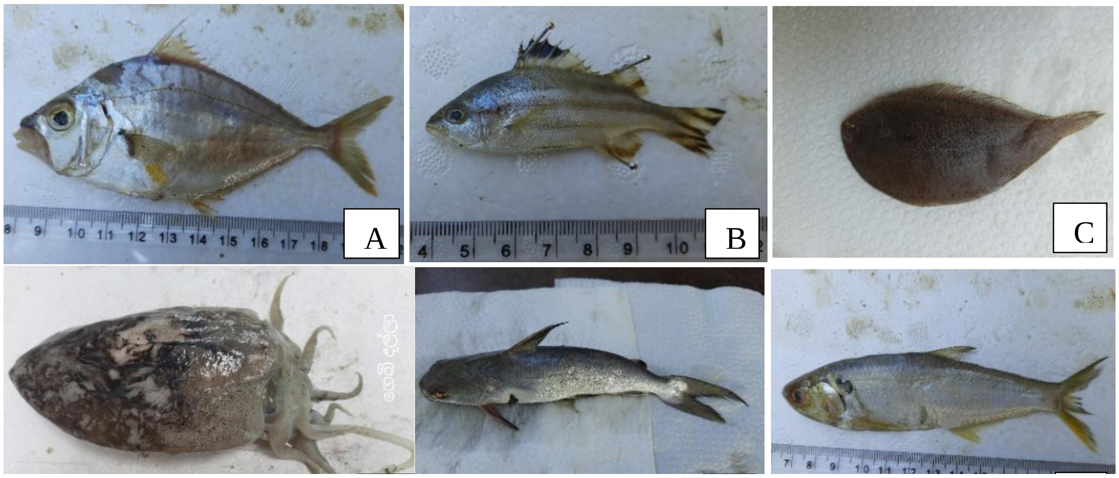


Plate 7: By-catch species caught in Trawl fishery in Mannar & Kalpitiya; *Leiognathus* sp(A), *Terapon* sp (B), *Solea elongata* (C), *Sepia* sp (D), *Arius* sp (E), *Sardinella* sp (F)

Kalpitiya trawl fishery:

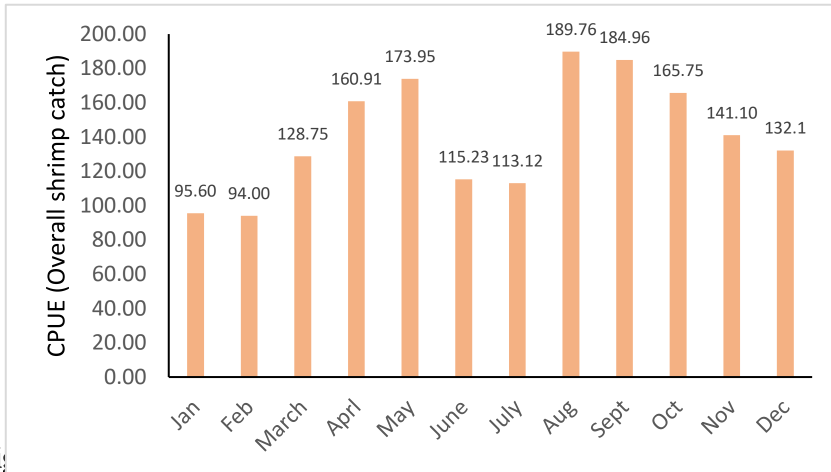
I. Catch Per Unit Effort (CPUE) for shrimp species caught in Kalpitiya shrimp trawl fishery 2021 (per trip)

Table 6: Monthly CPUE for shrimp caught in Kalpitiya

Month	CPUE (Large size) in kg	CPUE (Medium size) in kg	CPUE (Small size) in kg	CPUE (Very small size) in kg	CPUE (overall total) in kg
Jan	29.10	54.40	8.60	3.50	95.60
Feb	27.50	61.25	3.63	1.63	94.00
March	32.75	82.63	9.88	3.50	128.75
April	54.34	61.22	38.27	40.41	194.24
May	86.67	80.72	19.03	0.43	173.95
June	52.24	62.99	0.00	0.00	115.23
July	44.55	68.57	0.00	0.00	113.12
Aug	64.59	125.17	0.00	0.00	189.76
Sept	71.50	113.45	0.00	0.00	184.96
Oct	55.26	110.49	0.00	0.00	165.75
Nov	44.60	87.20	7.80	1.50	141.10

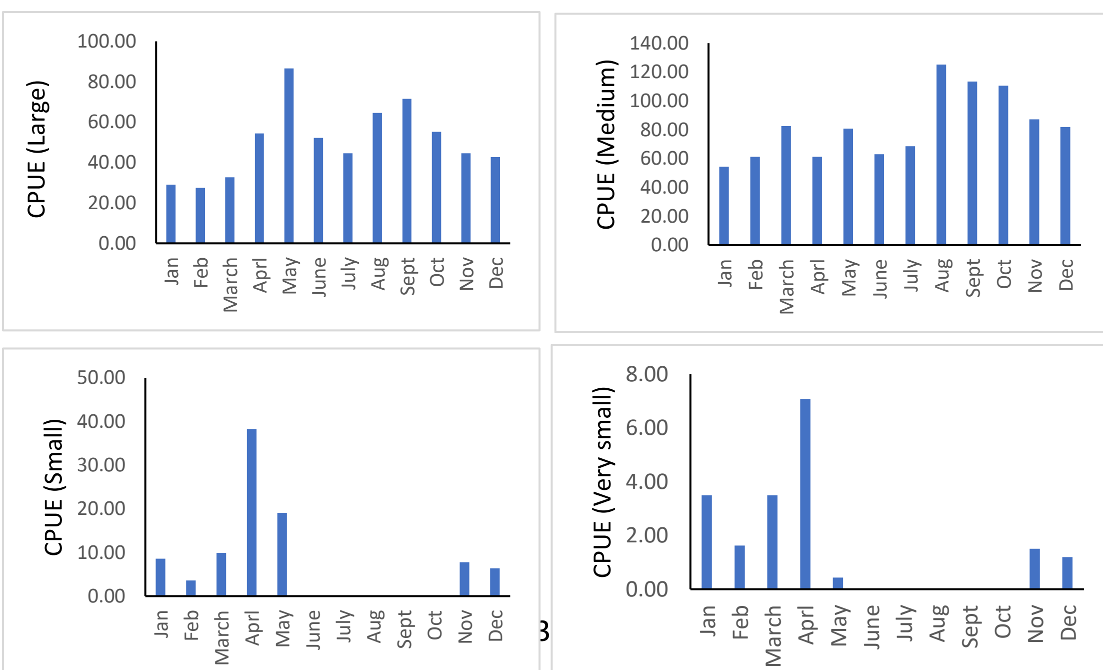
Dec	42.7	81.8	6.4	1.2	132.1

Table 6 shows the monthly catch per unit effort data of different sized shrimp caught through trawl fishing per trip. Where, the category indicates in weight range of large: Above 50g, medium: 30g - 49g, small: 13g - 29g and very small: 08g - 12g



Fi Kalpitiya

The CPUE of Kalpitiya trawl fishery range between 94kg – 189 kg throughout the year of 2021. The figure 1 shows that the lowest CPUE recorded in February period (94 kg) and highest CPUE in August (189.7 kg). The graph also shows there was a gradual rise in CPUE from February to May and gradual decline from August to December. Between these, there was a sudden decline also observed during the period of June-July.



3

Plate 8: CPUE monthly variation for different sized shrimp caught in Kalpitiya

The graphs clearly show that the highest value of CPUE representing small sized/juvenile shrimps mostly observed during the period of April and it could be the spawning and growing season of shrimp in particular trawl ground. However, the period of June – October, small sized shrimp catch was very low and limited. Also, when compare to other sizes, catch of medium sized (30g - 49g) shrimp was always dominates throughout the year.

II. Biological analyses findings

The initial plan was to find out the monthly variation pattern of biological parameters of shrimp catch, however due to the Covid 19 pandemic situation we cannot conduct the field visits in regular basis. So, the length, weight and maturity variation pattern were examined only for certain months.

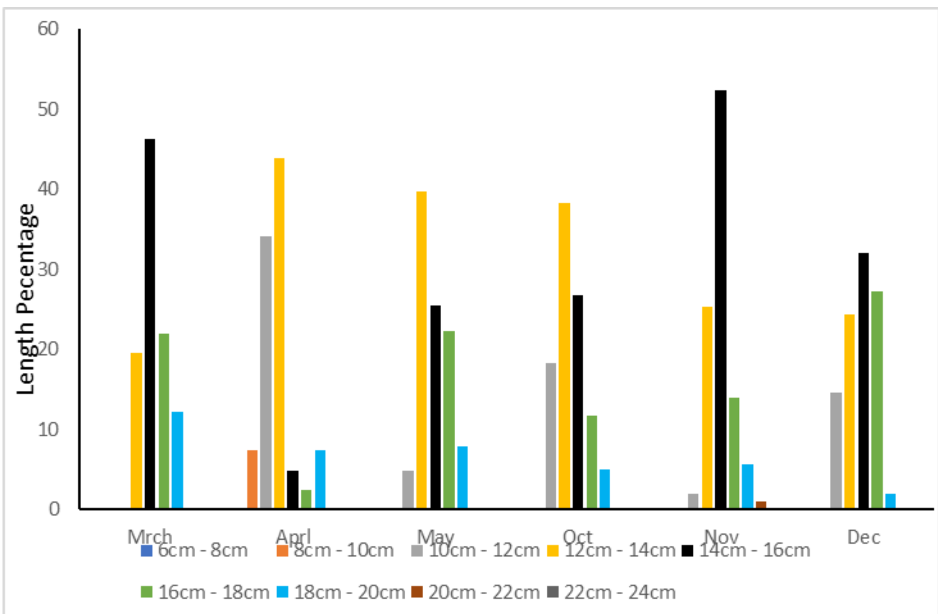
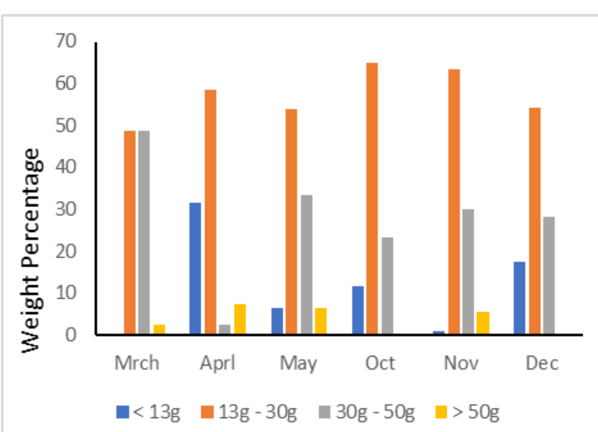


Figure 11: Length variation pattern of *Penaeus semisulcatus* shrimp catch



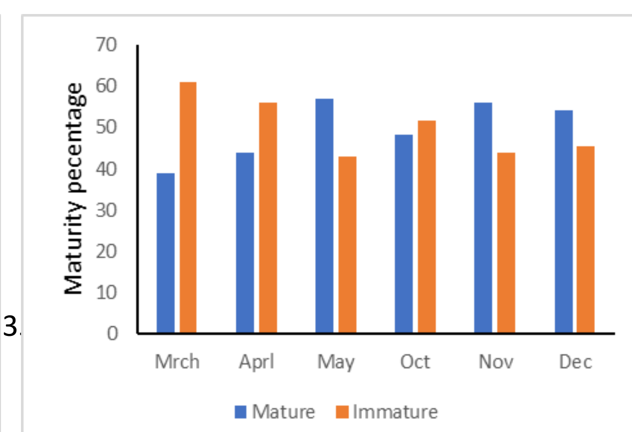


Figure 12: Individual weight variation pattern of *Penaeus semisulcatus* shrimp

Figure 13: Maturity variation pattern of *Penaeus semisulcatus* shrimp catch

In concern of length variation, there was a prominent caught of smaller sized (8 cm – 10 cm) shrimp observed in month of April. However, the length class representing 12cm-14cm and 14cm-16 cm, shows higher catch percentage throughout the year in comparison with others. The weight variation also shows that small and medium sized (13g-30g/ 30g-50g) shrimp always dominates in trawl catch throughout the year and smallest/juvenile sized (< 13g) shrimp catch percentage is prominent during the month of April when compare to other months. Maturity variation also shows that during the March-April period the catch percentage of immature shrimp was comparatively high and that overrule the matured one.

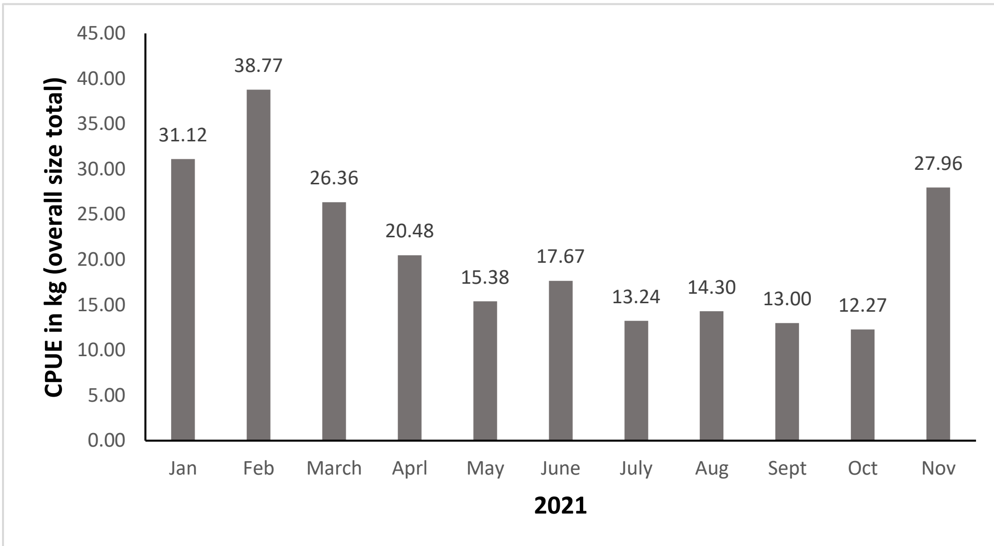
Mannar trawl fishery:

I. Catch Per Unit Effort (CPUE) for shrimp species caught in Mannar shrimp trawl fishery 2021 (per trip)

Table 7: Monthly CPUE for shrimp caught in Mannar

Month	CPUE (Large size) in kg	CPUE (Medium size) in kg	CPUE (Small size) in kg	CPUE (Very small size) in kg	CPUE (Overall total) in kg
Jan	1.61	3.67	16.98	8.86	31.12
Feb	2.83	6.03	22.96	6.95	38.77
March	1.82	5.20	14.11	5.23	26.36
April	3.06	3.49	11.01	2.92	20.48
May	3.50	2.83	8.20	0.85	15.38
June	4.31	3.95	9.24	0.18	17.67
July	3.90	3.07	6.05	0.22	13.24
Aug	4.21	3.02	6.78	0.29	14.30
Sept	4.13	3.26	5.53	0.09	13.00
Oct	2.51	2.72	6.93	0.12	12.27
Nov	2.89	5.15	18.28	1.64	27.96

Table 7 shows the monthly catch per unit effort data of different sized shrimp caught through trawl fishing per trip. Where, the category indicates in weight range of large: Above 50g, medium: 30g - 49g, small: 13g - 29g and very small: 08g - 12g.



The CPUE of Mannar trawl fishery range between 12kg – 38 kg throughout the year of 2021. The figure 14 shows that the lowest CPUE recorded in October (12.2 kg) and highest CPUE in February (38.7 kg). Graph also shows the catch rate is comparatively high in the period of January – April. During the period of May – October shrimp catch was low and average catch per trip calculates as the amount of below 20kg.

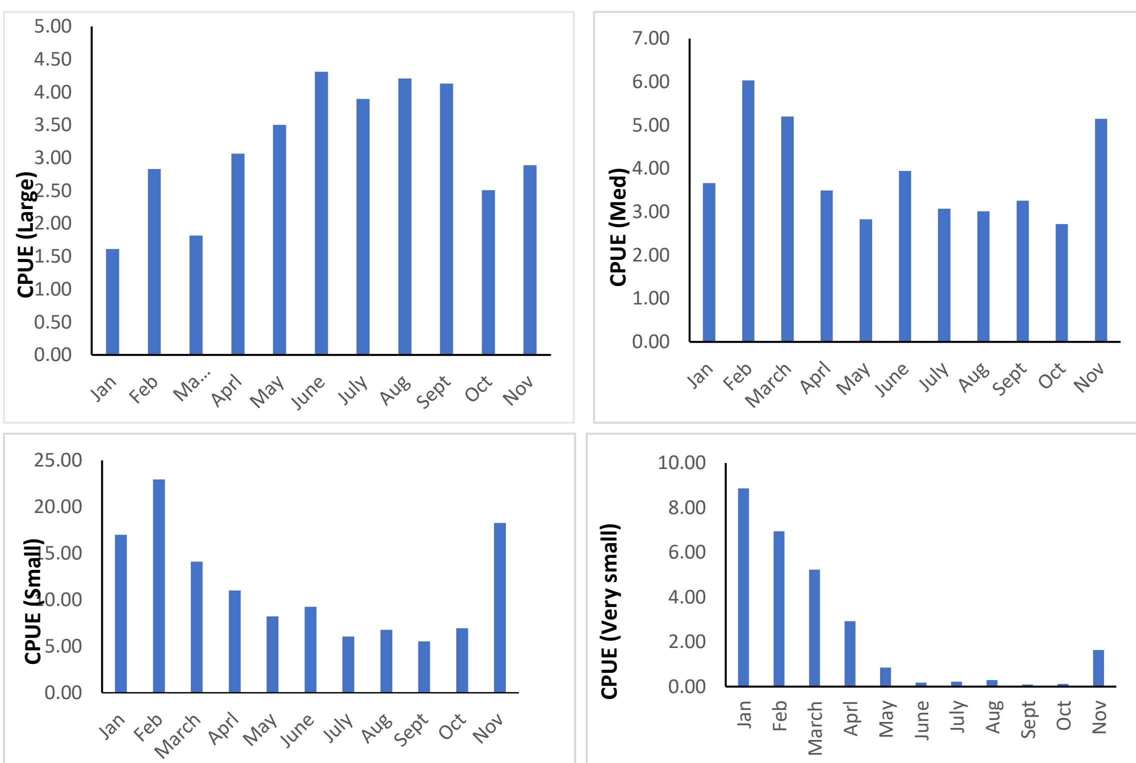


Plate 9: CPUE monthly variation for different sized shrimp caught in Mannar

The graphs indicate that the highest value of CPUE representing smallest sized/juvenile shrimps mostly observed during the period of January - March and it could be the spawning and growing season of shrimp in particular trawl ground. However, the period of June – October, smallest sized shrimp catch was very low and limited. Also, when compare to other sizes, catch of small sized (13g - 29g) shrimp was always dominates throughout the year.

II. Biological analyses findings

Due to the Covid 19 pandemic situation we cannot conduct the field visits in regular basis. So, the length, weight and maturity variation pattern were examined only for certain months.

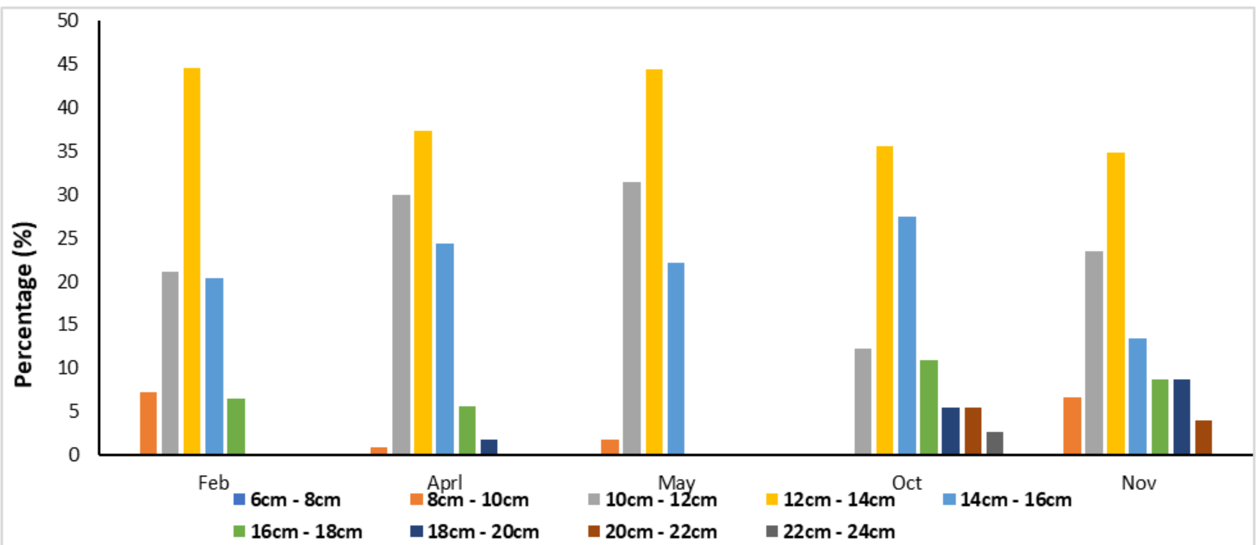


Figure 15: Length variation pattern of *Penaeus semisulcatus* shrimp catch

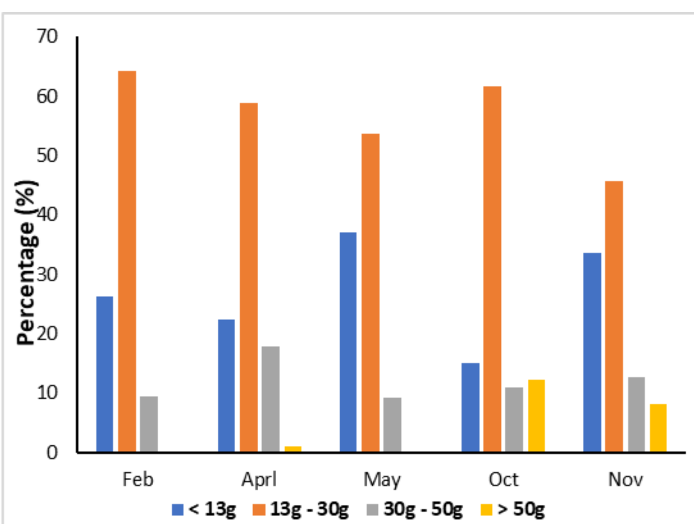


Figure 16: Individual weight variation pattern of *Penaeus semisulcatus* shrimp catch

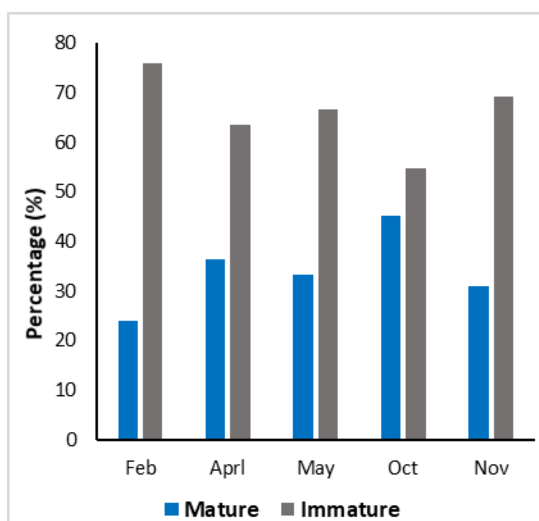


Figure 17: Maturity variation pattern of *Penaeus semisulcatus* shrimp catch

In terms of length variation, there was a prominent caught of smaller sized (8 cm – 10 cm) shrimp observed during the period of February - May and November. However, the length class representing 12cm-14cm shows higher catch percentage throughout the year in comparison with others. The weight variation also shows that smaller sized (13g-30g) shrimp always dominates in trawl catch throughout the year and smallest/juvenile sized (< 13g) shrimp catch percentage is prominent during the months of February, May and November when compare to other months. The lager sized (> 50g) shrimp catch was always lowest percentage and during the October only it exceeds above 10% of total catch. Maturity variation also shows that the catch percentage of immature shrimp was comparatively high and that overrule the matured one throughout the year.

(II) Fisheries Independent survey (Kalpitiya) findings

Total of 108 species recorded within the defined trawling ground that representing shrimp, finfish, shellfish and echinoderms. Total biomass estimated as 5.236 tons within the defined 4.3 nm^2 trawling ground and density of all recorded species within the area calculated as 1.2 tons/nm^2.

Seven shrimp species were identified during the survey period such as *Penaeus semisulcatus*, *Penaeus merguiensis*, *Penaeus indicus*, *Metapenaeus moyebi*, *Penaeus monodon*, *Penaeus vannamei* and *Penaeus canaliculatus*. Total shrimp biomass estimated as 1.66 tons within the defined 4.3 nm^2 trawling ground and total shrimp density was derived as 0.38 tons/nm^2. The estimated biomass and abundance values of recorded shrimp species in Kalpitiya trawling ground shows in Table 8.

In by-catch species, total biomass estimated as 3.576 tons within the defined 4.3 nm^2 trawling ground and total density was calculated as 0.819 tons/nm^2. About 68% of total biomass of defined fishing ground covered by non-shrimp by catch species. *Leiognathus dussumieri* is the most abundance by-catch species, it covers 14% biomass of whole fishing ground as well as 21% among by-catch species biomass

Table 8: Biomass estimates, abundance and density values for different shrimp species

SN	Shrimp species	Total biomass (kg)	Total Abundance (No of individuals)	Density (No of individuals /sq nm)	Density (kg/sq nm)
1	*Penaeus semisulcatus*	720.94	36546	8369	165.10
2	*Penaeus merguiensis*	601.15	19202	4398	137.67
3	*Penaeus indicus*	257.89	11459	2624	59.06
4	*Metapenaeus moyebi*	59.57	18755	4295	13.64
5	*Penaeus monodon*	19.10	241	55	4.37
6	*Penaeus vannamei*	1.38	34	8	0.32
7	*Penaeus canaliculatus*	0.07	34	8	0.02
Total		**1660.09**	**86272**	**19757**	**380.18**

The outputs of this research were

- Updated information about trawl fishery and fishing efforts in Mannar & Kalpitiya
- Catch per unit effort (CPUE) and its monthly variation of shrimp trawl fishery
- Weight/Length/Maturity variation in shrimp catch (monthly)
- Species composition, abundance and biomass estimation via real time independent survey

10.4 Development of ornamental fish feed and ornamental fish culture at Panapitiya Regional Research Center- NARA

Officer/s responsible: Mr. D. A. Athukorala (NARA), M. Epasinghe (NARA), Dr. H. C. Chalanika (NARA), Dr. M. W. C. D. Palliyaguru (VRI)

Budget: 3.6 Mn

Ornamental fish industry in Sri Lanka provides an excellent business opportunity for the people due to the prevailing high demand for ornamental fish in the local and international market. However, currently there are some emerging issues in this industry such as lack of quality seeds, lack of quality ornamental fish brooders and lack of cost effective quality ornamental fish feeds in the local market. Therefore, this project is mainly focused on the development of cost-effective quality ornamental fish feed and the introduction of quality ornamental fish brooders for small scale ornamental fish farmers. As there are provincial small-scale ornamental fish feed producers in Sri Lanka it is also hope to transfer the identified formulas to them and empower them with our technical know-how on the feed development.

Objectives:

objectives of the project are to introduce cost-effective ornamental fish feeds to small-scale fish farmers as an alternative to the imported ornamental fish feeds, to introduce scientifically tested feed formulas to small-scale fish feed producers to produce cost-effective quality feeds for koi carp and other ornamental fish, to supply good quality koi carp and other popular ornamental fish fingerlings and brooders for the ornamental fish farmers and to generate income by selling ornamental fish feeds and ornamental fish.

Activities carried out:

Two trial feeds for koi fish were formulated based on the proximate compositions of the fish feed ingredients, 02 koi carp feeds (imported fish oil-based and local fish oil-based) were prepared and experimentally tested to evaluate the growth performance of the fish. Water equality parameters of experimental tanks were monitored throughout the trial period. 05 Platy varieties, 05 Sword tail varieties, 01 red Guppy variety, and 01 multi color Guppy variety were produced and sold as juvenile fish, adult fish and brooder fish for small-scale fish farmers. 03 formulated ornamental fish feed types (Nursery, Grower/02 mm and Grower/5mm) were produced at Regional Research Center, Panapitiya. After being used produced feeds for the ornamental fish at Regional Research Center, Panapitiya and for ornamental fish at NARA Head Office; the excess feed production was sold to the small-scale ornamental fish farmers. Income generated by selling fish feeds was handed over to NARA head office.

Extension work:

1. Advisory services for ornamental fish farmers in Kalutara district on ornamental fish culture, water quality control in ornamental fish farming.

2. Advisory services for small-scale ornamental fish feed producers in Kalutara district on fish feed preparation.

Results:

Table 1. Growth of fish

Feed	Initial Sample	Final sample	Weight Gain /g	SGR /g	Survival %
Control	0.801±0.029	8.676±1.448	7.875±1.470	2.422±0.200	60.00±17.32
F1	0..694±0.128	9.944±2.950	9.250±2.992	2.699±0.401	83.33±15.28
F2	0.762±0.024	12.183±1.355	11.421±1.370	2.824±0.140	60.00±26.46

Table 2. Water quality of experimental tanks during the trial period

Feed	pH	Temp / C^0	DO/ mg l^{-1}
Control	6.99±0.46	27.50±0.33	6.31±0.86
F1	6.93±0.35	27.73±0.49	6.57±0.56
F2	6.86±0.40	27.61±0.38	6.29±0.58

Table 3. Fish feed production progress

Month	Grower Feed (Kg)	Nursery Feed (Kg)	Total Production (Kg)	Income (Rs)
January	41.75	11.50	53.25	12,822.50
February	31.75	10.25	42.00	10,175.00
March	0.25	0.50	0.75	200.00
April	0.17	7.00	24.00	5,870.00
May	-	-	-	-
June	3.75	-	3.75	865.00
July	85.25	12.00	97.25	22,972.50
August	64.50	1.50	66.00	15,487.50
September	-	-	-	-
October	325.50	28.25	353.75	82,550.00
November	113.75	11.50	125.25	29,460.00
December	286.25	16.50	302.75	70,465.00
Total Income Rs.				**250,867.50**

Total feed sale - 1068.75 Kg
Total income - Rs. 250,867.50

Table 4. Ornamental Fish production progress

Month	Koi Carp (nos)	Gappy (nos)	Red Gappy (nos)	Sword Tail (nos)	Molly (nos)	Platy (nos)	Income (Rs)
January	5	28	98	118	-	411	13,925.00
February	2	18	26	179	-	510	12,330.00
March	-	30	56	25	14	423	9,300.00
April	-	-	-	-	-	129	1,675.00
May	-	-	-	-	-	-	-
June	-	8	-	-	-	4	180.00
July	-	6	-	12	-	24	850.00
August	-	-	-	-	-	10	170.00
September	-	-	-	-	-	-	-
October	-	-	20	290	-	140	5,970.00
November	-	02	86	885	-	259	17,360.00
December	-	12	72	754	-	817	23,005.00
Total Income Rs.							**84,765.00**

Total income - Rs: 84,765.00

Physical Progress

92 %

Output:

1. Developed ornamental fish feed formulas
2. Economical ornamental fish feeds for ornamental fish farmers
3. Quality ornamental fish brooders and other ornamental fish stages for ornamental fish farmers.

Outcome:

1. Increased production of quality ornamental fish and locally made economical ornamental fish feeds
2. Reduction of money spend to foreign ornamental fish feeds

Constrains:

1. Insufficient number of helpers and other staff for the center

Insufficient water supply in dry weather period which led to low ornamental fish production.

10.6 Community based ornamental aquatic plants propagation and production in selected abandoned lands in Matara District

Objectives:

To introduce Ornamental aquatic plants as a cottage industry in abandoned lands in Matara District

To compare growth performance of ornamental aquatic plants with Culture techniques

To investigate the income propagation of selected ornamental aquatic plants

Activities carried out

Site selection & site preparation

Selection of Suitable ornamental aquatic plant species

Maintaining ornamental aquatic plant nursery

Planting aquatic plants in selected sites,

Watering, Fertilizing, Weeding, & spraying pesticides

Monitoring growth performance (plant weight, leaf area)

Preparation aquatic plants for marketing (plant pots)

Major Findings and outputs:

Selected two sites for aquatic plants propagation – Abandoned paddy fields Algiriya (Malimbada DS division & Watagedara-East (Thihagoda DS division)

Selected ornamental aquatic plant species – *Limnophila aromatica, Ludwigia repence Echinodorous amazonicus*

Growth rate of aquatic plants - *Limnophila aromatica* (93 g/month) ,*Ludwigia repence (*28 g/month), *Echinodorous amazonicus* (140 g/month)

Production of aquatic plant pots for market – 500 plant pots each species in 3 months

Cost and benefit analysis - (100 plants each species, 3 months growing period) cost benefit ratio for each species 2.65

Out put

Aquatic plant nursery & Aquatic plant beds for market production

Plants pots – for ornamental aquatic plant market

Recommendations:

Selected two sites for aquatic plants propagation – Abandoned paddy fields Algiriya (Malimbada DS division & Watagedara-East (Thihagoda DS division) Suitable for aquatic plants propagation & production.

Selected ornamental aquatic plant species – *Limnophila aromatica, Ludwigia repence Echinodorous amazonicus* suitable for growing in abandoned paddy fields.

Ornamental aquatic plants propagation as a cottage industry in abandoned lands in Matara District is successful.

Progress: financial 100% Physical 86%

Constraints:

Lack of proper knowledge in ornamental aquatic plants

Marketing difficulties

Lack of positive attitude in farmers

Covid 19 Situation of the country

10.7 Development of Re-Circulating Aquaculture System consists of bio-filters for rearing Zebra and Malawi fish in cement tanks: potential for ornamental fish market.

Objectives:

To evaluate system water quality as a function of filter in a re-circulating aquaculture system.

To compare growth performance of Malawi and Zebra ornamental fish with culture techniques.

To investigate the income rearing ornamental fish in cement tank with culture techniques

Activities carried out

Preparation of Six cement tanks (15x10x2 feet) for each fish variety (Malawi & Zebra fish)

Preparation of 3 low cost filters for each fish variety

Rearing Malawi & Zebra fish fries in cement tanks (stocking density 4000 fries/tank)

Feeding fish fries at a rate 3% body weight

Monitoring growth performance of fish,

Monitoring water quality parameters in rearing tanks every fortnight

Major Findings and outputs:

Initial length of Malawi & Zebra fish were (8-10 mm) & (5-8 mm) respectively.

Final length of Malawi & Zebra fish were (3.5-3.70 cm) & (2.3-2.5 cm) respectively.

Growth rate of Malawi & Zebra fish at end of the culture cycle were (0.36 mm/day) & (0.26 mm/day) respectively.

Culture period of Malawi & Zebra fish were 75 days & 90 days respectively.

Survival rate of Malawi & Zebra fish were 82% & 79% respectively.

Cost and benefit analysis - Malawi and Zebra fries rearing (one cement tank, 3months) Cost benefit Ratio 1.65 & 1.95 respectively.

Water recalculating system with filters increase survival rate & income 12% -15%.

Out put

Introduce water re-circulating aquaculture system with filters increase ornamental fish production

Recommendations:

Bio-filter increased survival rate & income 12% -15% Malawi & Zebra fish production through water re-circulating aquaculture system.

water re-circulating aquaculture system can be used for rearing Malawi & Zebra fish successfully.

Progress: financial 100% Physical 76%

Constraints:

High cost in planning water recirculation system with filters (High capital cost)

Diseases out breaking in rearing period (high stocking density)

Lack of technical knowledge in famers for operating water recirculation system

Covid 19 Situation of the country

10.9 Study on the possibility of culturing *Pethia cumingii* and *Belontia signata* under high density up to grow out stage

Introduction :

The ornamental fish trade in Sri Lanka has developed rapidly during the last few decades due to high export demand. This industry largely depends on more colourful and fancy exotic fish species. Export of ornamental fish from Sri Lanka not only comprises of production from Sri Lankan farms, but also includes harvesting from wild (Adikari *et al*., 2011).In countries like Sri Lanka, where many endemic freshwater riverine fish species are under threat due to habitat degradation and unrestrained exploitation for ornamental fish trade (Amarasinghe *et al*. 2006; MOE 2012) as well as damming of rivers and streams for hydropower development (Silva and Silva 2015).

The endemic fish *Pethia cumingii* (Cuming's barb or the two spot barb) and *Belontia signata*are found in actively flowing streams and rivulets of Sri Lanka. The species are identified as a highly endangered species in the National Red Data List (IUCN, 2012). However, under Fisheries and Aquatic Resources Act No 2 of 1996, this fish species is classified as only restricted (not prohibited) for exportation. Since *P. cumingii* is under highly threatened status and *Belontia signata* is not protected by Protected by FFPO (No. 2 of 2009) SCHEDULE VI, it is vital to conserve them from further declining in their population. Apart from the habitat rehabilitation, according to Senanayake and Moyle (1982), translocation is the possible and the most effective process of conserving a number of fishes in the natural habitats. Therefore, captive breeding and rearing of the young prior to reintroduction are very important tasks for conservation.

With the rapid increase of the human population, urbanization and climate changes, the space has become as a key factor for culture practices. On one side, stocking density could be potentially affecting fish growth, survival, feed efficiency, reproduction performance, and productivity. Further, high stocking density could lead to degradation of water quality and physiochemical factor, and also increase aggression among fish which possibly causing stress (Luo *et al* 2013). On the other side, it is vital to investigate the possibility of culturing ornamental fish within less space with high density for assess level of increasing the production level by managing all factors which cause negative influences in high density fish culture.

Specific objectives:

To study the possibility of culturing selected endemic fish species under high density

To enhance the knowledge by conducting awareness programs regarding ornamental fish breeding and culture for selected fish

Activities proposed to be completed during the period

Brood stock collection

Wild collection of brood stock from Kalu river basin for *Pethia cumingii* and Nilwala river basin for *Belontia signata* will be collected initially. Host fishes will collect from average age and size class for the population as 20 specimens for each species and identified using the diagrams and keys.

Maintenance of Brood stock

Mature males and females will acclimatize for a period of 4 weeks in indoor tanks providing the conditions similar to their natural habitat as far as possible. Water temperature will maintain around 26 °C and will monitor using a thermometer. Water pH will monitor using a pH meter. Live floating and rooted plants such as *Vallisnaria* and *Hydrilla* will provide to imitate natural environmental conditions and a constant flow of water will maintain using a power filter.

Breeding under captive conditions

Captive breeding experiments will conduct using healthy mature males and females using 2:1 ratio. Natural environmental conditions will imitate to stimulate fish for breeding. Indoor glass tanks and outdoor cement tanks will utilize for fish breeding experiments. Water quality parameters in breeding experiments will measure using following methods. Temperature, Total dissolved solids and Specific conductivity will measure by a portable conductivity meter. The pH will measure with a standard pH meter and Dissolved Oxygen will estimate titrimetricaly by Winkler's method. Formulated food will give once a day in the morning. Growth parameters will monitor and survival rate will express as a percentage of the number of fish introduced into each tank and number of mortality. The fish will treat whenever they showed signs of disease. Series of fish breeding experiments will conduct to increase fish number for high density fish culture.

Management of fish culture (fry to grow out stage)

Under water quality management, water temperature will maintain around 26 °C and will monitor using a thermometer. Water pH will monitor using a pH meter. Stocking density will record for each fish species for the culture of fry to grow out stage separately with respect to the life stage. Growth performance with respect to the life cycle stage will assess based on the length and weight parameters. Live and artificial feed will provide three times per day. Continuous supply of Oxygen will maintain by aeration for constant flow of water will maintain using a power filter.

Data Analysis

Breeding performance (hatching rate, survival rate of fry) and growth (length gain, weight gain)data of different stages will compare using two - way Analysis of Variance procedure at 95% significance level, using Minitab statistical software package. Survival rate will express as a percentage of the number of fish introduced into each tank and number of mortality as a percentage with respect to the fish species and life cycle stage.

Results: Activities carried out

Glass tanks were prepared for fish larval rearing and grow out fish rearing. Cement tanks were utilized for the rearing of brood stock. As brooders, healthy *Pethia cumingii* and *Belontia signata* were collected from Baduraliya area. Host fishes were collected from average age and size class for the population for each species and identified using the diagrams and keys. Mature males and females were acclimatized for a period of four weeks in outdoor tanks providing the conditions similar to their natural habitat as far as possible. Water temperature was maintained around 26 °C and monitored using a thermometer. Live floating and rooted plants such as *Vallisnaria* and *Hydrilla* were provided to imitate natural environmental conditions and a constant flow of water maintained using a power filter. Captive breeding experiments were conducted using healthy mature males and females using 2:1 ratio. Breeding experiments were repeated for the purpose of increasing fish fry number.

Conclusions

Captive breeding experiments of selected endemic fish species (*Pethia cumingii* and *Belontia signata)* resulted lesser number of fish fry which were insufficient to maintain fish cultures under high density.

Recommendations

Further long term studies needed for investigate the possibility of culturing selected endemic fish *Pethia cumingii* and *Belontia signata* under high density.

Constrains

Due to rare condition brood stock needed to collect from several locations. Difficulties were there to obtain required vehicle facilities and manpower.

Travel restrictions were imposed by the government due to COVID-19 pandemic. Hence, restrictions were there for field visits across provinces.

Unavailability of equipments and chemicals

Financial allocation (Rs.) : 555 000.00

Financial progress (%) :16.1

Physical progress (%) :50

10.10 Water quality monitoring of Negombo Lagoon and the impact of accumulation of the heavy metal in selected food fish species.

Introduction:

The Negombo coastal wetland area consists of 10,694 ha, which includes 3164 ha of marsh proper, 3068 ha of Negombo estuary and 4462 ha of high ground located on the western coast of Sri Lanka. The Negombolagoon is approximately 12.5 km in length and its width varies from 0.6 to 3.6 km. The lagoon receives fresh water from three sources: the Ja-Ela, DandugamOya and the Hamilton Canal.

The Negombo lagoon is one of the most productive brackish water ecosystems in Sri Lanka in terms of associates flora and flora including mangrove, seagrass, fresh, brackish and marine finfish and shellfishspecies. (Dahanayaka, 2008). Previous studies have assessed the status of the Negombo lagoon through accumulation of heavy metals in selected constituents,e.g. water, sediment and fish (Indrajith &Pathiratne, 2006; Indrajith*et al*., 2008)water, sediment and algae (Asanthi*et al*., 2007); water and fish (Mendis*et al*., 2015a & b).In total, about 10,000 people directly or indirectly depend on fishing in Negombo lagoon for their livelihood (Jayakody &Dahanayaka, 2005). The fishery is small scale mainly target for fish, shrimps and crabs. Fishing is mainly carried out by traditional fishing crafts such as dugout canoes and log rafts (Theppam).

Meanwhile, Negombo lagoon plays an important livelihood for numerous people living in the area. These uses have expanded in the present with increasing urbanization and industrialization of the area.Lagoon may be polute due to X-PressPearl ship. Chemicals and plastic waste was added to the lagoon and it was affected the lagoon fishery, it is crucial to identify the current status of the water body and impact of heavy metal accumulation of selected edible food fish species, since the lagoon directly and indirectly plays a major role in the fisheries production as well as the livelihood development of the nearby residence.

Specific objectives:

To analyze the current impact of water quality in Negombo lagoon

Access the accumulation of heavy metal in selected high demand fish and shellfish species in Negombo lagoon.

Activities proposed to be completed during the period

Site selection and sample collection

Assessment of water quality in Negombo lagoon will be done by monthly analyzing of water quality collected from eight sampling stations of Negombo lagoon.

Water from Hamilton canal connect to the lagoon

Water from Dadugamoya connect to the lagoon

Waste water canal coming from Katunayake industrial zone area connect to the lagoon

Urban waste water coming from mangrove environment near Kadolkale RRC

Pitipanawhere dry fish processing activities located

Associated waste water canals from shrimp farm at Dummalapitiya area

Fish market area where fish waste release to the lagoon

Pitipanaveediya where recently dredged

Thaladuwa where urban waste directly water released to the lagoon.

Dutch canal start from the lagoon

Middle of the lagoon (Reference site)

Lagoon mouth area

Sample analysis

Water temperature, pH, salinity and turbidity will be measured using a Thermometer, HACH Sension 1 portable pH meter, Refractometer and portable turbidity meter (Model: Eutech-TN 100) are used for determining water turbidity. Dissolved Oxygen concentration is determined by Winkler titration procedure (Mackereth et al. 1978) and biological oxygen demand is measured using methods according to APHA (1998). The chlorophyll-a concentration is determined spectrophotometrically after filtering samples through Whatman GF/C filters using the method described by Parsons et al. (1984). Ex-situ analysis is conducted for the determination of Nitrate -4500 E Cu/Cd Reduction Method (APHA,1998), Nitrite -4500 B Colorimetric method NED/Sulphanilamide (APHA, 1998), Phosphate - 4500 P E Ascorbic acid method (APHA 1998), Ammoniacal nitrogen (NH3-N)- 4500 NH3 F Phenate method (APHA, 1998) COD 5220 Open reflux method (APHA,1998). Three replicates are used for determining each water quality parameter. All the chemical analysis will be done with the help of divisions of ESD and IARAD of NARA

For the analysis of heavy metal level in tissue samples of selected edible finfish and shellfish species will do collaborate with IPHT division of NARA.

The analysis of heavy metal contamination in the finfish and shellfish species, samples will be digested using acids. Each sample will be directed for oven drying in a pre-cleaned glass container at 103 ± 2 °C for 3 h until the sample reached a constant weight. The samples once dried were powdered using mortar and pestle and stored in glass bottles at 30 °C until digestion. Three replicas of 1 g of each specimen will be taken in a 250-ml digestion flask. To each digestion flask, digestion di-acid (a mixture of HNO3 and HClO4) will be added in the ratio of 2:1 and heated at a temperature of 130 °C on a hot plate (Canli*et al*. 1998). The samples will be heated until the formation of a clear solution which indicates the completion of the process. Then samples will be filtered using a 0.45 mm Whatman filter paper for removing the suspended particulate matter. The filtrate will be diluted using de-ionized water to a final volume of 30 ml and examined using atomic absorption spectrum (AAS) (Bartram, J. and Ballance, R. eds., 2015).

The metal concentration in each sample was calculated as (Weher 2008): ppmR x Dilution factor

Where, ppmR is the AAS reading of the digest.

Dilution factor =Volume of Digest used / Weight of digest use

For the analysis of heavy metal level in water samples, collected water samples will be analyzed using atomic absorption spectrum (AAS) (Bartram, J. and Ballance, R. eds., 2015). To assess the impact towards the of accumulation of the heavy metal level in selected food fish species, data gathering will be done from the fishermen who do fishery activities in Negombo lagoon by a questionnaire survey.

Data analysis

The basic statistical analysis will be applied to the data using Minitab statistical software (2017) and the values will be presented as mean ± standard deviation.

The Metal Sensitivity Index (MSI) will be calculated by the formulae given by Nair *et al*. (2006). MSI is defined as the relative metal accumulating capacity of tissue for a particular metal. MSI will be calculated as:

MSI = (Absolute concentration of metal in a tissue /Total concentration of all metals in that tissue) x 100

Metal Pollution Index (MPI) will be calculated to evaluate the total metal concentration in a fish species and will be calculated using the equation (Jia*et al*. 2017):

$MPI = (C_{Hg} \times C_{Pb} \times C_{Cd})^{1/3}$

Where, CCd (μg/g of fish sample) is the concentration of Cadmium metal in a fish sample and so on.

Results: Activities carried out

Investigated high demand food fish species in Negombo lagoon

Investigation on current high demand lagoon food fish species was conducted via a questionnaire survey in landing sites of Thalahena, Seththappaduwa, Kepungoda, Aluthkuruwa, Katunayake, Rajapakshapura, Wahatiyagama and Dalathura. In each landing site, data collection was conducted from all lagoon fishermen who conduct fishery activities in that area as well as customers if available. Whole population was investigated for data gathering.

Landing site	Identified high demand lagoon food fish specie /s
Thalahena	*Siganus* (Rabbit fish) , *Epinephelinae* (Grouper)
Seththappaduwa	*Penaeus indicus*, *Mystus* sp. (lagoon cat fish)
Kepungoda	*Penaeus monodon (Kalapu issa)* , *Mystus* sp. (lagoon cat fish)
Aluthkuruwa	*Crassostrea* sp.
Katunayake	*Siganus(*Rabbit fish), Mullets (Godaya), *Penaeus indicus*
Rajapakshapura	*Siganus(*Rabbit fish),
Wahatiyagama	*Penaeus monodon (Kalapu issa), Mystus* sp. (lagoon cat fish)
Dalathura	*Penaeus monodon (Kalapu issa)*

Water samples collected from selected locations (12 locations)

Water samples were collected from all above mentioned sample collecting sites (12 locations) to well clean sample collecting bottles and taken into Kadolkale RRC initially. GPS locations of the sampling sites were recorded separately. In situ data of water quality were recorded at each site with respected to GPS location. The other water quality parameters including DO, BOD, COD and nutrients were analyzed with the collaboration of ESD laboratory.

Recommendations

Further long term studies needed for investigate the water quality level and its impact on aquatic flora and fauna.

Constrains

Travel restrictions were imposed by the government due to COVID-19 pandemic. Hence, restrictions were there for field visits.

Unavailability of equipments and chemicals

Lack of manpower

Financial allocation (Rs.) : 700 000.00

Financial progress (%) :21.8

Physical progress (%) :60