Are large-scale flow experiments effective for science and management?

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USGS
science for a changing world

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Why examine large-scale flow experiments?

Reversibility of impacts	Many dam operations are unsustainable, but modified operations are feasible
Scientific opportunity	Unrivaled experimental situation for ecosystem-scale learning (compare to other whole-system experiments)
Need for evidence of benefits from modified dam operations	Increasingly used in adaptive management of water resources

Terminology

Flow manipulations – storing or releasing water from a reservoir or other hydraulic structure (a management action)

Flow experiments (FEs)– manipulations conducted to test a hypothesis (a scientific exercise)

Different standards for “effectiveness” but they are linked by social contract: no experiments without manipulations; water management should be based on evidence of net benefit

Global Scope

20 countries, 98 river systems, and appreciable portion of the world's streamflow

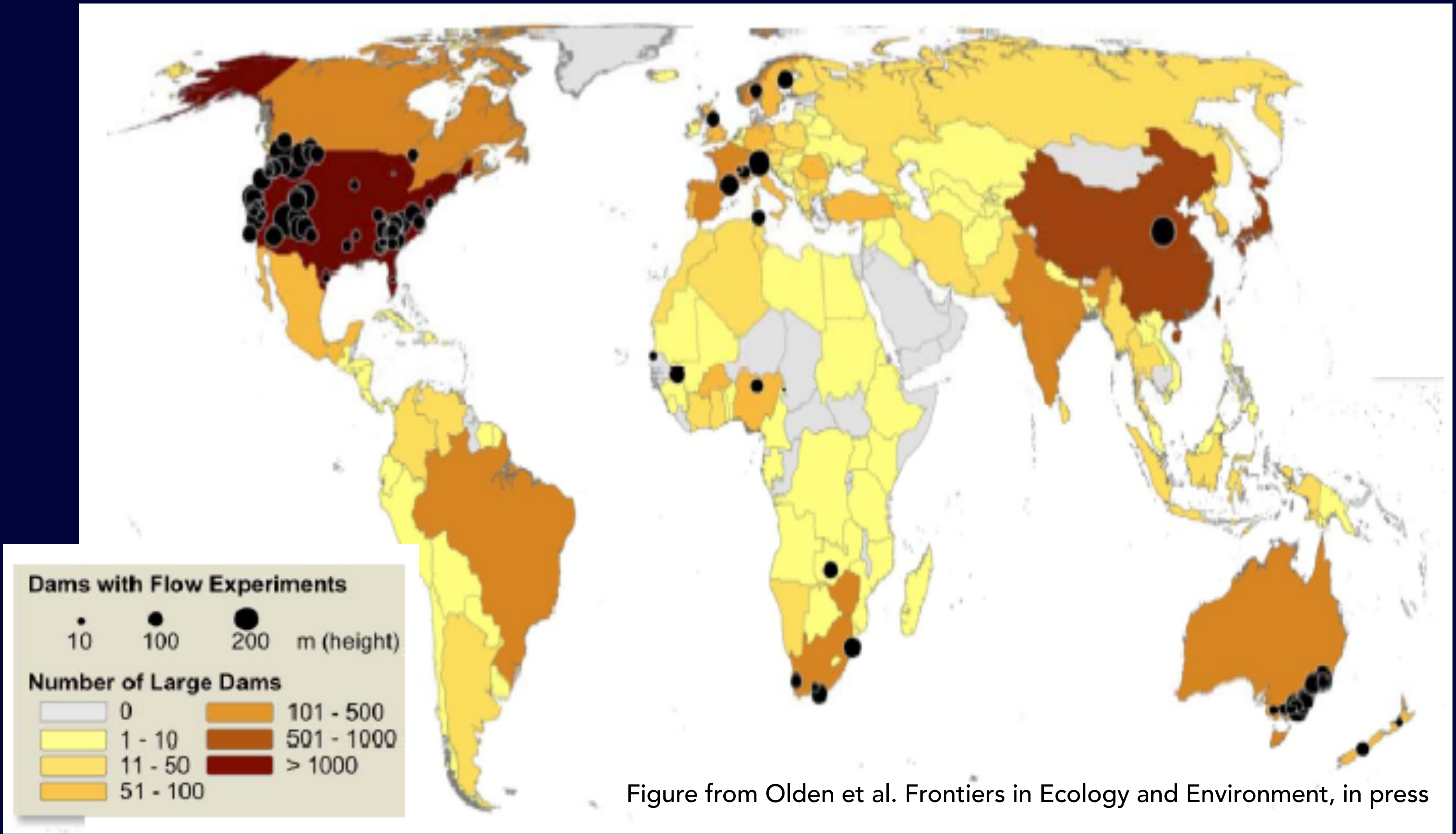
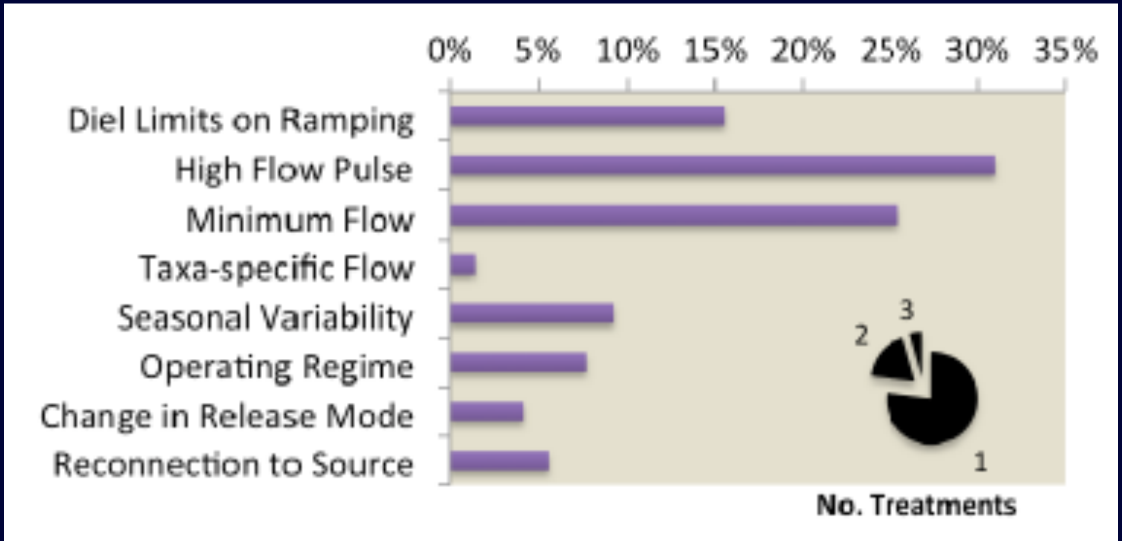


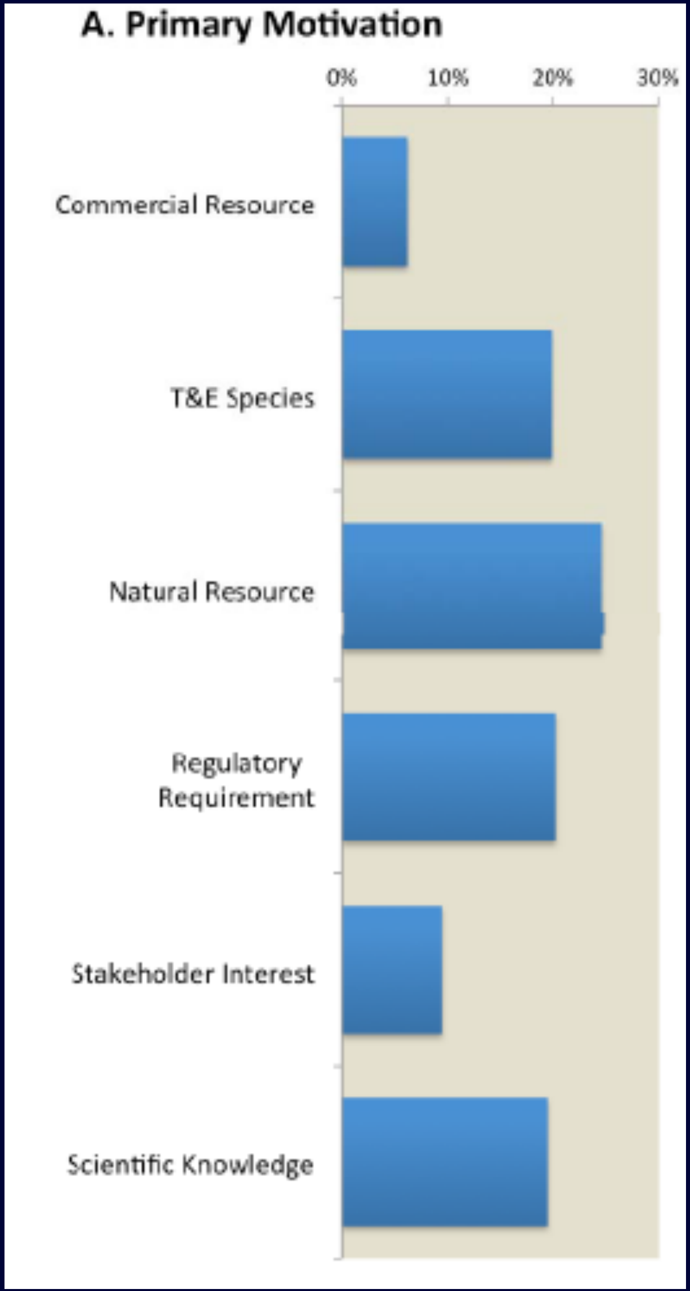
Figure from Olden et al. Frontiers in Ecology and Environment, in press

FEs are not monolithic

- range of motivations for manipulating flows

- variety of "treatment" types





Figures from Olden et al. *Frontiers in Ecology and Environment*, in press

Many different expressions of flow treatments

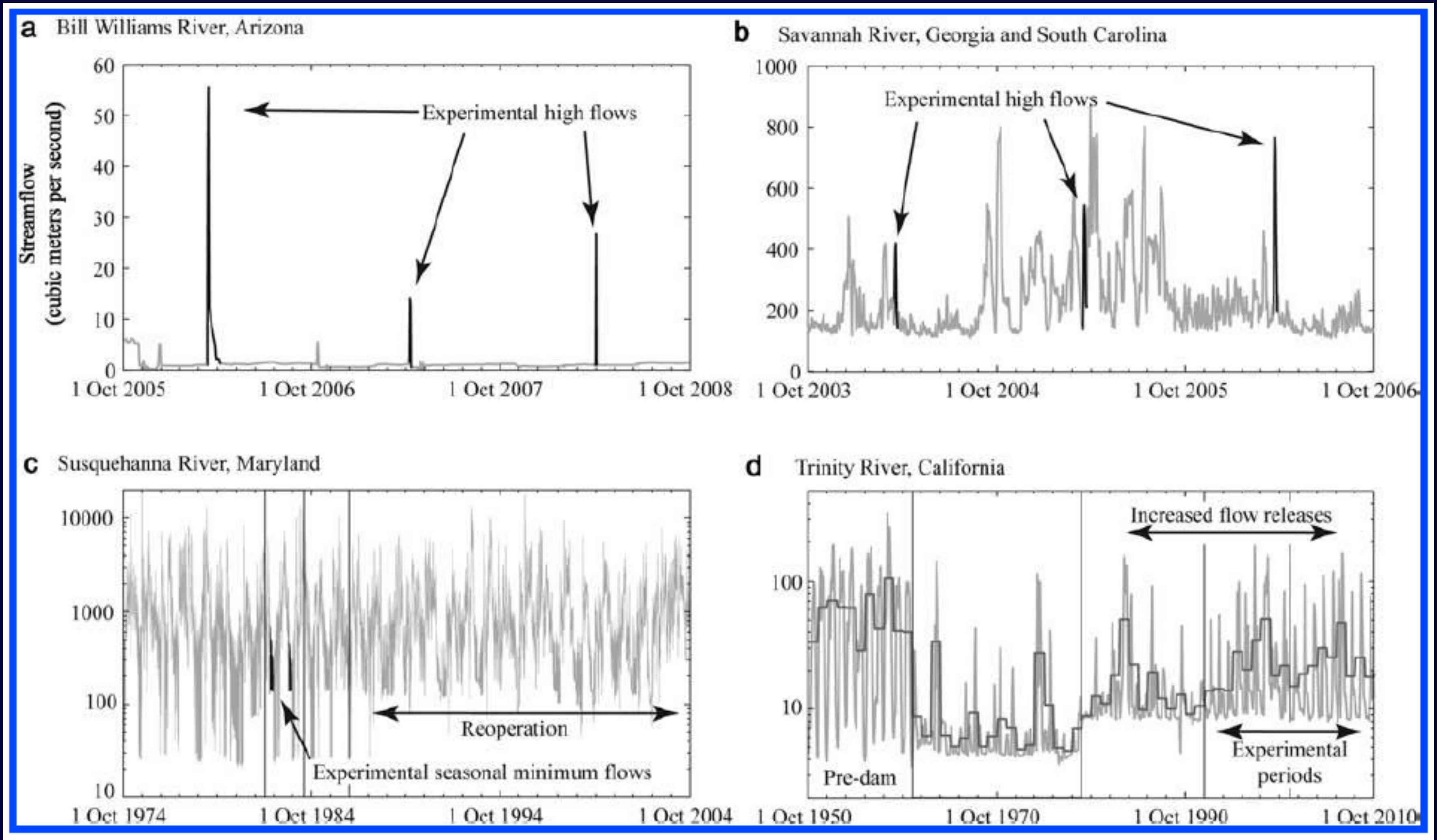
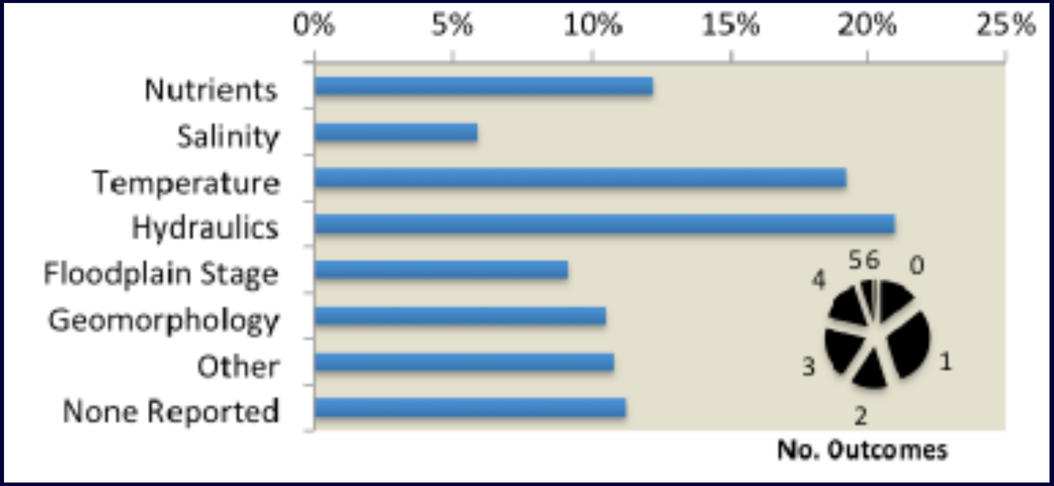
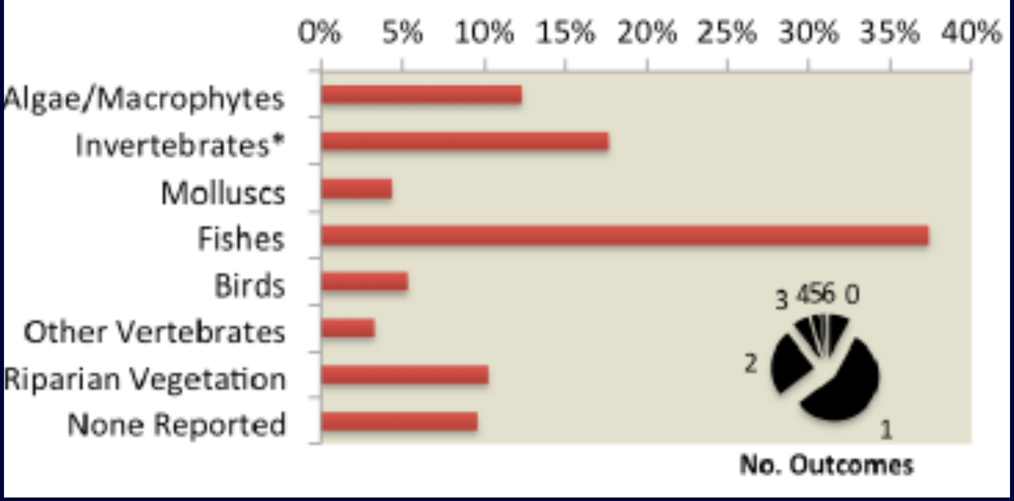


Figure from Konrad et al. 2011, *Bioscience* 61: 948-959

Variety of ecosystem responses have been documented





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Do FEs advance science?

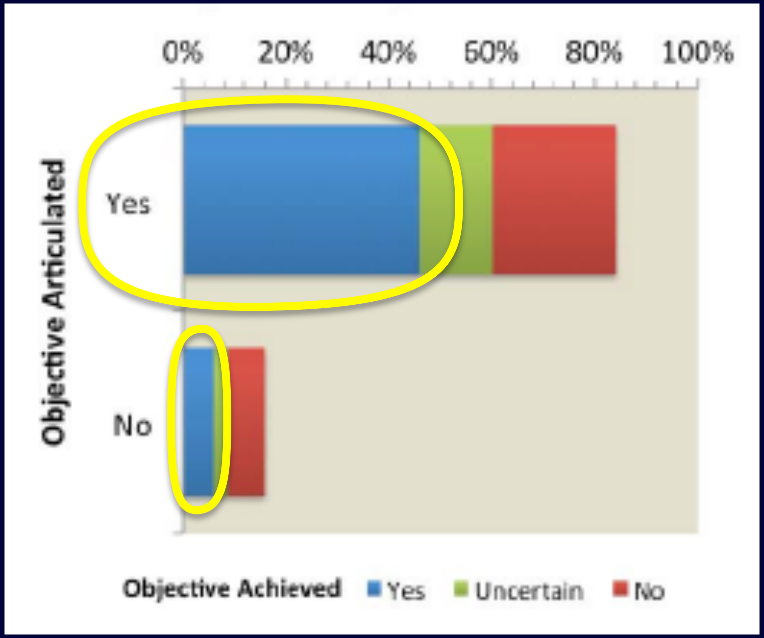
Large-scale experiments in general provide an opportunity for inter-disciplinary learning about ecosystems

FEs on't meet highest standards: randomized, repeated trials of a specified treatment

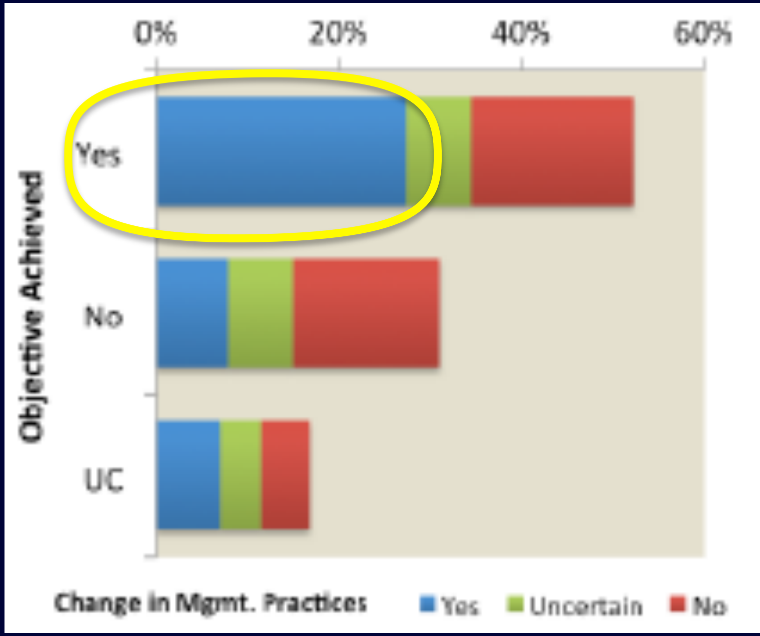
May be most useful for resolving site-specific issues with precision

Deliberate design can address broader community/ecological theory (*serial discontinuity, community response to disturbance regime, dis-synchronous biotic responses to environmental change*)

Management Outcomes



FEs with management objectives more often lead to changes in management practices



Most FEs have clearly articulated and documented management objectives, which can be used to evaluate success of manipulation

Figures from Olden et al. *Frontiers in Ecology and Environment*, in press

Documented ecological benefits from FEs

Native fish growth, reproduction, diversity, or abundance

Tallapoosa River, USA (Travnichek et al. 1995)

French Broad River, USA. (Layzer and Scott 2006)

IRhone River, France. (Lamouroux et al. 2006)

Susquehannah River, USA (Weisberg and Burton 1993).

Eau d'Olle River, Neste d' Aure RIver, Lignon-du-Forez River, Roizonne River, France (Sabaton et al 2008)

Skagit River, USA. (Connor and Pflug 2004).

Increase in fish (Rio Grande Silver Minnow) YOY survival. Rio Grande, USA. (Platania and Dudley 2009)

Narran River, Australia. (Rolls and Wilson 2010)

Rio Grande, USA. (Platania and Hoagstrom 1996)

Invertebrate assemblage diversity

Susquehanna River, USA. (Weisberg 1990)

Tennessee River basin (9 sites) (Bednarek and Hart 2005).

Glenelg River, Australia. (Lind et al 2007)

Groot River, South Africa. (Cambray 1991)

Riparian and aquatic vegetation, water quality, habitat mosaics

Owens River, USA (Hill and Platts, 1998)

Kissimmee River, USA (Toth et al. 1998)

Ichkeul River, Tunisia (Smart 2004)

St. Lucie River (Heilmayer et al. 2008).

Broken River (Victoria Gov 2008, 2009, 2010)

Opuha Opihi River, New Zealand (Arscott et al. 2007)

River Spol, Switzerland (Ortlepp and Murle 2003;Murle et al. 2003; Uehlinger et al. 2003; Robinson and Uehlinger 2008)

Bill Williams River, Arizona (Shafroth et al. 2010)

Truckee River (Rood et al. 2003)

River Senegal (Duvail and Hamerlynck 2003; Hamerlynch and Duvail 2003; Duvail and Hamerlynch, 2005)

Colorado River(Grams et al. 2007; Topping et al. 2003; Hazel et al. 2010; Schmidt et al. 2001).

Campaspe River, Victoria, Australia (State Government of Victoria 2010)

Yellow River (Shang 2009).

Provo River (Erwin et al. 2010).

Are flow experiments effective for management?

Many beneficial outcomes, but no guarantee of success (~ 50% of FEs achieved mgmt objectives)

Demonstrate limits on management

- ecological outcomes often are contingent on weather (reservoir and tributary inflows) and post-FE flows
- manipulations are often small compared historical standards/dam impacts
- manipulations alone do not address many impacts (changes in energy sources, thermal regime, migration patterns/population range, sediment flux)

Because everything flows, flexibility is as important as certainty in water resources management

Flow experiments provide water managers a way to:

–predict the effects of changing dam operations with greater certainty

-- develop new operating rules for changing circumstances (e.g., climate change impacts, needs for energy, flood control, flow regimes to sustain key species)

- to balance competing values for water resources

Panta Rhei
IAHS
AISH
Everything Flows
Change in Hydrology and Society

Kromme River/Estuary, South Africa

Estuary of the Indian Ocean; a breeding ground for commercially-important marine fishes, regulation and diversions have led to hyper-saline conditions.

Image source: G. Bate and J. Adams

Goal of FE: reduce salinity and increase productivity across aquatic community.

Unimpaired streamflow:
106 x 10^6 m^3/yr (3.4 cms)

Manipulation: release of 2 x 10^6 m^3 over a two week period.

Outcomes and Lessons Learned form the Kromme River/Estuary Experiment

Outcome:

low-density freshwater inflows flowed over high salinity water with no response in microalgae, zooplankton, or larval fish

Was this a successful experiment?

Management objectives were not achieved, but there were lessons learned . . .

Importance of long duration (40 days) baseflow to maintain freshwater-salt water interface for phytoplankton production

Larger manipulations may be needed to flush sediments from estuary and mix water column to increase nutrient availability.

How to will flow experiments be most useful?

Designed for learning

- discrete treatment, direct responses
- on-going monitoring of long-term, indirect responses
- multi-disciplinary (abiotic/biotic, community level)

Answers questions relevant to management decisions

- what outcomes are feasible from operational changes?
- what is treatment strength is sufficient?
- how frequent must treatments be applied?
- what antecedent conditions are needed for successful outcomes?

Summary of large-scale flow experiments

An unprecedented tool for water resources management: global scope; flexible and reversible; system-scale

Have documented many ecological benefits, achieved management objectives in some cases, and have led to changes in dam operations

Can be accepted as a best practice for operating dams:

- understanding current capabilities and tradeoffs , and
- predicting outcomes from new operations in anticipation of changing needs in managing water resources
- verifying and refining predictions for more effective and efficient management of water resources

Panta Rhei!