Regional Workshop on Tools to Implement LBSA Protocol and WIOSAP Regional Task Force Meeting

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Impacts of rivers in mediating marine pollution

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Outline of Presentation

- Importance of river flows on marine ecosystem integrity
- Drivers of change impacting on river flows integrity
- Potential sources, processes and impacts of river mediated pollution
- Any case study on intervention to ameliorate challenges

Importance of river flows on marine ecosystem integrity

- **Marine ecosystems** cover approximately **71%** of the Earth's surface and contain approximately **97% of the planet's water**. They generate **32% of the world's** net primary production.

- **Marine ecosystems** can be divided into the following **zones** (Nafisat, 2007):
  - oceanic (the open part of the ocean where animals such as whales, sharks, and tuna live);
  - profundal (bottom or deep water);
  - benthic (bottom substrates);
  - intertidal (the area between high and low tides);
  - estuaries;
  - salt marshes;
  - coral reefs; and
  - hydrothermal vents (where chemosyntheticsulfur bacteria form the food base).

Importance of river flows on marine ecosystem integrity

- **River flows (Freshwater)** and **saline water** along with the **nutrients** brought by both **water flows** provides some of the **world's most productive ecosystems** - the **estuarine** and **coastal ecosystems**.

- In the tropics, **seagrass beds** cover the **estuary** and **coastal offshore muddy/sandy bottom**, where
  - **marine fish** come to **breed**,
  - provide shelter for **juvenile fish** from larger marine predators of the open sea, as well as
  - **food** in the form of **submerged aquatic vegetation** and **marine invertebrates** (Bwathondi & Mwamsojo 1993).

Importance of river flows on marine ecosystem integrity

- About **90% of global fisheries** occur in **estuaries and their associated near shore and continental margin systems** (Wolanski *et al.,* 2004).
- **Many species of mangroves** frequently are found growing along the **river banks** and **coasts of tropical** and **subtropical estuarine** environments.
- **Their roots** protect the coast from **erosion** and from **tropical storms**, and also **slow down flow** thereby facilitating **sedimentation** and **nutrient deposition** (Semesi 1991).
- **Mangroves** and **seagrass** beds are **critical nursery areas** for **marine fish**, and **coastal fisheries**.

Importance of river flows on marine ecosystem integrity

Freshwater Inflows - Lifeblood of an Estuary

- A **river's ecological health** and **viability** is **dependent on** its **natural flow-regime** that creates and maintains **hydrological, biogeochemical** and **ecological connectivity** between the channel, floodplain, wetland and estuary. *Ecosystem function and biodiversity has evolved under this* ***natural variation in river flow***.

- Rivers with highly **altered flows** lose their ability to support natural processes of maintaining **water quality** and **supporting a healthy diverse ecosystem**.

Importance of river flows on marine ecosystem integrity

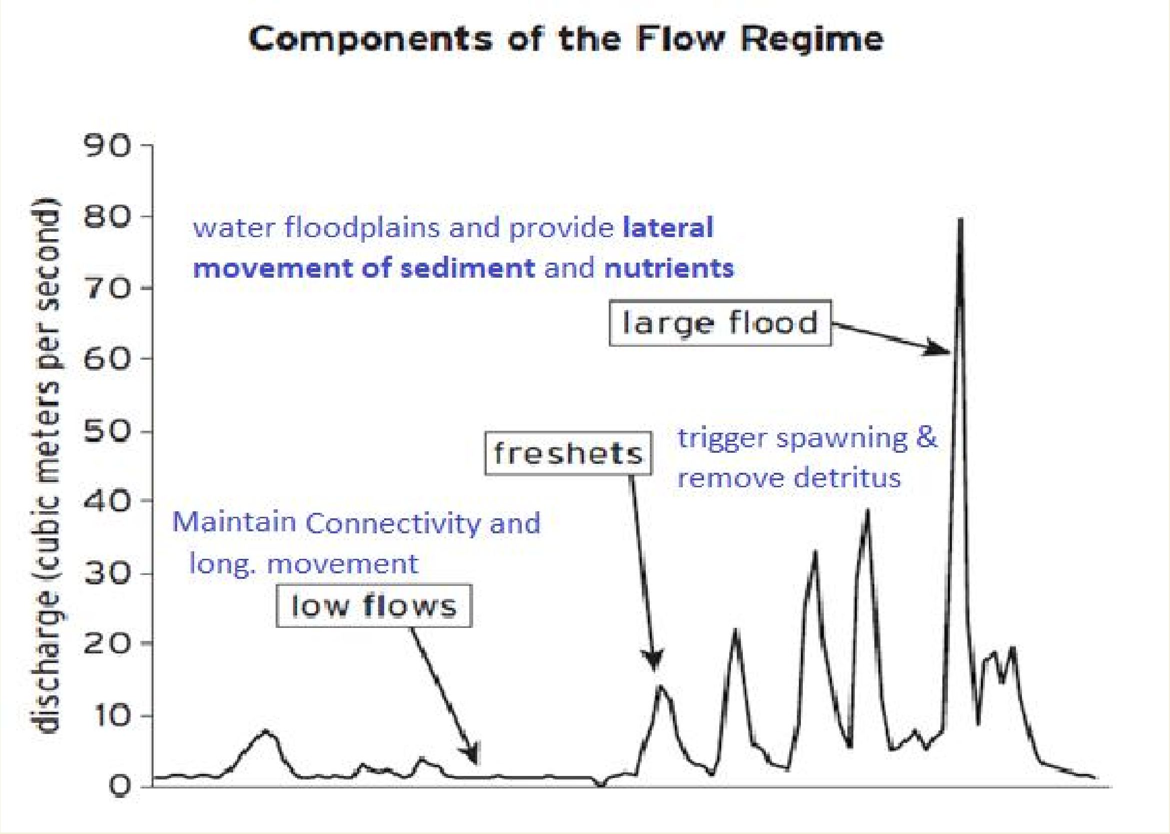
- Large departures in freshwater inflows from the natural seasonal cycle can lead to **abrupt changes in salinity in estuaries**, with detrimental effects on the **early life cycle** stages of fish and other aquatic organisms.

- **Sediment** and **nutrients** brought in by the river contribute to the significantly **higher productivity** of the **estuary** as compared to the open ocean.

- **Freshwater being the lifeblood of an estuary**, are thus extremely susceptible to **large upstream freshwater abstractions** and **land cover change**.

Importance of river flows on marine ecosystem integrity

- It is thus essential to **understand the linkages between seasonal freshwater inflow** and the **estuarine ecosystem**. *This understanding can help* ***develop a set of inflow guidelines*** *in wet and dry seasons, in years with low and normal rainfall.*



Drivers of change impacting on river flows integrity

- Population growth

- Poor land-use practices (intense deforestations of catchment areas, farming along river-banks, and livestock numbers have increased considerably especially in the lowland areas)

- Traditional furrow system by most small scale farmers very inefficient and loses are quite high

- Limited law enforcement

- Climate change

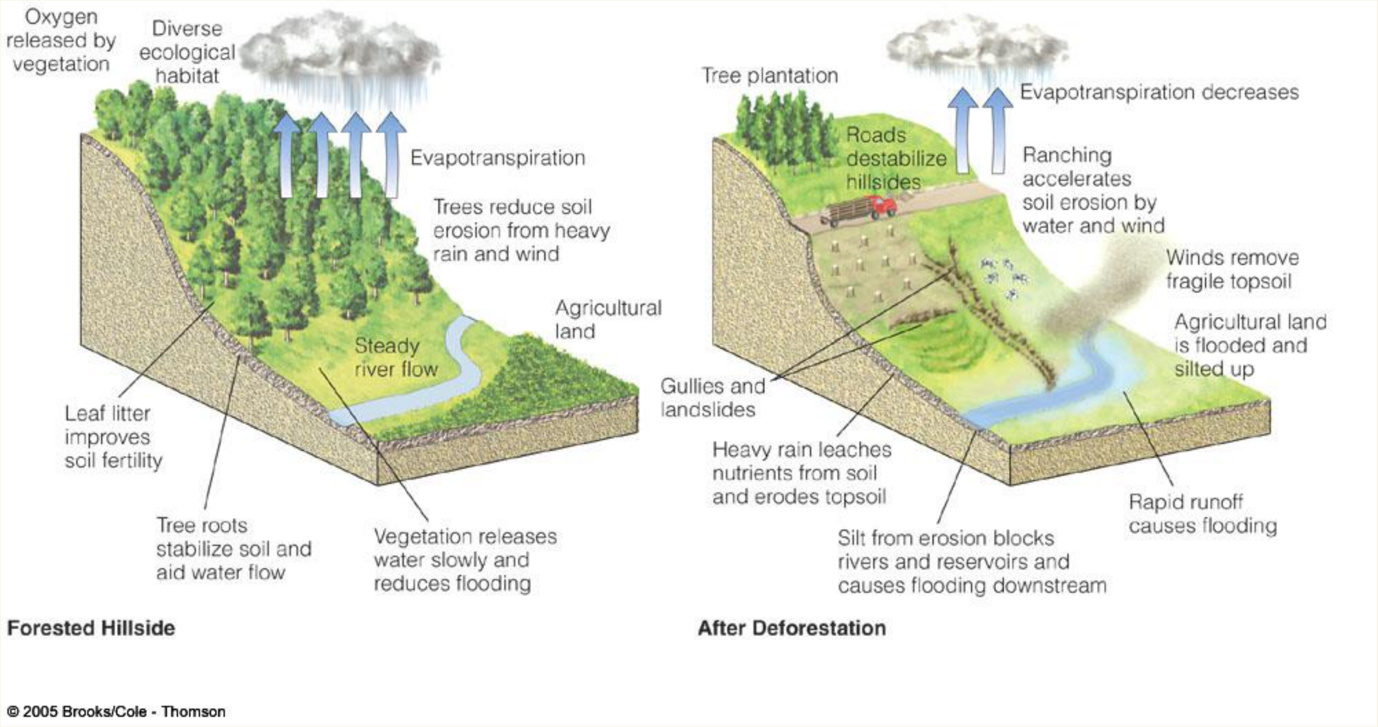
Potential sources, processes and impacts of river mediated pollution

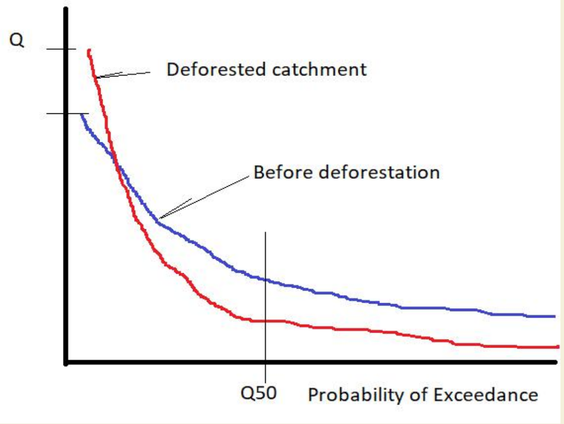
Potential sources pollution

- Pesticide and fertilizer use
- Untreated Wastewater disposal
- Mining Activities
- Shifting cultivation
- Unmanaged Solid waste
- Use of pit latrines
- Rampant Bush fires
- Overgrazing
- Unplanned settlements

Potential sources, processes and impacts of river mediated pollution

LULC & river flow regime





Change in flow pattern

Potential sources, processes and impacts of river mediated pollution

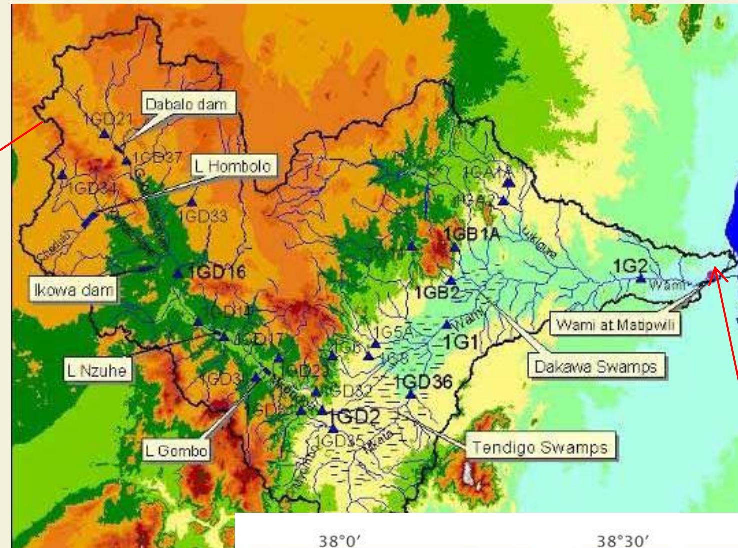
Anthropogenic pressures

- **Pollution**
  - Low pneumatophore density
  - Stunted growth
- **Excess input of sediment**
  - Burial of roots
  - Reduced productivity, mortality
- **Deforestation & land-use conversion**
  - Reduced biodiversity
  - Modification of soils → slower nutrient cycling
  - Microclimate alteration → increase in temp.
  - Alteration of hydrology → impacts regeneration

Any case study on intervention to ameliorate challenges

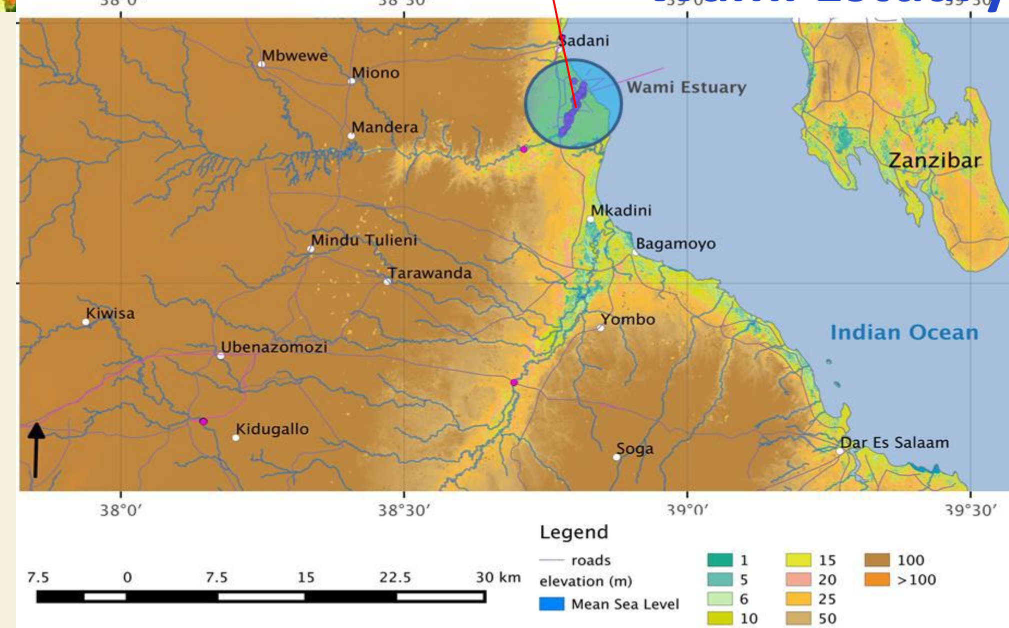
Freshwater Inflows (EF) for the Wami River Estuary

9 Water Basins of Tanzania



Wami sub-basin

Wami Estuary



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Environmental Flow Assessment for the Wami Estuary: the process

1. Presentations on the state of knowledge and fieldwork results (aquatic, riparian, terrestrial), human resource use and hydrology of the estuary.
2. PES of each ecosystem component, the trajectory of change, and the desired target for restoration/maintenance with the assignment of Grades A-F.
3. Determining the minimum depth necessary to prevent disappearance of various ecosystem components, including flood pulses along with their magnitudes.
4. Confidence estimates for each EFA component.
5. Obtaining discharge values from corresponding minimum depth values using a hydrological model developed for relating depth to discharge at study site.
6. Establishing minimum set of environmental flow recommendations for each month. This was done in a manner that replicates the seasonal variation inherent in the historical flow average data.
7. Comparison of the recommended EFs with the historical flow data, to see whether the magnitudes of the recommended minimum flows lie within the historical flow range.

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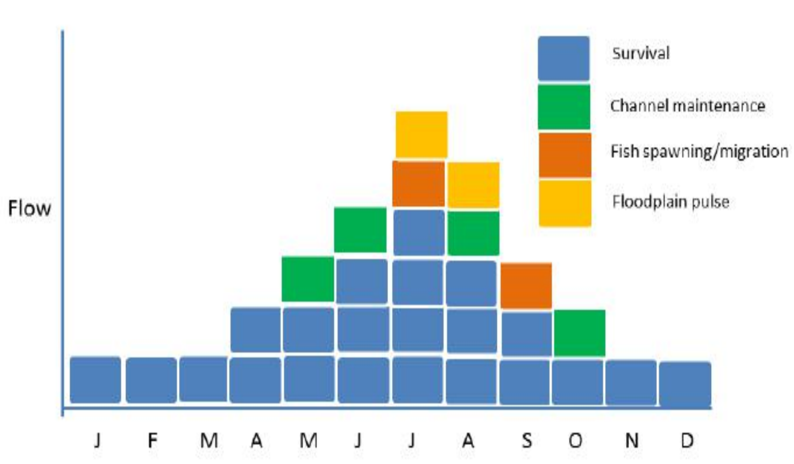
Method: Building Blocks Methodology (BBM) for Environmental Flows Assessment (EFA)



Experts Involved

- Socioeconomist
- Inverts and Fish Specialist
- Hydrologist
- Wildlife Biologist,
- Hydraulic Engineer
- Geomorphologist
- Water Resources Specialist,
- Ecohydrologist
- Hydrology Technician
- Electronic Instrumentation
- Fisheries Technician,
- Geo-Surveyor

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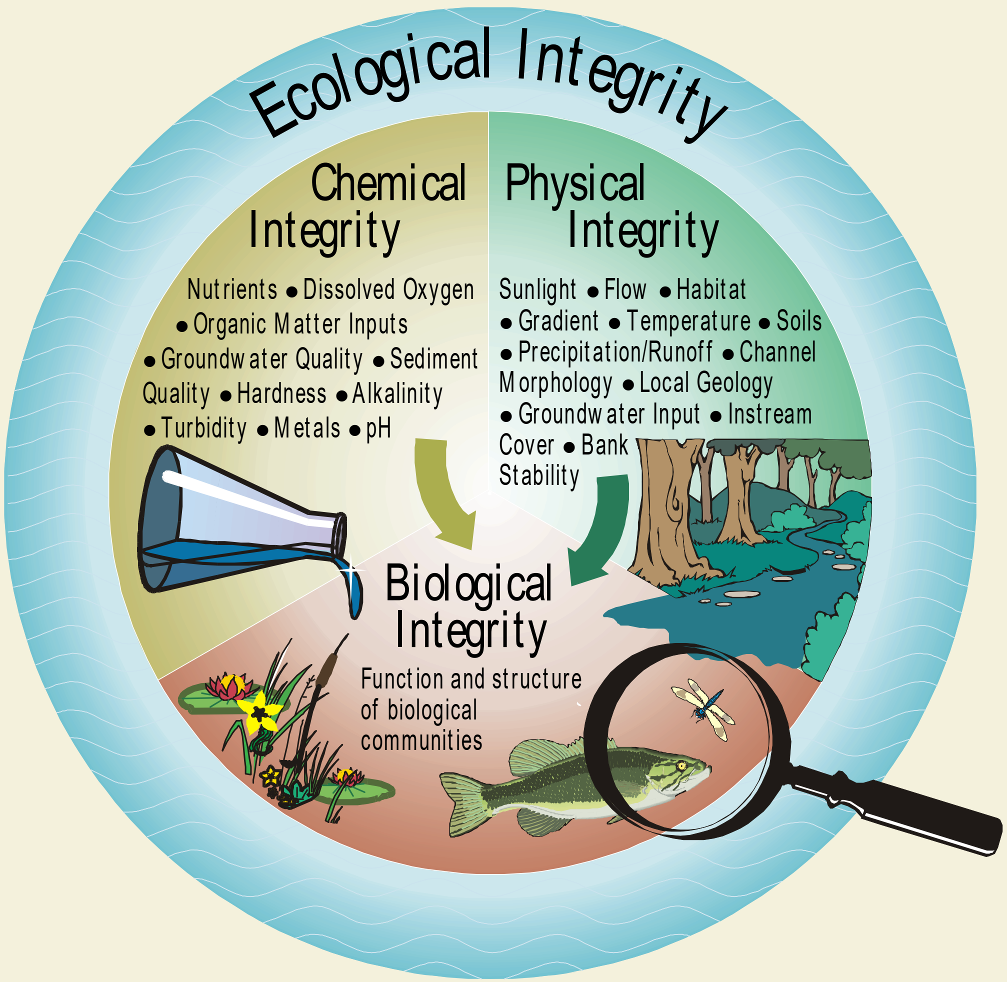
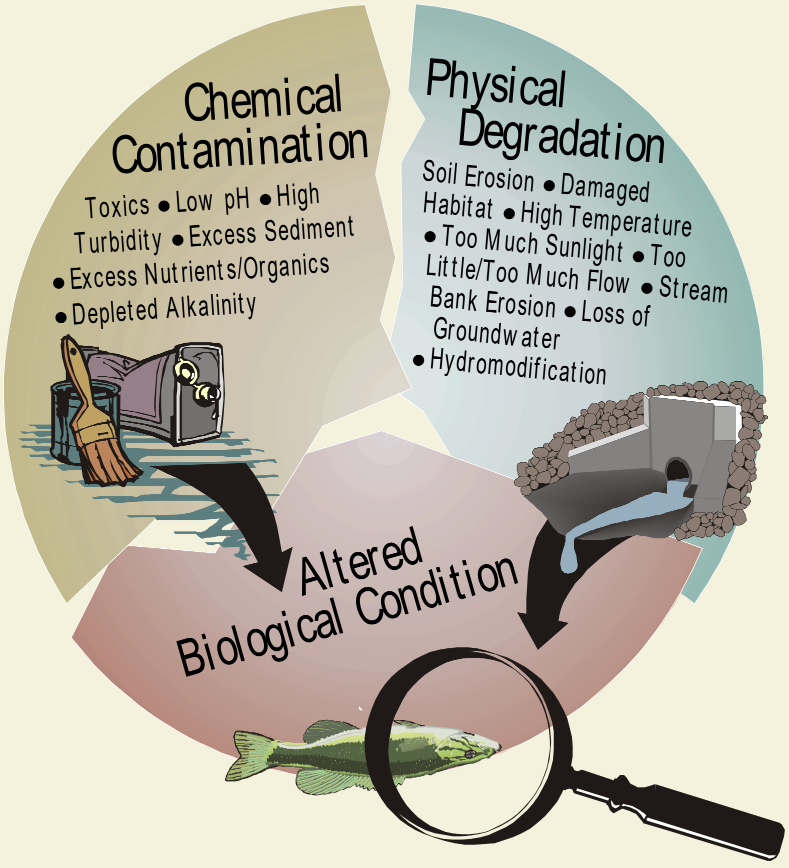
Chemical, Physical, and Biological Integrity





Source: Steve A. Dressing & Donald W. Meals, 2008

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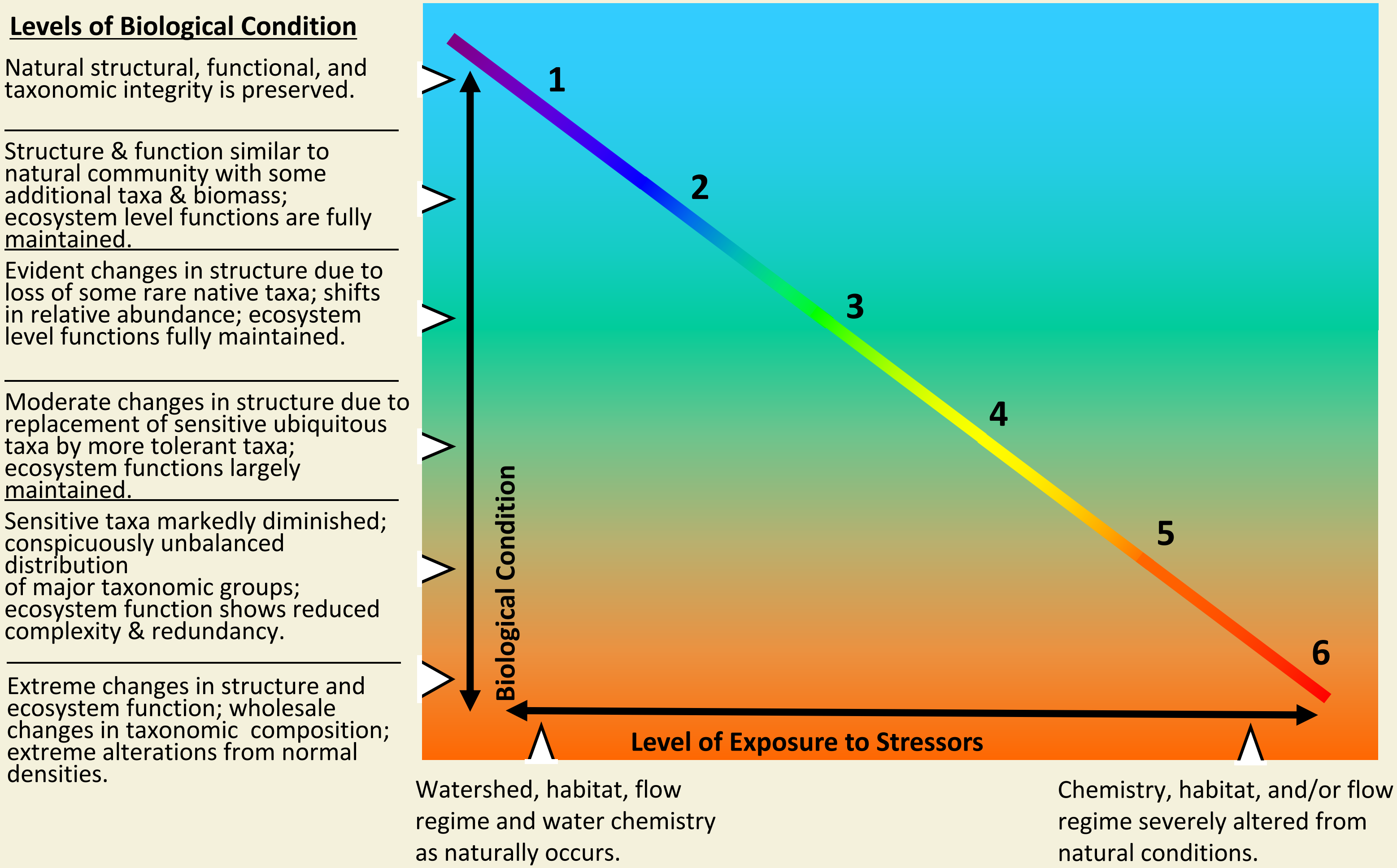
Monitoring Ecological Condition

The Biological Condition Gradient: Biological Response to Increasing Levels of Stress



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Freshwater depth/flow requirements for critical ecosystem processes

Season, flow, normal/dry year	Average Water Depth (m)	Discharge At Gama (m^3/s)	Motivation for depth/flow requirement	Consequences of not providing minimum flow/depth
Dry season, LOW flow, DROUGHT year	1.5	6.6	SURVIVAL of organisms; critical importance of maintaining flowing water and to avoid the river becoming a set of pools (that leads to large drop in dissolved oxygen levels, algal blooms and drastic change in water quality).	Mortality, possibly local extinction of organisms; dry conditions in riparian zone allows fires to spread from inland – very destructive for riparian vegetation that typically is not adapted to fire
Dry season, LOW flow, MAINTENANCE year	2.4	16	SURVIVAL, maintenance of dry season organism function (health) for growth and reproduction in following wet season; river habitat connectivity, critical importance of maintaining flow	Mortality; lower water levels create stress that affects growth and reproductive fitness in the following season; fires
Wet season, LOW flow, DROUGHT year	3	25	Wet season is the main period of water and nutrient availability; thus the major growth and reproduction season for almost all organisms	Species survival is at risk; Inadequate water flow/availability limits nutrient uptake, habitat connectivity, impaired water quality and fish spawning.
Wet season, LOW flow, MAINTENANCE year	4	46	Maintenance years allow reproduction at normal levels compared to drought years which can see very low reproduction	Same as above row; fish migrations from channel to floodplain or upstream along channel depend on adequate connectivity and flow.
Wet season, HIGH flow pulse, DROUGHT year	6	150	Flushing of sediments and salts from river channel; replenishment of nutrients and water to floodplain and oxbow lakes; suppression of invasive herbaceous vegetation along riverbanks; cues for fish spawning and migration.	Inadequate flushing of channels and floodplains, invasive herbaceous vegetation gets established; migration of fish and wildlife affected; oxbow lakes and floodplain become nutrient impoverished
Wet season, HIGH flow pulse, MAINTENANCE year	7	200	1-2 Flood pulses (peak flow) needed for replenishing nutrients and water to floodplain and oxbow lakes; spawning cues for fish; clearing channel of sediment and salt.	Same as above row. Normal years require 2-3 flood pulses to flush the system.

minimum water needs to enable critical ecosystem processes

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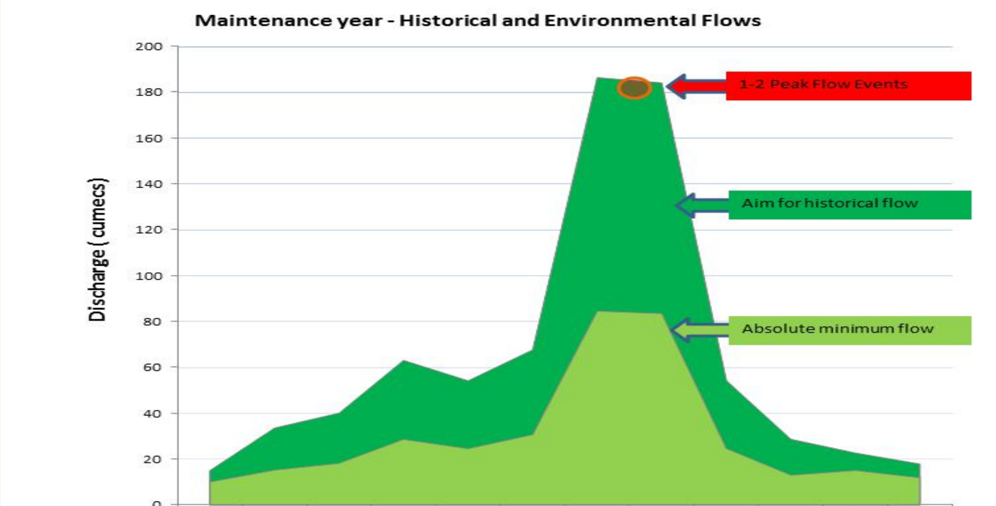
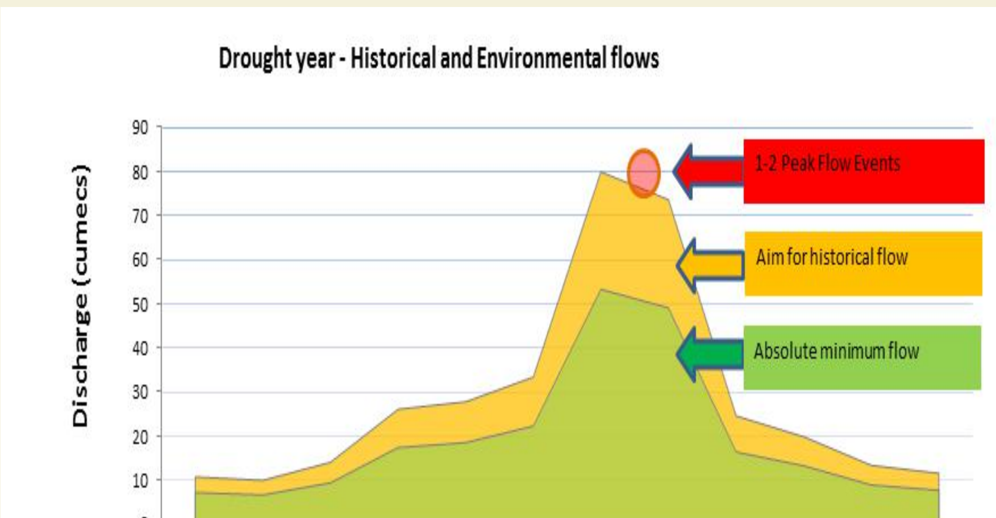


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Historical average	15	33.5	40	63	54.1	67.6	186.3	184	54.2	28.6	22.6	17.8
EF	10.00	15.20	18.15	28.58	24.55	30.67	84.52	83.48	24.59	12.98	15.07	11.87

the **dark green plot** shows the historical monthly flow in cubic meters per second (~1950-2010) averaged for years with normal rainfall (ecosystem maintenance year). **Light green plot** depicts the minimum environmental flow (EF) necessary in Wami River at Gama Gate to maintain estuarine ecosystem for a given year.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Historical Average	10.7	9.9	14	26	27.7	33.3	79.8	73.5	24.5	19.8	13.3	11.5
EF	7.13	6.60	9.33	17.33	18.46	22.20	53.19	49.00	16.33	13.20	8.87	7.67

the **yellow plot** shows the historical monthly flow in cubic meters per second (~1950-2010) averaged for drought years (years with rainfall lower than one standard deviation below the average rainfall). The **lime green plot** depicts the minimum environmental flow (EF) necessary in the Wami River at Gama Gate to maintain estuarine ecosystem for a drought year.

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Environmental flow guidelines

- **Minimum EFlows** represents conditions for **survival.**
- In order to maintain ecosystem function in its natural state, the historical flow magnitudes and patterns are necessary.
- However, **providing the full amount of historical flows** every year could be a challenge on account of **increasing water demand and human impacts** throughout the basin.
- Hence the EF concept has emerged to avoid catastrophic change in the ecosystem.
- **Hence, the EFs are just a guideline for minimum flows for a year, and river basin water management efforts should strive to allow more flow than the minimum EFs, whenever possible.**

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Key actions by the WRBWB

- Incorporated the findings in the IWRMDPs
- Formation of WUAs and Catchment Committees
- Holding multi-stakeholder platforms to create awareness on EFs as part of INTEGRATED catchment management
- Collaborating with CBOs on catchment restoration campaign and piloting water saving measures at catchment level – e.g. System of Rice Intensification (SRI)
- Rehabilitating and installing new monitoring stations
- Piloting LU plans with LGAs
- Raising awareness on bio-indicators and bio-monitoring

Thank you