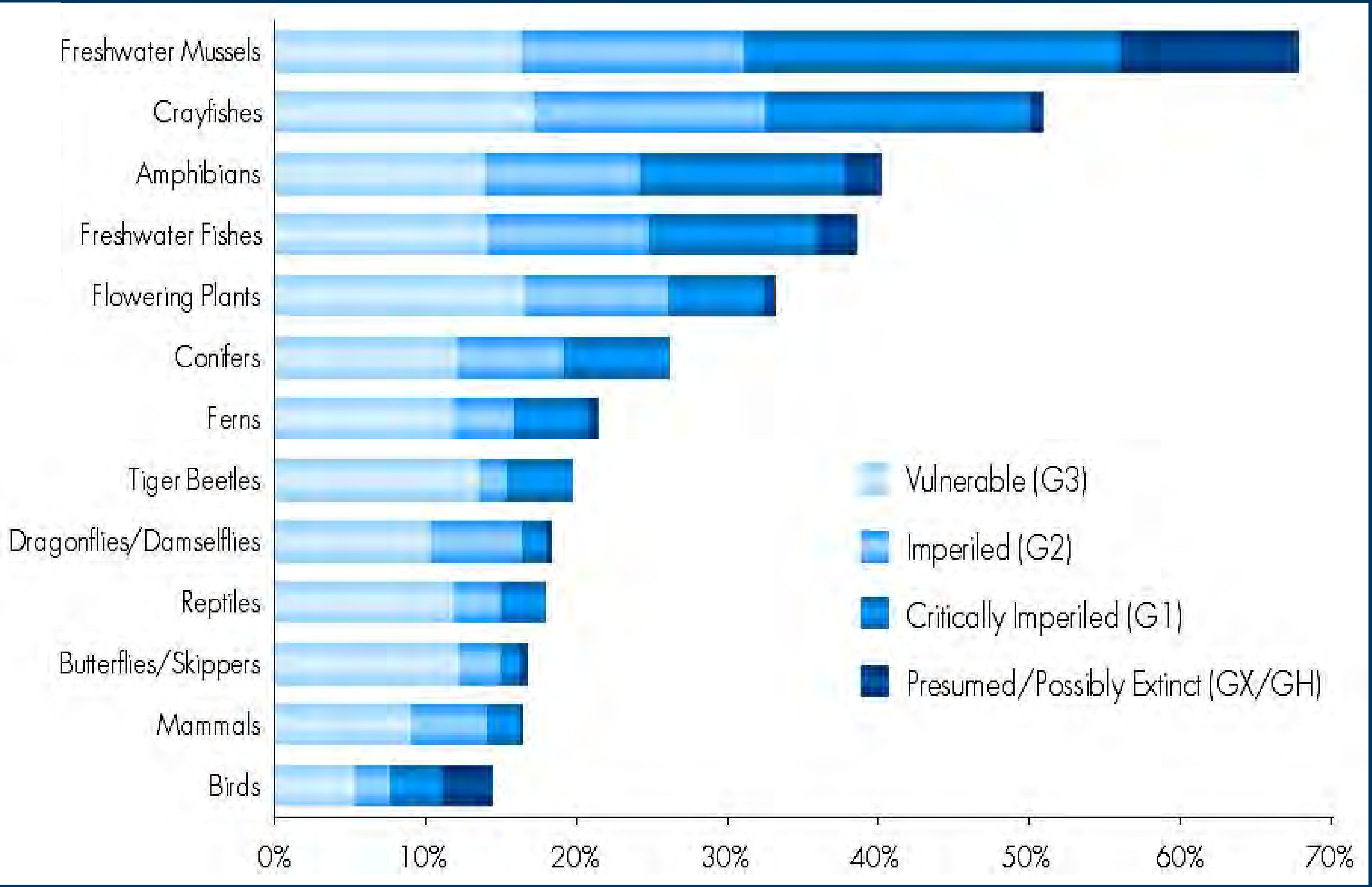
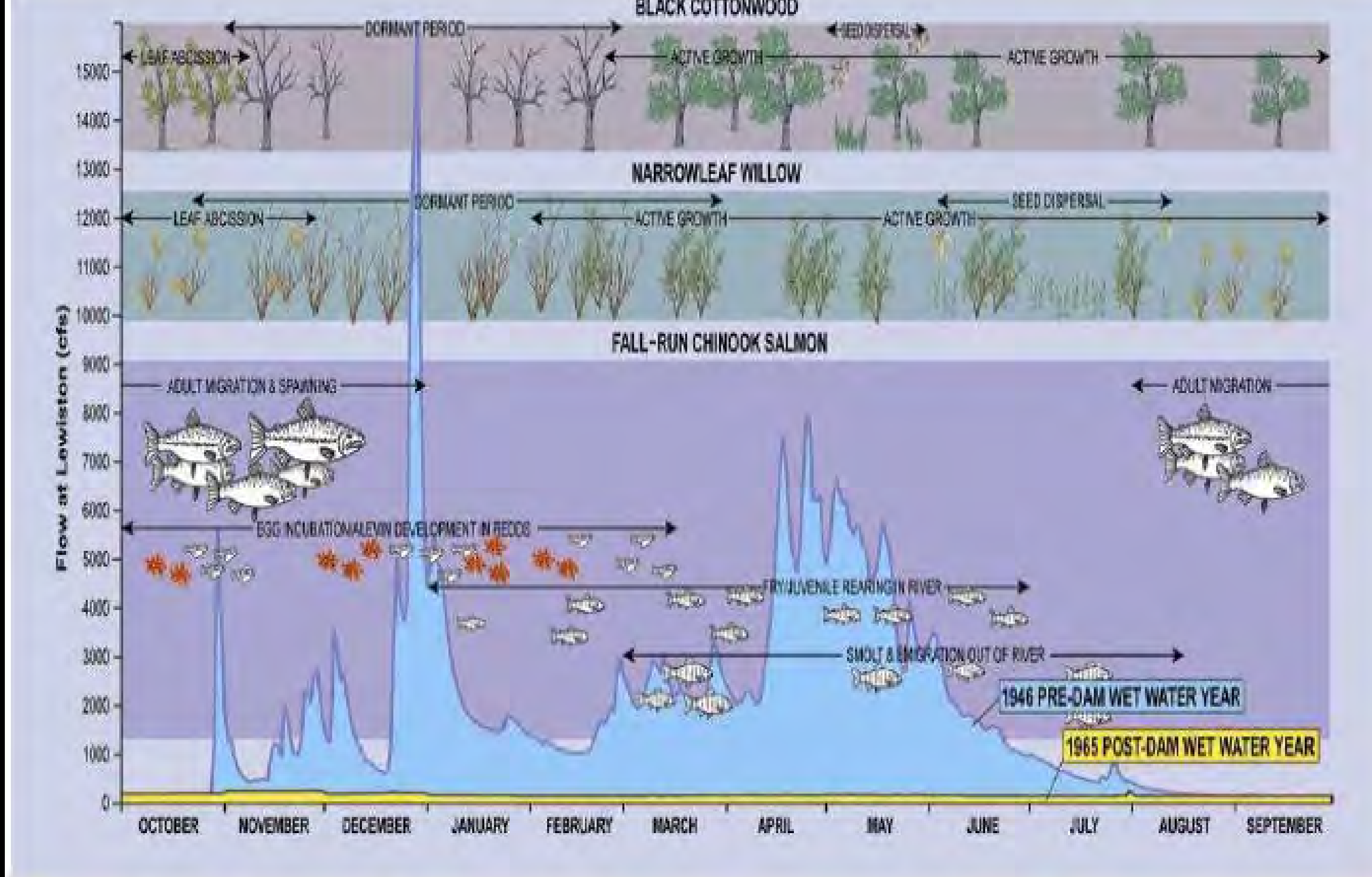
Ecosystem Flows

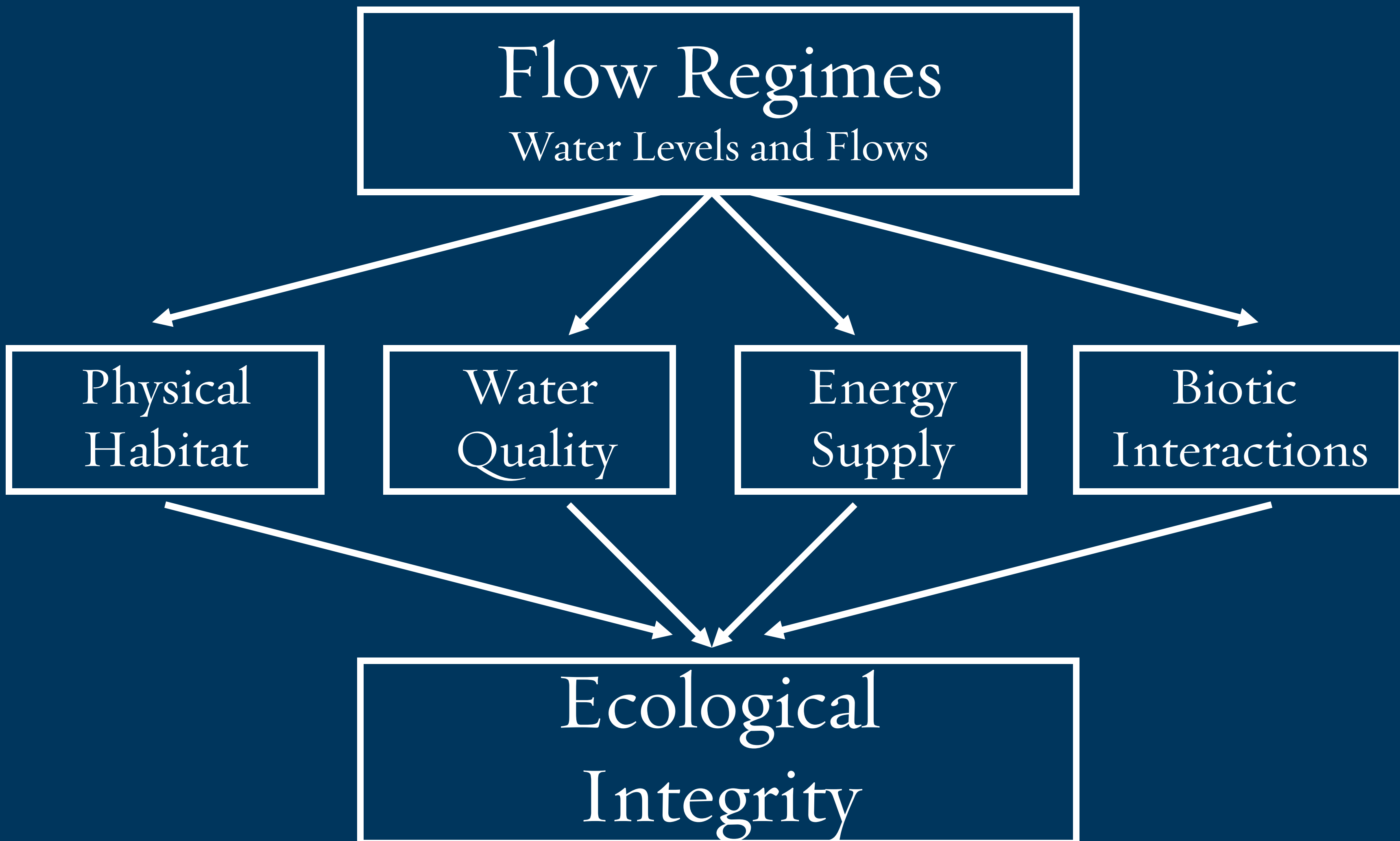
How much water does a river need?

Proportion of U.S. Species at Risk




BLACK COTTONWOOD
DORMANT PERIOD
SEED DISPERSAL
LEAF ABCISSION
ACTIVE GROWTH
ACTIVE GROWTH
NARROWLEAF WILLOW
DORMANT PERIOD
SEED DISPERSAL
LEAF ABCISSION
ACTIVE GROWTH
ACTIVE GROWTH
FALL-RUN CHINOOK SALMON
ADULT MIGRATION & SPAWNING
ADULT MIGRATION
EGG INCUBATION/ALEVIN DEVELOPMENT IN REDDS
FRY/JUVENILE REARING IN RIVER
SMOLT & EMIGRATION OUT OF RIVER
1946 PRE-DAM WET WATER YEAR
1965 POST-DAM WET WATER YEAR
Flow at Lewiston (cfs)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER

Flow: a master variable



From Poff et al. 1997

The Natural Flow Paradigm

"The full range of natural intra- and inter-annual variation in hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems."

(Poff *et al.* 1997)





The Brisbane Declaration (2007)

- ***Ecosystem flows* describe the <u>quantity, timing, and quality</u> of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.**

- **Ecosystem flow *management* provides the water flows needed to sustain freshwater and estuarine ecosystems <u>*in coexistence with*</u> agriculture, industry, and cities.**

See <u>eflownet.org</u> for the full Brisbane Declaration and Call to Action

The Nature Conservancy
Protecting nature. Preserving life.

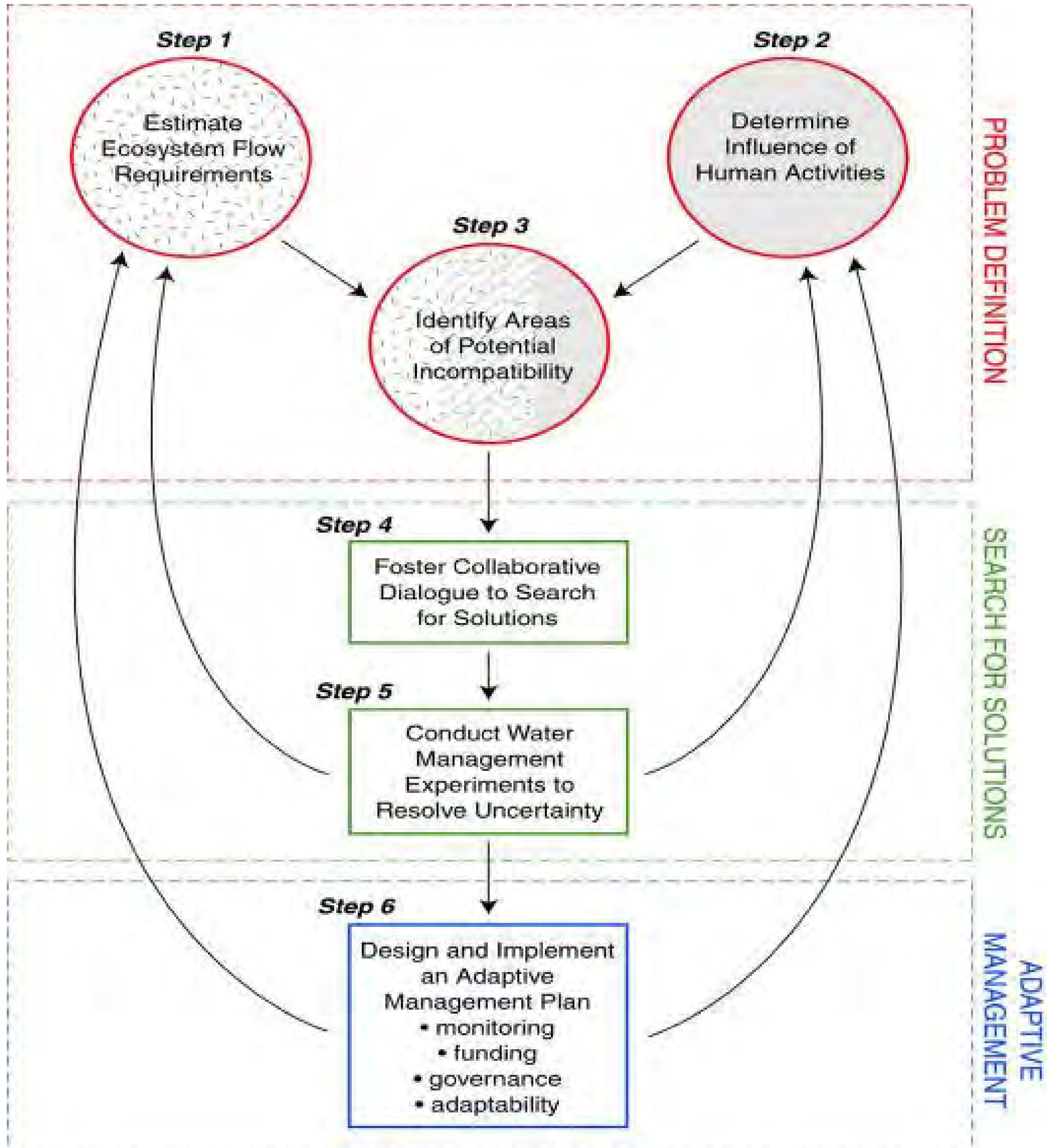
The Brisbane Declaration (2007)

- Estimate environmental flow needs everywhere immediately.
- Integrate environmental flow management into every aspect of land and water management.
- Establish institutional frameworks.
- Integrate water *quality* management.
- Actively engage all stakeholders.
- Implement and enforce environmental flow standards.
- Identify and conserve a global network of free-flowing rivers.
- Build capacity.
- Learn by doing.

See eflownet.org – The Global Environmental Flows Network

Framework for Ecologically Sustainable Water Management

Richter *et al.* 2003



The Nature Conservancy
Protecting nature. Preserving life.

What are Ecosystem Flows?

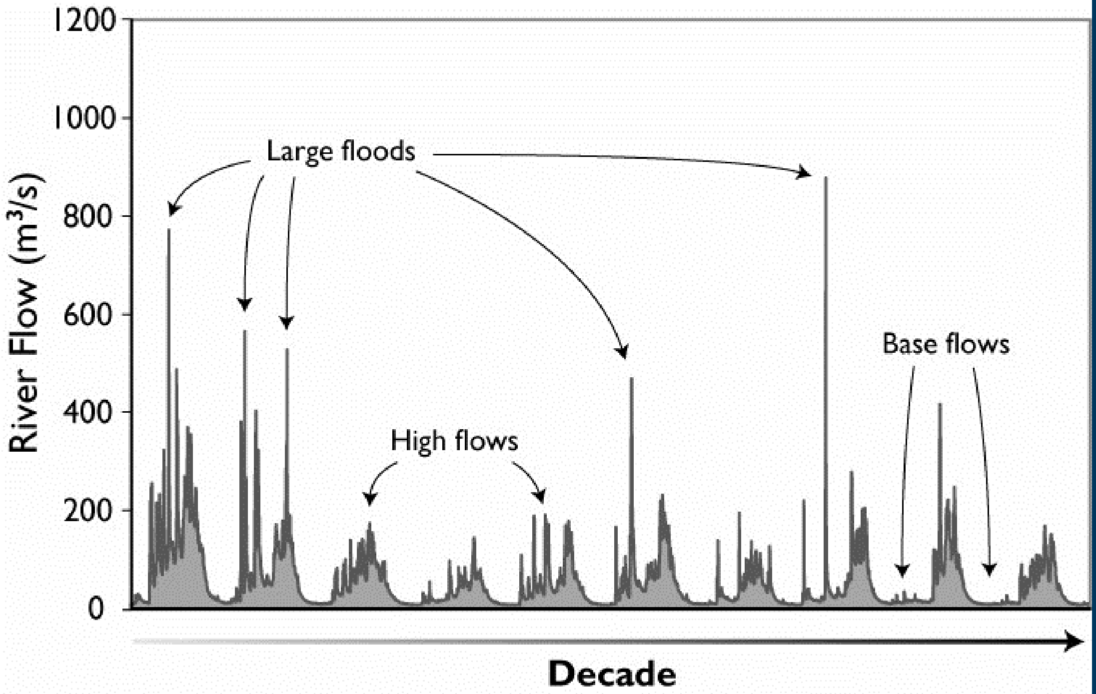
© U.S. FWS, Washington F&W

©Talkeetna Chamber of Commerce

The flow of water that sustains healthy ecosystems and the goods and services that humans derive from them.

TNC's Ecosystem Flow Principle

Conserve and restore hydrologic regimes and their natural variability to support ecological functions

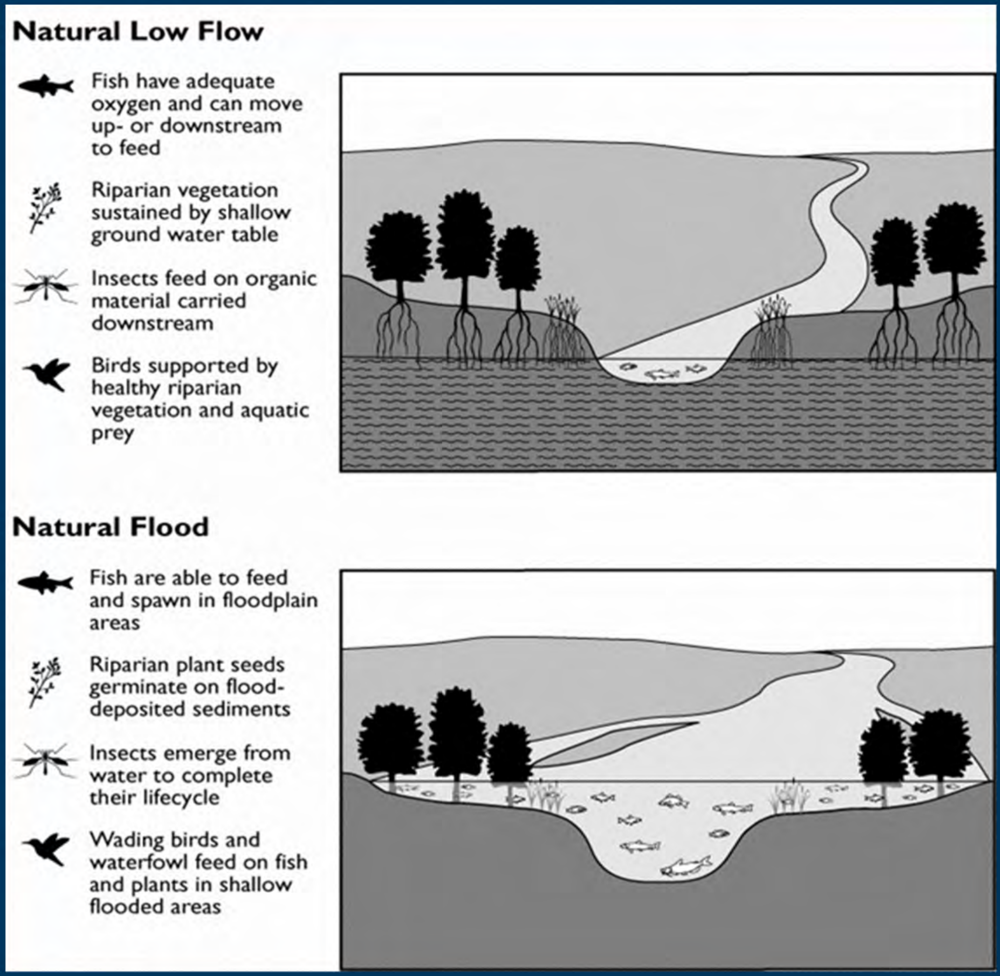


Postel and Richter 2003

The Nature Conservancy
Protecting nature. Preserving life.™

TNC's Ecosystem Flow Principle

Conserve and restore hydrologic regimes and their natural variability to support ecological functions



Postel and Richter 2003

Flow components

- Extreme low flows
- Low flows
- Seasonal or ‘typical’ flows
- High flow pulses
- Small floods
- Large floods

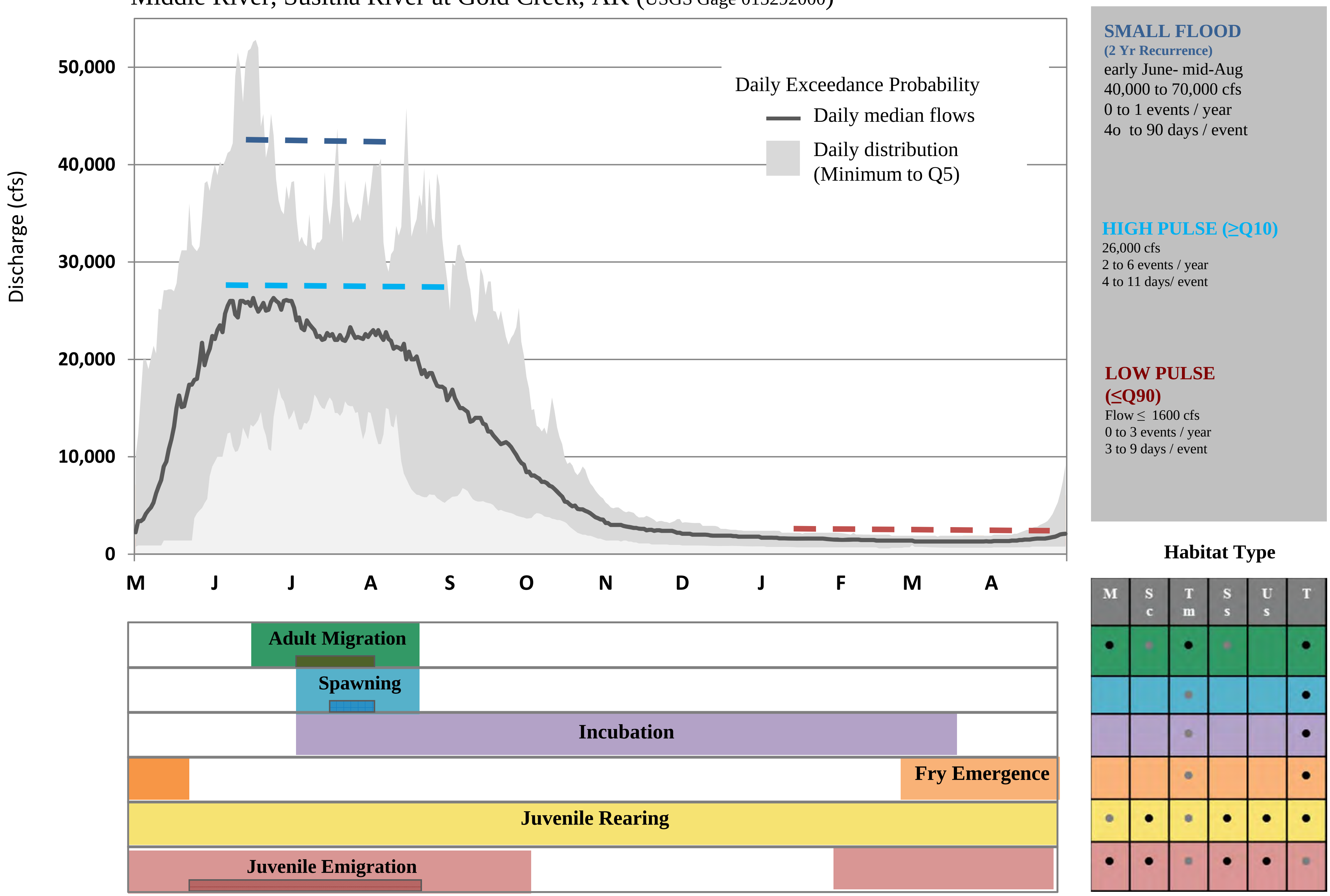
Mathews and Richter 2003

Alteration to the flow regime

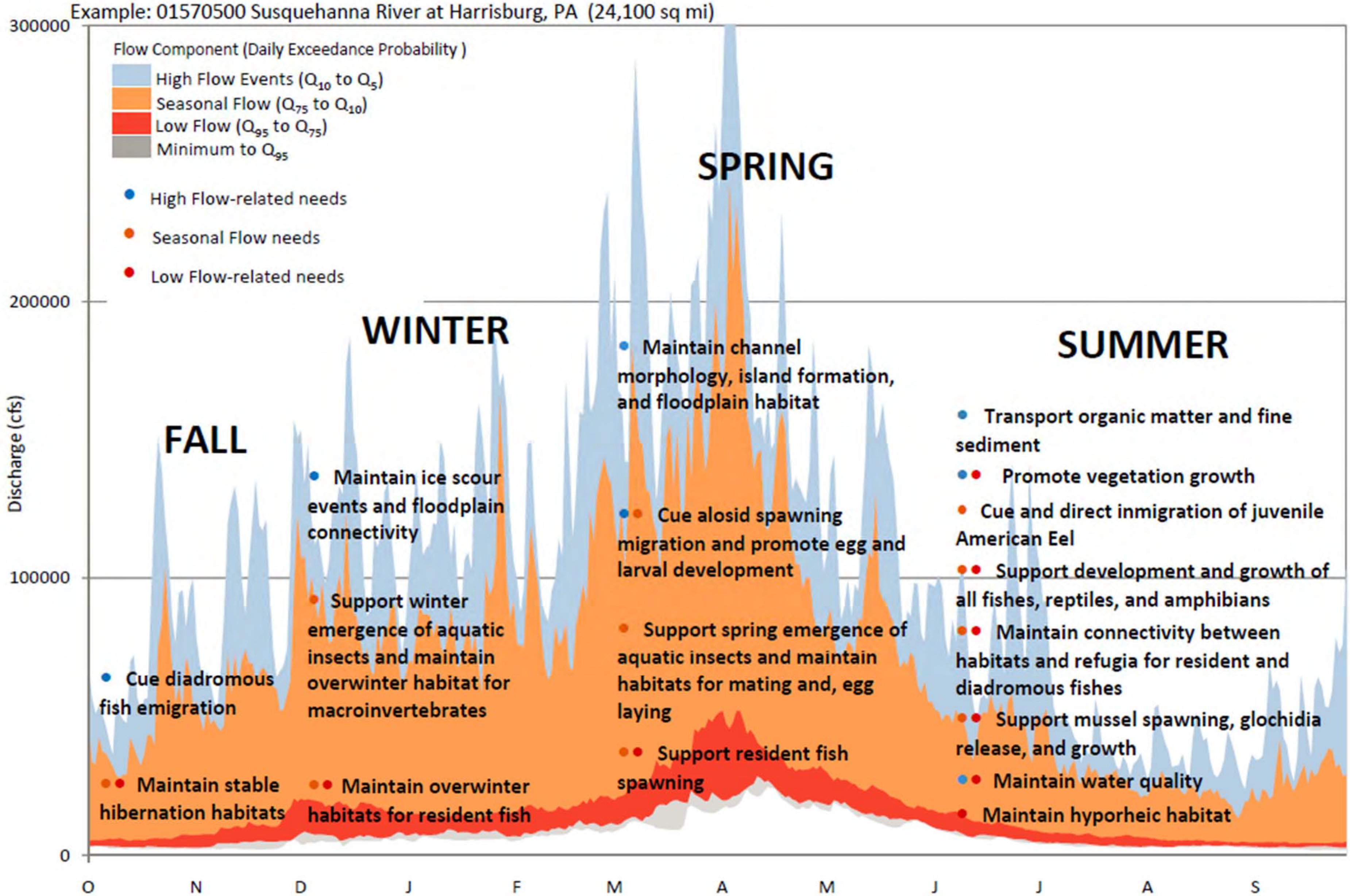
- Dams
- Levees
- Surface water withdrawals
- Groundwater withdrawals
- Land use change
- Climate change

Flow-Ecology Diagram: Chinook Salmon

Middle River, Susitna River at Gold Creek, AK (USGS Gage 015292000)



Flow Components and Needs: Mainstem



DePhilip et al. 2010

Partnerships, Science, Policy and Tools

- Sustainable Rivers Project
- Hydropower Sustainability Assessment Protocol
- Ecological Limits of Hydrologic Alteration
- HEC-EFT
- Indicators of Hydrologic Alteration

Proposed fish passage design on Savannah River

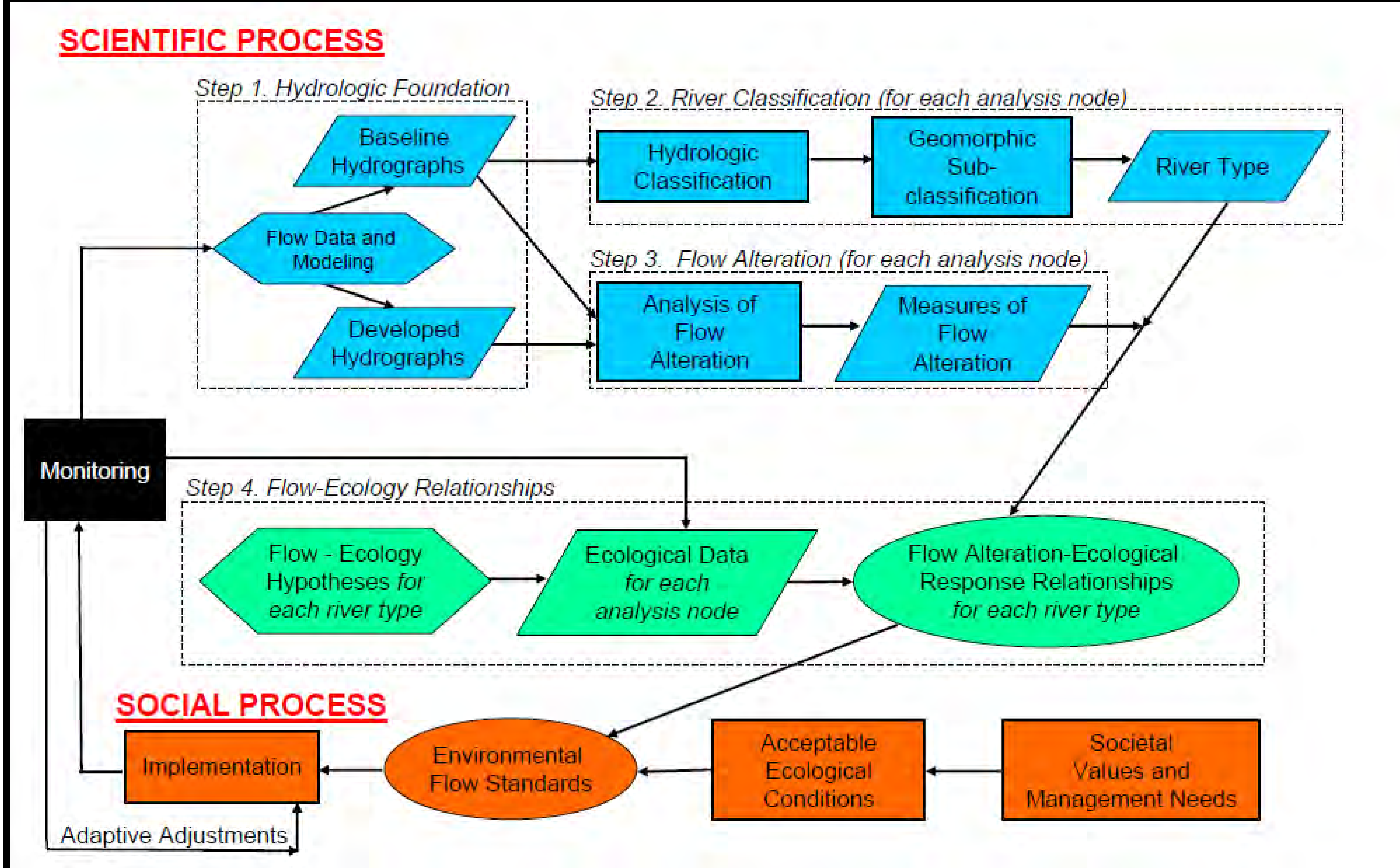
Ecosystem Flow Prescriptions by River

Rivers for which environmental flows have been or are being prescribed

Ecological Limits of Hydrologic Alteration

- The Ecological Limits of Hydrologic Alteration (ELOHA, Poff et al. 2010)
- A framework for assessing environmental flow needs over broad geographic areas when site-specific studies cannot be conducted for all rivers

Ecological Limits of Hydrologic Alteration (Poff et al 2010)



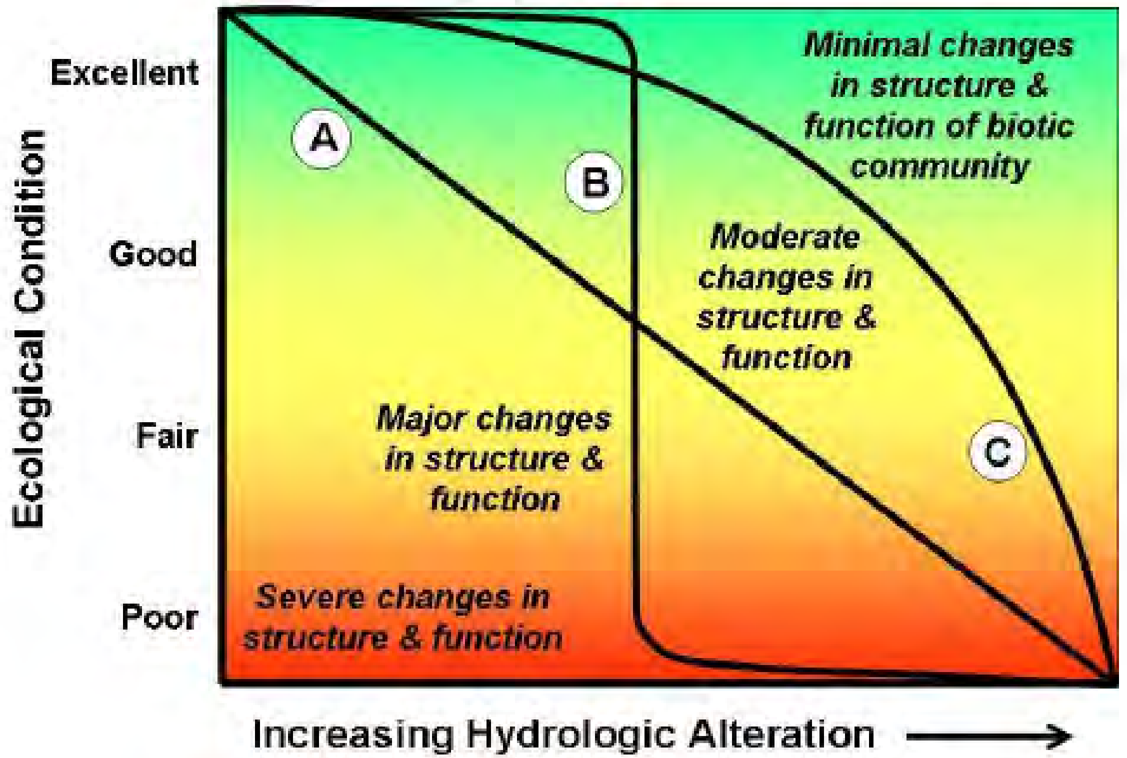
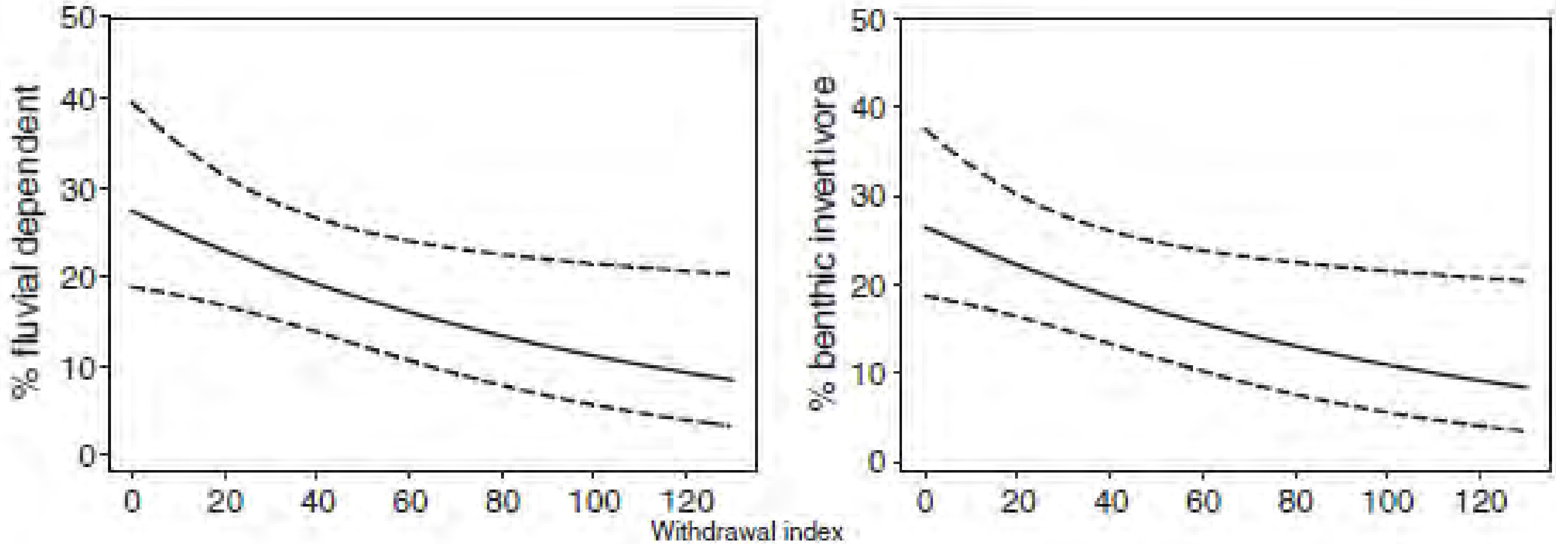
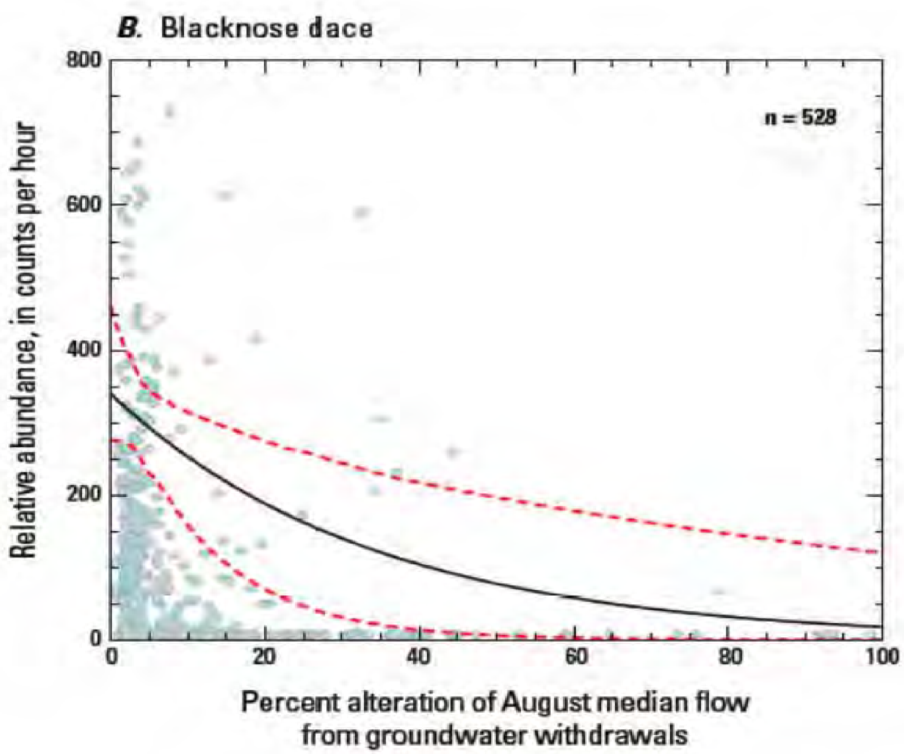


Figure 2.1 Conceptual flow-ecology curves showing possible forms of the relationship. A: linear, B: threshold, C: curvilinear. The graph represents one river type. After Davies and Jackson (2006).

Kendy et al 2012 . A practical guide to Environmental flows for Policy and Planning

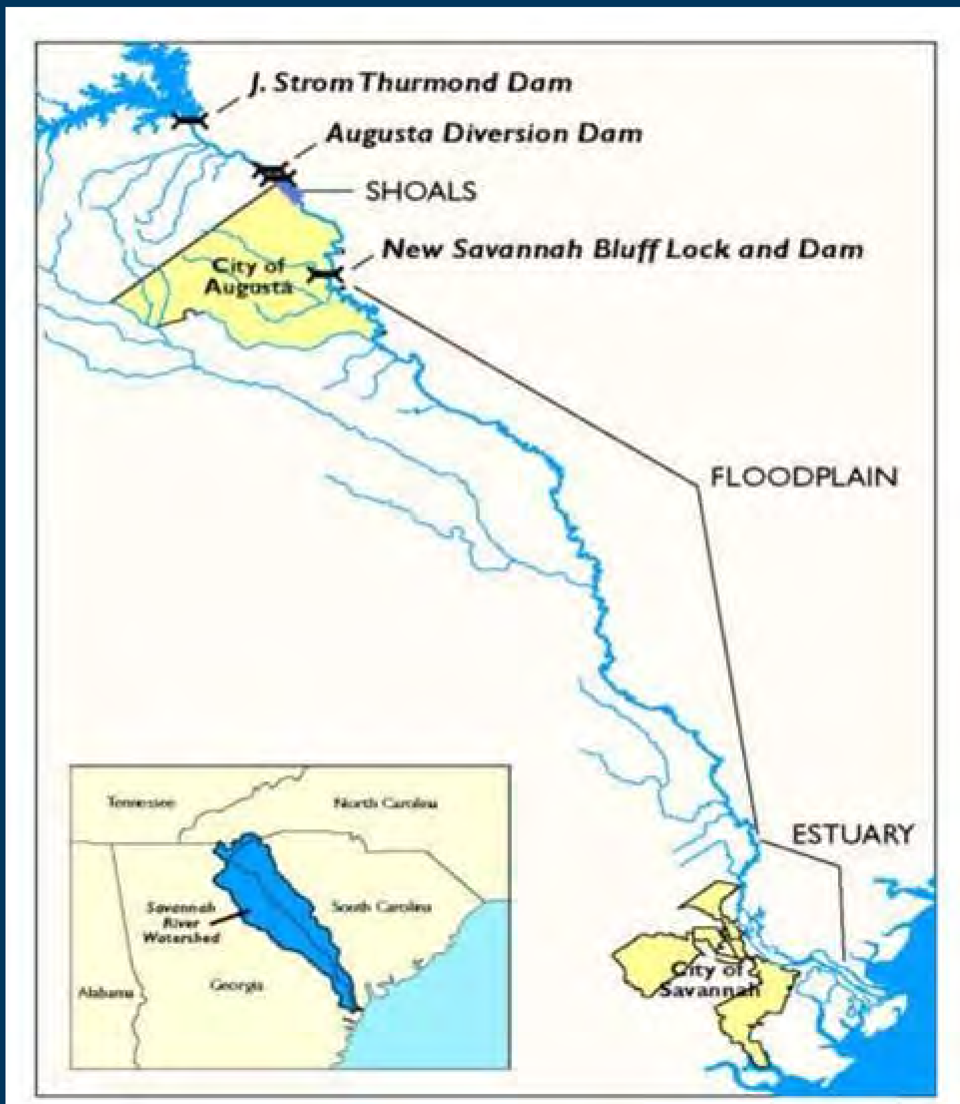


Kanno and Vokoun 2010

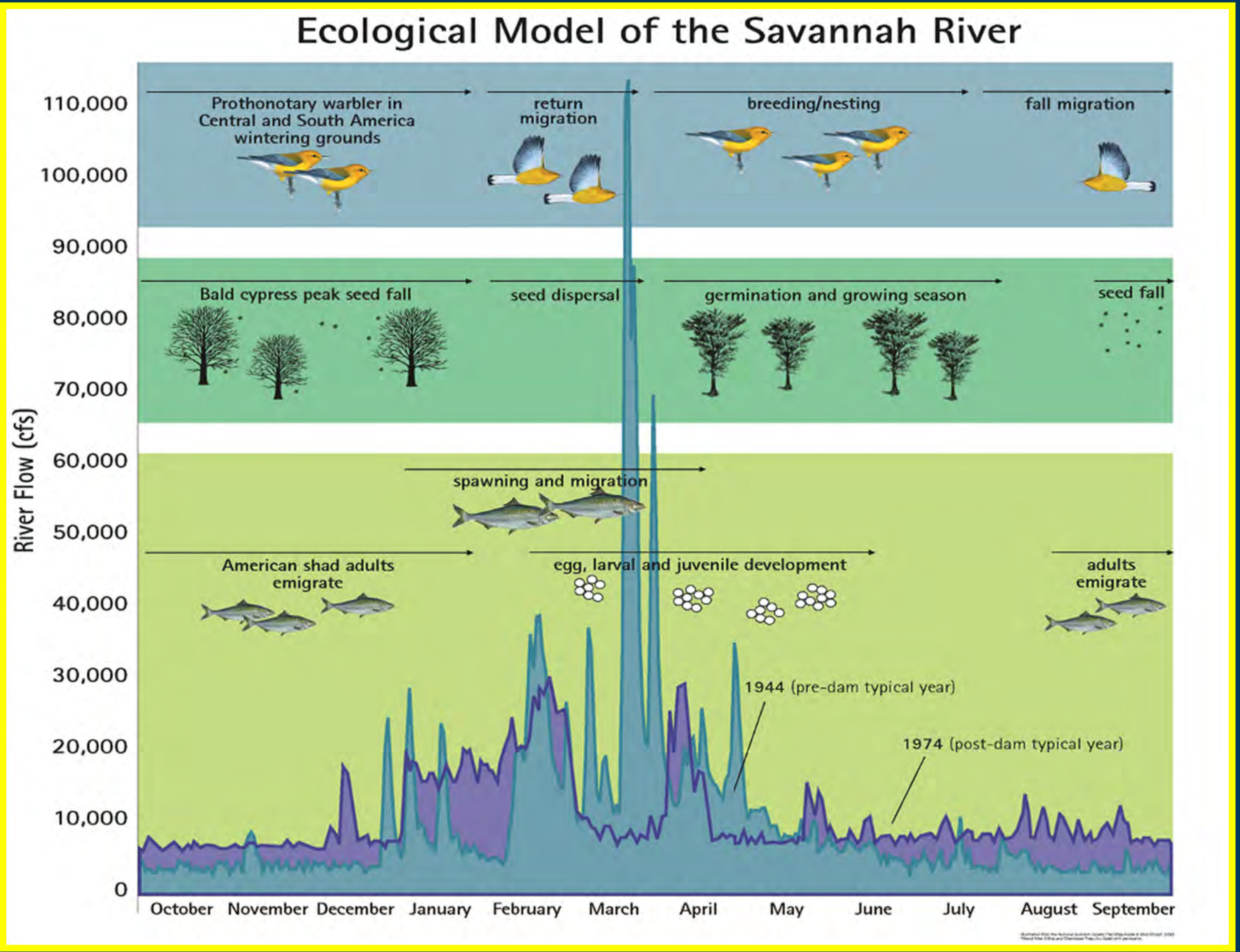


Armstrong et al. 2011

Case Study – Savannah River and Estuary



Savannah River – Relating flow to ecology



Ecological Flow Tool on Sacramento River: Focal Species

The Nature Conservancy
Protecting nature. Preserving life.™

Steelhead
(***Oncorhynchus mykiss***)

Chinook Salmon
(Oncorhynchus tshawytscha)

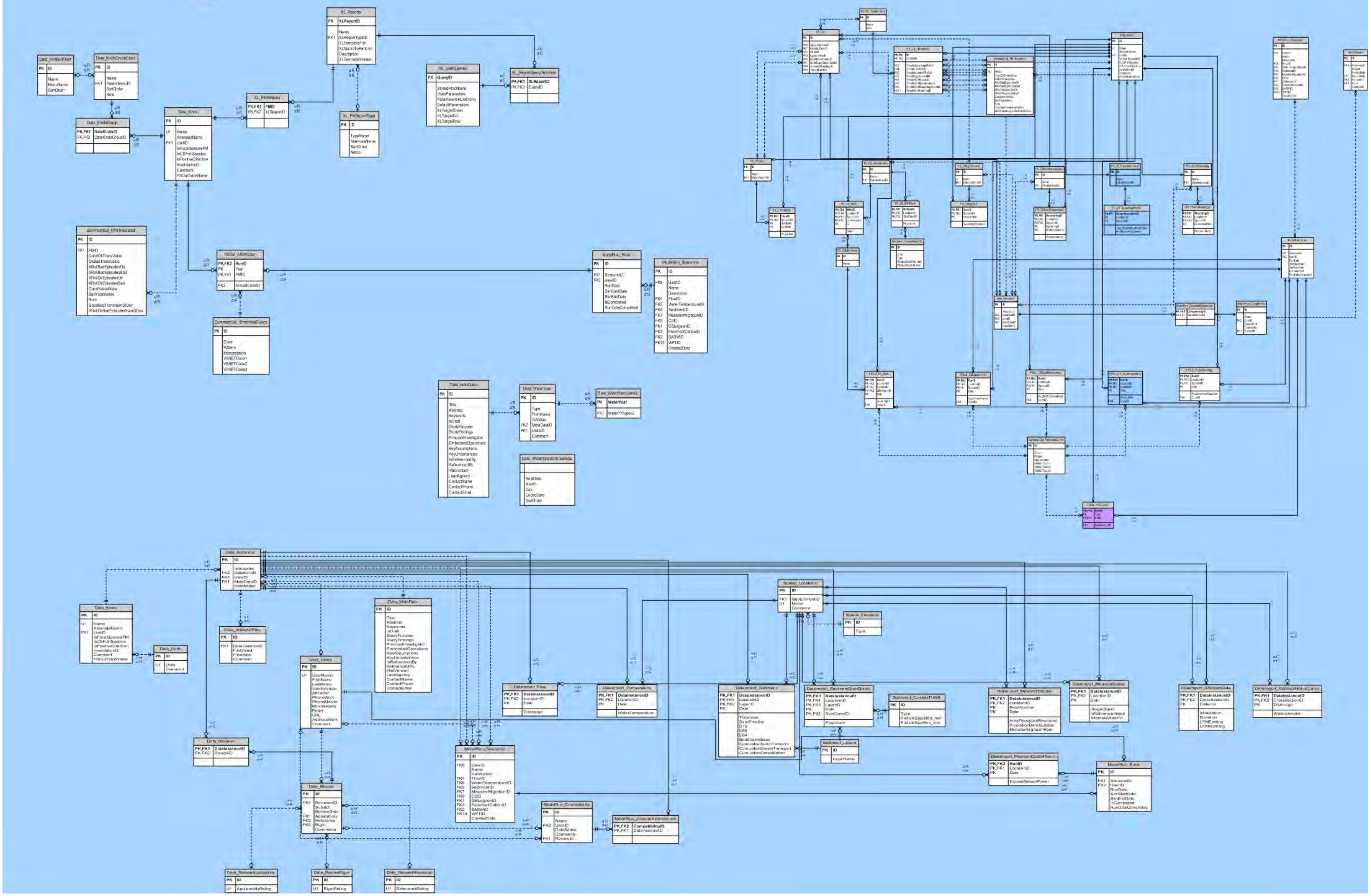
Green Sturgeon
(Acipenser medirostris)

Bank Swallow
(Riparia riparia)

Western Pond Turtle
(Clemmys marmorata)

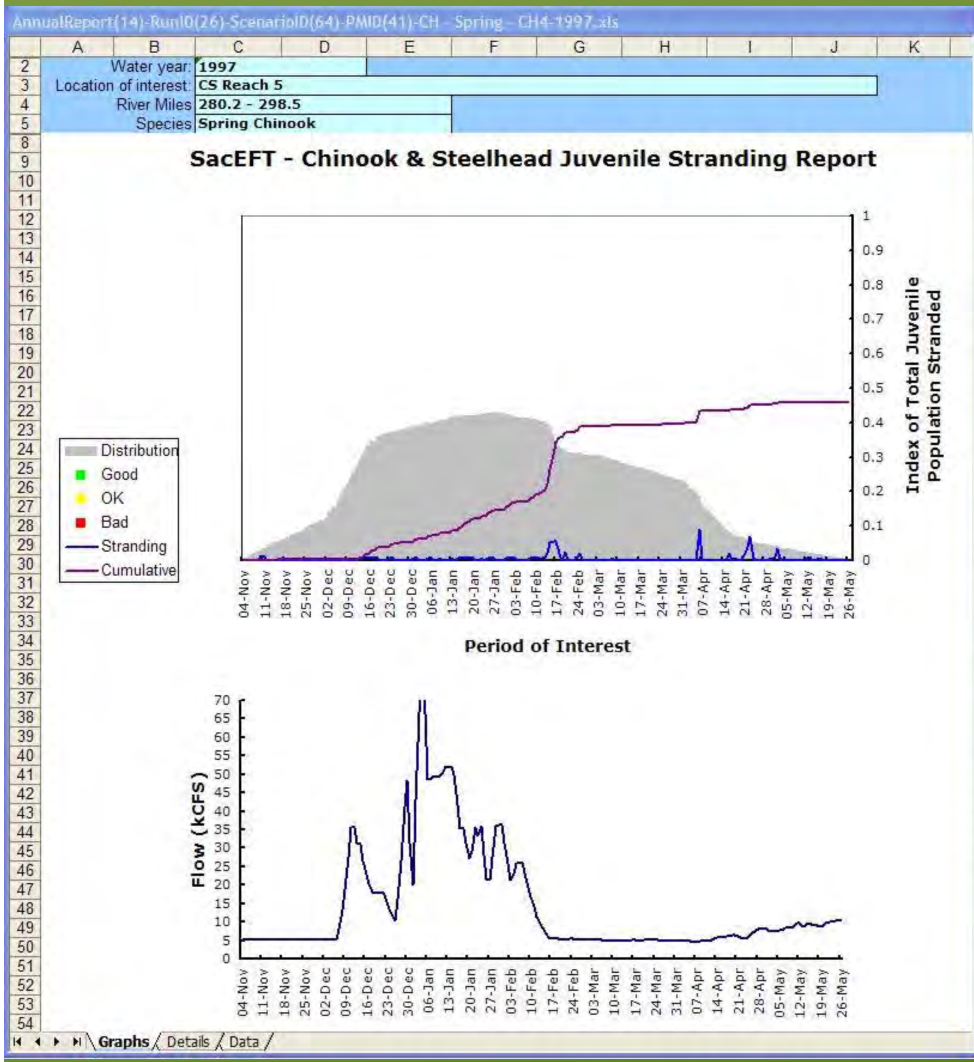
Fremont Cottonwood
(Populus fremontii)

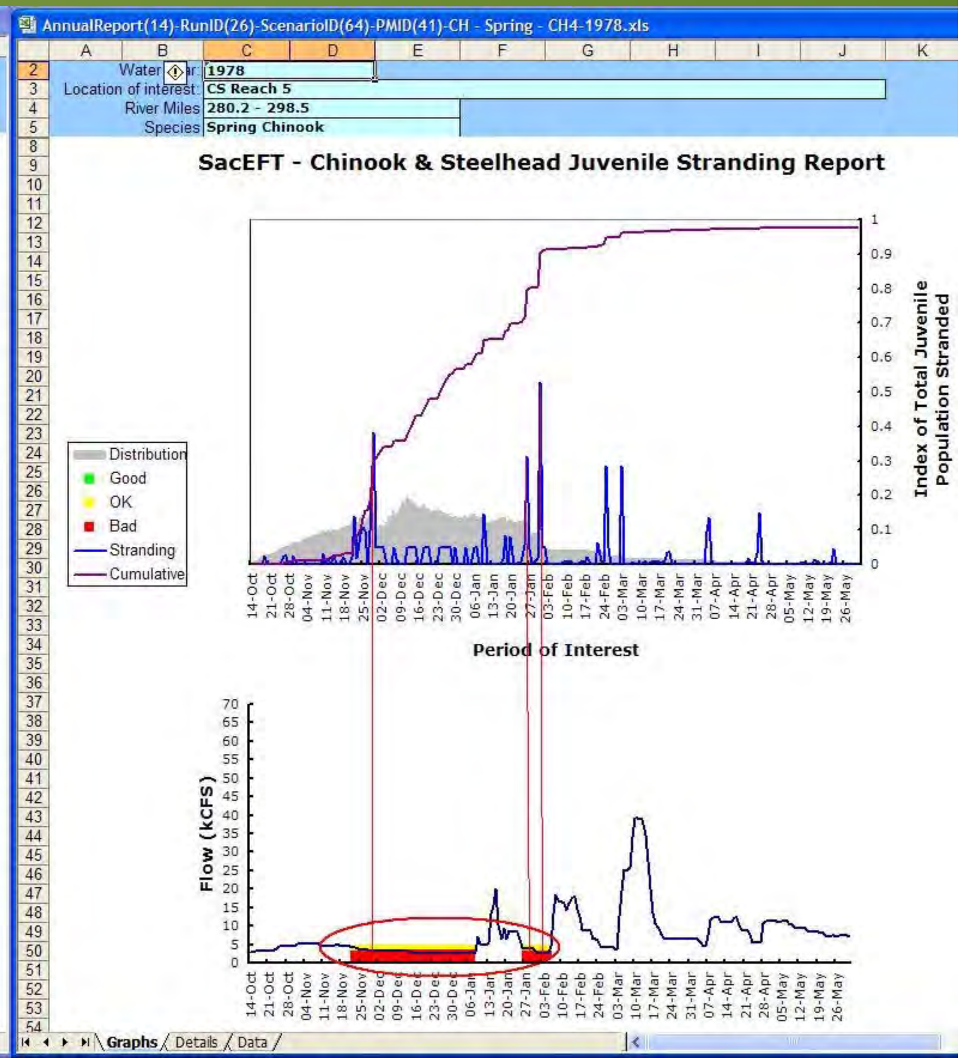
Decision Support System: SacEFT used manage data and link different tools/datasets



Output Example: SacEFT's juvenile stranding report

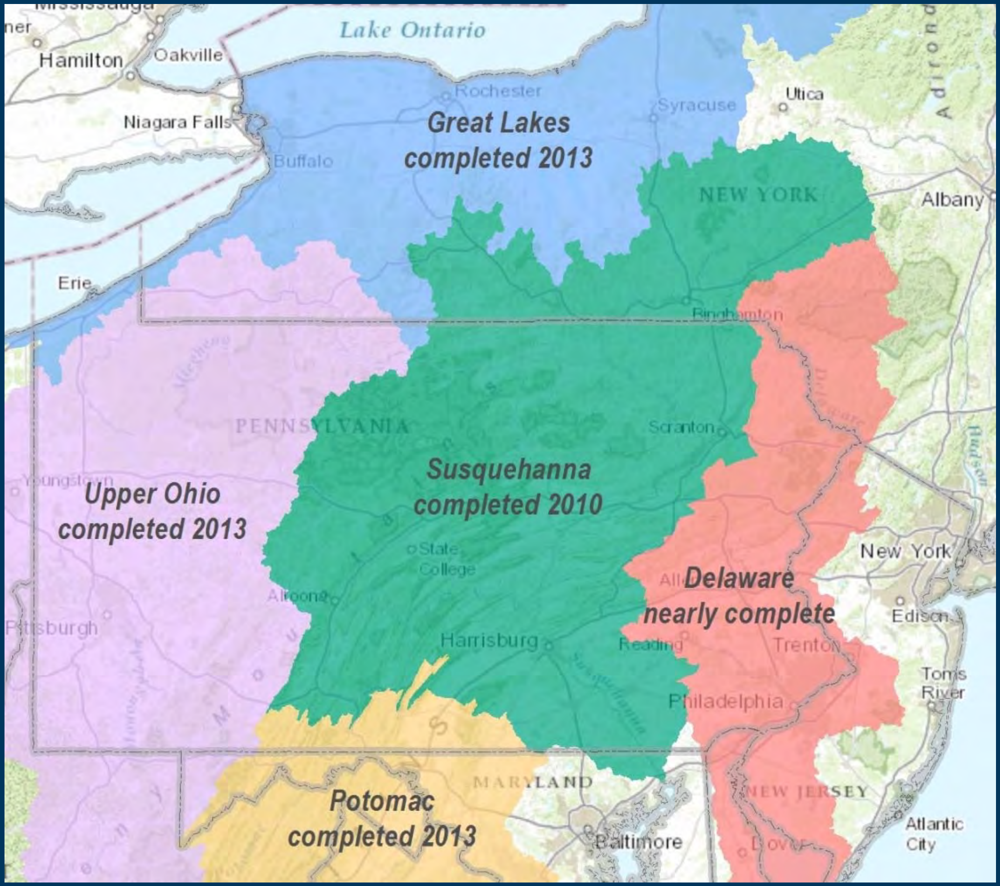
good year | poor year



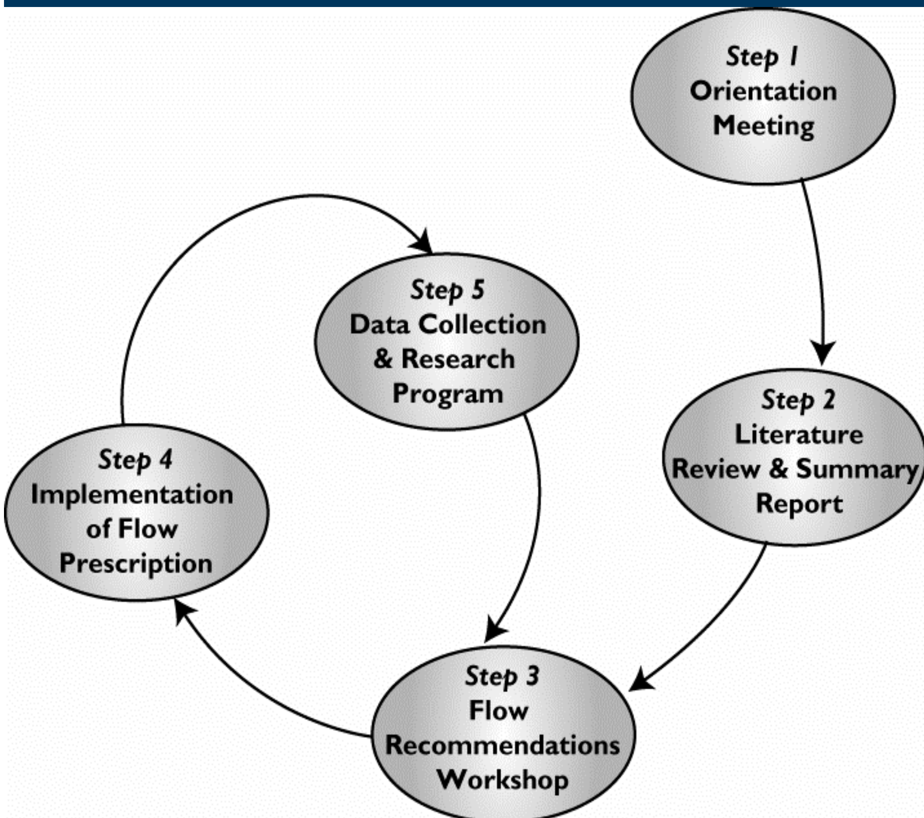


Basin-wide Ecosystem Flow Recommendations

Objective: to develop science-based flow recommendations based on existing information that are useful to water managers.



Research Process and Study Questions



Richter et al. 2006

What are the variety of hydroecological settings?

Within each setting (type), how do flow conditions affect species and ecological processes throughout the year?

What range of flows would protect these species and ecological processes?

How does the ecosystem depend on flow?

- Represent taxa, communities, and habitats characteristic of Ohio River basin stream types
- Group species with shared flow-dependencies
- Capture range of traits
  - distribution
  - mobility
  - habitat associations
  - feeding and spawning habits
  - longevity

Photo by Western Pennsylvania Conservancy

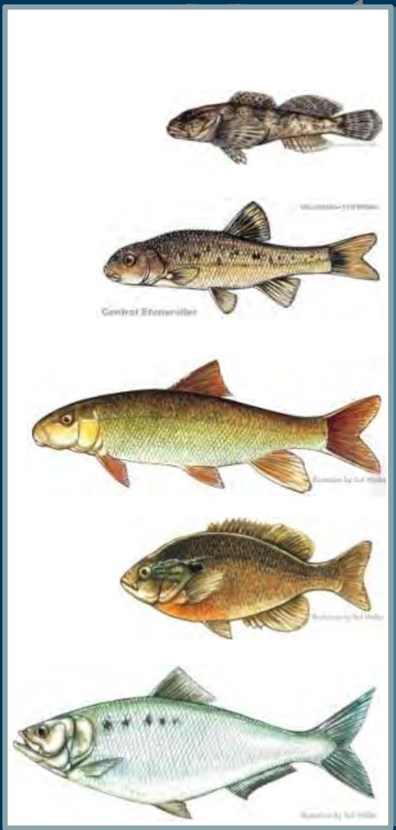
Photo by P. Petokas

How does the ecosystem depend on flow?

Selected more than 60 species (20 species groups) and 7 Physical and Chemical processes

- Fishes

illustrations by Ted Walke, PFBC



Cold headwater – brook trout, brown trout, *Cottus* spp

Riffle-obligates – Margined madtom, longnose dace, central stoneroller, fantail darter

Riffle-associates – White sucker, northern hog sucker, shorthead redhorse

Nest-builders – Fallfish, creek chub, river chub, redbreast sunfish, smallmouth bass

Diadromous – American shad, alewife, American eel

Flow-sensitive groups and processes

Fishes
Cold headwater
Slow spring fed
Riffle-obligates
Riffle-spawners
Nest builders
Potadromous
Diadromous

Mussels
Mod gradient, small river
Moderate to swift
Slow, low gradient
Great rivers (mainstem)

Reptiles and Amphibians
Aquatic lotic
Semi-aquatic lotic
Riparian and floodplain habitat spp.

Floodplain and Aquatic Vegetation
Submerged and emergent beds
Riparian forest and shrub
Low scour floodplain
Scour-dependent floodplain

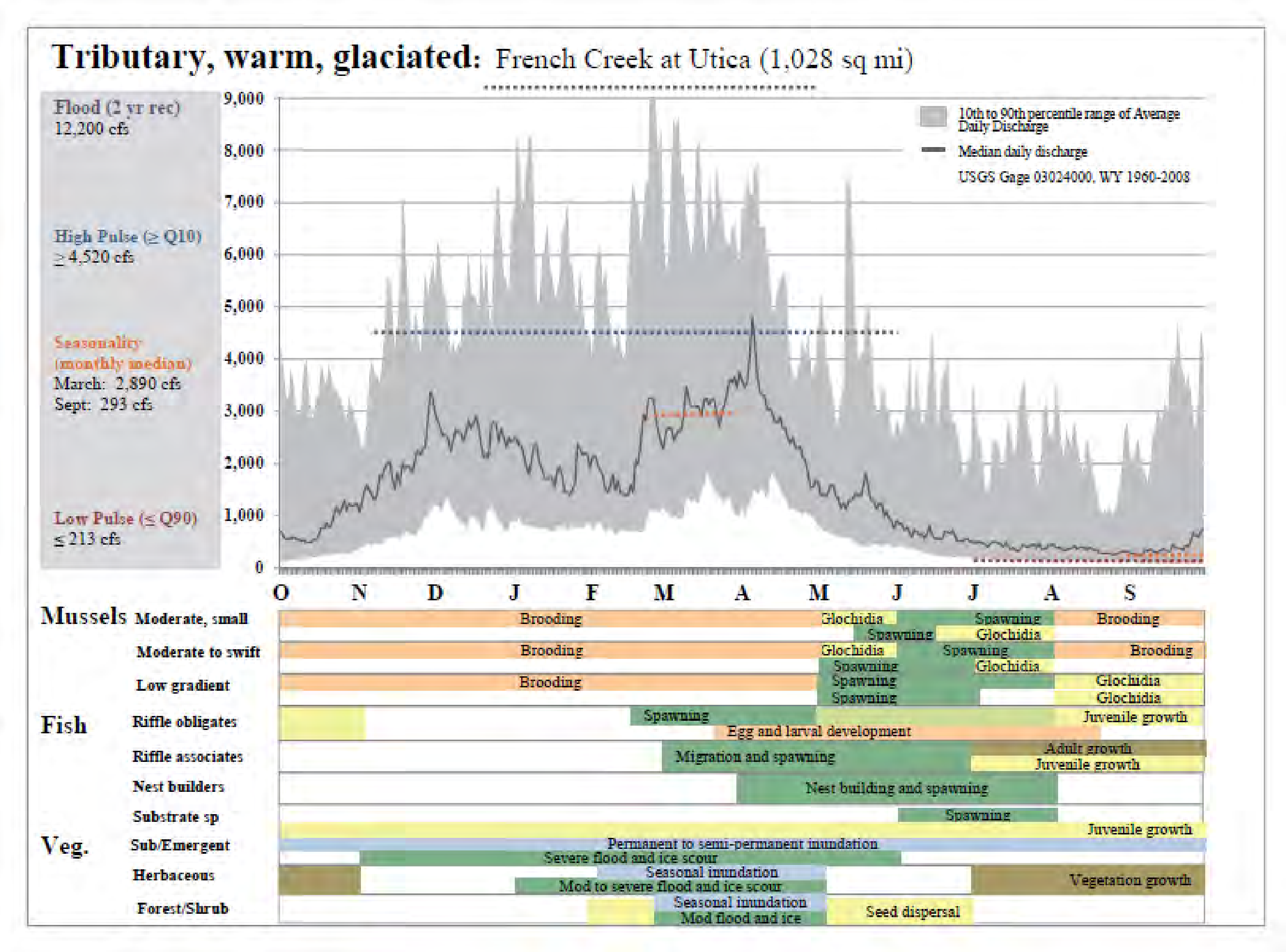
Aquatic Insects and Crayfish
Habitat associations
Trophic traits
Species assemblages

Birds and Mammals
Rely on stream-derived food and habitat

Water Quality

Floodplain and Channel Maintenance

Eighty (80) **FLOW-ECOLOGY HYPOTHESES** describe *who* (species or guild) is affected by *what* (flow component), *when* (month or season), *where* (habitat), and *how* (hypothesized ecological response).



Eighty (80) FLOW-ECOLOGY HYPOTHESES **describe *who* (species or guild) is affected by *what* (flow component), *when* (month or season), *where* (habitat), and *how* (hypothesized ecological response).**

EXAMPLE FISH HYPOTHESES

H1 ● A decrease in seasonal flow magnitude may result in loss of persistent habitats and a shift in fish assemblage.

H2 ● A decrease in low flows may reduce access to and abundance of food, including algae and benthic macroinvertebrates, impacting individual growth

Eighty (80) **FLOW-ECOLOGY HYPOTHESES** describe *who* (species or guild) is affected by *what* (flow component), *when* (month or season), *where* (habitat), and *how* (hypothesized ecological response).

Hypotheses are consolidated into **FLOW NEEDS** (20) and qualitative support for needs is assessed through Weight-of-Evidence.

EXAMPLE FLOW NEED FOR FISH

●●*Maintain heterogeneity of and connectivity between habitats for resident and migratory fishes*

Eighty (80) FLOW-ECOLOGY HYPOTHESES describe *who* (species or guild) is affected by *what* (flow component), *when* (month or season), *where* (habitat), and *how* (hypothesized ecological response).

Hypotheses are consolidated into FLOW NEEDS (20)

FLOW RECOMMENDATIONS to support FLOW NEEDS defined by:

- **Qualitative and quantitative support assessed with Weight-of-Evidence.**
- **Hydrologic characterization**
- **Expert review and confirmation**

Seasonal flows	• Less than X% change to seasonal flow range **(monthly Q10 to Q50)** • Y% change to **monthly median**; • Z% change to seasonal flow range **(monthly Q50-Q75)**
Low flows	• X% change to **monthly Q75;** and • Y% change to **low flow range (monthly Q75 to Q99)**

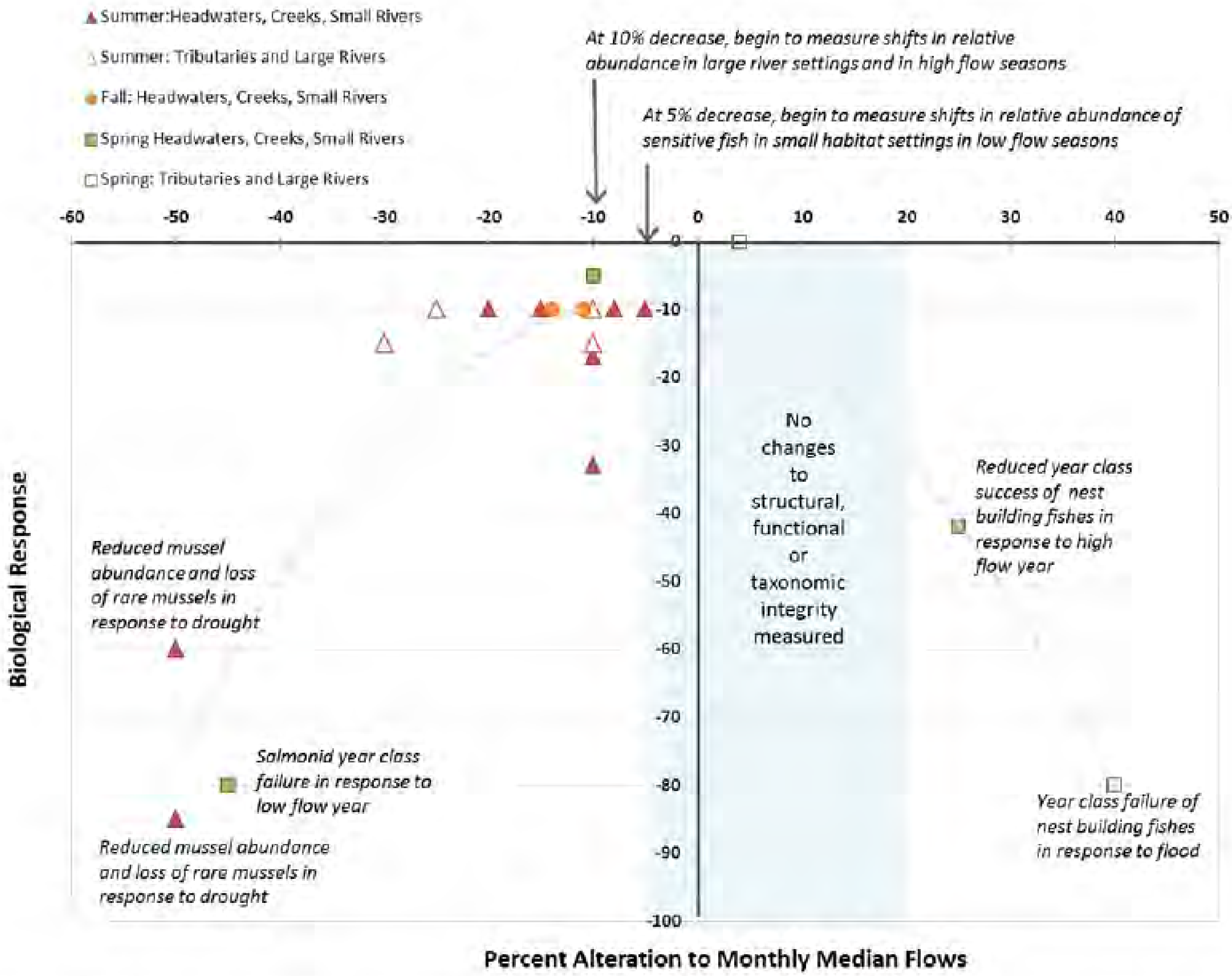
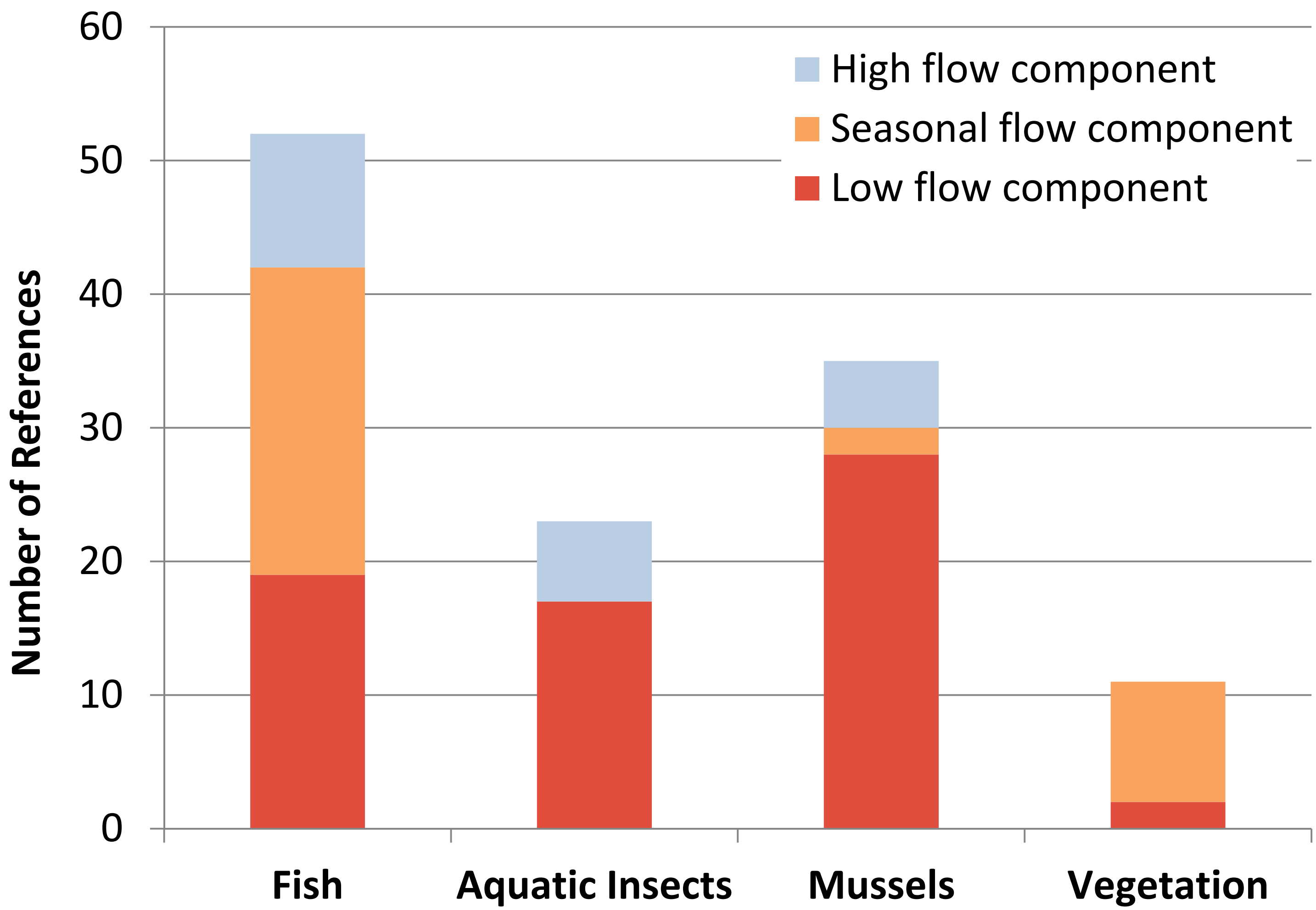
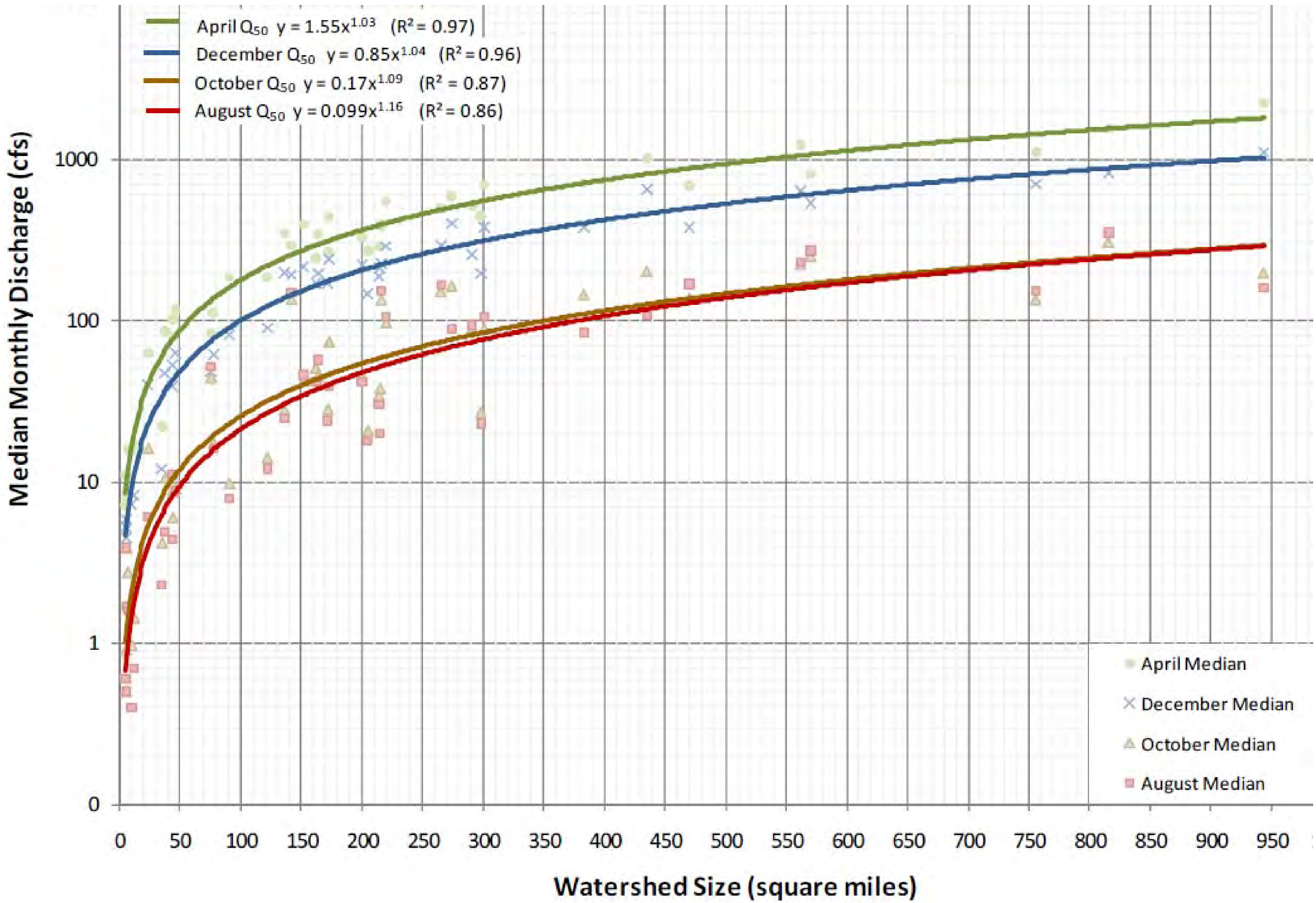


Figure 5.5 Relationships between flow alteration and biological condition. Quantitative biological responses to alteration of monthly median flows.

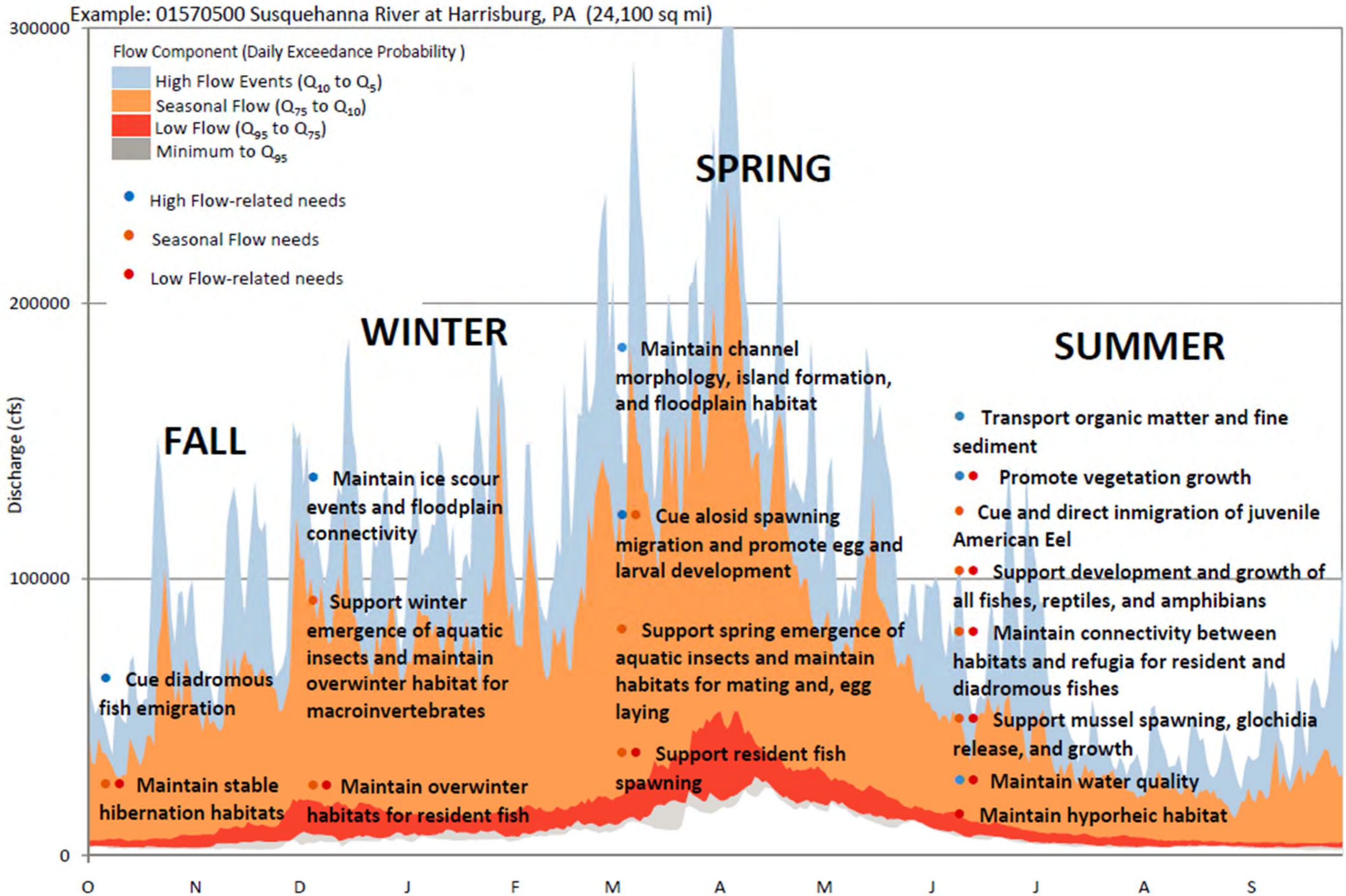
Evidence to Support Summer Recommendations





April Q_{50} $y = 1.55x^{1.03}$ ($R^2 = 0.97$)
December Q_{50} $y = 0.85x^{1.04}$ ($R^2 = 0.96$)
October Q_{50} $y = 0.17x^{1.09}$ ($R^2 = 0.87$)
August Q_{50} $y = 0.099x^{1.16}$ ($R^2 = 0.86$)
Median Monthly Discharge (cfs)
1000
100
10
1
0
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
Watershed Size (square miles)
April Median
December Median
October Median
August Median

Flow Components and Needs: Mainstem



DePhilip et al. 2010