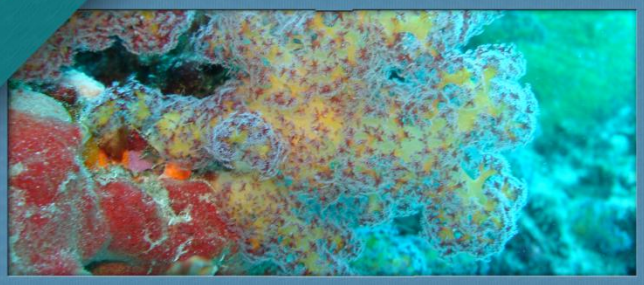
Bay of Bengal Large Marine Ecosystem Project



Education, capacity development and monitoring in support of Bar Reef Marine Sanctuary management, Sri Lanka

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Education, capacity development and monitoring in support of Bar Reef Marine Sanctuary (BRMS) management

Final report

National Aquatic Resources Research and Development Agency

Colombo, Sri Lanka

March 2015

Food and Agriculture Organization of the United Nations

Executive summary

The Bar Reef Marine Sanctuary (BRMS) is the largest of the Marine Protected Areas (MPAs) in Sri Lanka. Although the Bar Reef Marine Sanctuary was declared in 1992 under the Fauna and Flora Protection Ordinance, there has never been active management of the protected area. The BOBLME Project component 3.2. *Marine Protected Areas in the conservation of regional fish stocks* works towards obtaining consensus on approaches to the establishment and management of marine protected areas and fish refugia for sustainable fish management and biodiversity conservation objectives. Given the importance of BRMS, the BOBLME had decided to support this work, and collaborate with NARA to take the main role in assessing the status of the Bar Reef Marine Sanctuary and implementing the other objective of the project together with all other stakeholders especially the Special Area Management(SAM) committee.

The expected outcome will be the implementation of a strengthened and effective MPA management process leading to an improved conservation status of the MPA.

Hence the study was aimed at generating information on the biophysical and socio-economic status of the Bar Reef MPA and the associated habitats at Kalpitiya which will be used for better management of the Bar Reef. Awareness and education of community members and the young generation also conducted to support management and conservation. The biodiversity of BRMS is linked to the surrounding environment including the Puttalam Lagoon. Hence the studies were focused to BRMS and the upper part of the Puttalam Lagoon from December 2013 to February 2015. The studies at BRMS had to conduct only during good weather conditions, generally in between October to March in the each year. Biological assessments were conducted for coral reefs, associated habitats such as mangroves and seagrasses, status of ornamental fisheries, status of artisanal fisheries, benthic and planktonic organisms, avifaunal studies and water quality conditions. Socio-economic studies were conducted to provide information on economic and marketing aspects of marine ornamental fishery in order to management of BRMS, to improve understanding on recreational fishery and visitor pressure on BRMS and to identify social aspects and anthropogenic issues of BRMS associated ecosystems.

The results of the biophysical assessments revealed that hard corals were in good condition at the Bar Reef compared to damaged areas but the percentage of live coral cover has been reduced by 10%. Percentage of rubble coral and the physical damages also have increased from 2014 to 2015. Presence of high demand rare marine fish families of ornamental value e.g. Balistidae, Chaetodontidae, Caesionidae and Labridae indicates the ecological significance of the Bar Reef area. Records of *Chaetodon* species are very significant due to their high values. Most dominant mangrove species encountered at the lagoon was *Rhizophora mucronata* which was found in water front areas of the land ward mangroves as well as islands. *Avicennia marina* was found to be the second most common benthic species in Puttalam Lagoon and Dutch Bay. *Enhalus acoroides was* the most dominant seagrass species found around the islands at a depth of 0.5 m to 1.5 m. *Halodule pinifolia* and *Halophila ovalis* were observed in the shallow areas which are exposed to the air at low tides. Very few seargrsss patches were encountered around the BRMS. Molluscan species were the dominant benthic species. The zooplankton order Copepoda consistently occurred at all stations and was the most abundant group dominated mainly by eight Calanoid, three Cyclopoid and four Harpacticoid forms of the genera *Pseudocalanus*, *Acartia*, *Paracalanus*, *Microcalanus*, *Eucalanus*, *Temora*, *Centropages*, *Cyclopina, Oithona, Microsetella and Corycaeus.* A total of twenty four species belonging to eleven orders were encountered with the chank survey and the presence of massive numbers of egg sacks of chanks (*Turbinella* sp.) reveals the importance of Bar Reef as a breeding ground for them. The only globally threatened species observed during the survey was the Spot billed pelican (*Pelecanus philippensis*). Most common fishing gears used in the area are gill nets, purse seines, long lines, cast nets and trammel nets while there are two types of gill nets as drift nets and bottom set gill nets. Surukku del and Laila nets were observed as a type of purse seines.

Overall results of water quality studies indicated that average values of the pH, nutrients and dissolved oxygen levels were within the standard limits for the fish and aquatic life according to the proposed quality standards for different use classes of coastal water in Sri Lanka.

The visitor pressure on the BRMS per year was about 156.24 visitors per km^2 of BRMS and of which 121.34 were local visitors and 34.9 foreign visitors. The non-use value of BRMS in terms of recreational purposes is higher compared to other protected areas as it provides livelihood source for the associated community. Fishing is the main reef related activity but ornamental fish, chanks and *beche-de-mer* collection and tourism related activities such as scuba diving and snorkeling and whale watching are also major. A total number of 4 730 fishers, 38 ornamental fish collectors, 58 chanks and *beche-de-mer* collectors and 122 boat tour operators are getting support for their livelihoods from BRMS and its associated ecosystems over the years.

More than 15 000 people benefited from these economic activities. According to the statistics of the Department of Wild Life Conservation, 10 937 people have visited BRMS in 2013 for leisure purposes and of them 78% were locals while 22% were foreigners. The total earnings from leisure activities and ornamental fish collection were 23 and 50 million LKR in 2013, respectively. The BRMS contribution for the total earnings from ornamental fish collection was said to be 30% and therefore, there were 15 015 000 LKR (at producer price) worth ornamental fishes collected from the BRMS in 2013.

All stakeholders and communities are well aware of the importance of BRMS and its associated ecosystem services for their livelihoods and natural environmental health. But most of them are not happy with present management practices, institutional arrangements and institutional strengths related to BRMS management and eager to actively participate in implementing better management practices for the sustainable utilization of resources. This will pave the way to eliminate illegal economic activities some of which are presently practiced.

Lack of properly established mechanism for gathering reliable static and real time information hinders real social and economic value estimations related to BRMS which may lead to the over exploitation of the reef related resources.

The final evaluation results that the management effectiveness of MPA is not up to satisfactory level when considering the changes of biophysical factors and governance factors while it is positively impacted with the sociological changes. Conclusions and suggestions of the study will be submitted to the Department of Wild Life Conservation (DWLC) which is the main authorized body for managing of MPA and Ministry of Fisheries and Aquatic Resources. Formation of community surveillance groups and implementation of co-management has already been proposed.

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Acronyms used

APHA	American Public Health Association
BOBLME	Bay of Bengal Large Marine Ecosystem
BOD	Biological Oxygen Demand
BRMS	Bar Reef Marine Sanctuary
CBO	Community based Organizations
CCC	Community Coordinating Committee
CCD	Coast Conservation Department (Sri Lanka)
CCEF	Coastal Conservation and Education Foundation
DFAR	Department of Fisheries and Aquatic Resources
DWLC	Department of Wild Life Conservation
ETP	Endangered, Threatened and Protected
FRP	Fiberglass Reinforced Plastic
GIS	Geographic Information System
GPS	Global Positioning System
IDP	Internally Displaced Persons
IUCN	International Union for Conservation of Nature
LKR	Sri Lanka Rupees
MEAT	Management Effectiveness Assessment Tool
MPA	Marine Protected Area
NARA	National Aquatic Resources Research and Development Agency ,Sri Lanka
NGO	Non-Governmental Organisation
NTU	Nephelometric Turbidity Units
OFRP	Out-board engine Fiberglass Reinforced Plastic
SAM	Special Area Management
TDS	Total Dissolved Solids
USA	United States of America

1. Introduction

The Bar Reef Marine Sanctuary (BRMS) is the largest of the Marine Protected Areas (MPAs) in Sri Lanka covering an area of 306 km^2, located West of the Kalpitiya Peninsula in the North western coastal waters and borders the Puttalam Lagoon. This is considered as a specific location in Sri Lanka that has many coastal ecosystems (coral reefs, mangroves, seagrass beds, coastal sand dunes/spits and a large lagoon) in a single area. The large extent of the BRMS ensures that there is adequate space for spawning aggregations and for juveniles to move among various habitats that form the nursery grounds. The BRMS was established based on recommendation by NARA in 1990 .Hence the main purpose of declaring the BRMS was to protect the coral reefs, their biota and to safeguard abundant fish stocks. The Act states that no person shall take any aquatic organism from a national reserve or sanctuary which is on state land without a permit from the Department of Wild Life Conservation (DWLC). Because of this rule, extraction of aquatic organisms such as reef fish, corals, sea cucumber etc., are officially illegal. However, the area declared it is not functioning as a sanctuary because of poor monitoring and inadequate governance. The original plan recommended the demarcation of Core zone and a Buffer zone (Rajasooriya 1990). However the declaration of the BRMS does not specify these two zones and includes the entire area as a single unit. Fishing is the main economic activity within the BRMS and variety of fishing activities are carry out in both the Core zone and Buffer zone of the BRMS. Allowed as well as prohibited fishing activities are listed in the Bar Reef Special Area Management (SAM) plan, published by the Coast Conservation Department in 2005. Department of Fisheries and Aquatic Resources (DFAR) has the authority to control the fishing activities in the area and it is the authorize body to issue license for necessary fishing. Since the BRMS is still threatened by illegal fishing methods, the DFAR has an important role in future interventions of management. Recently Sri Lanka Navy has laid four buoys for the demarcation of the inner coral area of the Bar Reef which is time worthy effort for the control of illegal activities inside that area. Since the Navy is the only authority that is actually regularly physically present on the reef, they have an important role in controlling illegal operations in the BRMS area.

Since the survey in 1989 by the National Aquatic Resources Research and Development Agency (NARA) and the declaration of the sanctuary in 1992, many types of fishing activities have been introduced including purse seining with the assistance of scuba divers to spot the schools of fish and to operate the net. The collection of sea cucumber, chanks and marine aquarium fish have also expanded to a level where the high value sea cucumber species have become rare. The Government of Sri Lanka has declared Kalpitiya and the islands located in the Puttalam Lagoon as a special tourism development area and covered under a tourism promotion project. The area is already popular for whale and dolphin watching, viewing of coral reefs and leisure games such as wind surfing. There is, however, considerable damage to corals by tourists walking on coral beds during low tide, boats hitting corals or damage caused by boat anchors.

As Bar Reef and the environs of Kalpitiya was identified for Special Area Management (SAM) planning in the Coastal zone management plan for Sri Lanka, a planning process was carried out from 2000 to 2005 resulting in an Environmental profile and a Special Area Management plan for the sanctuary and the environs of Kalpitiya. Although the Bar Reef Marine Sanctuary was declared in 1992 under the Fauna and Flora Protection Ordinance, there has never been active management of the protected area. The Department of Wild Life Conservation lacks adequate resources to manage the MPA.

For measuring effectiveness of MPAs, it is necessary to develop evaluation techniques using biophysical, socio-economic and governance indicators. The present study is aimed at generating information on the biophysical and socio-economic status of the Bar Reef MPA and the associated habitats at Kalpitiya which will be used for better management of the Bar Reef. Work on the status

of governance including stakeholder involvement in surveillance, monitoring and enforcement procedures, should be performed based on the biophysical studies. It seems that the proposed collaborative partners still not conducted the task due to the fact that may be the uncertainty of availability of funds. Hence, this study will target to assess the changes of habitats, areas showing signs of recovery, recruitment successes, habitat distribution complexity, water quality, focal species abundance, focal species population structure, fishery and other resources, type and level of fishing effort and the various impacts on the resources surrounding the MPA.

Monitoring of the health of the ecosystems is vital for the long term goals of conservation and management of the Bar Reef MPA and its associated ecosystems including the Puttalam Lagoon. The biodiversity of BRMS is linked to the surrounding environment including the Puttalam Lagoon. Hence the studies were focused to BRMS and the upper part of the Puttalam Lagoon.

Awareness and education of community members and the young generation should be an ongoing activity to support management and conservation. The fisher community should be educated to eliminate destructive fishing practices including the exploitation of spawning aggregations. Hence educational and awareness programmes will be conducted for the above target groups on the importance of conservation of resources and management of the MPA.

NARA will play this role while incorporating the information for the management plan to come up with community level monitoring and management to support informed decision making. NARA has also played a key role in conducting research and monitoring of these ecosystems in the past. These research programmes have provided the necessary data for the preparation of the Environmental profile and management plan for the Bar Reef and the environs of Kalpitiya. The proposed assessment will be important for documenting the changes of the habitats and the biodiversity in the area.

2. Objectives

The overall objective of the BOBLME Project Component 3.2. “Marine Protected Areas in the conservation of regional fish stocks” works towards obtaining consensus on approaches to the establishment and management of Marine Protected Areas and fish refugia for sustainable fish management and biodiversity conservation. Given the importance of BRMS, the BOBLME had decided to support this work, and collaborate with NARA to take the main role in assessing the status of the Bar Reef Marine Sanctuary and implementing the other objective of the project together with all other stakeholders especially the Special Area Management committee.

The expected outcome will be the implementation of a strengthened and effective MPA management process leading to an improved conservation status of the MPA.

The work on the BRMS aimed at following objectives;

1. Contribution for measuring the effectiveness of MPA and associated habitats at Kalpitiya, through developing evaluation techniques using biophysical and socio-economic indicators which will be used for better management of the BRMS
2. Implementation of education, awareness and training programmes targeting mainly school children, but also for the local communities including CBOs on ecosystem values, importance of habitats, best practices in tourism as well as conservation for the sustainable utilization of the resource for the benefit of future generations
3. Evaluation of management effectiveness of BRMS as far as possible using the data gathered
4. Provision of information for the adaptive management of the MPA

3. Methodology adopted

The project start up meeting was held in September 2013; the key stakeholders were brought together and discussed the proposed project on "Education, capacity development a monitoring in support of Bar Reef Marine Sanctuary (BRMS) management." The workshop enabled to select final indicators (22) to be tested for the evaluation of effectiveness of MPA. And the report on the project inception meeting was submitted accordingly.

Subsequently training workshops on importance and effectiveness of MPA were carried out for the younger generation and for the local people.

The testing (primary data gathering) of selected indicators was undertaken from December 2013 to February 2015. The studies were focused to the Core zone and Buffer zones of the BRMS (**Figure 1**), and the upper part of the Puttalam Lagoon .The studies within the boundaries of BRMS had to be conducted only during calm weather conditions, generally in between October to March in the each year.

Biophysical indicators were tested using standard techniques, such as visual census for reef fish and random line transects for habitats such as coral reefs, mangroves and seagrass beds. Socio-economic indicators were tested using household surveys and existing data collection. Governance indicators were tested using existing information. Final validation/concluding workshop was carried out in May 2015 to present the quantitative highlights of biophysical monitoring and socio-economic survey.

Nineteen indicators are used for evaluation, eight biophysical indicators that largely measure the changes of focal species, status of capture fisheries and coastal habitats; five socio-economic indicators that largely assess the economic status and the perceptions of the coastal communities and the six governance indicators that measures the various aspects of MPA management.

Evaluation is conducted to assess performance of the MPA in terms of the current condition (2014) against past available baseline information. Based on the study the MPA evaluation was conducted and the recommendations made in this report can be used for the adaptive management.

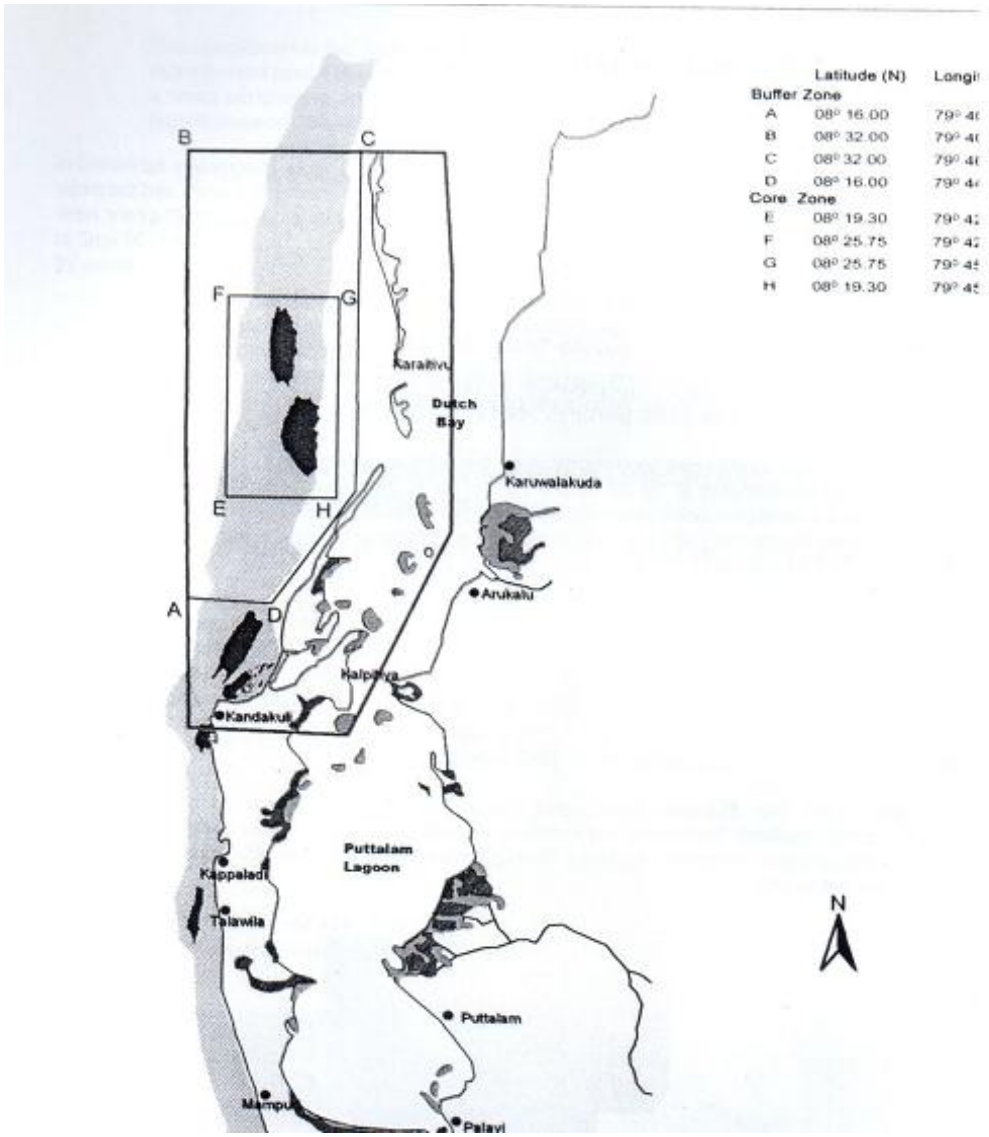

Figure 1. Boundaries of MPA Bar Reef Marine Sanctuary and the Puttalam Lagoon where studies were carried out

A, B, C and D – Buffer zone; E, F, G and H - Core zone

4. Biophysical studies

4.1. Assessment of coral reef ecology

A total of nine 50 m line intercept transects for benthic cover and fish belt transects were done at the core area of BRMS (**Figure 2**).

Figure 2. Sampling points for the coral reef study

The results revealed that while live hard corals were in good condition at the Bar Reef, some areas have been affected by the movement of coral rubble formed after the coral bleaching event in 1998 which destroyed most of these reefs. The western margin of the shallow coral areas of the reef has sustained considerable damage due to recent storms. The damage was caused mainly by coral rubble shifting and smothering the live corals. It could be observed that there is an increase in the rubbles due to recent illegal activities carried out in the reef.

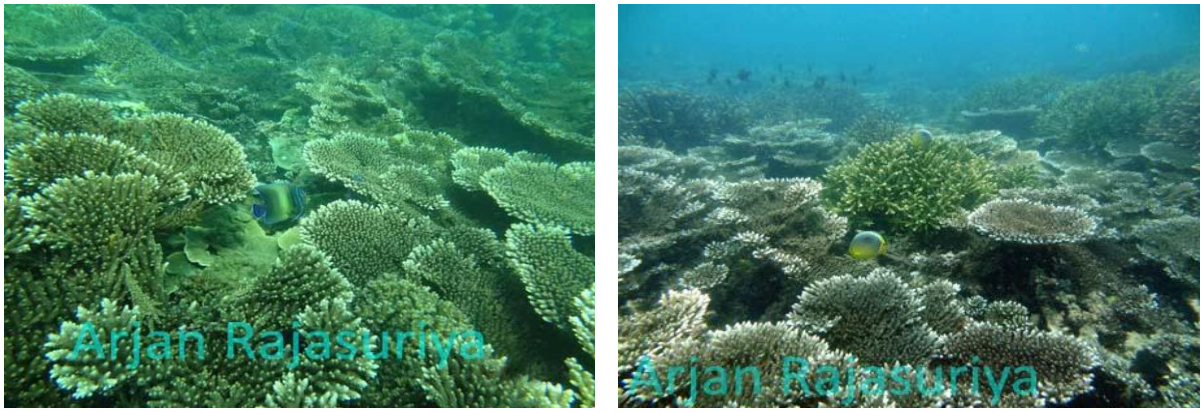

Figure 3. *Acropora cytherea*, the dominant coral species found in BRMS

Tabulate corals (*Acropora cytherea)* dominate the reef (**Figure 3**) as it is a relatively fast growing species. Other common species are *Pocillopora damicornis, Montipora foliosa, M. aequituberculata, Echinopora lamellosa, Acropora intermedia, Acropora formosa.*

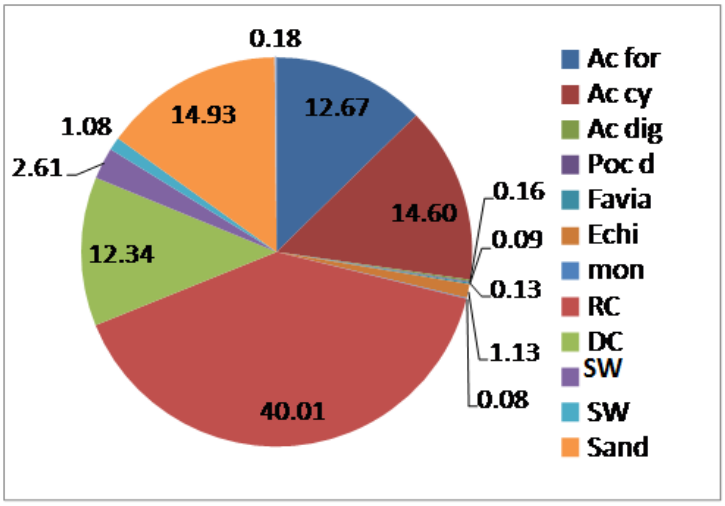

Figure 4. Overall status of surveyed area of Bar Reef in 2014-15

(Ac for - *Acrofora formosa,* Ac cy - *Acropora cytherea,* Ac dig - A*cropora digitifera* sp., Poc d - *Pocillopora damicornis,* Favia - Favia sp., Echi – *Echinophora,* mon - *Montipora* sp., Rc - Rubble coral, Dc - Dead corals and SW – Seaweeds)

In the overall assessment it was recorded that live coral – 30%, dead coral – 12%, coral rubble – 40% and seaweed - 3.6% (*Halimeda* 2.6%, other 1%)

Figure 5. Damages to the corals by net entanglement

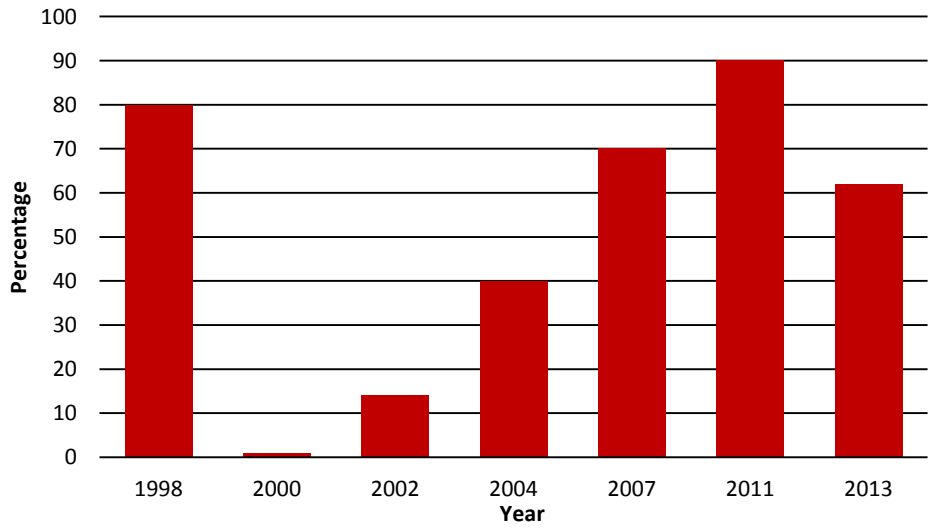

Figure 6. Comparison of live coral cover

Several coral bleaching events have caused reduction of coral cover by 1% in 1998 and subsequently severe coral cover reduction was observed in 2000 (**Figure 6**). A reduction of coral cover seen in 2013 was due to damage from coral rubbles, smothering of live corals by 1998 bleaching and physical damage due to fishing activities such as Laila net operations, use of dynamite, physical damages due to net entanglement, over harvesting, spear fishing for groupers and hump head wrasses, anchoring of boats and damage due to fresh water inflow in 2014-2015. The eco-tourism based activities are not well guided so that ecological destructive tourism activities such as walk over corals in the shallow areas, snorkelers and divers often stand on them, were identified as indirect threats. Reef walking at low tide was observed to be very popular among tourists. This causes a lot of damage to reefs in areas with a highly developed cover of fragile corals.

4.2. Study on current status of marine ornamental fish

A total of eight fish study sites (**Figure 7**) were randomly selected using the Arc GIS software package. In the field, skilled scuba divers were conducted to survey the selected sites. The fishes were identified up to species level as much as possible and their numbers were counted along 50 m transect by visual census. This study was supplemented with underwater video and digital photographs taken at each site to site wise assess species richness. Finally percent relative abundance of each fish family was estimated using Excel in Windows 2007. Direct interviews with local people as well as the ornamental fish collectors were made to gather all relevant information on current status, threats and impact.

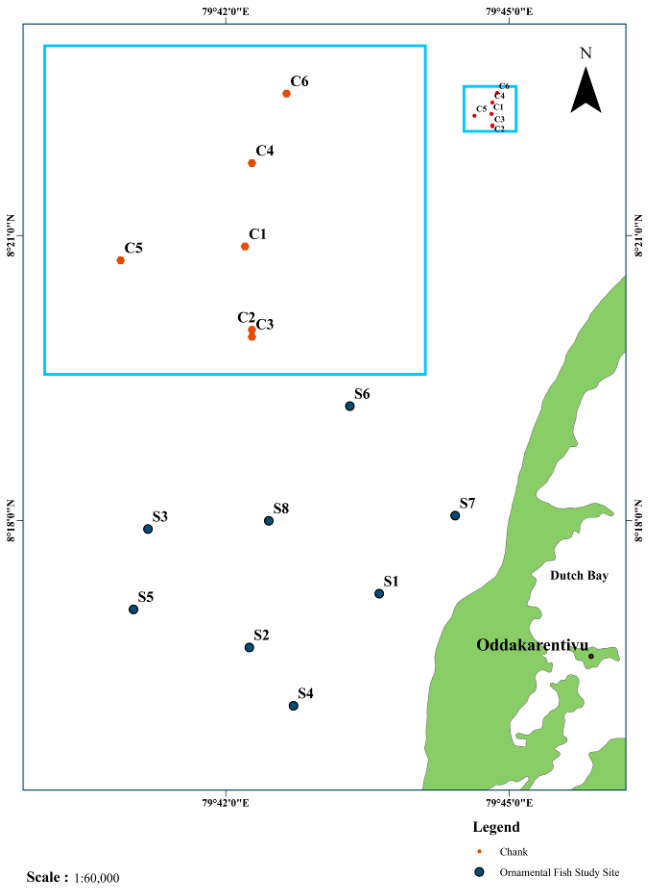

Figure 7. Study locations for the chank (C) and ornamental fish studies (S).

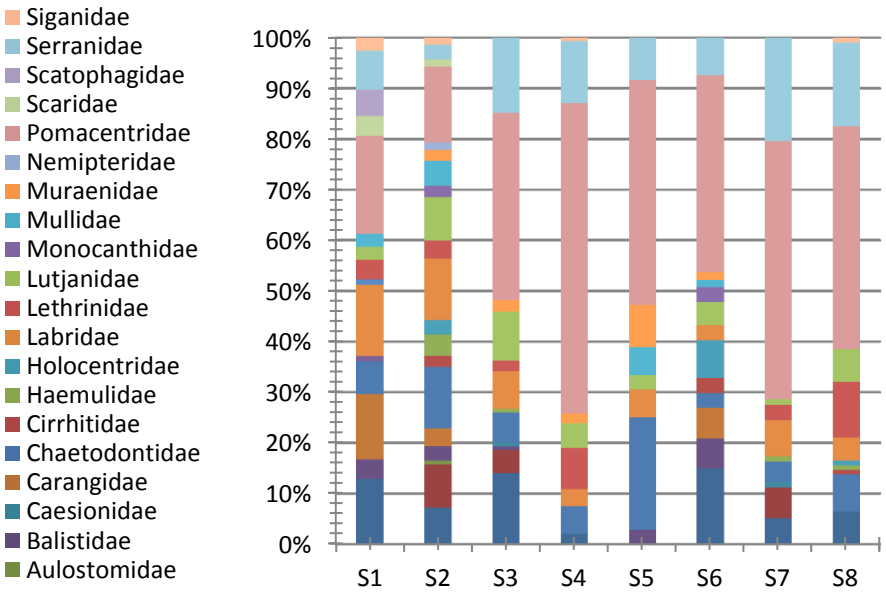

Figure 8. Percentage relative abundance of different fish families of ornamental value in each site surveyed in Southern Bar Reef area in 2013 to 2014

(Key- S1-8 are sampling sites, Figure 7)

Reef fish diversity

The reef ornamental fish species richness in Bar Reef marine sanctuary accounts for 99 species in 24 families, they aggregate in different habitats e.g. thick coral, rock coral, sand and sea weed etc. Family Pomacentridae is the most diverse fish family (15 species.), accounting for nearly 13% of the entire population of reef fish. This precious ecosystem is still home to a number of rare reef fish species of high demand in export oriented ornamental fish industry. Majority of them are in family Balistidae, Chaetodontidae, Caesionidae and Labridae. The Bar Reef marine sanctuary is still thriving with good populations of rare *Chaetodon* species namely *C. decussatus, C. lineolatus, C. lunula, C. trifasciatus, C. vagabundus* and *C. xanthocephalus* of which some are restricted only to the particular reef ecosystem. This clearly indicates the ecological significance of Bar Reef which provides ample aggregation, spawning and nursery grounds for the reef fish therein.

The fish species richness was reported to vary at different sites. This might be possibly due to variation in micro habitats and quality. However, all sites recorded more than 9 different families indicating good habitat quality in the area. But the highest species richness was 60 in 22 families in Site 2. The lowest species richness was 17 in 9 families at Site 4.

Presence of high demand rare marine fish families of ornamental value e.g. Balistidae, Chaetodontidae, Caesionidae and Labridae indicates the ecological significance of the Bar Reef area. The Bar Reef Special Management Area plan also reported presence of some *Chaetodon* sp. restricted only to the Bar Reef area. Therefore, their habitat protection is vital.

Collecting of reef ornamental fish is not a key livelihood activity now, it is a seasonal fishery. Only few individuals in Kalpitiya peninsula are getting sensational amount of earnings. Due to resource depletion people aggregated to collect reef ornamental fish in Bar Reef core area illegally. But this collection highly depends upon the export market demand. At present only 3-4 groups consisting of 5-8 individuals are engaged in this activity. They mainly collect the Damselfish, Clownfish, Butterfly fish, Red shrimps and Groupers. Of these, collection of Blood red fire shrimp (*Lysmata debelius*) is very high and selective as they can fetch a high price. Majority of these fish species are collected not totally from Bar Reef but also from other reef patches in the peripheral area as well in offshore areas. The industry seems to be not expanding as some people who earlier engaged in ornamental fish collecting are now shifting to eco-tourism based activities. This trend may possibly be due to easy money and more benefit they get.

During the fishing season the ornamental fish collectors in other parts of the island are coming to the Bar Reef area, stay on until the season is over. It seems there is a conflict between local fishing community and migratory fishing people. A well adopted ornamental fishing management strategy therefore is required in order to keep sustainability of the resource. It was found that fish collectors catch reef ornamental fish selectively using some harmful methods such as pulling out large groupers in rock cavities and holes. They insert a Palmyra leaf shaft with a fishing hook at its tip into the crevices where grouper fish hide in. Once the fish entangled they pull the Palmyra shaft with the grouper fish making it to come out. This is a new method adopted by ornamental fish collectors recently. This is a harmful method as it leads to harvest only the selective colourful ones including spawning individuals.

Threats and impacts

The study showed the Bar Reef is still under threat from human activities also well as from some natural phenomena. Over-exploitation of fish resources is mostly done by migratory fishers. Unsuitable fishing methods and pollution from human activities were identified as major threats. Fish are taken in nets or killed by poisons or explosives. Due to the use of moxi nets for collection of reef fish for the aquarium trade, the coral reefs are damaged and nets left behind eventually lead to ghost fishing. The moxi net is used mainly by skin divers. It is similar in shape to the cast net, closed at the top and with the bottom of about 1.5-2 m in circumference. A float is attached to the top and the lead weights are fastened around the perimeter at bottom at 30 mm distance. Divers used to catch the fish in the shallow coral areas as it is easier to use than the scoop nets. More similar threats have been identified in other coral reef areas in Sri Lanka by some workers (Rajasooriya *et al*., 1994 and Rajasooriya *et al*., 1995). It was evident that poverty of many coastal dwellers in the area aggravates fishing in coral reefs. This scenario has also been discussed in the Bar Reef Special Management Area plan stressing the Muro-ami netting pounding reefs with weighed bags to scare fish out of crevices, trawling also directly damages the corals. These methods are generally non-selective and lead to wipe out non targeted marine species as well as the corals. In addition to these threats lack of monitoring or management of the marine ornamental fish trade has resulted in over exploitation. At certain instances reef walkers move or over turn boulders to view animals beneath them. This can cause death of the species if these boulders are not replaced. These were observed to bring negative impacts on the ecosystem and eventually to fish diversity.

The marine ornamental fish species in the Bar Reef are highly diverse and most of them are habitat specific. Due to rough sea condition in later part of the study, the entire Bar Reef area could not be surveyed as targeted. Nevertheless, the remaining area was surveyed in February 2015.

4.3. Assessment of impacts of the seagrasses and mangroves in the MPA

4.3.1. Mangroves

A base map was delineated for the distribution of mangroves. The studies were carried out in eight mangrove stands (**Figure 9**) at the upper part of the Puttalam Lagoon. Each stand consisted of one or two 10 m wide and 50 m long belt transects which were divided in to 10 m × 10 m plots. In each plot of transect, all the individuals were identified and their diameter (at 1.3 m height; above the upper most intersection of the prop roots of *Rhizophora*) and heights were noted. Structural indices established for the forest vegetation characteristics; species density; basal area, relative density, relative dominance, relative frequency and species density were calculated.

Analysis was conducted to calculate the Complexity Index (CI) and Importance Value Index (IVI) (Cintron and Novelli, 1984). Complexity Index denotes the diversity and abundance of flora within the forest community. It is calculated combining the number of species, stand density, basal area and height. Importance Value Index indicates the structural importance of a species within a stand of mixed species. It is calculated by summing up the relative percentages of basal area, density and frequency, each weighed equally for each species, relative to the same dimensions for the entire stand.

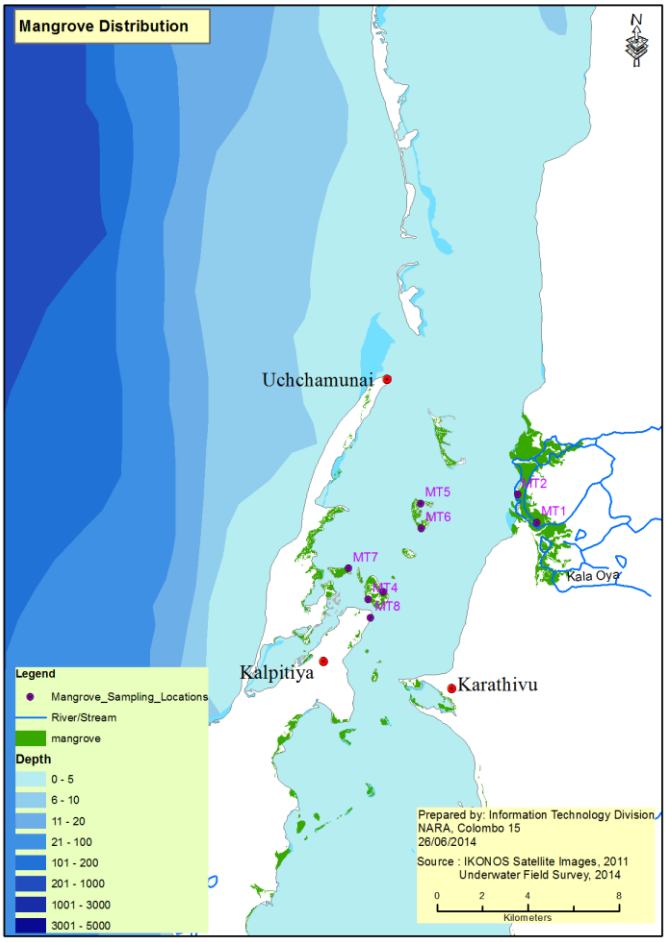

Figure 9. Mangrove distribution and sampling locations at Puttalam Lagoon and Dutch Bay

MT1 - Dutch Bay (land ward), MT2 - Dutch Bay (land ward), MT3 & MT4 – Erumathivu, MT5 & MT6 – Periyaarachchi, MT7 – Purawasankuda and MT8 - Kalpitiya

A. marina is the most dominant mangrove species encountered in the Puttalam Lagoon (Erumathivu, MT4 location,**Figure 9**) with relative dominance value of 89 and the importance value of 241 while *R. mucronata* is the second most dominant species with relative dominance value of 86 and the importance value with 222.5 (Erumathivu, MT3 location; **Figure 9**). Structurally highly developed *R. mucronata* could be observed at MT3 transect of Erumathivu Islands. Highest importance values exhibit *A.marina* in MT4 location of Erumathivu Island while second highest Importance value exhibit *R. mucronata* at another transect (MT3) of the same island. Maximum number of species (6) was observed at MT5 location at Periyaarchchi Island which comprised of higher number of *Pemphis acidula* and *Sonneratia cassiolaris. A. marina* has the highest importance index for landward fringe mangroves (MT8) at Puttalam Lagoon as the relative frequency of *A. marina* is highest (83) at this stand. Highest stand density (4683 trees/ha) as well as the Complexity Index (CI) was encountered in MT6 which has five species of mangroves (**Figure 10**). Structural studies of mangroves at Erumathivu Islands in 1990 recorded a Complexity Index of 1.95 and structural importance, IMV for *A. marina* of 122.4, while it was 177.6 for *R. mucronata* (Amarasingha and Balasubramenium, 1992). When compared with those findings, structural importance, IMV of species and the diversity and the abundance, CI have increased in the fringing mangrove island habitat after a 24 year of period. Despite of that, riverine mangroves of Dutch Bay (**Figure 11**) showed a Complexity Index from 8 to 22 while in the present study it ranged from 2.9 to 8.2 proving that structural diversity has decreased after 24 years. It could be observed that the lower structural complexity is due to decrease of structural characteristics such as stand density, basal area and

number of species encountered in the present study area except tree height. Despite of the lower density, high regeneration capacity was observed in each plot of study.

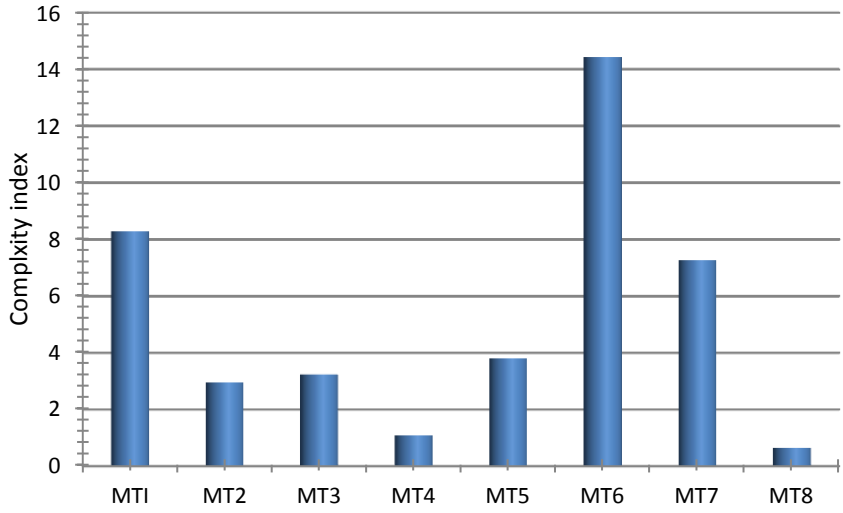

Figure 10. Complexity index of mangroves at study locations in the upper part of the Puttalam Lagoon.

Figure 11. Working at structurally complex *Rhizophora* trees in estuarine mangroves of Dutch Bay

4.3.2. Sea grasses and associated flora in Puttalam Lagoon (upper part)

Biophysical monitoring of seagrass meadows has been completed around islands of Kalpitiya, Western and Eastern borders of Puttalam Lagoon (Kalpipitya to Uchchamunei and Gangewadiya, Serakkuliya) and Dutch Bay in the Puttalam Lagoon. Seagrass/seaweeds survey was conducted within the Bar Reef in 09 spots by deep diving (**Figure 12**).

The locations and extent of the sea grass beds were delineated in a base map using GIS technology, satellite images and available maps followed by field verification while mapping of seagrass beds were started using GPS technology. Sampling of seagrasses commenced from the Northern end of the Puttalam Lagoon. Twenty eight line transects (50 m in length) perpendicular to the shoreline of the lagoon/islands were conducted. 1 m x 1 m quadrate was used for measuring seagrass cover and species distribution. Identification of seagrasses and the determination of percentage of seagrass cover were performed at the field.

The species composition in the study so far conducted was dominated by *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides* and *Halodule pinifolia* (**Table 1**). *Enhalus acoroides* was the dominant species observed at Western and middle areas of the lagoon while *Cymodocea* species were prominent at the Eastern bank of the lagoon (**Figure 15**). *Enhalus acoroides was* also the most

dominant species found around the islands at a depth of 0.5 m to 1.5 m. *Halodule pinifolia* and *Halophila ovalis* were observed in the shallow areas which are exposed to the air at low tides.

A location (T13,**Figure 13**) in Northern end of the Eastern part of the lagoon consists of *Gracilaria edulis* which is epiphytic on Cymodocea. The seaweed species (*Gracilaria edulis)* was not recorded in the lagoon for about 13 years, although it was abundantly found in the lagoon before that. Sargassum, Jania and Padina were the other taxa of seaweeds found epiphytic on Cymodocea. It was noted that this particular location has a rocky substrate. Apart from that adjacent location (T14,**Figure 12**) to above has the limestone substrate which supports *Jania sp.* and *Cymodocea sp.*

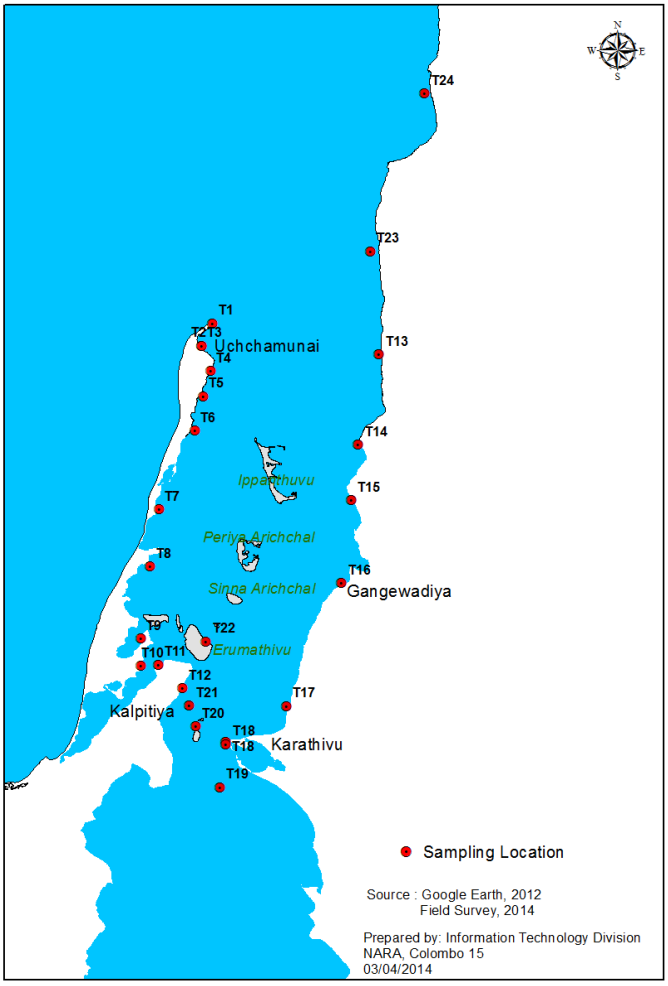

Figure 12. Seagrass and benthos sampling locations at the upper part of the Puttalam Lagoon and Dutch Bay area

Figure 13. Seagrass habitats in shallow water around islands of in Puttalam Lagoon

Figure 14. Macroalgae, *Chaetormorpha, Padina* associated with seagrasses

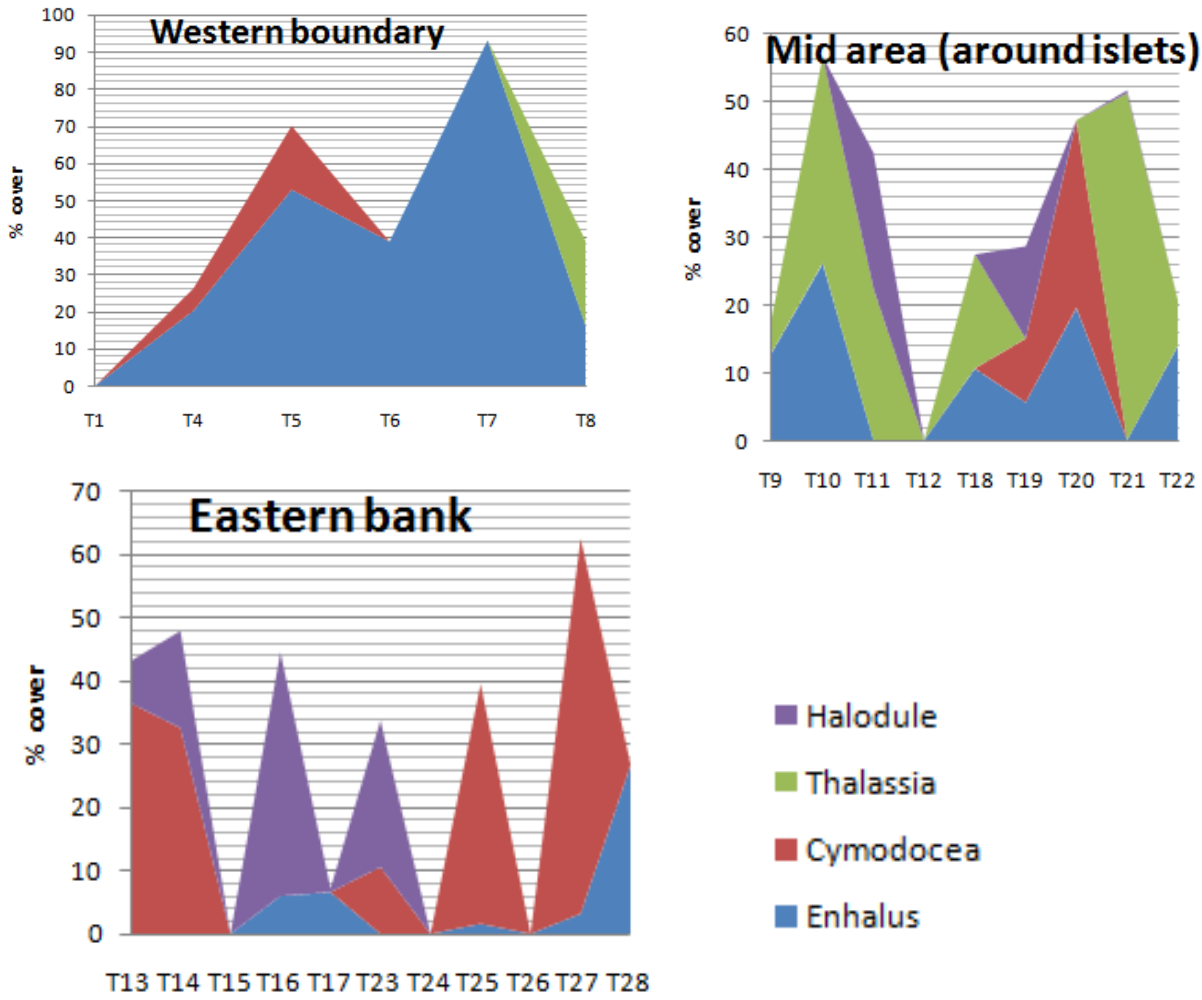

Figure 15. Distribution pattern of seagrass (percent cover)

The impacts from fresh water input and the elevated turbidity levels on the sea grass beds were identified. In areas of fresh water inputs there common seagrass species were not observed and on the other hand seaweeds were observed in association with seagrass in the vicinity of sea mouth areas where more saline water input is there. Elevated turbidity (**Figure 13**) can cause light deprivation which is a main impact on reducing productivity of seagrasses leading to low survival. Pulsed turbidity events are caused by factors such as sediment resuspension during strong winds, dredging activities and flooding rivers. The lagoon receives high fresh water inputs with sediment loads in the rainy seasons from Kala Oya and Mi Oya. Macro algae such as *Cheatomorpha aerea*, *Padina* species could be observed (**Figure 14**) at shallow and turbidity elevated areas and those species could be taken as bio-indicators of such impacted areas.

Table 1. Abundance of seagrass species in the upper part of the Puttalam Lagoon

Species	Eastern boundary	Middle area	Western boundary
Enhalus	+++	++	+
Cymodocea	++	++	+++
Thalassia	++	+++	+
Halophila	+	+	-
Halodule	++	++	+
Syringodium	+	+	-
Associated algae	++	+	+++

"-" : Not abundant, "+" : less abundant, "++" : moderately abundant and"+++" : highly abundant

Seagrass/seaweeds within the BRMS

Seventeen spots were investigated for seagrass/seaweed survey around the Bar Reef (**Figure 16**). Seagrasses were not encountered in the core zone of the BRMS but some macro algal species were associated with the reef. Several species of seaweed such as *Halimeda* sp., *Padina , Acanthophora, Gracilaria*, *Kallymenia, Dictyota* sp., *Stypopodium* sp. and *Dasya* sp. were recorded in the sampling locations while very few isolated patches of seagrasses species such as *Cymodacea serrulata* and *Halophila ovalis* were encountered.

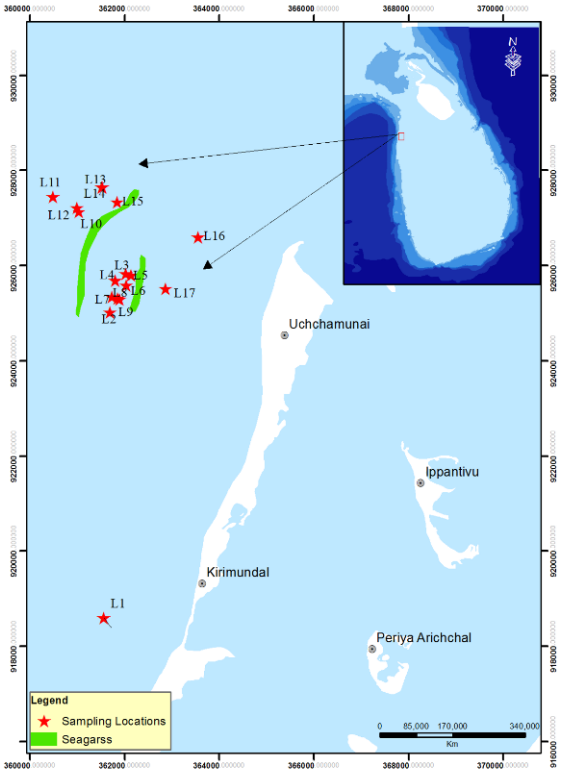

Figure 16. Seagrass and seaweed sampling Bar Reef area

Halimeda and Padina are coralline algae while other algae found are the non calcareous algae. Such algal populations may contribute to a major portion of the total primary productivity to the reef. The sparse mats of fast growing opportunistic filamentous algae usually are responsible for the very high primary productivity per unit area in most biotic reefs. They are more productive than dense stands of macro algae because of their high surface to volume ratio. These types of sparse mats of filamentous algae were observed in the core area of the BRMS. Herbivorous fishes by their scrapping mode feeding continuously provide new substrata and thereby select for opportunistic macro algae forms as well as long lived scrape tolerant coralline algae.

Locations were in a depth range between 4 m to 7 m, and light energy received to the bottom was about 1 to 2% of the light energy available at surface which might be due to the turbidity and no seagrasses were available at those locations. Anyhow, it could be observed that macro algal species such as brown algae mats, red algae mats, and *Halimeda* occur in those areas.

Extensive patches of seagrasses were observed in the area (L16 and L17, **Figure 16**) located two kilometres away from the shore which contains *Enhalus acoroides, Thalassia hemprichii, Halodule pinifolia* and *Syringodium isoetifolium* observed as dominant species.

Chanks and some sea cucumber species were the economically most important species observed in association with seagrasses. Edible and marine ornamental fishes were predominantly found in the areas where sparse macro algal beds are available. Seagrass leaves appeared to be particularly suitable surface for algal settlement as evident by the fact that they support many species of algae

and invertebrates leading to food web integrity. Polychaete worms (see the benthic chapter) were abundant in shallow and exposed flats in the lagoon where many seabirds were observed.

4.4. Determination of status of benthic biodiversity

Benthic macro fauna plays an important role in aquatic ecosystems as primary and secondary consumers. Survival, distribution and abundance of macro benthos depend on the characteristics of their environment such as salinity, organic matter content, soil texture, sediment particles and the ability to construct permanent burrows in the substratum (Perkins 1974).

The species richness and the abundance (the counts of individuals for every species) were determined: Gastropod 17 families, Bivalve 03 families and Polychaete 22 families were identified. Highest abundance of polychaetes was recorded in sampling at T7 (**Figure 12**) as 58 and the 2nd highest abundance was recorded in sampling at T21 (**Figure 12**) as 27. Highest numbers of polychaete and gastropod families were recorded in the samples at T 7 and T12 (Figure12) respectively. Among them, the sample at T7 represented 31 members of Amphinomidae family and 11 members of Pisionidae family. The samples at T 21 represented 23 members of Oweniidae family. The crustaceans, some of which potential predators of polychaete worms and the locations might be good nursery grounds for fish and the initial levels of the food web. And also it was apparent that the abundance of the polychaete worms was highly associated with the distribution of sea grass beds.

4.5. Assessment of zooplankton fauna from associated habitats

Puttalam Lagoon

Zooplankton recorded during the present study of Bar-reef and Puttalam Lagoon constituted the following group members of protozoa, coelenterates, ctenophores, polychaete larvae, gastropod and bivalve larvae, copepods, cladocerans, crustacean larval stages, malacostraca, larval stages of echinoderms, chaetognaths and chordates. As far as zooplankton diversity and densities are concerned, the Puttalam Lagoon presented high abundance of crustaceans during the investigation period. Phylum Arthropoda (crustaceans) contributed 77.53% of the total zooplankton population followed by Protozoa and Mollusca which are represented 11.21% and 7.8% of the total zooplankton respectively (**Figure 17**). A total of 8 groups of zooplankton were identified within the crustacean population. The copepods were represented by four orders, Calanoida, Cyclopoida, Harpacticoidea and Poecilostomatoida with the larval stages and most dominant group was copepods, which comprise of 69.5±4.59% followed by crustacean larvae (28.29±4.22%; Figure 20). Out of the copepods majority were represented by 43.64±2.0% of calanoids and 17.12±3.09% of cyclopoids of total crustacean population. Major copepod species identified were *Paracalanus, Eucalanus, Acartia sp., Calanus sp., Calanus finmarchicus, Microcalanus, Oithona sp. Cyclopina, Oncaea sp., Microsetella and Corycaeus sp*., while cladocerans were represented by *Evadne* sp. The mysids, euphasids, and decapods were represented by malacostraca, while there were a number of larval forms also present. Meroplanktonic forms encountered include juvenile stages of different animal phyla such as Arthropoda (nauplius, zoea, caridean, brachyuran larvae), Chordata (fish larvae), Annelids (polychaete and spionid), Mollusca (gastropod and bivalve larvae) while the larvaceans were the highest abundant group represented by *Oikopleura* sp.

Considerable reductions of crustacean percentage (33.95%) and increase of protozoans (23.75%) and molluscans (10.59%) (**Figure 19**) were recorded during in 2015 due to the large amount of diatoms and bivalves represented by sampling locations of the southern part of the lagoon.

Bar Reef

The composition of zooplankton showed that crustaceans represented the major component (79.01% and 306 organisms/L) followed by molluscans and protozoa which represented 12.25% (13.44 organisms/L) and 6.38% (2.95 organism/L) of the zooplankton community in six sampling sites

of Bar Reef during the investigation period (**Figure 22**). Highest percentage of 58.93% and density (228.78 organisms/L) of copepods were recorded of total zooplankton population followed by larval stages of crustaceans, including nauplius larvae which represented 18.99±8.35% (73.15±68.33 organisms/L) of the total zooplankton density in Bar Reef Marine Sanctuary. Out of the copepods, majority were represented by Calanoids, Harpacticoids and Cyclopoids copepods ranging from 47.42% (185.56 organisms/L), 14.04% (6.52organisms/L) and 7.61% (29.55 organism/L) respectively.

Variation of environmental parameters such as temperature, nutrients and salinity, food and hydrology are explaining the differences in the densities and diversity of the zooplankton in the lagoon.

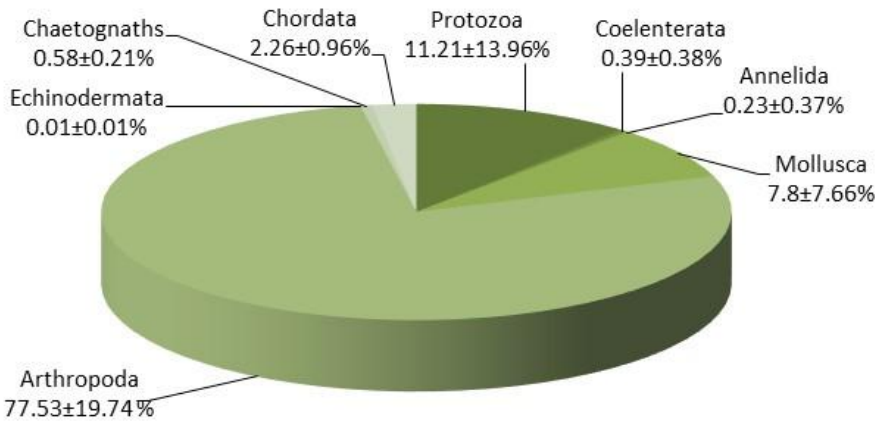

Figure 17. Mean composition (percentage ± SD) of major zooplankton taxa in fifteen sampling sites of Puttalam Lagoon during sampling period of 2014-2015.

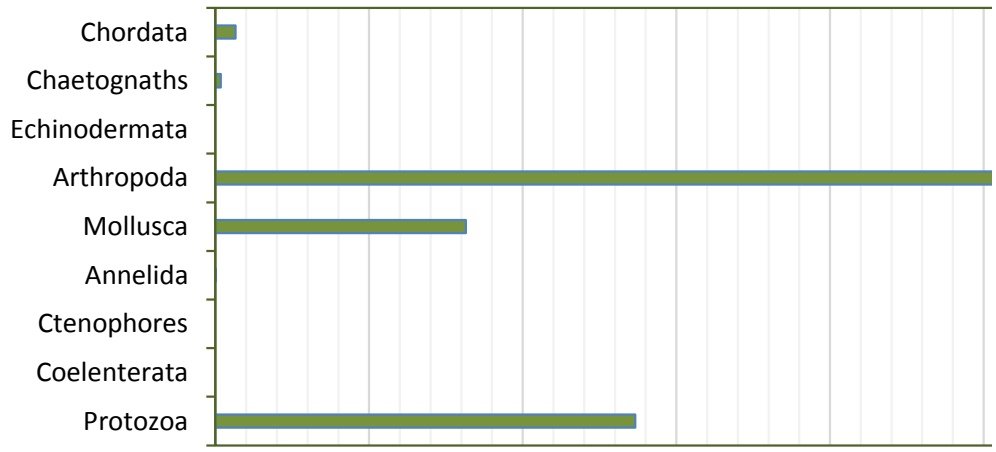

Figure 18. Mean composition (organisms/L) of major zooplankton taxa in fifteen sampling sites of Puttalam Lagoon during sampling period of 2014-2015

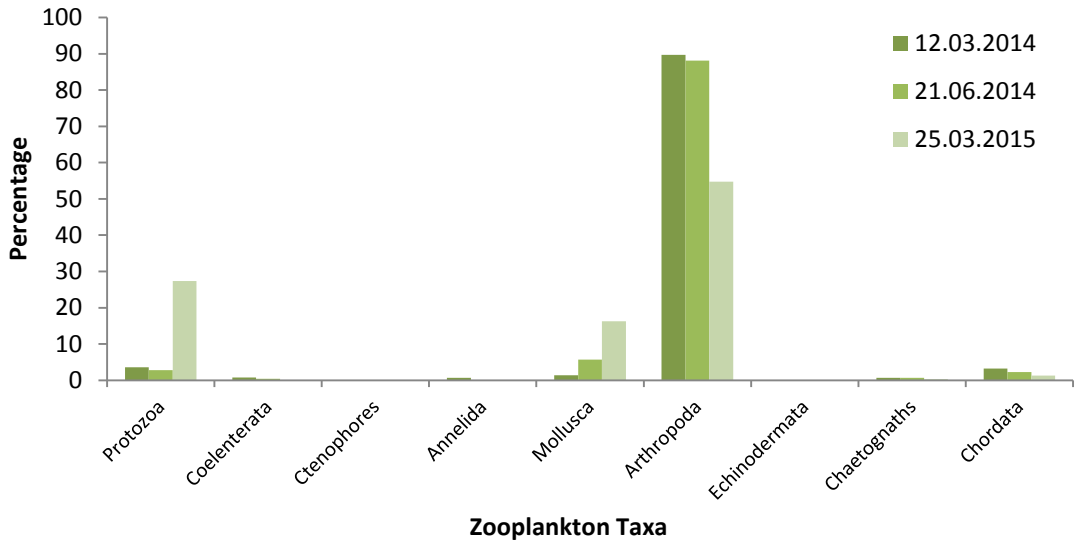

Figure 19. Variation of percentage of major zooplankton taxa in sampling dates of Puttalam Lagoon

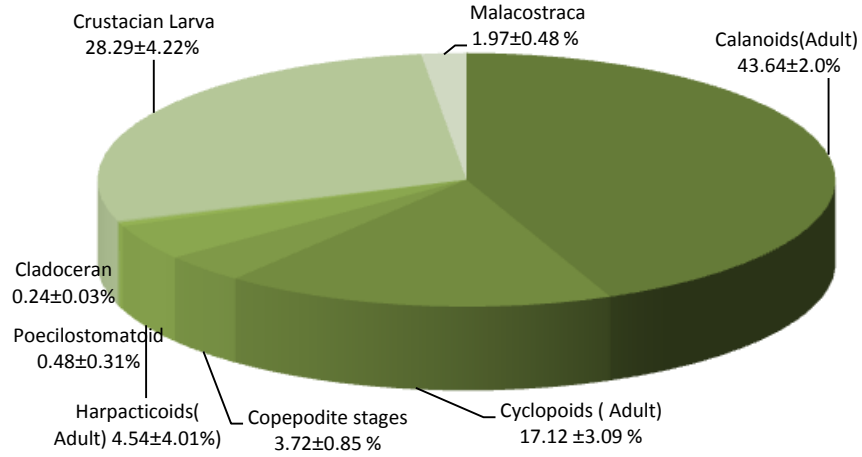

Figure 20. Mean percentage composition ± SD of crustacean zooplankton in fifteen sampling sites of Puttalam Lagoon during sampling period of 2014-2015

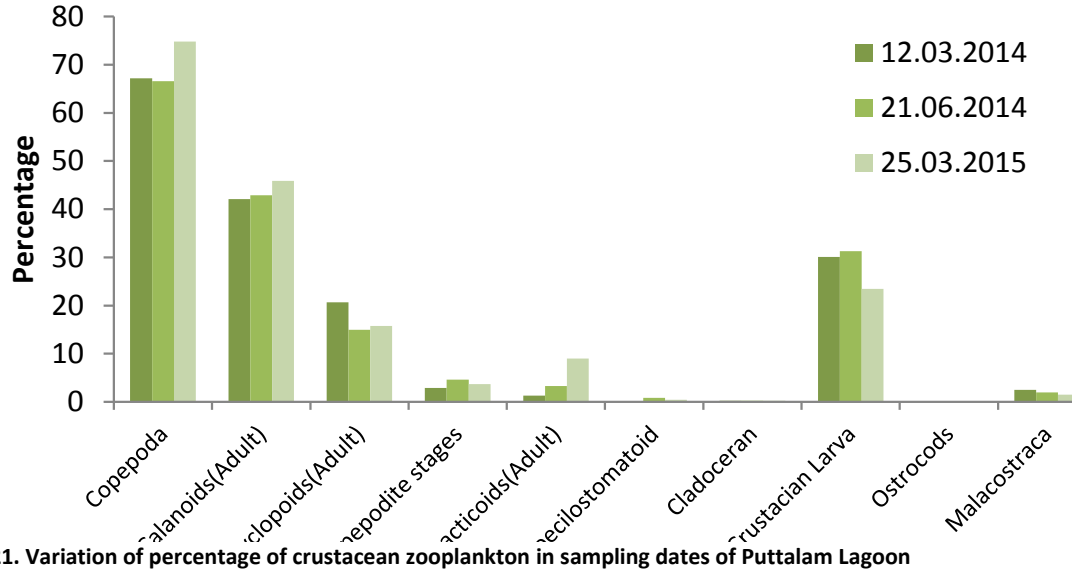

Figure 21. Variation of percentage of crustacean zooplankton in sampling dates of Puttalam Lagoon

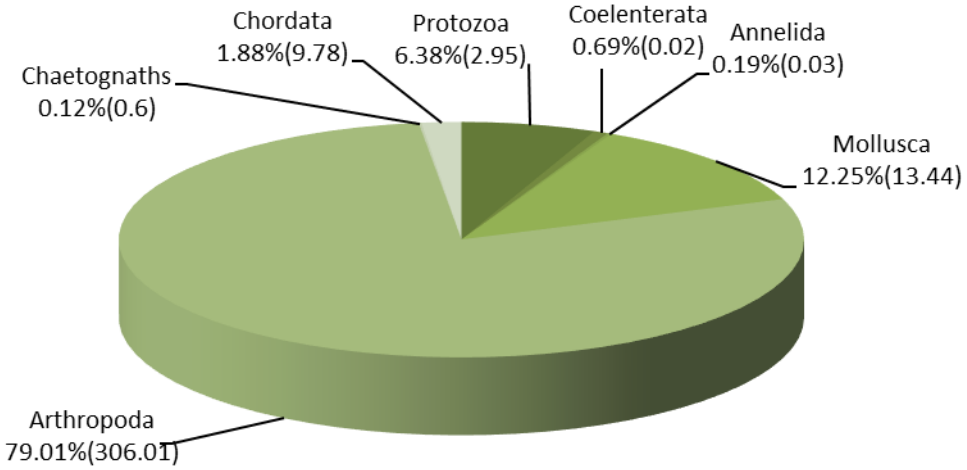

Figure 22. Mean composition (percentage and number/L) of major zooplankton taxa in six sampling sites of Bar Reef during sampling period of 2014-2015

4.6. Diversity of molluscan species

Bar Reef is a one of the most famous live coral sanctuaries situated at Kalpitiya in Sri Lanka. The sanctuary is rich with many marine organisms as well as live corals and seaweeds. Molluscs are one of the most familiar invertebrate groups of organisms that dominate in the sanctuary. However the general view of scientists as well as fishing community is that the present stock state is decreasing gradually pointing out the urgent need of management measures for the conservation of the valuable resource. It is therefore that an assessment of natural stocks of molluscs abundant in the proximity of Bar Reef Marine Sanctuary was conducted from February to April in 2014 using under water visual survey. A Geographic Information System (GIS), geodatabase was assembled from existing bathymetric and habitat data extracted by heads-up digitizing of scanned and georeferenced nautical charts. The coastline, reefs and shoals were digitized from Landsat and ETM+ satellite data. Twenty sampling sites in a sanctuary ground of 306.7km^2 were randomly selected. All the molluscs found in each sampling site were collected by the trained divers and they were identified up to minimum possible taxonomic level using standard identification keys. A total of 32 mollusc species were recorded during first survey from January to April 2014 while 33 species were recorded during

the second survey from October to November 2015. The recorded species within the two surveys appeared to be more or less similar in the Bar Reef. However it was noted that there was a remarkable variation in the abundance of recorded species. Higher in the abundance of some mollusc species belonging to the families of Cypraeidae, Naticidae, Veneridae and Olividae were recorded during the second survey. Further, the presence of massive numbers of egg sacks of chanks reveals the importance of Bar Reef as a breeding ground for them. These findings will be important in implementing a proper management plan for the sustainability of the mollusc resources at the Bar Reef Marine Sanctuary in Sri Lanka.

4.7. Sea cucumber fishery in Bar Reef marine sanctuary area and associated coastal waters

Fishing activities are highly seasonal and greatly influenced by the monsoon winds. During the monsoons e.g. South west and North east, it brings much wave action and currents in the sea, by increasing the turbidity of water and making it difficult to spot animals. Moreover, the inter-monsoonal rains also discharge water from river mouths to coastal areas making the water more turbid. Hence, harvesting off the North west and North coasts occur intensively during the North east monsoon from October to April.

The Fiberglass Reinforced Plastic (FRP) boats powered with 9, 15 or 25 hp outboard motors are the major fishing crafts used for sea cucumber fishery in Sri Lanka. There are no special gears or nets devised exclusively to catch sea cucumbers and they are mainly harvested by hand picking either through scuba or skin diving. Scuba diving is carried out by almost all the divers and skin diving is mainly practiced in shallow areas especially in the season where water turbidity is very low (**Figure 23**). Two divers and a boat operator are on board when practicing scuba diving but sometimes there are three divers on board. On average, four scuba cylinders are used by each diver during a fishing trip and true fishing time varies from 30-45 minutes per cylinder. There are 6-7 divers on board when practicing skin diving.

a: Major fishing crafts

b: Skin diver is collecting sea cucumbers

c: Scuba diver is collecting sea cucumbers **d:** Catch per boat per day

Figure 23. Commercial sea cucumber fishing activities in Sri Lanka

Both day and night fishing activities are practiced in the Northwest. The fishing crafts leave around 07:00-08:00 hours and return around 15:00-16:00 hours when day diving activities are carried out while they leave around 18:00 hours and come back next day early morning around 02:00 hours for night fishing. There are considerable variations in fishing depths with the fishing time. Day diving is carried out down to a depth of 20-25 m while the night diving is restricted to 10-15 m. However, the effective fishing time ranges from 2 to 2.5 hours per boat per day in both day and night diving activities. Around 280 boats were engaged in sea cucumber fishing activities in the Northwest during 2007 to 2009 (Dissanayake & Stefansson, 2010) but only around 150 boats presently.

In the study area, around 200-250 fishing families are directly or indirectly dependent on the sea cucumber fishery for their livelihoods. Due to religious activities, almost all fishers (Muslims or Catholics) do not go for fishing one day a week (either Friday or Sunday). Hence, the fishing operations are conducted six days per week and the active number of fishing days varies with the weather conditions as it requires clear and calm seas for successful fishing.

Table 2. Major sea cucumber species and the values

No	Scientific name	English name	Value	LKR
1	*Holothuria atra*	Lolly fish	Low	90.00
2	*Holothuria edulis*	Pink fish	Low	90.00
3	*Thelenota anax*	Amber fish	Medium	180.00
4	*Stichopus chloronotus*	Green fish	Medium	200.00
5	*Thelenota ananas*	Prickly red fish	Medium	200.00

Pink fish (*Holothuria edulis*) and Lolly fish (*Holothuria atra*) were the most abundant species that we observed in commercial catches from Bar Reef area.

4.8. Study on the avifauna in associated habitats of BRMS

The Puttalam Lagoon and sea area is well known for its rich avifaunal diversity. The area consists of many habitats including open water, mud flats, sand bars, mangroves and marshes. Since many migrant birds enter the island from this area the diversity is higher during the migration season. A preliminary survey was carried out in the Northern region of the lagoon covering the sand bars, islands, lagoon area and adjacent land area.

A total of 92 species of birds were encountered during this survey. Only 24 migrant species were observed with four species of gulls among them. The sea birds observed on the sand bars close to the Northern tip of the Kalpitiya Lagoon was dominated by terns belonging to seven species

including four migrant species. Shore bird species were dominated by the plovers. Roosting sites in the islands contained large numbers of little cormorants, Little egrets (*Egretta alba*) and House crows. Although the area is known for many pelagic sea birds no special birds were seen during the survey; as the sea area was not visited during the migration season. The only globally threatened species observed during the survey was the Spot billed pelican (*Pelecanus philippensis*).

4.9. Investigation of the status of the fishery

The fishing crafts of the small-scale sector mainly consist of FRP boats, some traditional fishing crafts such as Paru, Vallam, Madel oru and Theppam. Boats are made up of glass fibre Reinforced Plastic (FRP) and size may vary with 5-6 m in length and are mainly used for small mesh gill netting. Paaru are used for carrying beach seines while Vallam are for drift netting and long-lining. Theppam are mainly used for small mesh gill netting.

Most common fishing gears used in the area are gill nets, purse seines, long lines, cast nets and trammel nets while there are two types of gill nets as drift nets and bottom set gill nets. Surukku del and Laila nets were observed as a type of purse seines.

Small pelagic fish species such as sardines, herrings, shads, and sprats were mainly caught using small mesh gill nets. The major clupeid fish species found during the survey were *Amblygaster sirm* (Hurulla), *Hilsa kelee* (Karattaya), *Sardinella albella* (Sudaya), *Sardinella gibbosa* (Matta salaya) and *Sardinella longiceps* (Pesalaya). The major carangid fish species found were *Decapterus russelli* (Indian scad), *Elagatis bipinnulata* (Rainbow runner) and other *Caranx* species. *Rastrelliger kanagurta* (Kumbalawa) was mainly found in small mesh fish catches. Pony fishes such as *Gazza* sp. and *Leiognathus* sp. were also found among the gill net catches. The demersal fish catches mainly consisted of lutjanidae (snappers), lethrinidae (emperors), Serranidae (groupers), Carangidae (jacks, trevallies and scads), leiognathidae (pony fishes) and Dasyatidae (stingrays) families. The other commercially important fishery resources mainly consisted of crabs, prawns, lobsters, squids, cuttlefish and sea cucumbers. *Portunus pelagicus* and *Scylla serrata* were dominant among the crab species. *Penaeus indicus* and *P. semisulcatus* were dominant among the penaeid shrimps. Among cephalopods, most abundant were *Sepia pharaonis* and *Loligo duvauceli.* Sea cucumber fishery is also a major fishery in some areas. Catch mainly consisted of *Holothuria scabra* (Sand fish) and *Stichopus chloronotus* (Green fish). Lobsters are also abundant in some parts of the BRMS mainly *Panulirus homarus* (Scalloped spiny lobster). Details of the fish species observed have been documented (**Appendix I**).

4.10. Monitoring and investigation of the impact of fisheries activities, fishing gears and methods around BRMS and Puttalam Lagoon

Fishing is the main economic activity within the BRMS and variety of fishing activities are carry out in both the Core zone and Buffer zone of the BRMS. Some of the activities are allowed and some of the activities are restricted or prohibited according to the Bar Reef Special Area Management plan, published by the Coast Conservation Department in 2005. Bottom set nets, gill nets and moxy netting for ornamental fish catching are banned and not permitted in both the zones. Collection of ornamental fish, sea cucumber, chanks and lobster is permitted within the Buffer zone by scuba diving or snorkelling. Angling also is permitted only in the Buffer zone.

A variety of fishing gears and methods including gillnet, bottom set gillnet, and bottom longline, hand line and snorkelling/scuba diving are being used for resource exploitation in the Gulf of Mannar. The coastal fisheries conducted in the shallow seas mostly target small pelagic fish (herrings and sardines etc.). Small mesh gillnets and beach seines are the mainly used fishing gear for catching small pelagic fish. A wide range of mesh sizes are being used in the gillnet fishery. Also, there is a strong seasonal variation in the catch of the small meshed gillnet fishery. The beach seines are seasonally operated, normally from October to April when the sea is calm.

Beach seine is a traditional fishing gear and it is still being widely used in both Puttalam districts.

Bottom trawling which targets mostly shrimps and pony fish are conducted at the shrimp trawling grounds in Kalpitiya Islands and Pesale. Department of Fisheries and Aquatic Resources (DFAR) has taken a policy decision not to issue operating licences for mechanised trawlers since bottom trawling is considered as one of the destructive fishing methods. Fishing operations with mechanised trawlers are still conducted in the above two sites, though fishing operating licences have not been obtained for such operations. Also, usage of encircling nets like "Surukku nets", bottom set gillnets, monofilament gillnets, moxy nets, push nets and other harmful fishing methods such as dynamiting are banned but some of these are widely used in this area.

Bottom set gillnets are widely used targeting crabs. Both nylon and monofilament gillnets are used. A wide range of mesh sizes of bottom set gillnets (nylon) is being used. Since monofilament bottom set gillnet is a non-selective fishing gear, use of such a gear could be very harmful in terms of long term sustainability of the resources.

Operating licences are issued by DFAR for some fishing operations using harmful encircling nets like "Laila". Usage of such gear cannot be accepted when considering the factor of long term sustainability of the fisheries resources. Also, usage of such gear could always lead to conflicts with other gear users in the coastal fishery. Since "Laila nets" massively catch carangids and there is no other efficient gear to catch carangids, DFAR may perhaps issue operating licences for "Laila". Therefore, if this gear is allowed to be used further, there should be an effective mechanism to minimize the negative impact of it on the resources as well as on other gear users.

4.11. Water quality at Bar Reef and associated environs

A total of 22 sampling locations were selected for the study representing16 sampling locations from the Puttalam Lagoon and six sampling locations from the Bar Reef.

Collected samples were analysed in accordance with the Standard methods for examination of water and waste water (APHA), 20th edition. The samples were analysed for various water quality parameters such as Ammoniacal Nitrogen, Phosphate, Nitrate-Nitrogen and Nitrite-Nitrogen, Chlorophyll–a, and Biochemical Oxygen Demand (BOD).

In-situ analysis were conducted for the determination of pH, which was measured using a pH meter (Orion 260A), Electrical conductivity, measured using Hanna portable multi range conductivity meter (HI 8733), Dissolved Oxygen (DO) concentration, measured using a portable meter (Orion 830A), and Turbidity, measured using portable meter (Hach 2100P). In addition, Total Dissolved Solids (TDS) and Salinity were measured at the site, during the time of sample collection.

Overall results indicated that average values of the pH, nutrients and Dissolved Oxygen levels were within the standard limits for the fish and aquatic life according to the proposed quality standards for different use classes of coastal water in Sri Lanka.

Table 3. Water quality parameters

	Puttalam Lagoon				Bar Reef			
Parameter	**Min**	**Max**	**Avg**	**St dv**	**Min**	**Max**	**Average**	**St dv**
pH	7.83	8.07	**7.99**	0.07	7.13	8.26	**7.75**	0.52
DO (mg/L)	4.32	6.94	**5.99**	0.86	5.14	6.85	**6.05**	0.55
BOD (mg/L)	03	11	**6.33**	3.08	01	04	**3.17**	1.17
EC (mS/cm)	35.90	53.40	**50.48**	5.41	52.80	55.10	**54.50**	0.85
TDS (g/L)	20.40	32.60	**30.18**	3.68	31.10	32.60	**32.28**	0.58
Salinity (ppt)	21.20	33.90	**31.39**	3.83	35.00	35.00	**35.00**	0
Turbidity (NTU)	5.14	25.50	**13.76**	6.02	0.47	3.54	**1.71**	1.21
Ammoniacal-N (mg/L)	0.001	0.703	**0.089**	0.175	0.022	0.022	**0.022**	0
Nitrite-N (mg/L)	ND	0.015	**0.003**	0.004	0	0.007	**0.003**	0.003
Nitrate-N (mg/L)	0.006	0.031	**0.016**	0.007	0.006	0.052	**0.028**	0.016
Phosphate (mg/L)	0.002	0.123	**0.015**	0.029	0.002	0.008	**0.005**	0.004

St dv= standard deviation

Among the parameters considered, it is found that average Biochemical Oxygen Demand (BOD) of the Puttalam Lagoon is above the proposed standards for different use classes of coastal waters in Sri Lanka. For most of the other important parameters, it is noted the levels in the Puttalam Lagoon and Bar Reef are within the standards. From this limited survey, no adverse water quality impacts or water pollution was noted.

5. Socio-economic study of Bar Reef Marine Sanctuary and associated ecosystems

Objectives of the study were

a. To provide information on economic and marketing aspects of marine ornamental fishery in order to support management of BRMS
b. To improve understanding on recreational fishery and visitor pressure on BRMS
c. To identify social aspects and anthropogenic issues of BRMS associated ecosystems

Methodology

Socio-economic survey methodology was employed to collect data and information on social, economic and marketing aspects of livelihood activities of the communities. The following data collection tools and techniques were used.

a. Structured questionnaire survey
b. Focus group discussions
c. Key informant survey
d. Secondary data and information

The sampling unit comprised of all categories of resource users and other direct and indirect stakeholders. Fishers, fish traders, scuba divers representing ornamental fish collectors, chanks and *beche-de-mer* collectors, recreational boat tour operators, community organizations, tourist hoteliers and local government authorities were among them. Sample for questionnaire survey comprised of 40 fishers, 19 scuba divers including ornamental, chank and *beche-de-mer* collectors, 3 ornamental fish assembles/agents, 3 chanks/*beche-de-mer* agents and 13 boat tour operators. Focus group discussions were conducted with tourist hotel owners and fisheries co-operative society office bearers. In addition, secondary data were also collected from Divisional Secretary Office, Kalpitiya and District Fisheries office, Puttalam and the Department of Wild Life Conservation. The study was conducted from June 2013 to December 2014. Data are analysed using SPSS software package.

5.1. Demographic factors

5.1.3. Ethnic composition

Sinhalese, Moor, Sri Lankan Tamils and Indian Tamils are major ethnic groups living in harmony since many decades in the area. Of them prior to 2001 the majority was Sinhalese while Moor and Sri Lankan Tamils were second and third in sequence. The ethnic composition in the Special Area Management (SAM) area has changed during the last decade remarkably mainly due to separatist activities prevailing in the Northern and Eastern provinces. Especially, influx of moor community settled in the Northern Province to Kalpitiya as Internally Displaced Persons (IDPs) resulted in greater changes of demography in the area. This situation further resulted in drastic changes in ethnic composition of the area. The changes in the ethnic composition of the area in 2001 and 2012 are shown in **Figure 24**.

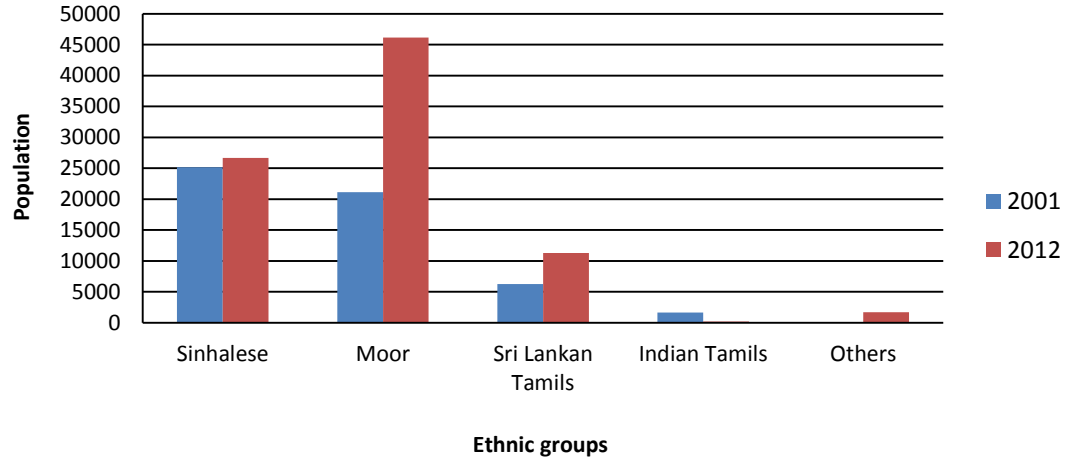

Figure 24. Changes in the ethnic composition in SAM area 2001 and 2012

Source: Data base, Kalpitiya DS Office

5.1.4. Population and density of the area

The Special Area Management (SAM), which was established in 1990 as a result of declaration of the Bar Reef Marine Sanctuary (BRMS). Within the boundary of the SAM area, there are 11 Grama Niladhari (GN) Divisions which is the lowest administrative unit of the government. The population changes that occurred in the SAM area are shown in **Figure 25**. The number of families has shown an increase but the average number of family members is below five except in Periyakudurippuwa GN Division. The **Figure 25** and **Table 4** depict population changes and density in the SAM area.

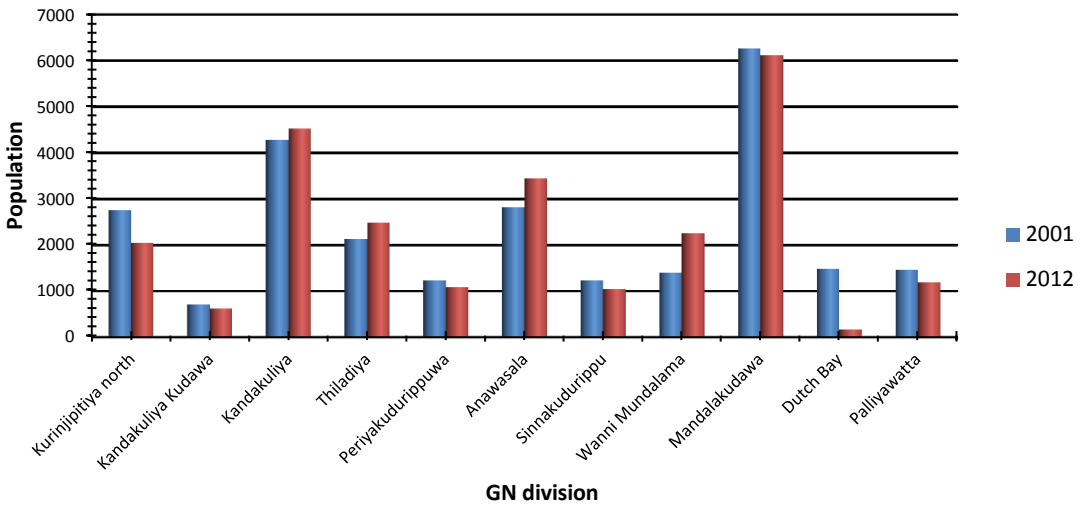

Figure 25. Population changes in the SAM area 2001 and 2012

Source: Data base - Kalpitiya DS Office

The highest density of population in the SAM area was recorded in Mandalakuda while Thiladiya and Kandakuliya were in second and third in sequence in both years. The lowest was Kurinjipitiya North in 2011 but Dutch Bay in 2012. In comparison to the year 2001 Kurinjipitiya North recorded the highest increased in 2012. The GN divisions with higher densities of population were among the places with higher percentage of fishing population.

Table 4. Population density/km^2 in the SAM area in 2001 and 2012

GN division	Year	
	2001	**2012**
Kurinjipitiya North	90	683
Kandakuliya Kudawa	177	154
Kandakuliya	1 429	1 508
Thiladiya	1 422	1 661
Periyakudurippuwa	175	154
Anawasala	470	574
Sinnakudurippu	245	210
Wanni Mundalama	280	452
Mandalakudawa	1 566	1 529
Dutch Bay	99	84
Palliyawatta	208	171

Source: Data base - Kalpitiya DS Office

5.1.5. Gender and age composition

The respective gender composition in the SAM area is more or less similar but signifies out number of female population in Mandalakudawa and Kandakuliya GN Divisions in comparison to the 2001 but inverse in Dutch Bay and Plaliyawatta GN Divisions due to higher number of migrant fishers. These migrant fishers were from Negombo and Chilaw areas and some of their family members are living in their native areas.

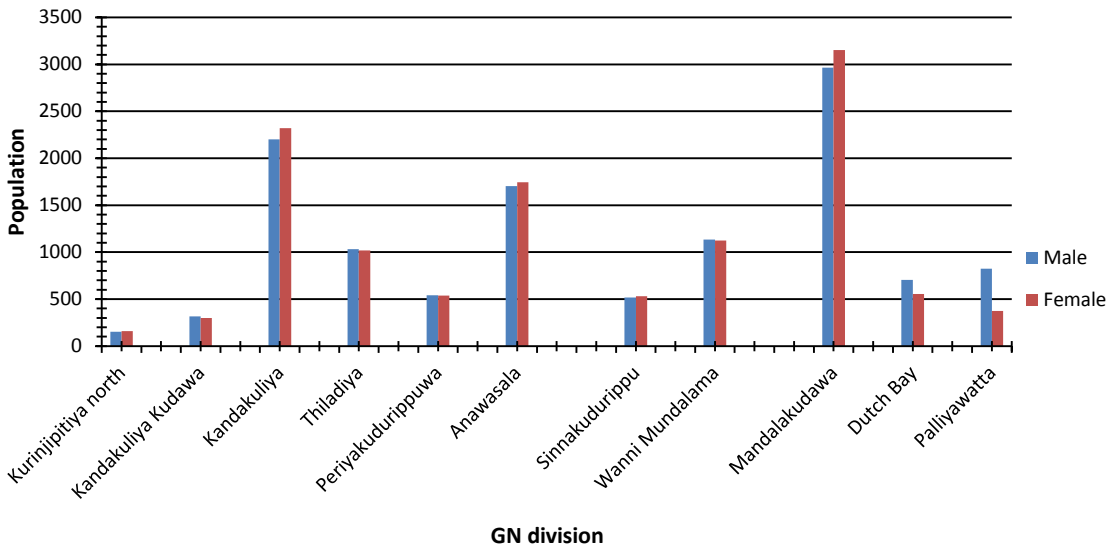

Figure 26. Gender composition of the population in SAM area in 2012

Source: Data base – Kalpit.iya DS Office

The age structure is mainly categorized into three groups; schooling ages of below 15 years, work force of between 15 to 59 years and elderly persons over 60 years which is always the lowest in all GN divisions. The economically active age group in the SAM area is proportionately out number compared to the age group of less than 15 years. This is significant in Palliyawatta GN Division compared to others. A higher number of work force and schooling ages persons are represented in Mandalakudawa, Kandakuliya and Anawasala respectively. **Figure 28** shows age structure of each GN divisions for the year 2012.

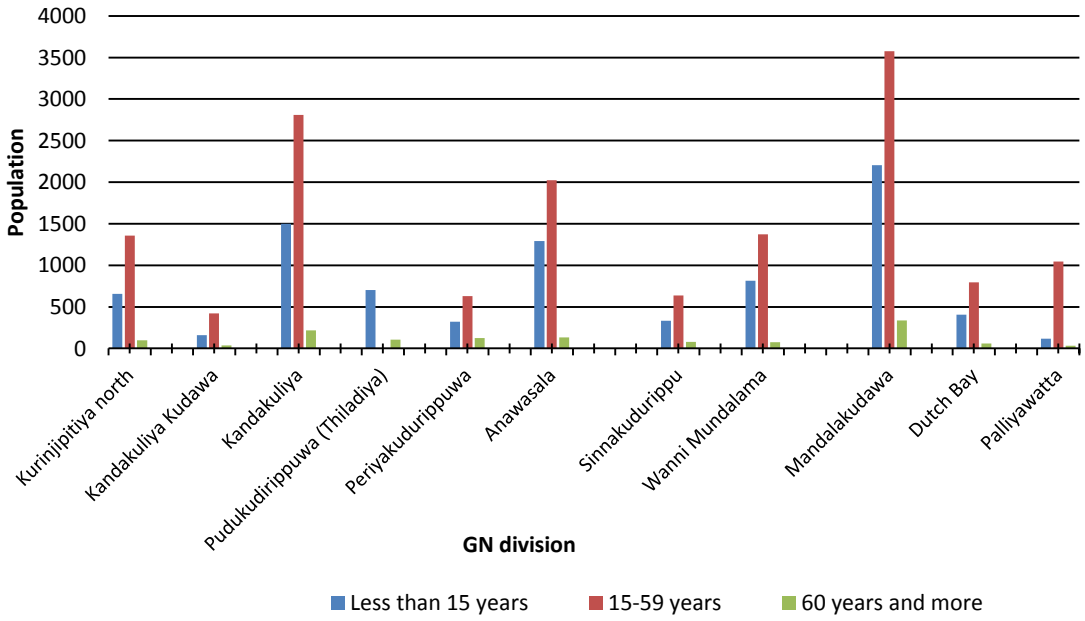

Figure 27. Age structure of the population in the SAM area in 2012

Source: Data base - Kalpitiya DS Office

5.1.6. Religious background of the population

The religious diversities of the population in the SAM area are shown in **Figure 28**. The main religious affiliations are Islam and Roman Catholic. In 2001 more or less the numbers of Roman Catholics and Islamic were same but in 2012 the Islamic population has shown a sharp increase. This was due to influx of Moors to the area. The Buddhist, Hindu and Christian religious populations were very low in both years in the area and have not shown a significant change compared to 2001 in 2012.

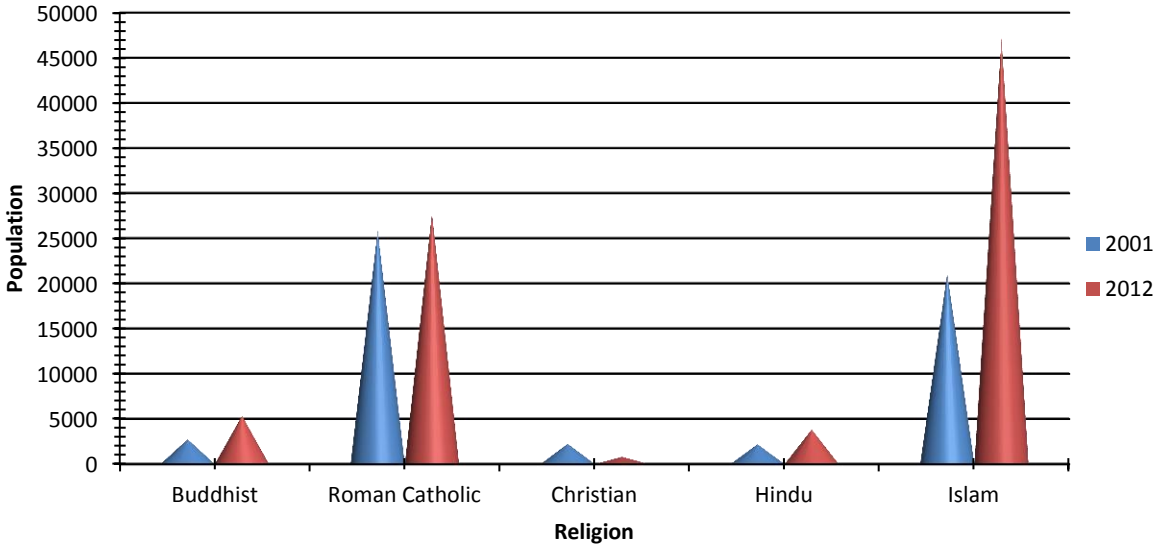

Figure 28. The population composition by religion in SAM area in 2001 and 2012

Source: Data base - Kalpitiya DS Office

5.1.7. Employment structure

A majority of people in the SAM area are fishers and they directly or indirectly made their livelihoods through BRMS associated ecosystems. The employment structure of the population in the SAM area is given in the **Table 5 .**The employment in the non-agricultural sector was the highest in numbers among all sectors. This sector mainly comprised of fishing and allied livelihoods. The contribution of this sector for the total employment was 40%. The agriculture and mining/estate labour works also contribute to the employment by 16% and 13%, respectively. The state and private sector contribution to the employment in the area were considerably lower. There was about 8% of the labour force who engaged in foreign employments.

Table 5. Employment structure in the SAM area in 2012

GN division	State sector	Private sector	Self-employment		Foreign employment		Mining/Estate/Labour works	Other	Total
			Agricultural	Non-agricultural (including fishing)	Full time	Part time			
Kurinjipitiya North	9	110	0	56	0	78	141	276	670
Kandakuliya Kudawa	1	0	0	109	0	4	12	3	129
Kandakuliya	30	63	70	815	1	84	90	55	1 208
Pudukudirippuwa (Thiladiya)	24	1	2	150	5	44	92	23	341
Periyakudurippuwa	38	12	31	88	9	9	32	38	257
Anawasala	22	19	598	62	25	36	99	82	943
Sinnakudurippu	41	15	0	196	15	19	28	26	340
Wanni Mundalama	34	46	0	872	23	44	56	0	1 075
Mandalakudawa	64	72	328	148	5	108	187	57	969
Dutch Bay	1	0	0	54	0	10	104	306	475
Palliyawatta	0	0	0	25	0	0	2	0	27
Total (%)	4.1	5.3	16.0	40.0	1.3	6.8	13.0	13.5	100

Source: Data base - Kalpitiya DS Office

5.2. Household and living status of the community

5.2.1. Lighting sources

The lighting source of the residents in the SAM area varies from electricity to bio gas. However, the main source of lighting was electricity except in several GN divisions. The residents in Dutch Bay and Palliyawatta mainly use kerosene and solar power for lighting purposes as the area is not connected to the national grid. The lighting from other sources is providing electricity is mainly by generators. There were 254 households using generator based electricity in Palliyawatta provided by private suppliers on limited scale. **(Source: Data base - Kalpitiya DS Office)**

5.2.2. Materials used for housing construction

Bricks or cement blocks were used by 69% of households. A 31% of houses were constructed using temporary materials such as *kadjan* or flank. Mainly for roofs, tiles were used and that was 65%. Only 2% used asbestos for roofs **(Source: Data base - Kalpitiya DS Office)**

The percentage of houses that used *kadjan/palmyrah* or straw was 28%. The temporary houses of migrant fishers constructed of temporary materials, especially, island residents due to difficulties to bring permanent construction materials, as no means of transportation facilities are available.

5.2.3. Sanitary facilities

About 75% of the households in the SAM area were equipped with toilet facilities within their house premises. Seven percent of households shared toilet facilities with close relatives. The households that do not have toilet facilities in the area were 11%. **(Source: Data base - Kalpitiya DS Office)**

5.3. Community perceptions on BRMS and associated ecosystems

5.3.1. Resource use pattern

The perceptions of the resource users regarding the establishment of BRMS were examined using Likert scale on the acceptance of presented statements. **Table 6** shows their responses to given statements.

Table 6. Resource user perceptions on BRMS and associated ecosystems

Statement	Acceptance level (%)				
	Fully agreed	Rather agreed	Fully disagreed	Rather disagreed	Don't know
BRMS helps to protect biodiversity	84.6	7.7	0	0	7.7
BRMS enhances fish abundance inside the area	9 2.3	0	0	3.8	3.8
BRMS enhances fish abundance outside the area	88.5	3.8	0	3.8	3.8
BRMS helps to attract tourists	84.6	7.7	3.8	0	3.8
BRMS benefits fishing/ornamental fishing	69. 2	11.5	3.8	0	15.4
BRMS benefits tourism	84.6	7.7	0	0	7.7
BRMS benefits scuba diving	61.5	15.4	3.8	3.8	11.5
Zoning system of BRMS helps to reduce conflict among resource users	15.4	11.5	42.3	23.1	7.6
BRMS helps to reduce illegal fishing	57.7	26.9	3.8	0	11.5
BRMS good for the local economy	65.4	19. 2	3.8	0	11.5

Source: Socio-economic survey SED NARA - 2013/2014

Generally, the awareness of the usefulness of BRMS and its associated ecosystems on their livelihoods remained at a high level. The economic value of BRMS and its associated ecosystems was well understood by all the resource users. The conflicts among the users of BRMS and its associated ecosystems prevailed due to competing interest of each other. Especially fishers and scuba divers for ornamental fish had some conflicts with each other because of spear fishing practiced by some scuba divers. According to them introduction of zoning system for resource users may intensify the conflicts. Therefore, 65% of them were opposed to the zoning of BRMS for resource users. However, majority of them believed that establishment of BRMS helped to reduce illegal fishing in and around the BRMS in general.

5.3.2. Reasons for choice and impacts

About 73% of users choose BRMS and associated ecosystems and its resources for their livelihoods due to abundance of fish or particular species. Nearly 4% of users chose BRMS and its associated ecosystems as it is located in close proximity of their settlements. About 23% of users said that due to other reasons such as tourism activities related to BRMS and its associated ecosystems they have chosen BRMS for their livelihoods.

Table 7. Reasons for choosing BRMS for the economic activity

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Abundance of fish	54	65.4	65.4	65.4
	Presence of particular species	6	7.7	7.7	73.1
	Proximity of fishing area	3	3.8	3.8	76.9
	Other reasons	15	23.1	23.1	100.0
	Total	78	100.0	100.0	

Source: Socio-economic survey SED, NARA - 2013/2014

It was asked to rank the impacts of BRMS for the livelihoods of resource users including fishers, scuba divers for ornamental fish and boat tour operators.

Table 8. Perceived impacts of BRMS for the livelihood of resource users

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Very positive	69	88.5	88.5	88.5
	Rather positive	9	11.5	11.5	100.0
	Total	78	100.0	100.0	

Source: Socio-economic survey SED, NARA – 2013/2014

All the resource users accepted that BRMS and its associate ecosystems have positive impact on their livelihoods. Of these, 88.5% and 11.5% said that these impacts were very positive and rather positive, respectively.

5.4. Economic activities related to BRMS and associated ecosystems

The sea based economic activities in the SAM area have rapidly expanded after 2009 as a direct result of lifting security limitations and infrastructure development took place in the area. The fishing and allied activities were permitted to be carried out without any objections from the security forces. As a result of this the number of active fishers in the Puttalam District has increased by more than 1 000 in 2012 compared to 2008. The ornamental fish, *beche-de-mer* and chank fisheries were some of the very important economic activities occurred in and around the BRMS. In addition, a number of tourism related economic activities are common in the area. A considerable number of tourist establishments emerged during last few years by providing ecotourism products especially for foreign tourists. Moreover, local community including fishers engaged in operating whale watching tours, coral watching tours and guided scuba diving in the BRMS. Anyhow lack of monitoring, management or enforcement of laws and regulations had led to those activities to happen in such magnitude in the sanctuary. The economic activities occur in and around the Bar Reef ecosystem can be broadly categorized into two as extractive and non-extractive ecosystem services uses.

5.4.1. Ornamental fish collection

The marine ornamental fish collection in the BRMS and associated ecosystems is mainly carried out by scuba divers from Kudawa and Kandakuliya areas. In addition to that some scuba divers from Trincomalee come to Kalpitiya in the peak season for marine ornamental fish collection. The peak season for ornamental fish collection is normally from October to May while the lean season is from August to September of the year, but collection continues all around the year. There are 16 resident scuba divers working in marine ornamental fish collection.

Operational aspects

The number of trips by scuba divers for marine ornamental fish collection in the season is on an average in the range of 18-22 days per month depending on weather and sea conditions. This declines from June to September, off season, to a range of 10-15 days per month. According to them they do not dive inside the core area of the BRMS. When they dive outside the BRMS one dive normally takes about 35 minutes and each diver performs on average five dives a day. Generally, one diver spends approximately 2.5-3 hours per day underwater for marine ornamental fish collection. The average depth of a dive is about 20 m.

Table 9. Marine ornamental fish varieties collected from BRMS and associated ecosystems

	Scientific name	English name	Local name
1	*Ecsenius* sp.	Mimic blenny	NA
2	*Amphiprion* sp.	Anemone fish	Muhudu mal Kichcha
3	*Acanthurus leucosternon*	Powder blue surgeon fish	Nil Orawa
4	*Rhinopias aphanes*	Scropion fish	Gal Maha
5	*Gymnothorax favagineus*	Honeycomb moray	Zebra Galgulla
6	*Cephalopholis miniata*	Coral hind	Rathu kossa
7	*Chaetodon meyeri*	Meyer's butterfly fish	Panawa
8	*Hipolis mata*	Red shrimp	NA
9	*Valenciennea* sp.	Goby	NA

Source: Socio-economic survey SED/NARA - 2013/2014

Capital investment and annual maintenance cost

The capital investment of scuba diving for marine ornamental fish collection comprised of the value of the motorized boat, oxygen cylinders, compressors and scuba diving gear. A unit of scuba diving team includes an OFRP boat, two scuba divers and one boat operator. Annual maintenance cost comprised of repair costs of boat engine, gas cylinders and compressors. Sometimes one collector employs 4 OFRP boats and 8 scuba divers and 4 boat operators per trip at a time.

Table 10. Capital investment and annual maintenance cost of marine ornamental fish collection

Fixed cost item	Amount (LKR)	Annual cost item (LKR)	Amount (LKR)
OFRP boat	160 000	Engine maintenance	65 000
Engine (25 hp)	325 000	Compressor repair	10 000
Compressor	650 000	Cylinder maintenance	10 000
Oxygen cylinders (10 cylinders)	255 000		
Total	1 390 000		85 000

Source: Socio-economic survey SED/NARA - 2013/2014

The highest capital investment is incurred for the engine while the lowest for the OFRP boat; likewise the highest annual maintenance cost goes to engine maintenance while the lowest to oxygen cylinder maintenance (**Table 10**).

Operational cost

The total operational cost per boat trip is derived from mainly boat hire if the operator hires a boat, fuel cost, expenses for food and boat operator wages. These costs are generally provided by the assembler/collecting agent on the basis of deduction of expenses from the total value of ornamental fish collected. At least this amount should be covered by two divers to achieve the break-even point of their operation. The average fuel requirement per trip varies at 40-90 L depending on the distance and location.

Table 11. Operational cost per trip of ornamental fish collection

Cost item	Amount (LKR)
OFRP boat hire	3 500
Boat operator fee	1 500
Fuel	4 000
Food	1 500
Boat launching and dragging	500
Total	11 000

Source: Socio-economic survey SED/NARA - 2013/2014

Among operational costs a larger proportion is incurred for fuel followed by the payments for boat hiring. Expenses for foods and wages for the boat operator are also a considerable amount in the operational cost of ornamental fish collection (**Table 11**).

Revenue and profit

The gross earnings of a trip were about 16 250 LKR. After deduction of operational cost, the net earnings per trip of a diver were 2 625 LKR. The average net income of a diver per year was 577 500 LKR and that for the assembler/collecting agent was 1 155 000 LKR. The collecting agent's income comes from 20% commission on total sales value. The total value of ornamental fish collected from BRMS and the associate ecosystems was 50 050 000 LKR per year. A 30% of total ornamental fish collected directly comes from the BRMS. Therefore, in terms of value the contribution to the total from the BRMS per year was 15 015 000 LKR per year (**Table 12**).

Table 12. Revenue of marine ornamental fish collection

Item	Revenue/trip (LKR)	Revenue/year (LKR)
Diver	2 625	577 500
Operational cost	11 000	222 000
Total earnings	16 250	3 575 000
Net operational income	5 250	1 155 000
Collecting agent's commission (20%)/diver	1 050	231 000
Total value of ornamental fish collected (16250 x8x11x20+16250x11x6x20)	308 750	50 050 000

Source: Socio-economic survey SED/NARA - 2013/2014

Social Benefits

There were about 51 families directly engaged in ornamental fish collection industry in the Kandakuliya/Kudawa area. The total dependence from this economic activity was 250 persons. In addition to this number a large number of persons are benefited along the supply chain (**Table 13**).

Table 13. Social benefits of ornamental fish collection

Beneficiary	Direct	Indirect
Collecting agent	2	12
Divers	38	152
Boat operators	19	78
Total	59	242

Source: Socio-economic survey SED/NARA-2013/2014

5.4.2. Chanks and *beche-de-mer* collection

The scuba diving for chanks and *beche-de-mer* collection in BRMS and associated ecosystems is mainly carried out by scuba divers from Kudawa, Kandakuliya and Kalpitiya areas. In addition to that some scuba divers from Trincomalee come for chanks and *beche-de-mer* collection. The reason for this migration is the nature of seasonality of theses fisheries. The peak season for chanks collection is October to March while for *beche-de-mer* from January to April. The average number of days per month of the activity undertaken is about 15 days and total number of days operating during the

season is in between 100-120. The total numbers of boats operating in these fisheries is about 100 and the total divers employed are 200.

Out of total collection about 70% of chanks and *beche-de-mer* comes from outside the BRMS. The chanks collector should obtain an operational permit from the Department of Fisheries and Aquatic Resources (DFAR) by paying a fee. The permit holder for collection of chanks can only transport chanks. There are 3 registered exporters in the Kalpitiya area who collect chanks from divers and sub collectors. According to the registered exporters, the chank and *beche-de-mer* collection has declined by 50% at present compared to the previous years. The chanks are exported to India and Bangladesh for producing of ornaments while *beche-de-mer* is exported to Singapore, Hong Kong/China, Malaysia and Taiwan as high value seafood. The shell has considerable significance in Hinduism and Buddhism.

Figure 29. Oxygen cylinders used for scuba diving

Figure 30. Chank catch

Operational aspects

The chanks and *beche-de-mer* operating unit comprised of an OFRP boat, a boat operator and 2 divers. A diver uses 5 oxygen cylinders per trip and generally one diver does 5 dives per day. The duration of a dive depends on the diving depth. Generally 0-5 minutes at the depth of 70 feet and at the depth in between 40-70 feet diving time is about 40 minutes. Diving for chanks specially is done in day time and for *beche-de-mer* both during day and night time.

Operational cost

The operational cost of these fisheries consists mainly of fuel cost, cost for oxygen, food and operator wages. There are two types of employing divers for chanks and *beche-de-mer* collection in general and according to that operational cost varies and decides who bares the total cost or a proportion of it. In the first system divers have to share the total operational costs of the trip by themselves. In this system, after the deduction of total operational cost from the total revenue of the trip one third of the divisible income goes to the boat owner/collector and the rest goes to divers equally. This system is mostly practiced in Kandakuliya. The second system means all operational costs are borne by the chanks/*beche-de-mer* collector. Divers are paid according to the catch of individual diver and this system is mostly practiced in Kalpitiya and Puttalam. According to this system the given price to divers is decided by the collector according to the prevailing market price.

Table 14. Operational cost of chanks and *beche-de-mer* collection

Cost item	Amount (LKR)
Fuel	5 000
Boat operator	2 500
Charge for 10 oxygen cylinders	2 500
Food	2 000
Total	12 000

Source: Socio-economic survey, SED/NARA - 2013/2014

The total operational cost of a trip of chanks and *beche-de-mer* collection is 12 000 LKR and a large proportion goes for fuel which is used by the boat for sailing (**Table 14**).

Price and revenue

The revenue per day per diver and collector depends on the total collection and the unit price. Generally, a diver income for a day is in the range of 5 000-15 000 LKR. The average monthly income of a scuba diver was in the range of 75 000 to 100 000 LKR. The price of a chank depends on the individual grading. There are five grades in practice for chanks depending on the physical size. **Table 15** shows the prevailing prices according to the grade during the time of field study carried out in 2013-2014.

Table 15. Grading and producer price of chanks

Grading as per diameter of the chanks	Price/piece (LKR)	
	2013	2014
1 (100 mm)	1 800	1 000
2 (95 mm)	1 500	800
3 (90 mm)	800	400
4 (80 mm)	800	400
5 (>70 mm)	350	50

Source: Socio-economic survey SED/NARA – 2013/14

It is obvious that according to the physical size of chanks the price varies and means a higher price for larger sizes. There was a sharp decline in prices of chanks in 2014 compared to 2013.The main reason for this was less demand from India as the main importer (**Table 15).**

Table 16. The unit price of fresh *beche-de-mer* according to the variety

Variety	Price/piece (LKR)
Gal attaya	450-500
Puna attaya	450-500
Nool attaya	200-250

Source: Socio-economic survey SED/NARA - 2013/14

5.4.3. Fisheries

Fishing is the most intensive and dominant economic activity in the BRMS and surrounding ecosystems. The OFRP out board motor boats are those mainly used for inshore and coastal fisheries while fibre log rafts (Tepppan) are used in lagoon fisheries. The net fishing gears outnumber the line fishing gears. **Table 17** shows different types of fishing gears and methods practiced in the area.

Table 17. Fishing gear used in the SAM area

Type of fishing gear.	Fishing gear	Target variety	
		Sinhalese name	English name
Drift net	Habarali del	Habaraliya, jeelawa	Gar fish, Barracuda
	Piyamessa del	Piyamessa	Flying fish
	Hurulla del	Hurulla	Trenched sardinella
	Salaya/sudaya del	Salaya and sudaya	White sardinella/sardinella
	Seraya del	Seraya	Grey mullet
	Kumbala del	Kumbala	Indian mackerel
	Pokirissa del	Pokirissa	Lobster
	Polo del	Galmalu	Rock fish
	Kakulu del	Kakuluwa	Crabs
	Madu del	Maduwa	Skates and rays
Seine net	Laila del	Galmalu, para	Rock fish
	Surukku del	Murali, jeela	Half beaks, Barracudas
Lines	Long lines	Kenda/Kelwalla	Big eye tuna, Yellowfin tuna
	Troll lines	Kelwalla/Atawalla	Yellowfin tuna, kawakawa
	Hand lines	Thora, Parava, Galmalu	Seer fish, Jacks, Trevallies, Rock fish
	Bottom long lines	Galmalu	Rock fish

Source: Socio-economic survey SED/NARA - 2013/2014

Operational aspects

Fisheries in the area are seasonal. The fishers by experience use a set of fishing gears during the fishing season. According the availability and catching potential of fish varieties, fishers change their fishing gears sometimes daily, weekly or monthly. The depth of fishing, consumption of fuel, requirement of bait, duration of fishing operation and trip as well as varieties caught vary according to the fishing gear used. Hence there is a significant variability of catch, operational cost and revenue generated from the fishing operation.

Capital investment

The capital investment of a fishing unit includes boat, engine and fishing gear cost. The average investment on boat and gear was 612 952 LKR. The investment on fishing gears depends on the type of fishing gear and quantity of net pieces and line gears purchased. The table depicts the average cost of fishing gears per fishing unit. A fishing unit may possess one or several types of fishing gears. Out of them ("Laila" net) incurs the highest cost which is about 600 000 LKR. Compared to netting gears, line gears incur lower cost.

Table 18. Capital investment of a fishing unit (LKR)

Capital item	Minimum	Maximum	Mean
Boat	35 000	800 000	153 823
Engine	50 000	400 000	307 058
Fishing gear	32 000	600 000	152 070
Total capital investment	85 000	1 140 000	612 952

Source: Socio-economic survey SED/NARA-2013/2014

Due to the wear and tear, fishing implements need to be replaced or repaired for the smooth running of the fishing operation. The annual maintenance cost of a fishing unit was about 93 235 LKR.

Table 19. Annual maintenance cost of a fishing unit (LKR)

Annual cost	Minimum	Maximum	Mean
Maintenance cost (LKR)	40 000	160 000	93 235

Source: Socio-economic survey SED/NARA - 2013/2014

Table 20 shows gear wise investment on different fishing gears. The cost of Laila net was the highest while the lowest cost is incurred by Piyamessa net which was 32 000 LKR. The life time of fishing gears depends on targeted varieties, mesh sizes and ply. The operational cost of fishing also varies according to fishing gear, distance to fishing ground and the seasonality. The major component of operational cost is fuel cost. That was in the range of 80%-100%.

Table 20. Average cost of fishing gears per fishing unit

Fishing gear	Amount (LKR)
Habarali net (Barracuda net)	220 000
Piyamessa net (Flying fish net)	32 000
Hurulla net (Trenched sardinella net)	156 666
Seraya net (Grey mullet net)	160 000
Kumbala net (Indian mackerel net)	140 600
Pokirissa net (Lobster net)	77 500
Madua net (Skate net)	175 000
Kakulu net (Crab net)	50 000
Laila net (Surrounding/ring net for mullets)	600 000
Maruwel pannaya (Long line)	42 000
Pudu/duwana pannaya (Troll line)	19 000

Source: Socio-economic survey SED/NARA-2013/2014

Figure 31. Fishermen sorting catch-Kandakuliya

Figure 32. Troll line catch

Cost and revenue

The gear wise cost and revenue of fishing operation per trip shows wide variability (**Table 21**). The troll lines, Laila net and long lines have comparatively higher revenue compared to other gears. The lowest revenue was from pokirissa net (lobster net). The higher fuel cost is incurred by the Laila net, long lines and troll lines.

Table 21. Average net revenue and share from fishing

Item	Amount (LKR)
Operational cost per trip	6 516
Revenue per trip	9 954
Divisible income per trip	3 438
Revenue per year	2 388 930
Divisible income per year	825 120
Owner's share per year	412 560
Crew's share per year	206 280

Source: Socio-economic survey SED/NARA-2013/2014

The average operational cost per fishing trip was 6 516 LKR. The divisible income of fishing operation is arrived after deduction of operational cost from the revenue. The divisible income per trip was 3 438 LKR. The yearly revenue and divisible income of a fishing unit was 2 388 930 and 825 120 LKR, respectively. Fifty percent of the divisible income goes to the boat owner and the remaining 50% is shared between two crew members. Accordingly, the annual share of a boat owner and a crew was 412 560 and 206 280 LKR, respectively.

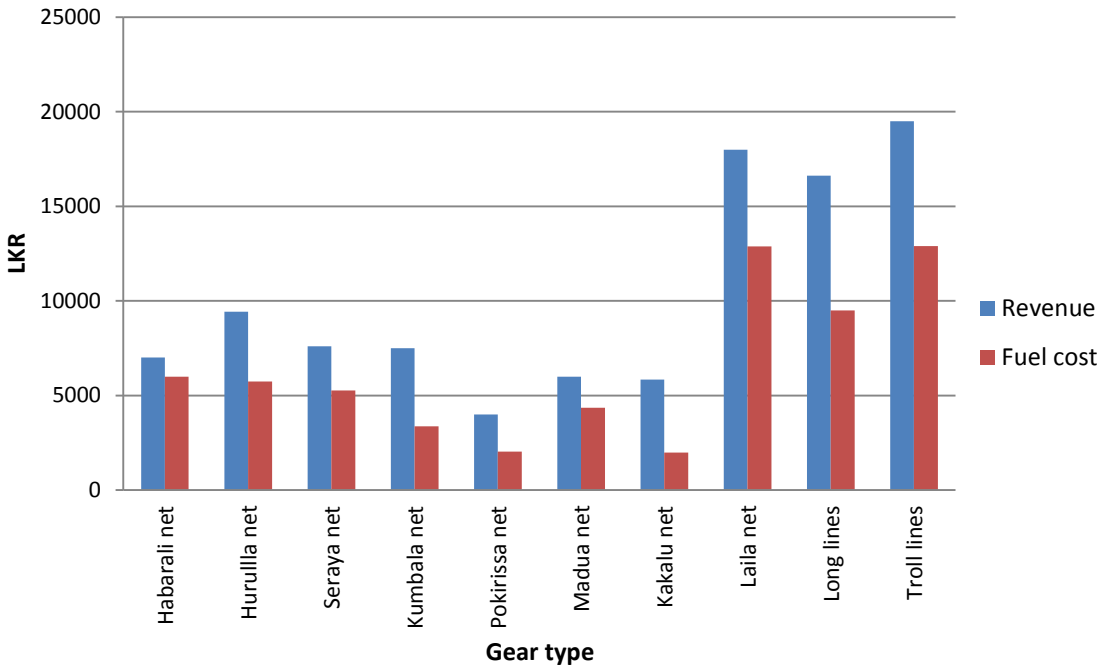

Figure 33. Gear wise comparison of revenue and cost per fishing trip

Source: Socio-economic survey SED/NARA-2013/2014

5.4.4. Recreational activities

The main recreational activity taking place in and around the BRMS was guided boat tours for locals and foreigners. These boat tours start from Kudawa, Kandakuliya and Kalpitiya areas. The boat tour operators have a society and without being a member nobody can enter into this activity. In addition all boat tour operators should be registered with the Department of Wild Life Conservation (DWLC) by paying an annual registration fee of 5 000 LKR. There are 122 registered boat tour operators at present. There were 8 494 local and 2 443 foreign visitors who visited BRMS in 2013 for recreational purposes. Of these 22% were foreign visitors. In 2013, 1 679 and 489 boat tours have operated for local and foreign visitors respectively. The total earnings from boat tours was 20 263 166 LKR and of them 14 156 666 from local visitors and 6 107 500 LKR from foreign visitors in year 2013. In addition, the DWLC has earned 2 572 480 LKR from entry permits in the same year. The amount charged from a local and foreign visitor per trip was 20 LKR and US$ 9, respectively.

Operational aspects

The boat tour operators provide two types of services such as whale watching and coral watching. The season for boat tours is from October to May of the year when the sea condition is calm. An outboard motor powered OFRP boat is used for these activities and seating facilities are available inside the boat for up to six persons. Generally, for local visitors and foreign visitors six and four persons are allowed to be accommodated on board at a time respectively. It is compulsory to wear safety jackets on board. Generally a boat tour around BRMS takes 2-3 hours while for a whale watching tour that is about 4-5 hours. **Table 22** shows operational aspects of boat tour operations.

Table 22. Operational aspects of boat tours

Tour activity	Number of tourist/boat		Tour duration
	Local	Foreign	
Dolphin/whale watching	6	4	4-5 hours
BRMS	6	4	2-3 hours

Source: Socio-economic survey SED/NARA-2013/14

Capital investment

The average total capital investment of a tour operating unit was 577 234 LKR. The capital investment included OFRP boat with an engine, fixtures and apparatus. Standard boats are having seating facilities for six persons and diving apparatus such as life jackets, fins and snorkels. **Table 23** shows the breakdown of capital investment of a tour operating unit in LKR.

Table 23. Capital investment of a tour operating unit (LKR)

Capital item	Minimum	Maximum	Mean
Boat	35 000	165 000	111 470
Engine	50 000	400 000	307 058
Fixtures (hut and seating)	100 000	140 000	110 000
Apparatus (life jackets, fins and snorkels)	38 000	57 000	48 705
Total capital investment	223 000	762 000	577 234

The annual cost of a tour operating unit mainly comprises of maintenance cost, license and insurance fee. The maintenance cost of the boat and the engine was annually incurred about 93 235 LKR. On the other hand license fee is 5 000 LKR per year. Apart from that visitor insurance premium per year is 5 000 LKR. On an average the annual cost of operating a unit was 103 535 LKR. **Table 24** shows composition of annual cost of a unit.

Table 24. Annual cost of a tour operating unit (LKR)

Cost item	Minimum	Maximum	Mean
Maintenance cost	40 000	160 000	93 235
License fee	5 000	5 000	5 000
Insurance	5 000	5 000	5 000
Local government fee (Pradeshiya Sabha)	300	300	300
Total annual cost	50 300	170 300	103 535

Source: Socio-economic survey SED/NARA-2013/14

Operational cost

The operational cost of a boat tour mainly includes fuel cost and boat operators' fee. Of them fuel cost is the major item and that is in the range of 3 700 to 4 800 LKR. Some boats employ a helper in addition to the boat operator and incur an additional cost. The total cost of a boat tour varies in the range of 5 200 to 7 800 LKR. The average gross profit is in between 2 800 to 2 200 LKR per boat trip. The operational income of a boat tour is in the range of 8 000 to 10 000 LKR. **Table 25** shows composition of operational cost and revenue of a boat tour.

Table 25. Operational cost and revenue per trip (LKR)

Cost item	Minimum	Maximum
Fuel	3 700	4 800
Boat operator and helper	1 500	3 000
Total cost	5 200	7 800
Revenue	8 000	10 000
Gross profit	2 800	2 200

Source: Socio-economic survey SED/NARA-2013/14

Estimated revenue of a tour operator

On the assumption that the maximum number of trips taking place per season per tour operator is 32 and the maximum revenue per trip is 10 000 LKR, the net profit of a tour operator is calculated, without leaving an allocation for depreciation of fixed cost, the net profit per season was 60 100 LKR per operating unit. **Table 26** shows the annual net income of a tour operator.

Table 26. Annual net return per boat tour operator

Item	Amount
Maximum number of trips per season	32
Maximum revenue per season (LKR)	320 000
Total operating cost per season (LKR)	249 600
Gross profit per season (LKR)	70 400
Annual cost per tour operator (LKR)	10 300
Net profit per season (LKR)	60 100

Source: Socio-economic survey SED/NARA-2013/14

Estimated economic benefits

There are 122 registered boat operators in the SAM area according to the official data. However, according to the results of the questionnaire survey, there were only 63 active boat tour operators in operation. The total revenue earned by operators per season was 2 026 240 LKR. During this period the Department of Wild Life Conservation generated 2 404 915 LKR from sales of entry tickets. Therefore, the total value of recreational boat tours in 2012/2013 season was 22 667 155 LKR. **Table 27** shows the estimated total economic value of recreational boat tours.

Table 27. Estimated total economic value of recreational boat tours (LKR)

Item	Value
Number of active boat tour operators	63
Number of boat tours per operator per season	32
Total number of boat tours per season	2 026
Revenue generated per boat tour (LKR)	10 000
Total revenue generated per year by boat tour operators (LKR)	2 026 240
Total income generated by the Department of Wild Life Conservation (LKR)	2 404 915
Total economic value of recreational boat tours per year (LKR)	22 667 155

Source: Socio-economic survey SED/NARA-2013/14

5.4.5. Visitor pressure

Measuring visitor impacts on marine protected areas and associated ecosystems is important for improving management and assuring the sustainable utilization and management of its resources. Visitor impacts on the Bar Reef ecosystem may adversely affect the integrity of the physical as well as biological environment. Therefore, measuring of visitor pressure and its effects will guide the policy makers and managers to take appropriate measures and activities in advance to mitigate adverse impacts to the ecosystem. The visitor pressure mainly generated on the BRMS by tour boats and persons visited is given in **Table 28**.

Table 28. Visitor pressure on Bar Reef Marine Sanctuary

Indicator	Value
Boat hours spent in the BRMS/year	3 039
Persons visiting per year	12 157
Annual visitor density/km^2 (Core zone)	174

Source: Socio-economic survey SED/NARA-2013/14

In addition to the impacts generated by boat tours, it is essential to measure impacts of fishing trips in terms of biological degradation in quantifiable manner. This area is not considered in this study and it is suggested for further research.

5.5. Management aspects and Issues

Special Area Management (SAM) for the BRMS commenced in 2002 with the establishment of a Community Coordinating Committee (CCC) with the Divisional Secretary of Kalpitiya as the Chairman (CCD, 2007). The objectives of the CCC have never been met due to a number of constraints encountered. As identified by the Coastal environment profile of the BRMS published by CCD in 2007, low level of education, poor low enforcement, poverty of the fishermen and failure in

changing attitudes were among the main constraints. However, according to this survey, the socio-economic status and attitudes of the surrounding community have been changed towards positive direction. Despite these improvements, poor law enforcement is one of the major constraints impeding the sustainable management of BRMS and associated ecosystems. All stakeholders are concerned about existing management practices related to BRMS ecosystem and its resources as well as related issues and their impacts on BRMS and associated ecosystem. Among them, following are major issues of concern to them.

I. Operating harmful fishing gears
   The operation of bottom set nets and Laila nets targeting reef fishes is said to be among the most harmful fishing activities associated with BRMS. According to the community some ill practices such as dynamiting used by Laila fishers have deadly effects on the live coral community as well as reef fish and other aquatic animals. The bottom set netting also break corals by entangling and leads to ghost fishing.
II. Spear fishing at BRMS
   The spear fishing within the BRMS has been increasing in recent times due to high demand for some varieties of fish in the export market. Therefore, unrestricted spear fishing has led to depletion of some high value reef fishes.
III. Night diving for *beche-de-mer*
   Night diving for *beche-de-mer* occurs in the BRMS. According to some divers' experiences, movements of *beche-de-mer* occur at night time and therefore, catching of them at night is easier than during the day time. This may lead to depletion of the resource within a short time period.
IV. Non-demarcation of boundaries of the Core area of the BRMS
   The Core area of the BRMS is the area of higher densities of the coral habitat which is highly sensitive and providing extensive ecosystem services. As there is not any type of demarcation, all types of resource users can use BRMS for getting ecosystem services without any limitation and permission. This may affect the sustainability of the coral community. Demarcation of areas will be a limitation measure for resource users to confine extensive use of sensitive habitats.
V. Seasonal migration of scuba divers from other areas
   In addition to divers in Kalpitiya, Kandakuliya and surrounding areas, divers from other parts of the country such as Eastern and Southern provinces migrate to Kalpitiya area for ornamental fish, *beche-de-mer* and chanks collection within and around the BRMS. This may lead to over exploitation of resources exceeding the carrying capacity of the ecosystem. Hence it is vital to limit issuing permits for scuba divers.
VI. Unregulated tourism
   At present the Bar Reef and associated ecosystems are increasingly becoming a hotspot of tourism due to tourist promotional activities by governmental and private entities. The local and foreign tourists visiting for coral watching, snorkelling and scuba diving have remarkably increased during the recent past especially from 2009. Among these tourists some inexperienced tourists are stepping and walking on the corals which cause destruction to the corals. Moreover, irresponsible or ignorant visitors dump plastics and polythene remains with them that harm corals due to wrapping and pasting as well as pollution of the environment in and around areas of the BRMS.

5.6. Markets and supply chains

There are a large number of fish assemblers/collectors in the Kalpitiya peninsula. The main centres of fish and fishery products exchange are Kalpitiya, Kandakuliya, Wannimundalama, Thiladiya, Kudawa, and Thalawila. There are a large number of fish assemblers in those places who purchase fish and fishery products such as dried and salted fish. In addition to that a few number of collection centres operate as branches of some fish exporters. The fish assemblers are linked with regional fish suppliers in Colombo, Anuradhapura, Kandy, Kurunegala and Kuliyapitiya. In addition a large number of retail traders daily travel to purchase their supplies from fishermen directly in the area.

Figure 34. Dried fish making-Baththalangunduwa Island

The dried and salted fish making is also a significant post-harvest activity taking places in the Kalpitiya Peninsula. Specially, the island based fishers such as those in Palliyawatta and Battalangunduwa produce dried and salted fish in large quantities due to difficulties faced by them in disposing their catch in fresh form.

The markets linkages prevailed in are product specific and the key players are as follows.

I. Fish assemblers linked with local/regional suppliers
II. Fish assemblers linked with local/regional and export agents
III. Dried fish whole sellers/local regional suppliers
IV. Ornamental fish collectors/assemblers linked with exporter/export agents
V. *Beche-de-mer*/chank collectors linked with exporter/export agents

Table 29. Market linkages and reef related fish and fishery products exchange

Reef related product	Local/regional market	Export market	Export destination
Mullets, breams, snappers etc.(*Galmalu*)	Yes	Yes	Singapore
Groupers (*Kossa*)	Yes	Yes	Singapore
Pompanos (*Vauvalaya*)	Yes	Yes	Singapore
Ribbon fish (*Savalaya*)	Yes	Yes	China
Parrot fish (Girava)	No	Yes	Singapore
Chank shell (*Hakbella*)	No	Yes	India, Bangladesh
Chank meat/operculum	No	Yes	Hong Kong, China
Beche-de-mer (*Attaya*)	No	Yes	Hong Kong, China, Singapore, Malaysia, Taiwan
Marine ornamental fish	No	Yes	EU, USA, Singapore,
Lobster (*Pokirissa*)	No	Yes	EU, USA

Source: Socio-economic survey SED/NARA-2013/14

Most of the reef related fish and fishery products are high value products due to available demand in export markets. Therefore, it can be assumed that the market driven demand for reef related fish and fishery products has contributed to increase the extraction rate of them by fishers and divers. Hence, it is essential to monitor continuously their activities for adoption and imposing of suitable measures for the sustainable management of the Bar Reef sanctuary.

Figure 35. Chank meat with operculum

Figure 36. Parrot fish

6. MPA effectiveness evaluation

Nineteen indicators are used for evaluation. While eight are biophysical indicators that largely measure the changes of focal species, status of capture fisheries and coastal habitats; five are socio-economics indicators that largely assess the economic status and the perceptions of the coastal communities, and there are six governance indicators that measure the various aspects of MPA management.

Regardless of their many social objectives and benefits, MPA are ultimately a tool for conserving biophysical conditions of our oceans and coasts for achieving the social benefits. As such using indicators to measure these conditions are the primary concern when evaluating the MPA. Most of the time there is a link between the biological state of the marine environment and the livelihoods, income and food security of the people who use and depend upon the resource, and this is explicit and intimate.

The evaluation rating for the biophysical indicators was largely negative (<75%; **Table 30**).The main concern was the coral species diversity and abundance. There was a decline in species diversity since few years. The stakeholder rating about the decrease in biophysical status (67%) as came up in the final work shop did not match up with the scientific findings (BOBLME, 2015)

Table 30. Evaluation for biophysical indicators selected in the study

Indicator	Changes
1. Focal species abundance	-
2. Habitat distribution and complexity (seagrasses, mangroves and seaweeds)	-
3. Population densities of other economically important species	-
4. Marine ornamental fish associated to the coral reef	o
5. Associated fisheries status	-
6. Use of illegal fishing gears	-
7. Food web integrity (benthic fauna and zooplankton)	o
8. Water quality	-

Note: "+": Positive change (towards MPA objective), "o": No change, "-": Negative change (in a direction away from MPA objective)

Table 31. Evaluation of socio-economic indicators selected in the study

Indicator	Average rating
1. Population density, Household income distribution by source	o
2. Local marine resource use patterns (three indicators)	-
3. Level of understanding of human impacts	+
4. Community perceptions on BRMS and associated ecosystems (ten indicators)	+
5. Visitor pressure	-

Note: "+": Positive change (towards MPA objective), "o": No change, "-": Negative change (in a direction away from MPA objective)

Evaluation ratings for the four socio-economic indicators are nearly 69% positive or towards MPA objective. The stakeholder perception about the socio-economic indicator improvement as expressed in the final workshop corroborates the research findings (BOBLME, 2015). Local marine resource use patterns indicate that the majority of coastal households are engaged in fishing as their primary occupation. Although they utilize the coral reefs the most, they also partly depend on mangrove and seagrass beds.

Table 32. Evaluation of governance indicators selected in the study (as observed)

Indicator	Changes
1. Level of resource conflict	-
2. Existence of a decision-making and management body	-
3. Existence and adoption of a management plan	-
4. Local understanding of MPA rules and regulations	-
5. Existence and adequacy of enabling legislation	-
6. Availability and allocation of MPA administration resources	-
7. Degree of interaction between managers and stakeholders	?
8. Clearly defined enforcement procedures	-
9. Degree of information dissemination to encourage stakeholders compliance	?

Note: "+": Positive change (towards MPA objective), "o": No change, "-": Negative change (in a direction away from MPA objective) and "?": No results could be determined (trend was uncertain or no data available)

Evaluating rating for nine governance indicators considered are largely negative although the indicator of degree of information dissemination to encourage stakeholders compliance is considered as positive. Only two indicators were rated as indeterminate. Anyway under the project

activities towards supporting awareness and stakeholder compliance were made as far as possible. But the governance of MPA should be better developed and improved.

7. Education and awareness

The education programme was carried out aiming at young children of the schools around Kalpitiya, while awareness workshops were conducted targeting fishers. Main objectives of the programme were education, awareness and assessment in support of Bar Reef Marine Sanctuary management for the protection of coral reefs and their associated biota and to safe guard still abundant fish resources. Accordingly awareness programmes was carried out to make the fishing community aware of the importance of conserving marine resources, the marine protected area and associated habitats for the sustainability of the fisheries. Further to that the younger generation of the targeted area was made aware of the importance of conservation of the habitats while highlighting the consequences of destruction. In concluding, the fishermen highly appreciated the awareness education programmes and requested for more awareness programmes for the entire fisher folk community. Suggestions were made towards better management of the MPA (Annex 4).

8. Concluding workshop

The final workshop on education, capacity development and monitoring in support of Bar Reef Marine Sanctuary (BRMS) management was held on 23rd May 2015 at Ecological Centre, Kandakuliya, Kalpitiya. The objectives of the workshop were to present the final output of the research adopted in support of the evaluation of BRMS to the stakeholders; to get their perception on evaluation of BRMS and to get their suggestions and opinions on the proposed recommendations. Final discussion was aimed to have perceptions of the stakeholders on the evaluation and the validation of the research findings at the BRMS. According to stakeholder perception approximately 55% of the biophysical indicators selected are in a direction away from MPA objective while 27% of the indicators remain without change and 18% of indicators are in an uncertain trend. Stakeholder perception on socio-economic indicators revealed that approximately 69% of the indicators are towards the MPA objectives and only 19% of the indicators are moving away from the MPA objectives. Approximately 13% of the indicators remained as unchanged. In addition, stakeholder perception revealed that the governance indicators considered in the study are 100% away from the MPA objectives. Workshop was concluded with final conclusions and recommendations which will be important in management of the MPA

9. Conclusion and recommendations

9.1. Conclusion

The basic research design was to assess performance of the MPA in terms of the current condition (2014) against past available baseline information. Based on the study the MPA evaluation report has been prepared which can be used for the adaptive management. Based on the evaluation with selected indicators, biophysical indicators are 75% and governance indicators are 100% negative or away from the MPA objective, while socio-economic indicators are 60% positive or towards the MPA objective. There is a need for more capacity development to provide essential training for the local people on the basics of MPA management effectiveness. The findings of the assessment and of the evaluation of effectiveness of MPA management has the potential to assist the managers, decision makers, donors and other interested parties to undertake adaptive management, thereby strengthening management actions, enhancing priority setting and ensuring accountability.

9.2. Recommendations

- Physical demarcation of the Core area to ensure that it is free from human activities other than non-harmful activities such as snorkelling, which will assure the health and sustainability of natural resources of BRMS. Specify zonation plan of Core and Buffer areas and denote the activities which can be either allowed or prohibited in each of the zones (according to the SAM plan) in BRMS Act of DWLC to enable sustainable utilization of the resources. This is a strong request made by the community who would seriously be affected in their livelihoods when the no take zone of 306 km^2 in the BRMS is declared as a single unit.
- Minimization of illegal and harmful fishing gears and apparatus usage in fishing, ornamental fish, chanks an*d beche-de-mer* collection within the BRMS. This will ensure sustainability of reef related resources and livelihoods of represented communities.
- Establishment of anchoring places for mooring tour boats (in addition to some anchoring points establish by IUCN). This will minimize damages for the coral community. Further, conduct awareness programs on eco-friendly tour procedures to minimize harmful impacts on BRMS.
- Involve and motivate the coastal communities to conserve coral reef fish as well as their habitats. As such it is very essential to conduct continuous awareness programs for different target groups to mitigate adverse effects of pollution, coral reef damage and over-harvesting of species from coastal and marine ecosystems.
- Introduction of code of conduct for responsible resource extraction from the BRMS for the sustainable utilization of resources. This will lead to increase the productivity of the BRMS as well as increase the awareness of all resource users of the importance of natural resources proper management such a way that will lead to betterment of their livelihoods.
- Strengthening the capacity of exiting management practices with getting participation of all stakeholders who use BRMS for their livelihoods. This will encourage the proper application and compliance of management measures for the sustainability of ecosystem services of BRMS.
- Establishment of continuous monitoring and surveillance mechanism related to resource use covering the whole area of the BRMS. This will discourage illegal resource use and enhance the sustainability of the BRMS.
- Multidisciplinary research and monitoring related to tourism, habitat protection, fisheries sustainability and socio-economic status is vital for the long-term goals of conservation and management of the MPA and its associated ecosystem Puttalam Lagoon.

- Generate community stewardship through recognizing the rights of local users for tourism, mariculture and fishing within the MPA.
- Establishment of a unit to collect data and information related to utilization of ecosystem services of BRMS by all stakeholders. This will facilitate special area management process providing up to date data and information and guiding policy makers for taking appropriate decisions.
- Introduction of a co-management plan for all natural resources utilization of BRMS. This will facilitate proper management of extractive as well as non extractive uses of BRMS resources.
- Develop streamlined coherent and consistent legal and institutional framework for a cohesive marine protected area.
- Strengthen enforcement through multi-agency collaboration and provision of appropriate penalties. The need was also felt for management to proceed simultaneously at the national, provincial, district and local levels with the collaboration of several state agencies, local entrepreneurs, NGOs and communities.
- Provide alternative employment opportunities to the community to reduce pressure on coral reefs and fishery resources
- Share a percentage of tourism revenue as a compensatory mechanism to fishing community when no take policy is fully enforced.

  Further evaluation of the MPA BRMS is suggested using MPA Management Effectiveness Assessment Tool (MEAT), Guide of the Coastal Conservation and Education Foundation, Inc. (CCEF, White *et al*. 2004) as modified by the Philippine environmental governance project and this could be used in modified form for Sri Lankan conditions with the Philippine expertise as agreed in the BOBLME MPA working group meeting in Penang, Malaysia, in 2014.

10. Output used for management decisions

The final evaluation results that the management effectiveness of MPA is not up to satisfactory level when considering the changes of biophysical factors and governance factors while it is positively impacted with the sociological changes. Conclusions and suggestions of the study will be submitted to the Department of Wild Life which is the main authorized body for managing of MPA and Ministry of Fisheries and Aquatic Resources. Formation of community surveillance groups and implementation of co-management has already been proposed.

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Appendix I Some important species found in the marine fishery in the Bar Reef and surrounding areas

Scientific name	Common name	Local name	Commercial importance [Low, moderate, high]	Abundance [Very rare, rare, average, common]
Family: Clupeidae				
Amblygaster sirm	Spotted sardinella	Hurulla	Moderate	Common
Amlygaster clupeoides	Bleeker's smoothbelly sardinella	Galhurulla	Moderate	Average
Nematalosa nasus	Bloch's gizzard shad	Koiya	Low	Common
Hilsa kelee	Kelee shad	Katukoiya	Low	Common
Sardinella gibbosa	Goldstripe sardinella	Matta salaya	Moderate	Average
Sardinella longiceps	Indian oil sardine	Pesalaya, yaksalaya	Low	Common
Sardinella albella	White sardinella	Sudaya	Low	Common
Family: Scombridae				
Rastrelliger kanagurta	Indian mackerel	Kumbalawa	Moderate	Average
Katsuwonus pelamis	Skipjack tuna	Baleya	Moderate	Common
Sarda orientalis	Striped bonito	Thora balaya	Moderate	
Auxis thazard	Frigate tuna	Alagoduwa	Moderate	Average
Auxis rochei	Bullet tuna	Baita	Moderate	Common
Euthynnus affinis	Kawakawa	Atawalla	Moderate	Average
Thunnus albacores	Yellow fin tuna	Kelawlla	High	Common
Thunnus obesus	Bigeye tuna	Asgedi kelawalla	High	
Acanthocybium solandri	Wahoo	Sawara, Hera maha	High	Average
Scomberomorus commerson	Narrow barred spanish mackerel	Ahin thora	High	Average
Scomberomorus lineolatus	Streaked seer fish	Anjilawa	Moderate	Common
Scomberomorus guttatus	Indo-Pacific king mackerel	Alu thora	Moderate	Average
Family: Carangidae				
Alectis ciliaris	African pompano	Kannadi parawa	Moderate	Average
Alectis indicus	Indian thread fish	Handhe panna	Moderate	Average
Alepes vari	Herring scad		Moderate	Average
Atule mate	Yellowtail scad	Ginnati paraw	Moderate	Common
Decapterus russelli	Indian scad	Linna	Moderate	Average
Selar crumenophthalmus	Bigeye scad	Asgedi bolla	Moderate	Common
Scomberoides commersonianus	Talang queen fish	Kattawa	Moderate	Common
Carangoides fulvoguttatus	Yellow spotted trevally	Thuba parawa	Moderate	Average
Carangoides gymnostethus	Bludger	Vattiya	Moderate	Average
Carangoides hedlandensis	Bumpnose trevally		Moderate	Average
Carangoides malbaricus	Malabar trevally	Labu parawa	Moderate	Average
Caranx heberi	Blacktip trevally	Guru parawa	High	Average
Caarnx ignobilis	Giant trevally	Atanagul parawa	High	Average
Parastromateus niger	Black pompfret	Kalu vavvalaya	Low	Common

Family: Lethrinidae				
Lethrinus harak	Thumbprint emperors	Meevatiya	Moderate	Common
Lethrinus nebulosus	Spangled emperor		Moderate	Average
Lethrinus lentjan	Pink ear emperor			
Lethrinus mahsena	Sky emperor			
Lethrinus microdon	Small tooth emperor			
Lethrinus olivaceus	Long face emperor	Uru hota		
Monotaxis grandoculis	Hump nose bigeye bream			
Gymnocranius elongatus	Fork tail large eye bream		Moderate	Average
Family: Lutjanidae				
Lutjanus fulviflamma	Blackspot snapper	Ranna	Moderate	Common
Lutjanus lutjanus	Big eye snapper		Moderate	Average
Lutjanus decussatus	Cheek red snapper		Moderate	Average
Lutjanus kasmira	Common blue stripe snapper	Irri ranna	Moderate	Average
Lutjanus madras	Indian snapper		Moderate	Average
Lutjanus quinquelineatus	Five lined snapper		Moderate	Average
Lutjanus argentimaculatus	Mangrove red snapper	Thambalaya	Moderate	Average
Lutjanus biguttatus	Two spot banded snapper		Moderate	Average
Lutjanus bohar	Two spot red snapper		Moderate	Average
Lutjanus fulvus	Black tail snapper		Moderate	Average
Lutjanus gibbus	Humpback red snapper		Moderate	Average
Lutjanus johnii	John's snapper		Low	Average
Lutjanus lunulatus	Lunar tail snapper		Moderate	Average
Lutjanus madras	Indian snapper		Moderate	Average
Lutjanus monostigma	One spot snapper		Moderate	Average
Lutjanus vitta	Brown stripe snapper		Moderate	Average
Macolor niger	Black and white snapper		Moderate	Average
Family: Nemipteridae				
Nemipterus sp.	Tread fin bream			
Family: Serranidae				
Cephalopholis argus	Peacock hind	Kossa	Moderate	Average
Cephalopolis formosa	Blue lined grouper		Moderate	Average
Epinephelus longispinis	Long spine grouper		Moderate	Average
Epinephelus malabaricus	Malabar grouper		Moderate	Average
Family: Scaridae				
Scarus rubroviolaceus	Ember parrotfish	Gireva	Moderate	Average
Scarus sordidus	Daisy parrotfish		Moderate	Average
Family: Caesionidae				
Caesio caerulaurea	Blue and gold fusilier		Low	Average
Caesio cunning	Redbelly yellowtail fusilier	Battalya	Low	Average
Caesio lunaris	Lunar fusilier		Low	Average
Caesia teres	Yellow and blueback fusilier		Low	Common
Caesio varilineata	Variable lined fusilier		Low	Average
Dipterygonotus balteatus	Motted fusilier			
Gymnocaesio gymnoptera	Slender fusilier			Average
Pterocaesio chrysozona	Gold band fusilier	Hemala		Average

Family: Haemulidae				
Plectorhinchus ceylonensis	Sweetlips	Boraluwa	Low	Average
Plectorhinchus lineatus			Low	Average
Diagramma pictum	Painted sweetlips		Low	Rare
Pomadasys sp.	Grunts		Low	Average
Family: Hemiramphidae				
Hemiramphus sp.	Half beak	Moralla	Moderate	Common
Family: Mugilidae				
Liza sp.	Mullet	Godaya		
Mugil sp.				
Family: Mullidae				
Mulloidichthys sp.	Goatfish			
Parupeneus sp.				
Upeneus sp.				
Family: Coryphaenidae				
Coryphaena hippurus	Dolphin fishes	Wanna	Moderate	Common
Family: Cynoglossidae				
Cynoglossus sp.	Tongue soles	Patha madiya	Low	Common
Symphurus sp.				
Family: Exocoetidae				
Cheilopogon sp.	Flying fish	Piyamassa	Low	Average
Cypselurus sp.				
Exocoetus sp.				
Family: Leiognathidae				
Gaza minuta	Tooth pony	Mas karalla	Moderate	Common
Leiognathus sp.	Pony fish	Karalla	Low	Common
Family: Siganidae				
Siganus lineatus	Gold lined spine foot	Orawa	Low	Average
Siganus javus	Streaked spine foot			Average
Family: Gerreidae				
Gerres sp.	Silver biddy	Keeli	Low	Average
Family: Kyphosidae				
Kyphosus cinerascens	Blue seachub		Low	Rare
Family: Engraulididae				
Stolephorus indicus	Indian anchovy	Handalla	Moderate	Average
Encrasicholoina heteroloba	Short head anchovy	Rahu halmassa	Low	Common
Thryssa sp.		Lagga	Low	Common
Family: Terapontidae				
Terapon sp.	Terapon	Iribataya, Gonga, Keeli	Low	Common
Family: Congridae				
Conger sp.	Conger	Anjalaya	Moderate	Average
Family: Hemiscyllidae				
Chiloscyllium griseum	Grey bamboo shark		Low	Average
Chiloscyllium indicum	Slender bamboo shark	Kana mora	Low	Average
Chiloscyllium plagiosum	White spotted bamboo shark		Low	Average
Family: Squalidae				
Centrophorus uyata	Little gulper shark		Moderate	Average
Centrophorus granulosus	Gulper shark		Moderate	Average
Family: Lamnidae				
Isurus oxyrinchus	Shortfin mako		Moderate	
Isurus pauca	Long fin mako		Moderate	

Family: Alopidae				
Alopias sp.	Thresher shark		Moderate	
Family: Carcharhinidae				
Carcharhinus melanopterus	Blacktip reef shark		Moderate	Average
Carcharhinus falciformis	Silky shark		Moderate	
Carcharhinus longimanus	Oceanic whitetip shark		High	
Carcharinus amblyrhynchoides	Grey reef shark		Moderate	
Family: Sphyrnidae				
Sphyrna sp.	Hammer head shark			
Eusphyra blochii	Wing head shark		Low	
Family: Dasitidae				
Dasyatis kuhlii	Blue spotted stingray		Low	Average
Taeniura lymma	Blue spotted ribbon tail ray		Low	Rare
Urogymnus sp.	Porcupine ray	Eramudhu maduwa	Low	Rare
Family: Myliobatidae				
Aetobatus sp.	Eagle ray		Moderate	Average
Aetomylaeus sp.			Moderate	Average
Rhinoptera sp.	Cow nose ray		Moderate	Rare
Family: Turbinellidae				
Turbinella pyrum	Chank	Hakbella	High	Average
Family: Holothuriidae				
Holothuria fuscogilva	White teat fish	Prima attaya	High	Common
Holothuria nobilis	Black teat fish	Polonga attaya	High	Average
Holothuria atra	Lolly fish	Nari attaya	Moderate	Common
Holothuria edulis	Pink fish	Keels attaya	Low	Common
Stichopus chloronotus	Green fish	Dhambala attaya	Moderate	Average
Thelenota anax	Amber fish	Puna attaya	Moderate	Average
Bohadschia marmorata	Chalky fish	Kiri nool attaya	Moderate	Rare
Bohadschia atra	Tiger fish	Duburu nool attaya	Moderate	Average
Family: Penaeidae				
Penaeus indicus	Indian white shrimps	Kiri Issa	High	Common
Penaeus merguiensis	Banana prawn		High	Rare
Penaeus monodon	Giant tiger prawn	Karawndu Issa	High	Average
Penaeus semisulcatus	Green tiger prawn	Kurutu Issa	High	Common
Metapenaeus affinis	Jinga shrimps		Moderate	Average
Metapenaeus elegans	Fine shrimps		Moderate	Average
Metapenaeus dobsoni	Kadal shrimps	Mal issa	Moderate	Average
Metapenaeus moyebi	Moyebi shrimps		Moderate	Average
Family: Palinuridae				
Panulirus ornatus	Ornate spiny lobster	Divi issa (Pokirissa)	High	Rare
Panulirus sewelli	Arabian Whip lobster		High	Rare
Family: Portunidae				
Portunus pelagicus	Blue swimming crab	Nil Kakuluwa	High	Common
Portunus sanguinolentus	Blood spotted crab	Kakuluwa		Common
Scylla serrata	Indo-pacific swamp crab	Mada kakuluwa		Common
Family: Sepidae				
Sepia acculeata	Needle cuttlefish	Dalla	High	Average
Sepia pharaonis	Pharaoh cuttlefish			

Family: Octopodidae				
Octopus sp.	Octopus	Buwalla	Moderate	Average

Appendix II Endangered, Threatened and Protected (ETP) marine species found in Bar Reef associated areas

Scientific name	Common name	Abundance [Very rare, rare, average, common]
Family: Chelonidae		
Chelonia mydas	Green turtle	Rare
Lepidochelis olivacea	Olive ridley turtle	Average
Eretmochelys imbricata	Hawksbill turtle	Rare
Caretta caretta	Loggerhead turtle	Rare
Family: Dermochelyidae		
Dermochelys coriacea	Leatherback turtle	Rare
Family: Alopidae		
Alopias sp.	Thresher shark	Rare
Family: Dugonidae		
Dugong dugon	Dugong	Very rare
Family: Kogiidae		
Kogia sima	Dwarf sperm whale	Rare
Kogia breviceps	Pigmy Sperm whale	
Family: Delphinidae		
Peponocephala electra	Melon head whale	Rare
Feresa attenutta	Pigmy killer whale	Rare
Delphinus delphis	Short beak common dolphin	Common
Stenella longirostris	Spinner dolphin	Common
Stenella coeruleoalba	Striped dolphin	Rare
Sousa chinensis	Indo-Pacific hump-backed dolphin	Rare

Appendix III Some fishing gears/methods use in Bar Reef and associated area, their seasonality and target species

Gear	Whether gear is less harmful/harmful/very harmful/illegal	Seasonality	Target species
Drift gillnet large mesh, offshore	Harmful		*Thunnua albacores* *Katsuwonus pelamis* *Scomberomorus commerson*
Drift gillnet large mesh, coastal	Harmful		*Thunnua albacores* *Katsuwonus pelamis* *Scomberomorus commerson*
Drift gillnet large mesh, coastal for shovel nose shark (Ula del)	Less harmful		*Scomberoides* *Selar crumenophthalmus*
Small mesh gillnet for anchovy	Harmful		*Stolephorus sp.* *Thryssa sp.*
Small mesh gillnet for sardines and herrings	Harmful		*Amblygaster sirm* *Sardinella sp.* *Nematolosa nasus* *Hilsa kelee*
Surrounding gillnet for sardines (Surukku dhel)	Very harmful		*Amblygaster sirm* *Sardinella sp.* *Nematolosa nasus* *Hilsa kelee*
Gillnet for flying fish	Harmful	October-April	*Cheilopogon sp.* *Cypselurus sp.* *Exocoetus sp.*
Drift gillnet for Indian mackerel	Harmful		*Rastrelliger kanagurta*
Drift gillnet for Queen fish	Harmful		*Scomberoides sp.*
Trammel net	Illegal		Shrimps, lobsters and small fish
Surrounding nets - Laila valai	Very harmful		Carangidae *sp.*
Beach seine nets	Harmful	October-April	*Stolephorus sp.* *Gaza minuta* *Leiognathus sp.* *Sardinella sp.* Carangidae *sp.*
Tuna long line	Less harmful		*Thunnus albacares* *Katsuwonus pelamis* *Scomberomorus commerson* *Carcharhinus sp.*
Trolling lines with artificial bait (Sura pannaya)	Less harmful		*Katsuwonus pelamis* *Thunnus albacares*
Cast net	Less harmful		*Penaeus sp.* *Metapenaeus sp.*
Traditional trawl - large			*Penaeus sp.* *Metapenaeus sp.* *Leiognathus sp.* *Arius sp.*
Bottom set net for skates	More harmful	October-April	*Dasyatididae sp.* Myliobatidae *sp*.
Bottom set net for lobster	More harmful	October-April	*Panulirus sp.*

Bottom set net for demersal fish	More harmful		*Lethrinus sp.* *Lutjanus sp.* *Epinephelus sp.*
Large mesh bottom set net for shark	More harmful		*Carcharhinus sp.* *Isurus sp.* *Sphyrna sp.*
Bottom longline for demersal fish	More harmful		*Lethrinus sp.* *Lutjanus sp* *Epinephelus sp.*

Appendix IV Mollusc species encountered at Bar Reef survey

Sampling location code	Species name
S1	*Cardites antiquate*
	Codakia punctata
	Donax incarnates
	Macoma litoralis
	Oliva sp.
	Conus bullatus
	Tapes aureus
	Gafrarium divaricatum
	Gena varia
	Cypraea sp.
S2	*Terebra sp.*
	Lambis lambis
	Semipallium sp.
	Trachycardium sp.
	Mactra sp.
	Cypraea sp.
	Oliva sp.
	Gafrarium sp.
	Polinices sp.
S3	*Bulla sp.*
	Polinices sp.
	Cypraea sp.
	Janthina sp.
	Trachycardium sp.
S4	*Cypraea sp.*
	Bulla sp.
	Volema sp.
	Meropesta nicobarica
	Begmina sp.
	Chank egg case
S5	*Cypraea sp.*
	Conus sp.
	Gafrarium sp.
	Donax sp.
	Tellina sp.
	Lioconcha sp.
	Anadara sp.
	Clams
S6	Chank egg case
	Conus sp.
	Pitar sp.

S7	*Teribra triseriata*
	Calpurnus verrucosus
	Sunetta contempt
	Mactra sp.
	Trachycardium sp.
	Meropesta nicobarica
	Terebra sp.

Appendix V Project team

Name	Role/Responsibility
V. Pahalawattaarachchi	Project coordination; Studies on habitats
H.M.P. Kithsiri	Marine ornamental fish
M.H.S. Ariyarathne	Benthic fauna
D.A. Athukorala	Lagoon fisheries
P.P.M. Heenatigala	Benthic fauna
M.G.I.S. Parakrama	Lagoon fisheries
S.S.K. Haputhantri	Marine fisheries
Chintha Perera	Marine fisheries
R.R.A.R. Shirantha	Marine ornamental fisheries
P.A.D.A. Kumara	Sea cucumber diversity
A.S.L.E. Corea	Avifaunal studies
M. Gamanpila	Zooplankton diversity
K.W.R.R. Amaraweera	Fisheries
A.A.S.H. Athukoorala	Mollusk fisheries
M.A.J.C. Mallawaarachchi	Mollusk fisheries
E.D.M. Epasinghe	Studies reef fish habitats
Arjan Rajasooriya	Coral reef studies
R. Weerasinghe	Coral reef studies
K.H.M.L. Amaralal	Socio-economics survey
M.M.A.S. Maheepala	Socio-economics survey
W. Wimalasena	Socio-economics survey

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Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand are working together through the Bay of Bengal Large Marine Ecosystem (BOBLME) Project to lay the foundations for a coordinated programme of action designed to better the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

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For more information, please visit www.boblme.org

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