Global Analysis of Threats to Freshwater Ecosystems:
What Does This Mean for Humans and for Nature?

Kyle C. McDonald on behalf of Charles J. Vörösmarty and *many, many colleagues*

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14-15 March, Tokyo, Japan

Earth System Science Partnership

GWSP Global Water System Project

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Goals for This Discussion

- Describe chief forces shaping the contemporary and future water systems
- Discuss a global framework to assess *Threats* from two perspectives: *human water security* and *aquatic biodiversity*
- Present key findings and implications

Sanitation & access to clean water

“Engineered” water

“Water…a profoundly local resource”
M. Muller (21 Sept.09)

Urban waters

Agriculture and Water

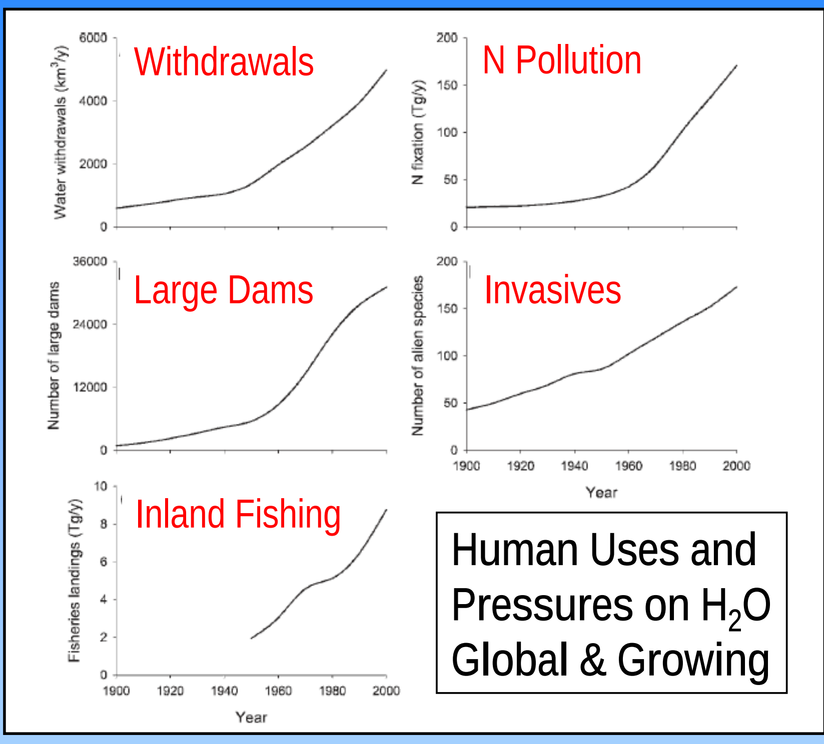
Water for development

Climate change and its extremes

Ecosystem services

Water quality

Yes! But…..



From: Strayer and Dudgeon (2010), J-NABS

Nature: September 30 issue

Can we capture the full dimensionality of this issue & move from a local to a fully global perspective?

…and thus be on par with the global climate change question

***Visit**: www.riverthreat.net*

Major Sources of Threat to Inland Waters: Four *Themes*

Watershed Disturbance

- *Cropland*
- *Imperviousness*
- *Livestock density*
- *Wetland disconnectivity*

Pollutants

- *Soil salinization*
- *Nitrogen loads*
- *Phosphorus loads*
- *Mercury deposition*
- *Pesticide loads*
- *TSS loads*
- *Organic (BOD) loads*
- *Potential for acidification*
- *Thermal impacts*

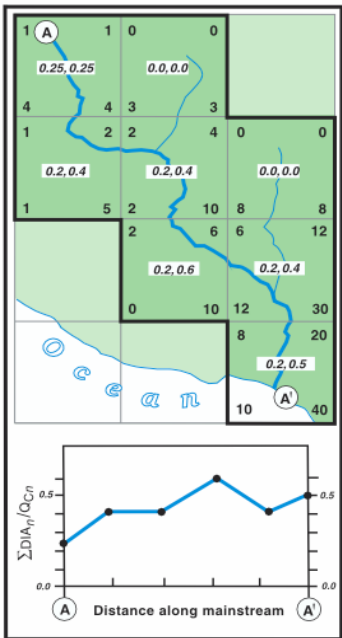
Water Resource Development

- *Small dam density*
- *River network fragmentation*
- *Consumptive use (loss/supply)*
- *Water crowding (population/supply)*
- *Cropland per unit supply*
- *Residency time change (large dams)*

Biotic Threats

- *Invasion level (non-native fish)*
- *Non-native fish species richness*
- *Catch pressure*
- *Aquaculture*

N = 23 global data fields



CALCULATION OF KEY WATER INDICATORS

DIA_n = domestic, industrial, agricultural water use ($km^3\ yr^{-1}$) in cell n

$\sum DIA_n$ = DIA in cell n plus all upstream cells ($km^3\ yr^{-1}$) $= \sum_{i=1}^{n} DIA_i$

R_n = locally-generated runoff (mm/yr)

A_n = area of cell n (km^2)

$Q_{Ln} = 10^6 * R_n * A_n$ = locally generated discharge ($km^3\ yr^{-1}$)

$Q_{Cn} = \sum_{i=1}^{n} Q_{L_i}$ = river corridor discharge ($km^3\ yr^{-1}$)

DIA_n/Q_{Cn} = local relative water use (unitless)

$\sum DIA_n/Q_{Cn}$ = water reuse index (unitless)

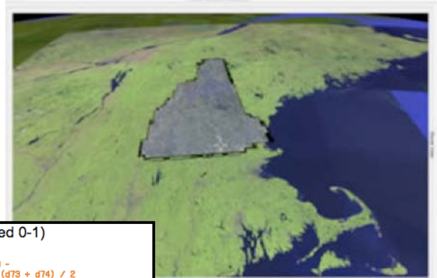
n = position of cell in river network
= total number of upstream cells plus cell in question

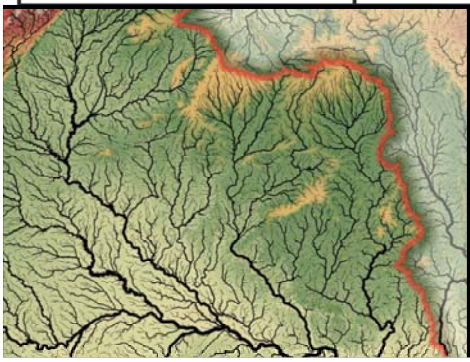
Key (cell n)

Global RIMS

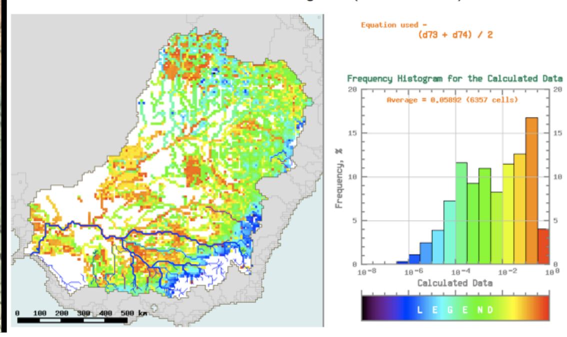
Global Rapid Indicator Mapping System for Water Cycle & Water Resource Assessment

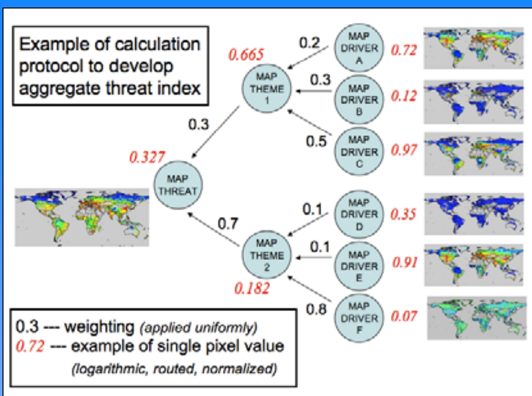
- *DEFINE WATERSHED STATE BASED ON LOCAL AND RECURSIVE INDICES*
- *GOOGLE AND OPEN MAP SERVERS*
- *MAP SYSTEM STATES OVER MULTI-SPACE & TIME SCALES*





Combined Indicator: N Pollution + Timing Shift (normalized 0-1)





Calculation Strategy

- Conjoin classes of threat through consensus-based weightings (0-1)

$$T^k = \sum_{j=1}^{5} \sum_{i=1}^{N_j} W_j^k \omega_{j,i}^k D_i^k$$

- 4 ***Themes***
- 23 within-*Theme* ***Drivers***
- Threat routed through networks, normalized

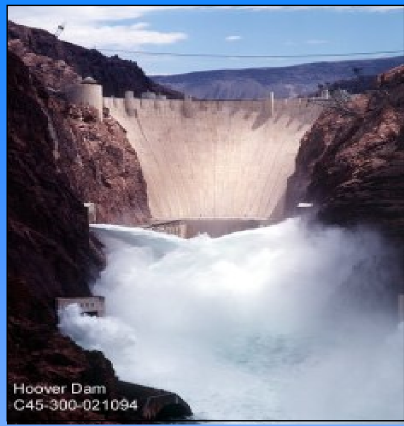
THREAT TO FRESH WATER

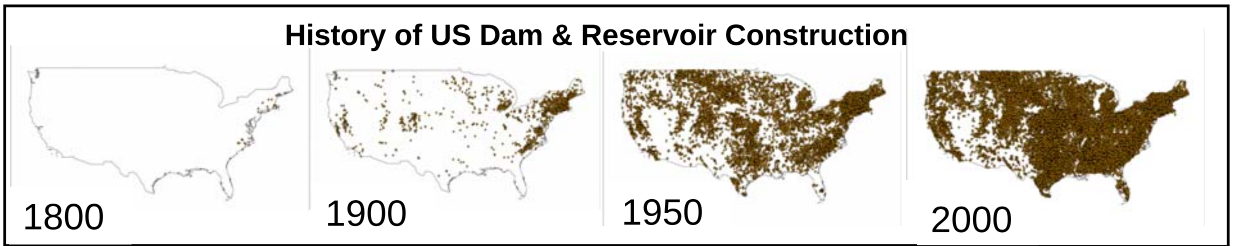
- Relative scoring
- Expert weightings
- Distinct perspectives for *Human Water Security* (*HWS*) and *Biodiversity (BD) Threat* (e.g. dams ⇧ for HWS but ⇩ for BD)
- Beneficiary investments in water-related infrastructure and services recognized for HWS*
  - -Flow stabilization
  - -Access to river corridors
  - -Clean drinking water

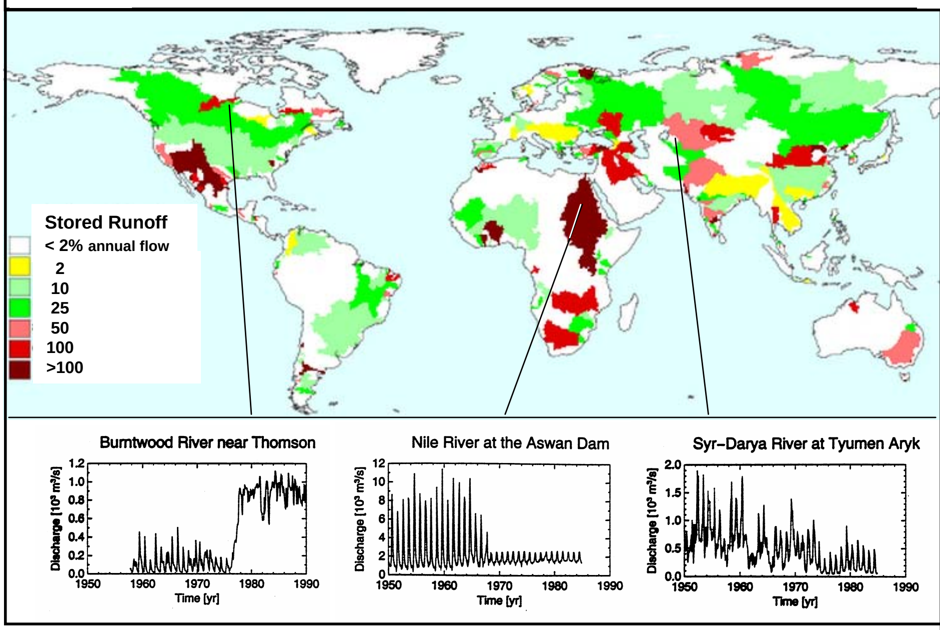
**Likely to be in the Trillions of USD*

Water Management: Engineering, Human Use/Overuse: Core Element of the Contemporary Earth System

- Widespread hydrological alterations arising from
  - *Irrigation*
  - *Dams and Reservoirs*
  - *Interbasin Transfer/Flow Diversion*
- Benefits & concerns: Among these are resource asymmetries in int'l basins
- These are costly “supply-side” or “hard path” solutions to water scarcity



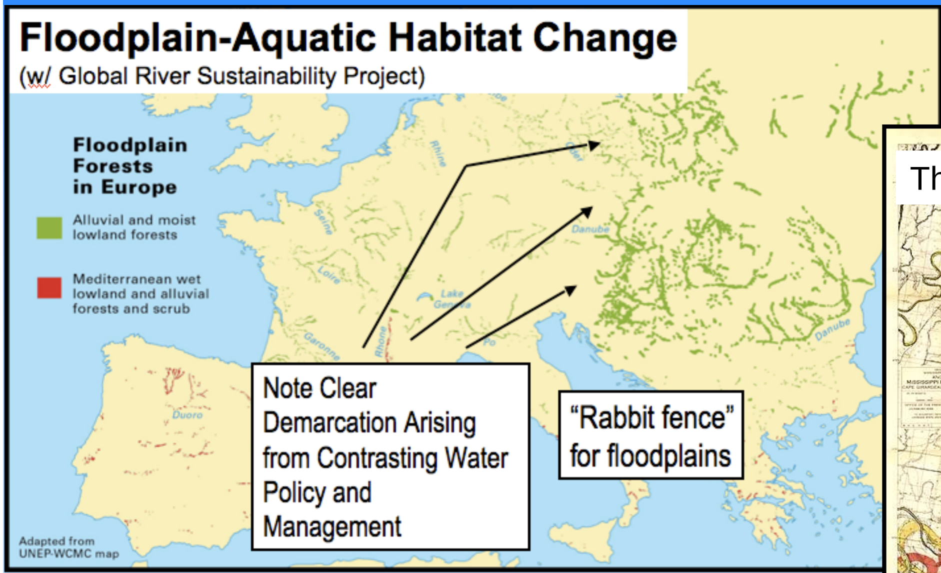


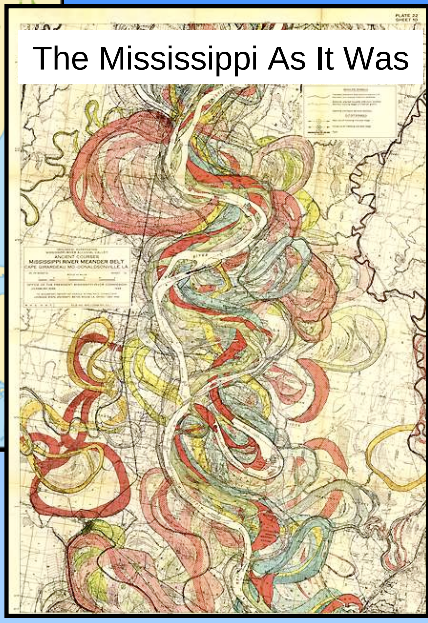


- 700% increase in water held by river systems
- Several years of residence time change in many basins
- Tripling of river runoff travel times globally (from 20 up to 60 days)
- Substantial impact on aquatic biodiversity
- Interception of 30% of continental TSS flux

Framing Committee/GWSP 2004, Eos AGU Transactions

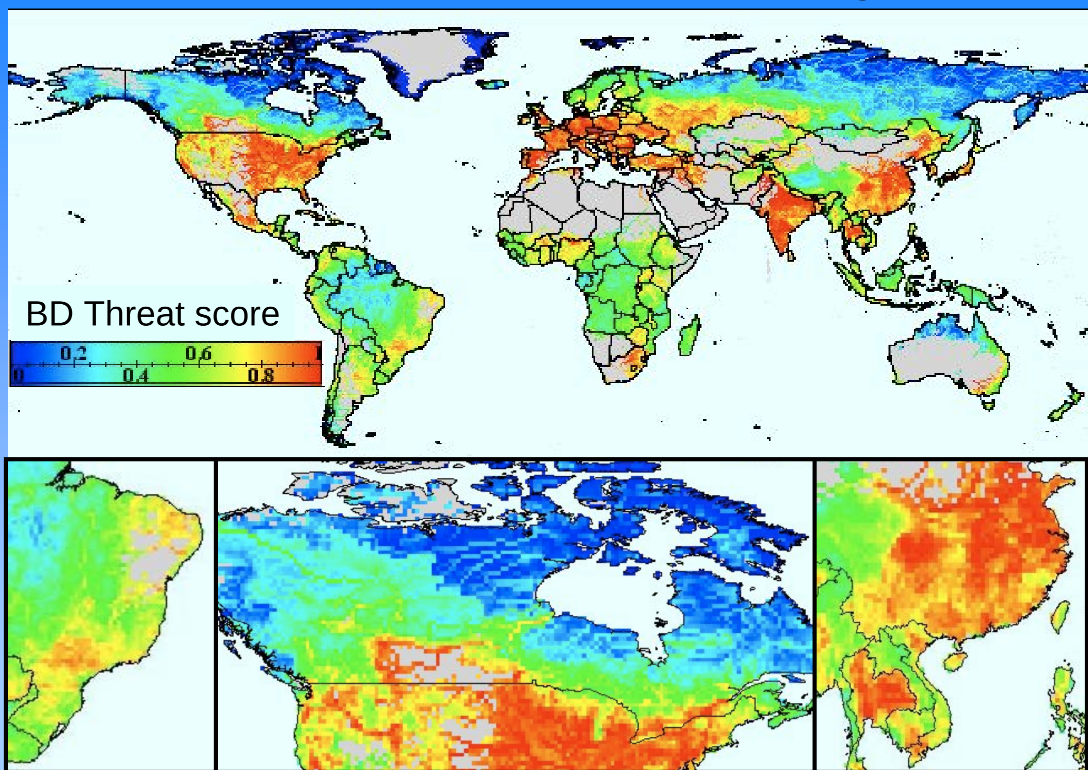
Ecosystem Infrastructure & Services





Globally: Value and impact of loss of natural flood control services are unknown

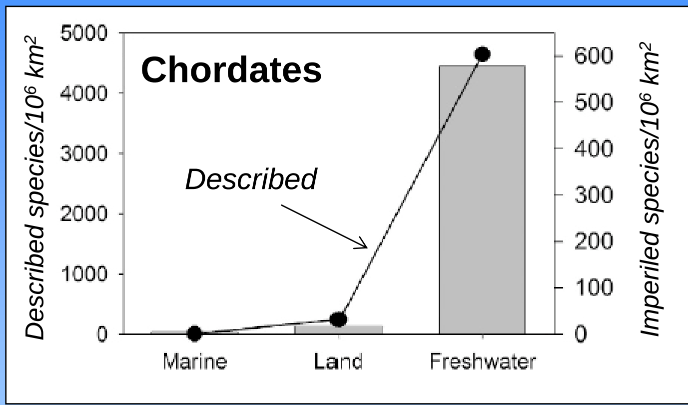
Threat to Biodiversity



- Pandemic
- Generally correlated to population, agriculture, development
- Non-local transboundary and broad transition zones prevail

An Underpinning / Corroboration of BD Loss?

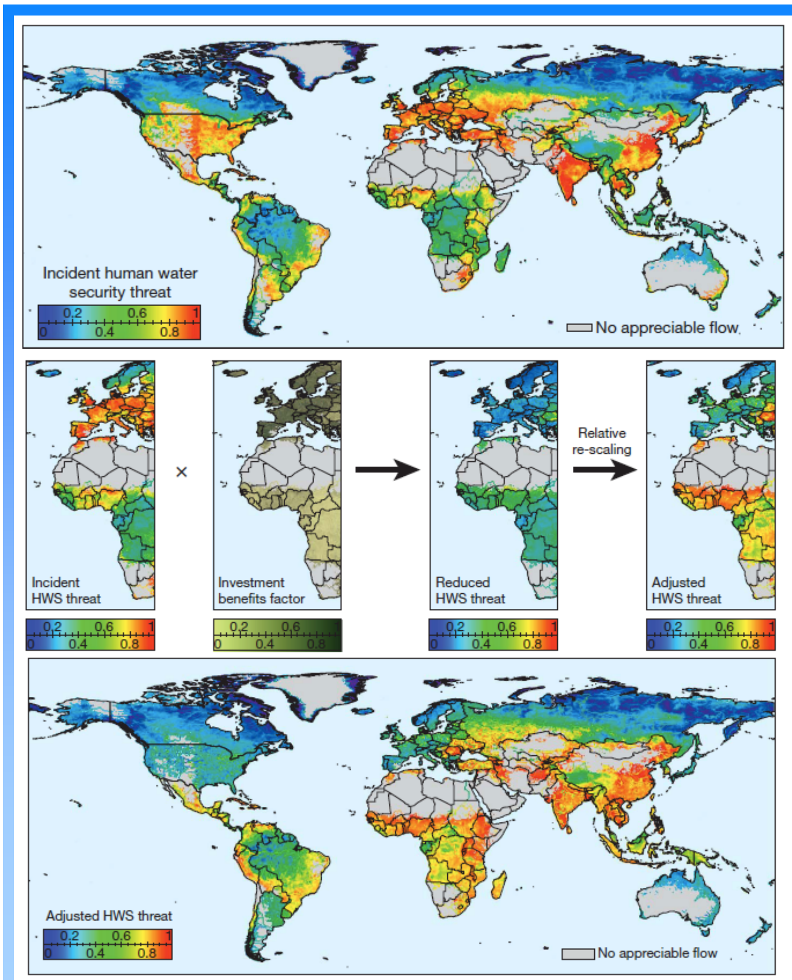
- Unusually high concentration of biodiversity: ~125,000 freshwater species described (~10% of known animal species) despite inland waters <1% of the Earth's area; high endemism…high risk



From: Strayer and Dudgeon (2010), J-NABS

- Globally 10,000-20,000 freshwater species are extinct or imperiled

- Have FW systems moved from the Holocene into the Anthropocene?



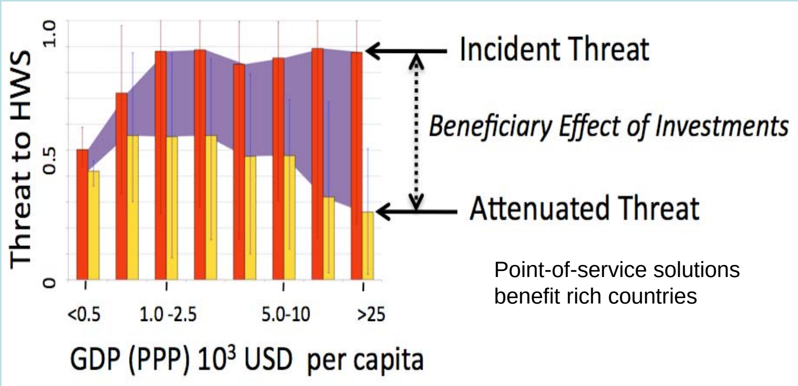
Attenuating the incident HWS Threat through beneficial engineering and technology investments (I_b):

- Access to clean water
- Moderate/"sustainable" water use
- Flow stabilization
-Access to river corridors

$T' = T\,(1 - I_b)$,
normalized, T', T, I_b

“INCIDENT”
(Ambient or Background)
WATER SECURITY
THREAT

REALIZED HUMAN
WATER SECURITY
THREAT



Large $$ & Energy Costs
- Treat symptoms rather than causes
- Strand poor & BD under high levels of threat
- Water management impacts (like from dams) impair BD and Ecosystem Services

Infrastructure investments are huge: $0.75Trillion/yr for OECD & BRIC alone by 2015

Why so different?

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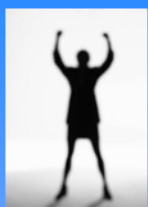

CENTRAL TENET OF THE GWSP

Humans are changing the global water system in a globally-significant way

without…..adequate knowledge of the system and thus its response to change

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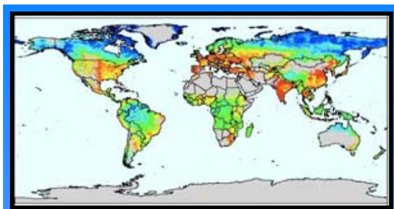
In Conclusion

- Pandemic fingerprint of human-induced impacts on water systems…*local effects move to global syndromes*
- Both *Human Water Security (HWS)* and *Biodiversity (BD)* at high levels of incident *Threat…likely to persist into the future*
- Engineering interventions reduce *Threat* to *HWS* in developed world*….”stranding” developing world HWS and global BD in state of high relative Threat*
- IWRM and “soft path” alternatives can spare the developing world the costly (in $$ & environmental terms) strategy of treating symptoms and not causes
- Frameworks like RIMS useful in IPBES context



Partners

- Charles Vörösmarty
- Mark Gessner
- Alexander Prusevich
- Stanley Glidden
- Caroline Sullivan
- Peter Davies
- Peter McIntyre
- David Dudgeon
- Pamela Green
- Stuart Bunn
- Cathy Reidy

OUTPUTS AND METHODOLOGY CAN BE FOUND IN*:*

Vörösmarty et al. (2010) “Global threats to human water security and river biodiversity”, *Nature* 467: 555-561 *(30 Sept. issue)*

For more information: www.riverthreat.net ; Email: contact@riverthreat.net

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