PAMPA PARIRAKSHANA SAMITHY

Reg No: 35/94

Project Report

Submitted to

The Kerala State Biodiversity Board

Thiruvananthapuram

BIODIVERSITY CONSERVATION IN PAMPA RIVER BASIN

Project Title: Management of Aquatic Invasive species in Pampa Riverine System, with special emphasis to *Cabomba*

FEBRUARY 2014

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1. Project Title : **Management of Aquatic Invasive species in Pampa Riverine System, with special emphasis to *Cabomba*.**

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    Reg.No: 35/94
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PAMPA PARIRAKSHANA SAMITHY

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FOREWORD

Pampa Parirakshana Samithy (PPS) is a Voluntary Environment Organization that has been working relentlessly for the cause of protecting River Pampa and other Natural Water Resources since 1993. The Samithy is engaged in the mission of bringing to light the miserable and tragic plight of the Holy River Pampa and its tributaries and branches.

We believe that Environmental Education and Awareness Campaigns are the integral part of the protection of natural resources and the ecology. The PPS have organized several Workshops and Seminars as well as public meetings and classes on various subjects in different parts of the river basin. PPS have carried out minor project in 2008 titled, “Creation of Environmental Resource information on Pampa River Basin” as part of “Science popularization program” supported by ‘Kerala State Council for Science, Technology and Environment’. Several renowned and distinguished scientists and senior personalities as well as people’s representatives have participated in our workshops, seminars and other activities.

We came to understand that various human interferences in the Riverine system have caused changes in the flora and fauna in the Pampa River and its tributaries. Unscientific sand mining have resulted in the destruction of feeding and breeding grounds of aquatic species and self cleaning capacity of the River water. Sand mining has caused notable changes in the eco- biology of benthic communities as per various studies conducted by Centre for Earth Science Studies. The PPS had recently found some invasive species, especially “*Cabomba*” in the Pampa River near Sathrakadavu, Aranmula during Samithy’s ‘Pampa Darsan program’. The spreading of *Cabomba* and like invasive species has evoked serious concern among Environmentalists and Scientists.

We have conducted a preliminary study on spreading of *Cabomba* and a representation was submitted to the Kerala State Biodiversity Board. Dr. Oommen.V.Oommen, Chairman and Dr .K.P Laladas, Member Secretary visited Environment Resource Centre and River Pampa and had a detailed discussion about the various biodiversity aspects of River Pampa. The Samithy has requested the Biodiversity Board to take immediate actions to declare the Pampa River as a “Biodiversity Heritage Site” in accordance with the provision of the Biodiversity act 2002. They consider the request favourably and took initiative to formulate an Action Plan to conserve Biodiversity in the Pampa River Basin. An in-depth study of various aspects about Bio-resources of Pampa Riverine system is necessary for formulation of an Action Plan. As part of it the Biodiversity Board has entrusted ‘Pampa Parirakshana Samithy’ and sanctioned a pilot Project titled **“Management of Aquatic Invasive species in Pampa Riverine System, with special emphasis to *Cabomba*”.**

The present Report contains locations and tributaries of River Pampa where the *Cabomba* is visibly spreading and the major ecological damages due to spreading of *Cabomba*. And also, Samithy propose some management strategies to eradicate the invasive species. The study is preliminary in nature and detailed scientific studies are inevitably needed for finding out practical process for eradication of invasive species from natural water-bodies.

N. K.Sukumaran Nair
General Secretary
Pampa Parirakshana Samithy

ACKNOWLEDGEMENT

Pampa Parirakshana Samithy expresses our sincere thanks to the Chairman, Dr. Oommen V. Oommen, Member Secretary Dr. K.P Laladas, and other officials and Scientists of State Biodiversity Board for their kindness to support this Research Project and for their guidance.

We place on record our sincere gratitude and indebtedness to Professor Thomas. P. Thomas, Head of the Department, Botany, Christian college, Chengannur, Dr. Prasanna Kumar, Assistant Lecturer, Department of Botany N.S.S College, Pandalam, Dr. P.S Harikumar, Senoir Scientist and Head, Water Quality Division, C.W.R.D.M, Kozhikode, Dr.P.R Unnikrishna Pillai, Department of Botany, S.D College, Alappuzha, Sri. Abraham Varghese, Asst. Exe. Engineer, Kerala Water Authority and the Environmental Engineer, Kerala state Pollution Control Board, Dr. N. Nagendraprabhu, Associate Professor, S.D College, Alappuzha for their support and guidance.

We are indebted to Dr. V.N Sivasankara pillai, Ernakulam, Dr. K.Sankaran Unni, Kottayam, Dr. N.Unnikrishnan, Kottayam Nature Society and Dr. K.N.P Kurup, Pandalam for their constant encouragements and guidance throughout the course of the study.

Special thanks to our Office bearers, members and well wishers for the help in various ways for the study.

Poovathur
28-02-2014

N.K Sukumaran Nair
(Gl. Secretary)

PAMPA PARIRAKSHANA SAMITHY (PPS)
Reg. No: P35/94

Pampa Parirakshana Smithy is a registered Non Governmental Voluntary Environmental Organization comprising of an expert group of Environmentalists, Scientists and Engineers which has been functioning since 1993. It has been working continuously with problems faced by the riverine systems, mainly the Pampa and its tributaries, collaborating with various government organizations like CESS, CWRDM, KSPCB and Kerala State Biodiversity Board for inculcating an awareness among the people in the matter of environmental issues of the river conservation, pollution, climate change and the conservation of energy as well as the conservation of Biodiversity.

This Samithy has organized several effective campaigns to focus attention on the degradation and pollution issues of Holy River Pampa and Kuttanad Water System .The Samithy have been instrumental for formulating the Pampa Action Plan to clean the polluted Pampa River under the National River Conservative Plan of MoEF. This Samithy has been entrusted by the Government of Kerala to carry out the projects of Environmental Education and Awareness Programmes as part of the Pampa Action plan. Series of seminars, workshops, and various programmes on Ecology, aimed at creating consciousness were conducted over the last two decades with active participation of renowned Scientists, environmental Activists, Technical Experts, People’s representatives, Ministers and top Officials from state and Central Government.

Samithy has also conducted several surveys and campaigns on ***Bio Diversity Conservation*** of Pampa River Basin. It includes various programmes connected with Environmental Education, Awareness Campaigns, Workshops, Seminars and Public Meetings at various Distiсts like Pathanamthitta, Alappuzha, & Kottayam in which people from various ranks in the society took part enthusiastically. The response from the media and the public was very much encouraging.

A Research wing, Environment Resource Centre (ERC) was established by Pampa Parirakshana Samithy in 2006 as part of Endogenous Tourism Project at Aranmula aided by Govt. of India and UNDP, at Poovathur on the right Bank of River Pampa, near Aranmula.

Pampa Parirakshana Samithy conducted a Project titled “Resource Information on Pampa River Basin” in January 2008, with the support of Kerala State Council for Science, Technology and Environment and the major finding was the **Biodiversity depletion of Pampa River** due to anthropogenic interference is alarming and immediate and fruitful actions are to be initiated for Biodiversity conservation.

We have conducted several workshops and seminars at Environment Resource Centre, in various Colleges and Schools in Alappuzha and Pathanamthitta Districts on the subject “Biodiversity Conservation of Pampa River basin” since 2008.

The ‘Vanamithra Award’ of dept. of Forest, for pathanamthitta District was conferred to pampa Parirakshana Samithy in 2010 and the ‘Haritha Award’ 2012 constituted by the Kerala State Biodiversity Board, was also conferred to the Samithy.

The Environment Resource Centre established by PPS in the beautiful rural background has been acknowledged as a shelter for the inquisitive Students and Researchers in the state.

The Samithy carried out this Project supported by Kerala State Biodiversity Board in prescribed time.

Management of Aquatic Invasive species in Pampa Riverine System, with special emphasis to *Cabomba*

CHAPTER 1

1.1 INTRODUCTION

The once biodiversity-rich Pampa basin now degraded and remains in a semi-natural condition. The few remaining wetland species are wholly depend on these remnant patches of habitats. The main habitats of this river system include riparian forest, river channels (which are important for the migration and breeding of fishes) and deep pools (which provide refuge for a number of fish species). Degradation of wetland habitats and hydrological regimes of the river system poses perhaps the real threat to the viability of the biodiversity. Widespread sand mining and pollution has degraded the habitats of many species, is believed to have caused the extinction of a number of endemic fish species. These problems have been exacerbated by socio-political issues, including widespread unemployment and real estate business induced high land value.

Pampa Parirakshana Samithy had requested the Central Government to declare the Pampa River as a Biodiversity Heritage Site (Protected Zone) in accordance with the provisions of The Biodiversity Act 2002 and formulate an Action plan to protect the Biodiversity in the River Basin.

As a part of the rejuvenation programme of River Pampa, Pampa Parirakshana Samithy had organized a Pampa Darsan programme, in which a team from the Samithy consisting Scientists, Engineers, Environmentalists and Experts had visited various sites along Pampa to study the degree of depletion. One of the prominent observations during **Pampa Darsan,** was the disastrous spreading of a weed along Pampa Riverine system.

The weed, an aquarium plant introduced into the Riverine system by mistake and all the other natural inhabitants had been suffered by it. Samithy noticed that dense population of this invasive species had reduced water flow and increased siltation and the plant had rooted in clayey bottom where the sand was removed. So it was concluded that the uncontrolled interference of human had led to the introduction of foreign weeds into Pampa River.

Pampa Parirakshana Samithy thus requested the Government to initiate programs for the eradication of these invasive weeds and submitted a project for the study of these weeds. Government directed Kerala State Biodiversity Board to undertake studies on environmental issues caused by the invasive water weed *Cabomba,* in 13th legislative Assembly, based on the reports received regarding the invasive aquatic plant. Accordingly Board invited suitable project proposals.

The Project envisages to the study of the alarming growth of different disastrous invasive weeds like, *Cabomba*, *Lymnocharis Cyperus, Utricularia, Vallisneria*, *Limnophila heterophylla* and *Hydrilla verticillata* along different regions of River Pampa. The spreading presence of these invasive species along the Aranmula Stretches of Pampa has evoked serious concern among local population and also the

Riverine ecology. The growth of these weeds should be taken as threat to the Riverine system. The *Cabomba* with its extremely dense strands which obstruct the free flow of water increased silting of the River, gradually making it shallow and dry. It suppresses the growth of other species around it due to its allelopathic effect. This alien weed has the capacity to change the entire ecology of water bodies.

The project proposal of Pampa Parirakshana Samithy **"Management of Aquatic Invasive species in Pampa Riverine System, with special emphasis to *Cabomba*"** was sanctioned by Kerala State Biodiversity Board, on 06.02.2013. The Project is a one year programme, started on 1st April 2013.The motive of this Project is the scientific study about the disastrous growth of this alien invasive species along the River Pampa.

1.2 OBJECTIVES

1. To make comprehensive study on Environment Degradation of Biodiversity due to the spreading of Aquatic Invasive Weeds.
2. Make a Report emphasizing the spread of Invasive weeds along the Riverine System.
3. Effect of pollution on the Riverine flora and fauna and study of ecological consequences.
4. To eradicate these aquatic invasive weeds from the wetlands of Kerala, especially along the stretches of River Pampa.

1.3 ACTIVITIES

In order to satisfy the objectives, the following methods are adopted.

1. Site visits: To study the presence of the invasive weeds along the River stretches and the main tributaries.
2. Preparation of map showing the locations of the affected area.
3. Documentation by photographs.
4. Water Quality analysis from the affected area.
5. Awareness campaigns and Study classes in schools and Colleges on the banks of the River.
6. Preparation of comprehensive report of the present study.
7. Formulate an Action Plan to eradicate these invasive species from the water bodies.

CHAPTER 2
RIVER PAMPA

Human civilizations have sprung up and developed along River basins. Rivers contribute to the Economic, Social, and Cultural development of people in the basins. Kerala is the state abundant with rivers and many streams. Obviously, it is the presence of the rivers that contributes immensely to the green canopy of nature and temperate climate of Kerala which in turn earned this state the name ‘God’s own Country’.

Undoubtedly, the rivers are the precious natural resources of our State. But unfortunately most of the rivers in Kerala State are environmentally degraded due to excessive human interventions and over exploitations of river resources and ultimately due to alarmingly high levels of pollutions.

The River Pampa is the Holy River in the Kerala State and known as ‘Dakshina Ganga, due to its Historic relationship with the Holy Shrine, Sabarimala Temple. It is the third longest river among the 44 rivers of Kerala. Pampa River Basin comprising Periyar Tiger Reserve (PTR), Ranni and Achenkovil Forest Divisions in the Western Ghats, harbour one of the most luxuriant stretches of evergreen forests. Many species of plants and animals in this River Basin are local endemics which are likely to become extinct in the near future. River Pampa is the lifeline of the three Districts of Kerala State Viz; Pathanamthitta, Kottayam and Alappuzha including Kuttanadu area and about 40 lakhs of people depend this river for their daily water needs.

The River originates from Western Ghats which is the *Hottest Biodiversity hotspot* and empties into the Vembanadu Lake, *a Ramsar site,* having a length of 176 km, and a catchment area of 2235sq.km, through the most densely populated regions of the State.

The River is a conglomeration of various streams from Pulichimala, Nagamalai, and Sundaramalai, which combines to riverlets like Gaviar, Kullar, and Meenar. Later it joins to Kakkiar at Thriveni, the Holy Pilgrimage Centre, and then united with four more riverlets like Njunangar, Puthussery, Azhutha and Panamkudanthayar. Further five more riverlets like Moozhiyar, Vettilayar, Veluthodu, Seethathodu, and Maniyar joined as Kakkattar into it at Perunadu. The Pampa- Kallar joins the main river at Vadasserykkara and river flow direction towards the west changes to South at Kuriannoor up to Vanchithra. From Vanchithra, the direction of flow again changes towards west. At Pandanadu, near Chengannur, the riverflow bifurcated and the north-west branch joins to Manimalayar, at Valanjavattom near Thiruvalla. The other branch (south- west) combines with Kuttamperoor river at Nakkada and further at Mannar again bifurcated and then the north west, first branch at Edathua, further bifurcated and its first branch flows through Pulikeezhu, Neerettupuram, Kidangara, Kavalam to Vembanadu Lake. The second branch bifurcated from Edathua also empties into Vembanadu Lake through Nedumudy, whereas the second branch (south-west) bifurcated at Mannar combines with Achencovil river at Veeyapuram near Haripad and flows through Thakazhi and Pallathuruthy and empties into the Vembanadu lake. (N.K Sukumaran Nair, Pampa Paristhithi Padanam).

PAMPA RIVER BASIN

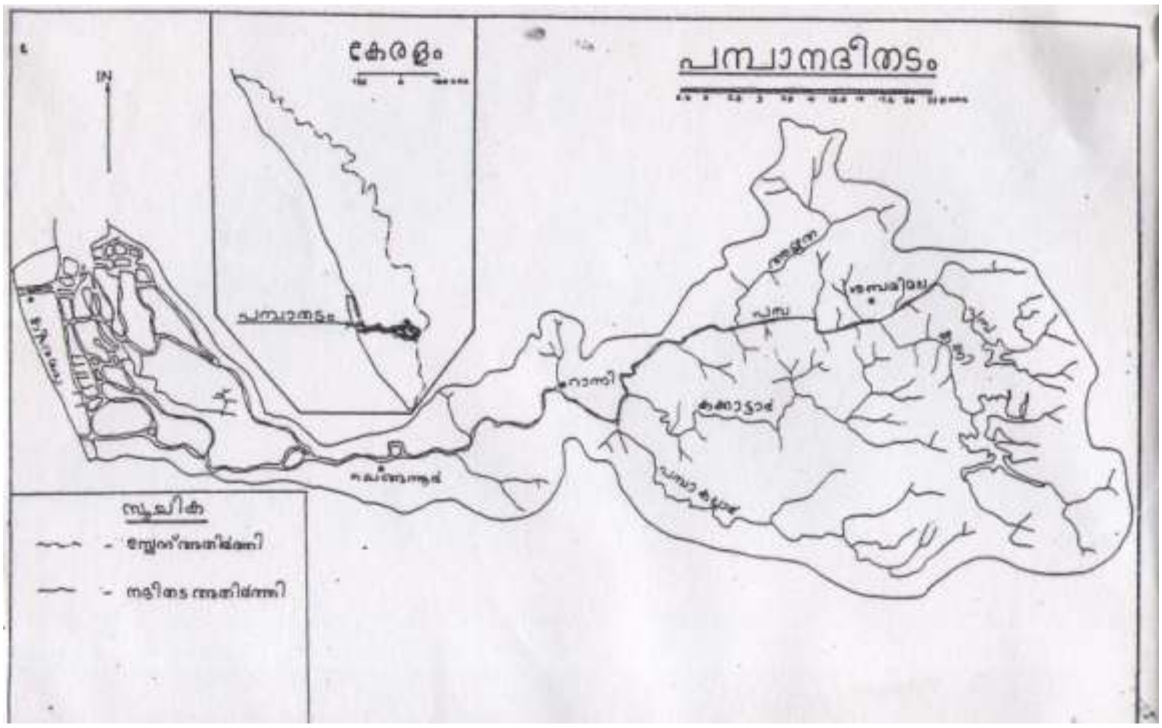
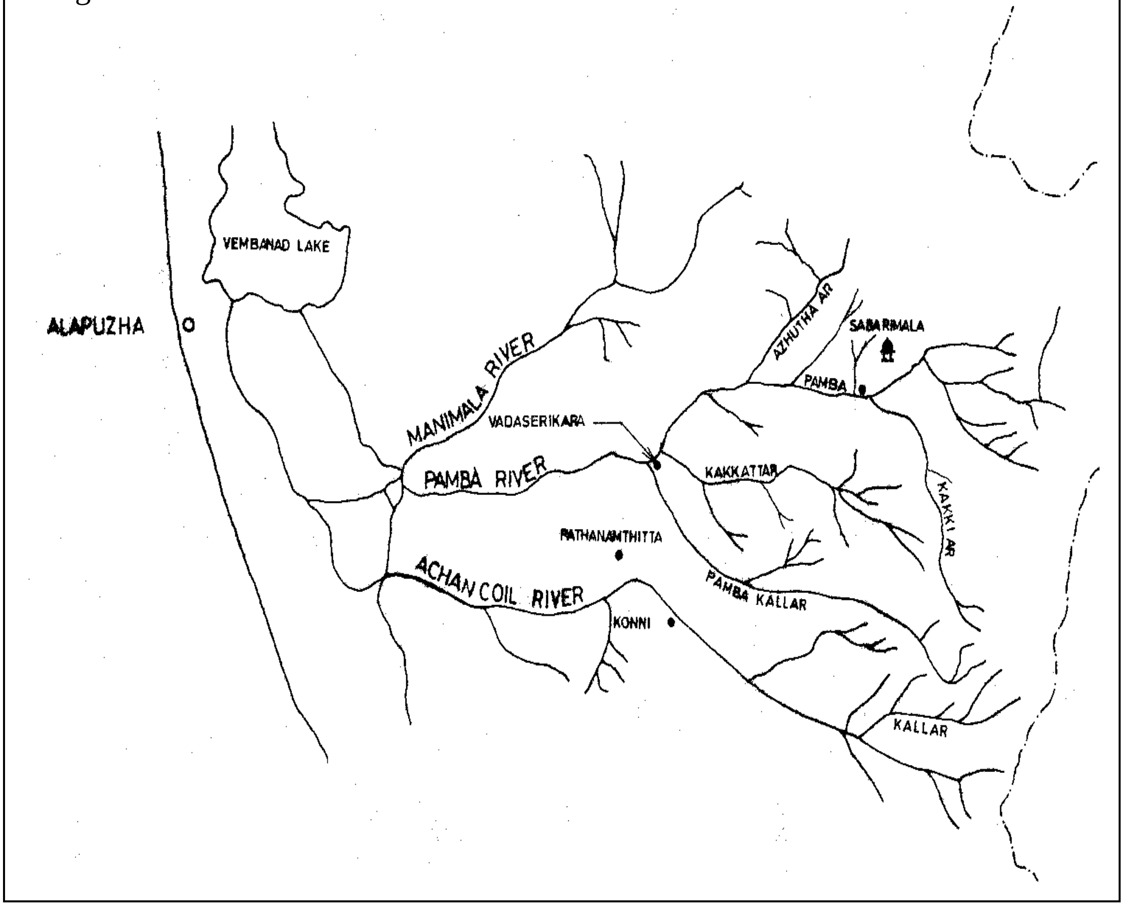


Fig: 2.1

Fig: 2.2. PAMPA- MANIMALA- ACHENKOVIL.



Salient Features of Pampa River.

Origin	Pulichimala (+1677m)
Latitude	09^0 24’ N’ - 09^0 30’ N
Longitude	77^0 10’ E - 76^0 20’ E
Catchment area	2235 sq km
Length of main stream	176 KM
Important Distributaries	Kakki, Azhutha, Kakkattar, Kallar
Important Tributaries	Manimala, Achenkovil
Average annual rainfall	3600mm
Average river flow	$3425x10^6/m^3$
Biggest irrigation project	Pampa Irrigation Project (Maniyar)
Hydroelectric Projects :-	
Sabarigiri	335 MW
Kakkad	50 MW
Maniyar (Private)	12 MW
Allungal	7 MW
Karikkayam	15 MW
Maniyar tailrace	4 MW
Hydroelectric project under construction:-	
Perunthenaruvi	6 MW
Important dams:-	
Sabarigiri Augmentation	Kullar, Gaviyar, Meenar
Sabarigiri Hydroelectric Project	Pampa, Anathodu, Kakki
Allungal Hydroelectric Project	Allungal
Pampa irrigation	Maniyar barrage
Kakkad Hydroelectric Project	Moozhiyar, Veluthodu

Table 2.1

2.1 Pampa river basin- Area coverage

- Forest land more than 60%
- Agriculture and plantation - 31%
- Built- up land - 1.12%
- Water bodies - 1.90%
- Grass lands - 2.4%

  (Kerala State Remote sensing and Environment Centre, Trivandrum)

2.2 Major Tributaries of River Pampa

2.2. a. Achancovil River

Achancovil river, originating from Pasukidamedu of the Western Ghats at an elevation of over 700 above MSL. in Kollam District. Several small streams originating from Pasukidamedu, Ramakkal teri, and Rishimala join together to form the Achancovil and flowing through Kollam ,Pathanamthitta and Alappuzha Districts.It is a perennial river and has a length of about 121km and a catchment of about 1699 Sq: km. The Achancovil River merges with Pampa River at Veeyapuram near Haripadu in Alapuuzha District.

2.2. b Manimala River

Manimala River was one of the perennial rivers in Kerala with a length of 90 km and a catchment of about 847 Sq.km. The river originates from Thattamalai Hills at an elevation of 1156m above MSL. The River spreads over Idukki, Kottayam and Pathanamthitta Districts. The River empties into the Vembanadu Lake after merging with Pampa at Valanjavattom near Thiruvalla. The river displays a dendrtic drainage pattern. The Koratty thodu flowing through Erumaly, a Holy place for the Sabarimala Pilgrimage, is one of its tributary and the main pollution source The River displays a dendrtic Pattern.

2.3. Major causes of Degradation of Pampa River.

a. Degradation of virgin forest at the catchments area.

b. Unscrupulous and unscientific mining of River Sand.

c. Degradation of Tributaries and Distributaries of River Pampa.

d. The water pollution of the River due to faecal coliform bacteria during Pilgrimage seasons, domestic and industrial effluents from houses, hospitals, rubber factories and markets along the River banks.

e. Abundant spreading of Invasive species.

2.3.a. Deforestation: A cause of degradation of River

The prime cause for the degradation was extensive deforestation in the catchment areas during 1940-1980. This has resulted in drying up of almost all tributaries of the Rivers and the Rivers loses their regular flow and turns to stagnant summer pools at the very beginning of summer seasons. The uncontrolled flood during unexpected time is also a regular feature.

2.3.b. *Sand extraction resulted in degradation of River*

While deforestation is a gradual process of deterioration, sand mining on a large scale hastens the death of the river .Unlike the other Rivers in India, the Rivers in Kerala are too small in size and resource capability. River sand is an essential ingredient of building constructions. It supports the socio- economic environment of the basinal area of the respective Rivers. Sand extraction is going on along its total length, as now a days they are even digging deep into its original bed to remove sand. Indiscriminate extraction of resources like sand and gravel from riverbed is disastrous, as this activity threatens the very existence of the River Eco System.

The quantity of in-stream mining is several folds higher than the sand inputs estimated in the gauging stations. Due to unregulated removal of sand, the river bed has lowered about 4-5 meters during the period from 1986-2004 at Edayaranmula. The river bed of River Pampa is 3 mtrs below the MSL. This in turn imposes severe damages to the physical and biological environment of the riverine system.

The over exploitation of river sand and gravel leads to reduction of sediment supply from catchments and erosion of its own channel during high flow regimes are very common in Kerala Rivers. These occasions may lead to channel deepening and undermining of engineering structures such as bridges, water supply schemes, and irrigation schemes. The Sandy River beds were venues of cultural and religious congregations. The annual famous religious *Maramon Xian Convention* and *Cherukolpuzha Hindu Matha Parishad* are being conducted on Pampa River bed. The unique Aranmula *Uthruttathy Boat Race* is being conducted every year during Onam in the River Pampa. All of these traditional events are being experienced very difficult for smooth conduct.

The state of bridges across the Rivers and the water pumping stations are precarious due to the rapid decline of river bed. According to the experts, the prime cause for the un-timely collapse of Ranni Bridge in Pathanamthitta District on 29-07-1996 was the removal of sand from its foundation region to an average depth of 3 to 4 meters (This was predicted by the Pampa Parirakshana Samithy even before 1994). Due to the sinking of the river bed, the filtration tanks of various Drinking water schemes in the Rivers are drying during summer season and become perched ineffectively above the water level resulting in severe water scarcity.

Due to thinning of fresh water flow in the river, salinity was reported up to, about 50 km up-stream of these Rivers from salt water front, and tidal effect is reported. This will make drinking water pollution all along its banks and destroy the original fresh water eco- system of the rivers. The whole fresh water ecology of the river is affected by the seeping of saline water.

When the river sand, is removed from the river bed, the hydraulic gradient increases dangerously. The sand mining of the river beds also destroys the groundwater recharge capacity of the rivers. Year after year, the water level in the wells near the banks is getting lowered and as a result, people are forced to deepen their wells. Drinking water, scarcity is being experienced even in area lying very close to the rivers (Sri. N.K Sukumaran Nair,Pampa Parirakshana Samithy).

2.3.c. <u>Water Scarcity, the net result in Rivers.</u>

The most parts in Kerala State are facing acute water scarcity because of the degradation of almost all the 44 Rivers and their tributaries. The Sand deposits that act as natural Check -Dams in the rivers have been plundered by the sand mafia. Indiscriminate and illegal river sand mining has lowered the river bed to drastic levels, polluting the drinking water sources in the river. Water is decreasing in quantity, and pollution is increasing alarmingly in all the rivers and lakes in Kerala.

2.3.d. <u>Water Pollution in the River Pampa</u>

The pollution and the disposal of human waste materials directly into the river have caused severe threat to the Ecology and the Public Health. The higher level pollution in the Holy River Pampa during the annual Sabarimala Pilgrimage Season is posing a serious health hazard to lakhs of Pilgrims as well as about 30 lakh of people living in the downstream reaches of Pampa River basin up to Kuttanadu. The Sabarimala Temple has over the past decades grown into a Major Pilgrimage Destination in South India. The Holy Temple is located in the midst of thick evergreen tropical rainforest on the banks of River Pampa. About 2 crore pilgrims visit Sabarimala every year.

The sanitary condition in Pampa and Sannidanam is far from satisfactory and the all kinds of wastes and escritoires carried by small streams are flown into the Pampa waters directly. Many village towns are fastly growing on the banks of River Pampa. The River water is further being contaminated with waste materials and sewage flown in from towns, markets, slaughter houses, hospitals and rubber plantations and factories. The chemicals such as Ferrous Chloride used for river treatment at Njunangar, a tributary which carries the filth from Sannidanam, joins river Pampa ,during last year contaminated the water further with heavy metals viz; Iron, Nickel, Zink and Cadmium.(National workshop on Conservation of the Wetland in Alappuzha, 24/01/2010).

2.3.e. <u>Invasive weeds in Pampa River</u>

Eichhornia crassipus, Limnocharis flava, Salvinia molesta, Water hyacinth, Utricularia, Hydrilla verticillata, Vallisneria, Potamogetan, Ludwigia parviflora, Nymphaea stellata and *Cabomba furcata* are seen in the River Pampa and its tributaries and distributaries.

The presence of *Cabomba* in River Pampa is an indication of fast decreasing river flow and alarming rate of degradation of the riverine system. Excessive exploitation of sand has exposed the clayey bottom of the River which has become ideal for the growth of these weeds. The major factor which promotes the growth of this weed is the high nutrient content of water. The source of nutrients is sewage, agrochemicals, and land washouts. Absence of normal vegetation on either side of the River facilitates enough sunlight for the fast spreading of these weeds.

The intense growth of *Cabomba* blocked the entry of sunlight into the water, affecting indigenous vertebrate and invertebrate fauna. These alien weeds are serious threat to the water bodies of Kerala. They have the capacity to change the entire ecology of the water bodies. So great is the concern about invasive alien species today that the International Convention on Biological Diversity (CBD) has ranked them as second amongst the foremost threats to Biodiversity and ecosystem functioning, worldwide. India, as a mega diverse country encompassing four of the 34 global biodiversity hotspots and with a very large number of endemic species has good reason, therefore, to be concerned about invasive alien species (The Hindu Environment survey; 2011;Page no: 38).

CHAPTER 3
BIO DIVERSITY DEPLETION IN PAMPA RIVER BASIN

Biodiversity is the totality of organisms, the whole biota, which is the product of nature and nurture. There are 3 kinds of biological diversity as the eco system diversity, species diversity and genetic diversity (*Jane, 1994*). Biodiversity is linked maintenance of ecological stability and productivity. These attributes are important in sustainable development and stable national economy (*Mc Neely, 1988*). The need for conservation of biodiversity significantly increases in degraded and fragile ecosystems to restore productivity and to arrest further degradation of such areas.

The diversity of plants and animals in the Pampa River Basin is now recognized as being of very high value. The Pampa River and its tributaries, distributaries, channels, associated paddy fields and wetlands support many unique ecosystems and a wide array of threatened species. The biodiversity of the Pampa River ecosystem is alarmingly declining due to the obstruction of river courses, regulation and diversification of water flow, sand mining, habitat destruction, loss of riparian canopy cover, soil erosion and high water pollution. (*N.K Sukumaran Nair, Pampa Paristhithi Padanam*).

3.1 Aquatic Plants in River Pampa

Eichhornia crassipus, Limnocharis flava, Salvinia molesta, Water hyacinth, Utricularia, Ceratophyllum, Hydrilla verticillata, Vallisneria, Potamogetan, Ludwigia parviflora, Nymphaea stellata, and *Cabomba furcata* are common in the River Pampa and its allied water bodies.

Spirogyra, Chara, Euglena, Nostoc, Diatoms, Scenidesmus, Desmids, Cyclotella like algae are also seen in the river. In the Pampa River, the major planktonic organisms collected from various stretches in the river were *Anabena, Ankistrodesmus, Chlorella, Navicula tintinnids, Pleurosigma and microcystis* (*Dr.S.Bijoy Nandan, Reader, School of Marine Sciences, CUSAT*).

3.2. Riparian vegetation of Pampa River basin

Riparian vegetation is an integral environmental component of River ecosystem as it plays an important role in maintaining the river health, stabilizing the river banks, providing habitat for wild life, storing carbon and there by regulating the level of green house gasses in the atmosphere, generating income to the local communities and ultimately enhancing the aesthetic value of the Environment. The riparian environment, in many rivers, contains a rich stock of rare and endangered plants, many of them are known for economic / medicinal potential. Unabated clearing and burning of riparian vegetation in the name of development of approach roads, sand storage centers, building constructions etc. could adversely affect the structure and function of river system (*Dr. D. Padmalal; CESS; Human interventions on biological environment of Kerala Rivers: An overview*).

Many of the grasses like *Panicum repens, Cynodon, Killinga, Bromus riparius, Imperata cylindrica, Phyllostachys aurea, Arundinella villosa and reed climber Schizostachys beddomeii, twiners likeVitis glauca, Smilax,Piper longum, Abrus precatorius, Mikania, Asparagus, Clitoria ternata, Acacia initia, Gloriosa superba, Vitis quandrangularis, Phaseolus multiflorus, Cyclea peltata, Artabotrys odorattissimus, Ichnocarpus frutiscens, Calapagonium and Ipomea spps* are abundant in the river bank. Medicinal herbaceous plants like *Cardiospermum halicacabum, Achyranthus aspera, A.indica, Alpinia galanga, Eclipta alba, Mimosa pudica, Vernonia conyzoids, Curculigo, Coleus aromaticum, Emelia zonchifolia, Leucas aspera, Plumbago, Cuscuta, Piper cubaba, Musa sapientum, M.paradisciaca,M.extensa, Biophytum sensitivam, Myxopyron, Aerva lanata, Oldenlandia umbellata, Centella asciatica, Boerhaavia diffusa, Zygophyllum, Sida rhombifolia, Tribulus terrestris, spermacos, Elephantopus, Scoparia, pepparomia pellucida, Phyllanthus nirurii* are also seen.

Bryophytes like Riccia, Mosses and ferns like *Nephrolepis, Drynaria, Drymoglosum are also met with the riverine ecosystem.* Gymnosperms like *Podocarpus, Thuja, Gnetum* are also seen.

Shrubs like *Ricinus communis, Glycosmis pentaphylla, G.cochinchinensis, Hibiscus rosasinensis, Ixora coccinea, Adhatoda vasica, Solanum indicum, Strobilanthus, Clerodendron infortunatum, Rauwolfia serpentina, cassia occidentale, Sida longifolia, Hibiscus furcatus, Breynia rhamnoids, Eupatorium odorattissimus, carrissa, Canthium didymum, Zyzyphus, Helicteris isora, Strobilanthus spps, Anona squamosa, Eugenia caryophyllata, Cassia amara, Cassia fistula,Glyrisida, Grewia microca, Pandanus spps, Saraca indica, Anona muricata, Ervatamia coronaria, Tabarnae mondana, Alamanda cathartica* are flourished well in the river basin.

Arborious plants like *Artocarpus grandiflora, A.heterophylla, A. hersuta, Tectonia grandis, Dalbergia latifolia, Tamarindus indica, Garcinia, Vateria indica, Ebony trees, Strichnos nux vomica, Macranga, Ailanthus malabarica, Thespesia, Borassus, Caryota, Magifera indica, Sizigium jambosa, Terminalia catappa, T.arjuna, T.paniculata, Swetenia mahagony, Cinnamomum zeylanicum, Erythrina,Coccos nucifera, Areca catechu,Hevea braziliensis, Bombax malabaricus* are luxuriently grown in the river basin.

Among the various types of human interventions, river sand mining and clearing vegetation are the most destructive activities that are prevalent in the last 4-5 decades. The former lowers the bed level of the rivers, whereas the latter aggravates bank failure incidences.

Areas close to urban areas shows high degree of environmental degradation. Caving of river banks along with natural vegetation is common at many locations. At certain streaches the riparian vegetaion is cleared for developmental activities.Burning of riparian vegetation is also common. Unscientific engineering constructions along and across the rivers may fragment the riparian vegetation further, thus disrupting the continuity and also free movements of riparian animals.

Loss of in-stream and riparian vegetation, removal of bed materials like sand and gravel during sand mining not only affect the feeding and hiding grounds of fishes and other aquatic animals, but also imparts spawning disorders especially to phytophilic (fishes that lay eggs on vegetal parts of instream plants), and psammophilic (fishes that lay eggs on sandy substratum) fishes. This may ultimately leads to decline in inland fishery resources and also protein and energy flow to fish feeding animals in the aquatic and terrestrial environments. All these clearly indicate the fact that the time has already reached, perhaps crossed to ban all activities within the naturally evolved bio productivity and ecological integrity of our fresh water system (*Dr. D. Padmalal; CESS; Human interventions on biological environment of Kerala Rivers: An overview*).

Revival of the true riparian vegetation is utmost essential, not only for the conservation of river ecosystem, but also for reduction in the ill effects caused by climate change. In short, the health of riparian and instream vegetations is an indicator of the health of the river ecosystem and the nature as a whole. (*Dr. Padmalal D, Dr. Maya K, Dr. Nagendra Babu K; Mr.Baijulal B; Environmental Appraisal and sand auditing of Manimala River, Karala, India*).

3.3. Impact of Invasive weeds on Natural vegetation in River Pampa

The invasive weeds suppress the growth of other plants around them. The growth of disastrous weeds along Pampa River should be taken as threat to the riverine system. *Cabomba furcata, Salvinia molesta, Utricularia, Limnocharis flava, Hydrilla* form dense growth of vegetative body, which obstruct the free flow of water. *Cabomba* like dominative plants contains high degree of allelopathic chemicals which influence the growth and survival of other species. This alien weed has the capacity to change the entire ecology of water bodies.

The spreading presence of *Cabomba furcata*, a fast growing submerged aquatic weed species along the Aranmula stretch of Holy River Pampa has evoked serious concern. The major factor which promotes the growth of this weed is the high nutrient content of water. The source of nutrients is sewage, agrochemicals, and land washouts.

3.4. Effect of Water pollution on Biodiversity

Water being the best and convenient dilution medium is the worst affected by pollution. It is frequently used as the cheapest convenient way for liquid and solid waste disposal. Organic pollution associated with pilgrimage is the worst Environmental problem facing the River Pampa.

Pollution due to domestic and urban sewage and run off from agricultural fields has led to water quality deterioration, fish mortalities and toxicity to organism. The insects like May fly, Dragon fly, Chironomids, Caddis fly and other insects of the order Dipteral are declining at faster rate due to indiscriminate scooping of sand from river beds. Decrease in the population of these beneficial insects which are actually the part and parcel of food chain, affect badly to other higher order aquatic organisms like Pisces and amphibians. Most of fresh water plants of natural vegetation in Pampa river cannot survive in the polluted water and invasion of alien species like *Cabomba* promoted.

3.5 Effect of Illegal Sand mining on Biodiversity

The once biodiversity-rich Pampa basin now remains in a semi-natural condition and the few remaining wetland species are wholly relent on these remnant patches of- habitats. The main habitats of this river system include riparian forest, river channels, which are important for the migration and breeding of fish, deep pools, which provide refuge for a number of fish species. Degradation of wetland habitats and hydrological regimes of the river system poses perhaps the real threat to the viability of the biodiversity.

There were huge depositions of sand in the river bed and river banks, twenty years back. It is said that during summer, (March-April) the local people cross the river through sand bridge. But now, deep gullies are formed in the river due to illegal sand mining and muddy ridges are seen instead of sandy looms. Even in the middle of the river, deep gullies filled with humus and clay is formed. Uncontrolled and illegal sand mining resulted in environmental hazards, depletion of biodiversity and drinking water problems.

Widespread sand mining and pollution has degraded the habitats of many species, is believed to have caused the extinction of a number of endemic fish species. These problems have been exacerbated by socio-political issues, including widespread unemployment and real estate business induced high land value.

Unscientific sand mining over the past decades has led to the alarming degradation of the Pampa river system. Rampant deforestation, intensive agriculture activities in the catchment areas, industrial, agricultural and domestic pollution and use of explosives and poison for fishing were the other major threats to the biodiversity of Pampa. Now many indigenous fauna including rare species of fishes have already become extinct.

Unscientific sand mining have also resulted in the destruction of feeding and breeding grounds of fishes and reduced the self cleaning capacity of the river water The habitat destruction and pollution was the major reason for the declining biodiversity particularly that of fishes In addition to physico-chemical changes sand mining can impose marked damages on the bio diversity of the aquatic and terrestrial environments according the study reports of the Centre for Earth Science Studies (CESS) Thiruvananthapuram. Sand mining from the past few decades has caused notable changes in the eco biology of benthic communities.

3.5.1 State of Environment of Maramon Sandy plain

As part of **Pampa Darsan**, a team of experts from ‘Pampa Parirakshana Samithy’visited Aranmula stretch of River Pampa. The sand deposit at Maramon is now totally changed to a grass land. The discharge of nutrient rich sewage from the Kozhenchery Township and silt reaching from the sand mining centres upstream during high flow seasons are responsible for the accelerated growth of grass and other vegetations. The unscientific granite structure for about 417 m length, indented mainly for protecting the sandy plain at Maramon is counterproductive as it contributes a low energy zone behind the granite construction. The low energy environment prevailing behind the granite structure during the monsoon season favours rapid settling of silts and clays from the flood waters. On the other hand, the narrow active channel between the granite structure and the right bank acts as a flow amplifier and hence accelerating erosion of sediments in an area naturally meant for deposition.

This aggravates channel incision of the active channel relative to the deposit at Maramon. All these, in one way or the other contribute a favourable environment for the prolific growth of weed plants over the sand deposits. Now a stage has reached to reclaim the historically significant area with sand brought from elsewhere every year for the smooth conduct of the internationally known Maramon Convention.

3.6 Depletion of Biodiversity

Biodiversity is often used as a measure of the health of all biological systems. 2011-‘20 has been declared as the International Decade of Biodiversity and at present, the most threatened ecosystems are those found in fresh water. Fresh water biodiversity supports a number of natural ecosystem processes and services that benefit society such as water purification, recycling nutrients and providing fertile soils and bio resources.

Depletion of Biodiversity is an alarming problem all over the world. However, it has to be agreed that demarcating out of the protected area system does to some extent, deny general access of people into such area and unrestricted use of forest produce in the same pattern as in allowed in other categories of forests. All the major river systems in India have become giant sewers for the human population threatening the very existence of aquatic flora and fauna.

In natural forests, the tree roots bind the soil and about 90% of the water falling on the forest is retained either in the humus or in the plant tissue. The forest thus acts as a soaking device and plays a vital role in hydrological cycle. The rain water, thus soaked up is gradually release over the days and weeks which supplies to streams and rivers, even during dry seasons. Hence, it is important to retain the forest cover in upland catchment area as an alternative to flooding the whole barren and uncultivable area. The washed away top soil silts the riverbeds and reservoirs reduce the holding capacity and causes natural calamities like flood in the surrounding area.

Due to gradual destruction of forest, wild life is disappearing and their number is becoming reduced for which Government should consider various aspects of forest management. Forest management program should be motivated by forest employees and general public to increase yield to avoid forest destruction and to prevent forest fires. Whenever, plant or timber is cut, that area must be reforested. Similarly any forest which has been destroyed by insects, diseases, epidemics, flood and heavy rainfall, that area should be reforested. The primary aim of the forest service is to make the greatest number of forest resources available to the maximum number of people.

Shifting cultivation is another practice which destroys the forest. Many farmers destroy the forest for agricultural purpose and soil is exhausted. Therefore farmers should use the same land for cultivation and they should apply better farming methods like organic farming so that soil fertility remains restored and the soil can be used again.

The Holy River Pampa Basins are rich in aquatic and riparian biodiversity with several endemic species. Surveys on the aquatic flora and fauna indicate that several species are in endangered condition. Biodiversity conservation in Pampa River Basin is very important.

It is absolutely necessary to protect and conserve all forms of life on earth as they are all interdependent and form apart of food chain. Nature has created them in a balanced manner that if one form of life is disturbed, it affects all the other lives too. The very existence of man depends upon the survival of other forms of life, both plants and animals. Hence Pampa Parirakshana Samithy requests the state Government to take immediate and fruitful actions to declare the Pampa River Bain as Biodiversity Heritage Site (Protected zone) in accordance with the provisions of the Biodiversity act 2002.

The various human interferences in the river leading to pollution have caused depletion in the flora and fauna in the River Pampa According to a study by CIFRI (2004). The algal and benthic bio mass and diversity was generally low in most of the stretches of River Pampa. 69 species of indigenous fishes and 10 species of exotic/non native fishes contributed to the fishery of the river during 2003-2004. Commercial fishery was supported by 57 species recorded during the study period and 30 species can be treated as threatened, of which, 5 species belonged to the endangered group and two species were absent. The presence of many rare and endemic forms of fishes in the river makes it qualify as fresh water sites of exceptional fish diversity (*Dr. S. Bijoy Nandan, Reader, School of Marine Sciences, CUSAT*).

The extinction of the producers and primary secondary like consumers in the food web cause break down of the food chain and brings down the survival of the higher organisms like carnivores, omnivores and even human beings. Shellfish, Pilaglobosa and Oysters are scares in the rivers. The so common Dragon flies in the past are very rare now a day, owing to the loss of their breeding place along with humus and sand looms in the riverbanks during summer.

The extinction of dragon flies caused the growth and multiplication of mosquitoes. The larvae of Dragon flies eat the larvae of mosquitoes. Whereas in the absence of the predators like dragon flies, the mosquitoes multiplies in the river banks, the shade of leaning bushes and branches of the trees where the breeding place of the fishes.

3.6.1. Fresh water flora and fauna

In Kerala 25% of the fresh water fishes are now facing extinction. Of the 617 rare species of fresh water fishes identified in the country, 210 were found in Kerala Rivers. Earlier studies revealed that 79 species belonging to 31 families were present in Pampa River (*Dr. K.G Padmakumar, Kerala Agricultural University; Ref: The Hindu 11/03/2007*).

The fish biodiversity of the river system is alarmingly declining due to a variety of reasons viz., obstruction of river courses, regulation and diversification of water flow, damming, sand mining & habitat destruction, loss of riparian canopy cover, deforestation leading to soil erosion, indiscriminate capture of the spawns during spawning season popularly known as *oothapidutham* and unethical fishing practices such as poisoning, dynamiting and electrical fishing. The river habitat is also subject to manmade interventions such as barriers and check dams that impair the natural movement of fishes. Reduced summer flow leading to drying up of rivers and pollution hazards from Agro-chemical, pesticides and sewage also lead to occasional mass mortality of fishes. (*Dr. K.G Padmakumar, Ref: Impact of Human Interventions on Fisheries and Ecosystems services in coastal Wetlands, Kerala.*).

Fish fauna from different stretches of the Pampa River system comprised of species belonging to 31 families. Out of them, 13 species were estuarine forms belonging to 7 families. Commercially important species constituted 72% of the total fish population. According to the IUCN categorization of threatened fishes, 30 species in River Pampa can be treated under threatened group, of which 5 species *Labeo dussumieri, Horabagrus brachysoma, Puntius denisonii*, *Tor khundree* and *Hypselobarbus curmuca* belonged to the endangered group. Two more species C*larias dussumieri* and *Channa punctatus* are also absent in Pampa River

The indigenous carps dominated the fishery of the middle, lower and estuarine stretch of the river followed by miscellaneous groups and catfishes. The exotic fishes formed a major component of the catch from 2000-2001 onwards. The study clearly revealed that the impacted nature of water quality coupled with other anthropogenic activities has seriously affected the species composition and catches structure of the fishes, particularly the indigenous varieties. (*Biju Vikram & B.C.Jha, Central Inland Fisheries Research Institute (ICAR), Alappuzha Center*).

Two endemic fish varieties – Cat fish (Nadan Mushi) and Eel (Malanjil) are feared to have disappeared from Pampa. No individuals of these species have landed in the nets of fishermen for the last three years triggering suspicion of their population loss. (The Hindu 25/10/2010).

3.6.2. Probable Causes for Decline in Fishery

Deforestation, construction activities and agricultural development caused excessive water runoff and soil erosion, leading to siltation of river water, which ultimately erodes the breeding and feeding grounds of fishes and also cause mass mortality of fishes. The silt and allochthonous materials make water turbid resulting in low primary production leading to decline of overall productivity of the system.

- Construction of dams have reduced water discharge, resulted habitat destruction due to impoundment and obstructed the migratory pathways of fishes.
- Sand mining have resulted in the destruction of feeding and breeding grounds of fishes and also lowering of the riverbed.
- Pollution due to domestic and urban sewage and runoff from agricultural fields have led to water quality deterioration, habitat destruction, fish mortalities and toxicity to organisms.
- Introduction of non-indigenous fishes is one of the major threats to the native fish fauna. These introductions resulted in habitat alteration, tropic alterations and gene pool deterioration.

(*Biju Vikram & B.C.Jha, Central Inland Fisheries Research Institute (ICAR), Alappuzha Center*)

3.7 <u>Biodiversity depletion is noticed through out the River Basin</u>

There are many causes such as,

- Obstruction of River courses
- Regulation and diversification of water flow
- Habitat destruction by human interaction.
- Loss of Riparian canopy cover
- Soil erosion
- Deforestation
- Flood in the downstream.
- Rampant clay and sewage accumulation in the river.
- Illegal sand mining.

Many of the medicinal plants like *Plumbago rossia, Azadirachta indica, Dalbergia latifolia, Podocarpus waluchiana, Gnetum uli, Gyngo biloba,* are all endangered. Now an alarming depletion in the native water plants also noticed with the invasion of Cabomba like weed plants in Pampa River. They are *Cabomba furcata, C. Aquatica, Eichhornia, Limnocharis flava, Salvinia mollusta*, and *Elodia.* The growth of all these plants is promoted by rampant clay accumulation due to human interactions. The illegal sand mining, deposition of sewage and the industrial and domestic effluents accumulated cause stagnation and deviation of water flow in the river. The direct fall of sunlight due to illegal cutting down of riparian vegetation promote the growth of invasive plants in the river. This results in depletion of biodiversity in the River water.

The present state of degradation of river systems in Kerala is due to high levels of human population and usage, including unplanned development pressures within the basin, degradation of watersheds, pollution, changes in hydrological regimes due to river water diversion and regulation, the ongoing mining activities for sand, clay and granite, and introduction of invasive alien species. Considering the biodiversity importance of the basin, especially due to the presence of a number of threatened fish species, there is a need to strengthen the capacity of organizations and people to develop sustainable livelihoods and manage wetland biodiversity resources wisely. At the river basin level, management planning are to be enhanced through a multi-sectoral approach, capacity building, and increasing public involvement. The information base needed to support sound wetland policy, planning and management decision-making will also to be strengthened.

At the local level, key sites have to be identified to demonstrate Protected Area System management planning and integrated community development. Recognizing that biodiversity information about the Pampa river is scattered among various institutions in public and private sector, there is also a need for developing a system of biodiversity overlays to provide a comprehensive planning and development tool.

To raise community awareness of wetlands issues, public meetings and campaigns should be better utilized to spread the awareness about the importance of protecting the ecological integrity of the river. In the unique situation of Kerala, local river conservation networks are to be developed with people's participation, using the capital money with the river management committees, with a stress on watershed based approach, linking biodiversity into river conservation programmes (*Dr. A. Biju Kumar, Dept.of Aquatic Biology & Fisheries, Kerala University)*

CHAPTER 4

ECOLOGY OF *CABOMBA*

Aquatic plants are valuable components of aquatic ecosystems that in most situations require protection. They provide cover, habitat, and food for many species of aquatic biota, fish, and wildlife. However, they can also limit certain water body uses. Too many rooted and floating plants can degrade water quality, impair certain fisheries, block intakes that supply water for domestic or agricultural purposes, and interfere with navigation, recreation, and aesthetics. In addition, noxious aquatic plant species such as Eurasian water milfoil can form dense populations that may pose safety problems for swimmers and boaters and can degrade wildlife habitat by out-competing native species or changing water chemistry (*Kathy.S. Hamel, 2012*)

The natural vegetations in Pampa Riverine Ecosystem is alarmingly replaced by the invasive species like *Salvinia molesta, Utricularia, Llimnocharis flava* and *Pistia.* Recently one South American invasive weed of international class 1 pest *Cabomba* dominated the entire water bodies in Kerala, especially in the Holy River Pampa. Natural vegetation in the River Pampa and its tributaries and distributaries are all replaced by the disastrous growth of *Cabomba furcata* and *Salvinia molesta.* Natural vegetations like *Nymphaea stellata, Nymphaea indica, Nelumbium, Potamogeton, Lymnanthemum, Polygonum, Jussaea repens, Ludwigia parviflora, Drosera peltata, D.indica, Eichhornia crassipus, Limnophila heterophylla, Pepparomia pellucida ,Hydrocotyle asciaticum,* and grasses like *Hygrorhiza, Arundinella villosa, Cynodon, Kyllinga, Panicum repens* and the algae like *Spirogyra, Chara* are all going to be vanished and replaced by the invaders like *Cabomba furcata* and *Salvinia molesta*. *Cabomba furcata* is so common in Kottayam and Pathanamthitta Districts, which cause toxicity in water and water dwellers like fish, *Pilaglobosa*, frogs, water snakes, snails and even centipeds and millipeds. Thereby food chains and food webs are all disturbed. Deficiency of Dragon fly and frogs cause multiplications of mosquitoes in the ecosystem which may reduce the populations of even the human beings. The diatoms are replaced by *Cyanophyceae* due to contamination of invasive weeds.

The growth of invasive species in Pampa River was promoted by rampant clay accumulation due to human interventions. The illegal sand mining, silting of river bank due to deforestation, deposition of sewage and accumulation of industrial and domestic effluents including plastics cause stagnation and deviation of water flow in the river. The direct fall of sunlight in the absence of canopies which is due to illegal cutting down of riparian vegetation, for the cultivation purpose of the modern farmers, promote the growth of invasive species in the river. There by depletion of Biodiversity together with monoculture formation of invaders results in the ruin of Pampa riverine eco system. Hence further growth of these invasive weeds should be eliminated by using appropriate methods. The total eradication of these weeds especially *Cabomba* is risky.

As an aquatic weed, *Cobamba* has a range of environmental, social and economic impacts. Generally aquatic plants are important parts of fresh water system, because they oxygenate water, provide shelter and habitat for fish and invertebrates and stabilize river banks and river beds. However dense strands of *Cabomba* cause many problems including:

- Increased resistance to flows, resulting stagnation of water and water pollution.
- Increased siltation, affecting bottom dwelling organisms.
- Degradation of water quality, thus increasing the cost of water treatment processes.
- Increased flooding.
- Blockage of pumps.
- Restriction of recreation and Boat races in the river.
- Swimming hazards.
- Displacement of native aquatic vegetation.

Cabomba is a small genus of aquatic plants originating in the neotropics and adjoining warmer temperate zones.

4.1. CABOMBA: REVIEW OF LITERATURE

4.1.1. Habitat

Cabomba is sensitive to drying out and requires permanent shallow water, usually less than 3 metres (but up to 10 meters) deep (*Australian Department of the Environment and Heritage, 2003*). It grows rooted in the mud of stagnant to slow flowing water including rivers and streams. It also grows in ponds, lakes, reservoirs, sloughs, ditches, and canals.(*WashingtonStateDepartmentofEcology,2003).*

It can respond to wide fluctuations in water depths and is a water column feeder that grows well in silty substrate and exhibits reduced vigour in hard substrates. It may be found that the growth of 50 mm a day has been reported in Lake Macdonald in Queensland, Australia. It grows well in high nutrient environments with low pH, but in more alkaline waters it tends to lose its leaves. High calcium levels inhibit growth and unlike other aquatic weeds, *Cabomba c*an grow well in turbid water. It prefers a warm, humid climate with a temperature range of 13-27ºC but can survive when the surface of the water body is frozen (*Australian Department of Environment and Heritage 2003).*

4.1.2. Centres of Origin

Cabomba originated in South America, and is widely naturalized in the south-east of the USA. It has become a weed worldwide, infesting body of water in climate ranging from tropical to cool-temperate. It is considered as a serious weed in the USA, China, Canada, Australia, Netherlands, Japan, India and is present in South Africa, Hungary and the United Kingdom.

In Australia, The National Weeds Strategy Executive Committee classified *Cabomba* as a Weed of National Significance because of its impacts on the biodiversity and function of freshwater and riparian ecosystems, on water quality, water storage and distribution infrastructure, and on recreational and amenity values (*Mackay A.P and Swarbrick J.T, 1997*).

4.1.3 Physical characteristics

Cabomba is a completely submerged aquatic plant, except for its emergent flowers and occasional floating leaves.

a. Stems

The soft branching stems can be up to 10 meters long but usually range up to 5 meters. Stems can be olive green to reddish brown and are often coated with a mucus-like secretion. They are slightly oval-shaped in cross-section, and 2 to 4 millimeters in diameter. Stems can have scattered, short, white or reddish-brown hairs. Up to 40 stems can arise from a single root mass. Stems are fragile and break and decay quickly. Thicker stems can lie prostrate and become partly buried in sediments. These are often referred to as rhizomes (underground stems bearing shoots and roots) but are not true rhizomes, and they sometimes have small, opposite leaves. Under the water, the stems and their leaves can have a tubular or columnar appearance.

b. Leaves

The submerged fan-shaped leaves generally occur in opposite pairs along the stems on leaf stalks approximately 1 centimeter long. However, leaves can also occur in whorls of three. The leaves are finely dissected, giving the characteristic feathery, fan-like appearance. Individual leaves can have up to 200 divisions each, with a combined diameter of approximately 5 centimetres per leaf. The leaves secrete gelatinous mucus that covers the entire plant. Narrow floating diamond-shaped leaves (5 to 20 millimeters long and 1 to 3 millimeters wide) may be produced during the flowering period. They occur alternately along the flowering stems and have a firmer texture than the fan-shaped leaves. These usually occur in groups at the tips of flowering stems and are attached to the stems by a leaf stalk from their undersides.

c. Flowers

Single flowers are raised 1 to 4 centimeters above the surface of the water on stalks. They are approximately 2 centimeters in diameter and can be milk-white, pale yellow or purplish (usually white petals with yellow centers). The flowers have three petals and three sepals, giving the appearance of six alternating petals. Flowers are short-lived, emerging from the water only for 2 days and only during the day, receding back into the water and closing overnight. Flowers open by mid-morning and begin to close and recede by late afternoon.

The raised flowers are often the main visible signs of a *Cabomba* infestation; infestations are most commonly found during periods of flowering in the warmer months. In a well established infestation, plants can produce up to 50 flowers per square meter each day.

d. Seeds

Cabomba in Australia is not known to produce viable seed, with the exception of the infestation in the Darwin River in the Northern Territory. Although flowering occurs throughout Australia, viable seed production has not yet been observed outside this infestation. Seeds have been produced in some other infestations but have not yet been observed to germinate.

The perianth encloses the fruits and in a few days, the anthocarp becomes submerged due to the recurvation of the pedicel. The fruit break away from the plant and fall to bottom, decompose and leave the seed at the bottom of the river. The perianth persists until the seeds are released after 14-30 days of anthesis. The seed is green when fresh with a scattered dark pigmentation and slowly turns brown. Globose to ovoid- oblong seed with slightly flattened ends. The seed anatomy is similar to Nymphaceae with abundant perisperm, little endosperm, a hostorial tube and a small dicotyledonous embryo and the embryo remains viable up to 8 hours, if allowed to desiccate

(*Schneider and Jeter, 1981*). The seed remains viable for more than two years and the germination is affected by red light, high carbon-dioxide concentration and temperature. The seed viability is 25% and immediate germination is only 5% (*Sanders, 1975 in Lousiana*). Seeds germinate after 5-10 weeks of fertilization (*Tarver and sanders, 1977*).

e. Seed setting

Seed setting is affected by the climate and environment in *Cabomba* species (Schneider and Jeter, 1982). In Australian plants, seeds are not at all reported. Flies were seen to carry pollen after taking nectar. The changes in morphology during flower development ensure that pollen is transferred from the anthers of two days old flowers to the stigma of one day old flowers. Only fertilized flowers were pulled under water by the peduncle. Flowers not dehisced on the second day are pulled under water, but become water logged and do not release pollen. Abscission of the fertilized flower is prevented by the secretion of the ovary and transported down the peduncle, which is thought to protect carpals from being broken from the peduncle by fish and severe water currents.

f. Roots

Cabomba plants have shallow fibrous root systems made up of numerous long, slender, branched roots. Roots are initially smooth, white and un-branched, becoming branched and dark brown or black with age. When the roots are young their colour can be closer to purple.

Roots can form at any node on attached and free floating stems, without the need for contact with a substrate. Nodal roots are thin, white and un-branched, and they can be up to 24 centimetres long. *Cabomba* does not take root very deeply, and its lack of strong roots limits its distribution to slow-moving waters.

4.1.4. Variation within the species

Cabomba can exhibit a high degree of physiological variation. Shoot colour, leaf size and leaf shape are strongly influenced by environmental variables such as water quality, nutrients and light availability. Plants in shade tend to be green to olive green. Plants growing in nutrient-rich water may have larger leaves. Plants exposed to full sun can have smaller leaves and be reddish.

4.1.5 Reproduction

In Australia, reproduction of *Cabomba* is mostly vegetative (i.e. the plants reproduce when stem fragments break away and take root in a substrate).

a. Vegetative reproduction

Cabomba can reproduce vegetatively by fragmentation or through the production of daughter plants (i.e. by clonal reproduction). A stem fragment capable of reproduction is called a propagule (any part of a plant capable of producing new plants). Any stem fragment that includes a node (pieces as small as 1 centimetre) can grow into a new plant. Stems break up easily when disturbed, and fragmentation also occurs naturally at the end of the growing season. Disturbance (e.g. by outboard motors) can break the stems into thousands of individual propagules, all capable of spread and reproduction. Anything that moves through an infestation (fishing gear, traps, humans, animals) can create large numbers of propagules.

Clonal reproduction occurs when plants lose buoyancy in autumn and winter, causing the stems to sink to the bottom. At this point stems can break down into small pieces, some of which remain viable and re-grow the following spring. Alternatively, the growing tips can take root in the substrate, producing new daughter plants. The connecting stem then breaks down. The many stems present in an infestation make vegetative reproduction prolific and allow *Cabomba* to be a highly invasive species that can rapidly colonise an entire water body.

b. Reproduction by seed

There is much uncertainty surrounding *Cabomba* seed production, seed viability and germination. Seeds are thought to be capable of dormancy, but conditions for germination are not yet known, although early studies have suggested that seeds dried and stored have a much higher germination rate (75%) than those kept moist (25%). This suggests that drying is a germination stimulant and could indicate that seeds are a means of overcoming fluctuating water levels or seasonal lack of water (e.g. in ephemeral water bodies), which would not support vegetative reproduction. Other studies have shown that desiccation over a 9-hour period kills seeds.

4.1.6. Spread

Stem propagules are easily spread, as they float on the water surface. Seeds do not float and are not moved as easily away from the parent plants. Propagules can be transported on fishing equipment, watercraft or animals. Individual stem fragments dry out very quickly (plant material rarely remains viable for more than 24 hours in dry conditions), but large bunches of stems that remain attached to boat trailers, fish or eel traps, nets or propellers are more likely to remain moist and therefore carry a viable propagules from one waterway to another. Stems in contact with moist soil can remain viable for weeks; even in hot or dry conditions. Seeds are thought to die when ingested by animals or birds.

The third method of spread through a waterway is the clonal production of daughter plants. Plants are able to colonize deeper water this way. The mother plant continues to deliver nutrients to the daughter plant through the attached stem until the daughter plant has grown into the photo zone (i.e. the zone where enough light is penetrating the water for plant growth to occur).

4.1.7. Seasonal variations

In tropical climates *Cabomba* grows and flowers seen throughout the year and plants remain upright in the water column. In subtropical climates plants stop flowering during the winter months, lose buoyancy, and sink down below the surface, although plant mass and abundance do not decrease. Growth can continue during mild winters.

In temperate climate, *Cabomba* sinks back to the substrate and completely fragments during winter, leaving stem fragments and root masses with only a few centimeters of stem attached. It can then grow rapidly back to the surface (from buds on fragments or root masses) with the beginning of the warmer weather.

4.1.8. Growth rates

Cabomba is considered to be fast-growing in ideal conditions. Growth rates of 5 centimeters a day have been recorded in Queensland. Growth rates increase with increasing light, temperature, nutrients and dissolved inorganic carbon.

Growth rates can decline over 27 °C because of increasing respiration levels at these temperatures.

Cabomba plants assume different habits at different depths. Occurrence of leaves along the stems, plant size, and plant population density are all affected by the depth of the water. The greatest biomass is found in water 2 to 3 metres deep. Plant size has been found to increase with water depth to 3 metres and then decline. Plant population density decreases with water depth.

4.1.9. Conditions for growth

In its introduced range, *Cabomba* has the ability to tolerate much more extreme conditions than it is adapted to in its native range. In Australia the environmental factors that appear to have most effect on the abundance of *Cabomba* include substrate type, water flow, water turbidity, dissolved carbon dioxide and pH. *Cabomba* can tolerate low light intensities.

Water depth, flow, turbidity and light availability

Cabomba grows well in slow-moving water, but it prefers bodies of permanent standing water of less than 4 metres depth. Rooted plants have, however, been observed at depths of up to 6 metres in Australia. It is often found along the margins of deeper water. Depth is the main environmental variable affecting *Cabomba* growth, the limiting factor being light availability.

a. Climate

Cabomba prefers a warm-temperate, humid climate with rain throughout the year. Its optimal temperature range is reported as 13-27 °C, although it can survive under ice in frozen lakes in temperate climates (Ontario, Canada). Air temperatures in these conditions drop below 0 °C, but water temperatures under the ice remain above 4 °C. The preferred mean annual temperature is described as 15-18 °C, although infestations in Canada survive a mean annual temperature of 6 °C.

b. pH

Cabomba occurs in both acid and alkaline waters, but the optimum pH for growth is 4 to 6, with growth inhibited when pH reaches 7 to 8. Above pH 8, the stems lose their leaves and growth is inhibited. The better growth in acidic waters is possibly caused by greater availability of nutrients in acidic conditions. Most freshwater bodies in Australia are considered to be slightly acidic, with average pH levels in the vicinity of 6.0 to 7.0.

c. Substrate type

Cabomba prefers areas with fine and soft silt sediments, and it tends to be less vigorous on sand or stony bases. On clay or sand substrates the thin roots struggle to hold the plants in place. In Australia *Cabomba* is less aggressive where it is growing on hard or stony substrates. In lakes with hard clay substrates, *Cabomba* will occur in depressions where layers of sediment have accumulated.

d. Nutrients

Cabomba grows well in nutrient-rich waters. It can also grow very well in water with very low calcium ion concentrations (more than 4 ppm of calcium inhibits growth).

Early experiments have shown that shoot sections of *Cabomba* take up much more phosphorus than root sections, suggesting that nutrient uptake occurs directly from the water through the shoots (*Elissa van Oosterhout, Cabomba Control Manual 2009*).

4.2. CABOMBA IN INDIA

Three common species of *Cabomba* seen in India are *Cabomba caroliniana, C. aquatic* and *C. furcata. A study held in Gujarath, revealed that, Cabomba aquatica* has been found for the first time in India. Both, submerged and floating leaves are epistomatic. The stomata are anomocytic and perigenous in their development. The metaxylem vessel elements have simple perforation plates and spiral side wall thickening. Vessel elements are found in roots, rhizomes and aerial stems. The venation pattern is of two types like the dimorphic leaves. On the basis of these and other features *Cabomba* deserves family rank.

C.aquatica is a perennial herb with heterophyllous petiolate leaves. Submerged leaves repeatedly dichotomously divided into 60-150 segments and aerial ones are entire, peltate, ovalor slightly cordate. Flowers solitary on long peduncles, regular hermaphrodite with six stemens and two or three carpels. (*J.A Inamdar and K.M Aleykutty, 1979*).

4.3. TAXONOMY OF *CABOMBA* IN KERALA

Cabomba, is generally known as fanwort is a submerged, sometimes floating, but often rooted, freshwater perennial plant with short, fragile rhizomes. The erect shoots are upturned extensions of the horizontal rhizomes. The shoots are grass green, olive green to reddish brown. The leaves are of two types: heterophyllous with highly dissected submerged leaves and anchor shaped floating leaves. The submerged leaves are finely divided and arranged in pairs on the stem. The floating leaves, usually seen along with flowering scape. They are linear and inconspicuous, with an opposite arrangement. They are less than 1/2 inch long and narrow. The leaf blade attaches to the center, where there is a slight constriction. The flowers are pink and small (less than 1/2 inch in diameter), and they float on the water surface.

C.furcata is an extremely perennial and competitive invasive weed with pink flowers and pinkish green stem, which is fleshy, branched and mucilaginous. It is heterophyllous and the anchor shaped floating leaves are visible only during flowering season amidst the inflorescence. The submerged leaves are dissected to resist the pressure exerted by the water currents. The flowers are auxiliary and solitary. Pedicels 5-6 cm long, fleshy and pinkish green; sepals 6 in number, pink coloured and1.5 cm long. The petals are three in numbers and oblong (1.5-2 cm long), pink in colour but, yellow at base. The inner tepals bearing nectories indicating insect-pollination. Stamens 6 in number, short (0.2-0.5 cm), alternate to petals and attached to the base of carpels. Gynoceum consists of 3 apocarpous pistils (0.5-0.7cm long) and ovary superior (3 mm long) and style very short and stigma capitates and hairy.

Similar findings observed (*Sreedevi B and Binojkumar M.S, 2003*) in a study of wetland flora of Alappuzha Disrict at Champakkara. There is a great deal of vegetative similarity among the taxa, making the genus taxonomically difficult (*Orgaard, 1991*).

A detailed study revealed that the *Cabomba* seen in Pampa riverine System is *Caboma furcata* with pink flower and pinkish green stem. *Cabomba* is closely related to *Nymphaeaceae*, sharing with several characters like, rhizomatous, perenneal stem, peltate, involuted leaves with palmate secondary veins and may be heterophyllous at times when flowering occurs and the flowers are solitary with apocarpous pistils. Only fertilized flowers were pulled under water by the peduncle. Those flowers which do not open on the first day, contract into the water, the next day and pollen grains are in-dispersed. Abscission of the fertilized flower is prevented by the secretion of the ovary and transported down the peduncle, which is thought to protect carpals from being broken from the peduncle by fish and severe water currents.

The family has an extensive fossil record from cretaceous with plants that exhibits affinities to *Cabombaceae* are aquatic, living in still or slow moving waters of temperate and tropical North and South America, Europe, Asia, Africa and Australia and even India, in Kerala State. Although found on all Continents, the plants tend to go in relatively restricted ranges (The family is part of the order *Nymphaceae*, which is one of the most basal flowering plant lineages) (*Else Marie Friis, 2011*). But the family is recognized as distinct in the Angiosperms phylogeny group III system (2009) of aquatic, herbaceous, flowering plants *Cabombaceae* in the *Botanical Journal of Linnean Society*. *Cabombaceae* consists of two genera viz, *Brasenia* and *Cabomba* with many species.

Under suitable environmental conditions it forms dense strands and crowds out previously well-established plants. Once established, this plant can clog drainage canals and freshwater streams interfering with recreational, agricultural, and aesthetic uses (*The Washington State Department of Ecology 2003*). It can also have an impact on native animals in northern Queensland platypus and water rat numbers are lower in infested creeks. It can significantly reduce water storage capacity and taint drinking water supplies. Water treatments costs can be increased by up to $50 a mega litre (*Australian Department of the Environment and Heritage 2003*).

4.4. METHODS

4.4.1. Field visits

Several visits were conducted to the study locations of Pampa River during 2013-14 and surveys on the aquatic and terrestrial flora and fauna are made seasonally.

Sites of Observation are,

a. Aranmula Sathrakadavu, Patteril kadavu, Parappuzha kadavu
b. Nalkkalikkal Koottathodu and Kozhithodu,
c. Kozhipalam, Anjilimoottil kadavu
d. Poovathur ,Koipram, Kizhavara kadavu
e. Ikadu thodu, Chengannur Kallissery, Prayar, and Umayattukara.
f. Mannar, Naakkada, Mangalam Kadavu, Kurattissery, Kuttamperoor, Budhanoor
g. Veeyapuram, Thuruthel kadavu, KSRTC Bus Depot of Edathua, Vaikathillom.
h. Kidangara, Vezhapra, Ramankary AC canal.

4.4.2. Analytical methodology

a. Vegetative Analysis

As per ecological methods for population, extensive investigations were carried out and the sampling transects of *Cabomba* encountered for their dominance in all transects. Fragments of the plant collected from the original invasion site was tested for survival in artificially made environment.

Plant fragments with rhizomes collected from the river were planted in a mixture of mud and river sand taken in buckets and beakers and the changes noted, every day. Two sets of experiments were set up; one is exposed to the sunlight and the other in the shade to notice the impact of sunlight on the growth of the plant.

b. Chemical Analysis

Cabomba samples collected are tested for heavy metals like Copper and Lead at Cochin Test House, Kochi. 25 grms of each *Cabomba* samples 1, 2 & 3 were weighed as Root, Stem and leaves and the samples are made up volumes to 25ml each in nitric acid and tested for copper and lead as per APHA method 22nd Edn. 3111B. The instrument used is Atomic Absorption spectrophotometer (AAS), Make Thermo Scientific Model 303, NIST traceable reference standards were used for calibration of the instrument. Copper measured at a wave length of 324.7 nm and Lead at wavelength 217.00 nm.

c. Effect of Weedicide

The effect of weedicide is tested on *Cabomba* based on conventional petridish analysis with standard Glyphosate in different concentrations of 20%, 40%, 60%, 80% and 100%. A single node of the plant with leaves was selected for each petridish. Each node of plant was placed on a Filter paper in each plate and wetted with 41% Glyphosate in various concentrations, every day. Changes noted for 21 days and the results were tabulated. Physico-chemical and bacteriological analysis of the river water from the study area were also carried out and results were tabulated.

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4.5. RESULT AND DISCUSSION

4.5.1. Vegetative Analysis

a. In **Aranmula streach** especially at Sathrakadavu, *Cabomba* plants were seen near river banks where the soil was muddy in nature. The muddy substratum helps the plant to attach firmly towards it. It was clear that the river beds with mud enhance the growth of the plant.

Physical characteristics: The **stems** were soft branching, reddish brown in colour, 2 to 3mm in diameter, and having a mucous surface. Most parts of the stem were submerged in the water. Underground stems bearing roots were observed. Group of stems along with mud together gave a turbid appearance to the water.

Two types of **leaves** were observed in flowering plants. The submerged fan like, striated leaves arranged in opposite pairs on the stem. The leaves were finely dissected and gave a feathery appearance in water.

The floating leaves were anchor shaped and appeared only during flowering season.

The **flowers** were found as fleshy in nature. Sepals were pinkish, having yellow base and six in number. The flowers were found fully opened only after 11 o' clock in the morning. **Seeds** were not seen.

The **roots** were firmly attached to the substratum and fibrous in nature. They were slender, and branched. Roots were seen at any node or attached to the stem. Nodal roots were thin.

Habitat: In Aranmula region comprising Sathrakadavu, Patteril and Parappuzha kadavu, the nature of water and the soil composition was found so suitable for the growth of *Cabomba* .It was seen that a high degree of pollution over here. Plastics and decayed wastes were seen floating over the water. It may due to the presence of high degree of contamination; the vegetative growth of *Cabomba* over here was very abundant. Organic and inorganic nutrients absorbed from these wastes may be the main source of existence of the plant.

The soil composition was found as muddy in nature, where the growth is flourished. This composition of substratum gave the plant a strong physical support.

Another major observation was the influence of direct sunlight. Places where the riparian vegetation was less and a direct entry of sunlight into the water surface, greater was the growth of this plant.

In Aranmula Sthrakadavu, Patteril and Parappuzha kadavu shaded area showed a less mass of the growth than that of light-exposed. The direct fall of sunlight enhances the plant's photosynthetic capability and the growth rate. The exposed plants were found with more shiny, healthy and fully opened flowers.

Propagules of the plant were seen floating over the surface. This may be the way of reproduction. They may settle, in a new location, where a suitable substratum is available and will develop into a healthy plant.

***Cabomba* and its associates:** *Cabomba* plants were seen in association with *Lymnocharis flava*, another invasive weed found commonly along Pampa river. *Salvinia,* also noticed in Parappuzha kadavu.

Seasonal variations: During summer, (April and may), healthy, flourished growth was seen in these areas. Summer season supported the vegetative growth, flowering and reproduction of the plant.

Heavy rain during June, July and August mask the plant as the river overflowed. Heavy rain brought a heavy load of mud from the upper region and sedimented over the Aranmula region of River Pampa. So the reappearance of the plant did not notice after the rain, during September to December.

In summer, (January and February), even though the safest time for *Cabomba*, they did not mark their presence in Aranmula streatch. the water level in the river became very low and a sandy loom appeared in the midst of the river. It is very dominant in Patteril kadavu. Muddy bottom never showed the signs of *Cabomba* growth. This disappearance may be due to the heavy deposition of mud during the rainy season.

b. At **Nalkkalikal, Kozhithodu** and **Koottathodu**, the plant species were found abundantly spread over the surface of water. The water flow over these sites is slow and this might be the reason for flourished growth. The stagnancy of the water helped in retention of nutrients in water and can be easily absorbed by the plant. The accumulation of humus and rampant clay due to the decayed plant parts, domestic effluents including plastics cause pollution and the stagnant water, which facilitates the growth of these weeds.

The depth of the stream was found favorable here, for the plant growth. The river is shallow over here and muddy in nature. Both helped the vegetative growth of the plant.

Physical characteristics: Stems were longer than that seen in Aranmula. 2 to 3 mm in diameter, and seen as fleshy and healthy. Group of stems appeared dispersed over the water surface. **Leaf** morphology is striated and arranged oppositely on the stem. **Flowers** were pink in colour, and yellow at base of sepals. **Seeds** were not fond. Roots were fibrous and strongly attached to the bottom mud.

The abundance of these weeds causes hindrance to recreational activities and even for drinking water needs. The river water is seemed to be highly polluted and could not be useful for the irrigation purpose.

During summer, heavy growth of the plant was seen over here. Flowers of *Cabomba* and *Nymphacea*e together gave a beautiful appearance in this area. *Cabomba* plants were seen attached firmly in the bottom mud and the areal parts of the plant dispersed over the water surface.

Associates of *Cabomba:* *Lymnocharis flava, Nymphaea stellata, Salvinia molesta* were another allied species found along with *Cabomba,* in these region. In Nalkkalikkal and Koottathode region, the growth of all these allied weeds was seen healthy and abundant. All the three species had flowers also.

Seasonal variations: During pre- monsoon, (April-May), the growth was good and flowering and reproduction stages were observed. During Monsoon, the whole growth submerged in water, and reappeared after monsoon with full strength. In December, the propagules of the plant reappeared and started to establish in the muddy bottom.

In January and February the flowering plants again seen all over the water surface.

c. At **Anjilimoottil kadavu**, where Kozhithode meets Pampa, another plant Typha was noticed. *Cabomba* plants were noticed along with *Utricularia, Eichhornia crassipus,* and *Limnocharis flava.* All these alien weeds seen *amidst Cabomba* near the bank. Here the muddy bottom of the river was very clear where the plants rooted very firmly. Fragments of plants were seen on the surface of water. Here the growth of these invasive plants was reported to obstruct the journey across the water. Local people considered this plant as nuisance.

In **Kozhipalam**, a slow flow of water was observed and fragments of the plant were seen floating through the water. The riparian shading over some areas of the river made a hindrance to the spreading of the plant.

Physical characteristics: Vegetative growth of the plant, showed healthy and striated **leaves**, attached to the fleshy, mucilaginous **stems**. The stems were intertwined and entangled with mud along the shore of the river. The **flowers** were found as pink and its morphology is same as that of other sites. The fibrous **roots** and thin nodal roots were found to be very helpful in attachment. Seeds were absent and propagules seen as floating over the water. The plants in the shaded areas of river, exhibited a slower growth rate than that of exposed to direct sunlight.

Associates of *Cabomba:* *Salvinia mollusta, Hydrilla, Utricularia, Potamogeton etc* were seen along with *Cabomba.*

Seasonal variations: In April and May, flowered plants along with other allied plant species seen over these areas. The growth seen in muddy river bank and very less in part of the river, where the water is flowing continuously. The flowing water thus an obstruction to the plant attachment and growth. The growth vanished during heavy rain and reappeared during the month of December. But the growth is not abundant as before the monsoon. Groups of plants seen, mainly towards the bank of the river, during January and February. The flowers were also observed.

d. At **Poovathur** and **Koipuram**, the growth pattern of *Cabomba* is seen as groups and not flourished. The groups of growth seen mainly towards the river bank. The soil character, here also found as muddy.

Physical characteristics: Groups of growth with fleshy, long **stems** along with fan shaped **leaves** were seen. The flowering plants showed two types of leaves, submerged and floating. The **flowers** were pink, with six sepals and **seeds** were not seen.

Slow flowing water, over here was helpful in the growth and attachment of the plant. Spreading of the plant biomass was noticed as very fast. Water pollution over these areas was another reason for spreading of the plant. Plant could be easily intake the micronutrients from the polluted water.

Associates of *Cabomba:* *Cabomba* plants were seen in association with *Salvinia molesta* and *Hydrilla verticulata and Nymphaeceae* here. All the three plant species prefer stagnant or slow flowing water.

After monsoon, isolated growth was seen along the river and flowers were not common.

Seasonal variations: During April- May groups of growth seen floating the water surface. Flowering plants were common and the flowers opened in the intense light. In June, July August and September, rain water masked the growth and even in November and December, they did not come back. In January small groups of plants appeared over water in certain locations. In other areas, heavy deposition of flood materials made a hindrance to the retrieval of the plant.

e. At **Kallissery**, **Chengannur** and **Ikkadu** region, heavy growth was seen. In these regions, waste disposal into the water is the major factor, which helps in the flourished growth of the plant. The nutrient content in the organic wastes, disposed into the water helped *Cabomba* to grow luxuriantly.

Physical characteristics: Heavy growth of plant was observed in these regions, especially in Ikkadu thodu. Ikkadu stream was heavily filled by this plant and the water flow was strictly obstructed. The still water and heavy load of nutrient over these areas enhance the growth of plant.

The water level is too low and the muddy substratum was also available for the alien weed. The plant parts such as **leaves**, **stems** and **flowers** were found as smaller in size, when compared to other sites. But growth and total mass were seen as abundant. The morphology of the plant parts was same as that of the others.

Associated plants: *Eichhornia crassipus, Limnophila heterophylla* were seen in associated with *Cabomba.*

Seasonal variations: During summer months (April-May), heavy growth seen due to the low water level and high degree of pollutants. Monsoon drastically changed the situation. During rain, as usual the plats were not seen. Post- monsoon months showed turbid water along the stream and the plant growth was significantly reduced. A heavy mud deposition in the river was responsible for the reduction in the plant growth.

Turbidity is a major factor which determines the quality of river water. After Monsoon season, these areas showed heavily turbid water without *Cabomba* growth. But during January and February, growth again appeared as groups along the river.

f. **Mannar, Pannai Kadavu, Nakkada, Mangalam kadavu, Budhanoor, Kurattissery and Kuttamperoor** : Mannar, Pannai regions showed less abundant growth, whereas in Nakkada, no growth seen. In Kuttamperoor, Budhanoor and Kurattissery, heavy growth was observed during April and May.

Physical characteristics: Nakkada is the only sterile place without any invasive weeds, among the Parumala region of Pampa. In Kuttamperoor, Budhanoor and Kurattissery, heavy growth was observed along with other allied species. These entire regions showed healthy plants with fan shaped **leaves**, arranged oppositely on the mucilaginous **stem**. Peripheral and submerged leaves were seen. The **flowers** were pink in colour and yellow at the base of the sepals.

Seeds were not observed. The **roots** were fibrous and attached to the muddy substratum. Nodal roots also identified.

Major Associates: Groups of growth observed in Mannar region and associated with *Salvinia molesta, Hydrilla, Utricularia, Eichhornia, and Nymphaceae.*

Seasonal variations: Well flourished growth seen all over the water surface in all these regions, except Nakkada during April and May. The heavy rain had a negative effect on the plant growth during monsoon. During post monsoon, in December, the plant retrived with full strength especially in Kuttamparoor and Budhanoor.

In Kurattissery, Kottakkal kadavu, the river was cleaned up by MNREGS program but regeneration from the plant fragments gave way to re-establishment of the plant. Groups of plants were seen at either bank.

g. In **Edathua, Veeyapuram, Anaprambal** and **Vaikathillam** – Here the impact of saline water on the growth of *Cabomba* was clearly seen. Veeyapuram region showed the particular phenomenon. The negative effect of salt water on the vegetative growth on this invasive weed can be used as a measure of management. But the viable fragments remained in the mud, which possess the potential for regeneration.

Physical characteristics: In Veeyapuram, Thuruthel kadavu, the plant growth was noticed as not in healthy condition. This may due to the negative effect of salinity of water, entered into the river, every year. Some fragments of the plant were seen floating on the water surface. The **leaf** morphology was striated and fleshy. The **stem** fragments were purple-green coloured and having 1-2 mm diameter. **Flowers** were less in number. The solitary flowers bearing fragments showed two types of leaves, peripheral and submerged. Nodal **roots** were present at each node of the floating stem. Cabomba plants cannot withstand salinity more than 2 ppm.

But in Edathua, Anaprambal and Vaikathillom healthy plants were observed throughout the year, except the rainy season. Fleshy, pinkish green stems with nodal roots were seen. The fan like leaves abundantly scattered. A bed of healthy flowers flourished on the water surface. In all these locations, waste dumping was a common phenomenon. These organic materials act as the carbon source for the plant.

Major associates: Plants of Nymphaceae family were flourished along with *Cabomba* over here. *Salvinia* and *Eichhornia* species were also noticed.

Seasonal Variations:

In Veeyapuram, *Cabomba* plants were not visible due to the entry of saline water into the river during April and May. But after flood, it reappeared. Fragments of the plant floating on the surface of water were seen. Actually the rhizomes of the plant is deep buried and perennate in the bottom mud, and reappear when flood comes which reduce the salinity.

During January and February, *Cabomba* was seen with flowers over here. Number of flowering plants was very low, as they regenerate after a struggle with salinity of water.

Other locations showed flowering plants in summer (April-May). Heavy rain masked the plant during monsoon. In post- monsoon, the plants reappeared with full strength.

h. In down steam area, like **Ramankary AC canal, Vezhapra and Kidangara**, abundant growth of *Cabomba* seen along with flowers. Salinity of the water here also affects the plant growth negatively. But during the last year, the entry of saline water was not noticed.

Physical characteristics: Healthy plants with pinkish flowers seen on the water surface. The **stem** was found as purplish green and fleshy. The **leaves** attached to the main stem were found as striated and greenish pink in colour. Achor shaped peripheral leaves seen along with pink **flowers**. Nodal **roots** were present. The roots helped in the strong attachment of the plant towards the muddy bottom.

Associates of the plant: In Ramankary AC Canal, The growth of *Cabomba* was seen in association with *Eichhornia* species. *Salvinia molesta* were also found along with the plant.
Seasonal variations: April and May enhanced the growth of *Cabomba.* During June, July and August (Monsoon) the river overflows with the heavy rain and most of the weed plants submerged and were not visible. The effect of heavy rain lasted upto December and the plants never seen on the water surface. In January, these weeds reappeared; however flowering could be seen only in February..

The aesthetic beauty of December - February predominantly noticed in the River Pampa with the purple coloured blooms of *Cabomba furcata* amidst the yellow flowers of *Limnocharis flava,* and the bluish cover of flowers of *Eichhornia crassipus* added a feather to the beauty of the River.

The Dipteran insects like *Drosophylla melanogaster*, Mosquitoes like *Anopheles, Culex*, Centipedes, Millipedes, frogs, snails like *Pila globosa*, Aphids, Moths, various bacteria and Cyanophyceae members of Algae Anabaena, *Scenedesmus, Pinnularia*, centipeds, millipeds, and frogs and water snakes and certain fish were seen amidst the blooms of *Cabomba* and allied plants throughout the river Pampa.

Kuttamperoor, Kozhithdu, and Vaikkathillam were the three places where the abundant and vigorous growth of this alien plant observed. In all the three sub-streams of Pampa, the growth of native plant species was outcompeted by *Cabomba.*

The management of *Cabomba* is a serious concern, because even a small fragment leaving behind after physical removal, will flourish easily within a few months. Definitely it is sensitive to some of the chemical treatments, but we cannot implement any of the chemicals into a riverine system.

Growth of *Cabomba* in artificial environment: *Cabomba* plants collected from affected areas of Pampa Riverine system were evaluated for changes in the environment artificially created. Vegetative part plucked from the mud was planted in beakers and buckets layered with river sand and mud.
Effect of sunlight also evaluated.

It was found that the plant fragments with roots and nodal roots survived in beakers with sand and mud for one month. The leaves and stems were found as healthy.

Major observations are,

- Plants in Beakers were found healthy for one month, whereas those planted in buckets, lasted only for three weeks. Surface are of the vessel thus affected the growth and survival of the plant.
- Plants exposed to sunlight were shiny and healthy than those kept in shade. Photosynthetic activity of the plants triggered by the direct sunlight than the scattered light in the shade.
- Flowers remain healthy and shiny for four to five days in different segments. They opened during the mid day and the flowers in the shade opened slowly than that in the sunlight.
- Seeds were not identified in the mud.

4.5.2 **Estimation of heavy metals in *Cabomba* samples.**

The accumulation of heavy metal Lead content is significant in the leaves of *Cabomba furcata* whereas it is non-significant in the Root and shoot–stem hence the Lead toxicity is noticed only in the leaves of *Cabomba furcata* samples as the toxicity detection level is 0.05ppm.

Estimation of Heavy metals in *Cabomba* Samples

Metal Detected	Sample 1 Root (in ppm)	Sample 2 Shoot (in ppm)	Sample 3 Leaf (in ppm)
Cu	0.12	0.10	0.43
Pb	BDL	BDL	0.23

Table 4.1

However, the toxicity for Copper is presenting all the 3 samples of *Cabomba* tested. Hence the whole *Cabomba* plants are more toxic with copper toxicity rather than that of Lead. These results are in agreement with the findings of Anderson (2000) in *Cabomba caroliniana.*

4.5.3 **Effect of weedicide on *Cabomba* growth**

Effect of the weedicide, Glyphosate (41%) in different concentrations (20%, 40%, 60%, 80% and 100%) was evaluated for a period of 21 days. The plant fragments started responding to the chemical within two days. In T5 plate the wilting was very clear within 48 hours. T1, T2, T3 and T4 showed a gradual response with respect to the concentration of chemical.

The plant fragments in all plates (except T0) gave a result of complete wilting within 15 days of experiment. Each fragment absorbed the chemical from the fitter paper. The shoot and leaves were becoming yellowish, may be due to the loss of chlorophyll content. The high concentration plates were more affected and a colour range from green- yellow-pale yellow-creamish white was observed during 15 days of observation. The control plate remains same.

The leaves were detached from the shoot system and seen separate in the plate. The plant nodes became weaker and weaker as days gone and this might lead to the detachment of leaves from the shoot. Both the plant parts degenerated and lost its consistency.

No. of Plants survived out of 10 in each petridish											
Control To	0%	10	10	10	10	10	10	10	10	10	10
Treatment T1	20%	9	9	9	9	8	9	9	9	8	8
Treatment T2	40%	7	6	7	7	7	7	7	7	6	7
Treatment T3	60%	4	3	4	4	3	4	2	4	4	3
Treatment T4	80%	2	2	2	2	1	2	2	1	2	2
Treatment T5	100%	0	0	0	0	0	0	0	0	0	0

Table 4.2

The effect of all the treatment levels viz. T1, T2, T3 and T4 showed a survival percentage of 87%, 68%, 35% and 18% respectively whereas the treatment level of 41% Glyphosate is effective in controlling the weed *Cabomba* with a survival percentage of zero. Hence Glyphosate can be used as a weedicide in small infested areas of Cabomba in Pampa River and its allied water bodies. Similar findings observed in Cabomba Caroliniana by Mackey A.P., 1996.

Biological control with weevils like *Hydrotemetis natans* are found to be more effective in controlling this invasive weed. The herbicidal treatment with the agri-crop rubber vine spray in water applied to underwater stems through submerged nozzles on hand held or boat- mounted booms is found to be effective in controlling *Cabomba.*

4.6. SUMMARY AND CONCLUSION

Alarming depletion in the native water plants also noticed with invasion of Cabomba like weed plants in Pampa river. They include *Cabomba furcata, Cabomba aquatica, Eichhornia, Limnocharis flava, Salvinia molesta, Ceratophyllum, Elodea* etc. They are all promoted by Rampant clay accumulation due to human interactions through illegal sand mining, deposition of sewage and the domestic and industrial effluents. The river flow become slow down and stagnant water with bright sunlight devoid of canopies due to cutting of the riparian vegetation for land use promote the invasive plant growth in the river. This cause depletion of biodiversity in the river and allied water bodies too.

Many of the medicinal plant like *plumbago rosea, Azadirachta indica, smilax* and Reed climbers like *Schizostachys beddomei*, *Ebonytrees*, *Dalbergia latifolia* and *Podocarpus walcuchiana, Ginko biloba* like Gymnosperms are all endemic. The evergreen forest is going to be converted into semi evergreen, deciduous forest and later dry deciduous.

In short the afforestation is recommended along the river banks to prevent soil erosion, flood and loss of biodiversity. It is good to promote organic farming and prohibit illegal sand mining from the Rivers. *Cabomba* weeds can be replaced with natural vegetation after treatment with 41% Glyphosate in small infested areas and by mechanical removal to a certain extent. The extracted *Cabomba* cannot be used as fodder as there are traces of Copper and Lead in it which cause toxicity.

Fig.4.1. *Cabomba furcata* seen in Pampa River.

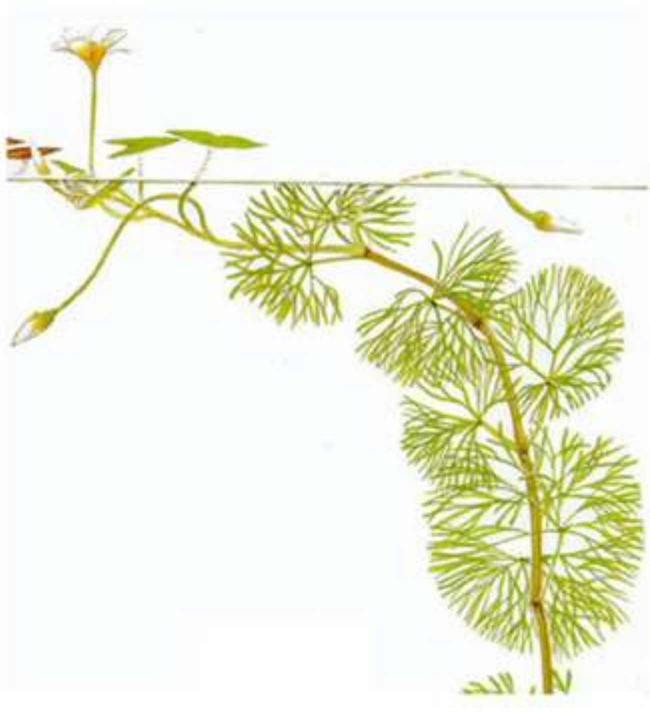


Fig. 4.2 *Cabomba caroliniana*

Fig. 4.3 **<u>Flowers of different species of *Cabomba*</u>**

Cabomba caroliniana

Cabomba furcata

Cabomba aquatica

Fig. 4.5a **Cabomba Growth - Pre Monsoon**

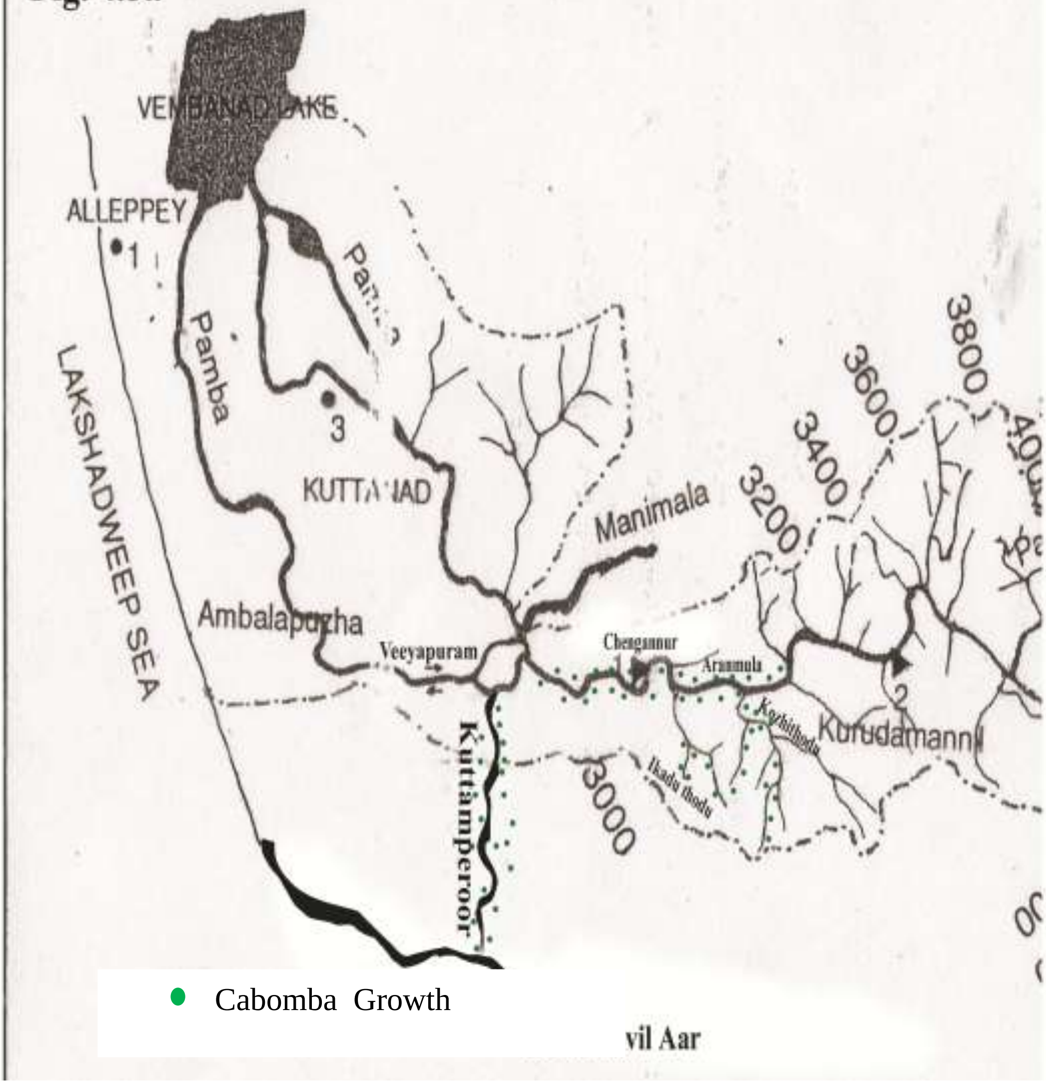
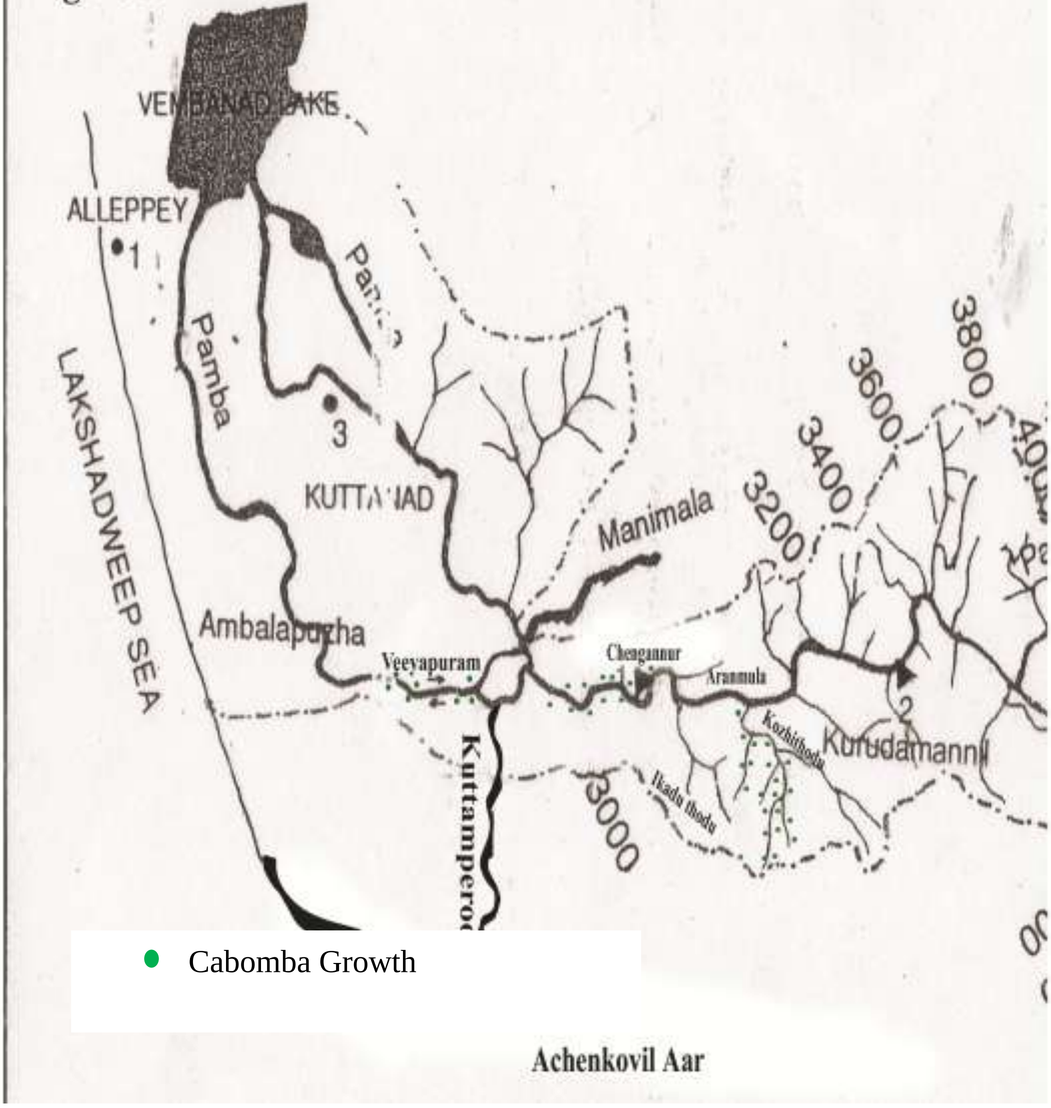


Fig. 4.5b **Cabomba Growth - Post Monsoon**



CHANGES OF GROWTH OF *CABOMBA* IN VARIOUS SITES DURING THE PERIOD OF PROJECT.

Fig: 4.6

Aranmula Sathrakadavu – Aranmula Panchayath.

04-05-2013 03-02-2014

Patteril Kadavu- Upstream of Aranmula- Mallapuzhassery panchayath.

17-05-2013 03-02-2014

Parappuzha kadavu- Upstream of Aranmula.

Nalkkalikkal – Kozhithodu- Aranmula Panchayath.

1

Koottathodu- Aranmula Panchayath

11-05-2013

03-02-2014

Kozhithodu- Edayaranmula.

Anjilimoottil Kadavu – Downstream of Aranmula- River Pampa.

17-05-2013

03-02-2014

Poovathur- Koipuram panchayath.

17-05-2013

03-02-2014

Ikkadu- Near Puthencavu.

17-05-2013

03-02-2014

Kurattissery – Mannar- Kuttamperoor River

17-05-2013 03-02-2014

Ennakkadu- Kuttamperoor River.

17-05-2013 03-02-2014

Budhanoor- Kuttamperoor River.

17-05-2013 03-02-3014

Vaikkathillom Thodu- Tributary of River Pampa- Nedumpram Panchayath.

17-05-2013 03-02-2014

Veeyapuram- Pampa- Manimala confluence. Effect of salinity

21-01-2013 17-05-2013 03-02-2014

Ramankary AC Canal

17-05-2013 03-02-2014

ENVIRONMENTAL EDUCATION AND AWARENESS CAMPAIGNS

‘Itegrated Water Resource Development in Pampa River Basin’. Christian College, Chengannur 09-01-2014.

‘Biodiversity Conservation in Pampa River Basin’ Catholicate College, Pathanamtitta. 10-12-2013.

‘Water and Biodiversity’ Environment Resource Centre, Poovathur. 22-05-2013.

Pampa Darsanam with students, N.S.S.H.S, Kaviyoor.08-11-2013.

’Pampa Darsanam’ with students of DIET, Chengannur.01-02-2014

‘Pampa Darsanam’03-11-2013

CHAPTER 5
WATER QUALITY ANALYSIS OF PAMPA RIVER

Water, being the best and convenient dilution medium is now the worst affected by pollution. It is frequently used as the cheapest and convenient way of liquid and solid waste disposal. Urban sewage disposal is a serious threat to the streams, rivers and Lakes in Kerala. Even primary treatment facility is not available for most of the towns in Kerala, the problem is growing to alarming magnitude.

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water (*Nancy 2009*).

5.1. WATER POLLUTION

Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. The sources of water pollution are categorized as being a point source or a non-source point of pollution. Point sources of pollution occur when the polluting substance is emitted directly into the waterway. A pipe spewing toxic chemicals directly into a river is an example. A non-point source occurs when there is runoff of pollutants into a waterway, for instance when fertilizer from a field is carried into a stream by surface runoff.

5.1.1. Types of Water Pollution

a. Toxic Substance -- A toxic substance is a chemical pollutant that is not a naturally occurring substance in aquatic ecosystems. The greatest contributors to toxic pollution are herbicides, pesticides and industrial compounds.

b. Organic Substance -- Organic pollution occurs when an excess of organic matter, such as manure or sewage, enters the water. When organic matter increases in a pond, the number of decomposers will increase. These decomposers grow rapidly and use a great deal of oxygen during their growth. This leads to a depletion of oxygen as the decomposition process occurs. Lack of oxygen can kill aquatic organisms. As the aquatic organisms die, they are broken down by decomposers which lead to further depletion of the oxygen levels.

A type of organic pollution can occur when inorganic pollutants such as nitrogen and phosphates accumulate in aquatic ecosystems. High levels of these nutrients cause an overgrowth of plants and algae. As the plants and algae die, they become organic material in the water. The enormous decay of this plant matter, in turn, lowers the oxygen level. The process of rapid plant growth followed by increased activity by decomposers and a depletion of the oxygen level is called *eutrophication*.

c. Thermal Pollution -- Thermal pollution can occur when water is used as a coolant near a power or industrial plant and then is returned to the aquatic environment at a higher temperature than it was originally. Thermal pollution can lead to a decrease in the dissolved oxygen level in the water while also increasing the biological demand of aquatic organisms for oxygen.

d. Ecological Pollution -- Ecological pollution takes place when chemical pollution, organic pollution or thermal pollution is caused by nature rather than by human activity. An example of ecological pollution would be an increased rate of siltation of a waterway after a landslide which would increase the amount of sediments in runoff water. Another example would be when a large animal, such as a deer, drowns in a flood and a large amount of organic material is added to the water as a result. Major geological events such as a volcano eruption might also be sources of ecological pollution.

5.1.2. <u>Specific Sources of Water Pollution</u>.

a. Farming:

- Farms often use large amounts of herbicides and pesticides, both of which are toxic pollutants. These substances are particularly dangerous to life in rivers, streams and lakes, where toxic substances can build up over a period of time.

- Farms also frequently use large amounts of chemical fertilizers that are washed into the waterways and damage the water supply and the life within it. Fertilizers can increase the amounts of nitrates and phosphates in the water, which can lead to the process of eutrophication.

- Allowing livestock to graze near water sources often results in organic waste products being washed into the waterways. This sudden introduction of organic material increases the amount of nitrogen in the water, and can also lead to eutrophication.

- Excessive amounts of sediment in waterways can block sunlight, preventing aquatic plants from photosynthesizing, and can suffocate fish by clogging their gills.

b. Business:

- Clearing of land can lead to erosion of soil into the river.

- Waste and sewage generated by industry can get into the water supply, introducing large organic pollutants into the ecosystem.

- Many industrial and power plants use rivers, streams and lakes to dispose of waste heat. The resulting hot water can cause thermal pollution. Thermal pollution can have a disastrous effect on life in an aquatic ecosystem as temperature increases, decrease the amount of oxygen in the water, thereby reducing the number of animals that can survive there.

- Water can become contaminated with toxic or radioactive materials from industry, mine sites and abandoned hazardous waste sites.

- Acid precipitation is caused when the burning of fossil fuels emits sulfur dioxide into the atmosphere. The sulfur dioxide reacts with the water in the atmosphere, creating rainfall which contains sulfuric acid. As acid precipitation falls into lakes, streams and ponds it can lower the overall pH of the waterway, killing vital plant life, thereby affecting the whole food chain. It can also leach heavy metals from the soil into the water, killing fish and other aquatic organisms. Because of this, air pollution is potentially one of the most threatening forms of pollution to aquatic ecosystems.

c. Homes:

- Sewage generated by houses or runoff from septic tanks into nearby waterways, introduce organic pollutants that can cause eutrophication.

- Fertilizers, herbicides and pesticides used for lawn care can runoff and contaminate the waterway. As with agricultural fertilizers, home fertilizers can lead to the eutrophication of lakes and rivers.

- Improper disposal of hazardous chemicals down the drain introduce toxic materials into to the ecosystem, contaminating the water supplies in a way that can harm aquatic organisms. (*Missouri Botanical Garden ,2006*)

5.1.3. Effects of water pollution

The effects of water pollution are varied. They include poisonous drinking water, poisonous food animals (due to these organisms having bio accumulated toxins), unbalanced river and lake ecosystems that can no longer support full biological diversity, deforestation from acid rain, and many other effects. These effects are, of course, specific to the various contaminants. (*Dr. Ken Rubin, Assistant Professor, Department of Geology and Geophysics University of Hawaii*).

5.2. WATER QUALITY PARAMETERS

a) **pH:** pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organisms biochemical reactions by either harming or killing the stream organisms.

   pH is expressed in a scale with ranges from 1 to 14. A solution with a pH less than 7 has more H+ activity than OH-, and is considered acidic. A solution with a pH value greater than 7 has more OH- activity than H+, and is considered basic.

   The pH scale is logarithmic, meaning that as you go up and down the scale, the values change in factors of ten. A one-point pH change indicates the strength of the acid or base has increased or decreased tenfold. Streams generally have a pH values ranging between 6 and 9, depending upon the presence of dissolved substances that come from bedrock, soils and other materials in the watershed.

Changes in pH can change the aspects of water chemistry. For example, as pH increases, smaller amounts of ammonia are needed to reach a level that is toxic to fish. As pH decreases, the concentration of metal may increase because higher acidity increases their ability to be dissolved from sediments into the water (*1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*).

b) **Acidity**: Acidity of water is its quantitative capacity to react with a strong base to a designated pH. Acidity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known. (*19th Edition, Standard Methods, 1995*)

c) **Alkalinity**: The Alkalinity or the buffering capacity of a stream refers to how well it can neutralize acidic pollution and resist changes in pH. Alkalinity measures the amount of alkaline compounds in the water, such as carbonates, bicarbonates and hydroxides. These compounds are natural buffers that can remove excess hydrogen, or H+, ions (*Stream keeper's Field Guide: Watershed Inventory and Stream Monitoring Methods, 1991*).

d) **Hardness:** Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (temporary hardness), largely combined with bicarbonate and carbonate and with sulfates, chlorides, and other anions of mineral acids (permanent hardness).

e) **Conductivity:** Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum. The presence of these substances increases the conductivity of a body of water. Organic substances like oil, alcohol, and sugar do not conduct electricity very well, and thus have a low conductivity in water. Inorganic dissolved solids are essential ingredients for aquatic life. They regulate the flow of water in and out of organisms' cells and are building blocks of the molecules necessary for life.

A high concentration of dissolved solids, however, can cause water balance problems for aquatic organisms and decrease dissolved oxygen levels (*Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods, 1991*).

f) **Turbidity:** Turbidity is a measure of the cloudiness of water. Cloudiness is caused by suspended solids (mainly soil particles) and plankton (microscopic plants and animals) that are suspended in the water column. Moderately low levels of turbidity may indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the fuel the food chain. However, higher levels of turbidity pose several problems for stream systems.

Turbidity blocks out the light needed by submerged aquatic vegetation. It also can raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight. Suspended soil particles may carry nutrients, pesticides, and other pollutants throughout a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen. High turbidity may result from sediment bearing runoff, or nutrients inputs that cause plankton blooms (*Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods, 1991*).

g) **Solids, Total:** Total Solids is a measure of the suspended and dissolved solids in a body of water. Thus, it is related to both conductivity and turbidity. To measure total suspended and dissolved solids, a sample of water is placed in a drying oven to evaporate the water, leaving the solids.

To measure dissolved solids, the sample is filtered before it is dried and weighed. To calculate the suspended solids, the weight of the dissolved solids is subtracted from the total solids (*Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods, 1991*).

h) **Nitrogen as Nitrate:** Nitrate or NO_3^-: Generally occurs in trace quantities in surface water. It is the essential nutrient for many photosynthetic autotrophs and has been identified as the growth limit nutrient. It is only found in small amounts in fresh domestic wastewater, but in effluent of nitrifying biological treatment plants, nitrate may be found in concentrations up to 30 mg nitrate as nitrogen/L (*19th Edition, Standard Methods of water quality, 1995*).

Nitrate is a less serious environmental problem, it can be found in relatively high concentrations where it is relatively nontoxic to aquatic organisms. When nitrate concentrations become excessive, however, and other essential nutrient factors are present, eutrophication and associated algal blooms can be become a problem (*Fundamentals of Aquatic Toxicology, 1985*).

i) **Dissolved Oxygen:** The amount of Dissolved Oxygen, or DO, in water is expressed as a concentration. A concentration is the amount of in weight of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen gas present, in milligrams per liter of water. Milligrams per liter, or mg/L, can also be expressed as parts per million, or ppm. The concentration of dissolved oxygen in a stream is affected by many factors:

i. <u>Temperature:</u> Oxygen is more easily dissolved in cold water.
ii. <u>Flow:</u> Oxygen concentrations vary with the volume and velocity of water flowing in a stream. Faster flowing white water areas tend to be more oxygen rich because more oxygen enters the water from the atmosphere in those areas than in slower, stagnant areas.
iii. <u>Aquatic Plants:</u> The presence of aquatic plants in a stream affects the dissolved oxygen concentration. Green plants release oxygen into the water during photosynthesis. Photosynthesis occurs during the day when the sun is out and ceases at night. Thus in streams with significant populations of algae and other aquatic plants, the dissolved oxygen concentration may fluctuated daily, reaching its highest levels in the late afternoon. Because plants, like animals, also take in oxygen, dissolved oxygen levels may drop significantly by early morning.

iv. Altitude: Oxygen in more easily dissolved into water at low altitudes that at high altitudes.

v. Dissolved or suspended solids: Oxygen is also more easily dissolved into water with low levels of dissolved or suspended solids.

vi. Human Activities Affecting DO:

- Removal of riparian vegetation may lower oxygen concentrations due to increased water temperature resulting from a lack of canopy shade and increased suspended solids resulting from erosion of bare soil.
- Typical urban human activities may lower oxygen concentrations. Runoff from impervious surfaces bearing salts, sediments and other pollutants increases the amount of suspended and dissolved solids in stream water.
- Organic wastes and other nutrient inputs from sewage and industrial discharges, septic tanks and agricultural and urban runoff can result in decreased oxygen levels. Nutrient input often leads to excessive algal growth. When the algae die, the organic matter is decomposed by bacteria. Bacterial decomposition consumes a great deal of oxygen.
- Dams may pose an oxygen supply problem when they release waters from the bottom of their reservoirs into streams and rivers. Although the water on the bottom is cooler than the warm water on top, it may be low in oxygen if large amounts of organic matter has fallen to the bottom and has been decomposed by bacteria.

Usually streams with high dissolved oxygen concentrations are considered healthy streams. They are able to support a greater diversity of aquatic organisms. They are typified by cold, clear water, with enough riffles to provide sufficient mixing of atmospheric oxygen into the water. In general, DO levels less than 3 mg/L are stressful to most aquatic organisms. Most fish die at 1-2 mg/L. However, fish can move away from low DO areas. Water with low DO from 2 – 0.5 mg/L are considered hypoxic; waters with less than 0.5 mg/L are anoxic.

j) **BOD:** The Biological Oxygen Demand, or BOD, is the amount of oxygen consumed by bacteria in the decomposition of organic material. It also includes the oxygen required for the oxidation of various chemical in the water, such as sulfides, ferrous iron and ammonia. While a dissolved oxygen test tells you how much oxygen is available, a BOD test tells you how much oxygen is being consumed.

BOD is determined by measuring the dissolved oxygen level in a freshly collected sample and comparing it to the dissolved oxygen level in a sample that was collected at the same time but incubated under specific conditions for a certain number of days. The difference in the oxygen readings between the two samples in the BOD is recorded in units of mg/L.

Unpolluted; natural waters should have a BOD of 5 mg/L or less. Raw sewage may have BOD levels ranging from 150 – 300 mg/L (1991, Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods).

k) **COD:** The chemical oxygen demand, or COD, is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD can be related empirically to BOD, organic carbon, or organic matter. The test is useful for monitoring and control after correlation has been established.

Oxidation of most organic compounds is 95 to 100 percent of the theoretical value. Ammonia, present either in the waste or liberated from nitrogen-containing organic matter, is not oxidized in the absence of significant concentration of free chloride ions (*19th Edition, Standard Methods, 1995*).

l) **Fecal Coliforms:** Human and animal wastes carried to stream systems are sources of pathogenic or disease-causing, bacteria and viruses. The disease causing organisms are accompanied by other common types of nonpathogenic bacteria found in animal intestines, such as fecal coliform bacteria, *Enterococci* bacteria, and *Escherichia coli*, or E. coli bacteria.

Fecal Coliform, *Enterococci*, and *E.coli* bacteria are not usually disease-causing agents themselves. However, high concentrations suggest the presence of disease-causing organisms. Fecal Coliform, Enterococci, and E. coli bacteria are used as indicator organisms; they indicated the probability of finding pathogenic organisms in a stream. To measure indicator bacteria, water samples must be collected in sterilized containers. The samples are forced through a filter and incubated at a specific temperature for a certain amount of time. The resulting colonies that form during incubation are counted and recorded as the number of colony producing units per 100 ml of water.

5.3. WATER POLLUTION IN RIVER PAMPA

Organic pollution associated with Sabarimala pilgrimage is the worst environmental problem facing the River Pampa. The disposal of human waste and other waste materials including plastic directly into the River Pampa has caused severe threat to the ecology and public health. The studies conducted by the Kerala State Pollution Control Board (KSPCB) have found the coliform bacteria count in the Holy River Pampa was found to be in the order of more than one lakh/100 ml of water whereas the maximum permissible limit is 2500 MPN/100ml and in the drinking water, it should be absent. Inadequate disposal and sanitation facilities coupled with every thin flow of the River have raised pollution in the river water to an alarming level. The pollutant load in the river fluctuate s widely due to the seasonal variation. (Sri. N.K Sukumaran Nair, Pampa Parirakshana Samithy; Ref. River treatment at Pampa using ferrous chloride).

Phospherous runoff from land is major source of contamination of water bodies. It promotes excessive growth of Algae and weeds in rivers and lakes, affecting fish and aquatic organisms. The presence of heavy metals is another water quality issue. Optically active substances, low pH, high turbidity, decreased level of dissolved oxygen and increased detection of organic matterin water bodies generate a complex challenge for water resource management. Pesticide pollution especially presence of DDT, lindane call urgent attention. High levels of Fecal coliforms in water bodies is a restricting factor (*Abraham Varghese, KWA; Conservation of Rivers and lakes).*

5.3.1. Water pollution and invasive plants

Excess growth of aquatic plants can affect beneficial uses of a water body, such as recreational and aesthetic enjoyment, irrigation and water supply uses, and wildlife habitat (Awad,A.S. Milham,P.J., and Toth, J. 1979. Proceedings of the 7thConference of the Asian- Pacific Weed Science Society, Sydney, 241-3). In addition, invasion by non-native (exotic) plant species, such as Cabomba can seriously damage an aquatic ecosystem. Exotic weeds can choke out native vegetation, and can form dense stands that are a nuisance to humans. Exotic weeds can also create poor habitat for fish and wildlife. (*Standard Methods for the Examination of Water and Waste-water, 1985*).

Depending on water quality, *Cabomba* grows best at depth of 0.5-5m. It has a home in
fast flowing or still waters. High nutrient content of water is a major factor leading to the flourishing growth of this killer weed. Sewage, agrochemicals and land washouts are the source of high nutrient content. (Dr. N. Unnikrishnan, Secretary, Nature Society, Kottayam Ref. The Hindu, 09/10/12). Thus water pollution directly enhances the abundant spreading of *Cabomba.*

The Project mainly aims on the water quality of different sites of Pampa River where the growth of Cabomba is in excess. Samples were being collected every month from specified sites. Site were selected each from upsteam, mid-region and downstream area of Pampa river. Aranmula sathrakadavu, Koipram, Pannai, and Kallissery were selected as sampling sites.

Water samples were collected in the middle of each month. Samples were collected in 1 litre bottles from each site separately and did the physicochemical and bacteriological analysis. Results were compared with that of other recognized Authorities like Kerala Water authority, Kerala State pollution Control board, and Centre for Water Resource Development and Management.

5.4. RESULT AND DISCUSSION

Average of water Quality parameters of locations where *Cabomba* growth seen

Parameters	Aranmula	Koipram	Pannai	Kallissery
pH	6.72	6.63	6.51	6.35
Turbidity(NTU)	7.99	17.46	11.53	17.98
Chloride(Mg/L)	16.67	15.33	14.89	15.1
Iron(Mg/L)	0.479	1.61	1.65	1.48
Nitrate(Mg/L)	9.66	2.07	3.69	5.66
COD(Mg/L)	3.89	3.44	5.22	5.89
DO(Mg/L)	7.3	6.83	5.74	6.92
Fecal Coliforms (No/100ml)	647	758	586	497

Table 5.1 (Ref: Quality Control Sub Division, Kerala Water Authority, Thiruvalla)

The average value of pH of Pampa River water, where *Cabomba* flourished was found within the range of 6.35 to 6.72. The tendency to be acidic may be contributed by the disposal of waste materials. The organic waste may be decomposed by the plant and the byproducts may be acidic in nature. The acidic pollution reached in the water system should be naturally nullified by the alkaline components of the water itself. But this is only up to a limit. The amount of acidic waste when increase, the buffering capacity of the water will be lost and its pH tend to be acidic.

Turbidity showed within a range of a range of 7.99 to 17.98 NTU. The turbidity level in all the four sites after the heavy rain fall (post- monsoon months) became in a huge value. In Kallissery it became 39.2 NTU. This turbidity may be a main factor of disappearance of *Cabomba* plants in some of the locations after the rain fall. Large amount of mud settled in the river bottom, where the roots of *Cabomba* firmly attached and may inhibit their growth. The result was significant in Ikkadu region.

Chloride in the form of chloride ion is one of the major anion in river water. The salty taste of produced by chloride concentration is variable and depend on the chemical composition of water. The range of Chloride ion in the affected area ranges between 14.89 and 16.67 mg/L. This ion could be absorbed by the plant for their growth.

Iron content showed their range in between 0.479 and 1.65 mg/L and Nitrate in a range 2.07 –9.66 mg/L and both the nutrients may be taken up by *Cabomba* plants as their micronutrients.

Chemical Oxygen Demand (COD) of the water ranged from 3.44 to 5.89 mg/L. COD measures the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. Ammonia released from the organic wastes is a major problem. It increases the COD level. Ammonia cannot be oxidized in the absence of significant concentration of free chloride ions. As the amount of organic matter increases in the water, it leads to water pollution and increases the growth of *Cabomba* like invasive plants.

Dissolved oxygen in the affected areas range from 5.74 to7.3 mg/L. Removal of riparian vegetation may lower oxygen concentrations due to increased water temperature resulting from a lack of canopy shade and increased suspended solids resulting from erosion of bare soil. The growths of invasive weeds also influence the dissolved oxygen level in streams. Intake of dissolved oxygen may decrease during the photosynthesis of green aquatic plants.

Fecal coliform count of the affected area ranged from 497 to 758 per 100 ml of water. Fecal contamination is very specific in these areas. Fecal Coliform, Enterococci, and E.coli bacteria are used as indicator organisms; they indicate the probability of finding pathogenic organisms in a stream. The presence of *E coli* in the water indicates fecal contamination; that is the water is contaminated by human excreta, and unsafe for consumption.

CHAPTER 6

MANAGEMENT OF AQUATIC INVASIVE SPECIES IN PAMPA RIVERINE SYSTEM

MANAGEMENT OF CABOMBA

Aquatic plants are vital part of aquatic ecosystems that in most situations, they provide cover, habitat, and food for aquatic biota, fish, and other fauna. But in some cases, too many rooted and floating plants can cause many problems in a natural water body. They may degrade water quality, adversely affect fisheries, block intakes that supply water for domestic or agricultural purposes, and interfere with navigation, recreation, and aesthetics. *Cabomba* is such an aquatic weed which requires prompt and effective eradication, as its presence in the water bodies of Kerala is dangerous to our water systems.

Aquatic plant management in Kerala Rivers is very significant and need utmost care, because, these rivers are the life and soul of millions of people. Even though many methods of management strategies are available, choosing the apt one is the matter of importance. Chemical methods may have significant adverse environmental impacts and that an Environmental Impact Statement was necessary.

6.1. IMPACTS OF INVASIVE WEEDS

6.1.1. Environmental impacts

Fast-growing submerged *Cabomba* infestations exclude native aquatic plants and alter the aquatic habitat for other organisms, ultimately reducing biodiversity. Light penetration is restricted, causing changes to food chain structures and species composition. *Cabomba* will outcompete many aquatic plants, such as the native pondweeds (*Potamogeton* spp.), stoneworts (*Chara* spp.), hornwort (*Ceratophyllum demersum*) and water nymph (*Najas tenuifolia*). There are many examples of such alteration of invasive aquatic flora has affected populations of native fauna. Temperature-dependent seasonal dieback of *Cabomba* infestations can leave large amounts of decomposing plant material and consequently reduce the amount of available oxygen in the water. These results in foul smelling, oxygen-deficient water and an increase in the rate of release of some nutrients from bottom sediments. *Cabomba* is now a Weed of National Significance in Australia.

6.1.2. Social impacts

Dense submerged stands of *Cabomba* create public safety concerns and make swimming areas unsafe. Fishing lines become entangled in the weed, and water sports, including boating, sailing etc. are also directly affected by the weed's dense growth. Occupational health and safety issues are created for a range of workers, including water supply engineers and managers, weed managers and protected-area staff. *Cabomba* infestations also reduce the scenic amenity values associated with water bodies. Clear rippled water surfaces become darker, still and partly stagnant in the presence of a *Cabomba* infestation.

6.1.3. Economic impacts

Cabomba will taint and discolour potable water, increasing the costs of water treatment processes. It blocks foot valves and pumps, increasing maintenance and running costs and reducing pumping efficiencies. In those infestations in Australia that are subject to control measures, the costs are currently estimated to be in the range of $600,000 to $800,000 a year. (*Cabomba Control manual, Weeds of National Significance, NSW Department of Primary Industries, Govt. of Australia*).

There are two major problems in relation to *Cabomba* management:

• New infestations are difficult to detect since inspections for this type of weeds are not regularly made and the weed is a fully submerged aquatic plant and is not easy to see until the affected area is quite large.
• The weed grows very quickly and it is highly invasive. Unless early control is initiated, the weed quickly establishes throughout the system and eradication is a hopeless task. (*A.P.Mackey, Pest status review series - land protection branch)*

6.2. CONTROL METHODS

Control methods may include physical, chemical, biological and mechanical control technologies. The preferred alternative is an integrated approach that uses the most effective and environmentally protective mix of management methods and includes adaptive management elements *(Department of Ecology, State of Washington; Publication no. 00-10-040Addendum1; January 2012*). In a recreational water body or river, protocols are needed to ensure the safe use of control method.

6.2.1 PHYSICAL CONTROL

As sunlight is the vital element for the flourishing of all the invasive species, especially *Cabomba*, one of the feasible physical methods is to obstruct sunlight in to the river surface where the plant is abundant. Habitat modification via re-vegetation is recommended and may offer some control if it produces shading effect (*Washington State Department of Ecology, 2003, Technical Information about Cabomba caroliniana)*. In drinking water supplies, the only recommended option is habitat modification via draw-down of water (*Australian Department of the Environment and Heritage 2003*).

In Australia, observations and experiments indicate light availability is a factor that greatly influences *Cabomba* distribution and abundance. Shade may reduce downstream spread if *Cabomba* propagules are forced to travel down water courses covered with a dense riparian canopy (*Shon Schooler, Mic Julien & Willie Cabrera Walsh, Bolivar; Progress toward Management of Cabomba: Biological control and ecology*). Preventing new outbreaks is critical and can be achieved by disposing plants using burning or drying-out methods and discouraging the deliberate seeding of waterways with *Cabomba.*

a. Shading

Shading is one of the effective methods for controlling *Cabomba* in foreign countries like Australia. Shading using blankets provide an inhibitory effect on *Cabomba* growth.

High levels of shade are known to kill *Cabomba*. Restriction of sunlight over a period of 3 or 4 months causes *Cabomba* to die, with higher levels of *Cabomba* mortality achieved in less time with higher levels of shade. It was found that shade created with a 99% light-blocking floating blanket (blocks out 99% of light) reduce *Cabomba* biomass at depths of 1 to 3 metres to 10% within 60 days and to 0% within 120 days. No live *Cabomba* material remained in the sediment. Shade created with a 70% light-blocking floating blanket reduced *Cabomba* biomass at depths of 2 to 3 metres. It did not reduce *Cabomba* biomass at a depth of 1metre. A shade level of 70% was created to represent that provided by a moderate amount of riparian vegetation containing trees and shrubs.

In simulated shading trials, black plastic was used to create shade over *Cabomba* growing in 100-litre plastic tubs. Wherever 100% shade was maintained, 100% kill rates resulted 1 month after treatment. Where minute amounts of light were able to enter, very small amounts of *Cabomba* remained viable and capable of re-growth. These trials have shown that shading is able to achieve 100% kill rates if all light can be excluded for at least 1 month. As a control method, shading can be used to suppress and possibly eradicate small *Cabomba* infestations less than 1 hectare in surface area (i.e. small farm dams or public ponds). Costs and logistics generally prohibit the use of constructed shade on a large scale.

Shading can be used to create clear areas in dense *Cabomba*; allowing better management of irrigation, recreation, or revegetation in infested areas. Shade can also benefit by reducing flowering and seed set where *Cabomba* is known to produce viable seed. Two types of shading can be constructed over a *Cabomba* infestation, floating blankets and benthic blankets. Riparian vegetation will also provide some degree of shade, and water dyes have also been used to restrict light penetration, but with less effect for *Cabomba* control. Floating blankets have been tried a number of times with success in Australia.

Floating blankets

The most commonly used floating blankets for *Cabomba* control in Australia have been constructed in-house from builders' black plastic. Builders' black plastic completely excludes light, giving 100% shade. Successful small-scale trials have used pool covers, but these are expensive. A floating blanket must prevent light from entering the water. Lengths of rope or cable need to be attached along the edges to allow it to be secured and to keep the edges afloat on the water surface.

If a floating blanket is being installed over a section of water (i.e. along edges of an infestation or when treating sections of a larger water body), hanging side curtains must also be installed. Side-curtains must block all light that can enter through the water column from adjacent un-shaded areas. Side-curtains have been made out of black plastic and attached to the edges of the blankets.

Floating blankets can be secured with star pickets or steel rods driven into the substrate in the corners and along the edges of the plastic.

Advantages

On a small scale and with ongoing follow-up, shading with floating blankets can drastically reduce biomass. It may be able to eradicate *Cabomba,* if complete shade can be achieved, or if follow-up control is able to remove all re-growth.

Disadvantages

Shading will alter the physical and chemical environment by reducing dissolved oxygen levels, increasing carbon dioxide levels and reducing pH. In trials in south-east Queensland, the presence of two dead fish and one dead eel raised enough public concern to cause a shading trial to be abandoned.

Floating blankets present a drowning hazard. In any site it is important to restrict public access. Constructing and maintaining shade over small areas is physically difficult and requires effort and dedication. Constructing shade over larger areas (i.e. greater than1 hectare) is generally cost prohibitive and physically difficult. Floating blankets need to be checked regularly and repairs are often needed.

Benthic blankets

Benthic blankets (also known as bottom screens, bottom covers, pond liners, benthic barriers) sit over the substrate at the bottom of a water body, both compressing aquatic plants and blocking out sunlight. Bottom blankets need to be durable and light blocking. Materials such as PVC plastics, polyesters and woven synthetics have been used as bottom blankets (plants can grow through woven fabrics or easily take root from above). Commercially made benthic blankets are produced in the USA and Canada for the purpose of aquatic weed control. Products such as fibreglass 'stabilising paper' have also been tried successfully.

Benthic blankets will accumulate layers of sediment on top where fragments of aquatic plants, including *Cabomba,* can take root. Depending on the water turbidity and flow rates, sediment can build up quickly (i.e. in 2 or 3 weeks) and has been known to accumulate to a depth of over 40 centimetres within a single growing season. In sites where benthic blankets are installed, resources are usually made available for regular removal of sediments or recolonising plants (usually by SCUBA divers), particularly when the blankets are used to treat only a section of a *Cabomba* infestations.

Blankets must be strongly secured to the bottom. Rocks, sandbags and concrete blocks can be used to anchor the blankets. Poorly maintained anchors and unsecured blankets can create safety hazards for swimmers and navigation.

Gases can build up underneath blankets, causing them to lift. Very small longitudinal slits can be cut to allow gases to escape, but this may allow small amounts of light to reach the bottom. Some specifically made semi-permeable American products allow gases to permeate, but they eventually become clogged by debris and micro-organisms. This has been addressed by using PVC or timber frames to allow the blanket to sit a small distance above the substrate, still effectively blocking light but allowing gases to escape. Install blankets in winter, when aquatic plants are more prostrate. If growth is tall, the *Cabomba* canopy needs to be reduced before the blanket is installed.

Advantages

Benthic blankets can kill plants within 1 or 2 months. Benthic blankets are most appropriate for small dams or ponds where the entire bottom can be covered, thereby reducing re-colonisation on top of the blanket by floating *Cabomba* fragments. Benthic blankets may be useful as a follow-up measure after treatments with herbicide, floating blankets, riparian shade or physical removal have been used to suppress an infestation, particularly in areas where *Cabomba* is thought to be producing viable seed.

Disadvantages

Benthic blankets require ongoing maintenance to prevent sediment build-up; recolonisation by *Cabomba* fragments; gas build-up and billowing; breakdown of the blanket itself; and dangers to swimmers and boaters created by poorly anchored blankets or the anchoring structures themselves. Benthic blankets can have impacts on invertebrate populations and fish spawning.

The need to reduce the height of the canopy before installing a blanket limits the economy of this control method. Experience in Australia with benthic blankets for *Cabomba* control is limited.

Benthic barriers for *Cabomba* control in Canada

Benthic barriers were successfully tested on *Cabomba* infestations in Kasshabog Lake in Canada. Sheets (4m x 4m) of landscape fabric held down with bricks at the corners, with slits every 0.5 metres to allow release of gases were positioned over stands of *Cabomba* from September 2002 to May 2003. The benthic barriers blocked out almost all light and the result was the elimination of between 95% and 100% of the *Cabomba*. Two months after removal of the blankets, *Cabomba* had not recolonized the areas. The researchers concluded that the use of benthic blankets was a low-cost option for small, newly established *Cabomba* infestations in the lake, or in sites subject to high-intensity use.

b. Water dyes

Water dyes aim to reduce penetration of the kind of light that is necessary for plant growth. This method is effective only in ponded water bodies at depths over 1 metre. While water dyes are relatively standard practice in the USA, there are no products registered for use in Australia.

c. Drawdown

Drawdown is a method of managing aquatic weeds by draining or lowering a water body for a period of time. Drawdown is possible only where water levels can be controlled through pumping or outflow, usually only in water storages, reservoirs and dams. Natural lakes and ponds are less appropriate sites for drawdown; they could suffer significant ecological impacts and are less practical for achieving drawdown. To control, *Cabomba* it is necessary to completely drain a water body and allow the substrate to dry out, in order to destroy (though drying) all the vegetative parts of the *Cabomba* plants, including the roots. If the soil remains damp there is a greater than 50% chance of *Cabomba* surviving and re-establishing. Even if the soil is completely dried, there is a chance that some *Cabomba* will survive. This risk is reduced if drawdown is done when temperatures are at their extremes, in summer and winter.

Drawdown for *Cabomba* management should be considered only where the risks of spreading *Cabomba* fragments in the pumping out or outflow of water can be minimized. In catchments where *Cabomba* is not present downstream of the proposed drawdown site, the risks of spreading the infestation are high. In these cases any water that is pumped or drained must be either:

• moving downstream to areas where salinity levels are high enough to prevent further establishment of *Cabomba,* or

• pumped onto dry land, where there is no risk of backflow into un-infested water bodies.

Advantages

• Option for potable water.

• Chance of *Cabomba* eradication in small dams, particularly if integrated with other treatments.

Disadvantages

• Ecological implications of drawdowns for other aquatic organisms.

• Losses of large amounts of storage water.

• Alternative water supplies or storages may need to be provided during drawdown.

• *Cabomba* fragments may be moved downstream, resulting in further spread.

Follow-up after drawdowns

Monitoring for any re-established cabomba is very important once the water body is refilled. High levels of suppression can be maintained if areas of regrowth are found early. Hand-pulling has been the most effective follow-up treatment for small patches of regrowth after drawdowns.

d. Manual removal

Manual removal is an important control method for *Cabomba* infestations in specific contexts. It is usually done only in small infestations or in sections of larger infestations, or as a follow-up method in an eradication program. The method involves manually pulling *Cabomba* plants out by the roots (hand-pulling), either while wading through shallow water or by diving with SCUBA. The method has been developed to include hand-held suction hoses to dredge the plants out, roots and all. The method is quite thorough and target-specific and minimizes impacts on other aquatic vegetation.

Hand-pulling

Hand-pulling of *Cabomba* can be viable over small areas. It is time and labour intensive and therefore generally not practical or economically viable for large areas.

Hand-pulling while wading

Hand-pulling can be done by operators standing or wading through shallow (knee-deep) water, depending on the water visibility. This is really only practical as a follow-up method while looking for regrowth of *Cabomba* along edges of banks and shorelines.

Hand-pulling in conjunction with drawdown

Hand-pulling can be done in conjunction with drawdown, where operators can walk across the dry bed and remove exposed plants, as an alternative to treating the exposed plants with herbicide or waiting for them to dry out naturally.

Hand-pulling using SCUBA divers

In many cases hand-pulling is viable only if SCUBA divers are used. This is usually done when small new infestations are discovered, as a follow-up method after shading, or to keep priority areas free of *Cabomba.* Only qualified personnel may undertake this work.

Use of booms to avoid spreading fragments

Care is needed not to transport fragments on boots or clothing and not to create fragmentation through disturbance. Where possible, operators should stand. still and move very minimally through the water. Whenever hand-pulling is carried out in the water, floating curtain booms should be used to ensure fragments created by the disturbance are not able to float away.

Tips for hand-pulling

• Don't walk or swim out into or through the infestation; if possible, approach from the deeper side.
• Clear small areas completely before moving into a new area.
• Have extra people watching, ready to catch floating fragments.
• Pull out plants very carefully and slowly, taking time to feel your way down to the root ball and making sure you are removing the whole plant.
• Surround the area being pulled with a boom - either a rope with floats and netting or shade cloth attached to make a curtain, or a commercial curtain boom.
• Use divers where conditions are too difficult for wading (i.e. too deep, poor water clarity, thick infestations).

e. Diver-operated suction dredging

Diver-operated suction dredging is a form of manual removal that involves the complete removal of submerged plants from the substrate by using a vacuum suction dredge. Divers use hand-held suction hoses to remove whole plants, including their root systems. Suction dredging systems range in size from smaller pumps to large boat- or barge-mounted systems.

The technique is skill and labour intensive, and only qualified personnel are able to undertake the work, making it relatively expensive. It is more difficult when water visibility is poor.

Although the technique can disturb benthic habitats through sediment disturbance, it is usually used only in small, target-specific areas. The technique is used successfully for *Cabomba* control in Australia and has the advantage of being able to remove whole plants and roots without dislodging fragments. (*Elissa van Oosterhout, 2009*).

6.2.2. CHEMICAL CONTROL

In foreign countries, lake managers select herbicides based on effectiveness, impacts, cost, and suitability for the water body and targeted plant species. The effectiveness of an aquatic herbicide depends on its mode of action, suitability for the targeted plant species, its concentration and contact time requirements, and many other site-specific environmental factors. Herbicides used for aquatic plant management fall into general categories:

• Contact herbicides destroy only the parts of the plant exposed to the chemical (usually foliage). Plants generally grow back from roots after treatment with contact herbicides. Treatment with a contact herbicide typically causes treated vegetation to drop rapidly from the water column to the sediment, where it decomposes.

• Plants translocate systemic herbicides throughout the foliage and roots of the plant and these herbicides often kill the entire plant. Systemic herbicides are generally much slower acting than contact herbicides and it may take several weeks to months for plants to drop from the water column.

• Broad-spectrum herbicides kill or affect most, if not all plants, when used at an appropriate concentration and contact time.

• Selective herbicides affect only certain species (typically dicots or broad-leaf monocots). Sometimes applicators can use broad-spectrum herbicides selectively (e.g., low concentrations when the target plant is susceptible).
(*Department of Ecology, State of Washington; Publication no. 00-10-040Addendum1; January 2012*).

A herbicide is registered for *Cabomba* control in non-drinking water in Queensland and the Northern Territory but there is community opposition to its use (*Australian Department of the Environment and Heritage 2003*). There is no herbicide registered for *Cabomba* control in drinking water. In the North American region herbicide treatments have been used for *Cabomba* control. Endothall provides excellent control but it is a contact herbicide only. Fluridone provides good control.

a. Application of Fluridone

Mode of action: This systemic herbicide is absorbed by vegetative tissues and translocated throughout the plant, inhibiting the synthesis of carotenoid pigments. Lack of these auxiliary (protective) photosynthetic pigments causes susceptible plants to die slowly through reduced food production and damage by sunlight. Uptake must be nearly continuous over an extended period (>60 days preferred), necessitating extended exposure time.

Probability of successful control: Where adequate dose (>10 ppb for fanwort) and exposure time (60- 120 days) are maintained, fanwort can be eradicated. This has proven difficult to achieve, however, particularly partial in lake treatments. Use of slow release pellet formulations or sequestration of the target area with impervious curtains maximizes exposure time and limits dilution of the dose. Follow up actions, such as hand harvesting, are often necessary, and retreatment the next year may enhance control. Despite limitations, fluridone is a preferred chemical for fanwort control (Rapid Response Plan for Fanwort (*Cabomba caroliniana*) in Massachusetts, June 2005).

b. Use of 2, 4-D herbicides

Control with 2, 4-D n-butyl ester has been the only method that has achieved successful eradication of large cabomba infestations. A 2, 4-D-n-butyl ester herbicide product (Agricrop Rubbervine Spray®) was registered for use on *Cabomba* in Australia. 2, 4-D-n-butyl ester is an important component of the *Cabomba* Eradication Program in the Darwin River in the Northern Territory in Australia. (*Cabomba Control manual, Weeds of National Significance, NSW Department of Primary Industries, Govt. of Australia*).

6.2.3. BIOLOGICAL CONTROL

Various moths and weevils are found to attack different species of *Cabomba* in various parts of the world. Some of them use it as a feed. Natural enemies are the safest method for controlling the species spreading. Grass carp will eat fanwort, but it is not a preferred food (*Gibbons et al. 1993*).

Types of biological control agents

Three major groups of organisms are commonly used in biological control of aquatic weeds: arthropods (insects and mites), fish (primarily grass carp), and pathogens (fungi and bacteria) .

Biological control of aquatic weeds with insects has been remarkably successful in the U.S. Complete or substantial biological control of the floating macrophytes, water hyacinth, water lettuce (*Pistia stratiotes* L), *Salvinia* (*Salvinia molesta* D.S. Mitch.), and red water fern (*Azolla filiculoides* Lamarck) by insects has been achieved in most countries where it has been attempted. Although biological control of many introduced weeds is not always effective, the success rate for the control of aquatic weeds is much higher. A cursory examination of the various projects suggests this high success rate may be associated with the growth form of the weeds, the insect taxa used as biological control agents, susceptibility to disease-causing pathogens, fluid nature of the aquatic environment, or some combination of these elements. Historically, it was thought that herbivory on aquatic macrophytes was uncommon and unimportant.

One of the most controversial biological control agents currently used to control hydrilla and other submerged aquatic weeds is the Grass carp (*Ctenopharyngodon idella* Val.), native to cold and warm water regions of China and Russia. The fish is highly adaptable to a wide range of temperature extremes and has been introduced into many countries worldwide for aquatic weed control. The widespread use of Grass carp for aquatic weed control has been questioned because of concerns about its negative impact on water quality and non target species.

Pathogens with a capacity for rapid secondary reproduction (i.e., having the potential to cause secondary infections and disease spread) and capable of causing high levels of damage to the weed's vegetative or reproductive parts are most suitable as classical biological control agents. Several factors contribute to the effectiveness of these pathogens, including host-pathogen disjunction (i.e., lack of host pathogen homeostasis), presence of a target weed population that is predominantly or wholly susceptible (i.e., lacking in genetic diversity), and high levels of virulence and acceptable levels of host specificity of the pathogen. Presence of dense weed populations and environmental conditions conducive for epidemic build-up also are required. Currently, only one pathogen has been deployed as a classical biological control agent of an aquatic weed anywhere in the world. This fungal agent, *Cercospora piaropi* (*J. P. Cuda, R. Charudattan , M. J. Grodowitz R. M. Newman J. F. Shearer M. L. Tamayo and B. Villegas, Recent Advances in Biological Control of Submersed Aquatic Weeds, J. Aquat. Plant Manage. 46: 15-32).*

Natural Enemies found in Argentina are,

- *Hydrotimetes natans.* This Bagoini weevil feeds on plant tips while the larvae mine the plant stems. It develops in about 40 days in the laboratory. At high densities it can cause extensive tip damage with its adult feeding, as well as stem pruning and rotting from the larval mines.
- *Paracles sp.* The aquatic caterpillar causes heavy defoliation on *Cabomba*, and seems to prefer the leaves near the terminal shoots. It feeds underwater, keeping air bubbles amidst the short hairs on its dorsum

- *Paraponyx sp.* The gilled larva of this pyralid feed on the terminal shoots of *C. caroliniana*, causing a characteristic damage that stunts stem growth.

Cabomba surveys in Venezuela revealed that two weevil species were found on *Cabomba furcata* (two adult individuals of a small black weevil with striations on its elytra and one adult individual of a larger grey weevil with sediment caked on its elytra and specialized ridges along the underside of its tibia).Herbivore damage was apparent in the form of stem mining and pupal cases formed from the fusing of fruits. Insect larvae were associated with both types of damage. There were also pupal cocoons (on *C. haynesii* and *C. furcata*) that were within stems that had sand/sediment attached to the outside with fine hairs emerging from the sediment. These are probably made by *lepidopteran* larvae (*Shon Schooler, Mic Julien & Willie Cabrera Walsh, Bolivar; Progress toward Management of Cabomba: Biological control and ecology*).

CSIRO researchers are currently reviewing the weevil *Hydrotimetes natans* as a promising biological control agent for Cabomba. The larvae of this weevil feed in the stems of *Cabomba* and cause the plants to break down. Preliminary testing has shown the insect to be host specific (*Elissa van Oosterhout, Cabomba Control manual, Weeds of National Significance, NSW Department of Primary Industries, Govt. of Australia, 2009*).

6.2.4. MECHANICAL CONTROL

Cabomba is often mechanically cut and removed in large, established infestations, particularly where herbicides are considered inappropriate. Mechanical removal needs to be done continually in order to suppress *Cabomba*. Re-growth occurs so quickly that a clear body of water can only be maintained for a short time (several weeks). Mechanical removal is expensive, but it has been deemed cost effective in situations where priority areas within larger infestations need to be kept clear of *Cabomba* (for either safety or recreational reasons, or to limit spread by keeping areas near spillways clear). It has also shown to improve water quality in areas where *Cabomba* is removed.

Harvesting

Underwater cutting and removal of *Cabomba* is referred to as harvesting. A harvester is effectively a barge mounted with a sickle-bar cutting blade and a conveyor belt to load the cut plant material onto the barge; the system operates like an underwater mower. Most harvesters are paddle-wheel driven, and commercially built harvesters are available in a range of sizes, capacities and manoeuvrabilities. Most large harvesters have weed load capacities of 11 or 12 cubic metres and have to off-load to shore or to a shuttle barge.

Paddle-wheeled harvesters create a lot of disturbance, causing a high degree of fragmentation of the *Cabomba*. They are therefore not suitable for small or new infestations, as they will cause spread. Booms have been used to contain floating fragments in areas where *Cabomba* is being harvested.

Disposal

Disposal of harvested *Cabomba* needs to be considered. *Cabomba* dumped onshore will decompose within 3 or 4 weeks. This may be acceptable as long as there is no chance of it reentering the water. Harvested

Cabomba is too wet to compost well on its own. Left in a heap it becomes an anaerobic, sludge-like material. *Cabomba* can also contain large amounts of heavy metals and should be tested before any further use as composting material. Most harvesting operations use back-loading compacting garbage trucks to compress the *Cabomba* and transport it to a refuse depot. The water that is squeezed out when the *Cabomba* is compressed can contain large amounts of nutrients and heavy metals and may need to be collected and disposed of responsibly (proper facilities such as a hardstand with sump may need to be constructed onsite for collection and removal of runoff water).

Advantages

• Removal capacity is large enough to suppress substantial areas of *Cabomba* for short periods of time.

• The process can remove a significant amount of nutrients and heavy metals from the system.

• The process contributes to oxygenation of the water profile.

Disadvantages

• Uneven bottom contours, snags, high flows and high wind speeds restrict harvesting.

• Harvesting is not species selective, and it does result in the capture of a wide range of organisms, including small fish. (Larger fish and tortoises are able to avoid capture or jump off the conveyor back into the water. The operator can also reverse the conveyor if necessary.)

• Harvesting causes a high degree of fragmentation, increasing chances of spread.

• Expense of maintaining an ongoing program is high.

• Clear water or GPS equipment is required to view or track cutting lines in order to operate economically.

In a closed water body with a heavy infestation it is recommended to use strict hygiene regulations and mechanical control (involving cutting and removing plants and ensuring fragments are not spread). Ongoing mechanical control is expensive but may be the only option. In the case of isolated plants and in small area, hand pulling by divers can be used. (*Australian Department of the Environment and Heritage, 2003*). Care should be taken to remove all of the plant to prevent re-infestation.

The removed plants must be properly disposed of or destroyed. Great care must be taken not to create new fragments during mechanical control as this would only increase the spread of the plant. Removing the water and exposing the stems and leaves to sunlight, for several weeks can be effective as long as *Cabomba* material is allowed to completely dry out. This can be hard to achieve during the wet season (*Department of Agriculture, Fisheries and Forestry (DAFF) Queensland government*).

6.3. CONTROL OF *CABOMBA* IN KERALA

The weed *Cabomba* is an exotic weed that is reported to have come with aquarium ornamental plant. This has become a menace in North Kuttanad some 7-8 years back and, studied this problem. The weed can be controlled by application of common salt at 2 ppm, as it does not tolerate salinity. We cannot do it in Pampa. It is eradicated biologically, also by stocking Grass carp, *Ctenopharyngodon idella* fish at 1/ 10 m2. The fish start feeding the weed when it reach size above 75 g. so stock big sized fish But grass carp is exotic to Pampa. So we can adopt this method in swamps not directly opening to the river in enclosed systems in Aranmula. We can also use local native fishes Barboides carnaticus, Manjakoori , Tooli or even karimeen as all these fishes feed vegetation to a great extent. In paddy fields and swamps not connected to rivers bottom feeding fishes such as Cyprinus carpio is also suggested. But this is also exotic. Increasing turbidity is one method which is possible by stocking bottom fishes. *Cabomba* is now a common weed in Kuttanad since 1983 (*K.G Padmakumar, Kerala Agricultural University).*

6.4. PREVENTION OF SPREAD

A number of measures can be taken to reduce the spread of *Cabomba* by humans or animals.

Hygiene

Information about *Cabomba* and wash down facilities should be available at all public access points to waters with *Cabomba* infestations. Boat and canoe hulls, propellers, scoops, trailers, harvesters, diving gear and any other equipment used for recreation, water management or *Cabomba* control should be washed down and checked thoroughly before leaving an infested area.

Animal movement

In some situations preventing animals (such as feral pigs and cattle) from entering infested waters will also help to minimize spread of fragments.

Public awareness

It is important that as many people as possible are aware of *Cabomba*. High levels of awareness will help water and the movement of fragments on watercraft and trailers. It will also help in early detection of new infestations.

Awareness can be raised through information days; quarantine or warning signs; notices posted in public places (shops, service stations); advertisements in local newspapers; mail outs in relevant areas; brochures and information for distribution to industry outlets (bait and tackle shops, pet shops, nurseries); water managers (protected-area staff, council staff, researchers, Landcare groups, Waterwatch groups); and water users (nature-based clubs, fishing clubs, canoeing clubs or businesses).

Early detection

Regular monitoring of uninfested areas and water bodies close to known infestations will help in the early detection and possible eradication of small, new infestations. Good public awareness campaigns and aquatic weed identification training will lead to early detection of infestations. (*Cabomba Control manual, Weeds of National Significance, NSW Department of Primary Industries, Govt. of Australia*).

Aquatic re-vegetation

Revegetation with native aquatic plants has been performed after the removal of plants from affected areas should be done. Techniques for more successful aquatic revegetation have been tried, but the ability of revegetation to prevent further *Cabomba* establishment has not been fully determined.

6.5. MANAGEMENT OF INVASIVE SPECIES IN PAMPA RIVERINE SYSTEM

Pampa Parirakshana Samithy evaluated the spreading nature of *Cabomba* along Pampa Riverine system. Most parts of the river and its tributaries are attacked by this weed. The major concern at present is to stop further introduction of *Cabomba* into the riverine system, and to remove completely from the affected areas. *Cabomba* easily regenerate from its fragments, so control activities can actually contribute to spread of the weed if care is not taken.

As the plant is submerged, its growth is detectable, only after the well establishment. Early detection of *Cabomba* infestations is essential, for efficient eradication. In our study it was found that the plant is sensitive to 41% Glyphosate but chemical treatment is not possible in our streams, as they are the life lines of people in Kerala.

Biological control measures can be used as a remedial option, but the spreading capacity of *Cabomba* is too fast to be controlled by common insects. Introduction of new biological enemies is needed. The control methods such as physical, mechanical measures can be used in Pampa Riverine system.

Mechanical removal by hand pulling in a bulk amount can be done by Local Governance and MGNREGS programs. The introduction of MGNREGS and its emphasis on water conservation, biomass regeneration, afforestation and biodiversity conservation opened up avenues for local governments and communities to engage themselves in the watershed/river basin regeneration programmes. MGNREGS provides a unique opportunity for local governments, to take up programmes and activities at the grassroots level.

6.6. RECOMMENDATIONS

- **Riparian vegetation** offers some degree of suppression, particularly along stream edges, where the water is generally slower flowing. *Cabomba* growth is promoted by the direct fall of sunlight. Direct sunlight into the water surface promotes the photosynthetic capability of the plant and thus spread rapidly. The shading by the riparian vegetation on either side of the River can be done. So afforestation is one of the physical methods applicable in Kerala especially along Pampa River bank. Afforestation can prevent soil erosion, flood and loss of biodiversity, thus maintaining a natural riparian canopy on the banks of the river.

  However, *Cabomba* is known to grow well at low light intensities near the edges of rivers in foreign countries, the shade by the riparian vegetation may be enough to prevent *Cabomba* from becoming established in the deeper parts of the river. It was proved that 70% shade restricted *Cabomba* at depths of 2 to 3 meters, not at depth of 1 meter. Hence in Kerala, along the river banks, afforestation can be done to check the growth of these invasive weeds.

  Pampa river basins are rich in riparian vegetation with several endemic species, most of which are in endangered condition. Preservation of existing riparian canopy and also the re-vegetation along the basin will enhance the shading and thus can prevent a rapid spread of *Cabomba* and related invasive species.

- **Mechanical Removal** is tedious and hazardous as its economic burden on the general community as concerned. Mechanical removal with machines and hands by divers resulted instant clearing of the weed, but risky in large infested areas. Special machines designed to cut, load, carry and unload water weeds are common in USA. In Lousiana, 2200 machines help keep the States water ways clean. Advantage of mechanical removal is public safety, improved aesthetics, nutrient and pollution removal. *Cabomba* can be effectively removed by hand using professional divers. Diver removal is applicable to small, infested area or as a window dressing operation. It is extremely expensive and very dangerous. Aquatic weed control machines like HV3000 model by Noosa Shire (1994) with 3m wide x 3m deep cutting mouth can be used, but it is expensive. The cut weeds were lifted by a conveyor on to a storage area, when full they were transported to river bank and should be disposed off, carefully. But the machine was too large and cutting tooth got damaged on submerged objects.

  In Kerala rivers mechanical removal with large and expensive machines are really risky, but these repeated cutting has profound effect on *Cabomba. Cabomba* infestation took a very long time to recover after repeated cuttings, because *Cabomba* is sensitive to repeated cuttings. The machine operated for 20 days without any breakdowns, a big improvement was reported from foreign countries. The average cut was 0.8m depth and removed about 13 tones of *Cabomba* per hectare.

  The use of compactor is a big step forward handling of cut materials and it overcomes the legal obligation for secure and safe transport of this declared Class I pest plant, *Cabomba* in Macdonald. Anyway mechanical control improves water quality. It may be due to the capacity of assimilatory power of *Cabomba* in absorbing and adsorbing the pollutants in water including both organic and inorganic ions. Mechanical control is one management tool that will correct some of the abuse and provide wiser water use, even though it is a risky and expensive method. Native water plants are to be propagated and planted to provide long term, competitive *Cabomba* control.

  Proper mechanical removal of the plant from riverine systems, and careful disposal is very important. A mere slip in the implementation of mechanical removal will result in the escape of the plant into the water again, and will flourish very fastly.

- **Shading**

  As a control method, shading can be used to suppress and possibly eradicate small *Cabomba* infestations less than one hectare in surface area of the water bodies. Shading can be used to create clear areas where *Cabomba* is in dense population, allowing better management of irrigation, recreation, or re-vegetation in infested areas. Shade can also benefit by reducing flowering and seed set, where *Cabomba* is known to provide visible seeds.

Floating blankets have been tried a number of times, with success in Australia. Benthic blankets, another option of shading will compress the aquatic plants and block out sunlight.

The implementation of these types of blankets in Kerala Rivers, especially in Pampa is not practical. It may affect the physical and chemical environment adversely, as it reduces the dissolved oxygen levels, increase Carbon dioxide levels and reduce pH levels. Both variations of shading will affect the normal flora and fauna of the riverine system.

- **Biological control**

Classical biological control involves eradication of the plant with its natural enemies. The *Cabomba* plant has been spread as an aquarium specimen and its pathogens and insect fauna have been left behind in the country of origin, Guyana. This type of scientific recovery is expensive and there are no guarantees of success. It may control one weed species and may not work at all even though it is safe, natural and pollution free. Other South American water plants like Alligator weed, water hyacinth, *Salvinia molesta*, and submerged Hydrilla like plants are controlled by insect enemies. But it is cost expensive. But if we do nothing, it promotes spread of the weed in all the water bodies in Kerala, India and world at large. If ignores, public safety issues comes out drastically. It destroys recreational and nature conservation values, fishing and boating. We have do something against the spread of this declared class I pest plant which is being a weed of International significance.

The success rate for the control of aquatic is much higher and is associated with the growth form of the weed, the insect taxa used as biological control agents, susceptibility to disease causing pathogens, fluid nature of the aquatic environment or some combinations of these elements.

Neoclassical biological control could be applied to those cases, where native organism develops a new association with a non-native weed species.

Management of *Cabomba* with biological agents can be tested for natural water stream like Pampa River. Introduction of natural enemies of *Cabomba* into the water system,should be very carefully done. The new flora or fauna introduced, should not create an imbalance in the existing habitat.

- **Chemical control**

There are currently no effective registered herbicides for use on *Cabomba* in India 2, 4-D n- butyl ester was registered and effective against *Cabomba*, but its use is currently suspended. Research is currently underway to support new herbicide registration for use against in non-flowing water.

Pampa Prirakshana Samithy had evaluated the effectiveness of Glyphosate against *Cabomba* plant segments. The treatment with 41% Glyphosate is effective in controlling the weed *Cabomba* with a survival percentage of zero. Hence Glyphosate can be used as a weedicide in small infested areas of *Cabomba*, but cannot be recommended in Pampa River and its allied water bodies as they are the lifelines of people.

Control with 2, 4 D n-butyl ester is an important component of the *Cabomba* eradication programme in Darwin River in the Northern Territory. 2, 4 D n-butyl ester herbicide is used in a suspension of diatomaceous earth in water and is applied to underwater stems through submerged nozzles on hand held or boat mounted booms. Diatomaceous earth is a light silica soil that absorbs the chemical and makes it less mobile, increasing contact with the target plants and minimizing off-target effects. This herbicide is currently under suspension, and may be used only for *Cabomba* control under a minor use permit.

In foreign countries, like USA and Australia, Flouridone, hydrogel, and diquat 200g/L are used as chemical agents against *Cabomba*. Flouridone was successfully used to eliminate *Cabomba* from a lake in Florida. Hydrogel is a guar- gum carrier product mixed with diquat 200g/L. It is specifically designed to control submerged aquatic weeds. When applied as in a steady stream, the gel and the di-quat mixture sticks and attaches to submerged weeds and the diquat is released into the surrounding water. The gear-gum is a non-toxic polysaccharide, which can be mixed on site to any viscosity and retains a constant viscosity at constant temperature. The starch polymer is non-toxic and is dispersed in water. The hydrogel-diquat mixture is less effective on *Cabomba*, than on other submerged aquatic weeds, because a lower rate of retention of the gel on fan like *Cabomba* leaves *Cabomba* biomass was reduced to 47% after the treatment for 12 weeks and repeated use may control *Cabomba.*

- **Aquatic Re-vegetation**

Aquatic re-vegetation after the removal of *Cabomba* like aquatic plants is one of the key remedial measures which can be done effectively along Pampa River. Areas of the river should be re-vegetated with natural hydrophytes after the removal of foreign invasive weed

Cabomba had invaded most of the shallow littoral zones of Pampa riverine system. Submerged species replaced by *Cabomba* were *Hydrilla verticillata*, *potamogeton* species, and *Utricularia*. *Hydrilla* and *Vallisneria* species have been propagated for revegetation in water bodies and take care to set up aquatic plant nursery to provide native water plants for aquariums.

- **Maintainance of natural habitat.**

All the problems associated with a riverine system is due to the loss of its original consistency. The invasion of foreign weeds like *Cabomba* is facilitated by the imbalance of natural habitat of Pampa River. Destruction of riparian vegetation helps the direct entry of sunlight, which facilitate the growth of these weeds. So maintenance of natural vegetation and further plantation processes are also recommended.

Another physical factor, which aids the growth of *Cabomba* is the muddy bottom of the river. They strongly rooted in the muddy portion of the river bed. Unscientific sand mining from the river lead to the loss of sandy cover at the bottom. So illegal sand mining should be prohibited from the rivers to maintain their natural habitat.

- **Salinity**

Salinity is one of the natural enemies of *Cabomba.* During the study, it was found that in Veeyapuram area *Cabomba* plants were not visible during pre-monsoon time due to the entry of saline water into the river. But after flood in monsoon, reappears. Fragments of the plant floating on the surface of water were seen. Actually the rhizomes of the plant is deep buried and perennate in the bottom mud, and reappear when flood comes which reduce the salinity.

Introduction of saline water into Pampa River is not practical, as it is the lifeline of thousands of people. But, small infested area can be treated effectively with salinity.

- **Introduction of fishes to feed *Cabomba***

  The grass carp will eat the fanwort. Grass carp tend to feed in relatively shallow areas and near the surface of the water body, preferring to graze on the soft tips of tender submerged aquatic plants. Research works are going on to use *Cabomba* as a fish feed in Kerala.

- **Prevention of Pollution**

  High content of pollutants from houses, factories and farming fields are rich in nutrients which enhance the growth of *Cabomba* like weed. The water analysis from the sites where growth of *Cabomba* is abundant revealed that the water is nutritious and supplement all the essential nutrients to the growth of such aquatic plants. So the discharge of waste water from factories, house hold wastes and fecal contamination, all should be prohibited for the better eradication of these weeds.

  Proper sewage management programme should be implemented in all factories.

- **Restoration of distributaries**

  The entry of *Cabomba* into the main stream of Pampa river is aided by the flourished growth in tributaries, small channels and in paddy fields. So the eradication of *Cabomba* from Pampa River will be fruitful only when its tributaries, distributaries and associated paddy fields are free of these invasive weeds. So restoration of all associated riverlets should be done.

- **Development of sustainable agriculture practices**

  Farming with modern techniques using chemical fertilizers and pesticides should have a role in mixing chemical nutrients into the nearby streams during rainy season, and thus facilitates growth of unwanted weeds. Agriculture practices with traditional methods recommendable.

- **Public awareness**

  Public awareness about the weed is necessary. Increase identification skill of people to detect the weed, proper handling of the weed to prevent further spreading, water pollution and its enhancement for the growth of *Cabomba.* All these should be done by the local authorities.

  Common people should be educated through awareness campaigns and classes.

6.7. ABSTRACT OF RECOMMENDATIONS

1. Proper regulation of salinity in the Kuttanad region of Vembanad Wetland System.

After the construction of the Thanneermukkam salt water Regulator the salinity of the southern part of the Vembanad lake is highly reduced. This part of the lake became almost a fresh water system. This change induces or provides an environment for the growth and spreading of *Cabomba* and other invasive species. Gradually these plants spread to the river systems also. It is observed that this species completely disappear during summer months when the shutters of the barrage remain open. This shows that if the salt water is properly regulated, *Cabomba* can be eradicated. Dr.M.S.Swaminathan in his Kuttanad package recommended the proper regulation of the Thanneermukam barrier. The recommendations in Kuttanadu Package for regulating salinity shall be implemented.

2. Biological Control

Salvenia (African *Payal*) was once a major menace of the Vembanad system. It was successfully managed by introducing its natural enemies. This work was done by Kerala Agricultural University. Biodiversity Board can entrust this to a scientific institution to work on natural enemies of *Cabomba.* Suitable organisms can be effectively utilized for the management of this invasive species.

3. Manual Removal

In inland water bodies, manual removal of *Cabomba* is recommended. It can be included in MNREGS, so the local people get benefit out of it. If manual removal is continuously done for 2-3 years complete eradication of this weed is possible.

4. Revival of the riparian vegetation

Cabomba is a plant which requires high light intensity for its proper growth and development. The disappearance of the riparian vegetation is one of the factors which promoted the spreading of *Cabomba* in river system. Revival of the riparian vegetation along the sides of the river banks provides shade which may reduce the growth of this plant. An area of width of 4-6 mts along the river side can be declared as an eco-tone and rich vegetation can be developed there, as a green belt.

5. Water treatment plants

The high nutrient content in the water is a major factor which influences the luxuriant growth of water weeds. The source of these nutrients is sewage and municipal waste reaching the water bodies without treatment. So establishment of local treatment plants is also recommended. The proposed Pampa Action Plan, under N.R.C.P for the mitigation of pollution in River Pampa shall be implemented is a time-frame of two-three years.

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ENVIRONMENTAL EDUCATION AND AWARENESS CAMPAIGNS

29-05-2013 - Interaction on 'Biodiversity Conservation and Western Ghats', at Ranny in association with Malanadu T.V Channel. Dr. Bency Mathew, Secretary, Pampa Parirakshana Samithy, N.K Sukumaran Nair, General Secretary, PPS and Sri. Devarajan, Editor, Malanadu Channel, Ranny, participated.

22-04-2013- Earth Day Celebrations at Environment Resource Centre, Poovathur. Workshop on 'Climate Change and Biodiversity'. Dr. Vinod, Senior Scientist, K.V.K, Pathanamthitta, presented paper on Climate change and Water Resources. Dr. John Kuruvila was the moderator. Dr. K.N.P Kurup presented paper on people's biodiversity Register. Dr. K.M Nair, prof. M.V.S Nampoothiri and Sri.Sri. K.R Vinayachandran Nair spoke.

04-06-2013- Environment Day Celebratios at pathanamthitta in association with Press Club, Pathanamthitta.Seminar on Pampa – Achenkovil - Vaipar Project and its effect on Biodiversity.

Sri. N.K Sukumaran Nair, General Secretary, presented the Key Note Address. Adv. Peelippose Thomas, Former member, State Planning Board, Adv. Omalloor Sankaran, General Secretary, Kerala Karshaka Sangom, Sri.P.Prasad, District Secretary C.P.I participated in the discussion. Sri. Vinod, Elamannoor was the moderator. Sri. Sajith Parameswaran, welcomed the gathering and Sri. Biju Kurian, gave vote of thanks.

06-06-2013- Environment Day Celebration at Pandalam N.S.S College in association with Dept. of Botany. Sri.N.K Sukumaran Nair, presented a paper on 'Water, The Larger part of Ecology with reference to Holy River Pampa and its Ecology'.

12-06-13- Biodiversity Conservation in Pampa River. Training camp at Environment Resource Centre, Poovathur. Dr. K.N P Kurup, Sri. N.K Sukumaran Nair and Dr. Chandrasekharan Unnithan presented papers and led the discussions.

17-06-2013 - Conference of Rejuvenation of Pampa River at Collectorate, Pathanamthitta. Officials and people's representations participated.

23-06-13 – Workshop on Conservation of Western Ghats at Kottayam in association with Thapasia' Kottayam District Unit. Sri.N.K Sukumaran Nair, Dr. N.K Unnikrishnan, and others presented papers on Gadgil Committee Report.

04-07-013- Biodiversity Conservation in Pampa River

Workshop for people's representatives in Koipram Grama Panchayath and various Stake holders. Dr. K.N.P Kurup, Prof. M.V.S Nampoothiriand Sri. N.K Sukumaran Nair presented Papers on the subject.

26-07-2013- Public meeting organized in association with Bhoomithrasena Club.

26-09-2013- Seminar at Kozhenchery on World River's Day in association with media centre.

03-11-2013- "Paristhithi Koottayma" at Environment Resource Centre, Poovathur. Prof. T.N Ramakrishna Kurup, Prof. M.V.S Nampoothiri, Sri.E.G Reji, Otheraand others spoke on Rejuvenation of Pampa and Varattar and its Biodiversity. Dr. Jose Parakkadavil inaugurated the "Koottayma".

24-11-2013- "Varattar Gramasadas" at Puthukulangara, Othera. People residing on the banks of Varattar and the Officials of Senior Citizens Association attended the "Gramasadas".Adv. G.Rajeev, President, Eraviperoor Grama Panchayath inaugurated the meetingin a function presided over by Prof. M.V S Nampoothiri. Sri. N.K Sukumaran Nair presented the key note address.

30-12-2013- “Pampa River- Crying for help” Environment class for the Student police Cadets, St. Thomas High School, Kozhenchery.

10-12-2013- Biodiversity Conservation in Pampa River Basin on 10-12-13 at Catholicate College, Pathanamtitta in association with Dept. of zoology. P.B Noohu I.A.S, Assistant Collector, Pathanamthitta inaugurated the Workshop. Rev. Dr. Kuriakose Mar Climis Metrapolitha gave the benedictory speech. Prof. T.N.Ramakrishnakurup, Dr.M.SSunil, N.K.Sukumaran Nair, Dr. GeorgeVarghese, Prof. M.V.S.Nampoothiri, Dr. Mathew Joseph, Dr. M. J. Elizabeth, Dr. Philipose Oommen, Dr. G.Ramadevi spoke.

09-01-2014-‘Integrated Water Resource Development in Pampa River Basin’ at Christian College, Chengannur. The Workshop was inaugurated by Adv.U. Prathibha Hari, President, Alappuzha District Panchayath in a function presided over by Prof. T.N Ramakrishna Kurup. Prof. Thomas P. Thomas, Dr. Rajan David, Prof. M.V.S Nampoothiri, Dr. Abhilash R, Sri. Mathews Koodarathil spoke. N.K Sukumaran Nair, Dr. K. Jayachandran, Sri. AbrahamVarghese, Dr. G. Ramadevi presented paper on the subject.

14-02-2014 – 'Integrated Water Resource Development and Biodiversity Conservation’ at S.D College, Alappuzha. The workshop was inaugurated by the Principal Prof. R.Geethakrishna Pi. Dr. C. Dileep, Co-ordinator, Bhoomithrasene, welcomed the gathering. Sri. N.K Sukumaran Nair presented the paper about the subject. Prof. M.V.S Nampoothiri gave felicitation and Dr. G.N Prabhu gave vote of thanks.

18-02-2014 – Rejuvenation of River Pampa for the Training for Accredited Engineers of 21 grama Panchayaths on the banks of River Pampa. presided over by Annapoorna Devi, Block panchayath President. District Panchayath president, Dr. Saji Chacko, inaugurated the function. Smt. Nirmala Mathew, Koipuram Grama Paanchayath, Prof. M.V.S Nampoothiri, Vice President, Pampa Parirakshana Samithy gave felicitations. Sri. Rajan baba, District Co-ordinator, MNREGS and Sri.N.K Sukumaran Nair, Gl. Secretary, Pampa Parirakshana Samithy, presented papers on the subject.