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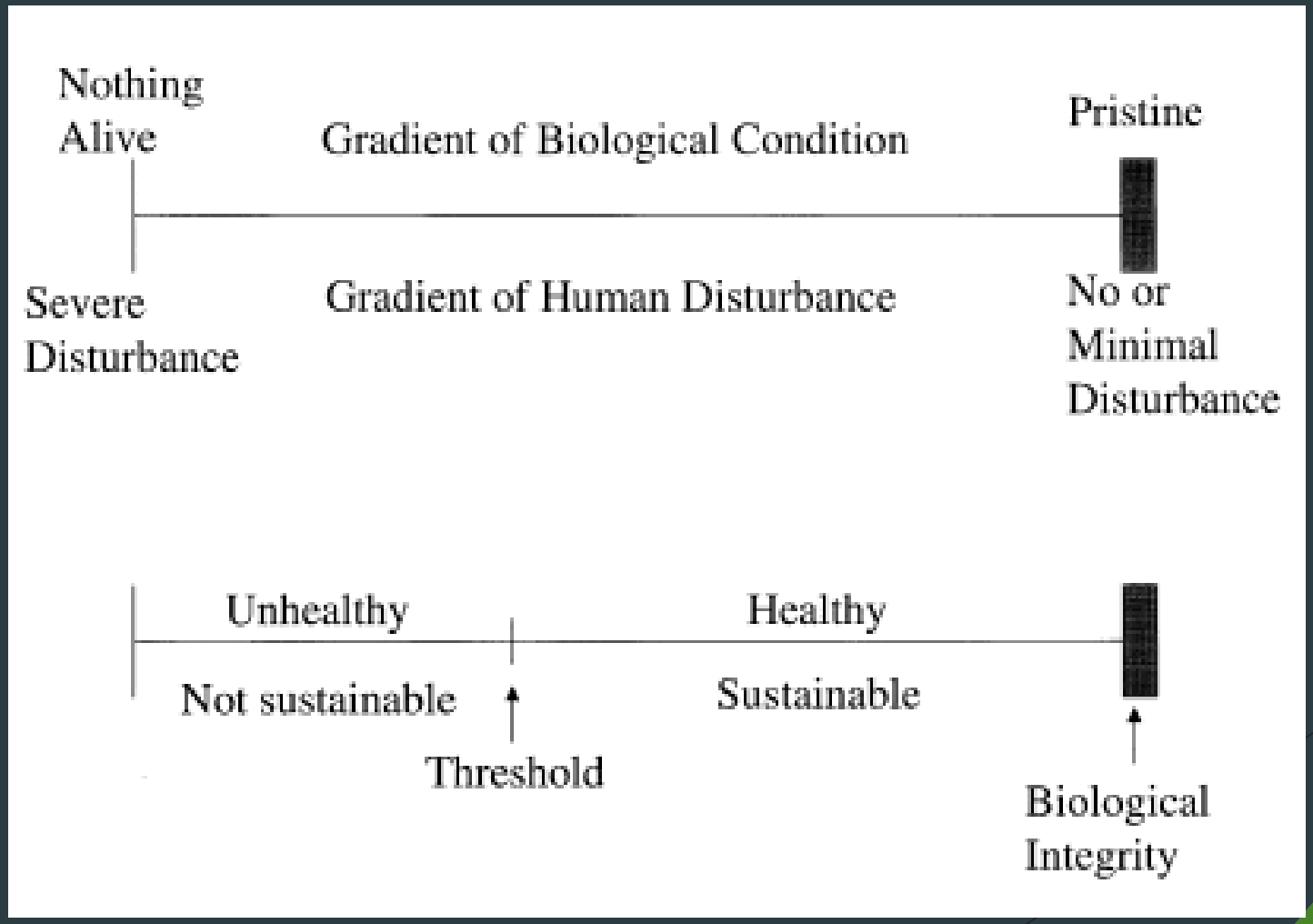
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Ecosystem Health and Biodiversity in the Pangani Basin

River Health: Integrity in ecosystem functioning, processes and supply for biota

RH helps to understand the relationship between human and their environment



- The river health assessment procedures in Tanzania is still under developed.
- Guidelines and regulations for conducting these assessments are not provided within the ministry in charge, Ministry of Water.
- This results in a number of challenges in conducting river health assessment such as:
  - poor selection of representative sites,
  - lack of classification frameworks for river systems and
  - lack of pre-established reference conditions for various river health indicator categories

Aquatic ecosystems in the Pangani Basin

How many sub basins (Msangazi, Umba, Zigi, Mkulumuzi)

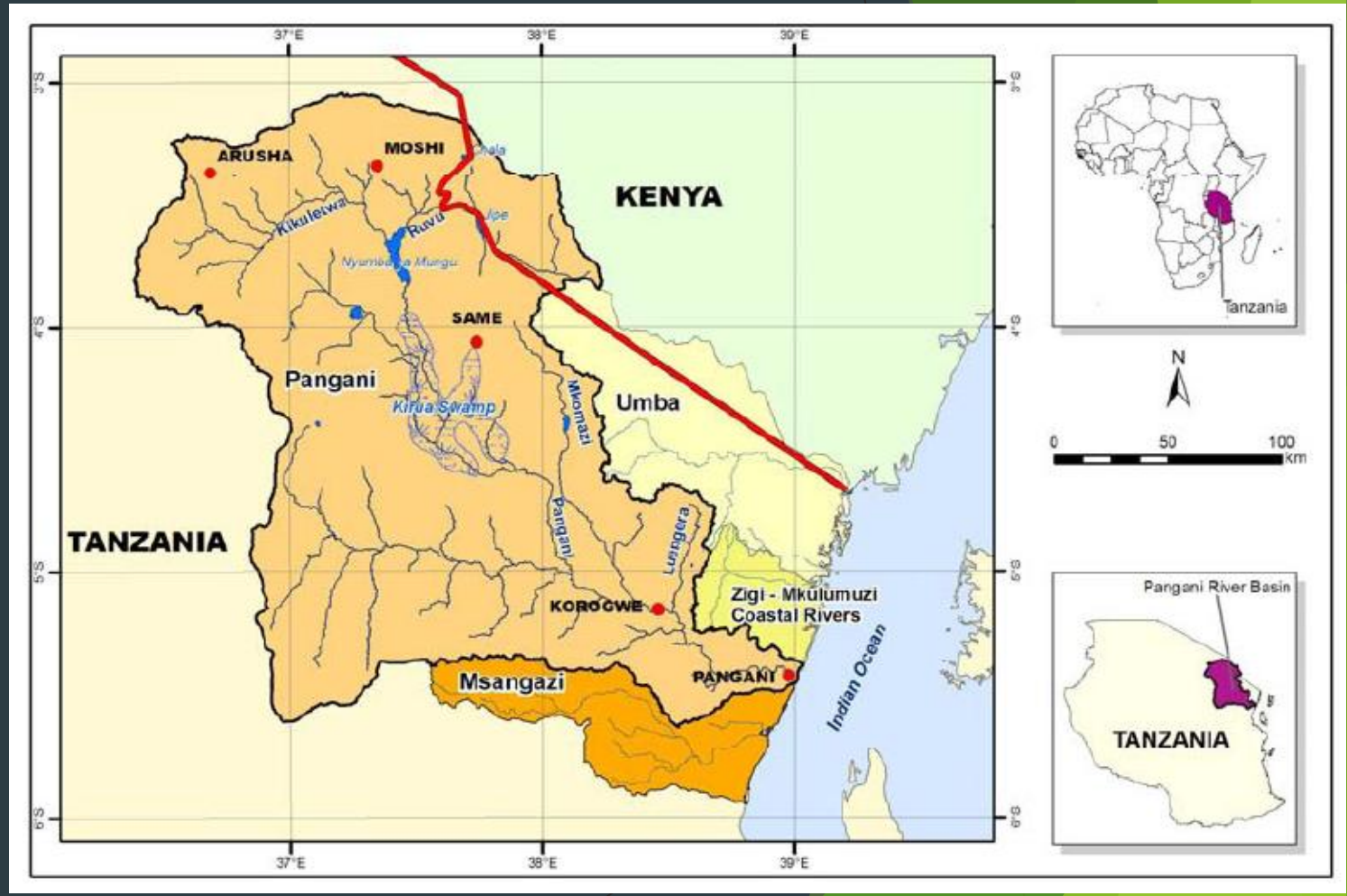
Ecosystem types:

Riverine ecosystems: Pangani RB, Sigi RB, Mkulumuzi RB, Umba RB, Msangazi RB

Lake ecosystems: Jipe, Amboseli, Chala

Dams: Nyumba ya Mungu, Kalimawe

Swamps: Kirua



Lakes, Dams and Swamps ecosystems

A review approach

Lake Jipe



- Up to 1960, the lake was thriving in fishery, a breeding and feeding ground for wild games and several water bird species
- Human activities have impaired these ecological processes and function in Lake Jipe
  - Reduced flow into the lake
  - Increased nutrient loads
  - Decline in water quality
  - Increased siltation
  - Significant expansion of *Typha* fringing the lake
  - COLLAPSE IN FISHERY

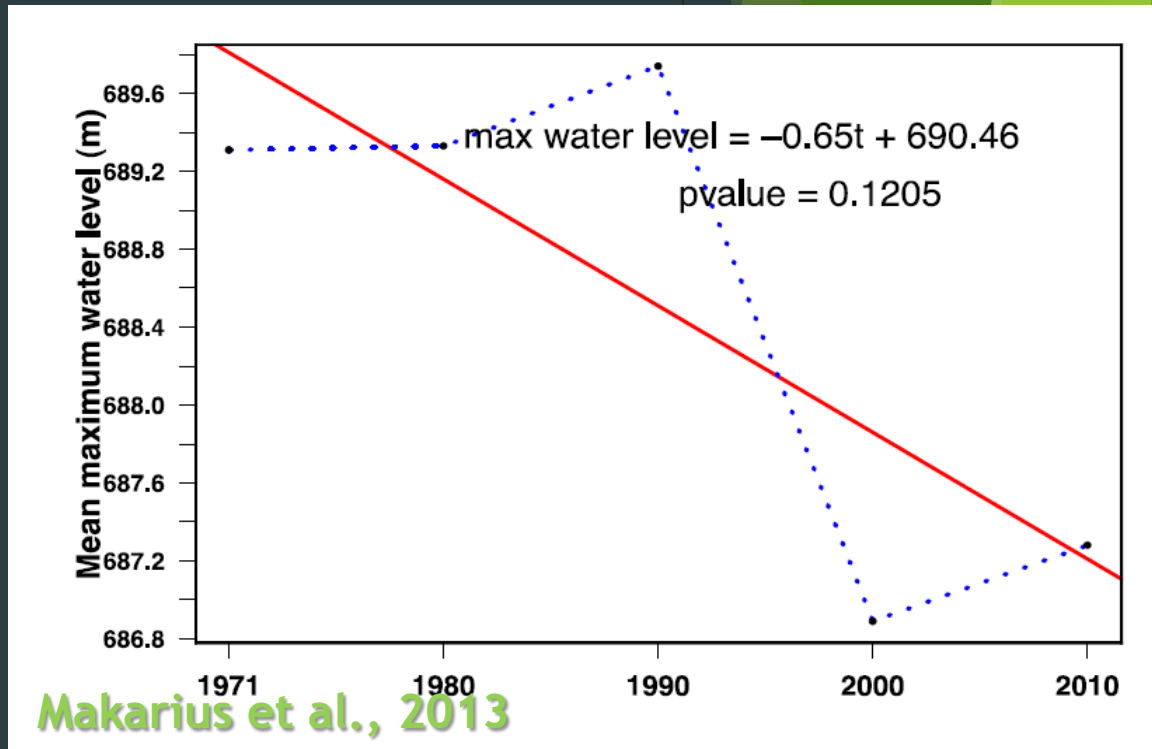
Ref: Pangani State of the Basin Report 2008

Nyumba ya Mungu dam



- There is a significant decrease in water level attributed to increased water abstraction US, climate change and rainfall variability/fluctuation

- Fishery decrease
- Hamper hydropower generation



Makarius et al., 2013

Kirua swamp

- Fluctuations and decrease in water level at NYM caused high flow reductions in the Kirua swamp where the wetland has been significantly reduced causing negative impacts on fish (spawning, feeding and productivity)

- Also impacted ecological processes (nutrient dynamics and sedimentation processes in the Kirua swamp)
  - Loss of nutrients delivery by annual flows
- Fishery has decreased and only restricted in the river channel



Riverine ecosystems

Field based

Measure of ecosystem health

- Physical ecosystem condition (channel and riparian characteristics, hydrology and hydraulics variables)
- Chemical (water quality monitoring)
- Biological assessment (Diatoms, Macroinvertebrates, Fish and Vegetation)

Evolution of RHA approaches in TZ

- Before 2005, the common practice was use of hydrology (discharge) and physic-chemical parameters (pH, Temp, DO, EC, TSS, etc)
- In 2005 the PBWO/IUCN initiative for RHA incorporated additional parameters (biota and catchment condition characteristics)- with use of indices not sensitized in Tanzania systems
- In 2009 Sigi RHA
- In 2010 in Pangani and Sigi river basins

Pangani River Health Assessment – PBWO/IUCN

Study area delineation

Methods for RHA

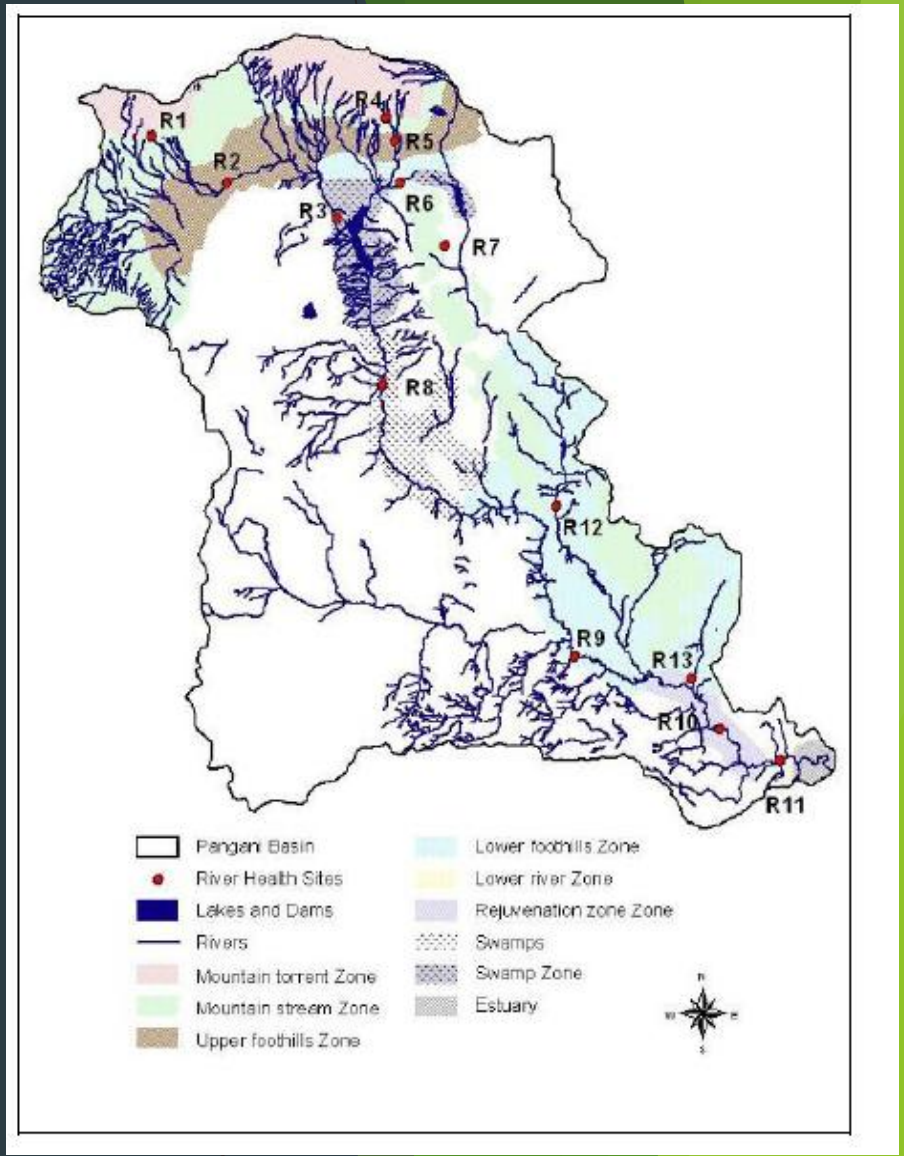
Results

Conclusion

Study Area Delineation

- Study Area was delineated in various components:
  - River zonation
    - Hydrological zonation
    - Geomorphological
    - Chemical zonation
    - Biological zonation
  - Socio-economic zones

- The Zones were **harmonized into 9 zones** (Mountain torrents, Mountain streams, Upper foothills, Rejuvenated foothills, Swamps, Floodplains, Lower foothills, Rejuvenated Bedrock Cascades and Mature Lower River)
- 13 sites were selected for the RHA representing the above zones



Methods used

- Water quantity/discharge (estimated from discharge and general knowledge on the extent of abstractions)
- Water quality (physico-chemical parameters) measured and analysed
- Local catchment condition: Index of Habitat Integrity (IHI) - instream (combined with land use and channel modifications) and Index of Habitat Integrity (IHI) - riparian
- Biological condition:
  - Invertebrates (SASS5)
  - Fish
  - Riparian vegetation
- **Overall assessment of river health**
  - A general overview of the river health at each site was obtained following discussion amongst the specialists and a table of the health of each of the components was derived for each site.

SITE SUMMARY OF RIVER CONDITION by RHA 2005-2008



Water

Vegetation

Aquatic Invertebrates

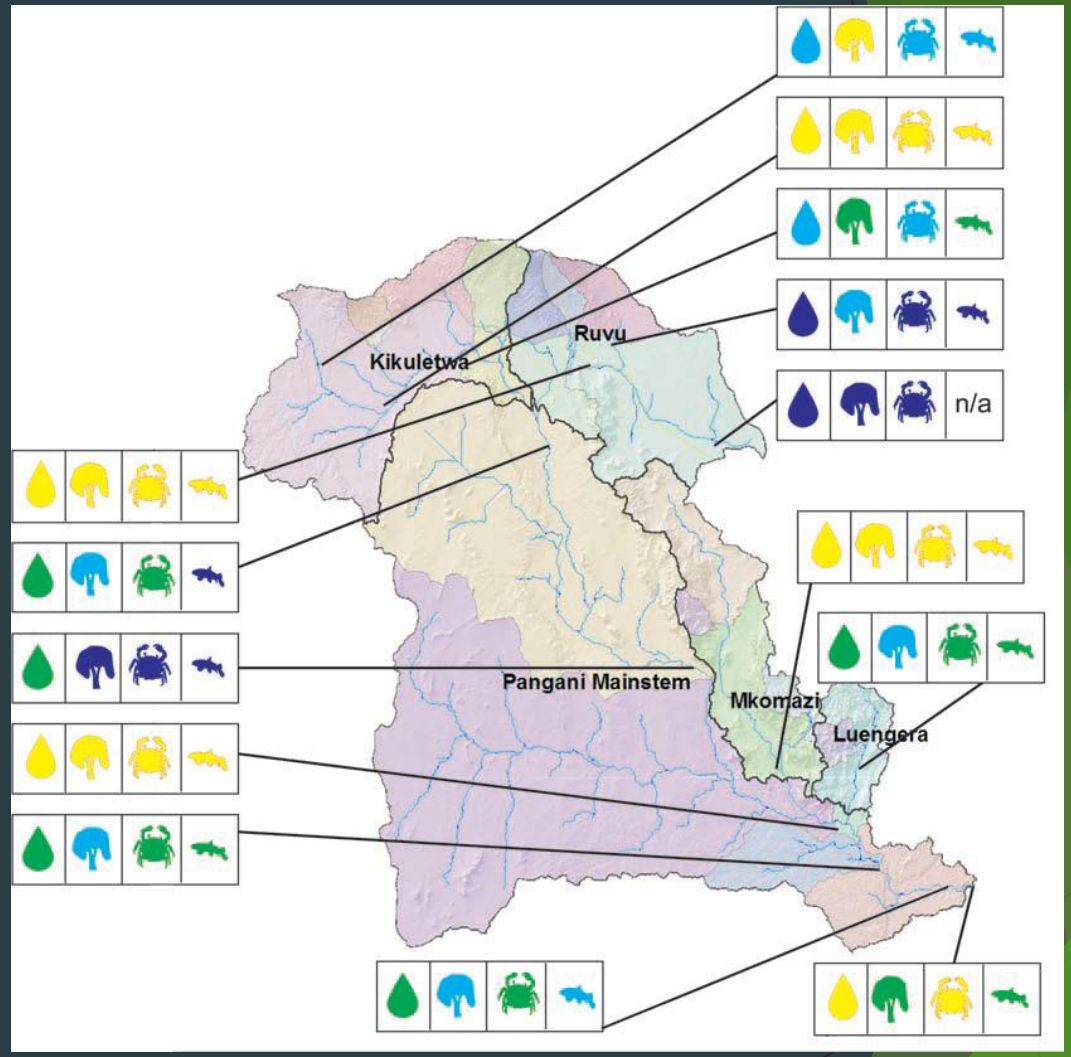
Fish

A Natural

B Largely Natural

C Moderately Modified

D Largely Modified



The PRB condition ranges from moderate to largely modified.
The poor river condition ranges from upper to lower reaches

Challenges

- Lack of reference conditions for Observed/expected comparisons
- many components were involved hence fewer sites were covered and involved a big group of professions from different disciplines
- Expensive

PhD Study (2010-2013)

Defining river types

Site Selection

TARISS Development

Results

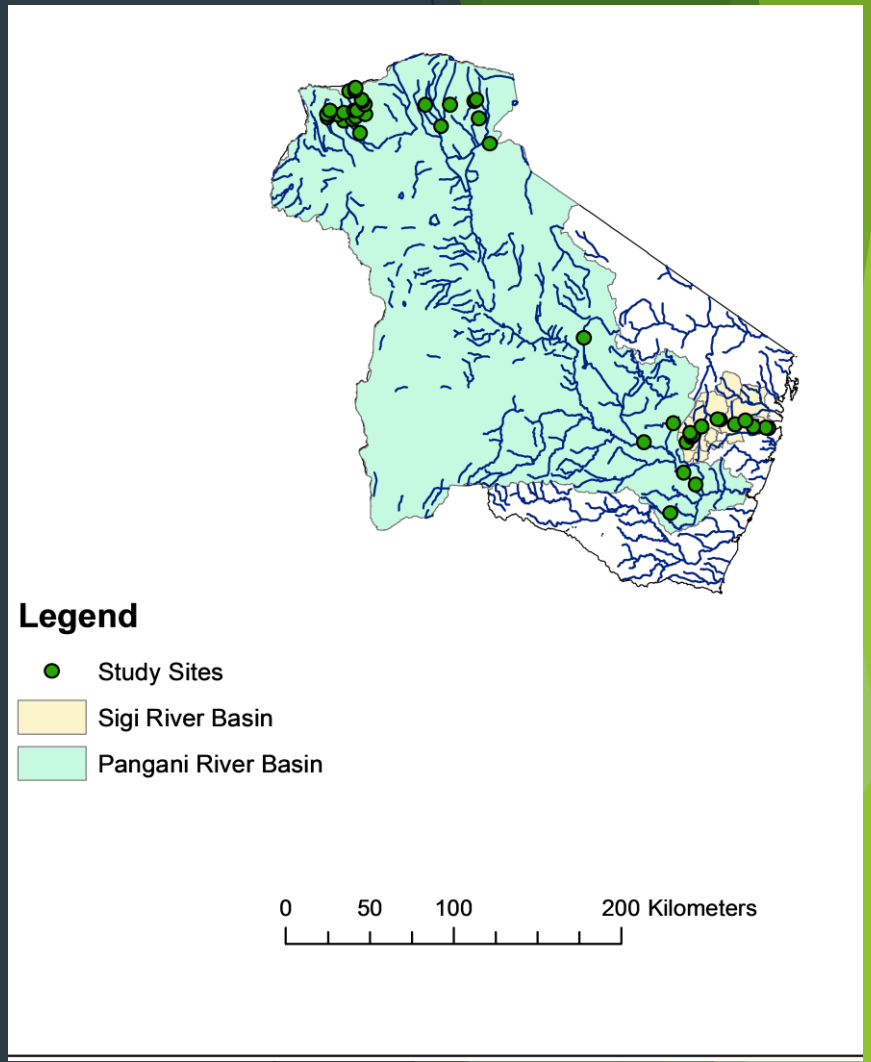
Conclusion

- Focused on use of one biotic component, catchment condition and physicochemical parameters
- Covered areas in the PRB and Sigi RB
- Reference conditions

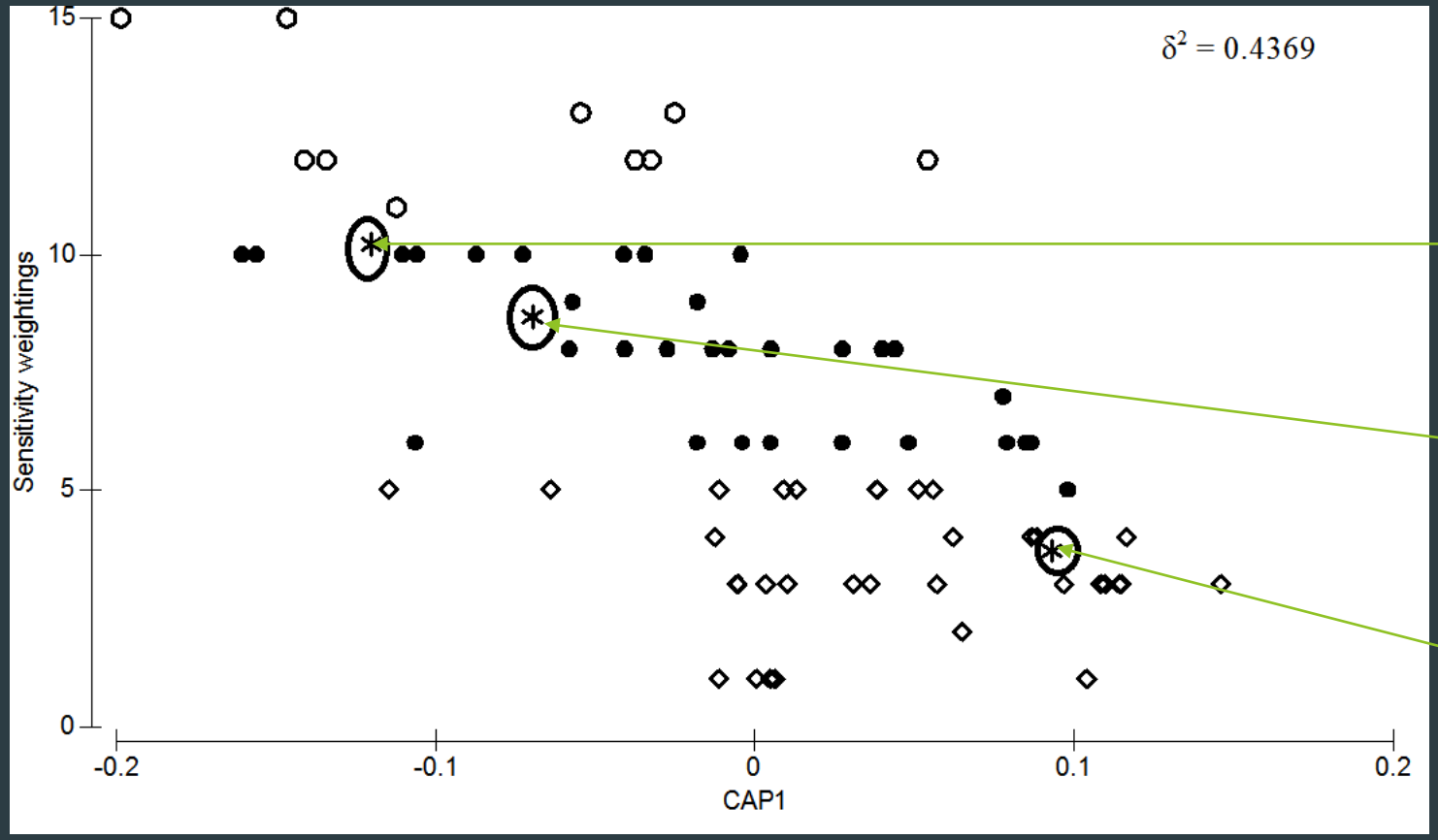
Defining river types

	Ecoregions of Tanzania derived in this study	Freshwater ecoregions of Africa (Thieme et al. 2005)	Climate zones (Indeje 2000)
1	Pangani lowlands	Pangani	Central and southern Tanzania
2	Pangani highlands	Pangani and Tana	Eastern highlands of Kenya and Tanzania
3	Pangani coastal		Coastal areas of Kenya and Tanzania

Level I (Ecoregion)	Level II (Geomorphologic)	
	Slope class	Landform
Pangani highlands (13)	2 – 8%: Upland (13)	Mountains (8)
		Hills and mountain foot-ridges (5)
Pangani coastal (9)	2 – 8%: Upland (9)	Mountains (4)
		Hills and mountain foot-ridges (2)
		Plains (2)
		Foot-slopes (1)



TARISS method

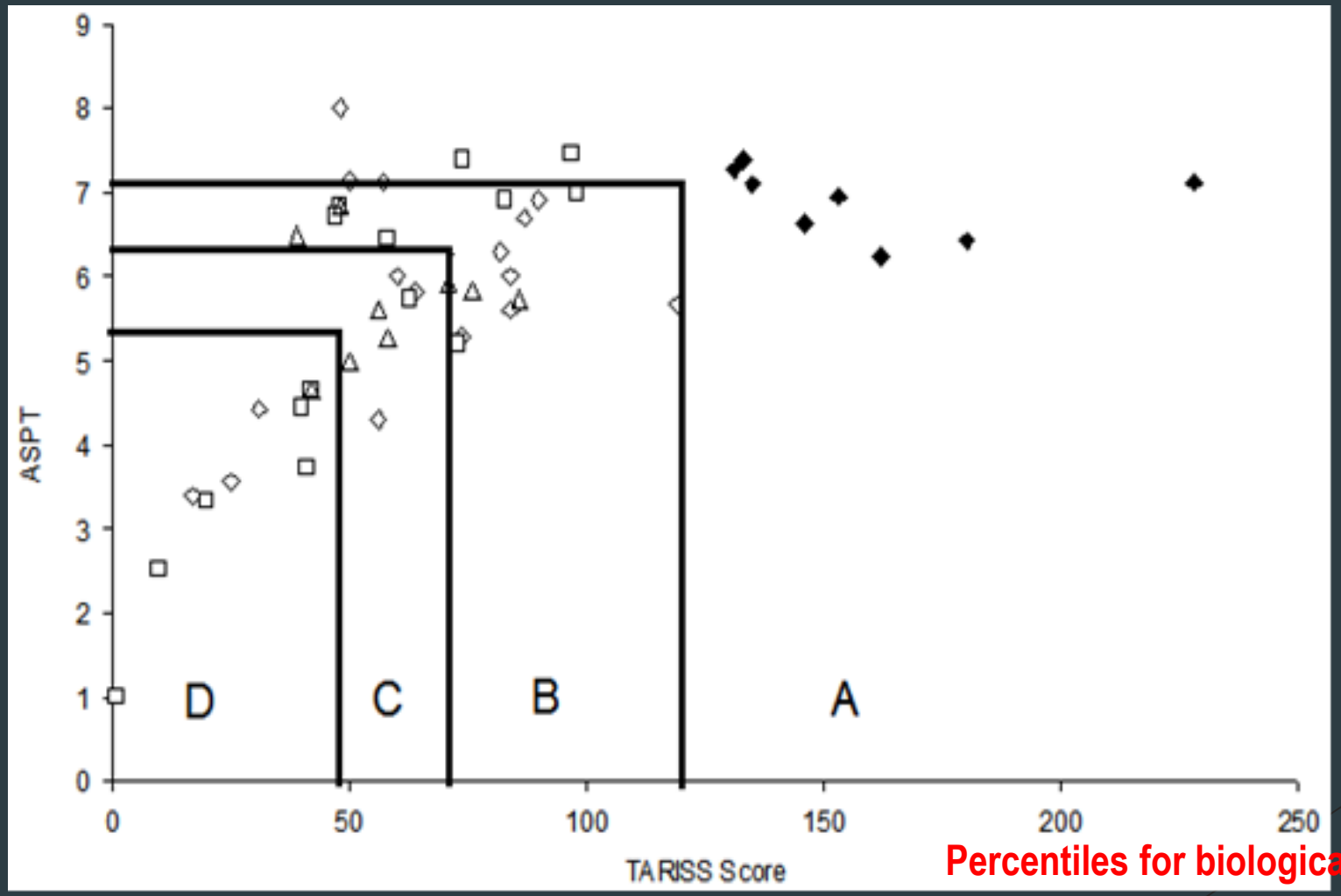


Canonical analysis of principal coordinates (CAP) ordination, showing position of new macroinvertebrates taxa into a gradient of macroinvertebrate sensitivity relative to sensitivity groups. (○ = highly sensitive, ● = moderately sensitive, ◊ = least sensitive and circled asterisk = new TARISS taxa).

Physico-chemical and biological reference conditions in Pangani highland uplands (PHU). Shaded columns represent validated spatial groups and plain columns represent preliminary reference conditions.

		PHU	
		Group 1	Group 2
Distinguishing variables		Conductivity: <1000 μscm^{-1} Altitude < 1500	Conductivity: ≥1000 μscm^{-1} Altitude ≥ 1500
Phyisco-chemical condition	Electrical Conductivity (μscm^{-1})	49.0-1000	1000-2336
	Temperature (^oC)	19-22.8	18-23
	SRP (µg/L)	116-1638	222-794
	Nitrates (µg/L)	0.056-173	0.842-38
	Ammonium (µg/L)	0.65-115	7-99
Biological condition	Number of taxa	≥18	12-26
	TARISS Score	≥130	80-160
	ASPT	≥7.0	5.8-6.8

Scatter plot of ASPT values as a function of TARISS Scores from reference and test sites in Group 1 in PHU. Biological bands calculated by percentiles are shown by the solid lines and labeled X, A, B, C, and D. Black symbols represent reference sites while transparent symbols represent monitoring sites.



Biological Band	Description	Band boundary	
		TARISS Score	ASPT
A Largely Natural	Reference Represent reference condition within a range of greater than 67.5th to 90th percentiles of TARISS Scores and ASPT for CEAU and CEAL and greater than 85th percentile for PHU. The 67.5th and 85th percentile marks the boundary between reference condition and impaired conditions	>134	>7.0
B Moderately Modified	Below reference TARISS Scores and ASPT values are slightly below the reference conditions. Moderate impairment of ecosystem's water quality or habitat loss resulting in loss or decrease of sensitive taxa. TARISS Scores and ASPT are bound between >45th to 67.5th percentiles in CEAU and CEAL; and between >56.7th to 85th percentiles in PHU	>75-134	>6.3-7.0
C Largely Modified	TARISS Scores and ASPT values are far below the reference conditions. Largely impairment of ecosystem's water quality or habitat loss resulting in major loss or decrease of sensitive taxa. TARISS Scores and ASPT are bound between >22.5th to 45th percentiles in CEAU and CEAL; and between >22.3th and 56.6th percentiles in PHU.	>48-75	>5.3-6.3
E Seriously Modified	TARISS Scores and ASPT values are critically below the reference conditions, under 22.5th in CEAU and CEAL; and under 22.3th percentile in PHU. Severe impairment of ecosystem's water quality or habitat loss resulting in domination of tolerant taxa.	≤48	≤5.3

Percentiles for biological bands in PHU were 85th, 56.7th and 28.3th

Macroinvertebrate Survey for River Health Assessment for Pangani Basin Report for IWRMD plan-2013

Study sites

Site Code	Main Catchment	River Catchment	River Name	Latitudes	Longitudes	Slope Class	River Zones
M01		Soni	Mkusu R at Kibohero	04° 43' 45"	38° 17' 10"	Upland (0.02-0.08)	Upper Foothill
L01		Luengera	Luengera R at darajani	05° 08' 00"	38° 34' 00"	Lowland (<0.02)	
P01	Pangani	Pangani	Pangani R at Korogwe	05° 10' 00"	38° 28' 00"		
S01	Sigi	Sigi	Sigi R at Lanconi	05° 00' 50"	38° 47' 59"		Lower Foothill
U01	Umba	Umba	Umba R at Mlalo	04° 35' 00"	38° 20' 40"	Upland (0.02-0.08)	Upper Foothill

Methods

- Macroinvertebrates were sampled using a recently established method for assessment of rivers using macroinvertebrates namely TARISS (Tanzania River Scoring System) (Kaaya, 2015).

- Local catchment human disturbance index (LCHD)

0=None
1= Limited
2=Moderate
3=spread
4=Entire

Criteria group		Criteria (land use/ecosystem stressor)	At site (100m stretch)		Upstream site (500m)
			Within Riparian Zone	Beyond Riparian Zone	Within Riparian Zone
Channel modifications	1	Construction (mainly roads and bridges)			
	2	Livestock (trampling)			
	3	Mining (sand and gravel extraction, mineral mining)			
Hydrological modifications	4	Impoundments (water supply, electricity and irrigation)			
	5	Irrigation at small scale			
	6	Water abstraction (presence of pumps and pipes)			
Destruction of riparian vegetation	7	Allien vegetation			
	8	Commercial afforestation			
	9	Large scale agriculture (large plantations)			
	10	Small scale agriculture for food crops			
Diffuse and point sources pollution	11	Direct domestic activities (bathing, car washing)			
	12	Direct sewage disposal			
	13	Dumping/littering of solid wastes			
	14	Industrial development			
	15	Informal settlement			
	16	Roads			
	17	Rural development			
	18	Urban development			
	19	Water treatment plants			
	20	Wildlife disturbance			

Results

Summary of river health categories for catchment sites in Pangani Basin based on Invertebrates and Local catchment human disturbance

River Name	Mkusu R	Luengera R	Pangani R	Sigi R	Umba R
Main Catchment	Pangani			Sigi R	Umba
Slope Class	Upland	Lowland			Upland
Invertebrates	C	C	C	B	E
Local Catchment Human Disturbance	C	D	D	C	E

Moderately to largely modified

Largely natural-moderately modified

Critically impaired

Biodiversity

Fish

Riparian vegetation

Biodiversity-Fish

Conservation status of fish in the Pangani River Basin

- A bout 50 fish species exist in the Pangani system.

- Some of these species are endemic to the Pangani River system:
  - *Oreochromis pangani*,
  - *Oreochromis jipe* (considered by IUCN Red list as Critically Endangered) and
  - *Oreochromis girigan*

Spatial trend of fish in the basin

- Of all the fish recorded in the basin Cichlids (*Tilapias*) and minnows/carps (Cyprindae) were the most widely distributed found in almost all zones except the Mature River Zone.

- Killifish (Cyprinodontidae) were the next most common and were recorded in all zones except the mountain streams and the lower mature zone.

- The least common families were Gobies (Gobiidae), Chanidae and Ambassidae, which were confined to the Mature River Zone.

- Eels (Anguillidae), African tetras (Characidae) and the catfishes: Squakers (Mochokidae) and catfish (Clariidae) had limited distribution.

- The Lower Foothill recorded the highest diversity of fishes of all the zones, followed by the Mature River Zone.

- The least diverse was the Mountain Stream zone in which only the minnow *Garra dembeensis* was caught, although there were some reports from local people that in the past cichlids were also found.

- Milkfish (*Chanos chanos*), and Ambassids (Ambassis unitaenia) that are found in the Lower Mature River are euryhaline, migrating between the ocean and the river. Because of the landscape barrier formed by the Pangani Falls Hydropower station these fish cannot migrate further upstream.

Riparian Vegetation

- A total of 233 plant species have been identified to the genus level including trees, shrubs, herbs, grasses, sedges and reeds. The width of the riparian vegetation varied from 5 to 200 m (left and right bank).
- the occurrence of invasive vegetation is listed below

Table 3.11 Occurrence of invasive vegetation at sites in the study area (0=absence; 1= rare; 2= sparse; 3= common; 4= abundant; 5 = entire)

	Left Bank													Right Bank											
Invasive vegetation	Site Code													Site Code											
Zone	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
Exotic species	3	0	0	2	1	1	2	0	0	2	1	5	0	4	1	0	2	1	1	2	0	0	2	1	5	0
Reeds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terrestrial Plants	2	2	0	0	0	0	0	0	0	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	1	0

Nduruma R

Mkomazi R

Conclusion









- Riverine ecosystems:
  - Pangani RB: Moderately to largely modified
  - Sigi RB: Largely natural to Moderately modified
  - Umba RB: largely to critically modified
- Lake ecosystems: Jipe: Largely modified
- Dams: Nyumba ya Mungu: Largely modified
- Swamps: Kirua: largely modified

Way forward

- Focus on RESTORATION