NATIONAL-LEVEL TRAINERS' TRAINING PROGRAMME

The Health & Restoration of Economically & Culturally important Rivers of India using Biological Indicators found in Kerala Streams, within the context of Climate Change Impacts & Sustainable Development

An initiative by: M. S. Swaminathan Research Foundation & Asia Pacific Network for Global Change Research

April 18 – 22, 2022, Pathnamthitta, Kerala

The water quality of our rivers is getting tainted over time along with increased demand for potable water. There is ample time to act to preserve our rivers before the pinnacle point of destruction. The prime focus of this initiative is to train and practice skilled veterans in river management & restoration. This programme aims to motivate a cohort of participants to monitor the comprehensive health and longevity of culturally and economically far-reaching Rivers, by compiling innovative management practices and through intense training. The eminent panel of trainers of the programme includes academicians, scientists, and practitioners who are long-experienced in the field of River Health, Biodiversity, Climate change, Sustainable Development Goals etc. The learner group includes a cohort of 22 people including scientists, academicians, and grassroot practitioners across 9 states of India.

The training comprises 5-day intense sessions led by eminent experts including invited lectures by international academicians and practitioners. Three days are dedicated to the theoretical framework of River Health Management. During the 2-day practical training sessions followed, participants will be taken for a field expedition trip across the Pampa River basin. While the participants go back after the training, they can practice River Health Assessment Tools at their respective locations and get in touch with a dynamic community of practitioners in River Health Assessment & Sustainable Restoration, across the globe.

Pampa River Basin, A Case Study for River Health Management

Pampa or else known for its vernacular name 'Dakshina Ganga', is the third-longest river in Kerala after Periyar, spanning about 176 km in total length. The exquisite attribute of the Pampa River is its unique topographical blending, to be precise, the River emanates from Pulachimala on the Peerumedu plateau of Idukki district and flows through the midlands of Pathanamthitta district, enriching the lowlands of Alappuzha-Kuttanadu, and eventually drains into Vembanad lake. Predominantly the Pampa River is renowned for its association with Sabarimala Temple. The River is hence considered the 'Sacred Pampa'. Millions of Pilgrims carry out the ultimate rituals 'The Holy Dip' at the Pampa River basin, eventually tainting the river, and hence considered to be one of the foremost sensitive points. Apart from this, we have other rituals, customs, festivals, and traditional ceremonies associated with the Pampa River basin-like, the Maramon Convention, the Aranmula Snake boat race, and traditional agricultural practices. Due to erroneous agricultural practices, excess pesticides, herbicides, and fertilizer effluents are discharged into the river, eventually ensuing in heavy metal accumulation, eutrophication, and algal blooms. There is a substantial degree of sand mining from the Riverbanks of Pampa like Pavukara, Cherukolpuzha, etc. Even though management practices & glorious initiatives are tackled by different players, the optimal health of the Pampa River and river ecosystem is still on the verge of disaster. Environmentalists and other veterans prognosticated the impending devastating phase of the Pampa River as it has already started perceivably implying the symptoms.

The participants of the training programme will be getting an opportunity to understand the River Health Assessment Tools, investigating across the Pampa River Basin.

A cohort of 16 people from Kerala has completed the same course during the REGIONAL-LEVEL TRAINERS' TRAINING PROGRAMME held from 14th to 16th of March, 2022.

Project Funding Partner

Asia-Pacific Network for Global Change Research, based at Japan is an intergovernmental network of 22 countries working towards an Asia-Pacific region, with special emphasis on recent trends in global change and sustainable solutions.

For more information:
Dr N. Anil Kumar, Senior Director & Project investigator, M. S. Swaminathan Research Foundation, Puthurvayal P.O, Kalpetta, Wayanad, Kerala, India-673 577
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M. S. SWAMINATHAN RESEARCH FOUNDATION
&
Asia Pacific Network for Global Change Research

River Health Monitoring and Restoration:
A Training Programme using Biological indicators for River health and restoration
March 14 to 16, 2022
Tarangam Mission Action Centre, Arattupuzha, Pathanamthitta

Day1 March 14, 2022 Monday			
10:00- 10:15	Inaugural Session	Lighting the Lamp and Inaugural Address	**H. G. Geevarghese Mar Coorilos Metropolitan**
10:30 to 11:15		Keynote Address: Healthy rivers- The lifeline for environmental sustainability with special reference to hydrology of Kerala rivers	**Dr E. J. James,** Pro - VC, Karunya Institute of Technology and Sciences

11:15- 11:45 Tea Break

11:45- 13:00	Technical Session 1	Ecology of rivers with special reference to Kerala	**Dr A. Bijukumar**

13:00- 14:00 Lunch Break

14:00- 18:30 (16:30 – 16:45 Tea Break)	Technical Session 2	Ecosystem services of rivers and its continuum – The Physical aspects & The Biological Aspects	**Dr T. Sabu** **Dr R. Ajayakumar Varma**
		Aquatic biodiversity	**Dr. A. Bijukumar &** **Dr S. Nandakumar**
		Riparian vegetation in Kerala's River basins: Diversity, ecological functions and restoration prospects	**Dr P. K. Shaji**
		Riparian biodiversity	**Dr Joby Paul**
		Rivers & avian fauna	**Dr N. Unnikrishnan**
		Water quality & sediment chemistry	**Dr V. P. Sylas**

18.30-18.45 Break

18.45-20:00	Invited talk	Why should the River Flow?	**Sri. S.P. Ravi**

20:30 Dinner

Day 2 March 15, 2022 Tuesday			
07:00 – 07:30 Break Fast at Tarangam			
Field Trip to Pampa River Basin, starting by 07:30 from Tarangam and reaching Attathode by 9:00			
09:00-12:00	River Health Assessment- Field Exploration in the upper stretches of River Pampa	Guided Walks with Lectures and demonstrations	**Dr R. Ajayakumar Varma** **Dr T. Sabu** **Dr P. K. Shaji** **Dr N. Unnikrishnan** **Dr V. P. Sylas** **Dr S. Nandakumar** **Dr N. Anil Kumar**
12:00-13:00	Community and Decentralized Democratic	With a community Interaction	**Dr Midhila Mallika**

	Approaches for Conservation and Management of Natural Resources – Experiences from the field		

13:00 – 14:00 Lunch at Attathode

Field Trip to Pampa River Basin, starting by 14:00 and reaching Vadasserikkara by 15:00			
15:00-16:00	River Health Assessment- Field Exploration in the middle stretches of River Pampa	Guided Walks with Lectures and demonstrations	

Reaching back at Tarangam by 17:00 & Tea

17:30- 18:00	Invited talk: Video recording	People centric and people partnered river health and river life management	**Dr Richard Storey**
18:00 – 19:00	Invited talk: Video recording	Freshwater Pollution in Asia and the Role of Insects in its Management	**John C. MORSE**
19:00- 20:30	Interactive Session	River rejuvenation: The Varattaar Case	**Adv. N. Rajeev**

20:30 Dinner

Day 3 March 16, 2022 Wednesday			
07:00 – 07:30 Break Fast at Tarangam			
Field Trip to Pampa River Basin, starting by 07:30 from Tarangam and reaching Veeyapuram by 9:00			
09:00-11:00	River Health Assessment- Field Exploration in the lower stretches of River Pampa	Guided Walks with Lectures and demonstrations	

Reaching back at Tarangam by 12:30 & Lunch

14:00- 15:00	Technical Session 3	Interactive session - State of the Environment of a River or River Health Assessment using DPSIR (Drivers, Pressures, State, Impact and Responses)	**Dr R. Ajayakumar Varma** & Team

15:00-16:30	Closing Session	Special address & Certificate Distribution	**Adv Raju Abraham**, Chairperson, Pampa River Basin Authority
15:30-16:00	Keynote Address	Policy influence, Regulations, Water literacy and People's participation in the river health restoration and management	**Prof Dr Mathew Koshy** Punnackadu, Member Pampa River Basin Authority
16:00 – 16:30		Reflections & Way forward	**Dr R. Ajayakumar Varma**
16:30 – 16:35		Vote of Thanks	**Dr N. Anil Kumar**

16:35 Tea & Closing

River Health Monitoring and Restoration: A Training Programme using Biological indicators for River health and Restoration
March 14 to 16, 2022, Tarangam Mission Action Centre, Arattupuzha, Pathanamthitta

Profile of Trainers

Dr E. J. James is a member of the Governing Body of Wetlands International South Asia. He is presently the Professor Emeritus and Director, Research and Consultancy & Pro Vice-Chancellor (Strategy and Operations), at the Karunya University, (Coimbatore), Tamil Nadu. Dr James is a renowned wetland hydrologist specialized in Hydrology, Integrated Water Resources Management and Irrigation Engineering. He has worked as a Scientist for 30 years in the Center for Water Resources Development and Management (CWRDM) at Calicut, retiring as Scientist-G and Executive Director of CWRDM and the Director of Irrigation Management Training Institute of Kerala.

Dr R. Ajayakumar Varma had a long-term successful career with the National Centre for Earth Science Studies, Thiruvananthapuram. He has also served in several govt bodies and missions in various positions such as the Member Secretary of Kerala State Council for Science Technology & Environment and Kerala Coastal Zone Management Authority; as the Executive Director of Suchitwa Mission, and as the Director of Clean Kerala Mission. His expertise is in Environmental management planning, Sustainable development and Geophysical explorations. He is acting as the Chair of the Academic Committee constituted for conducting the training programme in River Health Management.

Dr T. Sabu is with Centre for Environment and Development, Thiruvananthapuram as its Program Director. He has over 37 Years of experience in the NRM and Environment Management sector. His areas of expertise include Natural Resources and Environment Management, Biodiversity Conservation, Wetland Management, Urban Environment Management, Climate Change, Energy Conservation, Environmental Impact Assessment etc

Dr A. Bijukumar is Professor and Head of the Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram. He has got nearly 30 years of research and teaching experience in the areas of taxonomy of fishes, Crustacea and Mollusca, biodiversity documentation, aquatic ecology and fisheries. He has described several new genera and about 50 species of aquatic organisms from Kerala coast, with his colleagues and students.

Dr S. Nandakumar is with NSS College, Pandalam as an Assistant Professor and research guide in the Department of Zoology. His specialization is in aquatic entomological biomonitoring and Microbiology.

Dr P. K. Shaji was with Environmental Resources Research Centre (ERRC), Thiruvananthapuram as Principal Scientist & Deputy Director. He is an experienced scientist with a demonstrated history of working in the environmental services industry. He is skilled in Sustainable Development, Plant Ecology, Lecturing, Biodiversity, and Environmental Impact Assessment.

Dr Joby Paul is an Assistant Professor and Research Guide at St. Thomas College, Thissur. His expertise is in Plant Taxonomy and Ecology. He has extensively worked on the distribution and ecology of the riparian flora of pamba river basin.

Dr N. Unnikrishnan is a botanist and bamboo specialist, retired as Professor from SVR NSS College, Pathanamthitta. He is with Kottayam Natural Society as its secretary. His expertise is in Botany and Ecology.

Dr Sylas V. P. is an Assistant Professor at School of Environmental Sciences, Mahatma Gandhi University, Kottayam. He has nearly 15 years of research and teaching experience in various fields of Environmental Science. His research interests include Wetland Ecology, Biodiversity, Bioenergy, Bio-nanomaterials, Environmental Microbiology, Pollution Studies, and Water Quality.

Sri S. P. Ravi is associated with Chalakudypuzha Samraskhana Samiti and also The River Research Centre, Thrissur. He is an ardent environmentalist and eminent speaker and has been advocating the health, restoration and monitoring of the Rivers across Kerala. He is also a leader of the All-Kerala River Protection Council and spearheading a number of projects related to river monitoring and capacity building.

Dr Midhila Mallika is with Community Environmental Resource Centre of Ashoka Trust for Research in Ecology and Environment. Her primary focus areas are Grassroots Governance, Gender and Development with focus on principles of community leadership and citizen engagement and the roles of elected representatives in the governance of local communities. Midhila does research in Marginalized women, State Politics, civil society participation, leadership and Comparative Democratization with special reference to feminist theories.

Dr Richard Storey is a Postdoctoral Researcher at the Aquatic Ecology Centre, Kathmandu University. Had a long-term successful career as Fresh water scientist at National Institute of Water and Atmospheric Research, experienced in biological monitoring of rivers; ecology and hydrology of intermittent and headwater streams; citizen science; ecology of urban streams; nitrogen cycling and emissions in streams and wetlands. His Expertise is in Groundwater, Freshwater Ecology, Rivers, Water Resources Management, Water Analysis, Environmental Impact Assessment, Biodiversity, Ecosystem Ecology, Water Quality Monitoring, Water Quality Analysis

Dr John Morse is a Professor Emeritus of Entomology at the Agricultural and Environmental Science Department of Clemson University, SC, USA. His research interests are in Trichoptera systematics and historical biogeography, Aquatic insect faunistics and biology, Use of insects for water quality biomonitoring, Insect species diversity, and endangered species.

Adv. N. Rajeev was the President of Eraviperoor Gramapanchayath in Pathanamthitta district. It was under his leadership, the panchayath had bagged the Prime Minister's Award for Excellence in Public Administration in the year 2015 and had won the 'India Biodiversity Award 2018' under the category Best Biodiversity Management Committee. He was also spearheading the rejuvenation of Varattar River.

Dr Mathew Koshy Punnakadu

Dr. Mathew Koshy Punnakadu is a noted Environmental Scientist, Environmental writer and Environmental activist. He is now discharging his duties as the Honorable Director of the Department of Ecological Concerns of Church of South India (CSI). He was also a member of the Pampa River Basin Authority, constituted by Govt of Kerala. He was a former faculty of Chemistry and the Principal at Bishop Moore College, Mavelikkara. In 1990's, he had initiated the Green Church Movement in India.

Dr Nadesa Panicker Anil Kumar

Dr Anil Kumar is an Agrobiodiversity management practitioner at M. S. Swaminathan Research Foundation (MSSRF) based at its regional station- Community Agrobiodiversity Centre in Kerala. He leads the Community Biodiversity Management programme of MSSRF that focuses on synergized actions in conservation, cultivation, consumption, and commerce elements in sustainable plant genetic resource management in the biodiversity hotspots of southern India. He is an expert with over 25 years of experience in the area of Biodiversity mainstreaming in food, nutrition, health and agricultural production and consumption.

M. S. SWAMINATHAN RESEARCH FOUNDATION &
Asia Pacific Network for Global Change Research

River Health Monitoring and Restoration: A Training Programme using Biological indicators for River health and Restoration
March 14 to 16, 2022, Tarangam Mission Action Centre, Arattupuzha, Pathanamthitta

Profile of Participants

Sl No.	Name	Affiliation
1	ANAND ZACHARIAS	Researcher, Kerala Forest Research Institute, Peechi
2	ANIL KURICHIMUTTOM	Journalist, THE NEW JOURNAL
3	ASHI ANU MATHEW	Junior Project Fellow, OISCA INTERNATIONAL
4	ATHULYA P.	Research scholar, CUSAT, School of Environmental Studies
5	BLAISE JOSE K.	PhD scholar, Kerala Forest Research Institute, Peechi
6	GAUTHAM KRISHNA	Volunteer Coordinator, DC Volunteers, Pathanamthitta
7	GOPAKUMAR R.	Secretary, OISCA INTERNATIONAL
8	HAREESH KUMAR A. S.	Journalist, Malayala Manorama
9	HARSHA C. P.	MSc Human Genetics and Molecular Biology, Bharathiar University
10	JUBILANT J. KIZHAKKETHOTTAM	Professor, Saintgits College of Engineering, Kottayam
11	K. R. ASHOKAN	Padasekhara Samiti
12	MANEESHA M. S.	Project Fellow, Mahatma Gandhi University, Kottayam; Phycotechnology laboratory, Postgraduate and Research Department of Botany, Catholicate College, Pathanmthitta.
13	MANESH JACOB	Assistant Professor, Department of Mathematics, Mar Thoma College, Tiruvalla
14	OMANA T. K.	Founder, RASTA, Wayanad (SWRC/Barefoot College Tilonia)
15	POOJA SURESH	Research Scholar, Western Ghats Hornbill Foundation
16	RAHUL K. SUKUMARAN	Landscape Architect, SEED Architecture School, Muvattupuzha
17	RAKSHITHA R.	Project Fellow, Kerala Forest Research Institute, Peechi
18	SANOOP RAJAN	Programme Coordinator, Jaljeevan, Koipram Gramapanchayath Weather Monitoring Group
19	SARATH KUMAR P. S.	Social Activist, Koipram Gramapanchayath Weather Monitoring Group
20	SINDU SANTHOSH	Teacher, Koipram Gramapanchayath Weather Monitoring Group

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River Health Monitoring and Restoration:
A Training Programme using Biological indicators for River Health and Restoration
April 18 to 22, 2022
Tarangam Mission Action Centre, Arattupuzha, Pathanamthitta, Kerala

Day 0 April 17, 2022 Sunday 14.00-20.00 Arrival of Participants & Registration

Day1 April 18, 2022 Monday		
08:00 - 09:00 Break Fast at Tarangam		
09:00 - 09:10	Opening Session	Welcome: **Dr G. N. Hariharan** (ON-LINE), Executive Director, MSSRF
09:10 - 09:20		About MSSRF- Screening 25 year's Film
09:20 - 09:30		About the Training Programme: **Dr N. Anil Kumar**, Senior Director, MSSRF
09:30 - 9:50		Self- Introduction by the Participants
10:00 - 11:00		Key Note Talk: **Prof. T. Jayaraman** (ON-LINE), Senior Fellow, MSSRF Climate change – The Risks and Impacts on Water Management in India

11:00- 11:30 Tea/Coffee Break

11:30 - 11:35	Inaugural Session	Welcome: **Dr N. Anil Kumar**, Senior Director, MSSRF
11:35 - 11.40		Presidential address: **Smt. Sara Teacher**, Vice President, District Panchayath, Pathanamthitta
11:40 - 12:00		Inaugural Address: **Sri. Roshy Augustine**, Minister for Water Resources, Govt of Kerala Didn't attend
12:00 - 12.05		Felicitation: **Smt. Sheeja T. Toji**, President, Aranmula Gramapanchayath
12:05 - 12.10		Felicitation: **Smt. Sindhu Abraham**, Member, Aranmula Gramapanchayath
12:10 - 12.15		Felicitation: **Rev. Fr Jyothish Sam**, Director, Tarangam Mission Action Centre
12:15 - 12.20		Vote of Thanks: **Sri. Joseph John**, Scientist, MSSRF

12:20- 12:30 Group Photo
12:30- 14:00 Lunch Break

Technical Session I: Ecosystem Health, Climate Change and River Biodiversity	
14:00 - 15:00	**Dr Jayanta Bandyopadhyay** (ON-LINE), Rivers and Water security of South Asia

15:00- 15:30 Tea/Coffee Break

15:30 - 16:30	**Dr E. J. James** (ON-LINE), Healthy Water-related Ecosystems and Source-Sink Management
16:30 – 18:00	**Dr T. Sabu, Dr P. K. Shaji, Dr N. Unnikrishnan, Dr Joby Paul, Dr G. N. Hariharan** (ON-LINE) Riverine System Biodiversity in India

18:00- 18:30 Break

18:30 - 19:30	**Prof. John C. Morse**, (RECORDED VIDEO), Invited Lecture: Insects as Indicators of River Health

19:30 - 20:30	PANEL DISCUSSION I: Need for Scientific targets and Strategic Actions in River Health Monitoring and Management projects in India Session introducer: **Dr N. Anil Kumar** Panel: **Prof. John C. Morse** (ON-LINE), **Dr E. J. James** (ON-LINE) & **T. V. Ramachandra**

20:30 Dinner at Tarangam

Day 2 April 19, 2022 Tuesday	
08:00 - 09:00 Break Fast at Tarangam	
Technical Session II: River Health Assessment-Theory	
09:00 - 10:30	**Dr T. V. Ramachandra**, River Health Assessment application in India

10:30- 10:45 Tea/Coffee Break

10:45 - 12:00	**Dr A. Biju Kumar**, Framework for River Life Awareness and Management and Establishment of Best Management Practices (BMPs) to reduce vulnerabilities with respect to Catchment health, Channel health, Flow health, and Flood plain health
12:00 - 13:00	**Dr D. Padmalal**, Rivers and river health assessment: Some basic concepts within the context of ecosystem sustainability

13:00- 14:00 Lunch Break

Technical Session III: **River Health Assessment- Protocols, Tools & Practices**	
14:00 - 15:00	**Dr Harikumar P. S**. (ON-LINE), Vulnerability status and Health indicators of Rivers and formulation of RIVER VULNERABILITY INDEX considering land-use practices, forest quality, tributaries management, catchment protection, and water quality

15:00- 15:30 Tea/Coffee Break

15:30 - 16:30	**Dr Richard Storey**, (RECORDED VIDEO), People Centric River Health Management Practices Followed by discussion (ON-LINE)

16:30- 17:30 Break

17:30 - 19:30	PANEL DISCUSSION II: The Need for Science- Society linkage to engage local people and the local departments with Scientists and Engineers in river protection and management Session introducer: **Dr P. K. Shaji** Panel: **Dr. T. V. Sajeev, Dr. T. Sabu, Dr V. P. Sylas, Adv. Rajeev N.**

20:00 Dinner at Tarangam

Day 3 April 20, 2022 Wednesday	
08:00 - 09:00 Break Fast at Tarangam	
Technical Session IV: **River Health Assessment and Restoration**	
09:00 - 10:30	**Dr K. Ajayakumar Varma**, Comprehensive Vulnerability analyses using DPSIR (Drivers, Pressures, State, Impact and Responses) Framework; Major groups of bio-indicators for RHA and their identification and taxon and Methods to analyze Stressor Identification (SI) process to determine the causes of biological aspects of water body impairment
10:30 - 11:30	**Dr T. V. Sajeev**, Problems of Alien Invasive Species in Indian Rivers

11:30- 11:45 Tea/Coffee Break

Technical Session V: Policy influence, Regulations, Water literacy, and People's participation in the river Health restoration and management	
11:45 - 13:00	**Sri. S. P. Ravi**, People-centric and people partnered river health and river life management

13:00- 14:00 Lunch Break

Technical Session V: Policy influence, Regulations, Water literacy, and People's participation in the river Health restoration and management	
14:00 - 15:30	**Sri. K. J. Joy**, Identifying causes and setting goals for reducing river impairment - Policies and importance of regulations/controls and cooperation between the stakeholders, local community, and government officials on river restoration and health

15:30- 15:45 Tea/Coffee Break

15:45 - 17:15	**Group Discussion**: Empowering the Global Movement on Ecosystem Restoration Lead Talk: **Dr Archana Godbole** Lead Discussant: **Dr Jyothi Krishnan** (ON-LINE)**, Dr S. Sandeep, Dr Midhila Mallika**

17:15- 18:30 Break

18:30 - 20:00	PANEL DISCUSSION III: Restoring & Rejuvenating Rivers: Follow-up Actions Session introducer: **Dr T. Sabu** Panel: **Dr N. Unnikrishnan, Dr P. K. Shaji, Dr V. P. Sylas, and selected/volunteered 3-4 trainees**.

Day 4 April 21, 2022 Thursday	
07:00 - 07:30 Break Fast at Tarangam	
Field Trip to Pampa River Basin, starting by 07:30 from Tarangam and reaching Attathodu by 9:00	
09:00 - 12:00	Field Exploration in the upper stretches of River Pampa: Guided Walks, Rapid bio-assessment protocols (RBPs), Understanding the prevailing DPSIR (Drivers, Pressures, State, Impact, and Responses) **Dr T. Sabu, Dr P. K. Shaji, Dr N. Unnikrishnan, Dr V. P. Sylas, Dr S. Nandakumar, Dr N. Anil Kumar**
12:00 - 13:00	Community Interaction: Community and Decentralized Democratic Approaches for Conservation and Management of Natural Resources – Experiences from the field Facilitated by **Ms Parvathy Radhakrishnan**

13:00 - 14:00 Lunch at Attathodu

Field Trip to Pampa River Basin, starting by 14:00 and reaching Vadasserikkara by 15:00	
15:00 - 16:00	Field Exploration in the middle stretches of River Pampa

Reaching back at Tarangam by 17:00 & Tea

17:15- 17:00 Break

19:00 - 20:00	PANEL DISCUSSION IV: **Need for Scientific targets and Strategic Actions to protect Vembanad Lake and its River Basins** Session introducer: **Dr V. Shakeela** Panel: **Dr K. G. Padmakumar, Dr N. Unnikrishnan, Dr Midhila Mallika & Dr P. K. Shaji**

Day 5 April 22, 2022 Friday	
07:00 – 07:30 Break Fast at Tarangam	
Field Trip to Pampa River Basin, starting by 07:30 from Tarangam and reaching Veeyapuram by 9:00	
09:00-11:00	Field Exploration in the lower stretches of River Pampa: Guided Walks, Rapid bio-assessment protocols (RBPs), Understanding the prevailing DPSIR (Drivers, Pressures, State, Impact, and Responses) **Dr T. Sabu, Dr P. K. Shaji, Dr N. Unnikrishnan, Dr V. P. Sylas, Dr S. Nandakumar, Dr N. Anil Kumar**
11:00-12:00	Public Function at Veeyapuram: Commemorating Earth Day 2022: INVEST IN OUR PLANET

Reaching back at Tarangam by 01:00 & Lunch
13:00- 14:00 Lunch Break

14:00 - 14:05	Closing Session	Welcome: **Sri. Joseph John**, MSSRF
14:05 - 14:15		Presidential address: **Sri. Omallur Sankaran**, President, District Panchayath, Pathanamthitta
14:15 - 14:35		Valedictory Address: (To be confirmed)
14:35 - 14:45		Certificate Distribution
14:45 - 15:00		Special Address: **Adv. Raju Abraham** Member, Pampa River Basin Authority
		Keynote Address **&** Earth Day Message: **Dr Sanjay V. Deshmukh**
15:00 - 15.05		Felicitation: **Smt. Sheeja T. Toji**, President, Aranmula Gramapanchayath
15:05 - 15.10		Felicitation: **Smt. Sindhu Abraham**, Member, Aranmula Gramapanchayath
15:10 – 15:25		The Way Forward: **Dr N. Anil Kumar**, Senior Director, MSSRF
15:25 – 15:30		Vote of Thanks: **Smt. Parvathy Radhakrishnan**, MSSRF

Group Photo

Day 6 April 23, 2022 Saturday
Optional Excursion to Vembanad Backwaters

M. S. SWAMINATHAN RESEARCH FOUNDATION &
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River Health Monitoring and Restoration: A Training Programme using Biological indicators for River health and Restoration
April 18 to 22, 2022, Tarangam Mission Action Centre, Arattupuzha, Pathanamthitta

Profile of Trainers

Ajayakumar Varma, R. (Dr) had a long-term successful career with the National Centre for Earth Science Studies, Thiruvananthapuram. He has also served in several govt bodies and missions in various positions such as the Member Secretary of Kerala State Council for Science Technology & Environment and Kerala Coastal Zone Management Authority; as the Executive Director of Suchitwa Mission, and as the Director of Clean Kerala Mission. His expertise is in Environmental management planning, Sustainable development and Geophysical explorations. He is acting as the Chair of the Academic Committee constituted for conducting the training programme in River Health Management.

Anil Kumar, N. (Dr) is an Agrobiodiversity management practitioner at M. S. Swaminathan Research Foundation (MSSRF) based at its regional station- Community Agrobiodiversity Centre in Kerala. He leads the Community Biodiversity Management programme of MSSRF that focuses on synergized actions in conservation, cultivation, consumption, and commerce elements in sustainable plant genetic resource management in the biodiversity hotspots of southern India. He is an expert with over 25 years of experience in the area of Biodiversity mainstreaming in food, nutrition, health and agricultural production and consumption.

Archana Godbole (Dr) is the founder Director of the Pune-based Applied Environmental Research Foundation (AERF) and has more than 20 years of experience in the field of conservation and natural resource management. She was awarded the Whitley Associate Award for her long-term work on sacred groves. She is also an invited NGO member representative of the Clinton Global Initiative 2011.

Bijukumar, A. (Dr) is a Professor and Head of the Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram. He has got nearly 30 years of research and teaching experience in the areas of the taxonomy of fishes, Crustacea and Mollusca, biodiversity documentation, aquatic ecology and fisheries. He has described several new genera and about 50 species of aquatic organisms from the Kerala coast, with his colleagues and students.

Hariharan, G. N. (Dr) is the **Executive Director** of M. S. Swaminathan Research Foundation (MSSRF). His scientific contributions in lichen research have opened up new avenues to explore the potentialities of the much-neglected lichens of our country and also to link the ecological security of lichen-rich locations with the livelihood security of the rural communities, who depend on lichen collections as Non-Timber Forest Produce.

Harikumar, P. S. (Dr) is with the Centre for Water Resources Development and Management, Kozhikkode, as a Senior Principal Scientist. His area of expertise spans from Water Quality Management, Environmental Monitoring, Wetland Management, and Nanotechnology to Urban Water Management.

James, E. J. (Dr) is a member of the Governing Body of Wetlands International South Asia. He is presently the Professor Emeritus and Director, Research and Consultancy & Pro Vice-Chancellor (Strategy and Operations), at the Karunya University, (Coimbatore), Tamil Nadu. Dr James is a renowned wetland hydrologist specializing in Hydrology, Integrated Water Resources

Management and Irrigation Engineering. He has worked as a Scientist for 30 years in the Center for Water Resources Development and Management (CWRDM) at Calicut, retiring as Scientist-G and Executive Director of CWRDM and the Director of Irrigation Management Training Institute of Kerala.

Jayanta Bandyopadhyay (Dr) retired as Professor from IIM Calcutta in 2012 and is now a visiting distinguished fellow at the Observer Research Foundation, New Delhi. He is a researcher and author on science and the natural environment. He has been a Coordinating Lead Author for the global document Millennium Ecosystems Assessment. He has been an adviser to the International Union for Conservation of Nature (IUCN) New Delhi, the Water Diplomacy Program at Tufts University in the USA. He has been a Fellow of the India China Institute at the New School in New York (2010-2013). His research has promoted several important public interest litigations in India. Prof. Bandyopadhyay has authored fourteen critically acclaimed books and monographs, in addition to 140 research papers and popular articles.

Jayaraman, T. (Dr) has a long-term association with Tata Institute of Social Sciences, Mumbai as a faculty and now with MSSRF as a Senior Fellow in Climate Change.

Joby Paul (Dr) is an Assistant Professor and Research Guide at St. Thomas College, Thrissur. His expertise is in Plant Taxonomy and Ecology. He has extensively worked on the distribution and ecology of the riparian flora of the Pampa River basin.

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Joy, K. J., is with Society for Promoting Participative Ecosystem Management (SOPPECOM), Pune, as a Senior Fellow. He has been an activist-researcher for more than 30 years in the development sector, especially in water management. He has been coordinating the work of the Forum for Policy Dialogue on Water Conflicts in India, a loose network of people who want to engage with issues related to water conflicts in India. He has a special interest in people's institutions for natural resource management both at the grassroots and policy levels. His other areas of interest include water conflicts, drought and drought proofing, participatory irrigation management, river basin management, and multi-stakeholder processes, watershed-based development, resource literacy, right to water and sanitation, water ethics, and people's movements

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Midhila Mallika (Dr) is with the Community Environmental Resource Centre of Ashoka Trust for Research in Ecology and Environment. Her primary focus areas are Grassroots Governance, Gender and Development with a focus on principles of community leadership and citizen engagement and the roles of elected representatives in the governance of local communities. Midhila does research on Marginalized women, State Politics, civil society participation, leadership and Comparative Democratization with special reference to feminist theories.

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Padmalal, D. (Dr) is with National Centre for Earth Science Studies. His area of Expertise is in Quaternary Geology, Environmental Geology & Paleoclimate studies.

Rajeev, N., was the President of Eraviperoor Gramapanchayath in Pathanamthitta district. It was under his leadership, that the panchayath had bagged the Prime Minister's Award for Excellence in Public Administration in the year 2015 and had won the 'India Biodiversity Award 2018' under the category Best Biodiversity Management Committee. He was also spearheading the rejuvenation of Varattar River.

Ramachandra, T. V. (Dr) leads the Energy and Wetlands Research Group at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore. His expertise is in Environmental Sciences Energy, Renewable Energy, Integrated Energy Planning, Conservation of Terrestrial and Aquatic Ecosystems, Biodiversity-Ecology-Hydrology linkages, Ecological modelling, Wetlands, Soil and Water Pollution, Bioremediation, and Municipal Solid Waste Management.

Richard Storey (Dr) is a Postdoctoral Researcher at the Aquatic Ecology Centre, Kathmandu University. Had a long-term successful career as a Freshwater scientist at the National Institute of Water and Atmospheric Research, experienced in biological monitoring of rivers; ecology and hydrology of intermittent and headwater streams; citizen science; ecology of urban streams; nitrogen cycling and emissions in streams and wetlands. His Expertise is in Groundwater, Freshwater Ecology, Rivers, Water Resources Management, Water Analysis, Environmental Impact Assessment, Biodiversity, Ecosystem Ecology, Water Quality Monitoring, and Water Quality Analysis.

Ravi, S. P., is associated with Chalakudypuzha Samraskhana Samiti and also The River Research Centre, Thrissur. He is an ardent environmentalist and eminent speaker and has been advocating the health, restoration and monitoring of the Rivers across Kerala. He is also a leader of the All-Kerala River Protection Council and spearheading a number of projects related to river monitoring and capacity building.

Sabu, T. (Dr) is with the Centre for Environment and Development, Thiruvananthapuram as its Program Director. He has over 37 Years of experience in the NRM and Environment Management sector. His areas of expertise include Natural Resources and Environment Management, Biodiversity Conservation, Wetland Management, Urban Environment Management, Climate Change, Energy Conservation, Environmental Impact Assessment etc.

Sajeev, T. V. (Dr) is with the Department of Forest Entomology of Kerala Forest Research Institute as a Senior Principal Scientist. He has extensive research experience in Insect population dynamics, biocontrol, and Alien invasive species. Currently, he is involved in Managing Tree Health Helpline for the State of Kerala, research on the management of the giant African snail, an alien invasive species, Survey, risk assessment, spread ecology and developing management protocols for alien invasive plants in Kerala.

Sandeep, S. (Dr) is with the Department of Soil Science of Kerala Forest Research Institute, as a Senior Scientist. After obtaining post-graduation and doctoral degrees from the Indian Agricultural Research Institute, New Delhi he had worked on radioisotopes and soil carbon sequestration in major agricultural land uses of Indo - Gangetic Plains. He works on soil mineralogy, carbon stock assessments, land degradation, soil and water pollution monitoring and isotopic studies. He coordinated the projects for developing a database on tree allometric equations for carbon stock assessments in South Asia, under the aegis of UN - REDD programme.

Sanjay V. Deshmukh (Dr) is a Professor of Life Sciences at the University of Mumbai. He has also served as the Vice-Chancellor of the University. He is a recognized PhD Guide in Geography, Botany, Life Sciences, Environmental Sciences and Biotechnology. His research interests are wide and extensive which include Climate Change implications on coastal, inland, and agricultural biodiversity; Genetic resources conservation and management, Environmental economics, and Environmental Planning.

Shaji, P. K. (Dr) was with Environmental Resources Research Centre (ERRC), Thiruvananthapuram as Principal Scientist & Deputy Director. He is an experienced scientist with a demonstrated history of working in the environmental services industry. He is skilled in Sustainable Development, Plant Ecology, Lecturing, Biodiversity, and Environmental Impact Assessment.

Sylas, V. P. (Dr) is an Assistant Professor at the School of Environmental Sciences, Mahatma Gandhi University, Kottayam. He has nearly 15 years of research and teaching experience in various fields of Environmental Science. His research interests include Wetland Ecology, Biodiversity, Bioenergy, Bio-nanomaterials, Environmental Microbiology, Pollution Studies, and Water Quality.

Unnikrishnan, N. (Dr) is a botanist and bamboo specialist, retired as Professor from SVR NSS College, Pathanamthitta. He is with Kottayam Nature Society as its secretary. His expertise is in Botany and Ecology.

Profile of Participants

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22	SAROJA KUMAR BARIK	Wetland Expert at Department of Environment, Forest and Climate Change, BIHAR
23	SRI RANJINI T. S.	PhD Student at ATREE, Bangalore, KARNATAKA
24	SUDEEP SHUKLA	Scientist at Environment Pollution Analysis Lab, Bhiwadi, N. DELHI

Kerala River System Health Needs Assessment and Action Alliance

A Platform for Organizations, Youth, and Local Community leaders in Kerala working on River System Health Services and Management

Why this Platform?

Rivers in Kerala become sick to the extent many of the river ecosystem services are in decline! There are many indicators ranging from polluted water, narrowing flow channels, loss of flood plains, and degradation of catchment area and riparian vegetation, to continuous loss of fresh-water biodiversity and other river resources to show the river life and the river ecosystem services in the state, are severely deteriorated. If these trends continue unabated and are aggravated by climate catastrophes many of the rivers in the state may become life-less mere water channels or critically polluted waterbodies with the dominance of invasive species in near future. Any scientifically sound river health needs assessment portfolio cannot be reduced to testing the water quality alone; rather what is needed is a systemic approach to the research, rejuvenation, and reporting of the river health that is done collectively at the local level by an informed multi-stakeholder group who engage in the global movement on eco-restoration.

This Platform is to

Research, rejuvenate and report river health locally and empower the eco-restoration movement globally

This Goal is to be achieved by fulfilling four objectives:

(i) *Cross-disciplinary and participatory Assessment and Rejuvenation of River ecosystem services* (RES);

(ii) *Policy Advocacy in sustainable management of RES* notably riparian forests, river catchment, and flood plain ecosystems and river basin agricultural landscapes;

(iii) *Practical Actions for RES management* like the Payment for Ecosystem Services for local community members and their institutions for protecting the river in their geographic boundaries,

(iv) *Capacity development* activities at the level of grass root institutions on sustainable and equitable management of Rivers and River Ecosystem Services and reporting.

The Action Team

KRiSHNA3

Kerala River System Health Needs Assessment and Action Alliance is an open platform that has emerged as a result of the MSSRF-APN Trainers' training programs and campaigns in river system health management held at multi-tier levels in 2022. This alliance consists of scholars, teachers, students, practitioners, and community-level user groups who are committed to providing an undertaking of need-based action steps with help of science-based tools and skills in river health management and reporting. The team approaches the river health in its totality and undertakes the rejuvenation-action of the river health based on facts and values of Restoration Biology and Community/socio-cultural/ecological dynamics.

MSSRF-CAbC

The M. S. Swaminathan Research Foundation's Community Agrobiodiversity Centre is working with the mission of biodiversity-compatible agricultural innovations for ecologically responsible local development models. The Centre designs and implements its projects and activities by balancing both science-based evidence and traditional knowledge in the sustainable use of biological resources in the global biodiversity hotspot of the Western Ghats in partnership with the local community leaders and their representative institutions. The Centre's work impacted significantly in achieving steady progress in localization of the SDGs 1, 2, 13, and 15 by many of the elected Local Self Governments in Kerala. The Centre is actively engaged in the strengthening 2021-2030 decadal eco-restoration campaigns in the state.

Mahatma Gandhi University-School of Environmental Science

The School of Environmental Sciences (SES) is a prestigious department functioning under the umbrella of Mahatma Gandhi University, one of the top 30 universities in India. The SES is a Learning Centre for the academic and applied aspects of environmental science working with the major mandate of developing environmentally responsible and appropriate science and technologies and nurturing competent human resources for the conservation and sustainable utilization of biological resources. The Centres' GIS-Remote Sensing and biodiversity-anchored work in the environmental and disaster management field, particularly focusing on the Pampa River basin are well-known.

The Asia Pacific Network on Global Change Research (APN)

APN is an intergovernmental network of 22 countries working towards an Asia-Pacific region that is successfully addressing the challenges of global change and sustainability of natural resources in view of the impacts of natural and anthropogenic changes in the Earth's bio-geophysical system. The APN aims to tackle these issues through scientific research, capacity building, science-policy dialogue, and awareness rising. The major goals of APN include: (1) Supporting regional cooperation in global change research; (2) Enhancing capabilities to participate in global change and sustainability research; (3) Strengthening appropriate interactions among the scientists and policymakers for policy decision-making.

How can you get involved?

We are looking forward to the full involvement of individuals, individual households, Grama Panchayats, Block Panchayats, District Panchayats, various Departments of the Government, the committed NGOs and civil societies, and individuals who have an interest and commitment to protecting the river system in their respective locality. There is no membership fee! You can become a member by filling up and submitting the form circulated for this purpose. The members will be oriented toward undertaking exercises like the River Ecosystem Services Assessment covering all major areas of river health and rejuvenation-restoration practices by our expert team. The orientation will address the following aspects:

- Capacity gaps amongst those involved in various aspects of River ecosystem services health assessment and management
- Local-level avenues to involve students, teachers, local youth, and community partners in River protection and monitoring
- Skill development and Action plan formulation in preparing project proposals related to RES management;
- Capacity development of Grass root institutions and individuals in Eco-restoration.

For more information write to us: director@mssrfcabc.res.in

PAMPA RIVER REJUVENATION PLAN-2030:
A People's Framework for Action Projects
M. S. Swaminathan Research Foundation
Asia-Pacific Network for Global Change Research

Draft discussed
January, 2023

Background

1. The Pampa River in Kerala is sick to the extent that most of its vital ecological services are in a continuous state of decline! Despite several attempts from the part of government and non-governmental actors to rejuvenate its health, Pampa is being polluted more and more, and its feeding flow channels and the flood plains become narrowed and/or choked orin an altered state. According to various scientific studies, the vegetation and biodiversity of the catchment areas, instream and river banks of Pampa have severely degraded and it has impaired the natural environmental flow health of this river. Under the business-as-usual scenarios, this situation can worsen and the people of Kerala may lose this river in its pristine configuration and flow forever!

2. This Framework Action is formulated through consultations and meetings conducted at various levels with different stakeholder groups, mainly local community men and women engaged on a day-to-day basis in Pampa River utilization. The Plan sets out several strategies for practical actions that are of balancing the multiple roles of the Pampa River and the multiple objectives relating to specific human needs and natural river functions.

The purpose

3. This Plan is to provide insights and on-ground action targets based on a strategic system-based approach by recognizing physical, ecological, socioeconomic, cultural, and political aspects in Pampa River management. The strategies proposed will be of help to identify and respond to various links in the river system restoration portfolio for this river between external drivers, catchment and river functions, river health, ecosystem services, and societal priorities. The Plan is also to contribute to formulating specific action steps required to align and synergize various policies, strategies, and project-level plans already available in the state to restore Pampa, specifically to facilitate executing the powers and the key functions outlined in the Pampa River Basin Authority Act, 2009.

Conceptual Framework and Restoration Theory

4. River restoration is defined in this Plan as "the man-assisted recovery action of the ecological, socio-economic, and cultural roles and functions of a degraded, damaged, destructed, or abused river ecosystem". The hitherto approach of responding to the single issue of water quality of the Pampa River in the rejuvenation plan has been shifted to a more inclusive approach that addresses the total quality of river health. The approach suggested here is based on multi-dimensional aspects of river health such as the *ecological,* consisting (i) river catchment area integrity; (ii) river channel configuration; (iii) river biota diversity and richness; (iv) river floodplain area and services; (v) river environmental flow intensity, (vi) river water quality, *the socio-economic* and *cultural*.

5. The Framework concept considers the fact that a river system consists of several components and utility aspects. The main river body that originates from the headwater source gets modified by its tributary streams, oxbow lakes, and flood plains, including the

groundwater table of the area to the delta and estuary in the river mouth region, and above all by the local community who depend on this system. It also recognizes that these components together with their relationship fabric function in totality, and it varies in the upstream, midstream, and downstream course of a river.

6. It acknowledges that the physical, chemical and biological processes of the river system components drive river health in totality and a scientific understanding of this performance is very critical in effective restoration measures. The word 'rejuvenation' is preferred over 'restoration' considering the fact that it will be challenging and uncertain to restore the original configuration and nature of this river ecosystem whereas it is feasible to vitalize or revive many of its "lost" functions and services.

7. Further, the framework theory broadens that working at the appropriate scale to address the limiting factors to river health in restoration is very critical and thus a coordinated delivery of planning, implementation, and monitoring is needed with both regional and local-scale delivery capabilities. Therefore, the role, traditional knowledge, and capabilities of the local community including their Local Self Government Institutions to ensure the delivery, monitoring, and sustainability of the restoration outcomes are fully recognized in framing up the targeted actions. It accepts that linking restoration with the socio-economic values and considering the priorities of various user groups of the river, and involving them from the beginning of planning is very critical for a strategic river restoration plan.

8. The proposed processes and action cover both *active restoration steps* -the physical changes needed, and *passive restoration steps* -the policy and behavioural changes required for river restoration. The goals and targets are framed by considering factors of possible changes to ecosystem functioning and the provision of ecosystem services as well as the socio-economic needs. The Framework also has taken into account the importance of building resilience to future changes in the river landscape over time due to changes in climate, hydrology, land use, and pollutant loads. The latter two aspects are expected to change to their extreme level in near future considering the pressure from the fast-growing pilgrimage and infrastructure development in the pampa river basin.

Pampa River

9. Pampa is the third-longest river in Kerala after Periyar, spanning about 176 km in total length and enriched by 13 tributary streams (Azhuthayar, Kakkiyar, Kakkattar, Kallar, AadhiPamba, Varattar, Kuttemperoor, Utharappalliyar, Kolarayar, Njunungar, Madatharuvi, Kozhithodu, and Thanungattil thodu). The river, which emanates from Pulachimala on Peerumedu upper plateau of the Idukki district and flows through the midlands of the Pathanamthitta district, enriches the lowlands of Alappuzha-Kuttanadu, and eventually drains into Vembanad lake that joins the Arabian sea. The Pampa River is famous mainly for its sacredness associated with the Sabarimala Temple and Maramon Church pilgrimage. It is also known as the '*Dakshina Bhageerathi'*. Millions of devotees visit Sabarimala to carry out the ultimate ritual 'The Holy Dip' every year with the act of disposing of their clothes in the flowing river tainting the river significantly. Due to modern agricultural practices along the river basin and floodplain regions from the midstream to downstream areas, excess pesticides, herbicides, and fertilizer effluents are being discharged into the river, eventually ensuing in heavy metal accumulation, eutrophication, and algal blooms. There has substantial degree of sand mining been happened from the riverbanks of Pampa.

Goal and Targets

10. The Pampa River Rejuvenation Plan presented here has been proposed with one long-term goal and 10 restoration action targets that are to be achieved by 2030 through a mission mode implementation by the respective Local Self Governments of the Panchayaths along the pampa river corridor plan under the guidance of a dedicated cross-disciplinary team.

Goal 2030: Rejuvenation of Pampa River System health

11. Rejuvenation of Pampa River System health is ensured with enhanced quality of currently declined ecosystem services including the aesthetic functions, intact structural composition, balanced catchment, and environmental processes, supporting flow regime, connectivity, desired water quality, and rich habitat and biota diversity as well as the reduced rate of waste dumping, encroachment, invasion of alien species.

Table: The typology of measures suggested for the Pampa River restoration

River Ecosystem component	River restoration measures	Resultant changes
Catchment area	1. Catchment area land use-landcover management	• Water percolation and recharge capacity of the ground improved; • The quantity and quality of water and other matter that enter the river channel changed.
Flow regime	2. Flow modification	• Flow volume, timing, frequency, and duration changed
	3. Stormwater management	• Flow pattern and storage of runoff water changed
	4. Dam removal/retrofit	• Movement of sediments, flow pattern, and biodiversity functions like breeding behavior of species improved
Flood plain	5. Land reconnection	• Reduced flood risks • Increase assimilation of pollutants • Movement of sediments, other matter, and biota between the channel and floodplain improved
	6. Land acquisition	• Acquired the encroached floodplain land to improve the floodplain functions
River channel	7. River bank protection	• Reduced erosion and slumping off bank material into the river
	8. Channel re-configuration	• Increased hydraulic diversity, habitat heterogeneity, and decreased river channel slope.
	9. In-stream habitat improvement	• Enhanced biodiversity-friendly habitats
Riparian habitat	10. Riparian species management	• Improved diversity and richness of the Keystone riparian species
Biodiversity	11. Instream species management	• Improved species diversity and richness

	12. Removal of invasive species	• Improved native species diversity and water quality
Water quality	13. Water quality management	• Improved water quality and reduced chemicals and particulate load
Other (eg.Cultural)	14. Aesthetics and Recreation management and education	• Increased community value, access to, and knowledge of the river and riverine ecosystem.

Source: Adapted from River Restoration: A strategic approach to planning and management by the United Nations Educational, Scientific and Cultural Organization 7, place de Fontenoy, 75352 Paris 07 SP, France © UNESCO 2016

Pampa River Rejuvenation -2030 Action Targets

12. A set of 10 action-oriented restoration targets are suggested by covering some 14 river ecosystem health components (See Table). Each of these measures is detailed with the necessary ground-level action required specific to the Pampa River. However, specific detailed actions that are required to synergize other relevant plans of the state-specific bodies like the Water Authority, the Disaster Management Authority, and of the proposed Kerala River Management Authority need to be formulated to reach these targets.

Target 1. Practice science-based Catchment area Land use-landcover management of Pampa

13. Ensure that the physical, chemical, biological, and socio-economic impacts on the Pampa catchment areas are reduced through strict enforcement of the law and regulations and make sure the authorities have good control over the negative behavior from the part of the user groups on the protection of the original vegetation, land use, and land cover profile. Undertake widespread education among the community live in close to the catchment and river corridor to convince them that any negative efforts on their part eventually affect the river's health and an unhealthy catchment can cause an unhealthy stream and eventually unhealthy people. With people's participation, the essential factors of a healthy river catchment area such as good geological conditions, climatic conditions, the chemistry of river water, the texture of the soil, etc. to be managed with a science-based package of practices, and thereby the water percolation and groundwater recharge capacity, and the quantity and quality of river water are improved.

Target 2. **Maintain an optimum level for the Pampa River Environmental Flow regime**

14. Ensure that the floodplains, catchment areas, river channels, vegetation cover, and the other physical features of Pampa together with its 13 tributaries all along the 176 KM stretch of length have been managed scientifically based on a well-defined package of practices and help positive influence on the water flow. Need to build adequate awareness among the enforcement officials as well as the public on the stormwater management, frequency, duration, and size of hydrological events (flood and drought), range of precipitation, seasonal discharge, etc in addition to the change in the physical features of drainage basins (like the dams, weirs, land use, and lifting large amounts of water for irrigation) that lead to changes in flow regimes. The activities in this targeted area will have to ultimately improve the flood and drought water management, movements of no hazardous sediments, healthy flow patterns, and healthy water life.

Target 3: **Ensure improved Floodplain functions of Pampa**

15. Ensure that the disconnected floodplain lands of pampa get re-connected and its encroached land gets reacquired and altogether stopped any further encroachment of the floodplain. The floodplains must be maintained in their natural conditions to improve the multiple functions of this habitat such as reducing the flood risks and increasing the assimilation of pollutants by controlling overbank floods, and lateral erosions. The floodplain land use for agriculture, infrastructures and other human activities must be stopped completely. Extensive loss and damage to the floodplains of pampa have already happened by the developmental activities including human habitations along its corridors. The management of flood plain has to be promoted as a community-based effort to cause changes in water quality and the recharging capacity of the aquifers. The rich nutrients, sufficient water quantity, and sustainable biological productivity by the availability of organic matter from the littering of vegetation attract farming in the floodplain areas. But on the other side, the floodplain land used for agriculture or other farming purposes will lead to the degradation of the environment due to the change in natural ecosystems. So, this trade-off has to be tackled prudently.

Target 4: **Protect the geomorphology and hydrology of the Pampa River channel**

16. Ensure that the disturbance and degradation that continuously occur in the downstream aquatic environment of Pampa become less severe and that changes in the geomorphology and hydrology of the channel due to sand/sediment/clay deposition frequency and slope of the river are reduced. The physical form of the pampa has changed and its riverbed slope has decreased over the years because of the deposition of sand and clay, which reduced the velocity of stream water flow of this river. Necessary steps like river bank protection by using locally adapted methods including natural barriers in longitudinal connectivity, and maintaining the habitat heterogeneity with enhanced instream biodiversity as well as control over the physical form stressors that adversely influence the health of this river channel will have to be urgently taken up. Implementation of such measures would help to control the instream free flow, riverbank erosion, disturbance in the river bed, deposition of materials, sediment transfer, and the barriers in longitudinal and lateral connectivity.

Target 5. **Maintain a scientific portfolio for Pampa riparian vegetation management**

17. Ensure that the historically present rich buffer zone along pampa river corridors has been restored scientifically by following the principles and practices recommended by restoration ecologists with suitable native riparian forest tree species which act as the major source of shelter, food, and shade for macroinvertebrates, periphyton, fish, riparian species of birds, diatoms, freshwater algae, etc.

Target 6. **Ensure a rich river biota is maintained across the Pampa riverine ecosystem**

18. Action steps are urgent to maintain a sufficient quantity and diversity of river life across the pampa riverine system to assess its health as many of them are the most suitable indicators for river health assessment. The management action steps will have to lead recovery and conservation of all the historically available species in this river with a sufficient level of genetic diversity in each species. Along with this intervention, steps are also urgently needed for the removal of the invasive species, which have already a big menace in many of the lower pampa river region affecting the water quality and paving way for the destruction of innumerable forms of instream plant and animal life, mainly species of families, *Gentianaceae*, and *Nymphaceae*, and fish, reptiles, and mollusks.

Target 7. **Ensure water quality and reduced chemicals and particulate load to Pampa**

19. It is urgent to place an effective water quality management and monitoring system for this river as this is the most critical aspect because the water quality turns out to be poor, especially during summer months, and in the case of downstream areas almost all the time. The poor water quality condition is mainly due to the increased amount of nutrients that come from runoff, leaching, and erosion from the fertilized agricultural area in the floodplains, effluent from industries, pilgrimage, and household, sewage waste, detergent waste, etc. Eutrophication in the lower stream areas because of the increased level of nitrogen and phosphorus compounds in water becomes a major problem, which adversely affects the natural environmental process and causes the depletion of oxygen in the water, and eventually, this condition creates a non-suitable environment for aquatic life. The common measurement indicator should be improved water quality and reduced chemicals and particulate load.

Target 8. **Revive and enhance the cultural heritage functions of Pampa**

20. Ensure the aesthetics and recreation aspects of this river and the cultural role and heritage functions of various faiths and communities in connection with the pampa river system are revived and enhanced. This approach will be of help to attract wider societal support for the rejuvenation action The ongoing culturally significant events, festivals, and rituals to be done in an ecologically responsible manner, and the local community families to be incentivized for their role in the protection and upkeep of the river in its optimum health in their geographic boundaries.

Target 9. **Revive the socio-economic development role of** Pampa

21. Revival of the socio-economic development role of the pampa river is ensured through the formulation and implementation of environmentally responsible and biodiversity-compatible livelihood development projects including community-based river tourism. Such a project can be developed by the Local Self Governments of the Panchayaths along the pampa river corridor and contribute to the localization of each of the relevant global Sustainable Development Goals.

Target 10. **Research, Education, Public Awareness, and Communication around Pampa**

22. Research, Education, Public Awareness, Communication, and Capacity development with a focus on the local youth in particular, Media, and Political party leaders to ensure the rejuvenation outcomes of the Pampa River Ecosystem are sustained over the long-term through consistent exploration, monitoring, and reporting. Science-based assessment and long-term monitoring of the conditions of this river will help to build a knowledge base for making rational decisions for the rivers in general in Kerala, and for better monitoring as well as for adaptive management, especially in the light of climate change. School and College students are attracted to the pampa rejuvenation plan by organizing them through appropriate mechanisms and events.

Target 11. The **Resource mobilization and Implementation support mechanisms**

23. The importance of mobilizing the required funding support for achieving the above 10 targets is immense. The funding support for Pampa activities till recently has been largely through the plan funds of the state government and to some extent that of the LSGs of the respective Panchayaths for pollution management. The Fundraising should be against each of the proposed 10 high Impact Target Areas of river health, and in line with the sustainable development and climate mitigation priorities and agenda of the government of India. An **Implementation support team** headed by a senior-level River health expert with suitable

subject area personnel including community leaders as members to be constituted with the objective of long-term monitoring including raising funds from national and state governments, private industries, international donors, and the general public is urgent. It is crucial for this team to work with a clear division of tasks, set timetable, outcome indicators, and appropriate reporting mechanisms.

Conclusions

24. A healthy river Pampa can provide multiple benefits to the community through its societal, ecological, cultural, and economic values. The strategic targets that are built upon the understanding of the complexity of the relationship between river health and social benefits in river management will help to formulate scale-specific DPRs for reviving the healthy multi-potential pampa river. If we fail to see the system perspective and complexity of the relationship of the individual components in the river functions and management, it can only lead to further degradation and destruction of this riverine system, and greatly impact vulnerable communities such as smallholder farm families, the indigenous people, and those multi-user groups who depend on this ecosystem. It is suggested to campaign among individual households, Grama Panchayats, Block Panchayats, District Panchayats, various Departments of the Government, the committed NGOs, and civil societies, to individuals who have an interest and commitment to attract the attention of higher administrative authority of both the state and central governments for mobilizing necessary resource support for the implementation of this Plan.

Prepared/endorsed by a collective consisting of the representatives of:

1. Elected members of the LSGs
2. Community & NGO Leaders
3. Representatives of cultural groups
4. Officials of the Water Authority, DMA, and Health department
5. Media
6. Students and teachers
7. Scientists and Scholars

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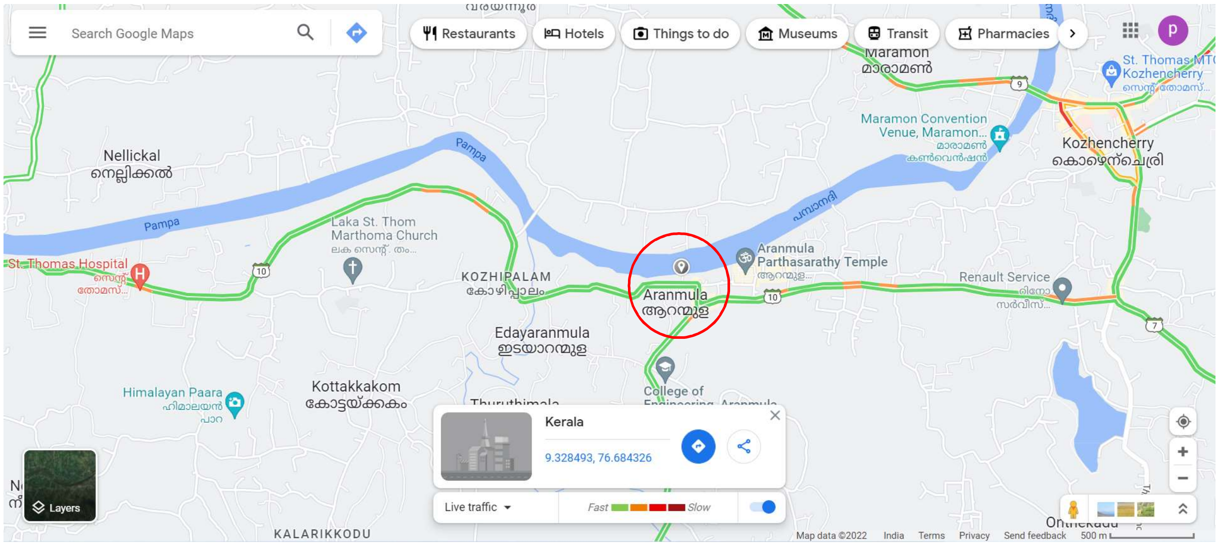
14. **Dr Jubilant Job (online)**
15. **Jibin Thomas (online)**
16. **Parvathy Radhakrishnan (online)**

Riparian tree saplings for Restoration of Vegetation (Pampa River)

Sl	Name	Local Name	Number
1	HOPEA PARVIFLORA BEDD.	IRUMBAKAM	75
2	ARTOCARPUS HIRSUTUS LAM.	ANJILI	4
3	CALOPHYLLUM AUSTROINDICUM KOSTERM. EX STEVENS	MANJAPPUNNA	2
4	CALOPHYLLUM INOPHYLLUM L.	PUNNA	75
5	CANARIUM STRICTUM ROXB.	PANTHAPPAYIN	5
6	CYATHOCALYX ZEYLANICA CHAMP. EX HOOK.F. & THOMS.	KODAVAZHA	20
7	HOPEA EROSA (BEDD.) VAN SLOOT.	IYYAKAM	4
8	HOPEA PONGA (DENNST.) MABBERLY	KAMBAKAM	20
9	HOPEA RACOPHLOEA DYER	THAMBAKAM	15
10	HUMBOLDTIA BRUNONIS WALL.	MALAYASOKAM	75
11	KNEMA ATTENUATA (J.HK.& TH.) WARB.	CHORAPPALI	100
12	GARCINIA GUMMIGUTTA	KUDAMPULI	50
13	MESUA FERREA L.	VAYANAVU	150
14	PALAQUIUM ELLIPTICUM (DALZ.) BAILL.	PALI	3
15	SYZYGIUM CUMINI (L.) SKEELS	NJAVAL	6
16	SYZYGIUM JAMBOS (L.) ALSTON.	MADHURANELL I	10
17	SYZYGIUM STOCKSII (DUTHIE) GAMBLE	KOLLINJAVAL	100
18	TERMINALIA ARJUNA (ROXB.)W. & A.	NEERMARUTHU	4
19	TERMINALIA CUNEATA ROTH.	KARIMARUTHU	50
20	VATERIA INDICA L.	VELLAPPAYIN	150
21	SYZYGIUM CARYOPHYLLATUM (L.) ALSTON	NJARA	3
22	PERSEA MACRANTHA (NEES) COSTERM.	KULIRMAVU	50
			971

Pilot site selected for the Restoration of Vegetation (Pampa River)



HANDBOOK OF RIVER HEALTH ASSESSMENT

A Framework for Biological Monitoring of Rivers

M. S. SWAMINATHAN RESEARCH FOUNDATION
ASIA-APCIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

01. INTRODUCTION

01. 01. Origin and general characteristics of rivers

Rivers, the linear water bodies that flow downhill by the force of gravity, are the lifeline of ecosystems and civilizations. Most rivers are tiny when they start high up in the hills, tumbling over rocks and rapids. They get bigger further down as they are joined by tributaries - streams or rivulets joining from either side of the watercourse. The flowing water body that is smaller in size is called a stream. All rivers, essentially originating as streams, have a starting point or a source where it begins to flow. This source is called headwater which generally develops from rainfall or snowmelt in mountains. Precipitation and groundwater add to the river flow. The other end of the river is called its mouth, where the flowing water is emptied into a larger water body of lake or ocean. A river changes dramatically in character as it runs down towards the sea. They tend to wind, especially as they approach the sea, where horseshoe shaped looping bends called meanders are formed. The biggest meanders occur where the river flows wide and smooth through soft muddy banks. They form partly because of the way water in the river spirals, and partly because of the way the river wears away its bed and banks in some places, and deposits grains of mud and sand in others. Nevertheless, this action widens the river valley. Rivers can also form an estuary, where salty seawater mixes with freshwater near the river mouth to become brackish water. The rivers can be wide or narrow and remain deep or shallow depending on the terrain characteristics of the basin through which they drain. Some rivers/streams flow year-round (perennial), while others flow only during a particular period, say rainy season (seasonal). Even when it is not raining, most rivers in moist regions are kept flowing by bubbling water from underground. This is because a lot of rain does not flow directly over the land, but seeps into the ground only to bubble up in places called springs.

The energy of flowing rivers comes from the force of gravity, which draws water downward. The steeper the slope of a river, the faster it moves to the lower land. The flowing water of a river has great power to carve and shape the landscape. The movement of water in rivers is called current which is usually strongest near the source/headwater upstream. A powerful river current can move even large boulders along the path. The boulders break apart while moving downhill with the current and the rough rock pieces get scratched to smooth pebbles and deposited in the river bottom or river bed. The river current gradually tears away rocks and soil along its bed, and carries them downstream. In the process, it carves a narrow, V-shaped valley or gorge. Rapids and waterfalls are common to rivers, particularly in the upper stretches near their source. While flowing downstream, the river leaves behind some of the rock, sand, and other solid materials it collected upstream which are generally termed sediment. Once the sediment is deposited, it is called alluvium. It may contain a great deal of eroded topsoil from upstream and from banks of its meanders. Because of this, a river deposits very fertile soil on its flood plain - the area next to the river that is subject to flooding. Where the river merges with the sea or a lake, it may deposit enormous sediment that new land, a delta, is formed. These deltas and floodplains are highly fertile agricultural zones that offer tremendous value to the surrounding people.

01. 02. Watersheds and drainage basin

A watershed is an area of land that drains rainfall (or snowmelt) into streams and rivers as gravity helps to guide the path that water takes across the landscape. In fact, every body of water has a watershed, which may vary in size depending on the terrain characteristics. Watershed of a tiny creek in a mountain/hillock might be as small as a few square meters, while some others are massive and usually encompass many smaller ones. Not all rain that falls on a watershed flows out in this way. A part of it seeps into the ground and gets in to underground reservoirs called aquifers. Other precipitation falling on hard surfaces such as roads and other impermeable surfaces may enter storm drains that feed into streams.

Watershed of an entire river system - an area drained by a river and its tributaries is conveniently called a drainage basin. In other words, drainage basin is a larger watershed covering a wide area, which is formed by merger of different small watersheds (sub-watersheds). Size of watershed and its characteristics, such as topography, land form, slope, land cover and land use assume significance in the management of rivers/streams as these factors affect the quality and quantity of flow through a stream or river at a given point.

01. 03. Importance of rivers

Rivers provide a range of life-support goods and services to both ecosystems and human communities. Throughout the history, people have constantly depended on rivers for numerous provisions. In prehistoric times, human beings settled along the banks of rivers, where they found fish to eat and water for drinking, bathing and cooking. Later on people learned that the fertile soil along rivers is good for growing crops of their choice. With the result, the great civilizations of the world emerged and flourished in the flood plains our rivers. They have provided waterways for shipping, fertile land for farming and convenient sites for building cities and towns. Besides, rivers have persistently provided water for drinking, agricultural and industrial purposes; fish and other produce for consumption; buffers against flooding; recreational services and power for domestic and industrial needs through hydropower projects.

Rivers are the integral part of biogeochemical cycles, and act as water purification systems. The water that flows in rivers is fresh, as it contains less than one percent of salt. However, rivers carry and distribute important salts and nutrients downstream to support plant and animal life. For this reason, some of the most bio-diverse habitats on our planet can be found nearby rivers. At the same time as moving water and essential nutrients to support a variety of habitats, rivers themselves function as ecosystems. In fact, rivers and river systems are a dynamic combination of water, sediments, aquatic organisms, and riparian vegetation. River ecosystems provide space for aquatic life, including plants animals and micro-organisms, which together play a very vital role in ensuring the health of river ecosystems and associated habitats. Rivers also help recharge ground water through seepage, and preserve estuarine conditions by preventing ingression of salinity. Thus rivers are integrally connected and inseparable from ecosystem and human health. However, uncontrolled exploitation of natural resources and rapid growth of urbanisation has not only destroyed the ecological balance of river ecosystems, but also has endangered the lives of plants, animals and human life.

01. 04. Degradation and pollution of rivers

During the past few decades, river systems have undergone tremendously high degradation, often attributed to intensive anthropogenic pressures caused by unscientific agricultural practices, construction of dams, development of cities and towns and related land use alteration; discharge of domestic wastes and industrial effluents; mining operations and encroachment. Dumping of plastic and other solid wastes add to the problem. Besides, the river systems are increasingly affected by invasion of alien species, loss or modification of riverine habitats and climate change. The hydrological response and climate resilience of river basins change due to variations in precipitation, temperature, topography, lithology, vegetation cover and other environmental traits. While some rivers experience increased flooding during rainy season, others remain water stressed due to anthropogenic and climatic factors. For instance, many rivers in Kerala become extremely dry during summer months (January to May) mainly due to deforestation in the catchment areas. Previously, the trees and plants of those areas used to help absorb and preserve rain water in the soil for the post monsoon periods. It was this stored water that kept the rivers alive during the summer months. Destruction of forests has also resulted in increased levels of soil erosion, which in turn has raised the floor levels of dam reservoirs, thus reducing their capacity. Flash floods in most rivers caused by high intensity rainfall during monsoon and untimely rains wreck havoc. Studies on the impact of climate change on precipitation indicate the possibility of high intensity rainfall of short duration and long dry spells that lead to flood and drought.

On the other hand, extensive use and abuse of rivers has contributed to their pollution. River pollution primarily results from directly dumping garbage and sewage, disposal of toxic wastes from factories, and ingress of agricultural runoff containing fertilizers and pesticides. Rivers are also facing the threat of choked flow and accumulation of pollutants. Restricted flow is considered a significant reason for unclean and polluted river conditions. Construction of dams along rivers not only restrains the river flow but also increases the level of pollutants in river water. On the one hand, flow is checked, and on the other all kinds of pollutants are accumulated to suffocate the river and the entire aquatic life forms. Extensive degradation of river ecosystems, combined with increasing demands on the goods and services, forms a major driver of biodiversity loss on a global scale. Particularly, severe degradation is evident in large rivers, their catchments, floodplains and lower estuarine reaches.

01. 05. Need for river health assessment and restoration

Rivers are main sources of freshwater that not only support human beings but also provide home to a wide range of flora and fauna. They have many vital ecological values while providing cultural, social and economic benefits to communities. Humans use rivers for irrigation in agriculture, for drinking water, for transportation, for producing electricity through hydroelectric projects, and also for swimming and recreation. Each of these uses affects the health of a river and its allied habitats through excess water abstraction, channel diversion, pollution, encroachment and habitat deterioration, among others. Extensive human interventions cause fast shifting of river systems from healthy sustainable entity to an unsustainable unit. Improving the health of river is, therefore gaining prominence worldwide, and becoming a prime mandate of governments and international bodies. An important precursor to improving river health is the establishment of a framework to assess the river health through community participation. It can help people to better understand and communicate the current state of local watercourses, and to take appropriate remediation measures for effective waterway management.

The concept of river health assessment (RHA) emerged as an attempt to measure the health of rivers using reliable protocols and tools. For long, RHA protocols have focused on water quality alone which covered analysing physicochemical properties of the water through periodic sampling and analysis. The approach offered a record of water quality over time and identified the situations where plant and animal life were put to risk, but did not provide inclusive information on the actual damage done. In other words, the nature and magnitude of impacts of disturbances on life forms and habitats were seldom considered in such attempts. In fact, health of a river depends on its ability to sustain its structure and function; to maintain key processes such as sediment transport, nutrient cycling and energy exchange; to recover after disturbances; to support local biota (including human beings); and thereby performing as an undisturbed ecosystem. Currently, RHA protocols emphasize upon factors which contribute to ecological fitness of the river such as catchment health, floodplain health, channel health, flow health, quality health and biotic health indicators.

01. 06. Biological indicators for river health monitoring

In general, a number of physical, chemical and biological assessments are carried out, individually or in combination, to understand the health conditions of a river system. For example, assessment of land use change coupled with soil erosion status indicates catchment area health. Similarly, physico-chemical and biological analysis of river water with respect to pH, electrical conductivity, salinity, dissolved Oxygen (DO), suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total phosphorus (TP), total nitrogen (TN), ammonia, *E. coli*, total coliform, etc. indicates water quality health. Since changes in hydrology are rapid and often difficult to estimate in running waters, such measurements cannot reflect integration of various environmental factors, including life forms, and long-term sustainability of river ecosystems. Use of biological indicators has been proven to be supplementary to those conventional monitoring techniques. Aquatic and amphibious organisms, such as diatoms and other periphytons, benthic micro- and macro-invertebrates, fishes, amphibians, reptiles, birds, riparian vegetation, etc. can serve as biological indicators to integrate the total river system and their responses to complex environmental conditions. In short, they offer the possibility to obtain an ecological overview of the status of streams or rivers.

As the species composition, diversity and pattern of distribution of these bio-indicators changes from river to river or even from different stretches of an individual river depending on various environmental and climatic factors. Therefore, geographical location of a river or given segment of the river is of relative importance and location/basin specific studies need to be carried out to evolve an effective framework. Such comprehensive RHA frameworks, which are scientifically sound, reflecting local conditions, easy to use and scalable will identify rivers or river stretches that are in poor health, recognize its causes, help prioritize river restoration and management and evaluate the effectiveness of subsequent management actions.

01. 07. Background of this handbook

XXXXXXX

01. 08. How to use this handbook

XXXXXXX

02. PAMBA RIVER SYSTEM: A CASE STUDY

02. 01. Pamba, the third longest river in Kerala

Kerala, the 550 km long land strip situated in the south-west corner of peninsular India, is hedged between the Arabian Sea (Lakshadweep Sea) on the west and the lofty heights of the Western Ghats on the east. The land has all characteristics of a distinct geographical unit, with an undulating topography, ranging in altitude from below mean sea level (Kuttanad wetlands) to 2694 m above mean sea level (Anamudi, the highest peak of the Western Ghats), and crisscrossed by 44 rivers and numerous rivulets, which are monsoon-fed and fast-flowing. Of the 44 rivers originating from the Western Ghats, all but three flow west to join the Arabian Sea through a chain of backwaters and lagoons running parallel to the west coast. Only four rivers *viz.* Bharathappuzha, Periyar, Pamba and Chaliyar, exceed 160 km in length while all others are relatively small with an average of length of about 64 km.

The 176 km long Pamba, the third longest river in the State of Kerala after Periyar and Bharathappuzha (Pamba had been the largest river of erstwhile State of Travancore), originates at Pullichimalai hills in the Peerumedu plateau (Idukki District) in the Western Ghats (*Sahyadri*) at an altitude of 1,650 m above mean sea level and flows through several places in Idukki, Kottayam, Pathanamthitta and Alappuzha districts including Kuttanad, an important rice cultivating centre, before emptying into the Vembanad Lake to join the Arabian Sea. Kakki, Azhutha and Kakkad are the major tributaries in the catchment zone of 2235 km^2 area. In the highlands and eastern part of the midland, the river drains over a spectrum of rock types including pyroxene granulites, charnockites and khondalites as the major constituents. Its course in the midland region (7.5 to 75 m above sea level) is mainly through laterites and Holocene sediments. In the lowland (< 7.5 m above mean sea level including the below sea level lying Kuttanad) the rivers flow through alluvial sands and clays of Holocene age. The river displays dendritic and trellis drainage patterns in higher altitudes. On entering the coastal plains, it takes a northward trend and joins the Vembanad Lake at Pallathuruthy near Alappuzha. The present northward trend in the lowlands has been caused by silting of this water body coupled with a northward tilt during Late Pleistocene-Early Holocene.

Box-01: Pamba, Kerala's third longest river
➢ Pamba is the third longest river in Kerala after Periyar and Bharathappuzha. ➢ The 176 km long Pamba originates in the Peerumedu plateau of the Western Ghats (*Sahyadri*) at an altitude of 1,650 m +MSL and flows through Pathanamthitta and Alappuzha districts including Kuttanad wetlands before emptying into the Vembanad Lake to join the Arabian Sea. ➢ Kakki, Azhutha and Kakkad are the major tributaries in the catchment zone of 2235 km^2 area.

02. 02. Cultural and religious importance of River Pamba

River Pamba has been regarded as the 'lifeline' of Central Kerala considering its linkages with culture and traditions, pilgrimage, socio-economic development, agriculture, power production, water supply and tourism, among others. Historical records show that the Pamba River had been vigorous and well linked for navigation, freshwater supply and cultural feasts in the erstwhile princely State of Travancore. River Pamba has witnessed great material and cultural progress from ancient times. Sabarimala, one of the greatest centres of pilgrimage in India devoted to Lord Ayyappa, is situated on the upper reaches of the river basin and the biggest religious gathering of Christians in Asia, the Maramon Convention, is held annually on the banks of the river downstream adjacent to the Kozhenchery Bridge. The river basin from time immemorial is known for its lush greenery. *Adhyatma Ramayanam* describes Pamba as the most exciting garden displaying the rare beauty of plants and flowers. Pamba has been adored as *Dakshina Ganga*, and devotees of Lord Ayyappa believe that immersing oneself in the Pamba is equivalent to bathing in the Holy Ganges.

The Aranmula Parthasarathy Temple, dedicated to Lord Krishna, is situated on the banks of Pamba in the midland region of the river basin. Aranmula in Pathanamthitta district is also known for the snake boat race (*vallamkali*), which is held every year during *Onam* festival. Annually about 35 snake boats, otherwise called *palliyodams*, participate in the *Aranmula Uthrittathi Jalolsavam*. *Valla sadya* is a ritualistic feast (organised primarily for the oarsmen of *palliyodams*), associated with the temple festival, during which rice with about 50 side dishes are served in banana leaves. Following the feast on the *Uthrittathi* day of Malayalam calendar, the village conducts the snake boat race in River Pamba. The snake boats move in the river to the rhythm of full-throated singing of *vanchippattu* (specifically composed songs to a rhythmic tune in praise of Parthasarathy-Lord Krishna) watched by an exciting crowd on both banks.

Aranmula kannadi, a metal mirror producing distortion-free images, is a rare piece of craft that has a fairly long history. This handicraft is as attractive as glittering gold and the mystery of its production is a family gift handed over through generations. It is one of the auspicious articles used in several Hindu religious rites including marriages, and also to adorn the grandeur of the houses. The metal mirror is famous for its secretive production method and uniqueness in the make which get patent protected with a Geographical Indication tag.

Apart from Maramon Convention which is held every year during the month of February by the Mar Thoma Evangelistic Association (missionary wing of the Mar Thoma Church), Cherukolpuzha Hindu Religious Convention is an annual event organized by the Ayroor-Cherukolpuzha Hindumatha Mahamandalam on the banks of Pamba at Ayroor, which is located about 12 km from Aranmula Parthasarathy Temple. Another important religious event associated the midland sector Pamba river basin is *Padayani*, a ritual art performed in the premises of the Devi Temple at Kadammanitta, a village in the vicinity of Pathanamthitta town.

Box-02: Cultural and religious importance of River Pamba
➢ Pamba has been regarded as the 'lifeline' of Central Kerala, considering its linkages with culture and traditions, pilgrimage, socio-economic development, agriculture, power production, water supply and tourism. ➢ Sabarimala, one of the greatest centres of pilgrimage in India devoted to Lord Ayyappa, is situated on the upper reaches of the river basin. ➢ Maramon Convention, the biggest religious gathering of Christians in Asia, is held annually on the banks of the river downstream in the midland stretch. ➢ Aranmula Parthasarathy Temple is another important shrine situated on the banks of Pamba in the midland sector. ➢ Aranmula is also known for the snake boat race (*vallamkali*), which is held every year during *Onam* festival, and an exclusive metal mirror - *Aranmula kannadi* - a rare piece of craft.

02. 03. Environmental attributes of Pamba river basin

Pampa river encompasses a basin area of approximately 2235 km^2 spread over four districts of the state of Kerala, *viz.*, Idukki, Pathanamthitta, Kottayam and Alappuzha. The area extends over thick tropical forests, plantations, urban and semi-urban settlements, few water bodies and a rich agricultural (rice) bowl called Kuttanad. The land use pattern of the river basin is unique and diverse. Physiographically, terrain of the river basin has three natural regions namely, lowland (about 229 km^2), midland (about 933 km^2), and highland (about 1073 km^2). The high land consists of high altitude areas with evergreen, semi-evergreen and moist deciduous forests, grasslands, forest plantations and agri-horticultural plantations. Rubber plantations are predominantly found in the low hills and of valleys highlands to the midland areas.

Agro-climatic conditions of the midland and lowland stretches of Pamba river basin suit the cultivation of a variety of seasonal and perennial crops including rice, coconut, rubber, tapioca, yams, taro, areca nut, pepper, cinnamon, nutmeg, ginger, plantain, pulses, vegetables, cashew nut, jackfruit and other fruit trees; the cultivation is mainly done by marginal or small farmers. While paddy is mainly grown for own consumption by many households, wide spread cultivation of rubber and coconut constitute the principal source of agricultural income. While river Pamba and its drainage network constituted by rivulets, streams and wetlands primarily contribute to irrigation, it also provides for domestic water security to several villages and townships of the region apart from providing water supply to few industries. Further, the wetlands associated with the river system (*e.g.* Aranmula *puncha*) and the randomly spread paddy fields and ponds in the watersheds ensure ground water recharge and thereby provide for the keep up of open wells. Seasonal alluvial deposition (fertile alluvium sedimentation during monsoon) on the river banks largely contributes to the development and sustenance of riparian vegetation and associated faunal habitats, which is significant for the protection of such natural refuges of the midland and lowland sectors of the river basin.

In the lowland sector, Pamba splits into two branches near Pandanad; one of the branches flows in south-westerly direction is joined by Achankovil River. The Manimala River joins Pamba near Nirettupuram. The river thereafter flows northward and debouches into the Vembanad Lake, one of the largest brackish-water lakes in the country, which joins the Lakshadweep Sea at Kochi. The lower stretch of the river basin is entirely within Kuttanad, the southern part of Vembanad-Kol wetland system, one of the Ramsar sites in Kerala. Kuttanad is well known for its scenic backwaters and low-lying agricultural fields. It is one of the lowest regions in India, with about 500 km^2 of area lying below sea level, and intercepted by lagoons, rivers and canals. Most of the area remains under water throughout the year. It is in fact a marshy delta in the southern part of Vembanad Lake, formed by a network of five rivers namely, Pampa, Achankovil, Manimala, Meenachil and Muvattupuzha together with the backwaters in and around the lake. A large part of this vast estuary lies below the sea level up to a depth of about 2.5 m, and remain waterlogged for most part of the year subject to flood and inundation during the monsoons and saline water intrusion during the summer months. Paddy and coconut cultivation are the major activities in the region followed by fishing, shell and clay mining and toddy tapping.

Box-03: Environmental attributes of Pamba river basin

- Highland stretch of the Pamba river basin encompasses evergreen, semi-evergreen and moist deciduous forests; grasslands, forest plantations and agri-horticultural plantations.
- Agro-climatic conditions of the midland and lowland stretches of Pamba river basin suit the cultivation of a variety of seasonal and perennial crops including rice, coconut, rubber, tubers, plantain, spices, pulses, vegetables, cashew nut, jackfruit and other fruit trees.
- Pamba and its drainage network constituted by rivulets, streams and wetlands contribute to irrigation and provides for domestic water security to several villages and townships of the region.
- The wetlands associated with the river system (*e.g.* Aranmula *puncha*) and the randomly spread paddy fields and ponds in the watersheds ensure ground water recharge and thereby provide for the keep up of open wells in the midland and lowland sectors of the river basin.
- Pamba drains into Vembanad lake, one of the largest brackish water lakes in the country which joins Lakshadweep Sea at Kochi; the deltaic formation of Kuttanad is part of the larger Vembanad Kol wetland ecosystem, one of Ramasr sites in Kerala.

02.04. Biodiversity associated with Pamba river system

Freshwater ecosystems play an important role in water cycle, nutrient cycle, maintaining the delicate balance of aquatic food chain, purification of water etc. Water in the right quantity, quality and season is critical to sustain mankind and also aquatic biodiversity. The change in behavioral parameters such as migration patterns, breeding, food availability for aquatic species will affect the biology of the river system. The pressure of increasing population, growth of industries, urbanization, loss of forest cover, lack of environmental awareness, untreated effluent discharge from industries and municipalities, use of chemical pesticides/fungicides/ herbicides/ insecticides, fertilizers, etc are causing water pollution.

Freshwater biodiversity is the over-riding conservation priority during the International Decade for Action-'Water for Life'- 2005 to 2015. Inland waters and freshwater biodiversity constitute a valuable natural resource. The major highlighted threats to freshwater biodiversity are overexploitation of faunal resources; water pollution; flow modification; destruction or degradation of habitat; and above all the invasion by exotic species. Their combined and interacting influences have resulted in reduction of freshwater biodiversity.

Protection of fresh water biodiversity which is a vital component for self purification of riverine ecosystem and supporting the livelihoods of the dependent communities experiences extreme challenges as it is influenced by upstream drainage network, changes in land use pattern, riparian zone. KSBB has already conducted a River fish monitoring programme for a systematic study of aquatic biodiversity in the 44 rivers of Kerala including Pampa. A pilot project has already been proposed covering 2 panchayats in each of the districts through which Pampa flows. Based on these and also drawing parallel from the river regeneration programmes being conducted elsewhere in the country, Kerala State Biodiversity Board is proposing an eco-friendly action plan for the conservation of Pampa river basin involving adaptation strategies, river bank restoration, reduction in pollution entering the river, protection of biodiversity and improved livelihoods for the affected community.

Pressures and Threats

Most of the aquatic organisms experience multiple threats such as habitat removal/damage by several anthropogenic influences, invasive species, altered sediment load, altered hydrologic regime, altered nutrient inputs and toxic contaminants, changes in land use pattern, increased pollution, unscientific sand mining etc. In Pampa, a variety of destructive fishing practices are practiced such as dynamiting, electric fishing, use of fine mesh net and fish poisoning and these have led to mass mortality of fishes, fish eggs and larvae resulting in the decline of fish 7 KSBB population (Kurup, 2000). Killing of brood fishes and juveniles by such practices have affected a number of food and ornamental fishes of upland waters, especially in rivers and streams (Dehadrai et al., 1994). Native fish stock in the river is dwindling under the impact of over exploitation, sand mining, pollution and introduction of exotic species. The introduction of exotic species in the upper stretch of the river Pampa replaced the endemic species. Moreover, the excessive withdrawal of water from the river courses for agriculture, domestic and industrial uses leaving inadequate water for comfortable fish life and unethical fishing practices is also a major factor responsible for the depletion of fish germplasm.

The changed land use pattern has reduced the riparian zone and associated species diversity in Vembanad lake region. The changed ecology is believed to have led to the loss of about 23 species of fishes, preventing migration of about 13 other species, decline of 33 % of bird population, brought in new predatory birds like Neerkozhi and increased population of reptiles. The Vembanad Lake and associated water body has endemics species like Pearl spot (Karimeen; Etroplus suratensis) and the giant freshwater prawn (Aattu konju; Macrobrachium rosenbergii) highly valued for their delicacy.

Reduction in riparian vegetation

The ecological functions attributed to riparian vegetation includes the stabilisation of the river banks, providing shade, large woody debris to increase complexity of in-stream fish habitat. Extensive deforestation and disappearance of riparian vegetation in highland and midland areas of river results in increasing soil erosion. This may destroy the spawning grounds of fishes. Riparian vegetation experiences threat from several factors like encroachments for agriculture and development, grazing and invasion of weeds.

Invasive species

The alien invasive species are the major threat to biodiversity conservation. Non-native fish are introduced around the world mainly for improving fisheries, sport, ornamental fish trade and for biocontrol of mosquito. Introduced fish frequently alter the aquatic ecology by changing water quality and also cause the extinction of native fish by predation and resource competition. Due to rapid depletion of wild population, the fish has been listed as endangered category in the Conservation Assessment and Management plan workshop for assessing the status of freshwater fishes of India. The Indian major carps are introduced 8 KSBB in to the Pampa, Manimala and Meenachil rivers. The ranching of Indian major carps may pose potential threats to indigenous species in future. Ompok bimaculatus is a vulnerable fish in the river Pampa. The population of three air breathing fishes and endangered fishes like Labeo dussumieri, Puntius denisonii, Batasio travancorica, H. branchysoma and Lepidopygopsis typus were declining alarmingly due to destructive types of fishing activities including dynamiting and poisoning, habitat alteration consequent to indiscriminate sand mining.

Unscientific and uncontrolled sand mining

The major human interventions in the basin is in the form of sand mining from river channels or from bank areas ultimately resulting in land and water degradation expressed in terms of ground water level depletion, destruction of flora and fauna etc. The river channels, in the midlands and lowlands of Kerala, are deteriorated drastically due to illicit scooping of sand even from prohibited areas close to the river banks, bridges, reservoir etc. In some of the cases, the river bank and the floodplain areas are being scooped out first for tile/brick manufacturing (overlying clay rich layers) and then for construction grade sand (underlying layers). The process ends up in the destruction of riparian vegetation, which provides habitat to many organisms. Dwindling of floral and faunal diversity within river basin; decline in terrestrial insects like mayfly, dragon fly, stone fly etc., whose larval stages are in the shallow water and sandy fluvial systems; habitat damage and changes in breeding and spawning grounds; reduction in inland fishery resources are the result of uncontrolled sand mining. Decrease in population of Dragon fly and other beneficial insects which form food chain affects badly higher order aquatic organisms like fishes and amphibians.

Encroachment and Reclamation

Lower stretches of the flood plain is affected by encroachment and reclamation of the area for agronomic purposes which has led to drastic reduction in water storage area, loss of habitat for flora and fauna, fishes, birds and eutrophication.

Pollution

Indiscriminate disposal of large quantities of solid and liquid wastes and the inadequacy in waste treatment facility during festival season and discharge of waste water from municipalities in the middle and lower reaches of Pampa causes deterioration of water quality and destruction of species diversity in the aquatic system. Agricultural runoff containing fertilisers and pesticides pollute the aquatic ecosystem severely and affect the food chain through bioaccumulation and biomagnification processes. Sabarimala, one of the best known pilgrimage destinations in Kerala is situated in the hills of Pampa plateau (within the extent of Periyar Tiger Reserve). It is one of the most popular pilgrim centres in south India and millions of pilgrims visit the shrine especially during the winter season, starting in mid-November and ending in mid-January. The temple attracts pilgrims not only from the southern states of India, but also from other parts of the country and abroad. The divine Pampa river plays an important role in the Sabarimala pilgrimage and is considered as holy as the Ganges. The gathering of very large crowds over a short period of time every year in to this ecologically sensitive area has given rise to various environmental problems. A survey conducted by the central Pollution control Board in collaboration with Kerala state Pollution control Board revealed that solid waste and sewage generated at Pampa during the festival season causes severe pollution of the Pampa river. Lack of sanitary latrines, sewage collection facilities and treatment, waste discharges from hotels are the major sources for the pollution of Pampa river (CPCB, Annual Report 2000). Various studies have recorded considerable changes in the land use, especially around Sabarimala shrine, during the past two decades. The changes were mainly in the form of conversion and degradation of forests into forest plantations and other non-forest activities due to human activities.

Water usage

As a river, approximately 50% of the river water is utilised for irrigation, 10-25% is for domestic purposes, 30-35% for power generation and 10-15% for commercial uses. The annual water requirement for paddy lands of Pampa river basin is ~ 1440 million cubic metre and about 50% of the garden land requires ~292 million cubic metre. Hence the ultimate irrigation water requirement comes to ~1732 million cubic metre per annum. Around 30 lakh people in the districts of Alappuzha, Pathanamthitta and Idukki, with an average population density of 736 per sq km in the river basin against a state average population density of 859 per sq km. depend on river Pampa for their daily use. This leads to a strong demand and competition for natural resources, especially water for domestic use and irrigation.

Environmental Flows

This is the flow required for the maintenance of the ecological integrity of rivers, their associated ecosystems and the goods and services provided by them. It is necessary for maintaining river regimes, for the river to purify itself, for maintaining aquatic biodiversity, recharging groundwater, maintaining sediment movement and supporting livelihoods. In the 10 KSBB absence of natural flows the riparian species face competition from alien plant species. The invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regime. Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes. Thus flow is a major determinant of physical habitat in river system, which in turn is a major determinant of biotic composition. Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.

Habitat destruction

Destruction of habitats for feeding, natural spawning and breeding grounds of the fishes through sand extraction and construction of physical obstructions across rivers has contributed to the endangerment of the freshwater fishes. 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 poses a real threat to biodiversity.

Soil erosion due to deforestation

When the ground surface is stripped of vegetation, the upper soils are vulnerable to both wind and water erosion. Soil is washed into rivers when it rains, and then out to sea. This destroys the ability for the land to regenerate because it has lost its topsoil. Shrinkage of forests in the upper catchment areas affects the biodiversity and hydrological regime of the basin.

Invasive weeds

The presence of Cabomba a fast growing submerged aquatic weed species along the Aranmual stretch of Holy River Pampa is prevalent. It grows in stagnant, slow flowing water bodies and regenerates fast and provides a threat to the river ecosystem. The Cabomba with its extremely dense strands obstructs the free flow of water and results in increased silting of river. This weed contains high degree of allelopathic chemicals which influence the growth and survival of other species. The major factor which promotes the growth of this weed is the high nutrient content of water due to the presence of Sewage, agrochemeicals and land washouts. Alien invasive species like water hyacinth is densely spreading in all upper reaches of water body, canals and drains contributing to further pollution to water, preventing water navigation, depletion of dissolved oxygen, interfering in the entry of sunlight into water and thereby reducing the productivity of the river.

02. 05. Environmental problems of Pamba river basin

The Pampa river basin experiences diverse environmental problems as in the case of otherriver basins flowing into Vembanad Lake. In the highland region of the basin, the majorproblems are the damages to luxuriant riparian vegetation, loss of instream biota, riverbank failure etc. The midland region experiences loss of sandy plains, channel incision,undermining of engineering structures etc. in addition to river bank slumping. In thelowland region, in addition to such problems, there are formations of deep pits in the rivercourse, flood plain mining, lowering of water table etc. Whereas the magnitude of theproblems is low in the highland terrain, they are moderate to high in the midland and lowland terrains**.**

Changes in landuse and land cover

Increasing urbanization and high pressure on land have changed the landuse pattern inPampa river basin. The upper reaches of the basin is characterized by the western slopes of the Western Ghats and therefore is a vital region. The reduction of forest land from 519.07 km2in 1977 to 465 km2in 1997 is verysignificant as the area is very rich faunistically as it is a part of the Periyar Tiger Reserveand the flora here is unique and diverse. The study also reported that the major part ofconversion and degradation of forest had taken place in and around the Sabarimala andPampa (Triveni) stretch, the proximal areas of different routes to Sabarimala and thedownstream reaches of R. Pampa upto Perinad. Significant changes in landuse have alsobeen reported from the downstream stretches of the river basin.

Indiscriminate mining and land degradation

It is reported that the in-stream mining for river sand was equivalent to 0.41 Mm3perannum as against the natural replenishment of 17883 m3/year. It indicatesthat the mining is 23 times more than the replenishment rate impacting adversely the riverbottom topography, ecosystem function of the river, engineering structures across theriver, river bank slumping, groundwater availability on the banks etc. The river stretches atmanyplaces are devoid of sand in its active channels and the river bed is now rockatmany places in Vadasserikkara, Chittar, Ranni-Pazhavangadi, Vechuchira, Ranni-Perunadand Seethathode Grama Panchayats. Removal of sand and clay from thefloodplains of R. Pampa for making bricks was also a major activity. The floodplain sand extraction was doubled in 5 years since 2003. It is also reported that theeconomic and environmental cost of clay mining is colossal, especially in terms ofagricultural production loss and groundwater availability. In addition, thereare a large number of hard rock quarries in the basin located in the midland and highlandareas of the basin.

River bank failure and encroachment

The lowering of river bed, construction on the banks and across the river, removal ofriparian vegetation etc. has caused the failure of river banks at various locations of R.Pampa. Atotal of 17.20 km stretch of river bank, both on the left and right banks require protectivemeasures. There are also encroachments in the river banks such as at Niliplavu andVayattupuzha in Chittar Grama Panchayat, Eruvattupuzha in Ranni-Perunadu GramaPanchayat, certain locations near Mannar, Ayiroor etc.

Solid waste accumulation

There are 69 Grama Panchayats (GP) and 2 Urban Local Bodies (Alappuzha andChengannur Municipal Corporation) in the watershed area of R. Pampa. The totalMunicipal Solid Waste (MSW) generation from the entire GPs is 175 tpd and while thatfrom the two Urban Local

Bodies (ULB) is 20 tpd only. In the GPs, 86 tpd is generated athouseholds, 39 tpd at commercial areas, 12 tpd in institutions, 11 tpd in markets, 2 tpd inslaughter houses and 26 tpd at other sources. In a rural setting, a considerable part of theMSW generated at household, especially the biodegradables, does not reach the GP streamas they are instantly used as food for animals or as manure. Similarly, most part of thepaper, metals, rubber and leather materials, bottles etc also do not reach the GP stream asthey are stored at source and sold for recycling. Therefore the total waste that reaches theGP stream is 160tpd (90% of the total MSW generated).The peripheral areas of twoMunicipalities are rural in nature forms only 3.4% of the MSW generated reaches themunicipal stream. The two Municipalities are urbanized and almost 51% of the wastegenerated reaches the municipal stream. Therefore, the total waste reaching the ULBsstream is 8 tpd. A total of 177 tpd of waste get accumulated at places in the entire basin ofwhich atleast 72% of the waste will be of biodegradable nature having moisture varyingfrom 50-60%. This, if left in the open, will lead to generation of leachates subject tomoisture content and putrefaction.

Septage and faecal sludge accumulation

Kerala has very low coverage of sewer lines and sewage treatment capacity. This has beendue to various factors such as undulating terrain conditions, homestead type of habitationand greater acceptability and appropriateness of on-site sanitation, land availabilityconstraints, inadequate technical and investment capacities etc. In the absence of seweragenetwork, most of the population depends on On-site Sanitation Systems (OSS). It ismandatory for residential flats and resorts having more than four flours and built up areaof 2000 m2and above, hotels with minimum 20 rooms and hospitals with more than 5bed strength to establish and operate waste water treatment plant to treat sewage and sullage. Therefore, the toilet coverage in the basin, as in other areas of the state, is very high to the tune 95% as per Census-2011. As per the National Sample Survey of 2008-09,the toilet coverage of GPs is 93% and that of ULBs is 97%. Among the households, on anaverage, 50.6% uses flush toilets with septic tanks and 46.6% uses pit latrines in theULBs. In the GPs, 71.7% uses pit latrines and 21.7% uses flush toilets with septic tanks.The OSS comprising the septic tanks and latrine pits gets filled up with septage and faecalsludge depending on its capacity and usage, necessitating desludging operations. However,it is not done periodically and is generally carried out when it overflows due to poor

The quantity of septage/faecal sludge generation in the Pampa river basin is estimatedbased on the number of households and the following considerations.

● volume of septic tank, on an average, is 2m3 and needs emptying every five years

● 20% of the latrine pits, located in the coastal areas, have a depth of 2m, on an average, and volume of 3.5m3 which needs emptying every ten years

●40% of the latrine pits, located in places other than coastal zone, have an average depth of 3m and volume of 5m3 which needs emptying every 15 years

●30% of the latrine pits, located in laterite terrain, have an average depth of 6m and volume of around 10m3, which needs emptying every 30 years

● 10% of the latrine pits are closed or emptied by making equivalent pits adjacently

●Emptying operations are done during 6 days a week in monsoon (26 weeks) and 5days a week in non-monsoon (26 weeks), i.e. operation is active during 286 days.

Canal irrigation and impacts

A study on the canal irrigation from Pampa Irrigation Project and its impacts revealed thatthe net irrigated area had decreased from 8.2% in 1991-92 to 6.7% in 1996-97 inAlappuzha district, the southern part of which falls in the ayacut (Chattopadhyay, 2002).These areas with sandy soil used to receive canal water in the initial years of 1994-95.However, in subsequent years, canal flow did not reach up to these areas. InPathanamthitta district, there was substantial growth of canal irrigation from 13% in 1991-92 to 20% in 1996-97. Crop specific analysis has indicated that irrigation of paddy landwas not very successful due to (i) paddy conversion to other land uses (tree crops/plantation/settlements) and (ii) unsuitability of the clay dominated Kuttanad area and sanddominated western parts for irrigation. However other crops, especially sugarcane andvegetables, were benefited. At places, indiscriminate irrigation posed problems due toexcessive soil moisture. The higher depth of canals at places modified the groundwatergradient and some of the wells dried. On the other hand, some of the dry areas are nowfeasible for tapping groundwater.

River water pollution

It is known that R. Pampa is highly polluted from the immediate upstream of SabarimalaSannidhanam to lower reaches especially during the pilgrimage season. The pollution is mainly due to due to the discharge of human excreta, food waste, cloths etc. The environmental measures for managing the solid and liquid waste are totally inadequate and hence the problems are on the increase. The conditions become worse during the month of December and January, the peak of the pilgrimage. It is reported that the Kunnar reservoir,the major source of drinking water to Sabarimala located in the upstream of Sannidhanam,is also marginally polluted. The water quality monitoring done by the Kerala State Pollution Control Board(KSPCB) revealed that the coliform bacteria count in R. Pampa. was found to be of the order of 3 lakh /100ml during the peak season against the maximum permissible limit of 500 MPN per 100 ml of water. The water quality reported from various stations located from the upstream to downstream portion of the river indicates that the entire stretch of the river is contaminated with coliform bacteria during the pre-monsoon and post-monsoon period and the lower reaches indicates pesticide contamination as well. The KSPCB reported Faecal coliform counts up to 31,000/100 ml in the water sample of R. Pampa at Thakazhy in Kuttanadu.

Hazards

The Hazard zonation map of Pampa river basin reveals that 45.66% of the river basin comes under 'Stable' category and 11% under 'Severe' from the point of view oflandslides.A sizeable area of the river basin in the Pathanamthitta district is prone to landslides during monsoon causing loss to life and property. One of the major landslides occurred on July 13, 1998 in parts of Chittar and Seethathodu Grama Panchayats subsequent to heavy rainfall leading to severe land disturbances in the form of debris flow,debris topples and mud slides causing damages to houses and loss of agricultural land. Alteration in landuse, interference with course of streamlets, blocking of valleys have combinedly contributed to the vulnerability in the region.

Flood is one of the natural hazards that have considerable impacts on the river basin. The PWD reported that the flood waters of R. Pampa in 1964 attained a height of 2.5m above the river bank at Pandanad which came down to 0.745m as it reached Pallathuruthy-Nedumudi area. Kuttanad and surrounding areas including parts of Pathanamthitta district were flooded as many as 6 times during the monsoon months in 1981, mainly due to the flood waters of R. Pampa. The flood of 1989 affected around 1.3 million people in Alleppey district alone. Around 10,000 ha of cropped area were damaged and the total estimated loss was to thetune of Rs.360 million. During 1992 flood 89 villages in Pathanamthitta district and 41 villages in Alappuzha district were affected. The wide spill area and number of channels used to reduce the flood level. But due to considerable reduction of spill area on account of diversion of lowlands/wetland for tree crops and settlements as well as due to the construction of roads across the lowlands and natural drains without provision for adequate drainage, the flood height and the time taken for draining out the flood accumulated water have increased in recent years. The Thottappally spillway was commissioned in 1955 to reduce the flood menace from R. Pampa in the lower reaches of the river in Kuttanad region. It was designed to discharge nearly 1813 m3 of water per day but the effective discharge achieved was only 566 m3 per day and therefore was not effective as expected. The Pampa river basin is confronted with different types of environmental problems such as water logging due to floods, spill over from the river due to increased floodplain occupancy and flash flood in the hill areas of Pathanamthitta due to large scale reclamation of paddy fields.

02.06 Biological indicators for river health assessment of Pamba

Since streams and rivers are among the most imperiled ecosystems in the world, there is an urgent need for thorough analytical techniques to assess the current condition of these ecosystems and to track the rate of change. Monitoring frequently starts with physical, chemical, and bacteriological measures since they offer a full range of data necessary for effective water management. Running waters, on the other hand, cannot account for the integration of various environmental elements and the long-term sustainability of river ecosystems due to their instantaneous character and rapid and difficult to quantify changes in hydrology. It has been established that in addition to those conventional monitoring procedures, bio-monitoring is essential. Diatoms and benthic macro invertebrates are examples of aquatic animals that can function as bio-indicators to incorporate their overall environment and respond to complex sets of environmental circumstances. They provide the opportunity to get an ecological picture of how rivers or streams are now faring.

River Ecosystem and Bio-indicators

Bio-monitoring, also known as biological monitoring is the systematic use of living things or their reactions to ascertain the state or changes in their environment. Bio-indicators must be able to respond to a fast change in the critical variables as well as to the long-term interactions of various environmental circumstances. Benthic macro invertebrates, periphytons, and fishes are the most often used biomonitoring indicators in streams and rivers among other alternatives. Therefore, biomonitoring is a technique for watching how external variables affect ecosystems and their growth over time, or for identifying variations between different locations.

Periphyton

In streams and rivers, periphytons serve as important environmental indicators. Periphytons are crucial for the basis of food webs in river ecosystems since they are the primary producers. Since periphytons often have quick reproduction rates and brief life cycles, it is reasonable to assume that they will exhibit short-term effects and abrupt changes in the environment. Because the assemblages typically adhere to a substrate, many physical, chemical, and biological changes occurring in the stream (or river) reach, such as temperature, nutrient levels, current regimes, and grazing, among others, can have a direct and sensitive impact on how well they grow and thrive. For river biomonitoring, periphytons, particularly diatoms, have been chosen. Similarity of the taxon richness and diversity assemblage species composition Biomass and chlorophyll a have both been mentioned as indicators of environmental stress. To further infer specific or general environmental conditions in streams and rivers, numerous biotic indices based on species-specific sensitivities and tolerances have been created. Numerous studies have effectively used a variety of biotic indices to gauge the health of river ecosystems, primarily in central and northern European rivers.

Fig. 1. Periphyton. Figure courtesy-wikipedia

<u>Benthic Macro invertebrate</u>

Aquatic food webs, which connect organic matter and nutritional supplies (such as leaf litter, algae, and detritus) with higher tropic levels, are mostly dependent on benthic macro invertebrates. Due to their primarily sedentary lifestyles, these species are typical of the ecological circumstances unique to each site. They have the capacity to assimilate the consequences of short-term environmental perturbations due to their sensitive life stage and relatively lengthy lifespan. Additionally, these assemblages contain a variety of species with differing tropic levels and pollution tolerances, giving solid data for interpreting cumulative effects. The foundation for the creation of biocriteria to assess anthropogenic influences is the frequent and predictable changes in community structure of the assemblages in response to environmental disturbances.

Fig.2.Benthic macro invertebrate Figure courtesy. Gustav paulay

Fish

Fish communities have long been used to track the health of river ecosystems since they are very visible and important parts of freshwater ecosystems. Fish are the top of the aquatic food chain and are crucial for determining contamination since they are ingested by people. They can serve as reliable indicators of long-term (several years) effects and general habitat conditions due to their unusually extended life cycles and mobility. Additionally, the community structure of fish assemblages, which span a wide variety of tropic levels, including the highest level occupied by top predators, is indicative of the overall health of the aquatic environment. Almost all anthropogenic perturbations, including as eutrophication, acidification, chemical pollution, flow restriction, physical habitat alteration and fragmentation, human exploitation, and imported species, result in a strong and predictable response from fish groups. Fish are used to assess environmental degradation due to their sensitivity to the health of nearby aquatic habitats. A number of fish-based biotic indices have been used extensively for the past 30 years to evaluate the quality of rivers, and the usage of multimetric indices, which were motivated by the index of biotic integrity (IBI) has increased significantly.

Fig.3.Fish.Figure courtesy.EPA

Common Approaches Used for Biomonitoring of River Ecosystems

There are numerous different biomonitoring methods used in river ecosystems today. The challenges being addressed and the resources at hand determine the best strategy to use. Diversity indices, biotic indices, multimetric approaches, multivariate approaches, functional feeding groups (FFGs), and several biological features are examples of potential biomonitoring techniques. Numerous river monitoring projects continue to include an important consideration for the bioaccumulation and toxicity of pollutants in indicator species. Additionally, based on the saprobic values of indicator species (primarily bacteria, algae, protozoans, and rotifers, but also some macroinvertebrates and fish), saprobic systems were once used (in Europe) to indicate oxygen deficits caused by biologically decomposable, organic pollution in running waters. However, by the middle of the 1970s, most European nations had rejected these indices due to their limitations.

<u>Diversity Indices</u>

Numerous diversity indices have been created as traditional biomonitoring methods to describe how a community responds to environmental change. These indices combine the three elements of community structure: richness (number of species present), evenness (uniformity in the distribution of individuals among the species), and abundance (total number of individuals present).

<u>Biotic Indices</u>

The biotic approach creates a single index or score by combining the relative abundance based on specific taxonomic groups with their sensitivities or tolerances. It is recognised that different species have different sensitivity and tolerance levels to many environmental factors, including organic pollutants, heavy metals, pesticides, eutrophication, and pH. Therefore, one can infer environmental conditions in a habitat from these species-specific contamination indicators. In several European nations, macro invertebrate and periphyton biotic indexes are utilized.

<u>Multimetric Approaches</u>

Multimetric indices provide robust and sensitive insights into how an assemblage reacts to natural and anthropogenic stressors because they integrate a number of variables or metrics that represent different structural and functional characteristics of an ecosystem (such as taxa richness, relative abundance, dominance, functional feeding groups, pollution tolerance, life history strategies, disease, and density).

<u>Multivariate Approaches</u>

Multivariate techniques were first utilised to evaluate the biological state of rivers in the UK. The biological evaluations are then carried out by contrasting the observed fauna at the site with the projected fauna using multivariate techniques, which use statistical analysis to predict site- specific fauna patterns that are anticipated in the absence of significant environmental stress. It has been demonstrated that multivariate methods are useful for biomonitoring. RIVPACS and its derivation, AusRivAS (Australian Rivers Assessment System), BEAST (Benthic Assessment Sediment), and the more current ANNA (Assessment by Nearest Neighbor Analysis) are only a few of the widely used multivariate predictive models. Recent research has created multivariate techniques for periphytons and fishes, excluding macroinvertebrates.

Functional Approaches

It is well acknowledged that information on both structure (pattern) and function (process) is necessary for an accurate categorization of ecosystems. So, despite the success of assemblage structure and composition in studies of impairment, function analyses have recently experienced a rebirth as a complementary strategy for expressing ecological integrity.

Functional Feeding Groups (FFGs)

The foundational elements of the river continuum idea, functional feeding group analyses (FFGs), have been used to evaluate ecosystem-level activities in rivers and wetlands. FFGs metrics have been applied to river biomonitoring in the forms of single feeding groups (as absolute or relative abundance), ratios between two groups, and composite trophic indexes. These parameters have recently been combined with other metrics and used in biomonitoring strategies.

These assessments have been made based on readily visible morphological and behavioural traits that are connected to feeding and forms of attachment, hiding, and movement, as well as life-history patterns and drift tendency.

Multiple Biological Traits

An understanding of the function structure of bioconosis is made possible by the relationship between biological traits, habitat parameters, and the biological and ecological roles of species. Freshwater biomonitoring has recently been established using a variety of biological qualities from aquatic and terrestrial animals (such size, body structure, life cycle, food and eating habits, reproductive, and other traits) in the context of environmental restrictions. Multivariate Approaches have typically been integrated with the use of numerous traits. The running rivers of Europe currently use a variety of biological qualities mostly for aquatic invertebrates, and pertinent research has recommended a number of traits that are weighted by the abundance or occurrence of the taxa.

Changing patterns in river ecosystem biomonitoring

Expanding the Use of Functional Measures

In order to measure how much human activity has affected the ecology of streams and rivers, numerous biomonitoring approaches have previously been created. Ecologists are currently confronted with increased demands for effective tools to correlate the existing status of ecosystems and the management for conservation and restoration due to new trends in environmental legislation. As a result, functional measures such as microbial enzyme activity, bacterial luminescence, photosynthesis, respiration, locomotory activity, fluctuating asymmetry, community metabolism (primary productivity and respiration), nutrient uptake and spiralling, and secondary production are being used more frequently in river biomonitoring.

Molecular Techniques

Recently, various attempts have been made to use molecular methods as biomonitoring instruments. The major goals of molecular methods utilized in biomonitoring are species identification and genetic diversity. The best way to get the most thorough examination of ecosystem health is without a doubt to use finer taxonomic resolutions. Unfortunately, obtaining genus- or species-level data on macroinvertebrates and periphytons takes a lot of work, and even with highly developed taxonomic skills, species misidentifications can happen. However, molecular markers enable quick identification of genera or species at any stage of life. Recent studies have shown that DNA-based techniques, such as PCR-RFLP, T-RFLP, and COI sequencing, which have been employed to monitor periphytes and chironomids in aquatic systems, are accurate and useful biomonitoring tools.

Fundamentally, biological populations exhibit genetic diversity, and notable changes in genetic diversity are a key indicator of population-level changes. Molecular approaches are a logical extension of previously described approaches to measure the variation of environmental status because genetic diversity data offer effective tools for analysing the current status of populations, deducing the history of population changes, and foreseeing future population directions. Such efforts go back more than 30 years to link the variation of molecular genetic markers to certain aquatic stresses.

These research have assessed the impacts of metals, acidity, pesticides, radionuclides, and complex effluents on fish populations using both field surveys and carefully monitored laboratory experiments. Additionally, USEPA has conducted a number of studies to evaluate the value of include a genetic diversity indicator in its assessment and monitoring efforts. There are several compelling reasons to think that molecular genetic measurements may eventually produce extremely useful bioindicators, even though the use of molecular genetic diversity in river monitoring is still in its infancy.

03. FRAMEWORK FOR BIO-MONITORING RIVER HEALTH

Aquatic plants are plants that have adapted to living in aquatic environments (salt water or fresh water).They are also referred to as hydrophytes or macrophytes to distinguish them from algae and other microphytes. Macrophytes include vascular flowering plants, mosses and liverworts, some encrusting lichens, and a few large algal forms such as the Charales and the filamentous green alga *Cladophora*. Light and current are among the most important factors limiting the occurrence of macrophytes in running waters. Microphytes are microscopic algae, typically found in freshwater and marine systems, and are often called microalgae. They are unicellular species which exist individually, or in chains or groups. Depending on the species, their sizes can range from a few micrometers (μm) to a few hundreds of micrometers. Examples include carotenoids, antioxidents, fattyacids, anzymes, polymers, peptides, toxins and sterol s.

03.01 MICROPHYTES AS INDICATORS

Microphytes are microscopic algae typically found in fresh water and marine environment. The chemical composition of microalgae is not an intrinsic constant factor but varies over a wide range of factors, both depending on species and on cultivation conditions. Some microalgae have the capacity to acclimate to changes in environmental conditions by altering their chemical composition in response to environmental variability. A particularly dramatic example is their ability to replace phospholipids with non-phosphorus membrane lipids in phosphorus-depleted environments. It is possible to accumulate the desired products in microalgae to a large extent by changing environmental factors, like temperature, illumination, pH, carbon dioxide supply, salt and nutrients. Microphytes also produce chemical signals which contribute to prey selection, defense, and avoidance. These chemical signals affect large scale tropic structures such as algal blooms but propagate by simple diffusion and laminar adjective flow. Microalgae such as microphytes constitute the basic foodstuff for numerous aquaculture species, especially filtering bivalves.

EXAMPLES OF MICROPHYTES

SI NO	COMMON NAME	SCIENTIFIC NAME
1	Green algae	*Chlorophyta*
2	Diatoms	*Bacillariophyta*
3	Dinoflagellates	*Dinoflagellates*

03.02 MACROPHYTES AS INDICATORS

Macrophytes provide cover for fish and substrate for aquatic invertebrates. They also produce oxygen and provide food for some fish and other wildlife. Macrophytes respond to a wide variety of environmental conditions, are easily sampled, do not require laboratory analysis and are used for calculating simple abundance metrics. The depth, density, diversity and types of macrophytes present in a system are indicators of waterbody health. Where submerged aquatic macrophytes are abundant, they can have a heavy influence on habitat structure, fishability, recreational use and nutrient dynamics. The absence of macrophytes may indicate water quality problem such as excessive turbidity, herbicides or salinization which interfere with plant growth and development. However, an overabundance of macrophytes can result from high nutrient levels and may affect ecosystem health, recreational activities and the aesthetic appeal of the system. Macrophytes are organisms with low mobility and cannot avoid any combination of flow, nutrient availability and other physical and chemical characteristics that influence their survival in aquatic systems. Thus, an assembly of such organisms in a river or lake can be an effective indicator of the integrated combination of the pressure and stress disorders that affect their habitat.

EXAMPLES OF MACROPHYTES

SI NO	COMMON NAME	SCIENTIFIC NAME
1	Cattail	*Typha latifolia*
2	Hydrilla	*Hydrilla verticillata*
3	Water hyacinth	*Eichhornia crassipes*
4	Duckweed	*Lemnoideae*

METHODS TO ASSESS THE PRESENCE OF MACROPHYTES AND MICROPHYTES

Classification of macrophytes and microphytes in the system of hydrobionts is presented, individual characteristics of each macrophyte and microphyte type according to the given classification are presented, environmental problems concerning uncontrolled development of macrophytes and microphytes in water media are considered and several biotechnologies of application of their sustainable development are characterized. Individual characteristics pf macrophytes and microphytes are identified by the river data used in this study were extracted from the RMD, which contained vegetation data sourced from the Environmental Protection Agency (EPA), National Parks and Wildlife Service (NPWS), National Biodiversity Data Centre (NBDC). The abundance of all aquatic plant species was quantified by Plant Mass Estimates (PMEs), following the method described by Kohler (1978). PMEs follow an exponential five-level scale (Janauer & Heindl 1998). PMEs can be used for further determination of dominance and distribution patterns, of rareness and of the degree of species endangerment. Habitat parameters (see Table MP-3) were assessed at each JDS sampling site regardless of the absence or presence of aquatic plants. Different sets of habitat parameters were considered in order to allow relations between macrophyte appearance and abiotic features to be integrated into evaluations Hydrobionts are considered as highly potential source for bioproduction (including energy carriers and fertilizers) and many biotechnological processes that include hydrobionts, particularly their biomass as a substrate are used in different fields of energy, cosmetology, medicine, pharmaceutics, aquaculture, agriculture, forestry etc. Latest developments prove efficiency in applying anaerobic digestion for purifying wastewaters from organic pollutants with the help of macrophytes and microphytes in conducting biomethanogenesis.

MODALITITES TO INCREASE THE NUMBER OF MACROPHYTES AND MICROPHYTES

Macrophytes play an important structuring role in shallow freshwater bodies. Macrophytes have traits that affect the ecosystem services that shallow water bodies provide as they can maintain clear water and nutrient retention, while they also strongly improve aquatic biodiversity by providing a habitat and food for many aquatic organisms. Many lake restoration projects have led to decreased nutrient loads and increased water transparency, the establishment or expansion of macrophytes and microphytes does not immediately follow the improved abiotic conditions and it is often unclear whether vegetation with high macrophyte and microphyte diversity will return.The potential bottlenecks for restoration of submerged macrophyte vegetation with a high biodiversity and focus on the biotic factors, including the availability of propagules, herbivory, plant competition and the role of remnant populations. The potential for restoration in many lakes is large when clear water conditions are met, even though the macrophyte community composition of the early 1900s, the start of human-induced large-scale eutrophication in Northwestern Europe, could not be restored. However, emerging charophytes and species rich vegetation are often lost due to competition with eutrophic species. Disturbances such as herbivory can limit dominance by eutrophic species and improve macrophyte diversity. We conclude that it is imperative to study the role of propagule availability more closely as well as the biotic interactions including herbivory and plant competition. If the right abiotic conditions exist (i.e. mainly enough light, nutrients and shelter), macrophytes can return to a restored shallow water body in the short-term, varying from a few weeks to a few years.

Sufficient treatment of municipal wastewaters is essential to save the environment and public health. The conventional wastewater treatment processes are significantly cheap and sustainable however, they are not green enough for the environment. Algal growing in wastewater can significantly share in the management of freshwater ecosystems and treat wastewater. Macrophytes and microphytes can be used to diagnose the types of pollution which harm macrophytes. As macrophytes are an important component of the river habitat, they assess one aspect of river quality. Macrcphyte monitoring can be used firstly to assess streams for the state of the microphytes. This may be needed for conservation, for the potential supply of fish food substrates, or for potential use for irrigation. Secondly, it can be used together with other methods to build up a more complete picture of river quality. Thirdly if the main interest is solely in a quick assessment of 'good', 'fair' or 'bad' (so that discrepancies between invertebrate and macrophyte scales on more extended indices can be ignored), the speed of the macrophyte method can make it useful in suitable streams.

03.03 RIPARIAN VEGETATION

By giving soil mechanical support through its root system, riparian vegetation serves as a means of protecting the soil, preserving water, and preserving the health of rivers. Riparian vegetation also had an impact on the physical characteristics of the soil. The quality and texture of the soil are both improved by riparian vegetation. The porosity of the soil is increased by the roots. The oxygen, nutrient, and sediment cycles in streams are influenced by aquatic and riparian vegetation, which also provides habitat and food for wildlife. The area of the landscape that is most likely to have accessible groundwater, either at the surface or at least within reach of phreatophytes, is invariably occupied by riparian vegetation. Even though riparian plants frequently rely on a steady supply of groundwater, they can nonetheless get stressed by a lack of water or an increase in transpiration requirement. Additionally, riparian vegetation makes it easier to remove suspended sediments from overland flow coming from either the uplands or the nearby river, along with any nutrients, carbon, or pollutants they may contain. This process is aided by the variety of structural sizes and resilience to flow. Effectively deposited in mature, diversified riparian forests and streamside grasses are sediments and sediment-bound contaminants conveyed in surface runoff.

Aquatic and riparian vegetation

Algae and aquatic plants flourish in the river channel. Most have roots or root-like structures in the sediment and can have floating leaves (e.g., water lilies), structures emerging from the water (known as emergent plants, e.g., water ribbons), or be completely under water. Some are completely free floating (e.g., filamentous green algae), but most have roots or root-like structures in the sediment. These are referred to as submerged vegetation and include sea grass and curly pondweed. Along the banks of a stream that extends to the edge of the floodplain, riparian vegetation thrives (also known as fringing vegetation). This comprises the riparian zone's ground cover plants, shrubs, and trees as well as the emergent aquatic plants growing at the waterway's edge.

As the environment shifts from permanently or seasonally aquatic habitats in the waterway channel and floodplain wetlands to frequently flooded habitats along the banks and close to the channel to drier habitats at the edge of the floodplain, riparian vegetation frequently exhibits zonation in the plant species present.

Fig. Aquatic and riparian vegetation. Figure courtesy.Department of water and Environmental regulation- Government of Western Australia

Riparian vegetation, aquatic plants, and algae all contribute significantly to the health of rivers by:

●Absorbing nutrients from groundwater, surface water, and water entering a river, as well as from the waterway itself.

●By allowing sediment and pollutants from the overland flow to collect in the bordering zone and deposit there, decreasing the water's flow over the land's surface into a waterway can help reduce sedimentation and pollution in the river.

●Preserving the waterway's bed and banks t o stop erosion, plant roots link the sediments.

●Supplying nutrients like carbon, nitrogen, and phosphorus to the food chain.

●Supplying habitat for terrestrial and aquatic animals, including migration routes for turtles and frogs.

●Shading a canal helps to regulate the water's temperature and decrease phytoplankton development, which helps to prevent algal blooms.

●Putting up a physical barrier to stop livestock from entering, which could cause erosion and nutrient inputs, and to stop weeds from spreading along the canal.

Value of riparian vegetation

It is well acknowledged that riparian vegetation is important for sustaining the physical integrity and ecological health of streams. One of the waterway values preserved by the inclusion of a foreshore area or foreshore reserve during the land planning and other approval processes is riparian vegetation; for more details, see foreshore condition assessment. Numerous streams have been harmed by the historical removal or deterioration of riparian vegetation as a result of land clearing for agriculture, grazing, mining, and weed invasion.

Remote sensing indicators to assess riparian vegetation and river ecosystem health

Environmental managers require data to swiftly identify the combinations of stressors that need to be addressed in order to stop the degradation of rivers across wide study areas. Riparian vegetation is one of the main targets of stressor-mitigation and conservation efforts due to its crucial function in regulating thermal regimes and inputs of light, nutrients, and organic matter. However, field-based monitoring of regional riparian conditions is expensive and time-consuming due to the dendritic and vast character of river networks. Current advancements in remote sensing provide an unmatched chance to tackle this problem.

The stabilisation of stream banks, the provision of food and habitat, the regulation of stream water temperatures, the filtration and cycling of sediments and nutrients, and many other crucial ecological tasks are all carried out by riparian vegetation, a vital part of riverine ecosystems. It is widely acknowledged that maintaining a natural flow regime is essential to maintaining the biological integrity of riverine ecosystems and that changing natural flow regimes through river control will have an impact on the mechanisms that support riparian vegetation communities. However, little is known about the relative significance of the many flow regime components, including magnitude, frequency, duration, timing, and rate of change, for the dynamics of riparian vegetation.

03.04 MACRO-INVERTEBRATES

Every form of stream and river on the planet contains macroinvertebrate ecosystems. The members of this component of stream systems are only absent in the most severe and harsh conditions or in situations when stream waters flow for only a few hours before drying. The movement of organic materials from different sources inside or outside of streams through the stream food web is largely carried out by macroinvertebrates, which are essential to the ecology of stream ecosystems. Aquatic insects predominate in the macroinvertebrate ecosystem of many streams around the world, while some stream and river types can also support high densities of mollusks and worms. All lentic and lotic inland hydrosystem types are colonised by benthic macroinvertebrates. Almost all invertebrate taxonomic groups—with the exception of a few wholly marine ones—occur in freshwater. They are significant players in the benthic-pelagic coupling of food webs because of their size, which ranges from less than 1 mm to several centimetres, and the amphibious life cycle of one of the main groups of aquatic insects. They link the detritus-based food chain with the primary-production-based food chain and provide reciprocal subsidies between aquatic and terrestrial ecosystems. Because of human activity, several species have spread around the world and are now invasive neobiota.

Fig. Macroinvertebrates. Figure courtesy. Friends of the Chicago river

Macroinvertebrates for biological monitoring in river ecosystems

Macroinvertebrates are among the aquatic species employed in bioassessments, and numerous studies have highlighted their advantages as outstanding bioindicators of the ecological quality of aquatic ecosystems.

These benefits consist of:

● Most aquatic habitats contain a variety of organisms known as macroinvertebrates.

● While large macroinvertebrate communities can be found in small order streams, fish are not frequently found there.

●The presence or absence of taxa can reveal details about the environment, such as the pollution level and stream velocity, oxygen concentration, pH, and substrate kinds.

●The majority of these taxa have sedentary lives and are restricted to the areas of the river where the physical and chemical conditions are favourable. This characteristic enables quick and effective evaluation of the local environmental conditions.

●Because the organisms can accumulate xenobiotic substances, they can measure the level of environmental contamination.

●Different pressures result in various taxa or communities of macroinvertebrates.

●In accordance with a rapid assessment technique, sampling macroinvertebrates is simple, needs few personnel and pieces of equipment, and has no negative effects on other creatures.

●They are the main food supply for fish that are significant for both recreational and commercial fishing, a negative influence on them may tend to affect the food web and specified uses of the water resource.

●They provide insight into the short- and long-term reactions of ecosystems.

The limitations include:

●Inadequate identification abilities (which could lead to mistakes, particularly in the early stages of macroinvertebrate larvae's life).

●The difficulty of collecting quantitative samples (which depends on the grade of the river and the location of the habitats).

●The assessment of such taxa is challenging because the occurrence and abundance of some species might vary even within the same area or river basin.

●The occurrence and abundance of macroinvertebrate species may also be influenced by other factors, such as current velocity and substrate types.

●Some taxa are challenging to species-level identify.

●There could be seasonal fluctuations in the distribution of taxa.

●Not every impact gets a reaction from them.

Methods of macroinvertebrate biological monitoring

Invertebrates are animals without backbones, whereas macroorganisms are those that can be seen with the unaided eye without the need of a microscope. Macroinvertebrates are an essential component of aquatic ecosystems and are frequently employed as markers of the ecological health and water quality of these systems. Because macroinvertebrates are one of the most effective and reliable ways to track the health of aquatic ecosystems, their important functions in stream and river health monitoring are well acknowledged. To evaluate diversity, similarity, and biotic indices, as well as multimetric and multivariate characteristics, many biomonitoring approaches and tools have been developed. Diversity indices incorporate data on the dominance, uniformity, and taxonomic richness of the elements that are used to depict how a community reacts to the quality of its surroundings. With the control and reference locations, similarity indexes are used to compare two or more populations or communities. Similarity indices are frequently used to determine how much of a difference an impact has had.

In general, the diversity of macroinvertebrates in wetlands is high.Some species in theAfrotropical region have distinctive characteristics that allow them to endure the dry stage of transient wetlands. In general, permanent wetlands have been studied more thoroughly than transient wetlands, and the Afrotropical region is no exception. Additionally, there is still a great need for more research on tropical wetlands in general as they have received far less attention than temperate systems. This is especially important for Afrotropical wetlands because the distribution records for macroinvertebrates and their ecology for these systems have significant gaps. Southern Africa, more specifically South Africa, is the focus of the majority of wetland macroinvertebrate study in the area.

03.05. FISHES

The use of fish as indicators requires a thorough understanding of fish taxonomy, ecological needs, and physiology. No other aquatic organism is suited for the application of such a wide range of techniques that allow the assessment of the severity of toxic impacts by determining the accumulation of toxicants in tissues, by using histological and haematological approaches, or by identifying morphological anomalies. The fish fauna is an essential indication of the ecological integrity of aquatic systems at many sizes, from microhabitat to watershed, due to its diverse habitat requirements. The interconnectedness of various habitat features in a broad spatial-temporal context determines the fitness of fish species both at the individual level (e.g., growth performance) and at the population level (e.g., population structure).

Fish as bioindicators

Fish have a long history in fishing and sport fishing, where they serve as vital indicators of the quality of the water. Because fish are used so extensively by humans as food, fish communities are taken into consideration when managing water resources. Bioindication through the use of fish frequently satisfies the requirements of both top-down approaches (evaluating changes in communities in the natural environment and testing for sources and causes of potential problems) and bottom-up assessments (using laboratory data to model changes in the more complex natural ecosystems the field). This depends on the problem and the indication approach chosen. There are only a few species, and they can all already be identified in the wild.

Fish are sensitive to a variety of disturbances, such as hydrologic alteration and the impact of pollutants, because they spend their entire lives in the water, unlike many invertebrates, and they thus continuously inhabit the receiving water and integrate the chemical, physical, and biological histories of the aquatic ecosystems. Fish living in aquatic environments that have experienced multiple disturbances are excellent models in which to analyse responses to multiple stressors. Fish are particularly helpful for determining regional and macrohabitat differences because they are less impacted by natural microhabitat changes than smaller creatures. Additionally, fish taxonomy is well-established. Additionally, fish are among the aquatic environments' most extensively researched groups in terms of their biological and physiological reactions. Ecosystems receive "goods and services" from fish, such as the output of fisheries. More importantly, different fish species occupy the top positions in the aquatic food chain and may have a direct impact on human health, making fish an important component of biomonitoring

Fig.Fish as a bioindicator. Figure courtesy.Researchgate

Problems with using fish as bioindicators

It is more challenging to talk about other man-induced degradations of aquatic ecosystems when there are fishery-caused changes present, such as species translocation, stocking, and overfishing. It is challenging to pinpoint not only the precise source of pollution but also the timing and length of exposure due to the movement of many species.

About 10% of the animal species on Earth live in freshwater systems, which also provide environmental services. However, human activity affects freshwater resources structurally and functionally, which limits its potential for use. Aquatic species need to be protected since freshwater environments are considered to be the most endangered on the planet. Aquatic ecosystem monitoring has proven to be successful with biological techniques. In this way, freshwater fish and macroinvertebrates, from the suborganismal to community level, demonstrate outstanding response signals to stressors given their biological and ecological properties. We examine the primary methods used to evaluate freshwater ecosystems using fish and macroinvertebrates in this article. Both organisation levels show spatial (locally and regionally) and temporal (past and present) effects of water quality conditions on the aquatic ecosystems. Biomarkers are excellent early warning indicators showing that organisms have been in contact with contaminants and the effects can be reversed. High organisation levels reflect an overview of the global impact on aquatic resources.

03.06. BIRDS

The ecology of water birds lends itself to their value as bioindicators in a number of ways. At both the species and community levels, as well as across short and long time scales (months and years), it has been demonstrated that water birds can detect environmental variations. Additionally, because many species are top predators and a variety of pollutants frequently accumulate along the trophic chain, these species may be utilized as markers of changes taking place at lower trophic levels. Third, humans either take advantage of the water birds themselves or their prey (via fishing and hunting, for example), therefore water bird hunting catches may be an indicator of productivity in nesting areas or bird breeding patterns may provide information on fish stocks. Birds are prevalent, noticeable, and diversified parts of freshwater ecosystems all over the world, as well as the wetlands and riparian zones that surround them. A whopping 11–23% of all bird species use inland waters or their margins at some point during their annual cycle, despite the fact that less than 4-5% of the geographical surface of the planet is covered by freshwater that is still standing. The essential significance, productivity, and wider ecological implications of water in all biomes are somewhat reflected in this diversity. It also depicts the riparian impact of flowing waters. Even though Britain alone has 80 000 km of streams and rivers, just 8% of the world's total river drainage comes from the continent of Europe.

BIRDS AS INDICATORS OF CONTAMINANTS IN WATERBODY

It has long been practiced in a variety of ecosystems to evaluate trace pollutants, particularly certain metals and persistent organochlorines, using the eggs or tissues of birds. In addition to serving as a monitoring tool, such work serves as a significant indicator. Due to the trophic level that predatory birds occupy pollutants that would otherwise be too scattered for straightforward assessment can accumulate in substantial amounts in their tissues through bioaccumulation and biomagnification. Furthermore, the material used is frequently biological waste, such as failed eggs or deceased birds. Both of these sources enable measurement without the loss of living things, but the method would be biased if the samples had consistently higher or lower contamination burdens.

Fig. Water birds.Figure courtesy.CSDevNet

<u>BIRDS AS ECOLOGICAL INDICATORS OF WATER QUALITY</u>

The application of biological markers of general water quality has advanced significantly. Aquatic invertebrates or smaller plants are typically used in studies that are conducted at the community level. 'Biotic indices' are frequently constructed from the limits of water quality that various species may tolerate. In such systems, a score is derived from the organisms present at a specific location and utilised to provide brief details about the biological and chemical status of the water. Despite the fact that index scores might reveal information about other factors affecting water quality, most schemes focus on organic matter, one of the most prevalent pollutants. Indicator species that represent the reaction of animal or plant communities to changed water quality have recently been identified using multivariate methods of categorization.

For a bird species, or group, to be a valuable indicator of water quality, it should have the following attributes:

●Its status need to be sensitive to changes in quality across time and space and ought to represent the quality of the water.

●Variables that are simple to measure and provide useful information should reflect the state.

●The way that reacts to changing water quality needs to be constant over time and space.

●Water quality for other significant biological resources should be reflected in the its status. In this situation, we could also want our chosen ornithological indicator to function more effectively than, or at the very least complement, prospective indications from other taxa.

●The effects of other components and changes to other habitat elements should be easily distinguishable from changes in its status brought on by changes in a specific water quality component.

Waterbirds as Bioindicators of Environmental Conditions

Water birds can serve as both local and regional spatial scale bioindicators of conditions found in wetlands. Large-scale changes in agriculture might potentially have an impact on the habitats of waterbirds. Some populations of snow geese, Chen caerulescens, have grown by 7% annually as a result of feeding on agricultural crops in the winter and migrating, and this growth has had a significant negative long-term impact on the intertidal salt-marsh vegetation at an Arctic coastal breeding site, which is 5,000 km from wintering sites. Research on northern fulmars, Fulmarus glacialis, which breed on cliffs above a coastal plain with freshwater ponds, has demonstrated that changes in the nitrogen budget of wetlands may also be caused by the actions of the birds themselves. Fulmars acted as biovectors, carrying significant amounts of pollutants as well as nutrients from the sea to the ponds. Compared to ponds not influenced by bird activity, these ones had higher concentrations of pollutants, chironomids, and chlorophyll. These bird activity markers could be utilized to monitor population shifts in other bird species for which chironomids serve as a significant food source.

Limitations on the Use of Waterbirds as Bioindicators

Waterbirds and the biotic and abiotic elements of wetlands have significant interactions, and the effects of the birds in these habitats may have significant implications on food webs. This demonstrates why waterbirds should be included in biomonitoring systems. The absence of connections between the diversity of waterbirds and other organisms is the main point of criticism. The degree to which patterns in community structure in a set of sites are comparable across various taxonomic groups is measured by community concordance. In some lakes, concordant patterns have been observed between guilds of waterbirds and even between waterbirds and fish, suggesting that tracking the condition of one group may serve as a helpful bioindicator of the condition of other groups.

Indicators of ecological change can often be found in long-term records of waterbird counts, which are a popular subject for research and monitoring. To properly assess trends, it is necessary to have a good understanding of the ecology of a given species because different waterbird species experience population variations for various reasons. As their populations grow owing to overgrazing, or because they act as carriers of toxins and nutrients, waterbirds can not only adapt to environmental change but also contribute to it. Birds may not always be used as substitutes for other creatures in biomonitoring projects because they may not react to wetland characteristics in the same manner as other groups of organisms. In other instances, though, birds can be trustworthy gauges of fish stocks, aquatic plant richness, or nutritional quality. In these last circumstances, birds may be thought of as relatively easily quantifiable surrogates since the challenges inherent in monitoring some groups of species (e.g. aquatic vegetation) could be better avoided if a reliable indicator is available. Clear monitoring programme objectives are crucial when utilising waterbirds as indicators.

Managing Common Pool Resources in Local Governments: A Role of Deliberation and Public Participation

Abstract

Governments across the world faces many challenges and constraints in managing the common pool resources (CPR's). Globally, all the major national governments and almost all developing countries have begun to implement decentralised policy and decision-making systems for delivering public services and management of environmental goods (Agrawal, 2001). In any government structure, the distribution of public goods is difficult as it will be changing to exclude potential beneficiaries from obtaining the goods, similarly, it's very difficult to exclude potential beneficiaries from obtaining benefits from common pool resources. In her phenomenal book on "Governing of Commons" Elinor Ostrom argues that the CPRs can be managed well at the local level. She argues there is a need for well-defined formal and informal institutions at the local level so that the actors can govern themselves to obtain joint benefits from the CPRs by avoiding problems of exclusion of beneficiaries, conflicts, and exploitation of resources (Ostrom, 1990). For establishing well-defined rules and norms it's important to have constant deliberation and participation of various actors for collective action in managing CPR. However, at the decentralised level majority of the local governments have given less attention to prompt decentralised decision-making in matters of CPRs and especially in matters of environmental resources (Agrawal, 2001). By extending these arguments made by Elinor Ostrom, in this article, I aim to study the capacity and role of local-level institutions in providing deliberation and public participation in managing common pool resources in the context of India. In this process, I also aim to discuss a case study in the management of river Pampa in the State of Kerala by highlighting the role of deliberation and public participation in managing common pool resources.

1 | Introduction

Managing resources is a major challenge in the social setting and it's a major policy problem in most countries. The three influential models that discuss the issues and use of resources are 1) Tragedy of Commons in which Hardin argues that the individual /community uses the resources without the limit, with natural resources which get depleted with overconsumption (Ostrom, 1990). 2) The Prisoner's Dilemma Game - it states that two individuals acting in their self-interest don't produce an optimal outcome and the third influential model 3) The logic of collective action - Olson argues that an individual has little or no incentives to contribute voluntarily when it is difficult to exclude the individual from getting the benefits of the resources (Ostrom, 1990). The current major policy solutions to address the issue of management of resources are focused on the principles that centralisation and privatisation are prescribed to address these issues. In both methods of policy solutions, the major assumption is that the governing authority has complete authority in managing the CPRs. But in reality, these institutions lack complete information on the availability of resources, the number of players or users of the resources and what quantity of the resources they consume. Ostrom argues that CPRs can be managed effectively by the community at the local level (Ostrom, 1990). The actors at the community level through interaction and deliberation collectively develop institutions that identify the availability of resources, issues and conflicts among the actors. At the local level, institutions that provide power to the local governments have been seen globally. Decentralization provides an institutional mechanism that provides power to solve issues at the local level through deliberation. However, at a decentralised level majority of the local governments have given less attention to prompt decentralised decision-making in matters of CPRs and especially in matters of environmental resources (Agrawal, 2001). By extending these arguments made by Elinor Ostrom, in this article, I aim to study the capacity and role of local-level institutions in providing deliberation and public participation in managing common pool resources in the context of India. In this process, I also aim to discuss a case study in the management of river Pampa in the State of Kerala by highlighting the role of deliberation and public participation in managing common pool resources.

2 | An Analytical Framework for Managing Common Pool Resources: IAD framework, Decentralization, and Deliberation & Public Participation

In Governing of Commons, Ostrom defines common-pool resources as a resources system either man-made or natural resources where the benefits of resources shared among a large population and it's difficult to exclude the beneficiaries from obtaining the use of resources. Generally, the availability of CPRs reduces as it is used by different actor(s) and it raises the issue of "Subtractability of Use" (Ostrom, 2005). The subtractability of use can be defined as the usage of resources increases the availability of resources to another beneficiary reduces and for CPRs, the "subtractability of use" is high (see table:1) (Ostrom, 2005). This situation of high subtractability and high excludability makes it difficult to manage CPRs. Access to CPR can be limited to individuals or communities but the situation to manage CPR gets complex as the area of benefit increases and when multiple actors get involved. In a complex system, where multiple appropriators (the actors who withdraw or use the resources from the resources system defined as "appropriators") are involved, and when the area of benefit is large these appropriators interact and deliberate with each other to devise rules and norms to manage CPR's (Ostrom, 1990). These rules and norms could be both formal and informal rules which are enforced collectively to shape individual behaviour in a complex social situation, and these rules and norms are defined as institutions (North, 1991). These institutions evolve through repetitive interactions and deliberation among the various actors. In a complex situation the role of institutions, how have the institutions are evolved and changed? Who deliberated these rules and norms? How these rules and norms are operationalised is important. So, in this section to provide an analytical framework a theory of Institutional Analysis Development Framework (IAD), decentralisation and deliberative & public participation were discussed.

Table 1: Types of Goods

		Subtractability of use	
Difficulty of excluding potential beneficiaries		**Low**	**High**
	Low	Toll Goods	Private Goods
	High	Public Goods	Common-pool resources

Source: Understanding Institutional Diversity (Ostrom, 2005)

2.1 | An Institutional Analysis Development Framework

Institutions defined as a set of rules, norms, and shared values (North, 1990 & Ostrom, 1994). These institutions are not visible and difficult to identify in the complex social structure. The institutions can be categorised as both formal and informal institutions. Formal institutions are rules, laws, and regulations. The formal institutions are written and found in the explicit form at the constitutional level or at an operational level which influences the decisions taken by participants and organizations. The institutions such as beliefs, norms, and customs forms through the traditional interaction among the people in a society, these institutions are defined as informal institutions (North, 1991). The informal institutions are often unwritten and sometimes shared as implicit knowledge. The rules are "enforced in particular situations by the agents responsible for monitoring conduct and imposing sanctions" (Ostrom, 1994). Whereas the norms are "shared prescriptions that tend to be enforced by the participants themselves through internally and externally imposed cost and inducements" (Ostrom, 1994). Both formal and informal institutions are "constituted and reconstituted by human interactions in frequently occurring or repetitive situations" (Sue E. S. Crawford, 1995). Ostrom (1994) has developed an "Institutional Analysis and Development Framework" (IAD) to analyse institutional arrangements. Using the IAD framework the institutional arrangements can be understood as "the rules used by individuals for determining who and what is included in decision situations, how information is structured, what actions can be taken and in what sequence, and how individual actions can be aggregated into collective decisions" (Ostrom, 1994). These rules are classified as rules-in-use and categorised into three types 1) Constitutional Choice Rules – At the constitutional level through governance, the decisions and collective choice rules can be modified. These modifications can determine who is eligible to participate in developing and changing the collective-choice rules which in turn can influence outcomes and operational rules (Ostrom, 1994). 2) Collective choice rules - At the collective choice level, the activities include – policymaking, management and decision-making. These activities can determine who can participate in decisions and how the rules can be changed. At this level the people involved in the collective choice situations deliberate and discuss the rules which can influence the activities and outcomes at the operational level (Ostrom, 1994). 3) Operational rules – At the operational level monitoring and enforcement takes place. It "includes decisions about when, where, and how to do something; who should monitor the actions of others; how actions should be monitored; what information should be exchanged or withheld; and what rewards and sanctions will be assigned to combinations of actions and outcomes" (Ostrom, 1994). The IAD framework can be used to analyse the common-pool resources (Ostrom, 1994). As the river is a common resource using the concept of rules-in-use the institutional arrangements for river management can be analysed.

2.2 | Decentralisation

One of the most basic principles of decentralisation is to have power, resources, and administrative capabilities for the local communities to govern themselves. The role of local governments is to provide accountability and responsiveness to the citizens for their basic needs and wants. The process of decentralisation of governance structure enables citizens to act collectively to redistribute resources through collective action. For many nations decentralisation is emerged as a major strategy for the provision of public services & goods.

The transfer of powers to local government in many nations was political and promoted by domestic or external pressures. And the transfer of powers to govern certain matters is reserved for a centralised system. However, the process of decentralisation provides an institutional arrangement to govern themselves and it allows the citizens to communicate their preferences to the elected officials through public participation these actions are aimed to carry out with minimal intervention by the centralised government system. In Governing of Commons, Ostrom argues that CPRs can be effectively managed at the local level. The institutional arrangement of decentralization is important to manage CPR and "the powers that are devolved to the local level have important effects on resource management-related outcomes" (Ostrom). This process of decentralisation affects actions at collective choice & operational level institutions. In India, the transfer of powers was due the domestic pressures, the 73rd & 74th amendment act enabled the decentralisation process. The constitutional level rules gave the power to local government in the distribution and allocation of public goods. The Gram Sabha, legislative at the local level act as the collective choice rules, and the deliberation at the collective-choice level affect the actions at the operational level. The Gram Sabha provides an institutional mechanism for deliberation and public participation.

2.3 | <u>Deliberation & Public Participation</u>

Deliberation is an ability to have consensus in the distribution of resources, resolve conflicts, improve knowledge & establish coordination among the members of the community which shapes their identity and preferences. In a complex society, collective choice decisions are made through discussions, debates, and critically analysing of the problems, through repetitive discussions to have a collective consensus among members of the community. In other words, it is a governance in which "free and equal citizens (or their representatives) justify decisions in a process in which they give one other reason that is mutually acceptable and generally accessible with the aim of reaching the conclusion that is binding in the present on all citizens but open to challenge in future” (Padvetnaya, 2017). It is a continuous & ongoing process which constitutes a public sphere.

3 | A Case Study: Management of River Pampa

3.1 | A brief of River Pampa

The Pampa River is known for its religious significance. It's the third-largest river in Kerala with a length of 176 km. The river originates at 1830m above mean sea level (MSL) and it occupies four districts and includes two Municipalities, 16 Block Panchayats and 67 Grama panchayats. The river can be categorized into upper basin, middle and lower basin. Water pollution, seasonal droughts and floods affect the life of the river Pampa. The Pampa Parirakshna Samiti is an NGO that played a major role in the protection of the river. The state government constituted the Pampa River Basin Authority in 2009. The major collective issues associated with rivers are sand mining, excess use of water resources for irrigation, water scarcity, and pollution. The current major issue associated with the rivers is floods. In this section using the analytical framework discussed in the previous section the institutional arrangements and deliberation for institutional change were analysed focusing on the issues of water pollution and sand mining.

3.2 | Institutional Analysis

As discussed in section 2 institutions are defined as formal rules, laws and regulations and informal norms, beliefs, and customs. These formal institutions were identified and analysed by reviewing the laws and acts at different levels. Based on the IAD framework the three levels of rules-in-use a) constitutional rules b) collective rules c) operational rules were identified and analysed. The constitutional rules can modify the collective choice and operational rules by determining who is eligible to participate. The collective choice rules include policy-making and decision-making, these rules can determine who is eligible to participate and influence the operational rules. The operational rules include who, when and how to do something, at this level rules are monitored and enforced.

Constitutional level – At the constitutional level, Article -21 states that every human being has the right to live a healthy environment and Article 51- A states that it's the responsibility of every individual to protect and manage the environment. The rules to manage the rivers at the constitutional level, identity that the power of regulation and development of the interstate rivers and river valleys are under the control of the Central government, and it can be declared by Parliament by law. The rules for the management of the interstate rivers are mentioned in the Rivers Dispute Act and issues are managed at collective choice rules through an inter-state river management board. Whereas at the constitutional level rules the regulation and development of rivers that follow within the state boundaries can be regulated and developed by the state government (Indian Constitution Seventh Schedule, Article-246, List-1, 56). In the case of Pampa, the state government has complete authority to manage the rules in use at the collective choice and operational level.

The 73rd and 74th constitutional amendment acts provide power to the local governments in the provision of water resources to the citizens as public goods. At the state government level, the government has enacted the "Kerala Panchayati Raj Act, 1994", this act provides the powers to manage local water resources and water supply. The act through its rules makes Gram Sabha and panchayats responsible for the management of water resources and supply and sanitation. However, the power to manage protection in the act was given much less attention. And the amendment act also has given less attention to prompt decentralised decision-making in matters of CPRs and especially in the matters of environmental resources.

Collective-Choice Rules – At a centralised level for the protection of rivers from pollution established Water (Prevention and Control of Pollution) Act, 1974 and was amended in 1988, the act directs the Central and State Governments to establish a Central Pollution Control board. The Water (Prevention and Control of Pollution) Cess Act 1977, and Environmental Protection Act 1986, are enacted by the central and state governments to protect the environment from anthropogenic activities. These acts are enacted after much deliberation and public participation at the constitutional level through the legislative process.

For the management and protection of the river from sand mining the Kerala State government has enacted the Kerala Protection of Riverbanks and Regulations of Removal of Sand Act 2001, it provides rules and regulations for "Protecting the riverbanks and riverbeds from large scale dredging of river sand" by regulating indiscriminate sand mining. Later in the year 2009, the state government to address the issues in concern with water resources and pollution enacted “The Pampa River Basin Authority Act 2009” “the act provides arrangements for the management of activities connected with the conservation of water resources in the Pampa River basin”. These acts are enacted with much deliberation and public participation in the state legislative process as collective choice institutions. These rules and regulations determine who can participate in decisions and influence the activities and outcomes at the operational level.

<u>Operational rules</u> – At the operational level, the monitoring and enforcement take. The concerned local government and district collector make decisions about when and who to act, who should monitor the actions of others and how actions should be monitored. The findings with discussion with panchayats helped in identifying the different rules in action. Multiple stakeholders such as communities, local groups and NGOs are involved. The combination of actions through different stakeholders led to outcomes in the rejuvenation of the river project. However, the challenges include such as conflict of interest between different stakeholders and a lack of technical knowledge that affected the outcomes at the operational level.

3.3 | Institutional Change through public deliberation

The institution changes and evolves with constant interactions and deliberations between the actors at various levels. In a collective action situation where multiple actors are involved in deliberative their preference and conflicts, in these situations, it’s important to identify who is participating in the deliberations and whose power influence the decision-making.

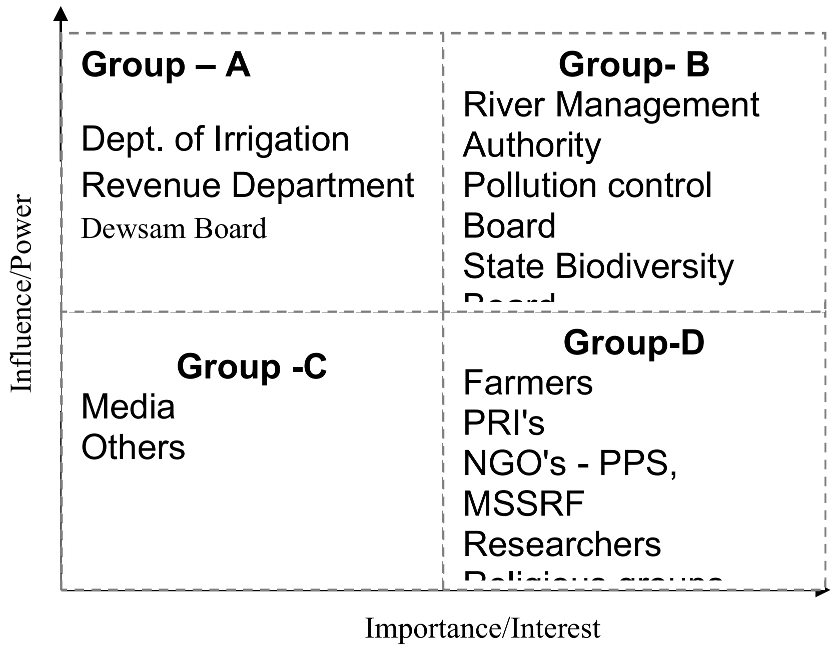
In the case of the pampa river management focusing on water pollution and sand mining, the collective choice rules were enacted with multiple deliberations and the institutions have evolved in the protection of the river. The major institutional change was the Kerala Sand Mining Act, which was enacted in 2001, the collective action among the group of people led to the establishment of the organization Pampa Parirashana Samiti. This NGO and along with a few stakeholders have been able to establish the collective choice rules for the prevention of sand mining in the river basin. At the operational level, the sand mining by certain actors led to conflicts among the farmers, fishing community and environmental protectors as it was affecting the ecosystem of the river. The collective action among these actors has led to the establishment of the sand mining act. These institutions at the collective level have evolved over the years, through the constant interactions and deliberation among the actors that led to the Pampa River Protection Act in 2009. However, these acts didn't influence the actions at the operational level. Water pollution and sand mining were consistent over the years. The studies found that the water quality of the river upstream has been affected due to the Sabarimala pilgrimage. The Sabarimala season is from October to February, and the increase in devotees can be found during December and January. The studies conducted during these months have found a decrease in water quality. Krishna and Kumar (2014) examined the water quality during this period in the Chengannur region in the year 2011 and 2012. It found an increase in pollution during this Sabarimala season (Krishna & Kumar, 2014). Similarly, a recent qualitative study conducted by Narayan (2021) on seasonal pollution, concludes that the pollution rates were seen higher in the Pampa River basin during the pre-monsoon season and winter (Narayan, 2021).

At collective choice, the actors who were negatively affected by the actions, certain actors, through constant deliberation among the actors were able to operationalise the institutions at the operational level in the protection and management of rivers. At the operational level, these NGO's Such as Pampa and MSSRF, panchayats and other environmental groups were able to influence the people in the prevention of population by educating the local communities on sources of pollution and prevention of sand mining through social policing.

The power to influence the decisions and the knowledge of actors were analysed using stakeholder analysis. Based on the constitutional and collective choice rules the power of influencing the discussion are high among the government institutions such as the Department of Irrigation and the Pampa River Management Authority. The local institutions and NGOs have medium power to influence the decisions at the collective choice level.

Primary Stakeholders: The primary stakeholders are those who have direct positive are negative effects. From the findings and literature, the primary stakeholders are Farmers & Dept. of Irrigation, the Department of Water Resources, Local Governments – PRI, the Centre for Water Resources Development and Management, religious groups, the River Management Authority etc.

Secondary Stakeholders: The secondary stakeholders are those who are indirectly affected by programmes and actions. From the findings and literature, the Secondary stakeholders are NGOs – MSSRF and “Pampa Parirakshana Samithi”, Media, Researchers & Kerala Institute of Local Administration.



S.no	Stakeholder	Power	Knowledge	Influence	Interest
1.	Farmers	Low	Low	Low	High
2.	Panchayats	Medium	Low	Medium	Medium
3.	Researchers	Low	High	Medium	High
4.	Pampa Parirakshana Samithi	Medium	Medium	Medium	High
5.	Dept. of Irrigation	High	Medium	Medium	Low
6.	Pampa River Management Authority	High	High	High	High
7.	MSSRF	Low	High	Medium	High

4 | Conclusion

Deliberation and public participation are crucial for the management of the CPRs. Through deliberation and constant interaction between the actor, institutions evolve and change. In the management, of river pampa, the institutions at the collective choice level have evolved in the supply of water for the public and irrigation to the protection of the biodiversity of the rivers. At, the collective choice level, the local bodies, NGOs and other environmental organizations had deliberated and taken actions at the operational level in addressing the issues of water pollution and illegal sand mining. However, the power of these organizations to influence the decisions made at the collective choice and operational level has remained weak. To address these issues at the collective choice level the decentralised mechanism level at local governments should focus decision-making on matters of CPRs at the decentralised level.

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Report: Aware the local stakeholders of the health of the Saptalingi River in Sangameshwar block, Ratnagiri district, Maharashtra

Submitted by

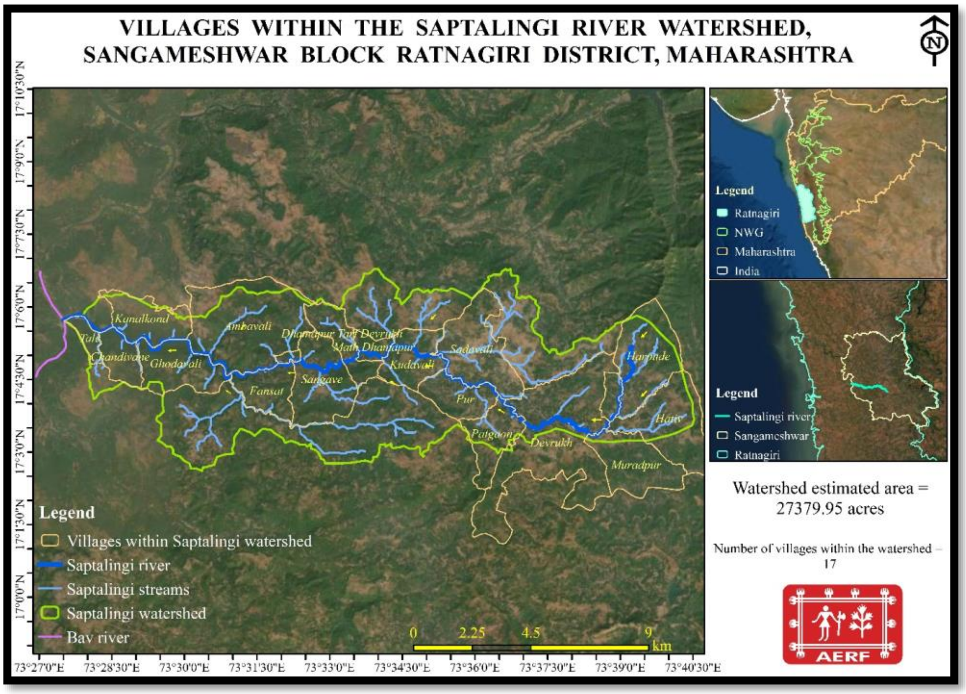
Gunwant Mahajan

I. Introduction-

The Western Ghats, also known as the Sahyadri mountains, is a UNESCO World Heritage site and a well-known biodiversity hotspot. This mountain chain is a major watershed of numerous rivers of peninsular India. As far as Maharashtra is concerned rivers like Godavari, Krishna, and Bhima originate in this Sahyadri mountain. The main development focus is on these east-flowing rivers as they are bigger in catchments and length than the west-flowing rivers in the mountain and are the lifeline of city people in all southern states in India including Maharashtra. The west-flowing rivers are small and hence mostly neglected in the development process. This has had a positive impact so far on these rivers and their ecosystem. These rivers still hold the natural flows and provide crucial ecological services to the local communities. However, the development has reached other ways to threaten these rivers. These rivers are now facing threats of change in land use, pollution, a lifestyle change from the local people, and a lack of awareness among them.

II. Site Description-

The Saptalingi River is a small west-flowing river in the Sahyadri mountains. It is a tributary of the Bav River. It originates in Harpude village and hardly flows 33 km before it meets the Bav River near Tale village in Sangameshwar block. It has a watershed of 27693 acres and flows through 17 villages in the block (Map-1). It mainly flows on the laterite plateau of Devrukh town and surrounding villages. It faces several threats that impact the ecological health of the river. For example, there is a lot of deforestation in the catchment, it gets polluted when it passes through human settlements due to non-degradable plastic waste and loss of biodiversity due to littering, drying up or flooding seasonally. The rivers in Sangameshwar are rich in biodiversity as these rivers are home to endemic and threatened species like *Cryptocoryne cognata* (plant, Endangered), Smooth-coated Otters (Mammal, Vulnerable) and Asian Small-clawed Otter (Mammal, Vulnerable). These rivers provide important ecological services to the local people like recharge of groundwater and food. To date, groundwater is the main source of drinking water in the Sangameshwar block. The local fishermen (the Ghorpi community) are completely dependent on these rivers for their livelihoods. Fishing is the traditional business of this community. They have very good knowledge of freshwater fish in this area. They catch freshwater fish from these rivers throughout the year and sell it in the local markets.



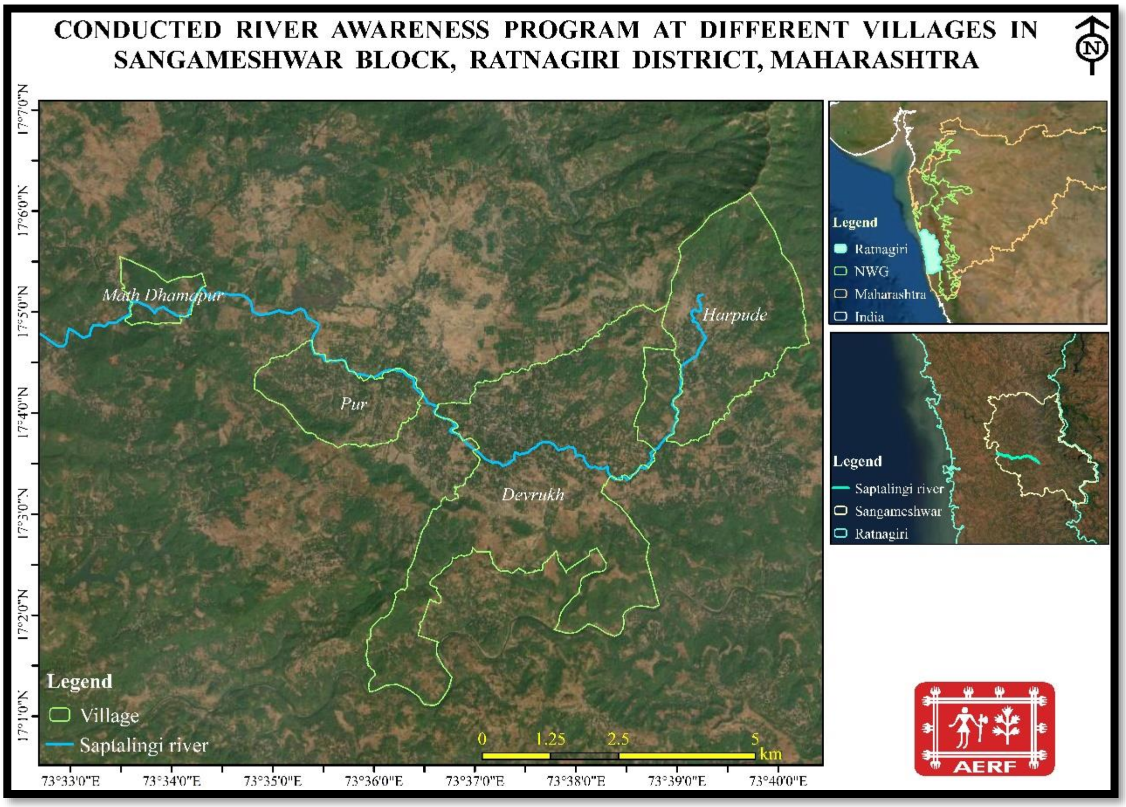
Map-1

III. Threats to the river-

Due to unprecedented development reaching the remote corners of the Sangamshwar block, the Saptalingi river is threatened. Regular deforestation, water pollution, and dumping of non-degradable waste aggravate the situation that results in the loss of valuable ecosystem services.

IV. Actions to conserve the river-

After identifying problems around the river's health and discussions with the AERF field team, I came up with a plan for generating awareness about the river and its health. I understand this is the first step towards its conservation and responsible efforts by the community in AERF collaboration. With the support of M S Swaminathan Research Foundation (MSSRF) and Applied Environmental Research Foundation (AERF), we as a small team for this purpose, organized awareness programs at Harpude, Devrukh, Pur and Math Dhamapur villages in Sangameshwar block, which form the catchment of Saptalingi.



Map-2

I visited these villages and had meetings with the village representatives and local leaders for planning awareness sessions. I prepared a PowerPoint presentation and posters for this awareness program in the local language Marathi. This PPT is about the availability of fresh water, its sources, the role of rivers in the distribution of freshwater in India, and the ecological health of the Saptalingi river. The objectives of this session were

A. To generate awareness among the stakeholders of the current status of the river concerning its watershed forest, flow, river bank, threats from pollution, and the role of stakeholders to conserve the river.
B. To explain different parameters that define the good or bad health of the river.
C. To understand the people's knowledge about the river.
D. To build their capacity to involve them in river restoration.

Stakeholders like the local authorities (Gram Panchayat and Town Council), farmers, students, traders, and teachers were present for these sessions. I conducted one session in each village. Because of heavy rainfall followed by a red alert in the block, I couldn't conduct outdoor sessions. I distributed banners displaying the current status of the river and the features of a healthy river.

The details of each session are as follows.

Sr. No.	Village	Stakeholders	Total number of participants	Date
1	Harpude	Sarpanch, Teachers, Gram Panchayat Members, Farmers, village president, students of 6th and 7th standard.	39	13th July 2022
2	Devrukh	Chief Executive Officer, town president, Social Workers, corporators, members of local organizations, staff of Devrukh Nagar Panchayat, members of traders' association, Principal of Athale-Sapre College.	25	15th July 2022
3	Math Dhamapur	Sarpanch, Gram Panchayat Members, villages, teachers, farmers, and students.	50	19th July 2022
4	Pur	Sarpanch, Gram Panchayat Members, teachers, and students of 6th and 7th standard.	19	20th July 2022

Table-1

V. Conclusion & way forward-

I successfully conducted the Saptalingi river health awareness programme in four villages i.e., Harpude, Devrukh, Pur and Math Dhampaur of Sangameshwar. These villages are strategically important for conservation action in the future. Harpude is in the source region and has a highly degraded watershed. Devrukh is the headquarter of the Sangameshwar block and is a growing town. It has an impact on the river in the form of pollution both plastic litter and wastewater as the river flows through the town. Pur and Math Dhamapur face the impact of sedimentation and pollution. Ahead of Math Dhamapur, the river flows through the hilly terrain of Sangave, Fansat, Ambavali, and Tale villages.

A total of 133 stakeholders from these villages participated in this programme. The number was limited due to heavy rainfall and the season of peak paddy operations. All stakeholders appreciated these sessions and showed interest to work with AERF for river conservation. All of them agreed on the following issues during the discussions.

1. The river flow has been reduced.
2. Sediment in the river channel is affecting the flow.
3. Ground water level is declined.
4. Pollution is impacting the water quality.

The Chief Executive Officer of Devrukh Nagar Panchayat shared his experience on work done by the Panchayat in the channel of the Saptalingi river. The Panchayat has built a few bunds to store water in the channel. At that time, they came to know that it is not gazetted river like other big rivers in the area and they face technical problems whenever they try to get government funds for the river. He has a keen interest to work in the conservation of this river and wants AERF's involvement to develop a river conservation plan. So, we had a separate meeting to discuss how to prepare the conservation plan at least for the part of the river that flows through the town. Likewise, the people in Math Damapur shared their experiences of plastic waste in the river and the impact of bunds that were built without technical knowledge of river bed and flow. They used to drink water from the river directly but not anymore.

I believe that this is an opportunity as well as a time to work for river conservation in Sangameshwar block before it gets too late. AERF presence will certainly be crucial to work on the ground. AERF is already working on forest conservation in the Sangameshwar block. AERF is protecting about 7000 acres of private forest in Sangameshwar. All of these are in the watershed of eighter of the rivers in Sangameshwar. As far as the Saptalingi river is concerned, villages like Talawade tarf Devrukh, Patgaon, and Ambavali are in the watershed of the river where AERF is protecting more than 200 acres of private forest since 2007. We need to assess the impact of this forest conservation initiative on the health of the rivers in the Sangameshwar block and set a conservation goal for these rivers. In the coming days, I will work on coordinating with the rest of the villages in the watershed of the Saptalingi river, aware them of the river's health, and prepare a comprehensive river conservation plan with help of all stakeholders.

Acknowledgements

I would like to thank MSSRF for providing me with valuable training on river health and financial support to carry out the Saptalingi River awareness program. I would like to thank Dr Anilkumar for inviting me to attend this 5 days national-level training program on River Health Monitoring and Restoration at Chengannur. Likewise, I am grateful to AERF Director, Dr Archana Godbole and Jayant Sarnaik for providing me with an opportunity to attend this training program, guiding and providing logistic support to conduct awareness sessions. My thanks and appreciation also go to my colleagues Sanjay Pashte, Pranav Panavalkar, Mahadev Sawant, Shruti Savla, Ruchi Bhadke, and Ganesh Shedge. I would like to thank Shri Yuyutse Arte, journalist and environment enthusiast, who is a well-wisher of AERF and accompanied me for these sessions. I also owe special thanks to Kajal Barman and Suchitra Naidu for providing their guidance and GIS data for the awareness session and this report.

Finally, I am sincerely thankful to the Sarpanch of Harpude, Pur, and Math Dhamapur as well as the president Municipal council of Devrukh who showed interest in river conservation and allow me to conduct this awareness program at their place. Finally, I would like to thank all the participants of the awareness sessions along the river Saptlingi.

Photos

Awareness session at Devrukh Nagar Panchayat

Awareness session in Math Dhamapur- Pranav explaining river fauna

Awareness session in Harpude- Mahadev explaining river flora

Awareness session in Pur- students going through posters

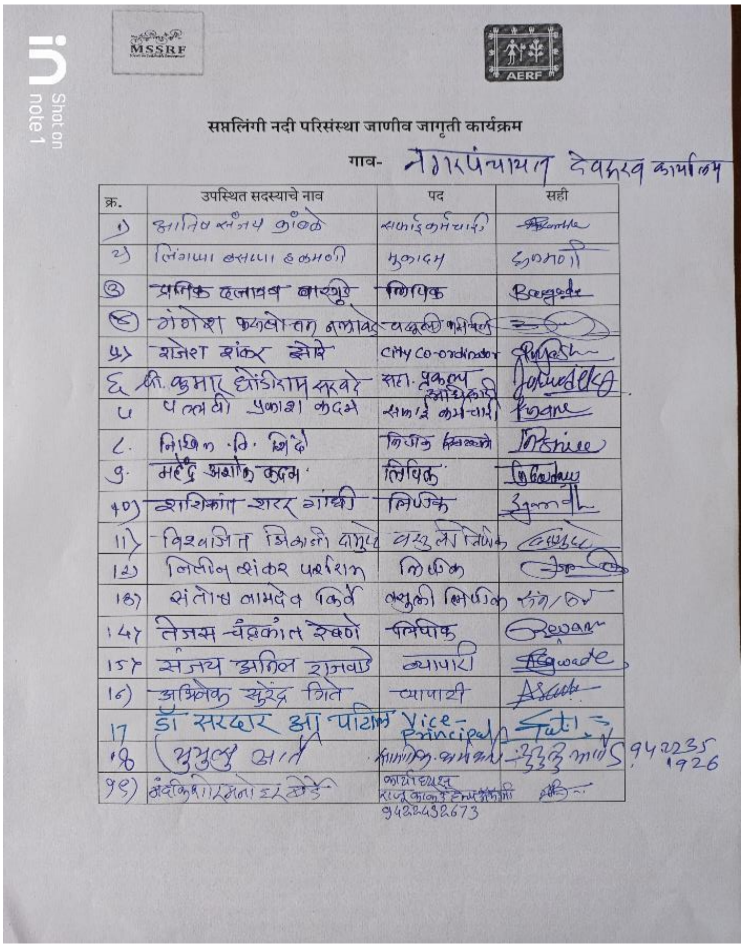
Awareness session- A teacher in Pur Primary School talking about the session

Awareness session in Math Dhampaur- Mr Gurav second from the left is talking about the waste litter in the river

Distribution of river health awareness posters in schools

List of participants-

Devrukh



सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम

गाव- नगरपंचायत देवरुख कार्यालय

क्र.	उपस्थित सदस्याचे नाव	पद	सही
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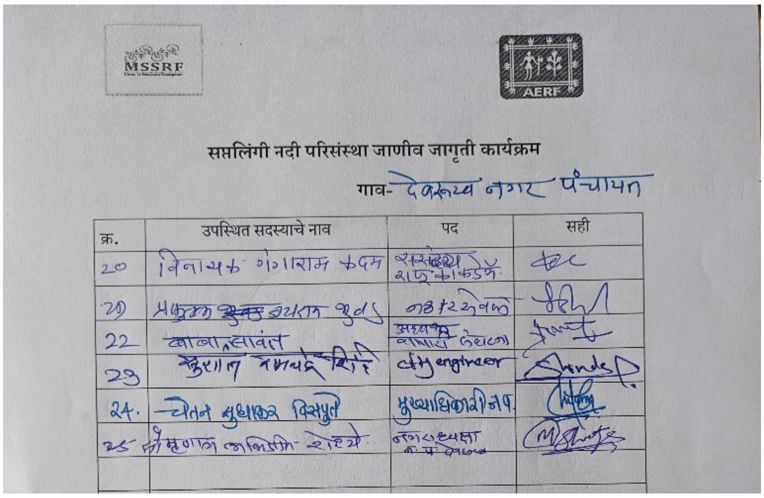
2)	लिंगाप्पा बसप्पा हकमणी	मुकादम	हकमणी
3	प्रतिक दत्ताराम बारगुडे	लिपिक	Bargude
4	गणेश फकीरा नलावडे	वसुली कर्मचारी	[illegible]
5)	राजेश शंकर झोरे	City co-ordinator	Rajesh
6	श्री. कुमार धोंडीराम सरवदे	सहा. प्रकल्प अधिकारी	[illegible]
7	पल्लवी प्रकाश कदम	सफाई कर्मचारी	[illegible]
8.	निखिल वि. शिंदे	लिपिक [illegible]	[illegible]
9.	महेंद्र अशोक कदम	लिपिक	[illegible]
10)	शशिकांत शरद गांधी	लिपिक	[illegible]
11)	विश्वजित शिवाजी दाभोळे	वसुली लिपिक	[illegible]
12)	नितीन शंकर परशराम	लिपिक	[illegible]
13)	संतोष वामदेव किर्वे	वसुली लिपिक	[illegible]
14)	तेजस चंद्रकांत रेवाळे	लिपिक	Rewale
15)	संजय अनिल रानवडे	व्यापारी	[illegible]
16)	अभिषेक सुरेंद्र गिते	व्यापारी	[illegible]
17	डॉ सरदार आ पाटील	Vice-Principal	[illegible]
18	युयुत्सु आर्ते	सामाजिक कार्यकर्ते	[illegible] 9422351926
19)	नंदकिशोर मनोहर बोंडे	कार्याध्यक्ष राजू काकडे हेल्प अकॅडमी 9422432673	[illegible]



सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम

गाव- देवरुख नगर पंचायत

क्र.	उपस्थित सदस्याचे नाव	पद	सही
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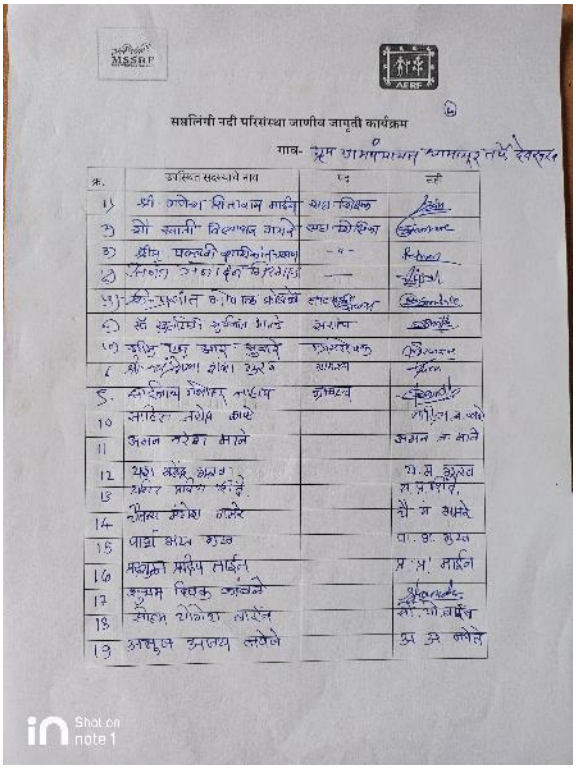
22	बाबा सावंत	अध्यक्ष व्यापारी संघटना	[illegible]
23	कुणाल नामदेव शिंदे	city engineer	Shinde
24.	चेतन सुधाकर विसपुते	मुख्याधिकारी न.प.	[illegible]
25	सौ मृणाल अभिजित शेट्ये	नगराध्यक्षा न.प. देवरुख	[illegible]

Math Dhamapur



सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम

गाव- ग्रूप ग्रामपंचायत धामापूर तर्फे देवरूख

क्र.	उपस्थित सदस्याचे नाव	पद	सही
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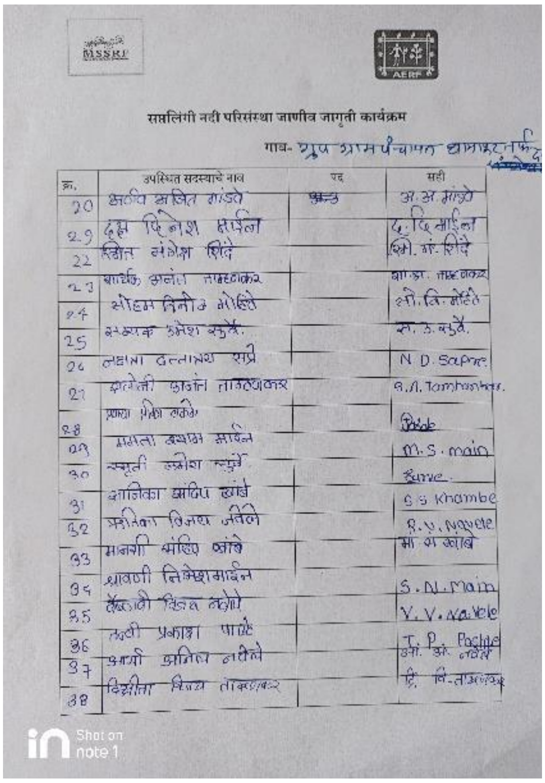
4)	[illegible]	—	[illegible]
5)	[illegible]	[illegible]	[illegible]
6)	[illegible]	सरपंच	[illegible]
7)	[illegible]	[illegible]	[illegible]
8	[illegible]	ग्रामस्थ	[illegible]
9.	[illegible]	ग्रामस्थ	[illegible]
10	साहिल नरेश काटे		साहिल न. काटे
11	अमन नरेश माने		अमन न. माने
12	[illegible]		[illegible]
13	[illegible]		[illegible]
14	[illegible]		[illegible]
15	[illegible]		[illegible]
16	[illegible]		प्र. प्र. माईन
17	[illegible]		[illegible]
18	[illegible]		[illegible]
19	[illegible]		[illegible]



सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम

गाव- ग्रूप ग्रामपंचायत धामापूर तर्फे देवरूख

क्र.	उपस्थित सदस्याचे नाव	पद	सही
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22	[illegible]		[illegible]
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25	[illegible]		[illegible]
26	[illegible]		N D. Sapre
27	[illegible]		S.A. Tambankar.
28	[illegible]		[illegible]
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30	[illegible]		Surve.
31	[illegible]		S S Khambe
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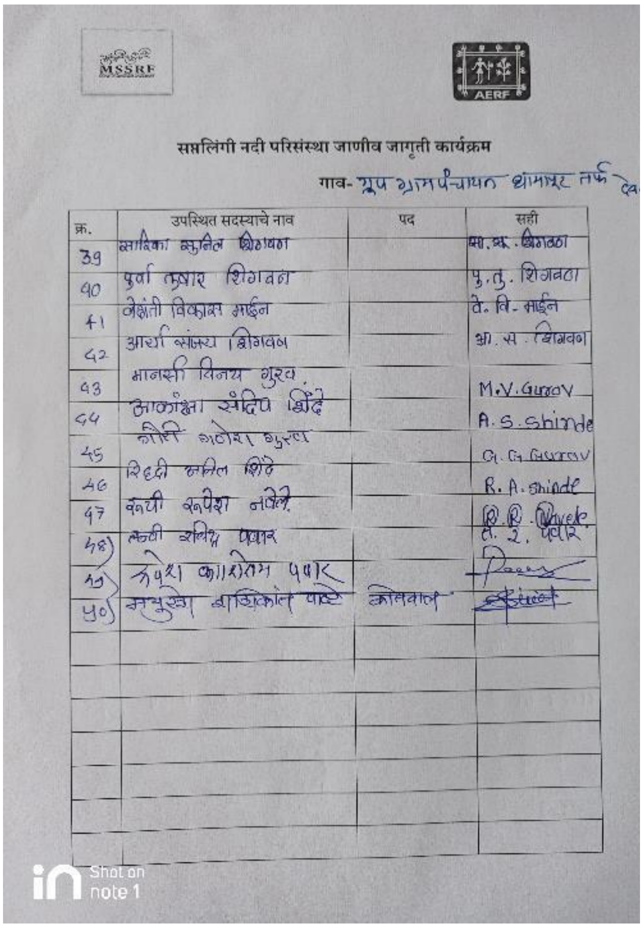
34	श्रावणी [illegible]		S.N. Main
35	[illegible]		V.V. Navele
36	[illegible]		T. P. Pashte
37	[illegible]		[illegible]
38	[illegible]		[illegible]

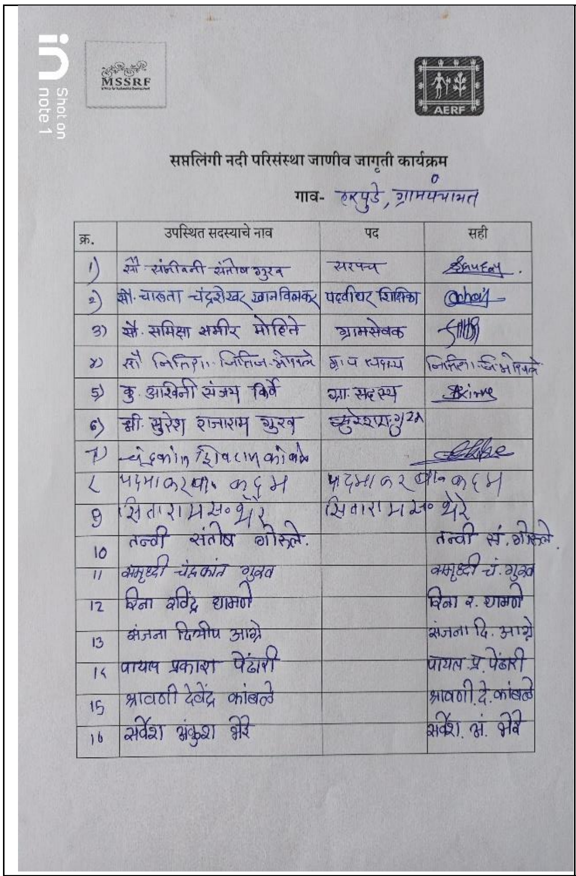


सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम

गाव- ग्रूप ग्रामपंचायत धामापूर तर्फे देव

क्र.	उपस्थित सदस्याचे नाव	पद	सही
39	सारिका सुनिल शिगवण		सा. सु. शिगवण
40	पुर्वा तुषार शिगवण		पु. तु. शिगवण
41	वेदांती विकास माईन		वे. वि. माईन
42	आर्या संजय शिगवण		आ. स. शिगवण
43	मानसी विनय गुरव		M.V. Gurav
44	आकांक्षा संदिप शिंदे		A.S. Shinde
45	[illegible] गुरव		G. G. Gurav
46	[illegible] शिंदे		R. A. Shinde
47	[illegible] नवेले		R. R. Navele
48)	[illegible] पवार		[illegible]
49)	[illegible] पवार		[illegible]
50)	[illegible]	कोतवाल	[illegible]

Harpude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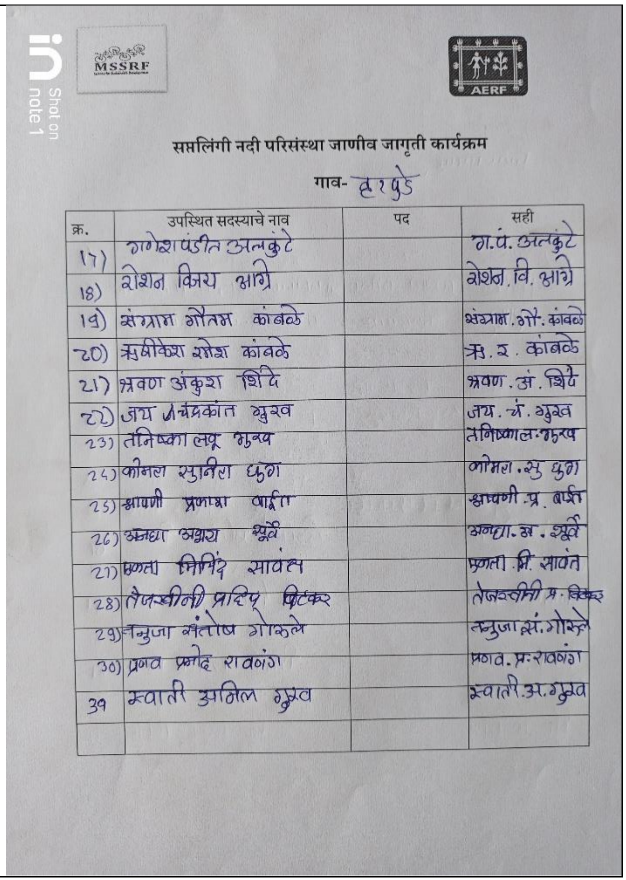
सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम
गाव- हरपुडे, ग्रामपंचायत
क्र. | उपस्थित सदस्याचे नाव | पद | सही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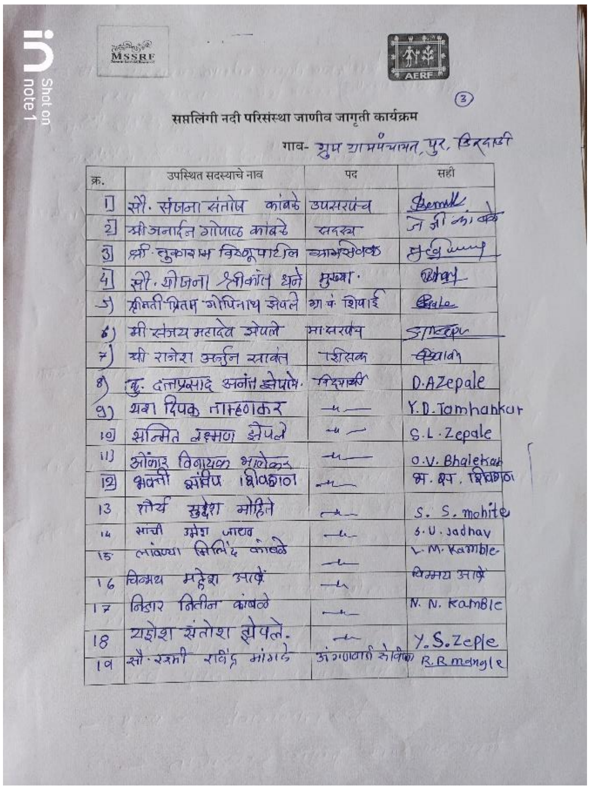
सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम
गाव- हरपुडे
क्र. | उपस्थित सदस्याचे नाव | पद | सही

Pur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सप्तलिंगी नदी परिसंस्था जाणीव जागृती कार्यक्रम
क्र. | उपस्थित सदस्याचे नाव | पद | सही

Posters distributed in schools

Features of a healthy river

VS

Features of a degraded river

Awareness programme at St. Thomas colleges, Pala: Lecture series on climate change and conservation in the context of river ecosystem

Over 100 young men, undergraduate students from the Zoology department and members of the National Service Scheme, attended two lectures by Dr TV Sajeev of the Kerala Forest Research Institute on July 27, 2022, at the St Thomas College, Pala, Kottayam district. These lectures were held as part of a follow-up programme to the River Health Monitoring workshop conducted by the M.S Swaminathan Research Foundation in April 2022.

The Meenachil flows right behind the college, but it was clear that the students did not feel connected to the river in any way – a question from Dr Sajeev about whether any of them had ever swum in the river showed that none of the students had ever stepped into the river.

The author of this report, a freelance journalist, lives near the Meenachil too. In her childhood, she remembers that her grandfather's house had no piped water – water had to be drawn up from a well, and it was easier for the family to gather unwashed clothes, go to the river, and wash clothes, have a bath, and return home with the washed clothes which would be hung out to dry. It was quite common for children to jump into the river and learn to swim in it. These days, however, thanks to the high pollution and the sand mining that has made it hard to estimate the depth of the water, few people venture into the river.

On Wednesday, Dr Sajeev introduced students to the reality of climate change – he asked questions and encouraged students who answered them to introduce themselves by name. This offered students a sense of being more engaged with the discussion, and some questions revealed gaps in understanding climate change that were quite basic – one question about the average temperature of the Earth elicited answers that were way off the mark, and in the interest of saving time the scientist then proffered the answer himself. He said the average temperature of the Earth was estimated at 14-15 degrees Celsius, and it was divergence from that temperature since the First Industrial Revolution that was estimated at 1.2 degrees Celsius.

It was evident that students listened with rapt attention, as Dr Sajeev draws the big picture and speaks with great ease, conducting himself with tremendous respect for his young audience. The discussion centered on interaction with nature, and how human beings were causing changes through seeking more and more convenience. Some of Dr Sajeev's suggestions may have appeared quite radical – from a podium in a Catholic institution, at a lecture where the first inaugural moments involved a silent prayer, he proclaimed that God does not exist.

Students were spurred to think, and when the lectures ended and the house was opened for questions, there was a spell of silence – one could hear young brains ticking. A news report of the lecture was carried on website Counterview, which offers a glimpse of the proceedings of the day: https://www.counterview.net/2022/07/go-against-tide-question-authority.html