

The global context of E-Flows, assessment tools, its importance in water resources planning and an outlook on the issue of transferability

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Hydropower in Austria



 www.boku.ac.at/ihg



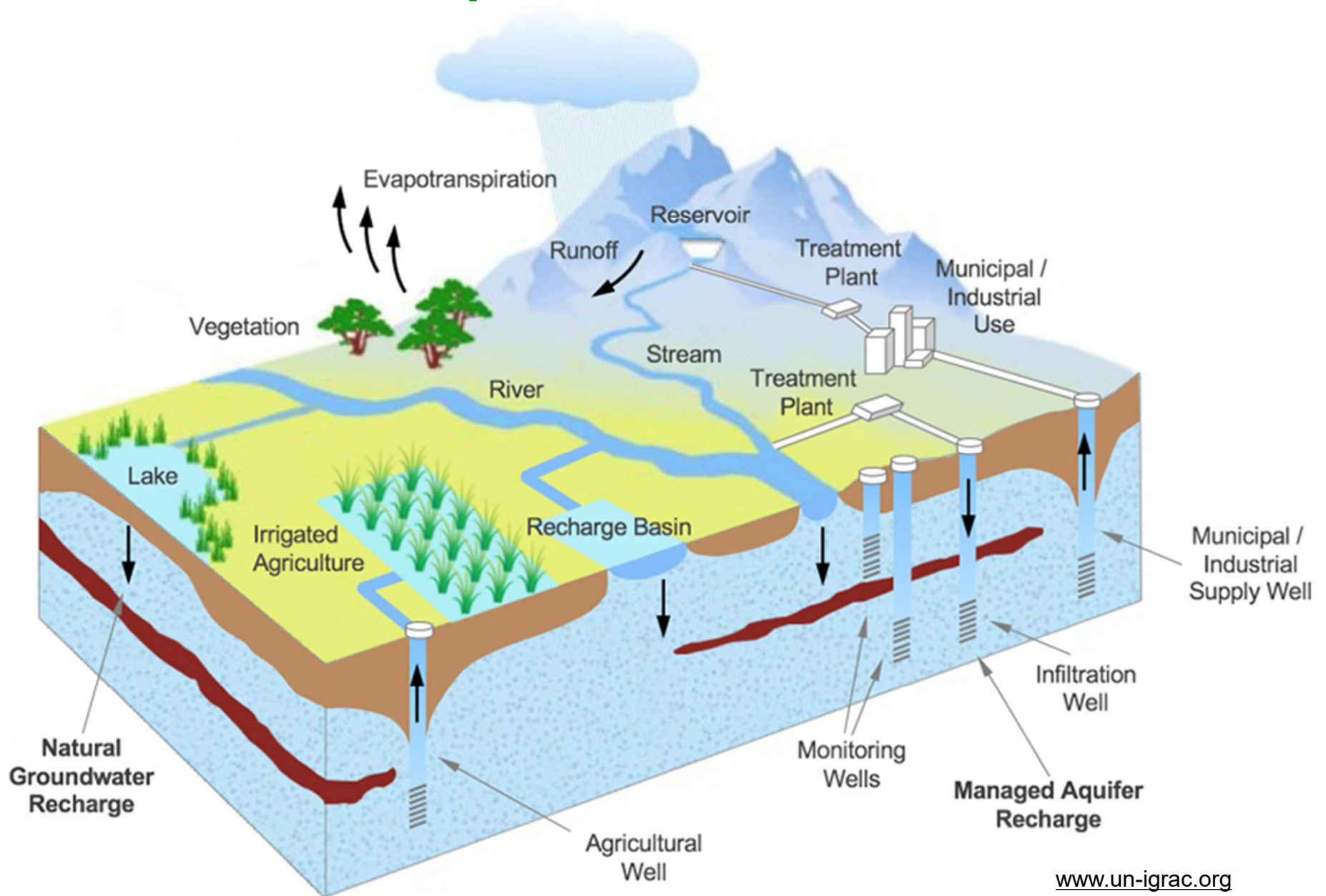
E-flow definition

E-flow is “a **regime of flow** in a river or stream that describes the temporal and spatial variation in quantity and quality of water required for freshwater as well as estuarine systems **to perform their natural ecological functions** (including sediment transport) **and support the spiritual, cultural and livelihood activities that depend on these ecosystems.**”

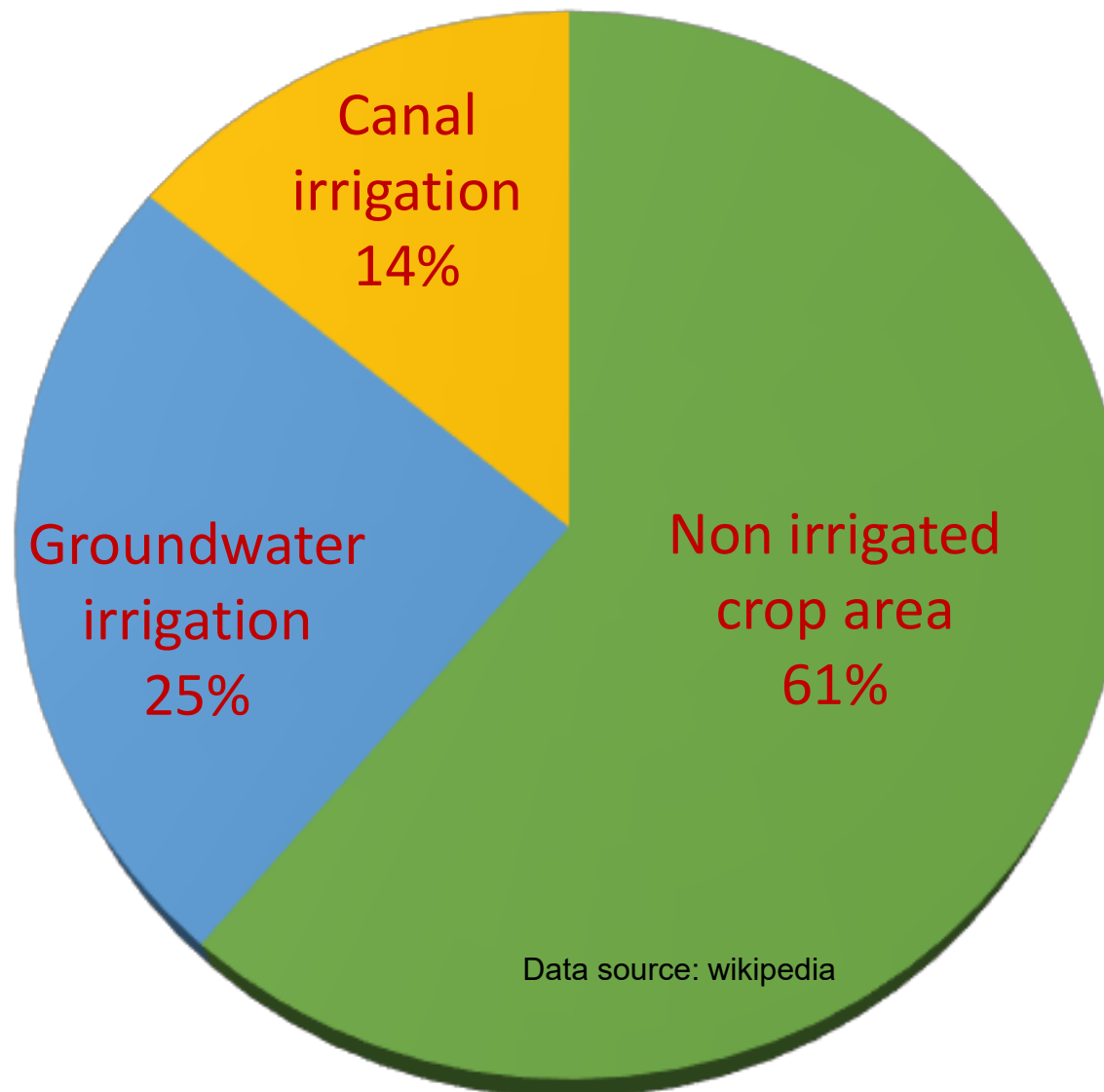
Indian Institutes of Technology consortium (2011):

Environmental Flows – State-of-the-Art with special reference to Rivers in the Ganga River Basins

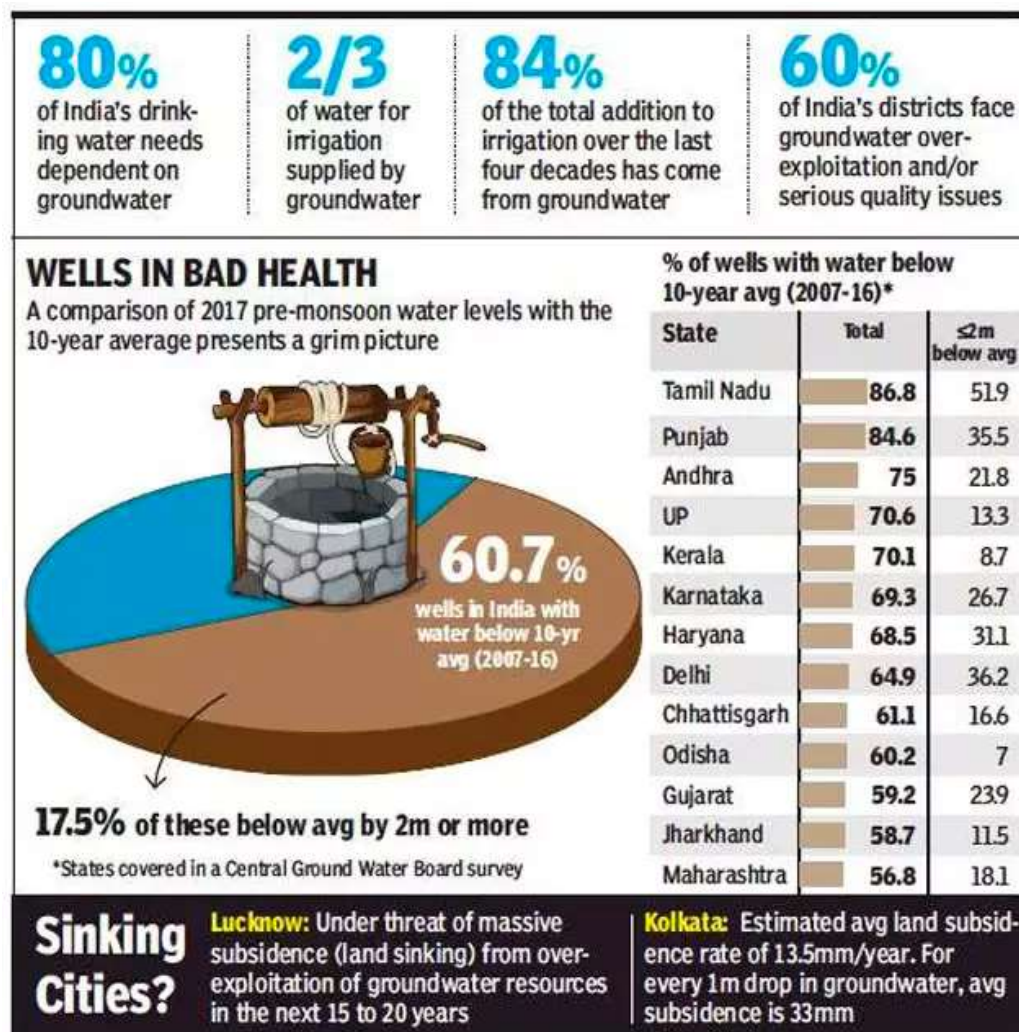
Cultural riverscapes



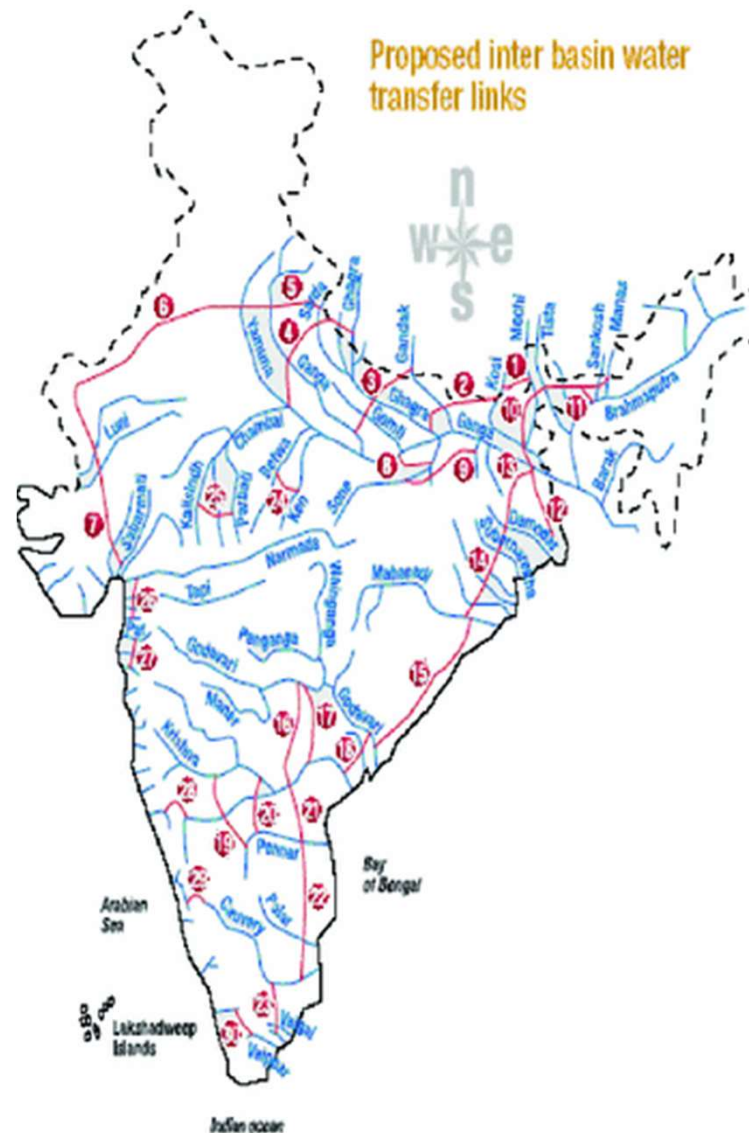
Water for food production in India



Groundwater overexploitation



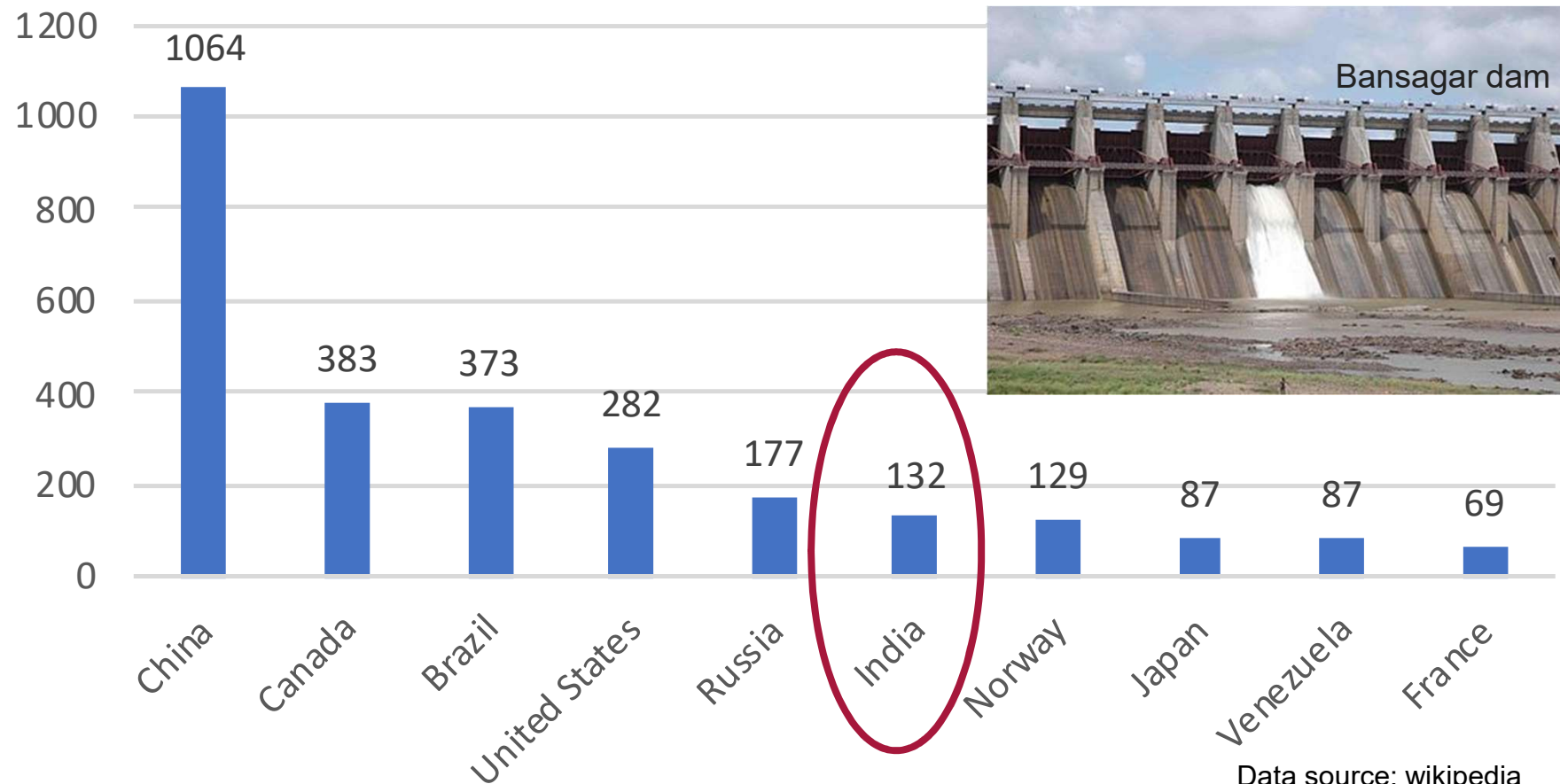
Inter water basin transfer



- 1 Kosi - Mechi
- 2 Kosi - Ghagra
- 3 Gandak - Ganga
- 4 Ghagra - Yamuna
- 5 Sarda - Yamuna
- 6 Yamuna - Rajasthan
- 7 Rajasthan - Sabarmati
- 8 Chunar - Sone Barrage
- 9 Sone Dam - Southern Tributaries of Ganga
- 10 Manas - Sankosh - Tista - Ganga
- 11 Jogighopa - Tista - Farakka (alternative)
- 12 Farakka - Sunderbans
- 13 Ganga (Farakka) - Damodar - Subernarekha
- 14 Subernarekha - Mahanadi
- 15 Mahanadi (Manibhadra) - Godavari (Dowlaiswaram)
- 16 Godavari (Inchampalli) - Krishna (Nagarjunasagar)
- 17 Godavari (Inchampalli) - Krishna (Pulichintala)
- 18 Godavari (Polavaram) - Krishna (Vijayawada)
- 19 Krishna (Almatti) - Pennar
- 20 Krishna (Srisaillam) - Pennar
- 21 Krishna (Nagarjunasagar) - Pennar (Somasila)
- 22 Pennar (Somasila) - Palar - Cauvery (Grand Anicut)
- 23 Cauvery (Kattalai) - Vaigai - Gundar
- 24 Ken - Betwa
- 25 Parbati - Kalisindh - Chambal
- 26 Par - Tapi - Narmada
- 27 Damanganga - Pinjal
- 28 Bedti - Varda
- 29 Netravati - Hemavati
- 30 Pamba - Achankovil - Vaippar

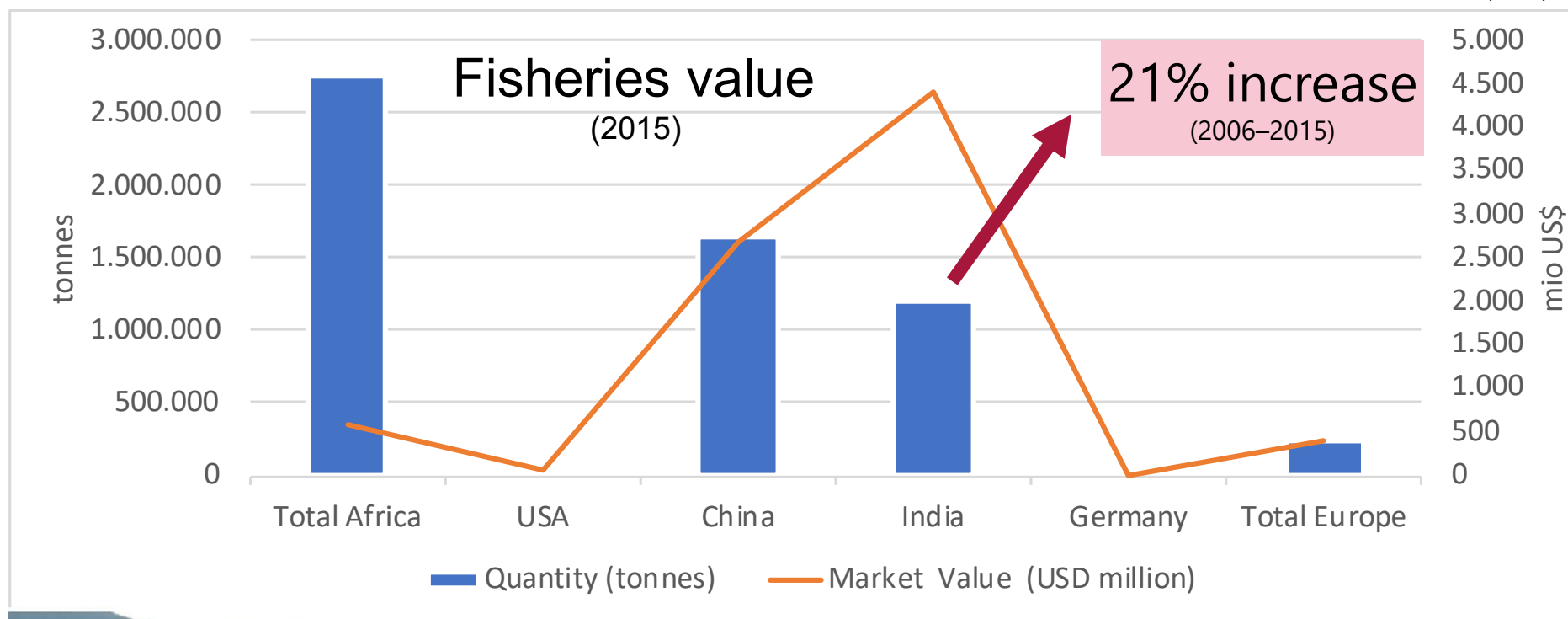
Hydropower

Production (TWh)



Ecosystem services: Fisheries

Data source: Smith, S. F. and Bennett, A. (2019)



India: 5 % of agricultural GDP
14 mio. employees

E-flow support the spiritual, cultural and livelihood activities that depend on these ecosystems



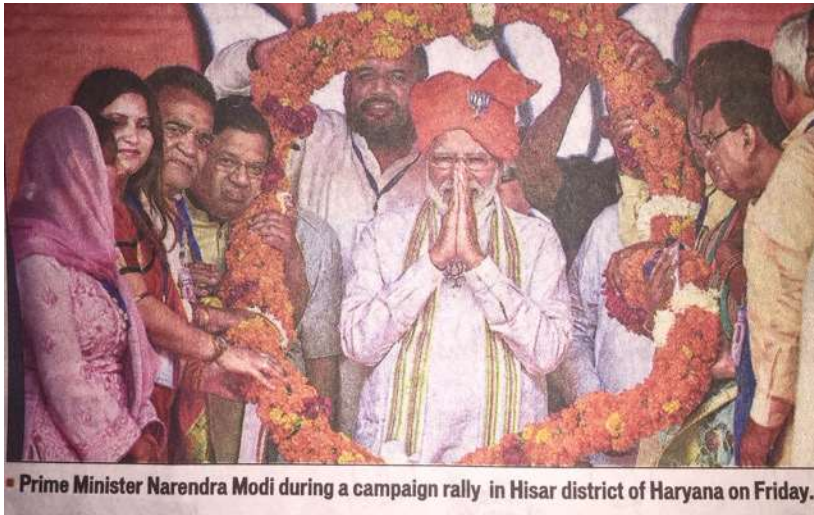
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WWF 2017

Political statements on water

TNN, 19 October 2019



for this. We have started India's biggest water campaign so that every house and every farm gets sufficient water," he said.

Rs 3.5 lakh crore will be invested for water in next 5 years: PM Narendra Modi

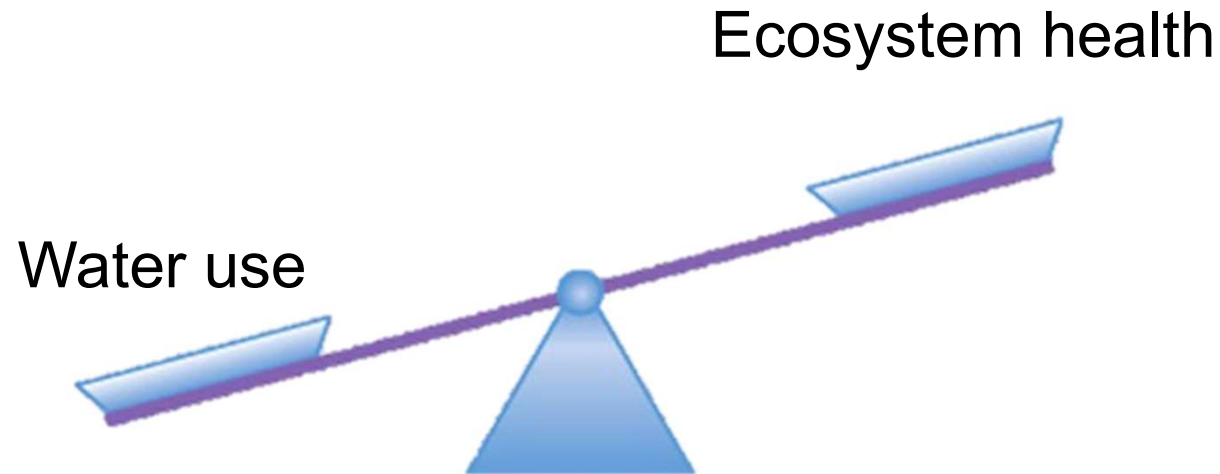
TNN | Updated: Oct 19, 2019, 7:56 IST

  A- A+

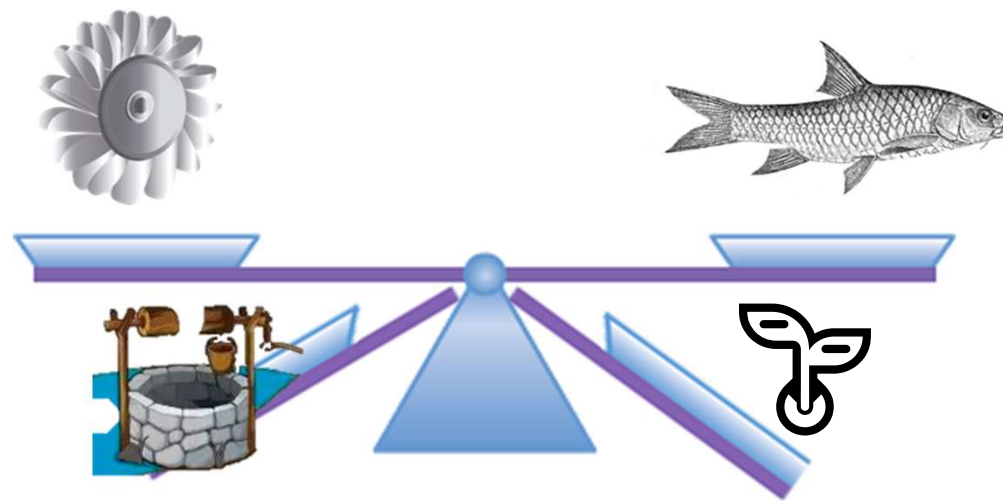


HISAR/GOHANA : Prime Minister Narendra Modi on Friday said that his government would invest Rs 3.5 lakh crore in five years to cater to the need of water for drinking and irrigation purposes.

The role of e-flow in balancing water use and ecosystem health



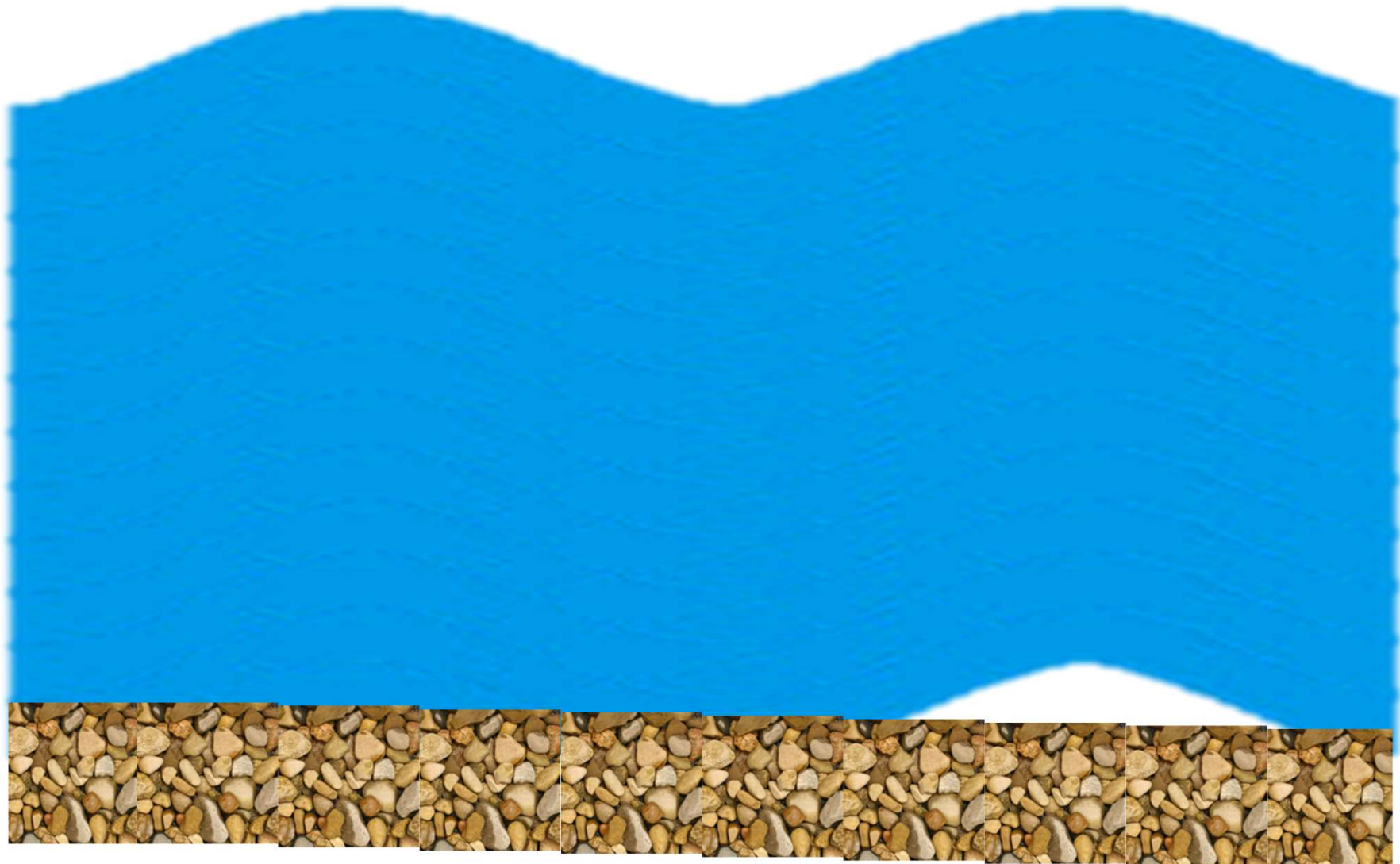
Balancing multiple ecosystem services



How much water does the river need?



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E-flow methods

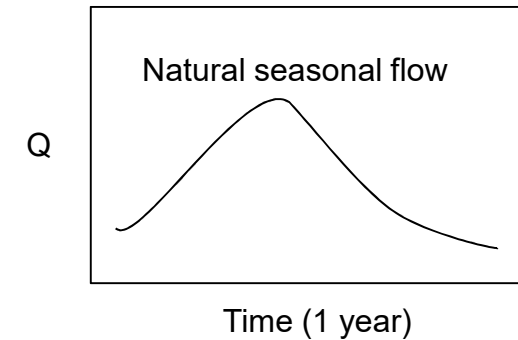
Predictive methods

Expert judgement

Hydrological methods



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E-flow methods

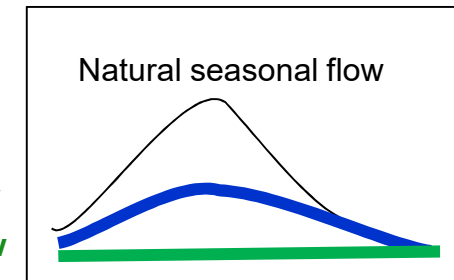
Predictive methods

Expert judgement

Hydrological methods

- Tennant or Montana method
 - % Q
- RVA: range of variability approach (Richter et al. 1997)
 - Criteria related to timing, duration, frequency, and rate of change

Q
Dynamic e-flow
Minimum e-flow



Discharge dynamics

4 important principles of natural flow

Principle 3

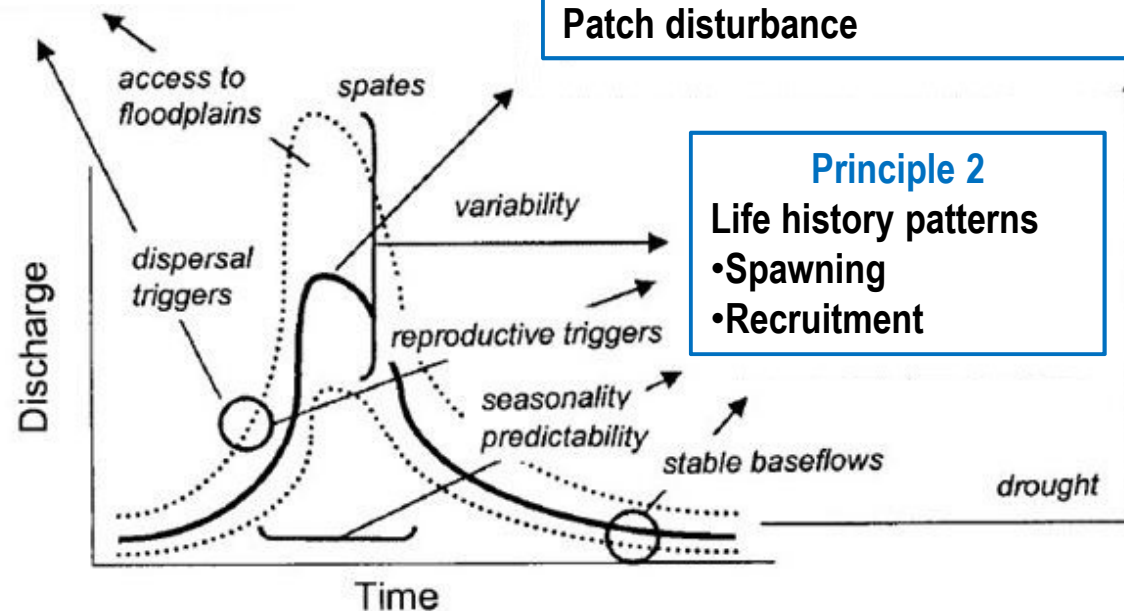
Lateral connectivity
Longitudinal connectivity

Principle 1

Channel form
Habitat complexity → biotic diversity
Patch disturbance

Principle 2

Life history patterns
•Spawning
•Recruitment



Principle 4

Natural regime discourages invasions

Ecological flow implementation in Austria

	Natural mean annual flow <1 m ³ /s	Natural mean annual flow >1 m ³ /s
Minimum flow	> lowest daily flow > 50 % mean annual low flow	> 33 % mean annual low flow
Dynamic flow	20 % of actual flow (recommended)	
Or: Case-specific habitat modelling		



E-flow methods

Predictive methods

Expert judgement

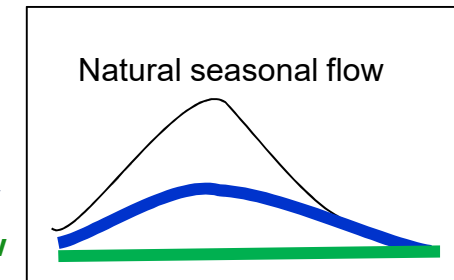
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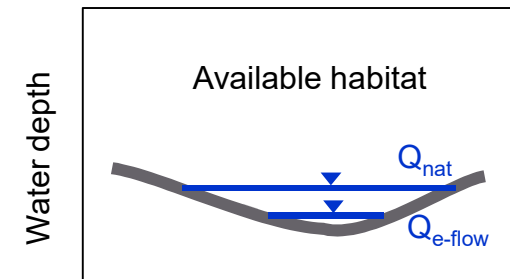
Hydraulic methods

- Hydraulic rating

Q
Dynamic e-flow
Minimum e-flow



Time (1 year)



River width

E-flow methods

Predictive methods

Expert judgement

Hydrological methods

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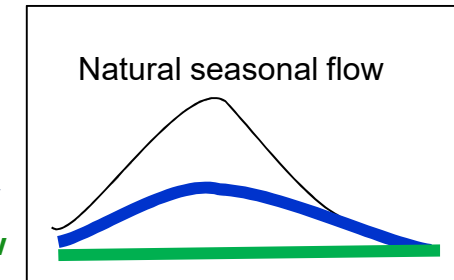
Hydraulic methods

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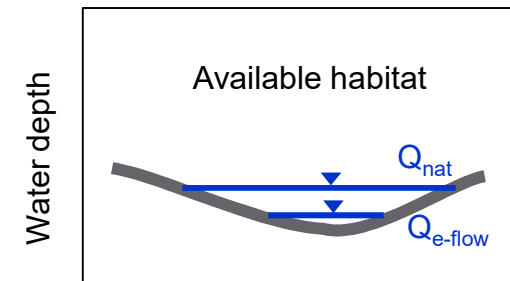
Habitat modelling

- Linking physical habitat with biotic requirements
 - PHabSim, Meso-Habsim, Casimir, etc.

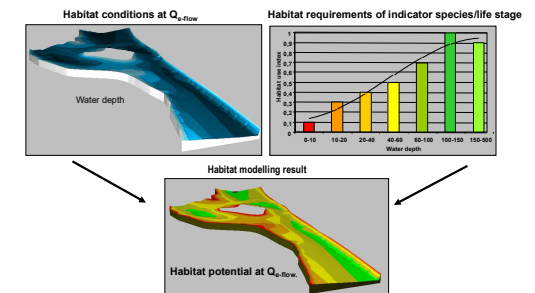
Q
Dynamic e-flow
Minimum e-flow



Time (1 year)

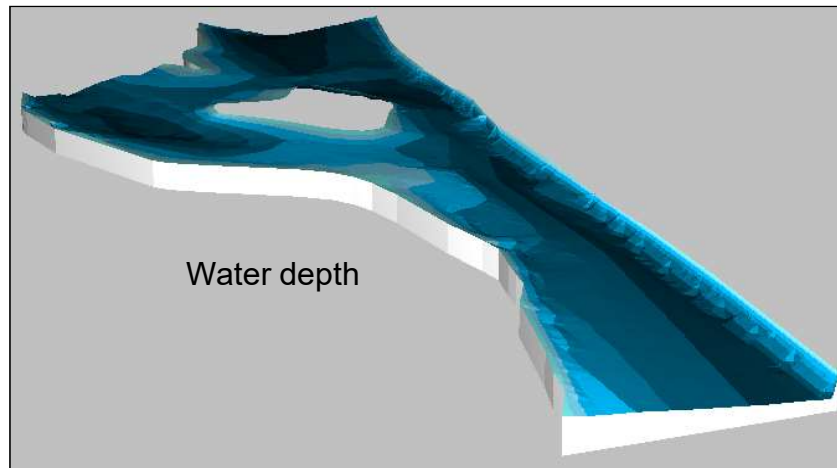


River width

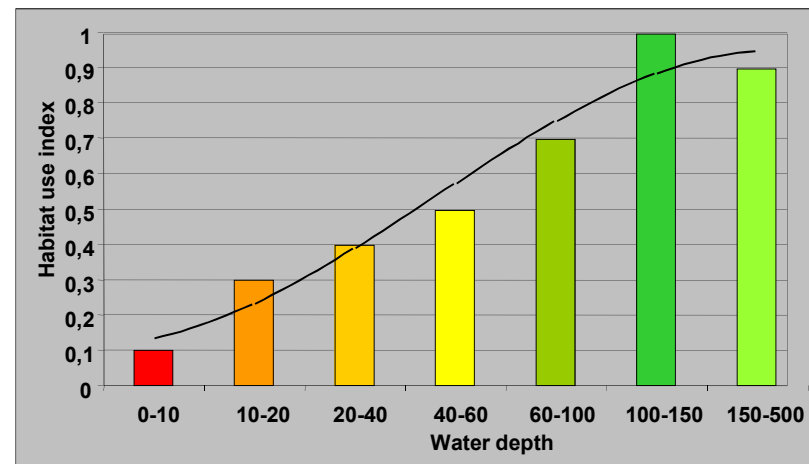


Habitat modelling

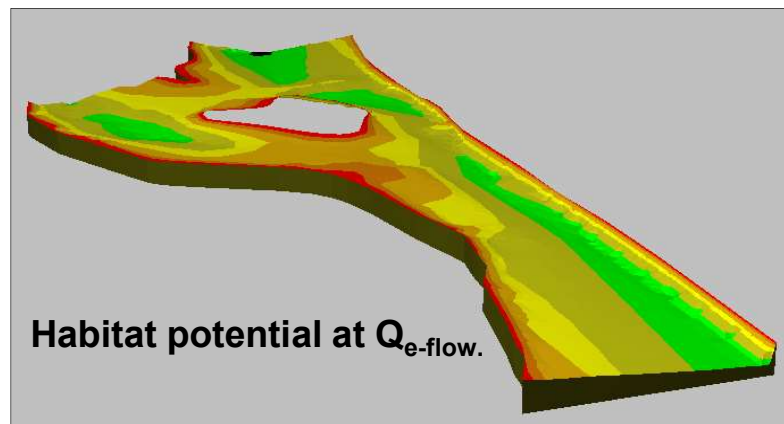
Habitat conditions at Q_{e-flow}



Habitat requirements of indicator species/life stage

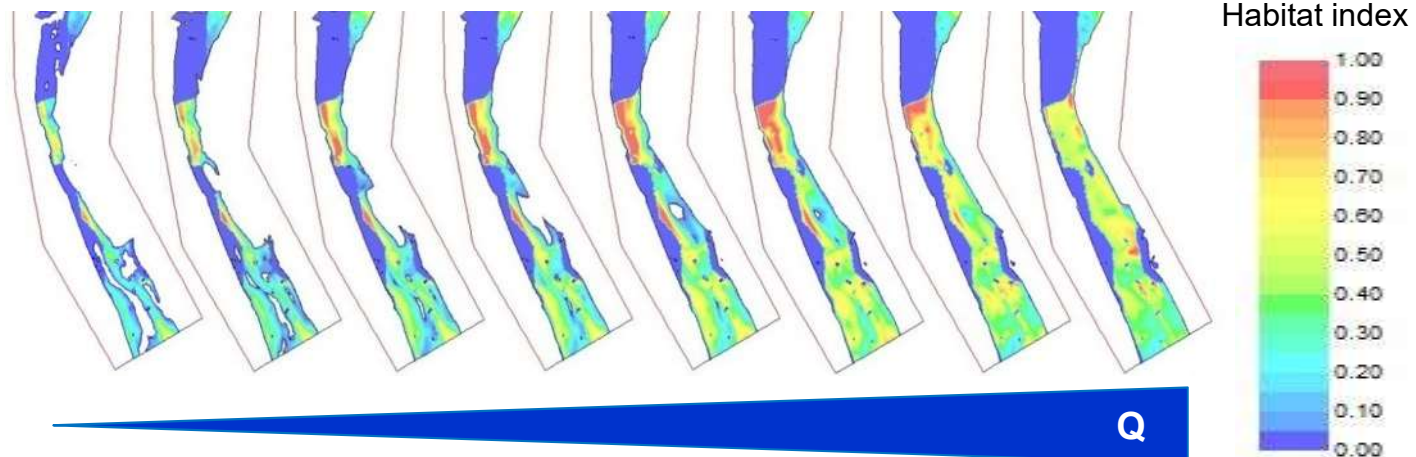


Habitat modelling result



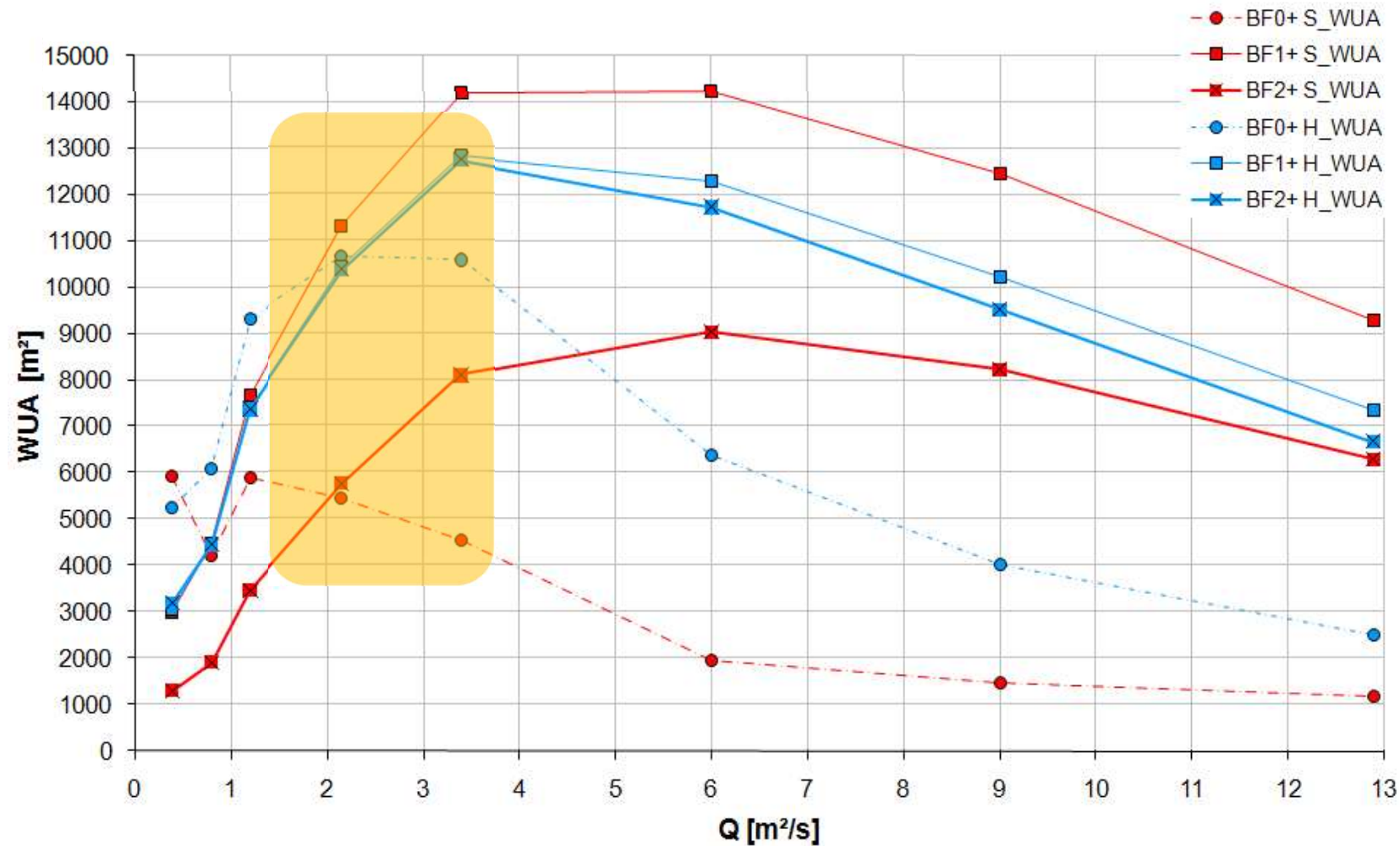
Habitat modelling

- **Linking hydrological changes with habitats and biotic responses**
 - Habitat of indicator species
 - Habitat conditions and habitat use
 - depth
 - velocity
 - substrate composition
 - cover
 - ...
- Expressed for different
- life stages
 - seasons
 - functions (e.g. spawning, feeding, resting)
- Quality and quantity of suitable habitat at different flows are assessed and compared



HABITAT MODELLING RESULTS

Habitat availability for brown trout (BF) juveniles (0+), subadults (1+) and adults (2+) during summer (S) and autumn (H)



E-flow methods

Predictive methods

Expert judgement

Hydrological methods

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Hydraulic methods

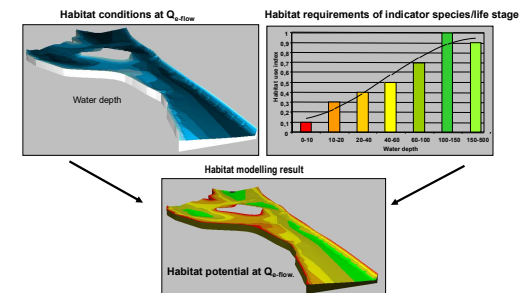
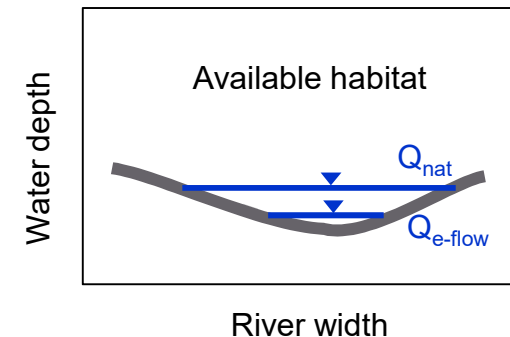
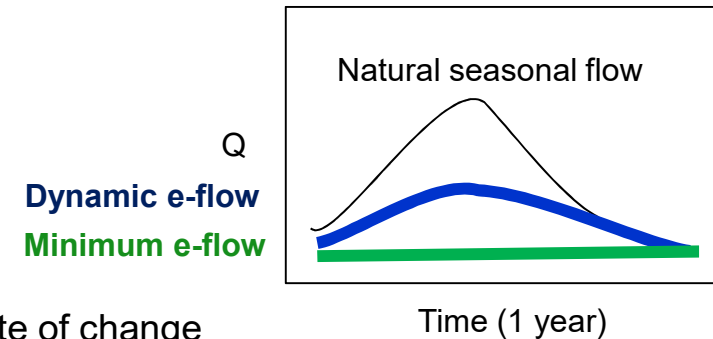
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Integrative methods

- multidisciplinary, multiple ecosystem components, various spatial temporal scales

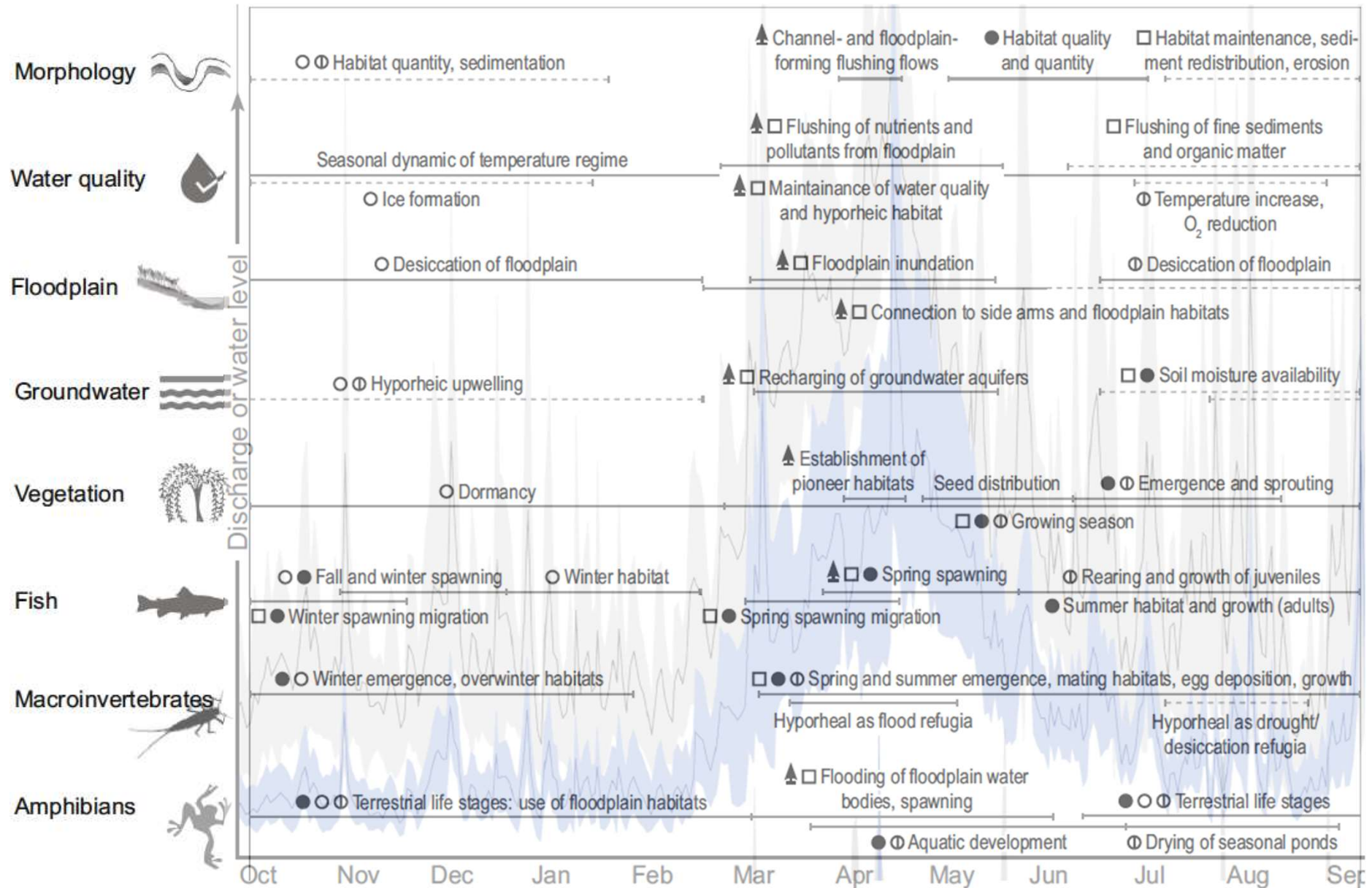


Integrative e-flow methods



- **Multidisciplinary**
 - Engineers
 - Ecologists
 - Socio-economists
- **Multiple ecosystem components**
 - fish, benthic fauna, macrophytes, riparian vegetation, floodplains
- **Various spatial temporal scales**
 - catchment approach, transboundary effects, short to long term effects
- **Scenario based**
 - Historical, present, future situation including management alternatives and climate change scenarios
- **Examples**
 - Building Block Methodology (BBM) (Tharme and King 1998; King et al. 2008),
 - Downstream Response to Imposed Flow Transformations (DRIFT) (King and Brown 2006),
 - Ecological Limits of Hydrologic Alteration (ELOHA) (Poff et al. 2010).

Integrative e-flow methods



E-flow methods

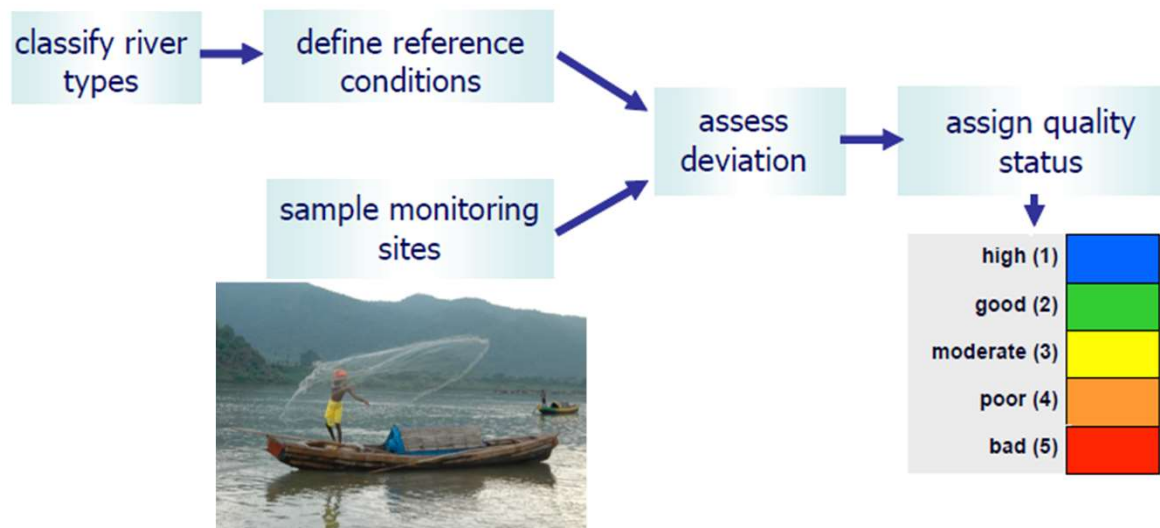


Post-implementation assessment methods

Assessing ecological status

EU-Water Framework Directive

- River need to achieve the good ecological status which ...
- ... is measured via biological quality elements



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

Levels of Biological Condition

Natural structural, functional, and taxonomic integrity is preserved.

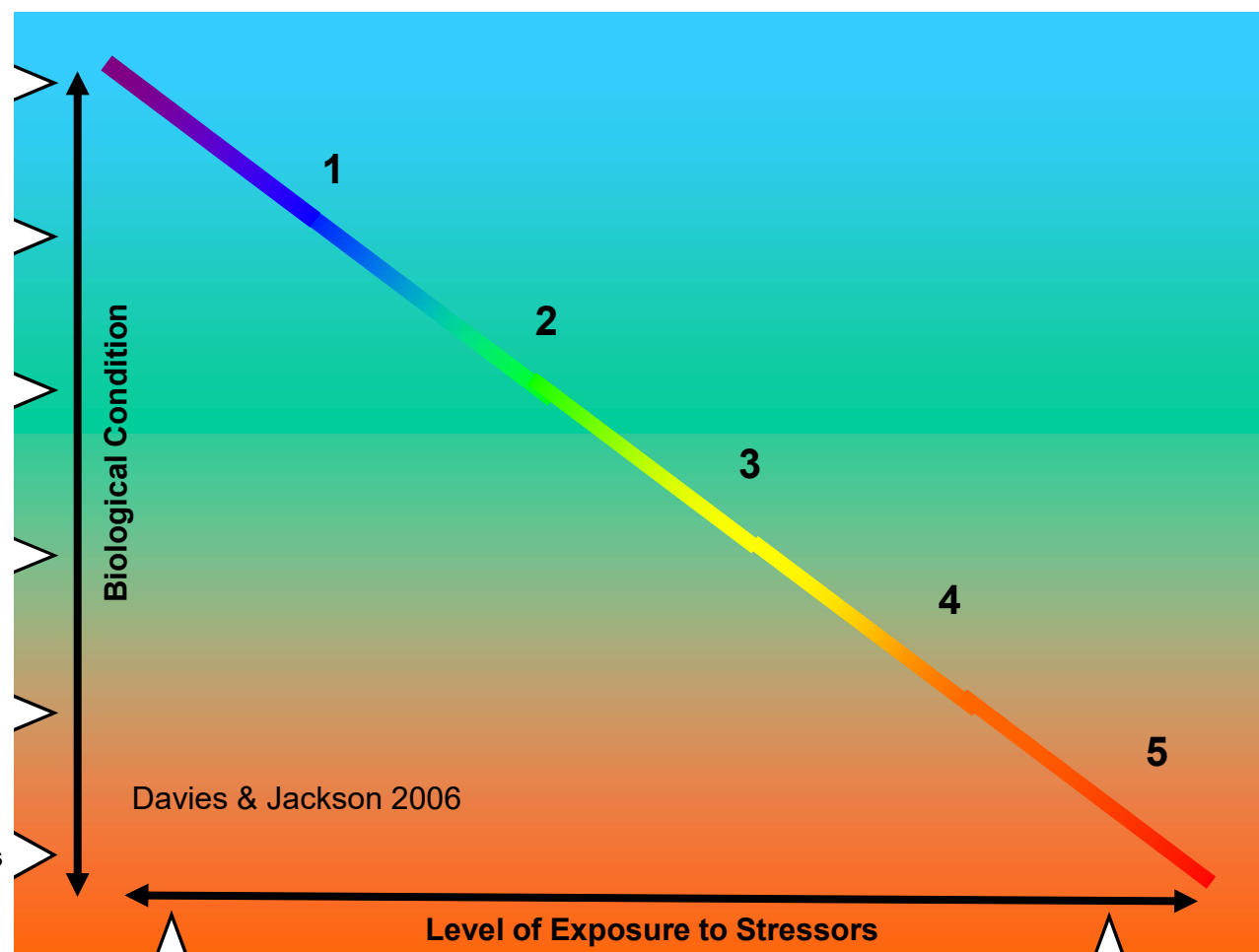
Structure & function similar to natural community with some additional taxa & biomass; ecosystem level functions are fully maintained.

Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained.

Moderate changes in structure due to replacement of sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained.

Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy.

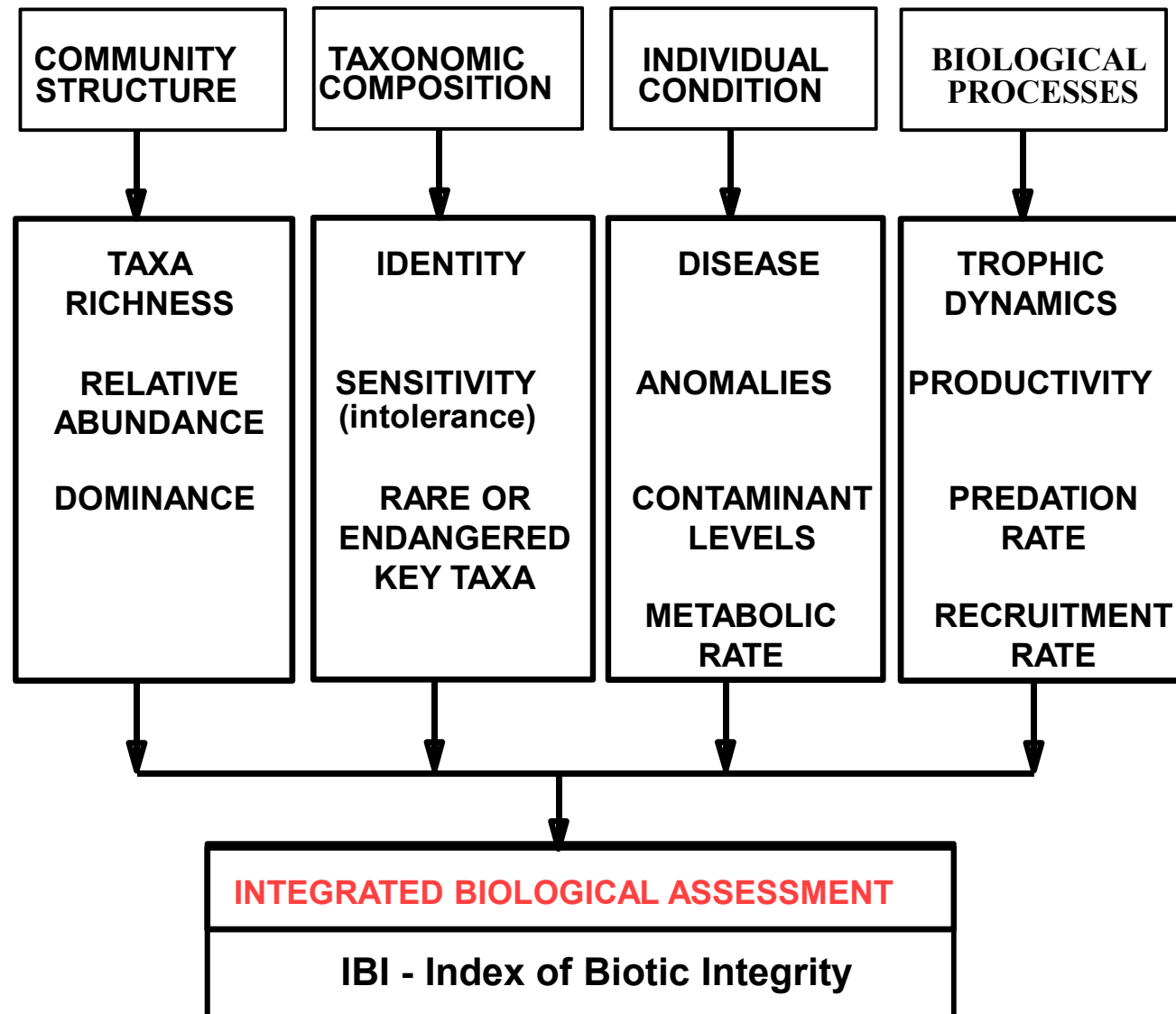
Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.



Watershed, habitat, flow regime and water chemistry as naturally occurs.

Chemistry, habitat, and/or flow regime severely altered from natural conditions.

ORGANIZATIONAL STRUCTURE OF ECOLOGICALLY RELEVANT ATTRIBUTES

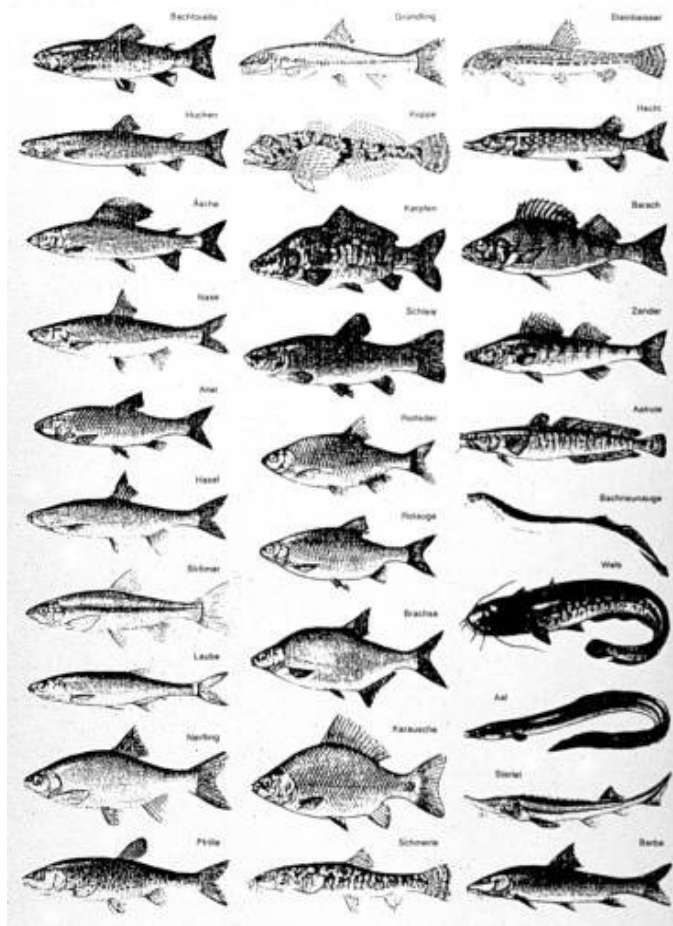


Species trait classifications

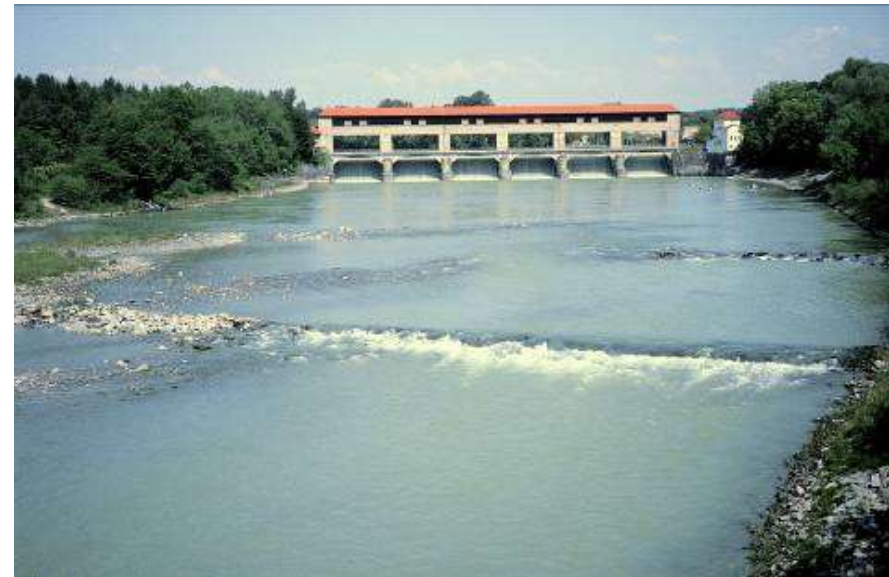
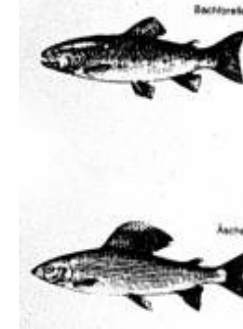
Habitat	rheophilous, limnophilous, eurytopic
Reproduction	lithophilous, phytophilous, psammophilous
Feeding	insectivorous, piscivorous, omnivorous,....
Feeding habitat	water column, benthic
Migration	diadromous, potamodromous
Body size	small, medium, large
Longevity	short-living, long-living
O₂ tolerance	tolerant, intolerant
General tolerance	tolerant, intolerant

After damming

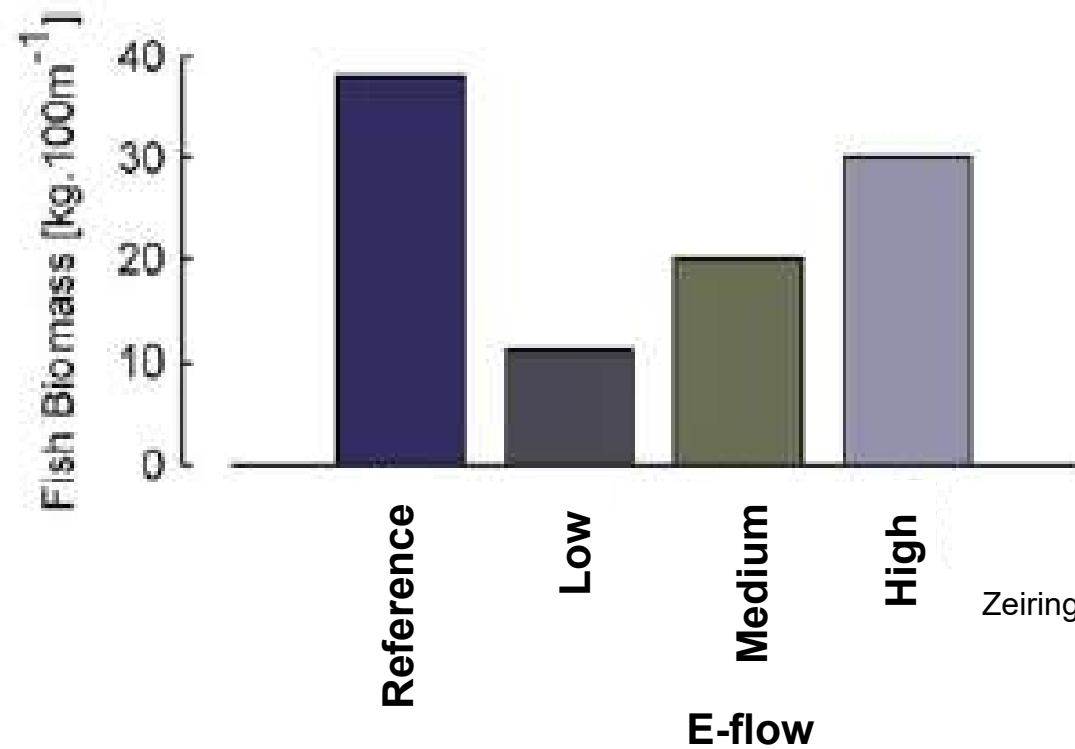
Species Diversity of River Inn until 1920



Species Diversity of River Inn 1989



More water - more fish production

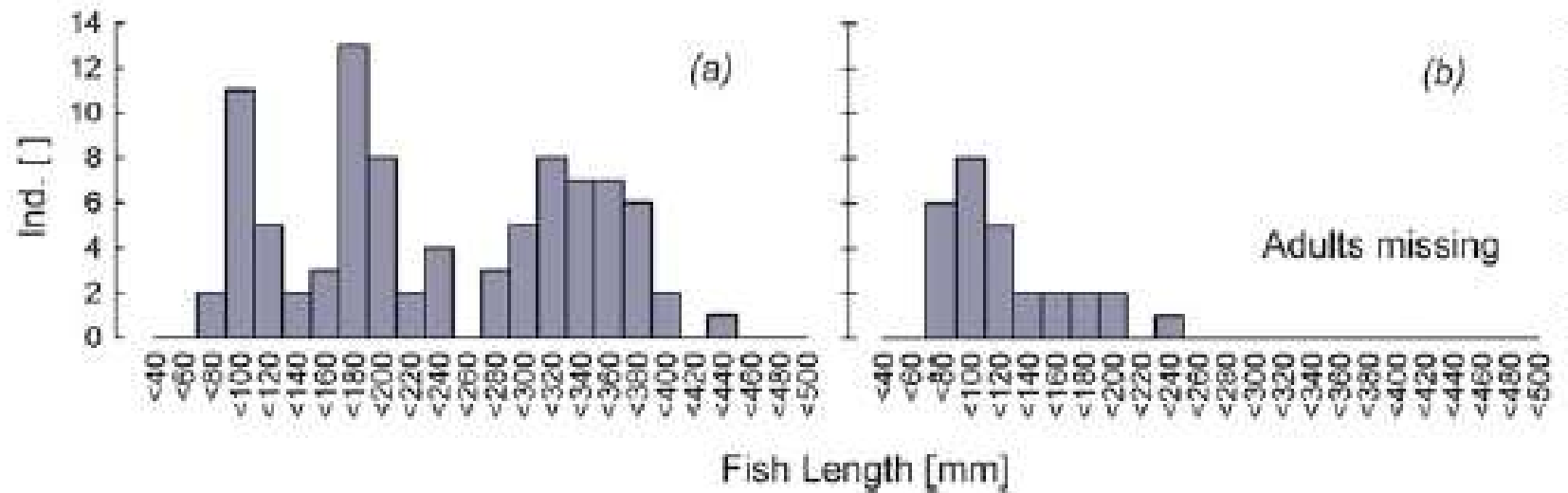


Zeiringer et al. 2018

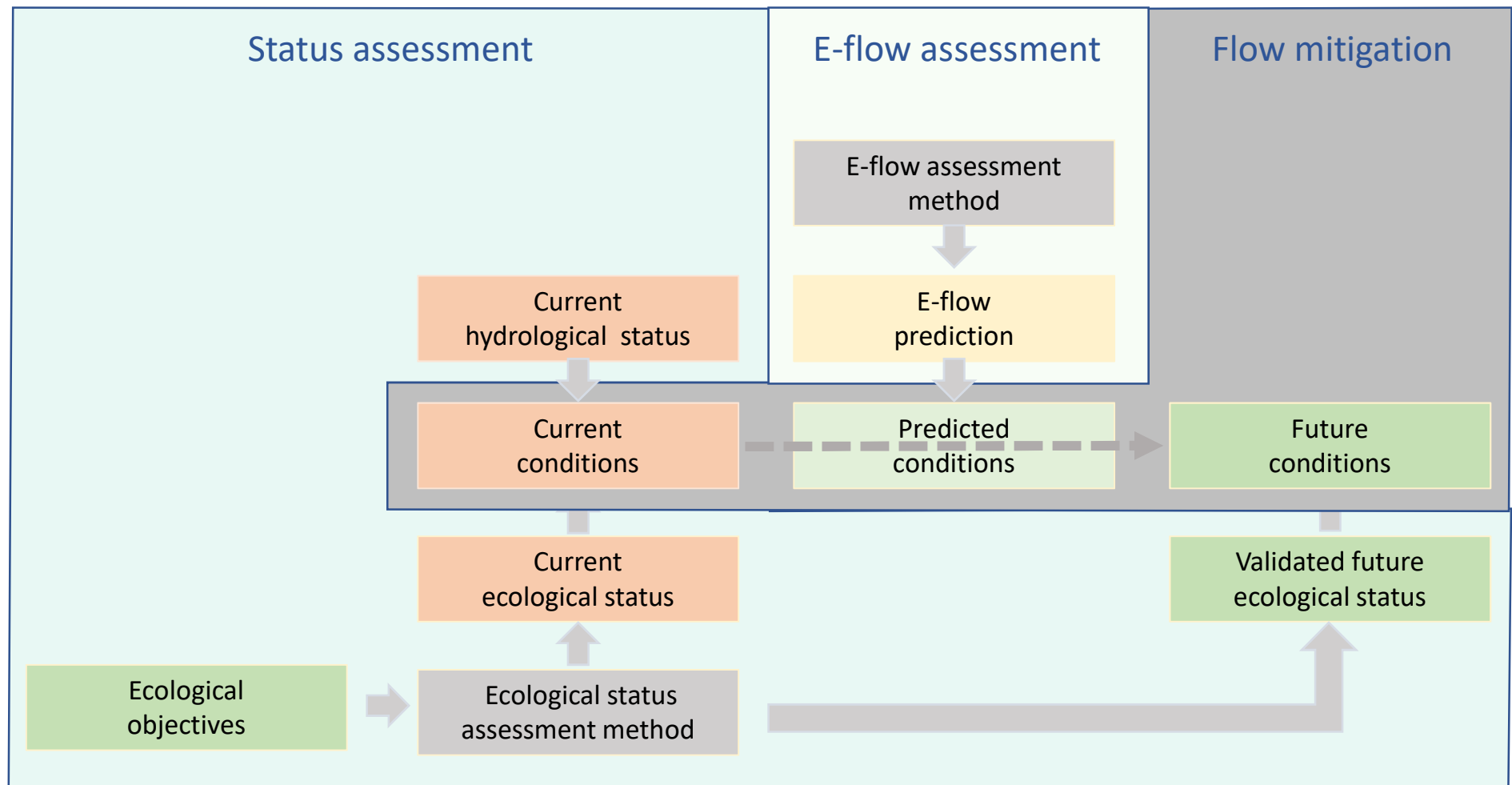
More water - larger fish

Full flow

Unsufficient e-flow



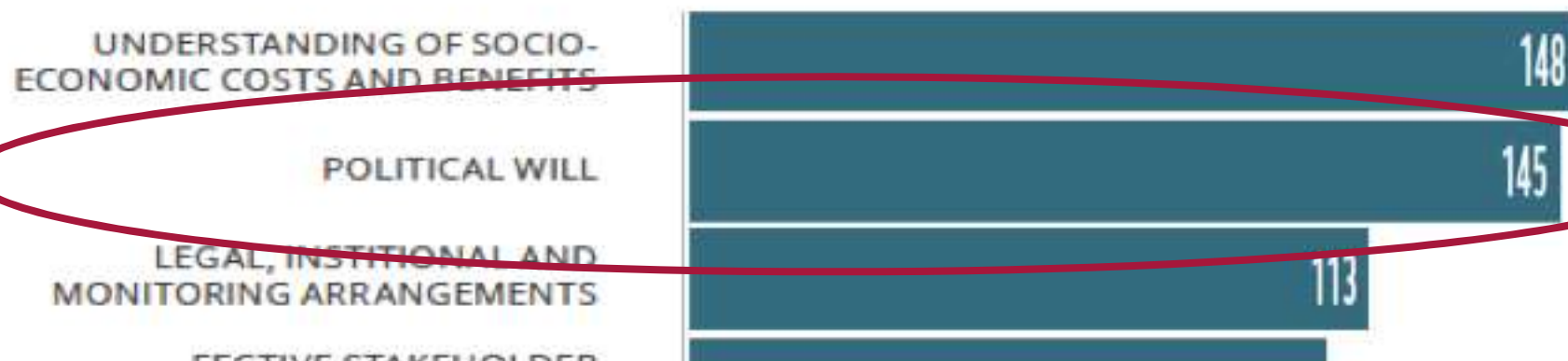
E-flow versus post-implementation assessment



E-flow implementation

Barriers in implementing e-flow

Moore 2004 in WWF 2017



Press Information Bureau
Government of India
Ministry of Water Resources

20-30% of flow
24-57 m³/s

10-October-2018 17:41 IST

Nitin Gadkari Says Notification of E-Flow for Ganga is a Significant Step

He Reiterates Government's Commitment towards Aviral and Nirmal Ganga Says Draft Ganga Act will Soon be sent to Cabinet for Approval



Data availability

Ecological data

- About **500 freshwater fish species** are known for India with around **65% being endemic** (wikipedia)
- **120 fish species are threatened** (EN, VU, IUCN criteria)



Ecological data



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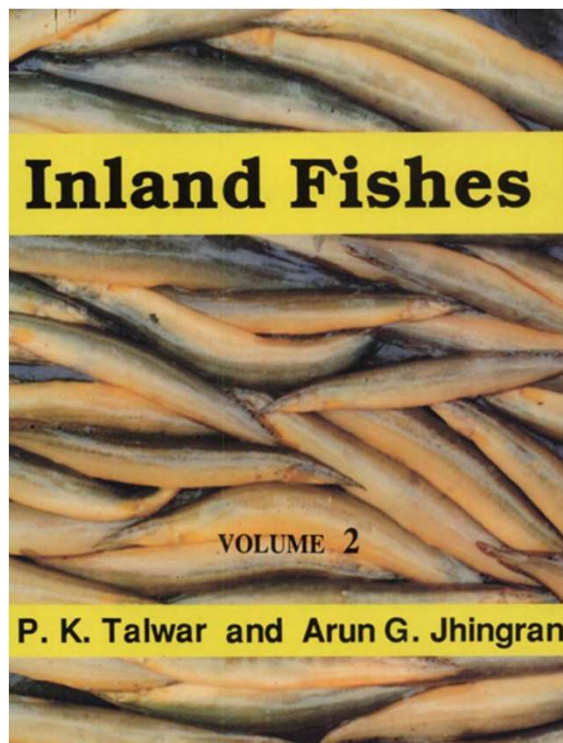
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Knowledge on fish fauna, diversity and assemblages



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Ichthyofaunal diversity of Nandurbar District (Northwest Khandesh Region) of Maharashtra (India).

S. S. Patole

Abstract

Ichthyofaunal diversity is carried out during the study period November 2013 to April 2014 in the rivers, streams, reservoirs or ponds of Nandurbar district lays in the northwest region of Maharashtra state. The district is transverse by the river Tapi and its principal tributaries, viz., the Gomti, the Vir, the Rangavali, the Daheli and the Shivan River etc. The survey was made from nine collection centers spread over the entire district. In present study of 83 specimens observed that the ichthyofauna belongs to 6 orders, 11 families, 24 genus and 32 species, were Cypriniformes order is dominant with 19 (59.40%) species followed by Perciformes and Siluriformes with 05 (15.60%) species. Belontiiformes, Clupeiformes and Osteoglossiformes contribute 01 (3.10%) species each. As no attempt had been made in the past to explore the ichthyofaunal diversity of this region. All the species reported in present investigation are reporting first time under mopping survey programme. It is concluded that the fish in this area are under threat due to anthropogenic activities such as overfishing and organic and inorganic pollution of the river. Therefore site based conservation action plants are needed for conservation of rare and threatened fish in this area.

International Journal of Applied Research

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Ichthyofaunal diversity of wan river, tributary of Tapi River

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³ Department of Zoology, Dr. Babasaheb Ambedkar Marathawada University Aurangabad

⁴ Department of Zoology, Late Pundalikrao Gawali Arts and Science Mahavidyalaya, Shirpur (Jain) Dist. Washim

Available knowledge on ecosystem assessment tools in India



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Full Access

Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India

V. Ganasan, Robert M. Hughes

First published: 04 January 2002 | <https://doi.org/10.1046/j.1365-2427.1998.00347.x> |

Cited by: 89



Integrative assessment of Western Himalayas streams using multimetric index

Summya Nazeer^a, Muhammad Zaffar Hashmi^{b,*}, Riffat Naseem Malik^{c,*}, Abdul Qadir^d, Altaf Ahmad^b, Kalim Ullah^b

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Journal
Aquatic Ecosystem Health & Management
Volume 16, 2013 - Issue 4: Ecology of the Mighty Ganges: Health, Fisheries and Management

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Original Articles

Fish diversity, community structure and ecological integrity of the tropical River Ganges, India

M. K. Das, A. P. Sharma, K. K. Vass, R. K. Tyagi, V. R. Suresh, M. Naskar & ...show all
Pages 395-407 | Published online: 11 Dec 2013

[Download citation](#) <https://doi.org/10.1080/14634988.2013.851592>

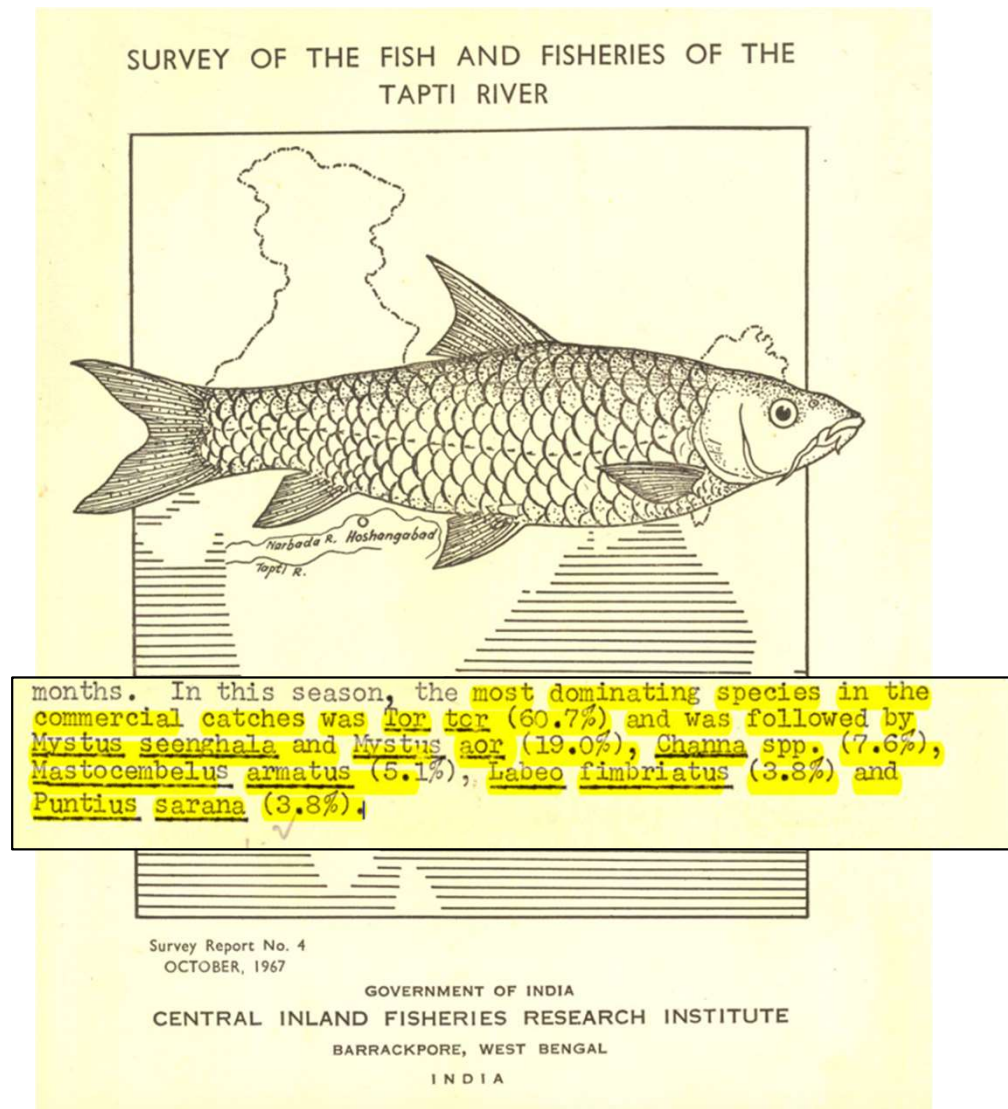
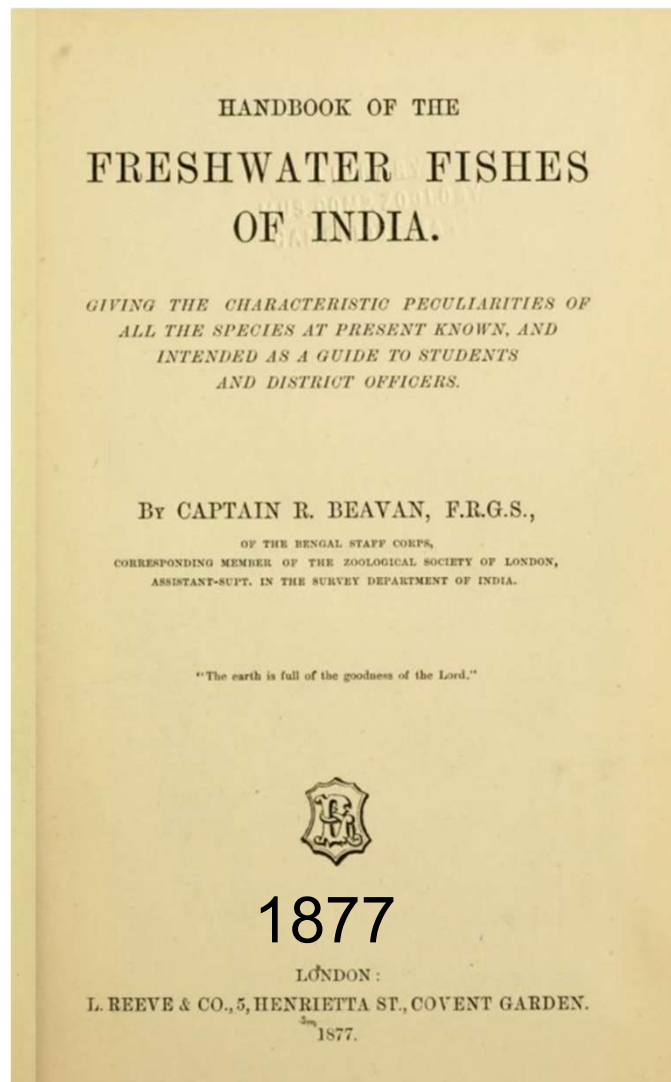
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- **Historic fish data**

Historic information on fish assemblages



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- **Historic fish data**
- However, **more efforts** are needed to **fill ecological information gaps** (e.g. habitat requirements).

Gaps in ecological field data

Sampling for habitat modelling

substrate classification



flow velocity



river morphology



fish sampling



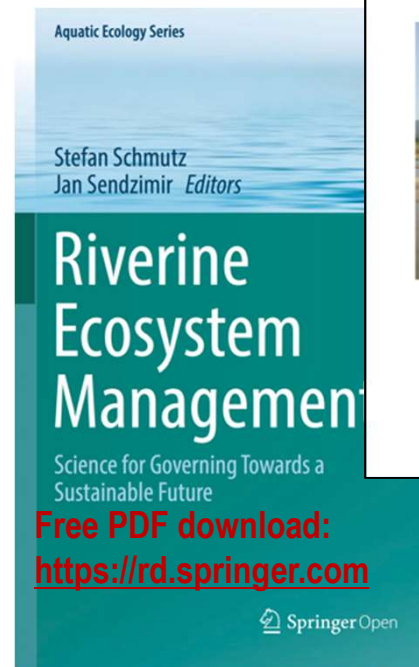
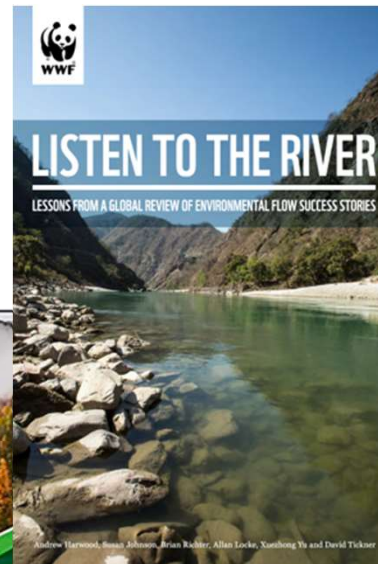
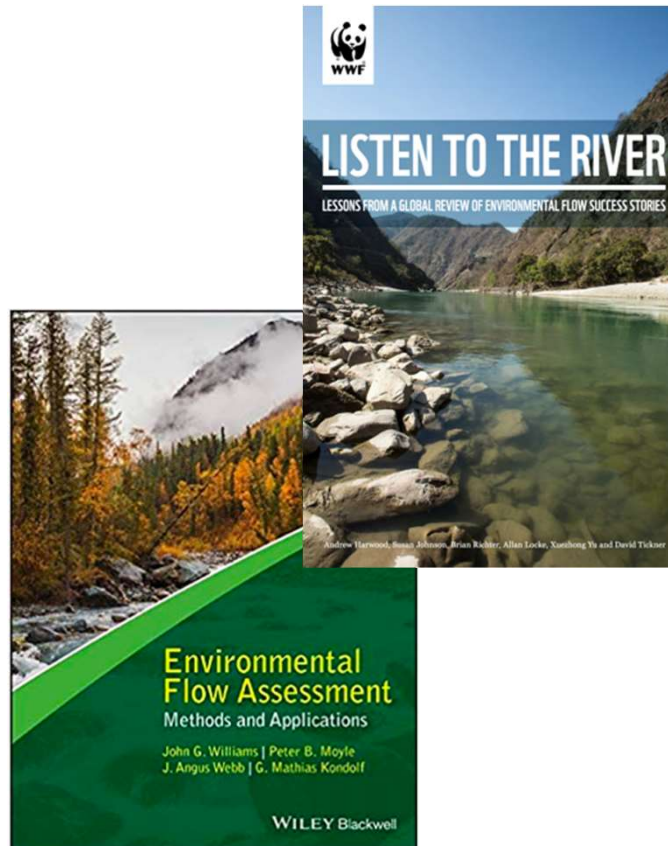
mapping of habitat features



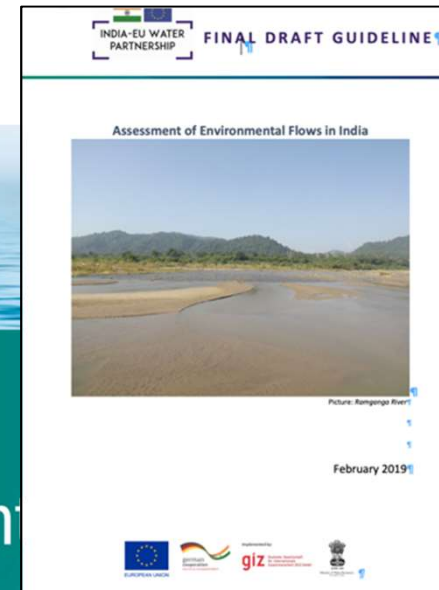
Examples of published books & reports related to e-flow



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And many others

Conclusions



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**The role of ecosystems and e-flow for
human wellbeing**

The role of ecosystems and e-flow for human wellbeing

