



Extreme Hydroclimatic Events and Environmental Quality

Use-inspired characterization of change, thresholds, and transitions

Shaleen Jain

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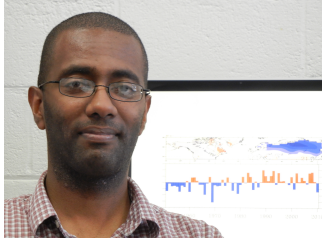
joint work with

Mussie Beyene, Nirajan Dhakal, and Anne Lausier, University of Maine

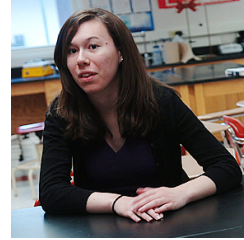
Jong-Suk Kim, University of Seoul

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Nanjing University of Information Science & Technology, Nanjing, China
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Mussie Beyene
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University of Maine



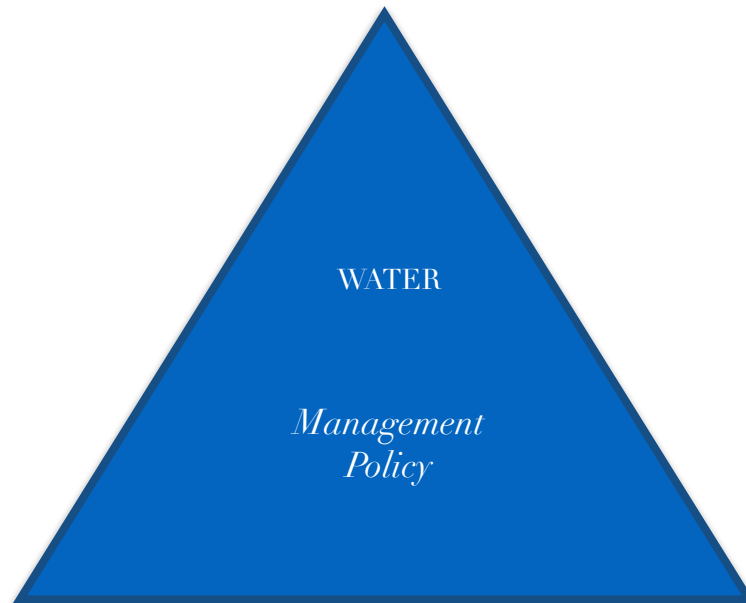
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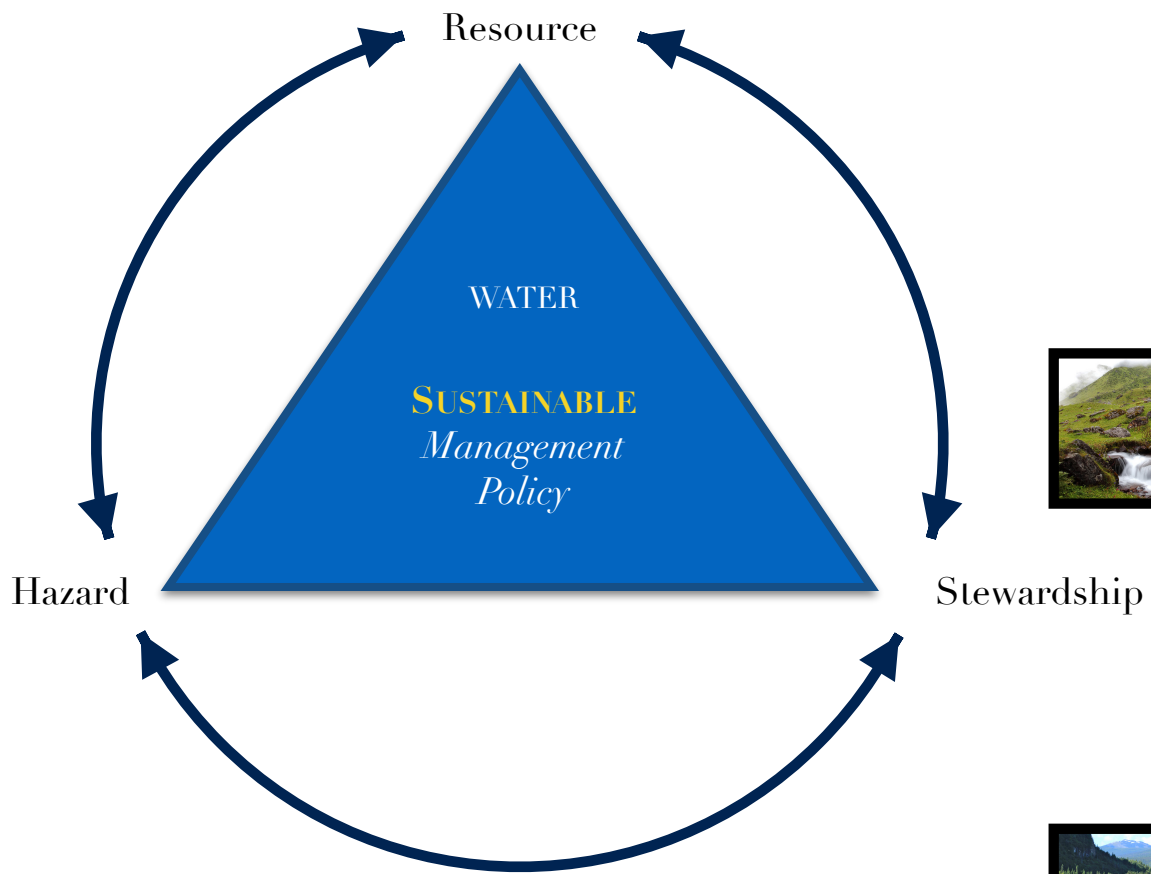
Resource



Hazard

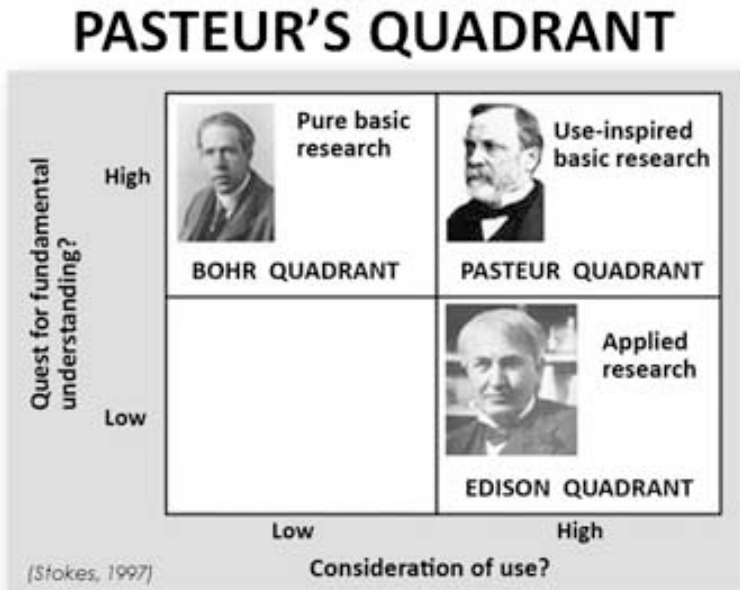
Stewardship





Usable Knowledge to address water problems

The missed opportunity matrix for reconciling supply and demand*



USE-INSPIRED RESEARCH: to pursue fundamental understanding but motivated by a question of use

Source: Princeton University

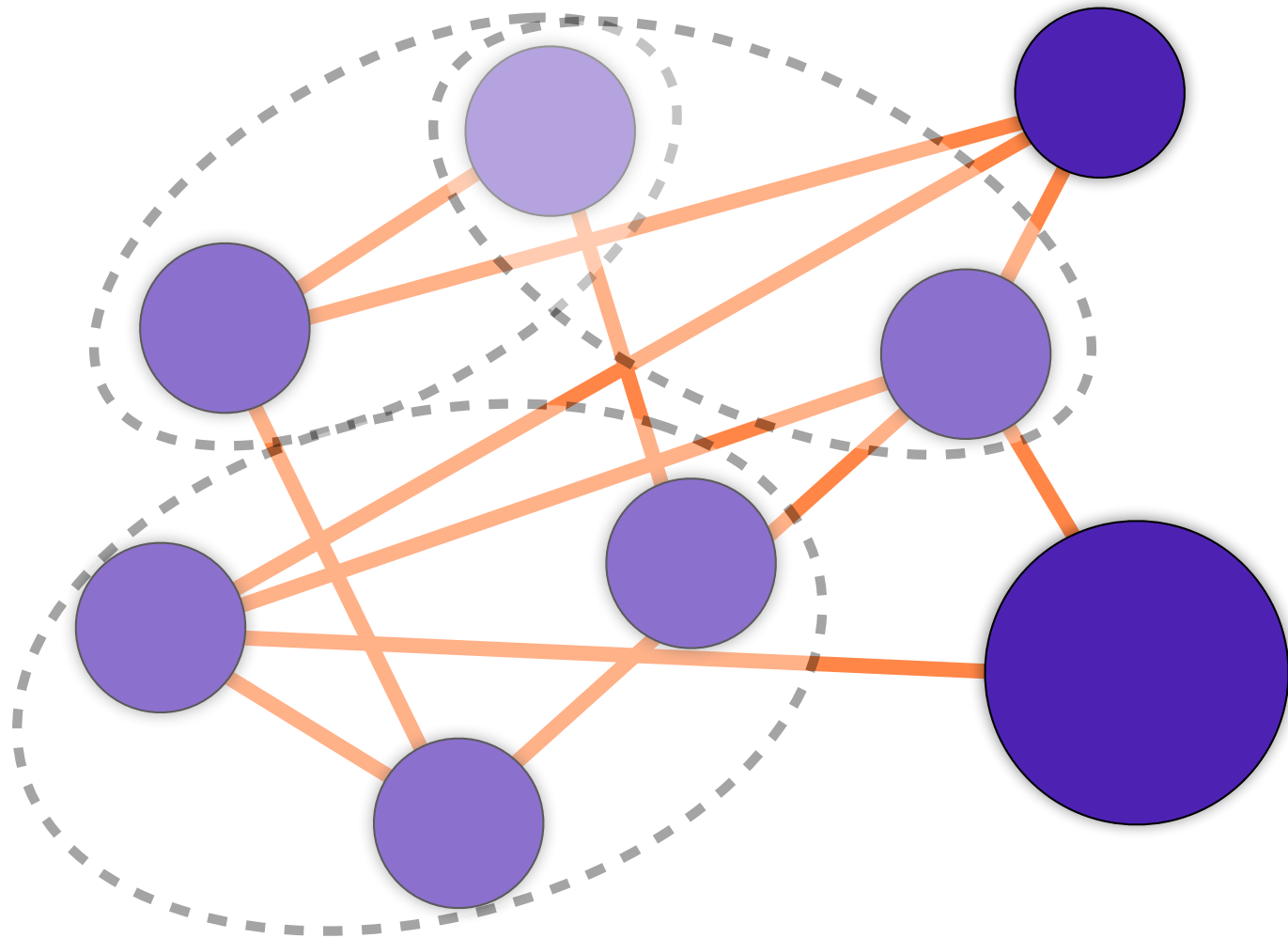
		Demand: Can User Benefit from Research?	
		YES	NO
Supply: Is Relevant Information Produced?	NO	Research agendas may be inappropriate.	Research agendas and user needs poorly matched; users may be disenfranchised.
	YES	Empowered users taking advantage of well-deployed research capabilities.	Unsophisticated or marginalized users, institutional constraints, or other obstacles prevent information use.

Area of positive reinforcement

*Sarewitz, D. and R.A. Pielke, The neglected heart of science policy: Reconciling supply of and demand for science. *Environmental Science & Policy*, 10, 5-16, 2007.

Mobilization of diverse knowledge

Need for carefully selected collaborative work between scientists, policy- and decision-makers at all levels of governance



Usable Knowledge to address water problems

- **Climate variability and change affords both challenges and opportunities for water resources management and policy**
 - Recurrent problems (for example, droughts, floods, inadequate water infrastructure) receive attention from the media
 - Water-related concerns cast a long shadow on long-term human well-being (economic, social, and environmental)
- **Complexity and human dimensions: Demands on research and policy**
 - use-inspired
 - simultaneous consideration of place-based, regional and global issues
- **Can we anticipate surprises or breakdowns in earth's life-support systems?**
 - Integrative Research (Climate+Hydrology+Ecology+Human Dimensions)
 - Pay great attention to interlinkages or nexus
 - A reappraisal of water resources governance

Usable Knowledge to address water problems

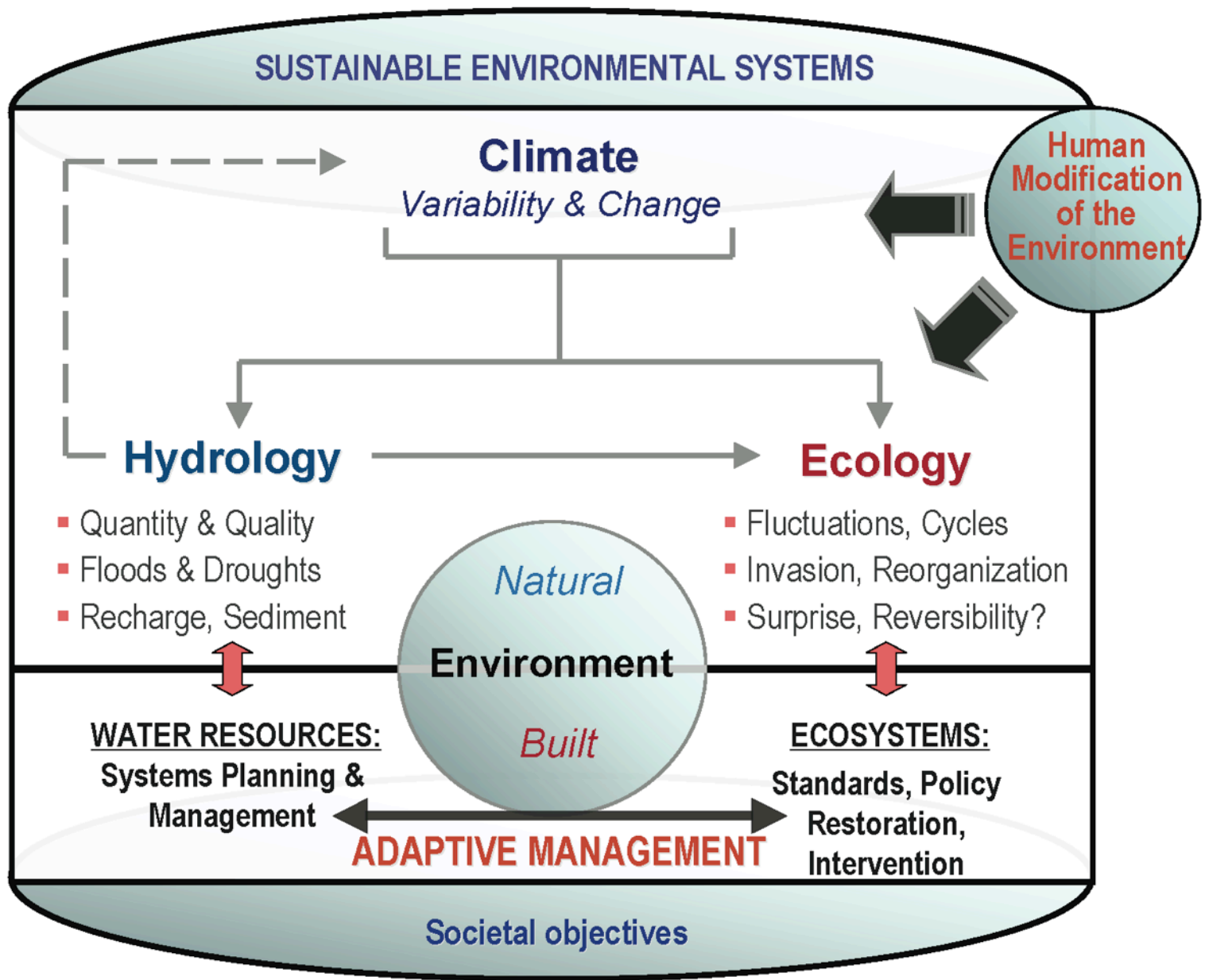
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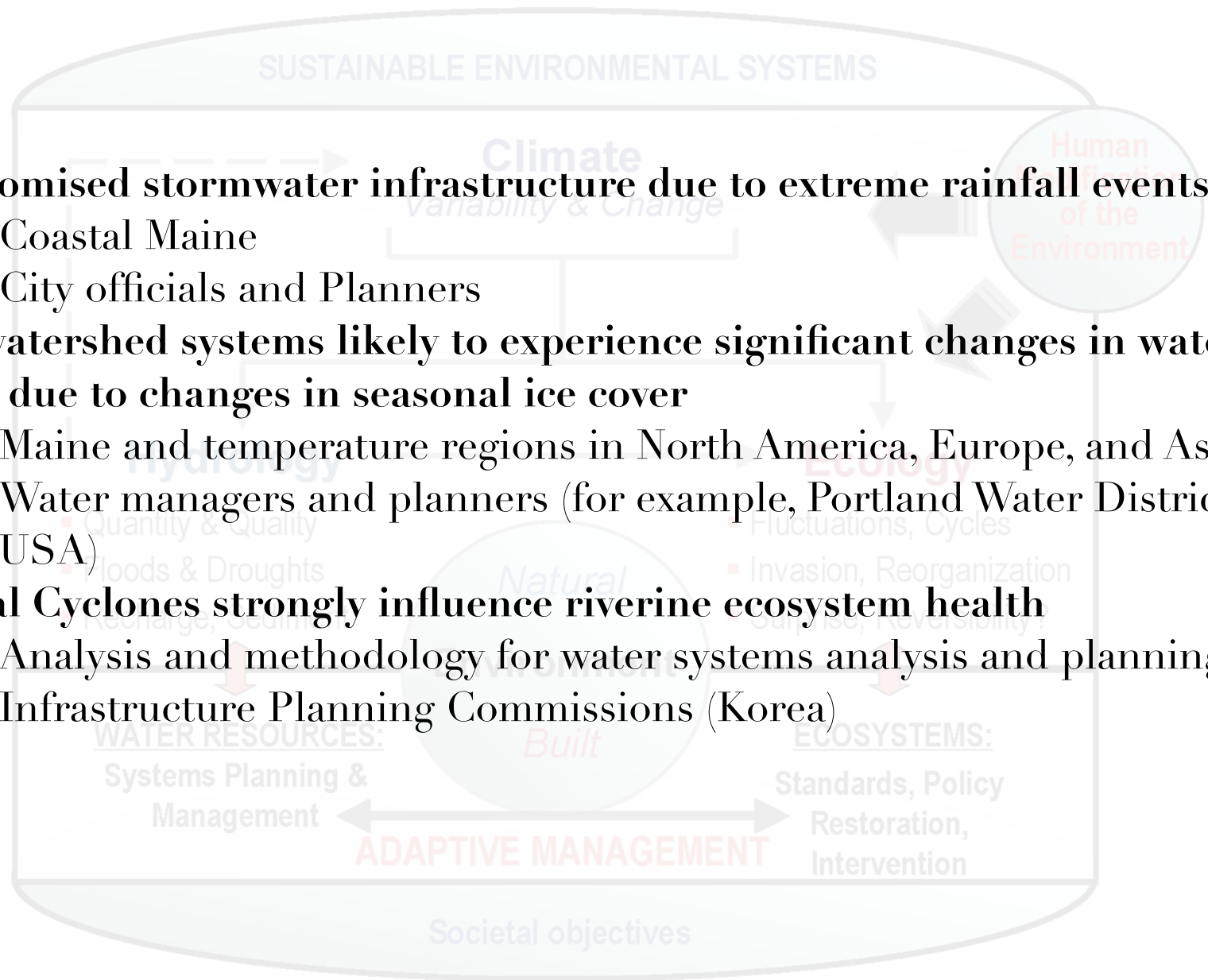
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- **Compromised stormwater infrastructure due to extreme rainfall events**
 - Coastal Maine
 - City officials and Planners
- **Lake-watershed systems likely to experience significant changes in water quality due to changes in seasonal ice cover**
 - Maine and temperature regions in North America, Europe, and Asia
 - Water managers and planners (for example, Portland Water District, Maine USA)
- **Tropical Cyclones strongly influence riverine ecosystem health**
 - Analysis and methodology for water systems analysis and planning
 - Infrastructure Planning Commissions (Korea)



The case of malfunctioning culverts



- **Compromised stormwater infrastructure due to extreme rainfall events**
 - Region: Coastal Maine
 - City officials and Planners
- **Up-front engagement and scoping of problems with city officials through questionnaires, interviews, workshops and focus groups**
- **Research Needs**
- **Design of culverts (updated assessment of extreme rainfall)**
- **Maintenance calendar (identify adaptation opportunities)**
- **Understand governance (design standards, decision tool needs, financing, local-state-federal government roles)**

*joint work with Esperanza Stancioff and Alex Gray (Maine Sea Grant)
Bob Kates (University of Maine)*

The case of malfunctioning culverts



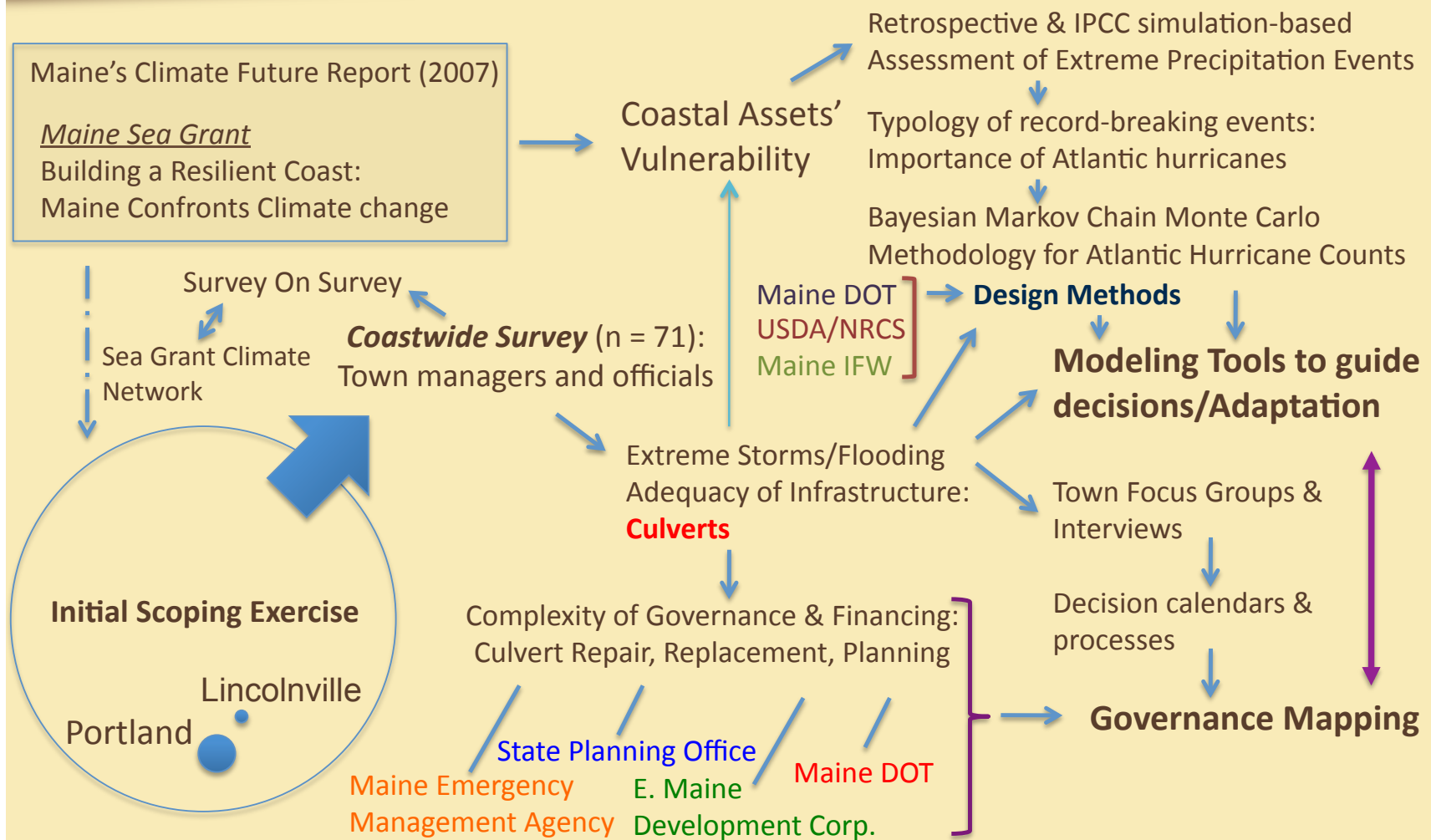
“It is easier to draw schematics than to describe what actually occurs”

— Bob Kates

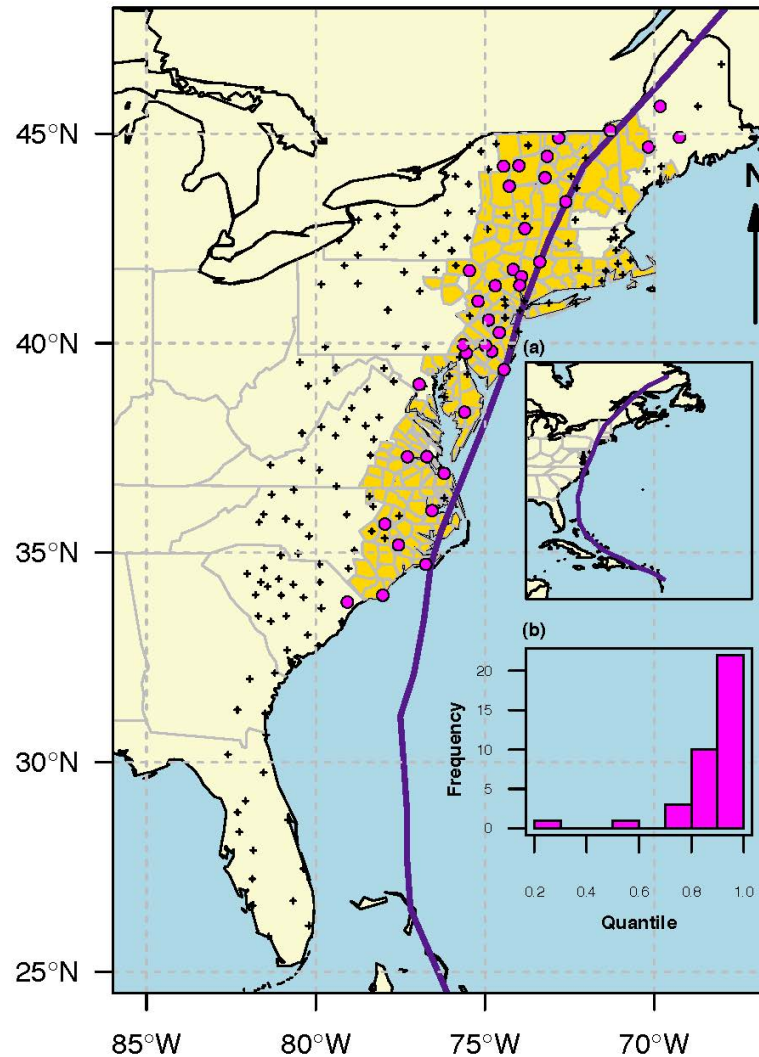
*joint work with Esperanza Stancioff and Alex Gray (Maine Sea Grant)
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The case of malfunctioning culverts

Delimited Knowledge System to support community-based adaptation with a focus on stormwater infrastructure



Hurricane Irene

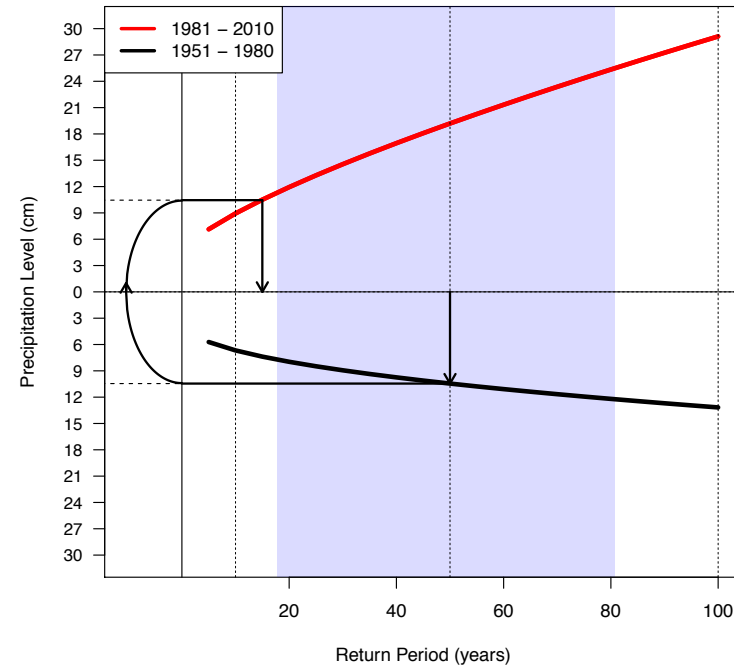
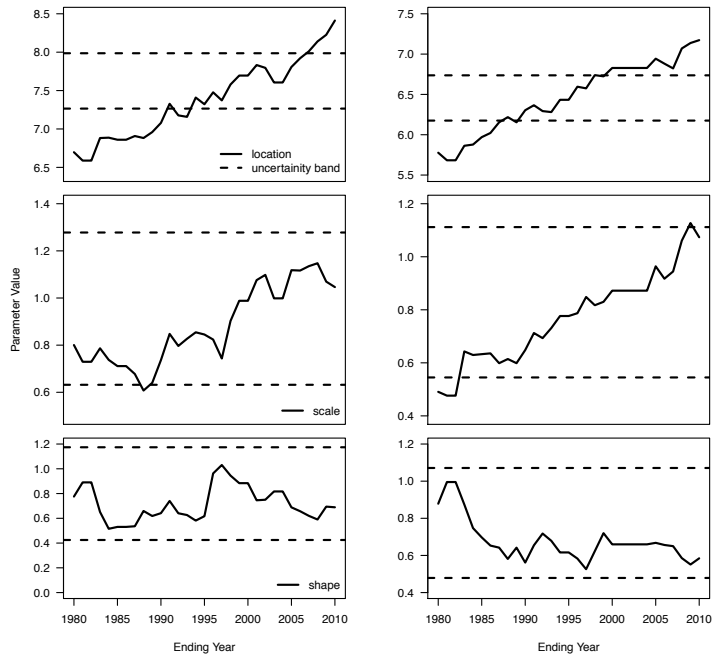


Best track position for Hurricane Irene. Counties where Federal Emergency Management Agency (FEMA) declared major disaster are highlighted in yellow. The circle in magenta represents USHCN stations where the annual maximum rainfall on that year is caused by the hurricane Irene while those stations which are within 500 km of the hurricane are represented by plus. Quantile corresponding to those are computed for each station from EVD and the histogram of them is shown in (b).

Extremes: Record Sewage Overflows

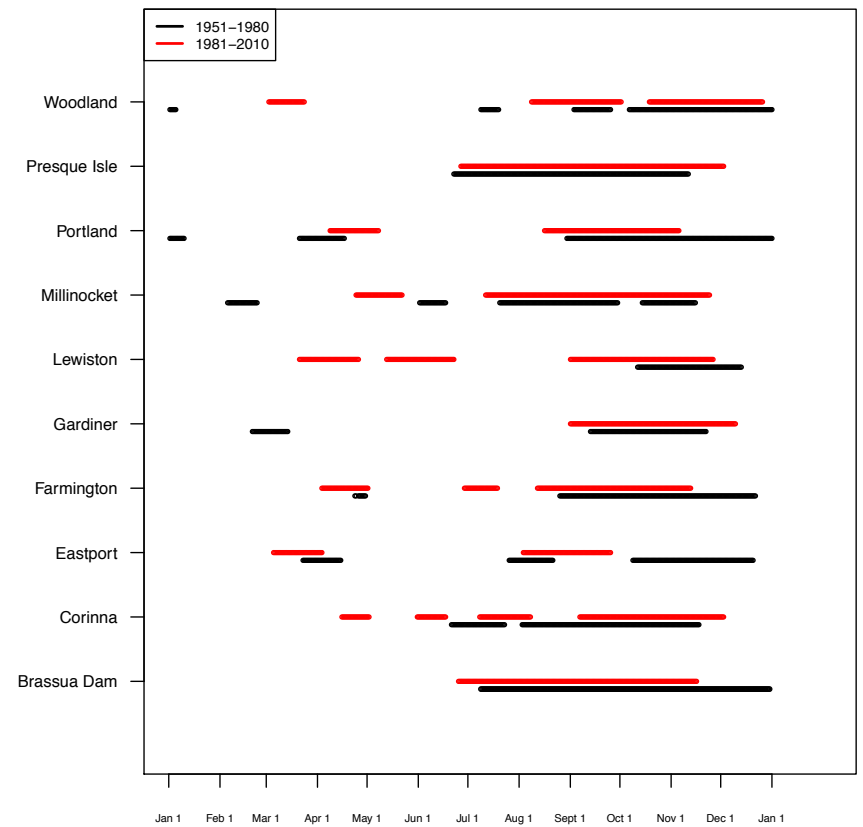
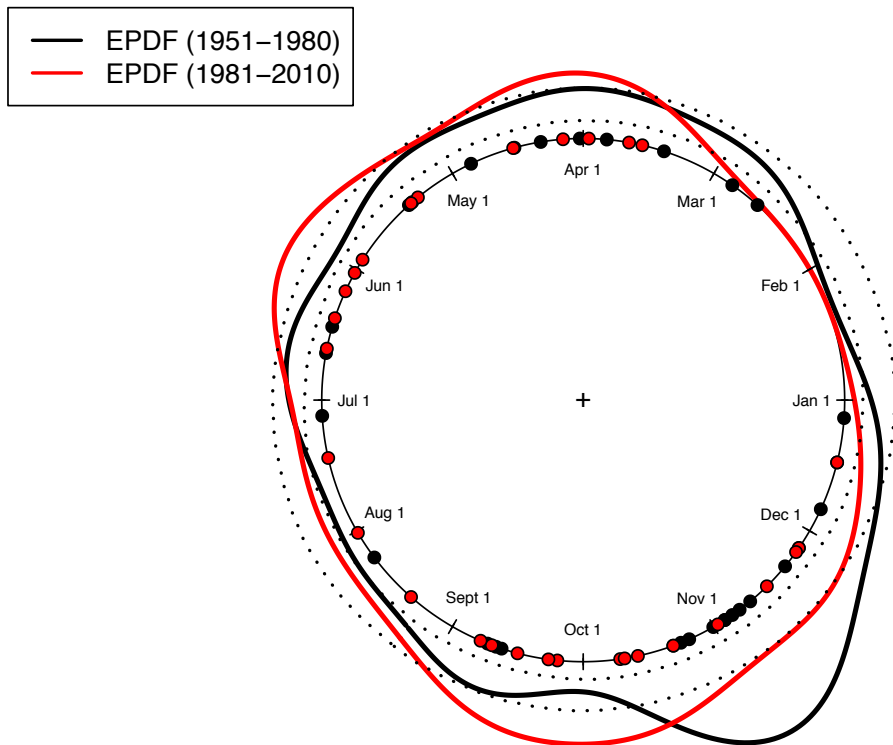
Rank	State	City	Facility	Volume (gallons)	Cause	Type
1	NJ	Newark	Passaic Valley Sewerage Commission, Wilson Avenue, Newark	3,080,000,000	storm surge and flooding	partially treated
2	NY	Bay Park	Bay Park Sewage Treatment Plant, Harbor Road, Bay Park	2,200,000,000	storm surge and flooding	partially treated
3	NY	Yonkers	Yonkers Joint Wastewater Treatment Plant, Yonkers	1,174,000,000	storm surge and flooding	partially treated
4	NJ	Sayreville	Two pump stations, Middlesex County Utilities Authority, Sayreville	1,135,415,490	storm surge and flooding	untreated
5	NJ	Newark	Passaic Valley Sewerage Commission, Wilson Avenue, Newark	840,000,000	storm surge and flooding	untreated
6	DC	Washington	Combined Sewer Pump Station, O Street, Washington	475,000,000	heavy precipitation	untreated
7	NY	Brooklyn	Coney Island Wastewater Treatment Plant, Sheepshead Bay, Brooklyn	284,000,000	storm surge and flooding	partially treated
8	NY	Staten Island	Oakwood Beach Water Pollution Control Plant, Mill Road, Staten Island	237,500,000	storm surge and flooding	partially treated
9	NY	Brooklyn	Coney Island Wastewater Treatment Plant, Sheepshead Bay, Brooklyn	213,000,000	storm surge and flooding	untreated
10	NY	Queens	Rockaway Wastewater Treatment Plant, Rockaway Freeway, Queens	165,000,000	storm surge and flooding	partially treated
11	NY	Bronx	Hunt's Point Wastewater Treatment Plant, Ryawa Avenue, Hunts Point, Bronx	153,750,000	storm surge and flooding	untreated
12	NY	Brooklyn	Newtown Creek Wastewater Treatment Plant, Greenpoint Avenue, Brooklyn	143,000,000	storm surge and flooding	untreated
13	NY	Bay Park	Bay Park Sewage Treatment Plant, Harbor Road, Bay Park	104,000,000	storm surge and flooding	untreated
14	NY	Brooklyn	26th Ward Water Pollution Control Plant, Van Siclen Avenue, Brooklyn	89,000,000	storm surge and flooding	partially treated
15	NY	New York	North River Wastewater Treatment Plant, Henry Hudson Parkway, New York	83,000,000	storm surge and flooding	untreated
16	NY	Brooklyn	Owls Head Wastewater Treatment Plant, Bay Ridge, Brooklyn	76,200,000	storm surge and flooding	partially treated
17	NY	Yonkers	Yonkers Joint Wastewater Treatment Plant, Yonkers	49,000,000	storm surge and flooding	untreated
18	NY	Queens	Rockaway Wastewater Treatment Plant, Rockaway Freeway, Queens	36,000,000	storm surge and flooding	untreated
19	NY	Staten Island	Port Richmond Water Pollution Control Plant, Richmond Terrace, Staten Island	30,000,000	power loss	partially treated
20	PA	Harrisburg	Harrisburg Advanced Wastewater Treatment Facility, South Cameron Street, Harrisburg	22,827,000	power loss	partially treated
21	NY	Staten Island	Hannah Street Pump Station, Staten Island	21,360,000	storm surge and flooding	untreated
22	MD	Savage	Little Patuxent Water Reclamation Facility, Greenwood Place, Little Patuxent	19,500,000	power loss	partially treated
23	VA	Suffolk	Suffolk Pump Station, Wilroy Road, Suffolk	18,285,000	equipment failure	untreated
24	RI	East Providence	Bucklin Point Wastewater Treatment Facility, Campbell Avenue, East Providence	17,540,000	other/unknown	partially treated
25	CT	Bridgeport	West Side WWTP, Bridgeport	17,100,000	storm surge and flooding	partially treated

Time-varying return periods



- *Extreme rainfall can be statistically modeled to incorporate changing baselines*
- *First step towards a design toolbox that incorporates dynamic risk (changes over time)*
- *Short record length*

Temporal changes in seasonality



- *Date of annual maximum precipitation events*
- *Nonparametric statistical framework to assess changes and characterization of PDF*
- *Short record length*
- *Aligns with culvert maintenance calendars*

Culvert maintenance calendar

CULVERT MAINTENANCE CHECKLIST FOR CULVERT MAINTENANCE AND REPAIR

Poorly working culverts can cause flooding during heavy rains and significantly damage roads and bridges. Even during normal wet weather, a crushed or plugged culvert that allows water to back up in roadside ditches will contribute to the deterioration of the road as the standing water prevents further drainage from the road base and subgrade. A soft base or subgrade will "give" under traffic, hastening break-up of the pavement.

Inspect your culverts at least once a year. After the inspection, prioritize the repair and maintenance they need, and schedule the work through spring, summer, and fall. Below is a general maintenance schedule and guide to culvert repair. Both were developed by the Maine LTAP Center and are presented here with permission.



ROUTINE SEASONAL CULVERT MAINTENANCE

SPRING

- Inspect the inside as well as both ends of the pipe.
- Remove blockages (trash, brush, cornstalks, etc.)

SUMMER

- Remove blockages.
- Clean and flush the length of the pipe.
- Repair, improve, or install headwalls, pipe ends, and splash pads.
- Trim and remove brush at pipe ends, and mow grass and weeds.
- Cut and remove trees and limbs that threaten to fall and block upstream ditches.
- Establish vegetation on bare slopes at pipe ends.
- Add fill to cover pipe more thoroughly.

FALL

- Remove blockages.
- Mark headwalls or pipe ends for snowplow operators.



- *Review of maintenance schedules*
- *Move some of the summer activities to spring*
- *Local expenditures to be adjusted accordingly*



Climate Change Impacts in the United States

16: NORTHEAST

CHAPTER 16 NORTHEAST

Convening Lead Authors

Radley Horton, Columbia University

Gary Yohe, Wesleyan University

MAINE'S CULVERTS: AN ADAPTATION CASE STUDY

Culverts and the structures they protect are receiving increasing attention, since they are vulnerable to damage during the types of extreme precipitation events that are occurring with increasing frequency in the Northeast (Ch. 2: Our Changing Climate, Key Message 6; Ch. 5: Transportation). For instance, severe storms in the Northeast that were projected in the 1950s to occur only once in 100 years, now are projected to occur once every 60 years.¹⁰⁰

The Maine Department of Transportation manages more than 97,000 culverts, but individual property owners or small towns manage even more; Scarborough, Maine, for example, has 2,127 culverts. When 71 town managers and officials in coastal Maine were surveyed as part of the statewide Sustainability Solutions Initiative, culverts, with their 50 to 65

year expected lifespan, emerged atop a wish list for help in adapting to climate change.¹⁰¹



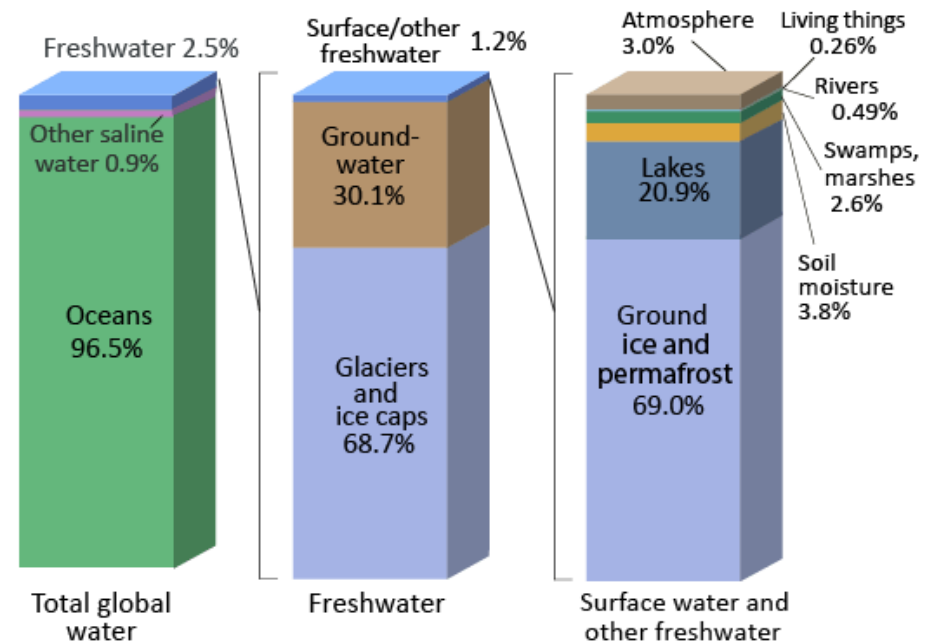
A research initiative that mapped decisions by town managers in Maine to sources of climate information, engineering design, mandated requirements, and calendars identified the complex, multi-jurisdictional challenges of widespread adaptation for even such seemingly simple actions as using larger culverts to carry water from major storms.¹⁰² To help towns adapt culverts to expected climate change over their lifetimes, the Sustainability Solutions Initiative is creating decision tools to map culvert locations, schedule maintenance, estimate needed culvert size, and analyze replacement needs and costs.

- *Research featured as an exemplary adaptation approach in the recent U.S. National Climate Assessment*

Climatic drivers of lake water quality transitions



Where is Earth's Water?



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*.
NOTE: Numbers are rounded, so percent summations may not add to 100.

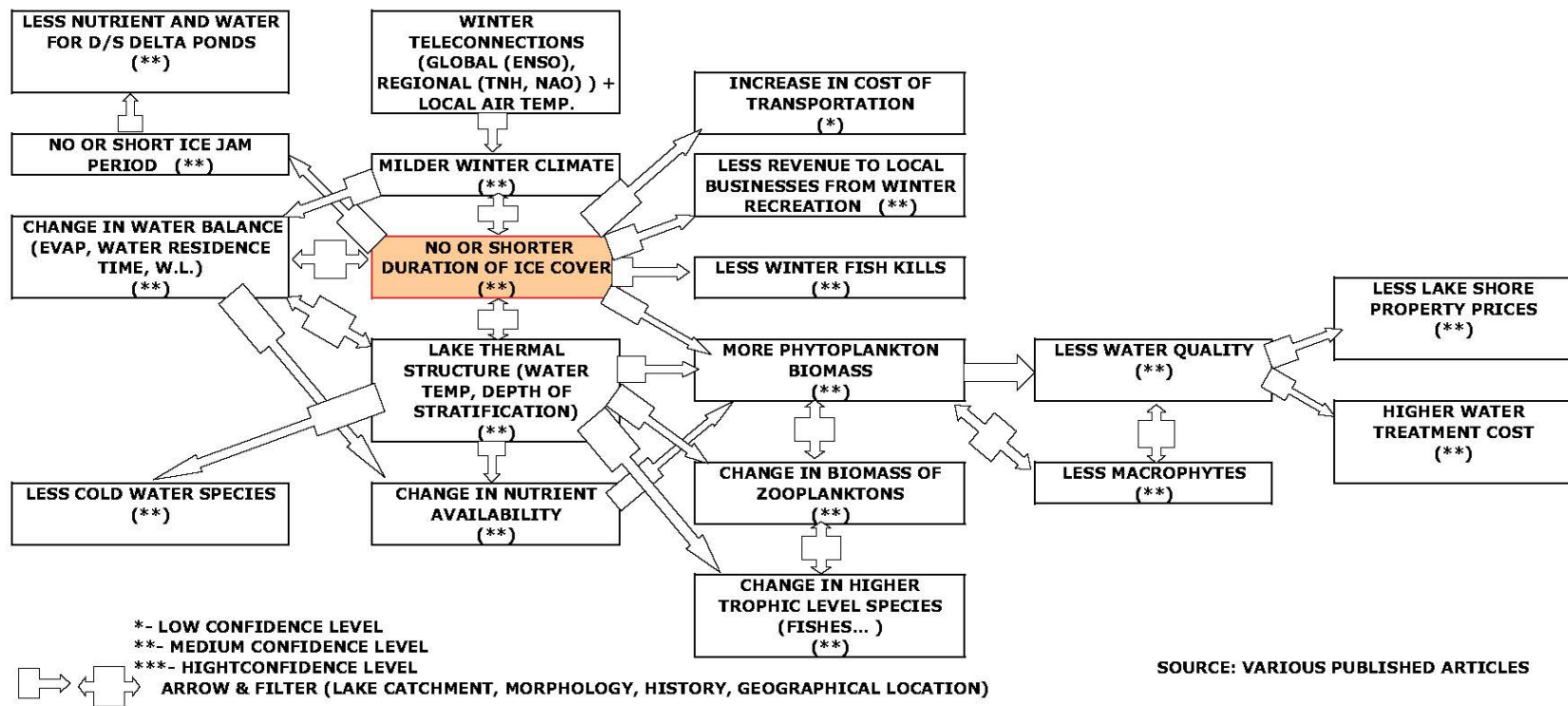
- **Lake-watershed systems likely to experience significant changes in water quality due to changes in seasonal ice cover**

Climatic drivers of lake water quality transitions

- **Lake-watershed systems likely to experience significant changes in water quality due to changes in seasonal ice cover**
 - Maine and temperate regions in North America, Europe, and Asia
 - Water managers and planners (for example, Portland Water District, Maine USA)
- **Maine's Sebago Lake**
 - Principal water supply for a large urban region
 - High water quality (no infrastructure for advanced water treatment)
- Significant incidence of early ice out in Maine
- Longer ice-free season increases the radiative heating of the lake
- Commingled influences from within lake biogeochemical processes and nutrient loading from surrounding watershed.
- Ice out date is an important threshold process that can lead to sudden and dramatic changes in lake phytoplankton.

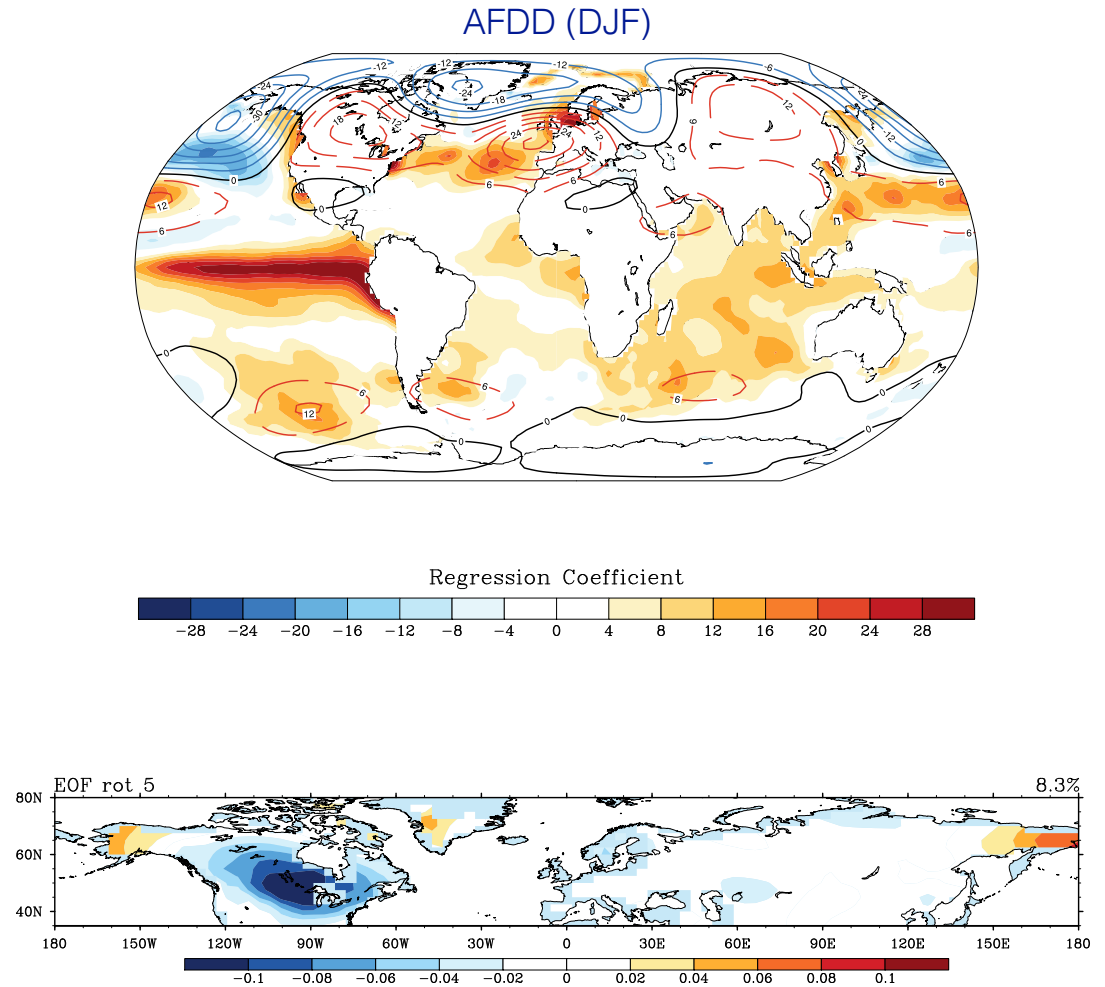
Early Ice out and lake water quality transitions

A TENTATIVE MODEL OF THE IMPACT OF AN UNUSUAL EARLY ICE OUT EVENT



Climatic drivers of lake water quality transitions

Large-scale patterns of AFDD show linkages to lake ice out, and linkages to tropical Pacific sea surface temperatures



Climatic drivers of lake water quality transitions

Ice-out date linked to large-scale atmospheric circulation and oceanic temperatures.

Season-ahead predictability likely to offer significant opportunities for planning.

Temperature thresholds identified.

Current work

Thresholds and transitions within a nonlinear dynamical lake model (Scheffer, 2003) linked to ice-out seasonality.

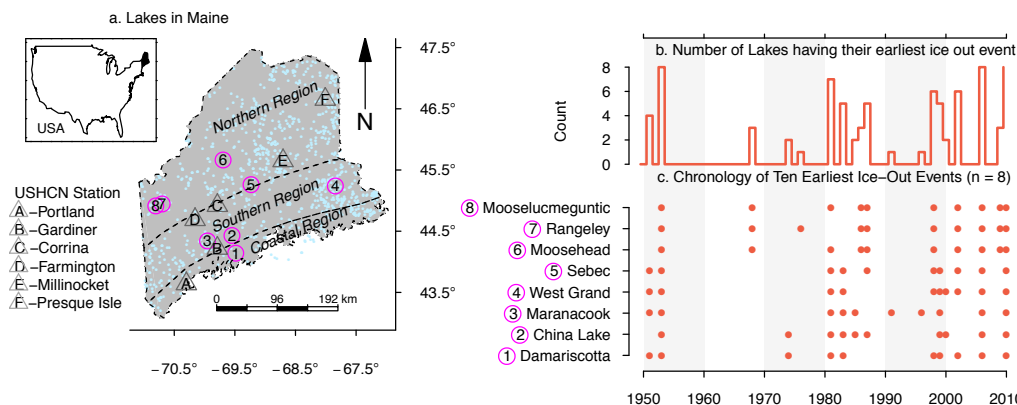


Fig 1a. The average 500mb geo-potential height and surface temperature anomalies during lower quartile TNH phases for the period 1950-2010.

Fig 1b. The average 500mb geo-potential height and surface temperature anomalies during upper quartile TNH phases for the period 1950-2010.

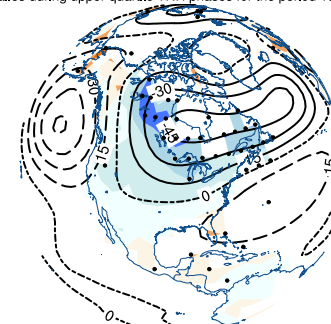
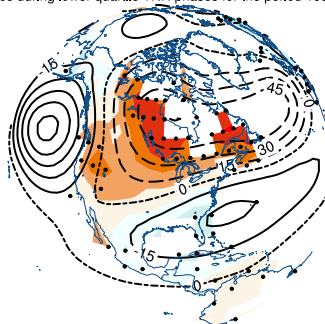
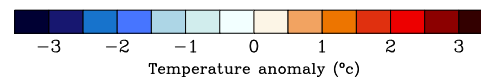
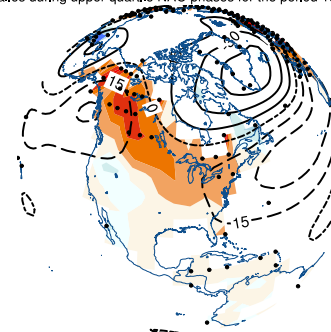
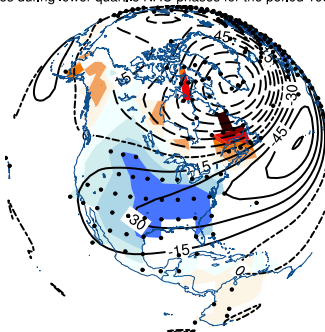


Fig 1c. The average 500mb geo-potential height and surface temperature anomalies during lower quartile NAO phases for the period 1950-2010.

Fig 1d. The average 500mb geo-potential height and surface temperature anomalies during upper quartile NAO phases for the period 1950-2010.



Inclusion of ecosystems as stakeholders: Climate- Environmental Flow Linkages

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Current Opinion in
Environmental
Sustainability

Environmental flows in the Anthropocene: past progress and future prospects

N LeRoy Poff¹ and John H Matthews²

Environ Biol Fish
DOI 10.1007/s10641-014-0243-x

Ain't no mountain high enough: the impact of severe typhoon on montane stream fishes

Jeng-Ping Chen • Colin Kuo-Chang Wen •
Pei-Jie Meng • Kah Leng Cherh • Kwang-Tsao Shao

Ecosystems (2011) 14: 1232–1248
DOI: 10.1007/s10021-011-9476-0

ECOSYSTEMS

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Protecting Indigenous Values in Water Management: A Challenge to Conventional Environmental Flow Assessments

Marcus Finn^{1*} and Sue Jackson²

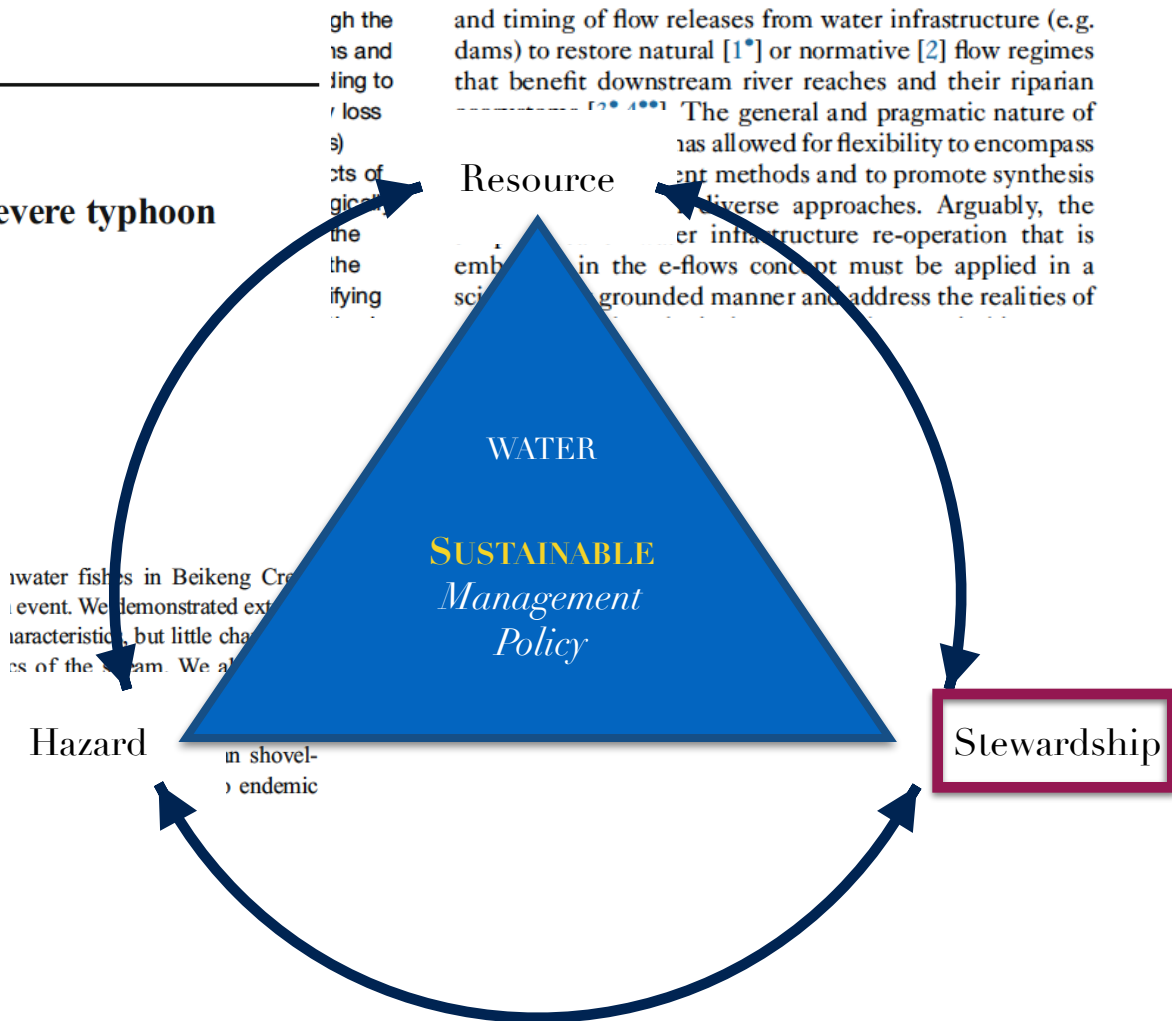
¹CSIRO Ecosystem Sciences, GPO Box 284, Canberra, ACT 2601, Australia; ²CSIRO Ecosystem Sciences, PMB 44, Winnell NT 0822, Australia

ABSTRACT

Although environmental flow assessments and allocations have been practiced in Australia for nearly 20 years, to date they have not effectively incorporated indigenous values. In many cases, even though indigenous people rely substantially on aquatic resources, environmental flows have been assumed to be an acceptable surrogate for the

or rarity may be important, it is common and widespread species that make substantial contributions to indigenous household incomes through customary use. The second challenge is to accommodate a different set of management objectives in environmental flow allocation. Environmental flows will need to meet the requirement of hunting

gh the is and ting to / loss s) ts of gical the the ifying and timing of flow releases from water infrastructure (e.g. dams) to restore natural [1*] or normative [2] flow regimes that benefit downstream river reaches and their riparian [2* 4**]. The general and pragmatic nature of has allowed for flexibility to encompass ent methods and to promote synthesis diverse approaches. Arguably, the er infrastructure re-operation that is emb in the e-flows concept must be applied in a sci grounded manner and address the realities of



Tropical cyclones and climate change

Thomas R. Knutson^{1*}, John L. McBride², Johnny Chan³, Kerry Emanuel⁴, Greg Holland⁵, Chris Landsea⁶, Isaac Held¹, James P. Kossin⁷, A. K. Srivastava⁸ and Masato Sugi⁹

Whether the characteristics of tropical cyclones have changed or will change in a warming climate — and if so, how — has been the subject of considerable investigation, often with conflicting results. Large amplitude fluctuations in the frequency and intensity of tropical cyclones greatly complicate both the detection of long-term trends and their attribution to rising levels of atmospheric greenhouse gases. Trend detection is further impeded by substantial limitations in the availability and quality of global historical records of tropical cyclones. Therefore, it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes. However, future projections based on theory and high-resolution dynamical models consistently indicate that greenhouse warming will cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increases of 2–11% by 2100. Existing modelling studies also consistently project decreases in the globally averaged frequency of tropical cyclones, by 6–34%. Balanced against this, higher resolution modelling studies typically project substantial increases in the frequency of the most intense cyclones, and increases of the order of 20% in the precipitation rate within 100 km of the storm centre. For all cyclone parameters, projected changes for individual basins show large variations between different modelling studies.

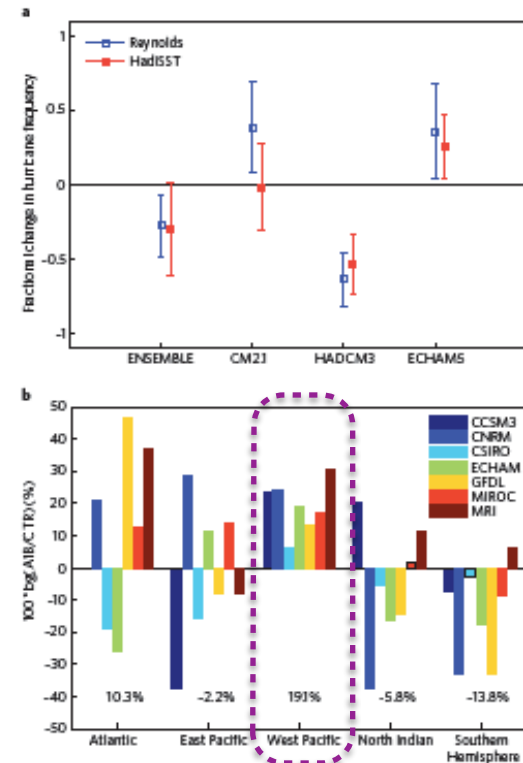


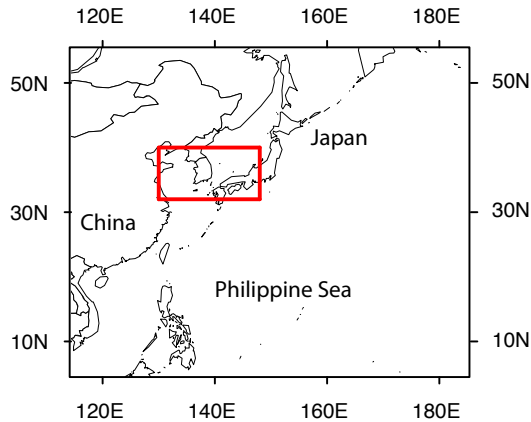
Figure 4 | Sensitivity of projected tropical cyclone activity to different climate models providing downscaling conditions. a, Projected fractional change in North Atlantic hurricanes (late twenty-first century) using a global atmospheric model to downscale SST projections from three individual climate models or from an 18-model ensemble. The two projections for each case (red and blue) used different controls based on different observed SST data. The vertical bars denote 90% confidence intervals. Reproduced with permission from ref. 29 (© 2009 AMS). b, Approximate percentage change in tropical cyclone power dissipation in various tropical storm basins projected for the late twenty-second century using a statistical/dynamical downscaling framework forced with climate change statistics from seven global models. The change here is given as 100 multiplied by the logarithm of the ratio of the twenty-second- and twentieth-century power dissipation (see ref. 11). Reproduced with permission from ref. 11 (© 2008 AMS).

- Western North Pacific typhoons expected to increase in frequency.
- Indicators of Hydrologic Alteration sensitively linked to typhoon variability
- Translation of typhoon impacts for future ecological impact assessment critical.

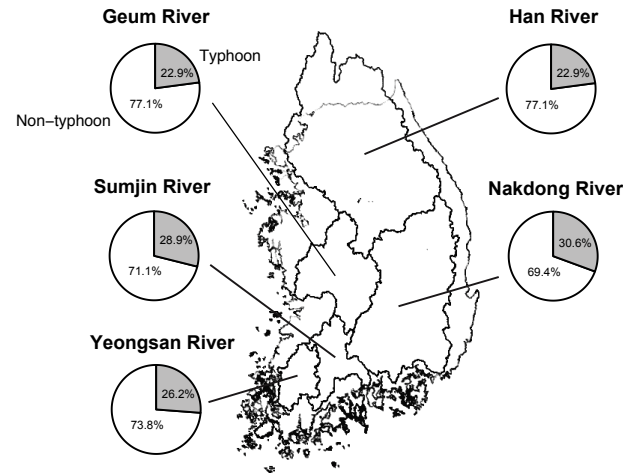
WNP Tropical cyclone and Environmental Flow Linkages

Korean Peninsula Case Study

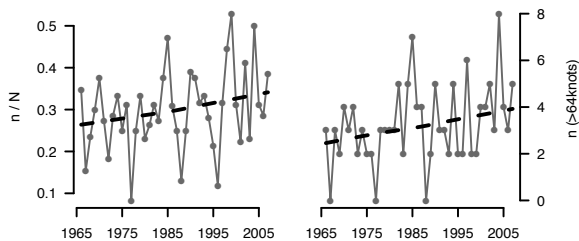
a. Map of study region



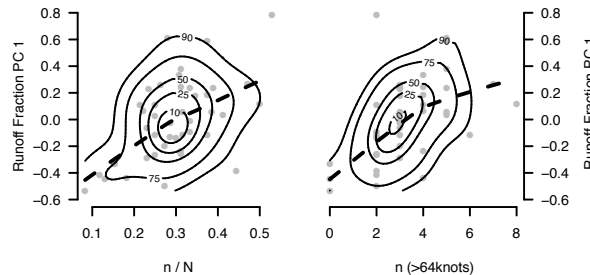
b. Fractional flow volume (June-September)



c. Typhoon variability and trends



d. Typhoon-runoff relationship



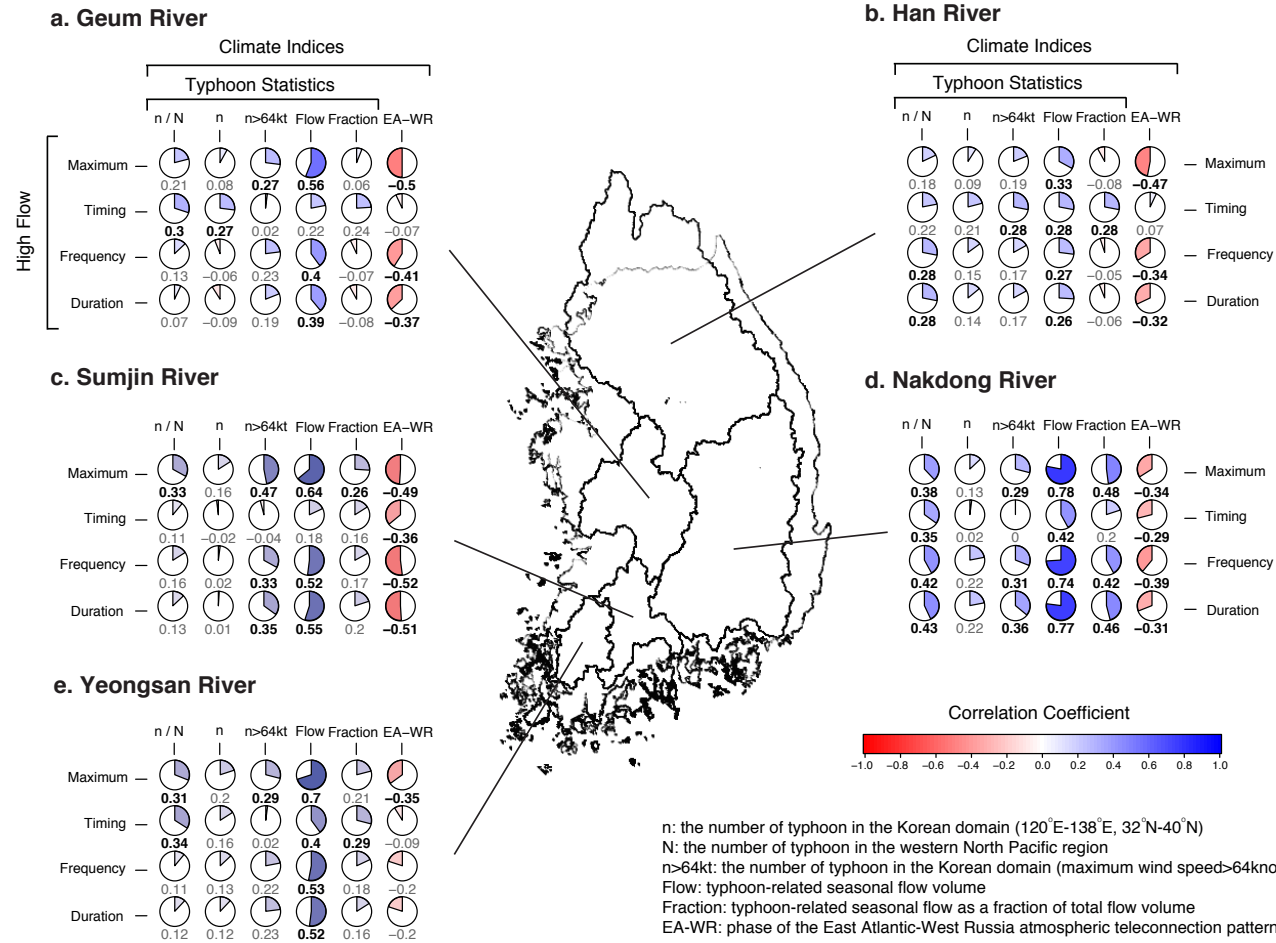
n: the number of typhoon in the Korean domain (120°E-138°E, 38°N-40°N)
 N: the number of typhoon in the western North Pacific region
 n>64knots: the number of typhoons in the Korean domain (maximum wind speed>64knots)

Kim, Jain, & Yoon, *Int. J. Climatol.* (2009)
 Kim and Jain, *Int. J. Climatol.* (2010)
 Kim and Jain, *Env. Res. Lett.* (2011)
 Kim et al., *J. Met. Soc. Japan* (2012)

- Separation of typhoon-related precipitation and streamflow
- Careful consideration of typhoons and teleconnections
- Use of Indicators of Hydrologic Alteration (suite of metrics based on daily streamflow)

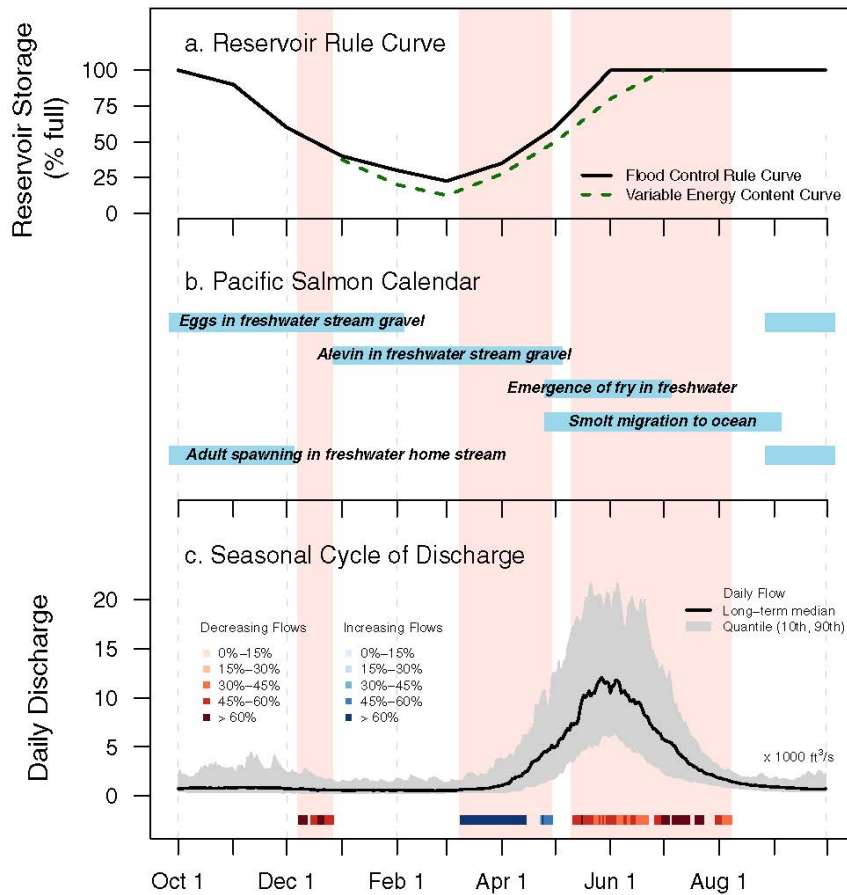
Typhoons in the western Pacific strongly influence riverine ecosystem health

Infrastructure Planning Commissions (Korea)

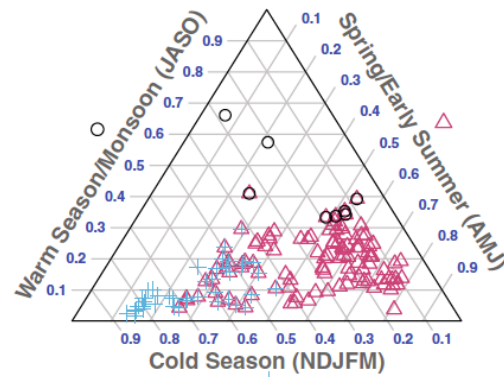


- Climate adaptation and water allocation strategies needs to carefully integrate extreme events impacts.
- Commingled influences due to non stationary climatic extremes and altered hydrologic regimes have large impacts of ecosystem health—need for a proactive and careful appraisal.

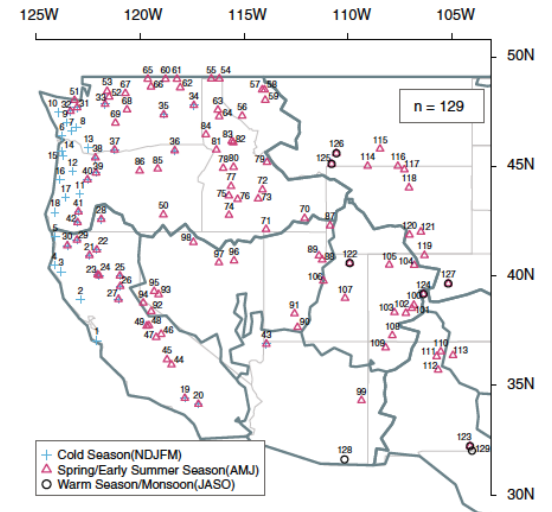
Changes in seasonality: Western US streamflow



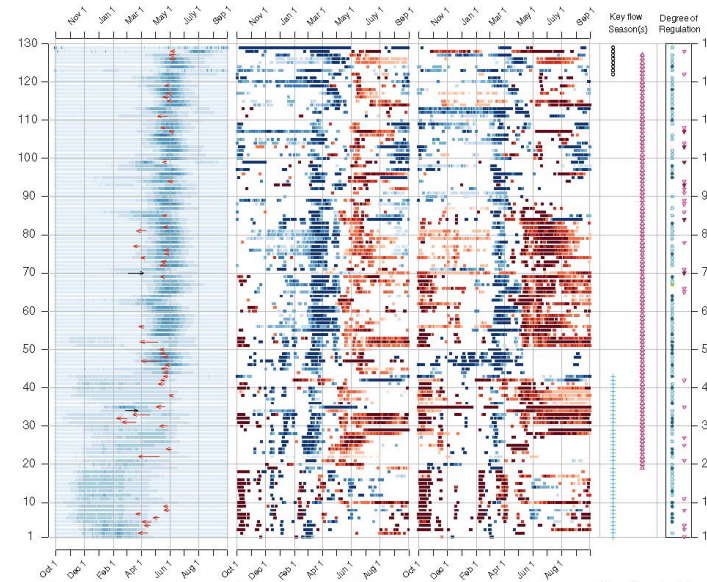
a Key Flow Seasons



b Gauge Locations (129 gauges)



a Seasonality



Summary: Challenges and Opportunities

- Advance water-climate research through a careful appraisal of emerging and salient problems and consideration of use; *accrued benefits for both researchers and stakeholders*
- Adaptive management and learning within an integrated resource-hazard-stewardship framework offers considerable opportunities for collaboration, co-production of knowledge, and synthesis.
- Hydrologic analyses and modeling informed by causal linkages to climatic drivers (teleconnections, identified processes, nonstationarity) is an important pre-requisite for impact and adaptation work related to water.
- Decision and Environmental System Analysis with a stewardship focus broadens traditional water resources management and planning approaches.
- Complexity of the sensitivity to water-environmental systems to climatic extremes require multiple place-based studies, and cross-comparisons to enhance the basis for knowledge translation.