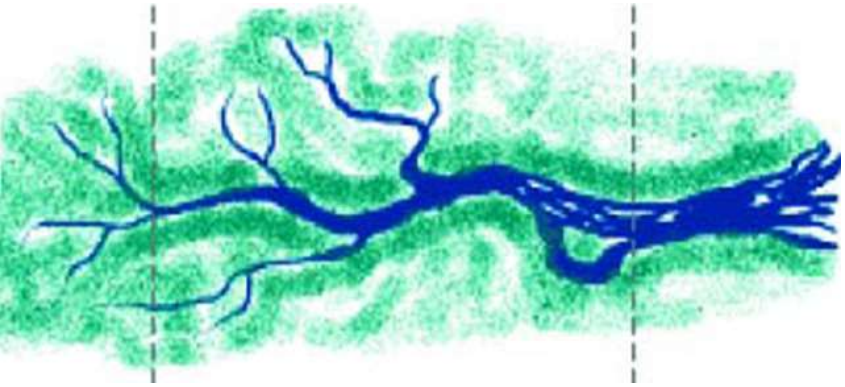
Estimation of eFlows through Fish based habitat profiling in lower stretches of river Narmada and Mahanadi



Amiya Kumar Sahoo, *PhD, ARS*
Principal Scientist, ICAR-CIFRI, Barrackpore
Member, EAC, River Valley Projects, MoEFCC
Fulbright-Kalam Climate Visiting Research Fellow, USA

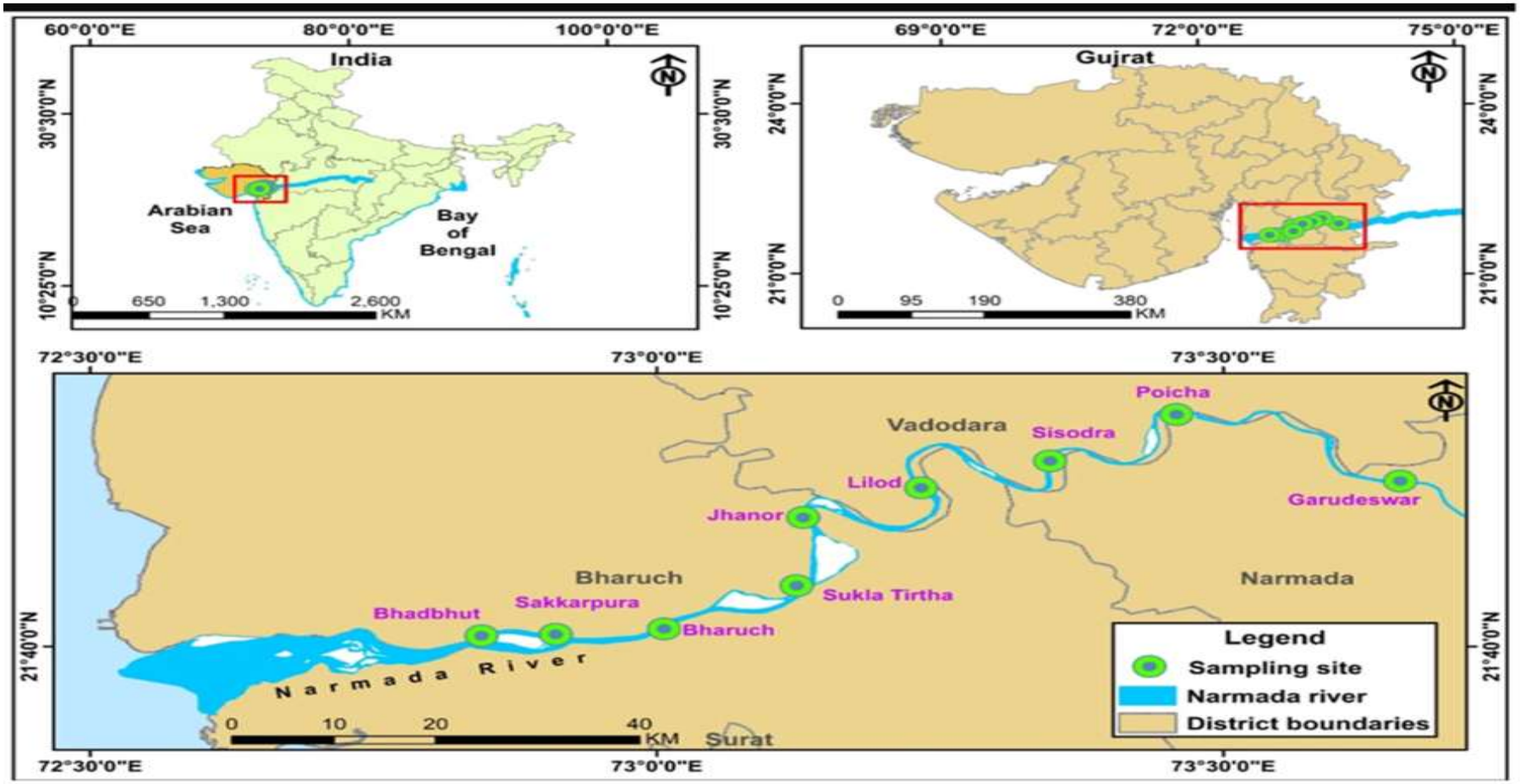
ECOLOGICAL FUNCTIONS:

Structures	Functions
Hydrology Hyraulics Geomorphology } **Habitat** ↑↓ → Fauna Flora Microbes } **Life forms**	• **Productivity** • **Energy Flows** • **Decomposition** • **Nutrient Cycling**





Study stretch: Garudeswar to Bhadbhut



Index map of sampling sites in river Narmada

Habitat: Zone I Zone II Zone III















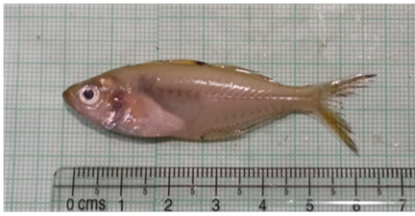




- Fish diversity, Fish life Cycle, Fish migration, Fish population and Fisherman Catch/Income
- Plankton and Benthic micro/macro invertebrate indicator of water quality/pollution and food chain
- Water and sediment quality parameters

Zone I





Zone II





C. reba

Zone III

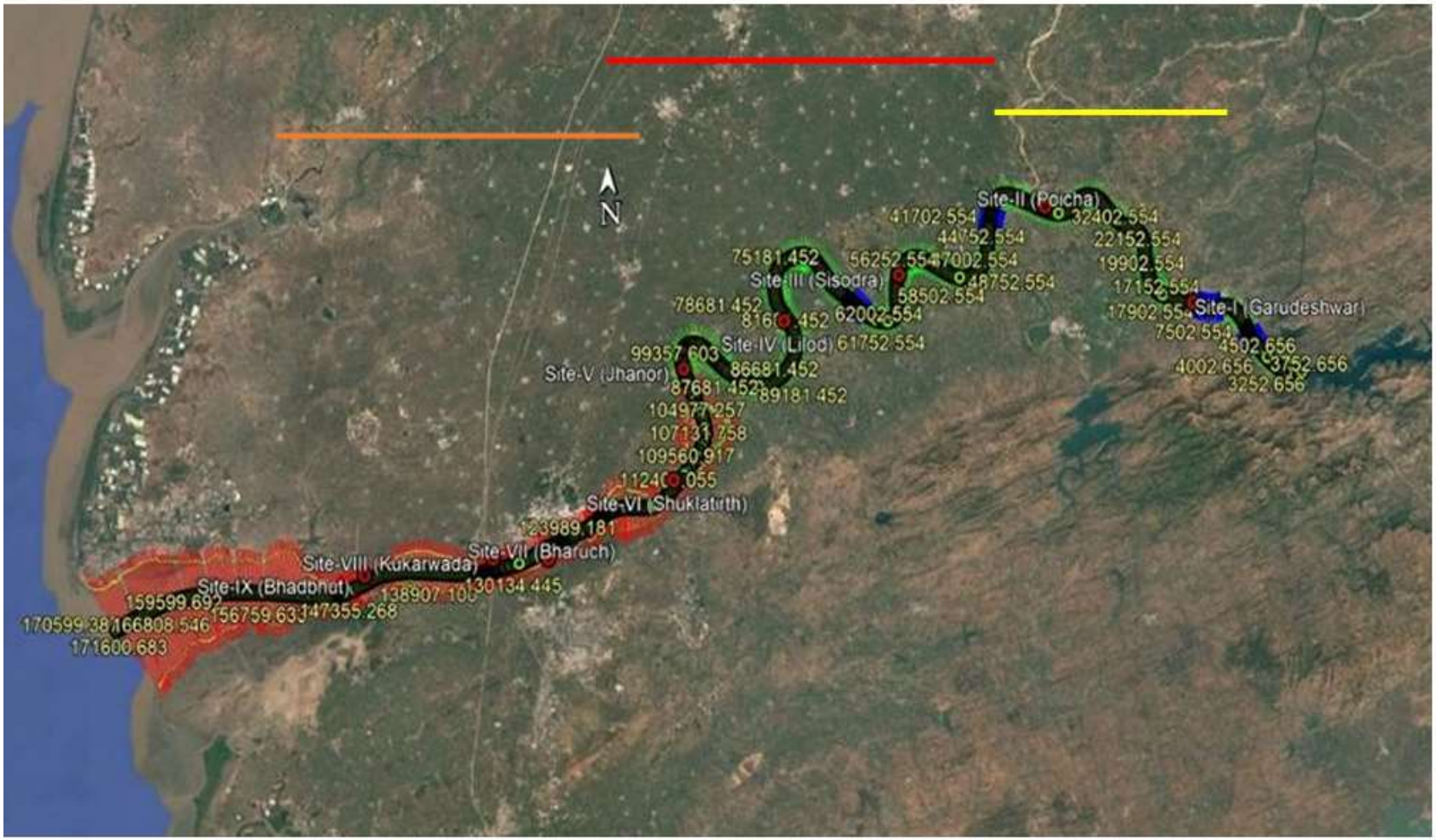


Tenualosa ilisha



Lates calcarifer

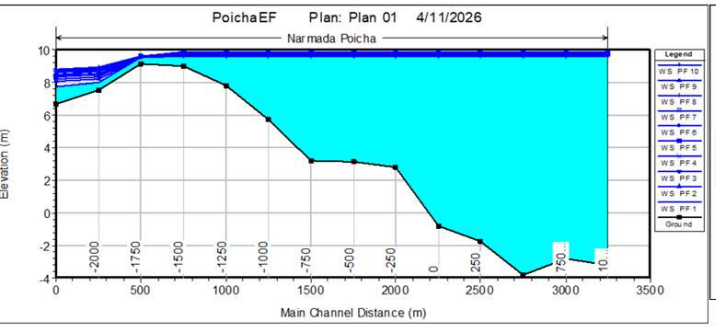
E-flows representing Garudeswar to Poicha site



Three zones

a) **Zone A:** from Garudeswar to Piocha where in Mahseer is the key stone species,
b) **Zone B:** from Poicha downstream to Jhanor wherein Carps are predominance with occasional hilsa availability
c) **Zone C**: from Jhanor downstream to Bhadbhut wherein Hilsa is predominance.

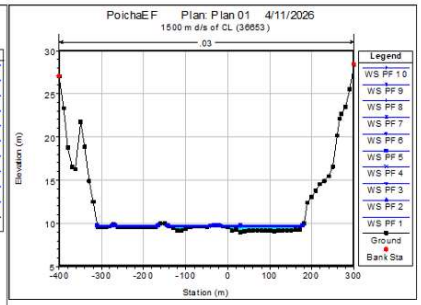
Study reach of the river is having very mild slop of the order of 1:3000 to 1:5000 with predominance of alluvium



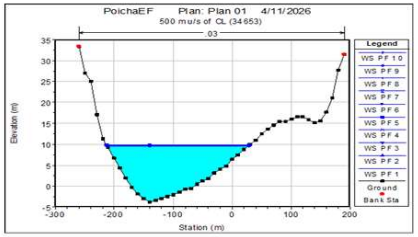
Longitudinal profile of study river reach at Poicha

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Depth	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m/s)	(m2)	(m)	
Poicha	-1500	PF 1	10	9.01	9.58	0.57	0.11	92.35	355.49	0.07
Poicha	-1500	PF 2	20	9.01	9.66	0.65	0.16	124.14	415.35	0.09
Poicha	-1500	PF 3	25	9.01	9.69	0.68	0.18	136.3	422.81	0.1
Poicha	-1500	PF 4	30	9.01	9.72	0.71	0.2	148.03	430	0.11
Poicha	-1500	PF 5	35	9.01	9.74	0.73	0.22	159.05	436.84	0.12
Poicha	-1500	PF 6	40	9.01	9.77	0.76	0.24	169.65	443.31	0.12
Poicha	-1500	PF 7	45	9.01	9.79	0.78	0.25	180.07	451.67	0.13
Poicha	-1500	PF 8	50	9.01	9.81	0.8	0.26	190.05	461.74	0.13
Poicha	-1500	PF 9	55	9.01	9.83	0.82	0.28	199.24	466.97	0.13
Poicha	-1500	PF 10	60	9.01	9.85	0.84	0.29	208.28	469.45	0.14

Simulation results at riffle location of Poicha



River Cross-section at Riffle location of Poicha



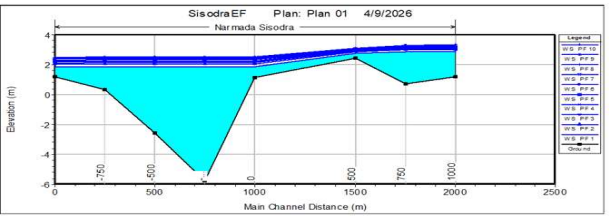
River Cross-section at Pool location of Poicha

E-flows representing from Poicha downstream to Jhanor



HEC-RAS model setup for Sidodra Site

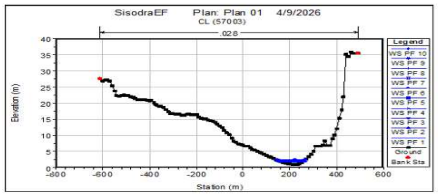
Cross section ID as per HEC-RAS model Setup	Location	Chainage as per surveyed cross section (m)
1000	1000 m U/S of Centre Line (CL)	56003
750	750 m U/S of CL	56253
500	500 m U/S of CL	56503
0	CL	57003
-250	250 m D/S of CL	57253
-500	500 m D/S of CL	57503
-750	750 m D/S of CL	57753
-1000	1000 m D/S of CL	58003



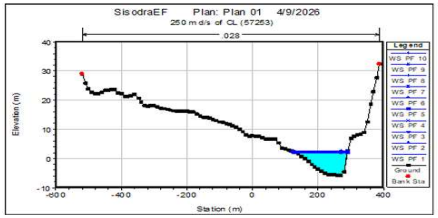
Longitudinal profile of study river reach at Sisodra

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Depth	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m/s)	(m2)	(m)	
Sisodra	0	PF 1	10	1.14	1.84	0.7	0.22	46.29	91.83	0.1
Sisodra	0	PF 2	20	1.14	2.05	0.91	0.3	66.05	101.97	0.12
Sisodra	0	PF 3	25	1.14	2.12	0.98	0.34	74	105.81	0.13
Sisodra	0	PF 4	30	1.14	2.19	1.05	0.37	81.43	109.24	0.14
Sisodra	0	PF 5	35	1.14	2.25	1.11	0.4	88.4	112.24	0.14
Sisodra	0	PF 6	40	1.14	2.32	1.18	0.42	95.82	115.32	0.15
Sisodra	0	PF 7	45	1.14	2.38	1.24	0.44	103.2	118.3	0.15
Sisodra	0	PF 8	50	1.14	2.43	1.29	0.46	108.42	120.36	0.16
Sisodra	0	PF 9	55	1.14	2.47	1.33	0.48	113.5	122.34	0.16
Sisodra	0	PF 10	60	1.14	2.51	1.37	0.51	118.39	124.21	0.17

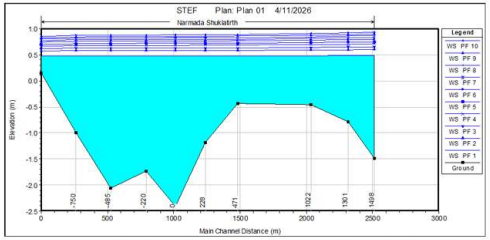
Simulation results at riffle location of Sisodra study reach



River Cross-section at Riffle location of Sisodra



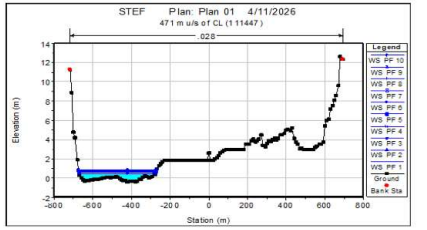
River Cross-section at Pool location of Sisodra



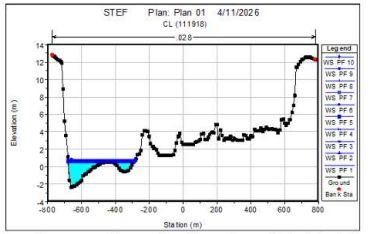
Longitudinal profile of study river reach at Shuklatirth

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Depth	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m/s)	(m2)	(m)	
Shuklatirth	471	PF 1	10	-0.44	0.48	0.92	0.05	219.99	392.58	0.02
Shuklatirth	471	PF 2	20	-0.44	0.58	1.02	0.08	261.76	395.06	0.03
Shuklatirth	471	PF 3	25	-0.44	0.63	1.07	0.09	279.62	396.11	0.03
Shuklatirth	471	PF 4	30	-0.44	0.68	1.12	0.1	301.06	397.37	0.04
Shuklatirth	471	PF 5	35	-0.44	0.72	1.16	0.11	316.33	398.26	0.04
Shuklatirth	471	PF 6	40	-0.44	0.76	1.2	0.12	333.07	399.24	0.04
Shuklatirth	471	PF 7	45	-0.44	0.8	1.24	0.13	346.32	400.01	0.04
Shuklatirth	471	PF 8	50	-0.44	0.83	1.27	0.14	358.59	400.72	0.05
Shuklatirth	471	PF 9	55	-0.44	0.86	1.3	0.15	370.43	401.41	0.05
Shuklatirth	471	PF 10	60	-0.44	0.88	1.32	0.16	381.78	402.07	0.05

Simulation results at riffle location of Shuklatirth study reach



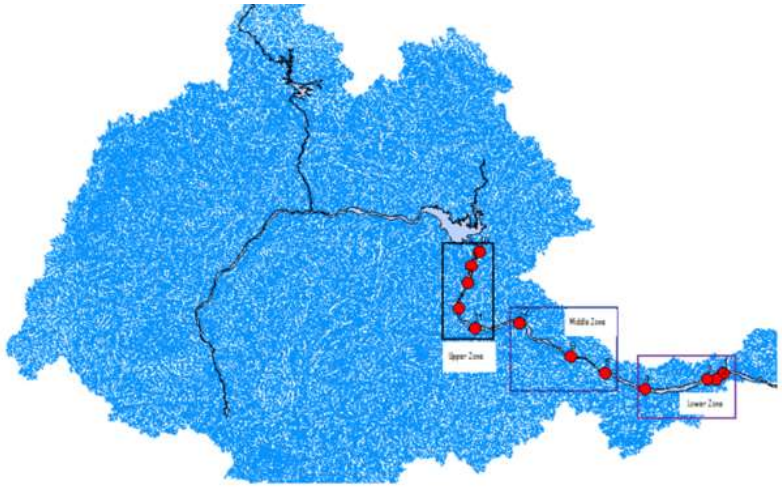
River Cross-section at Riffle location of Shuklatirth



River Cross-section at Pool location of Shuklatirth

E-Flows for Narmada river:

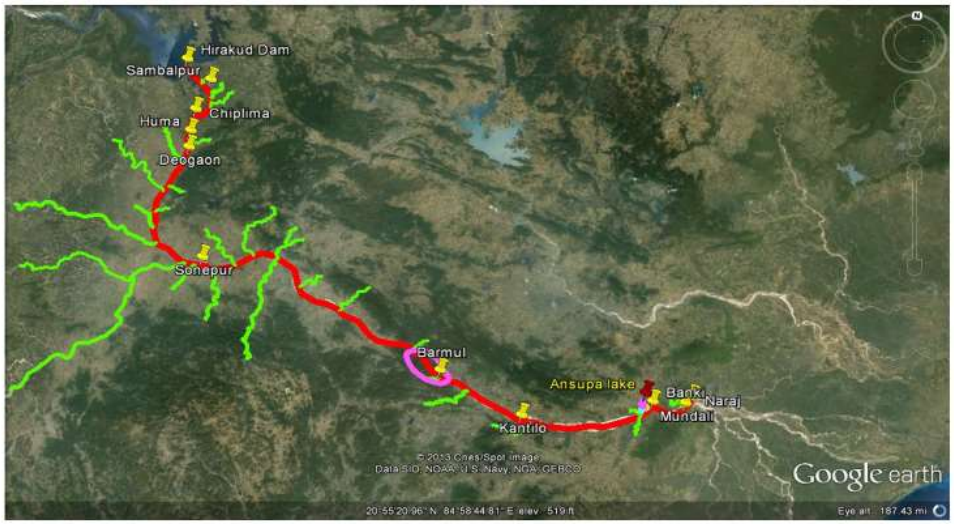
- Varried Habitat from Garudeswar to Bhadbhut (about 130 km) longitudinally suitable for 47 fish species, plankton and microbenthic communities.
- Index of Biotic Integrity (IBI) indicated Garudeshwar and Sisodra stretch was acceptable condition in terms of fish assemblages; the remaining seven sites were moderately impaired.
- Three Zones identified base on fish species (Mahseer, Major Carps & Hilsa) and were considered as Key species for environmental flows assessment.
- E-flows assessment was done by hydraulic rating method using HEC-RAS model
- Water requirement for these species varied with seasons. Keeping Pre-monsoon and Post-monsoon as important for sustainace and spawn (fish seed) survival and growth Poicha (35cumec), Sisorda (>35) and Shuklatirth (40cumec)would support the required habitat and key fish species survivality. Hilsa downstream migration is essential for which minimum 40cumec is recommended.
- Hilsa upstream migration majorly during monsoon (June to Sep.). Hence, monsoon discharge of 400-450cumec is estimated and observed the best for the required habitat. This recommended flows is the regular flows from SSD during monsoon as spillover as per the time series data analysis.



Mahanadi Basin

Mahanadi river: Basin area of 1,41,589 $km^{2,}$ nearly 4.3% of the total geographical area of the country

Length: 845 km

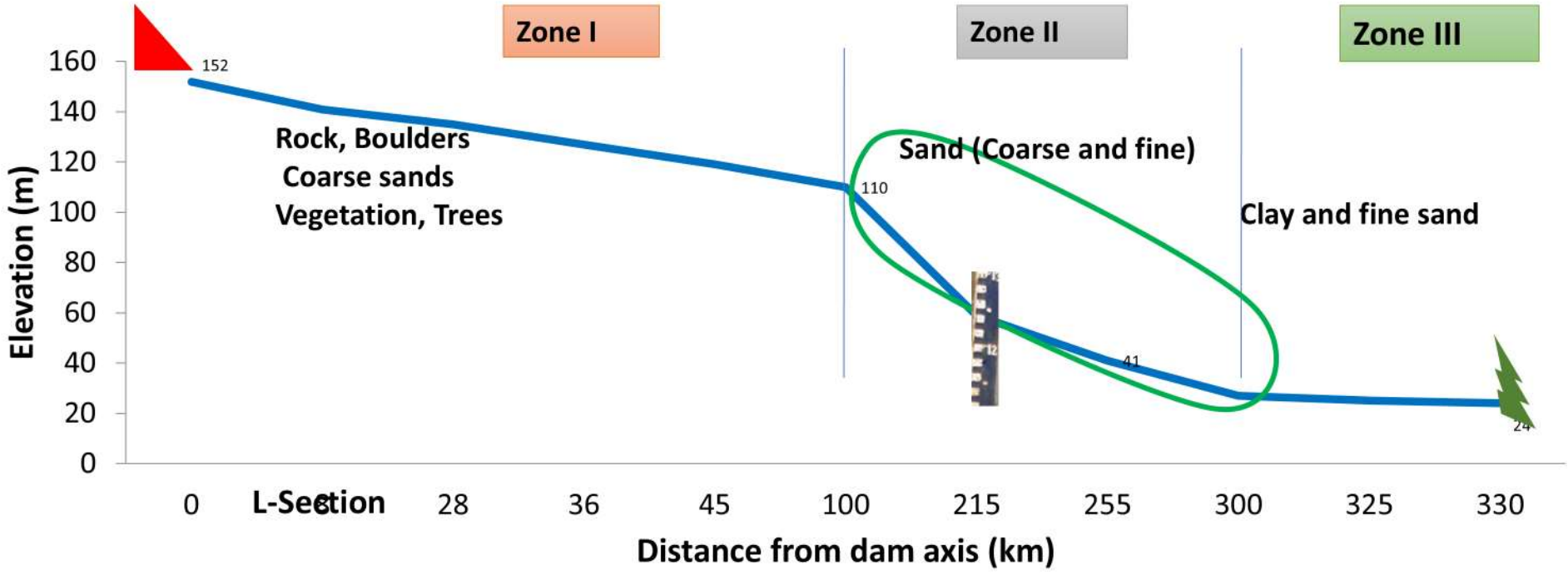








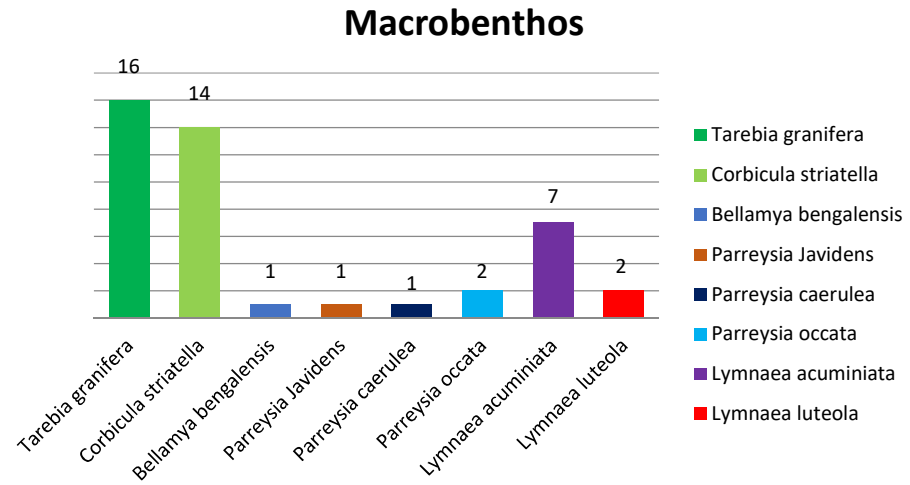



Zone I
Zone II
Zone III
Elevation (m)
160
140
120
100
80
60
40
20
0
152
110
41
24
Rock, Boulders
Coarse sands
Vegetation, Trees
Sand (Coarse and fine)
Clay and fine sand
0
L-Section
28
36
45
100
215
255
300
325
330
Distance from dam axis (km)


Mahanadi Basin
Naraj upstream
Naraj downstream
Naraj Barrage
Galadhari
Nuagarh
Kathajodi River
(99km) with freshwater and
estuary zones, Naraj Barrage
Image Landsat / Copernicus
© 2018 Google
Image © 2019 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
20°07'47.49" N 85°43'06.48" E elev 66 ft eye alt 75.03 mi

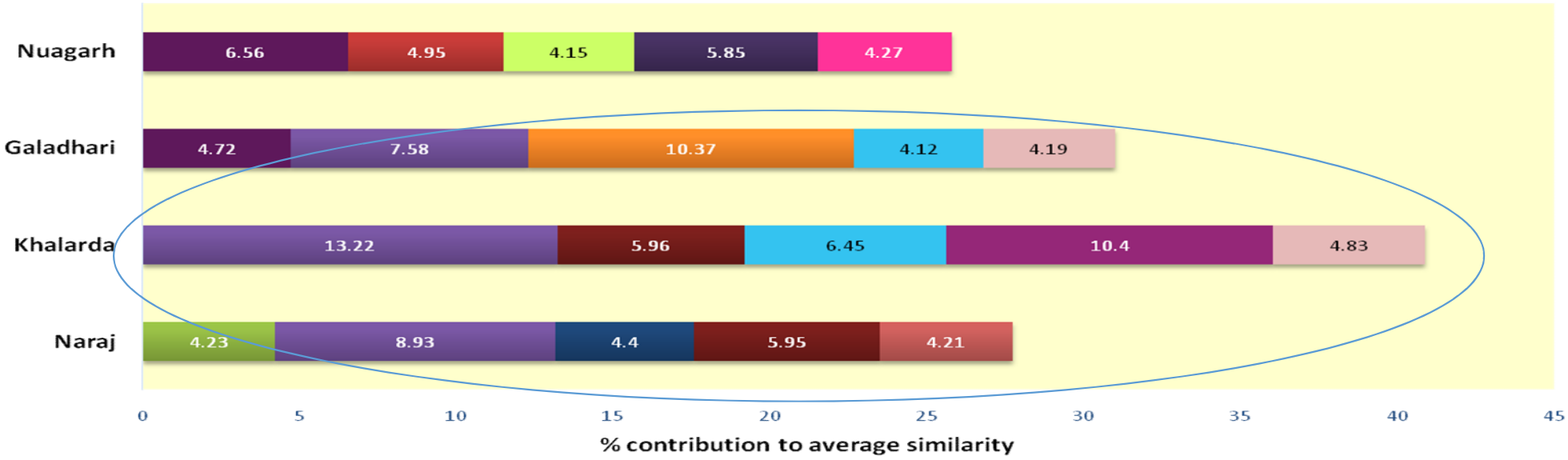






Mahanadi delta: E-flows estimation

Kathajodi river: Selection of Key fish species for e-flows



- *Ambassis ambassis*
- *Ambassis gymnocephalus*
- *Amblypharyngodon mola*
- *Cirrhinus reba*
- *Gerres filamentosus*
- *Gonialosa manmina*
- *Gudusia chapra*
- *Labeo bata*
- *Labeo boggut*
- *Mugil cephalus*
- *Pangasius pangasius*
- *Pethia conchonius*
- *Planiliza tade*
- *Wallago attu*

Species contributing to average dissimilarity – SIMPER pairwise comparison

	Khalarda	Galadhari	Nuagarh
Naraj	*Amblypharyngodon mola (-)*	*Ambassis ambassis (+)*	*A. gymnocephalus (+)*
	Awaous grammepomus (-)	*Awaous grammepomus (-)*	*A. ambassis (+)*
	Gonialosa manmina (-)	*G. manmina (+)*	*Cirrhinus reba (-)*
	Gudusia chapra (-)	*Gudusia chapra (-)*	*Mugil cephalus (+)*
	Pangasius pangasius (+)	*Labeo bata (-)*	*Planiliza tade (+)*
Khalarda		*A. ambassis (+)*	*A. ambassis (+)*
		Chanda nama (+)	*A. gymnocephalus (+)*
		G. manmina (+)	*Cirrhinus reba (-)*
		Labeo bata (-)	*M. cephalus (+)*
		P. pangasius (-)	*P. tade (+)*
Galadhari			*A. gymnocephalus (+)*
			Cirrhinus reba (-)
			G. manmina (-)
			M. cephalus (+)
			P. tade (+)

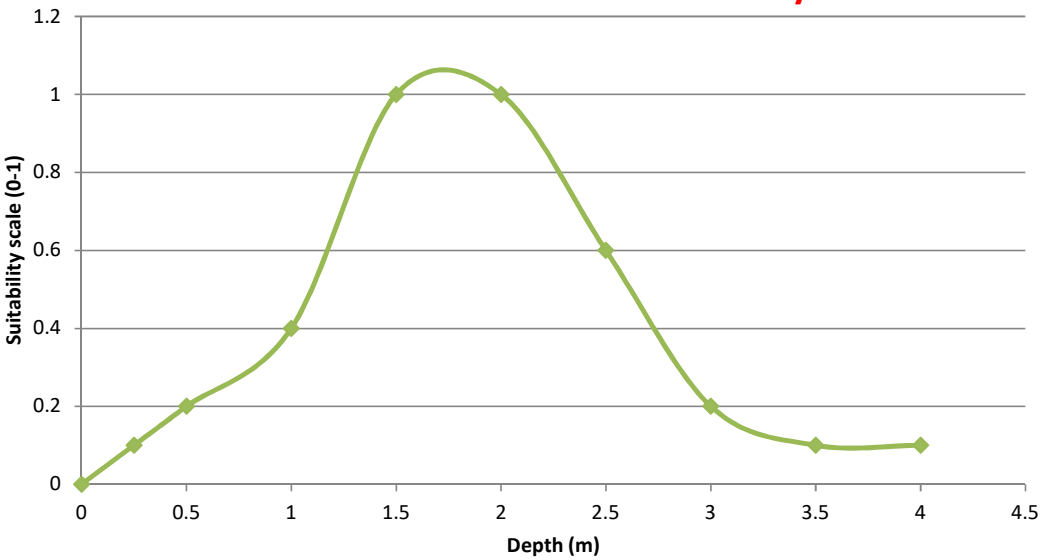
['**+**' sign indicate significantly higher mean abundance and **'-'** sign indicates significantly lower mean abundance for a species in a group (column) in correspondence with other group (row) in pairwise comparison]

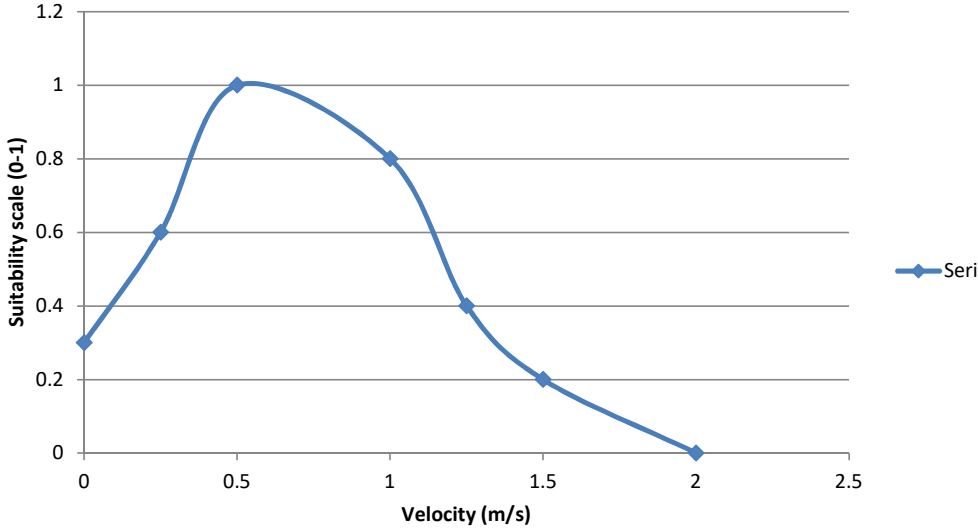


Mahanadi Tor



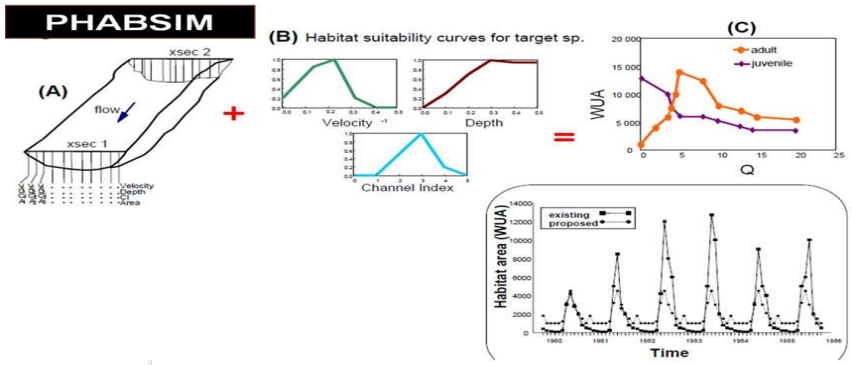
Habitat suitability curves for *C. reba*

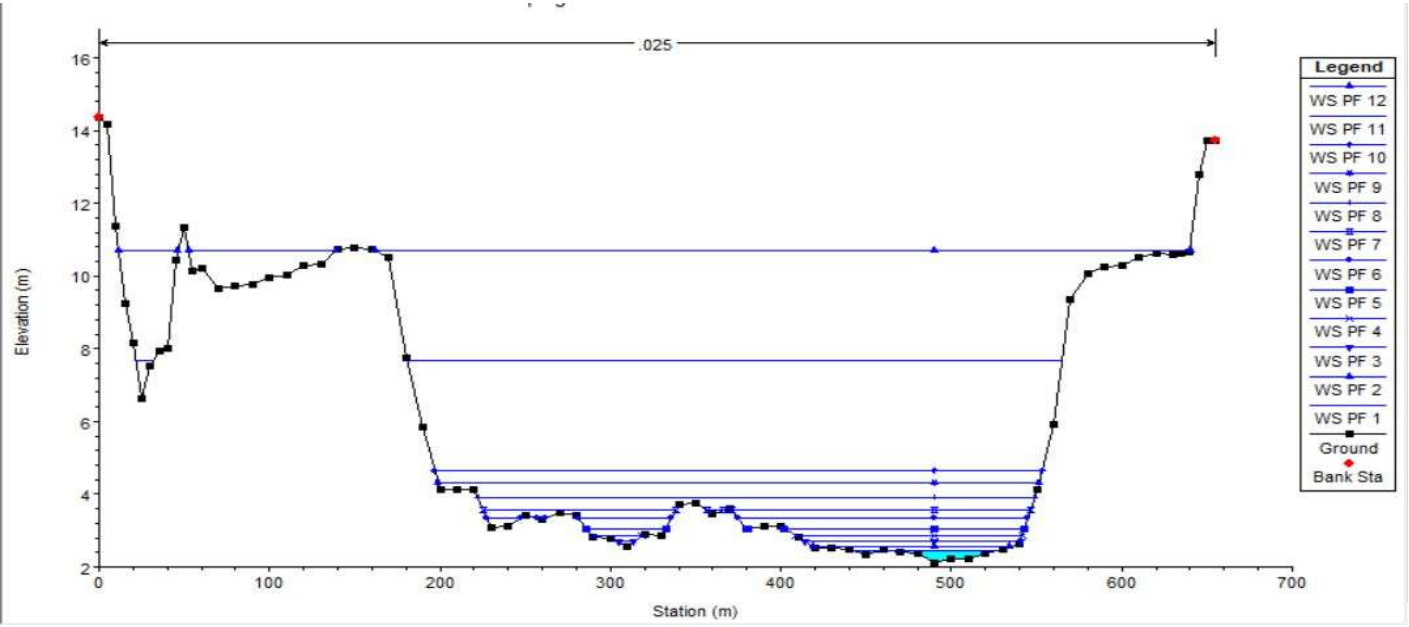


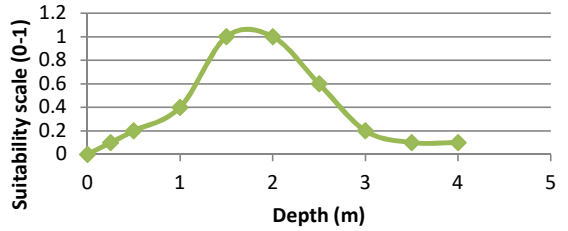


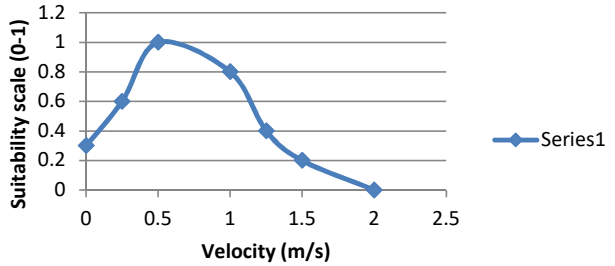
PHABSIM for river Kathajodi









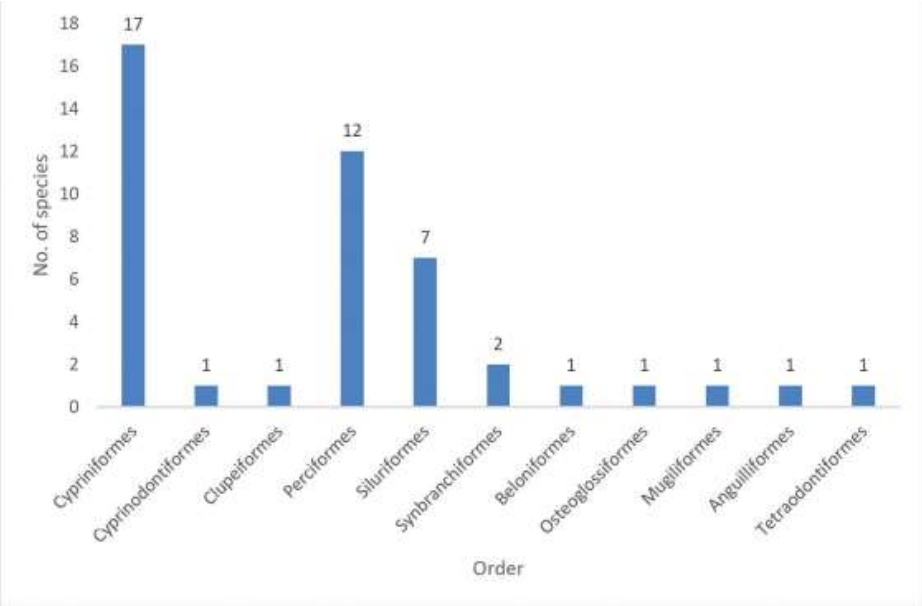


875-1500 cusec (Pre-monsoon and Post monsoon)

Flood pulse concept:









Increase in rainfall over the years could be one of the factors responsible for the fish recruitment in the Ansupa wetland, through river connectivity underlining the importance of flood for wetland fisheries recruitment and sustainability. (Sahoo et al, 2021)



Chilika Ramsar wetland, Odisha, India

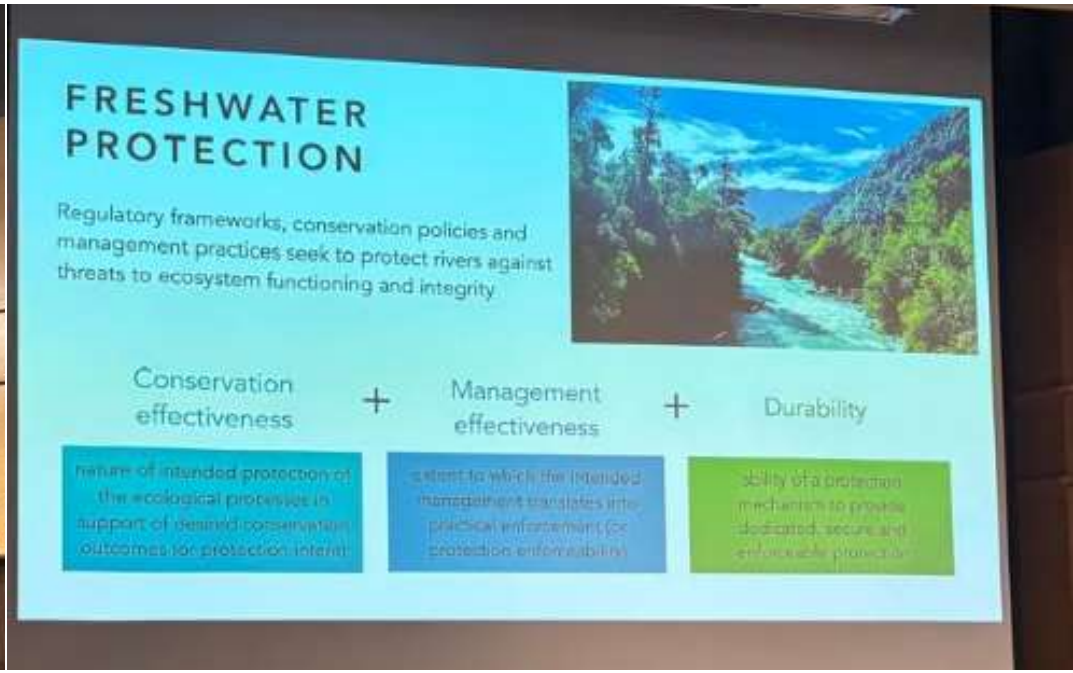
- More than 20 fold increase in annual fish and prawn landing
- Increase in salinity flux by 40%
- Increase in tidal flux by 45%
- Improvement of sediment flushing

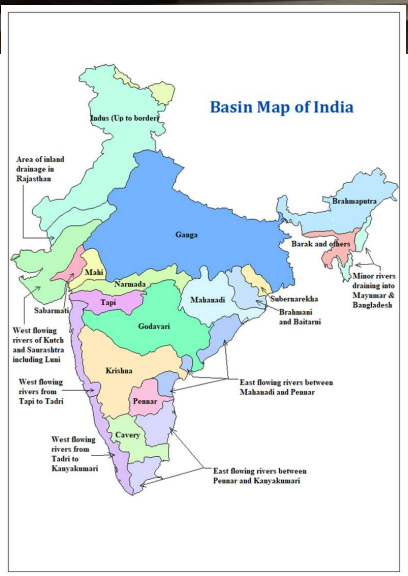
Environmental flows scenarios: 80% of fish production is sensitive to adequate salinity regimes

E-Flows for Mahanadi delta river:

- Deltaic rivers majorly dominated by sandy and clay habitats with carp varies (*Cirrhinus reba*) and estuarine mouth by Hilsa and other marine migrant fish species
- E-flows estimation for the *C. reba* showed 25-30 cumec representing the down stream of Jobra barrage
- E-flows is extremely important for the sustainability of floodplain wetlands (Ansupa and Chilka lake) supporting biodiversity and livelihood of millions.
- Eco-physiological study of fish (migration and breeding) must be considered during Depth and velocity scenario for estimation of E-flows.







- Need for a "Sustainable Rivers Ecology Consortium" integrating
" Assessment+Monitoring+Management" as Single Unit.
- SREC: Balancing Ecology with Economy for Ganga and Non-Ganga River Basins
- SREC initially at National further could extend to Regional

INDIA: e-FLOWS LEADER ? NOW OR NEVER

Ans….NOW (One Health-One Planet)





Acknowledgements: ***CWC, NMCG, ICAR, NCA, SSNNL, GIZ & MoEFCC***