The Hydrologic Regime:

linking river ecosystem processes and developing environmental flow recommendations

1

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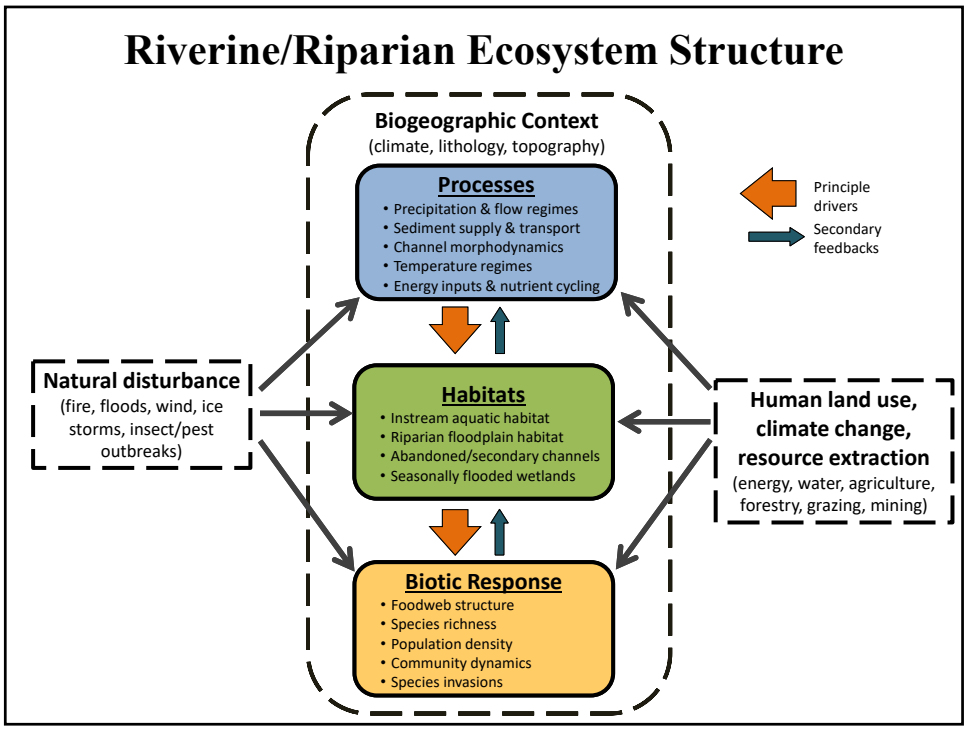
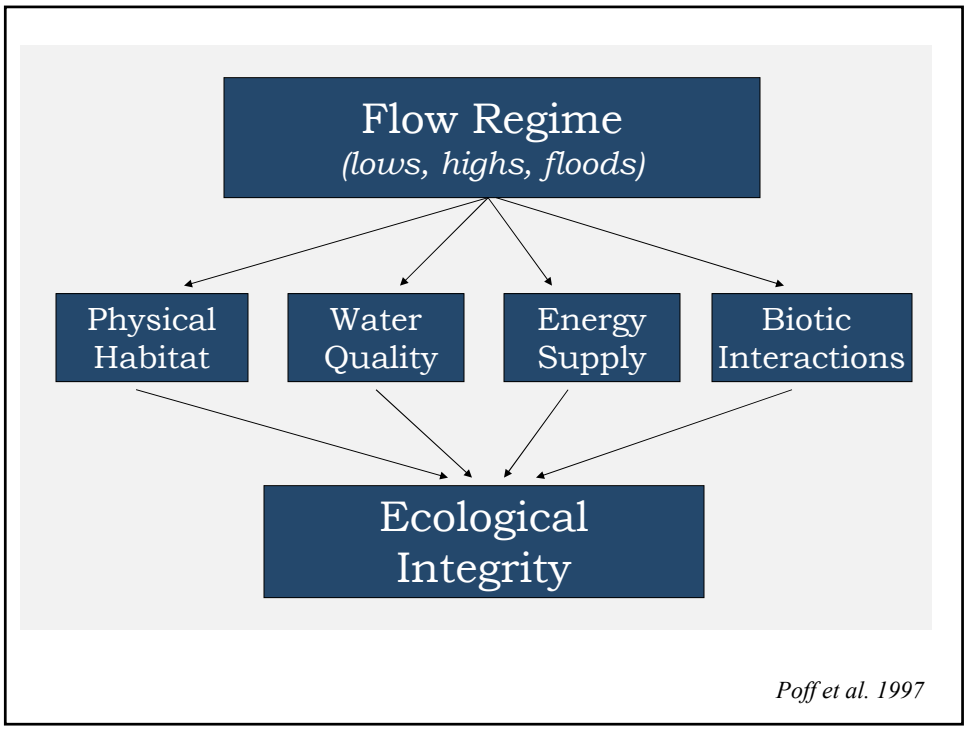
linking river ecosystem processes and developing environmental flow recommendations

2

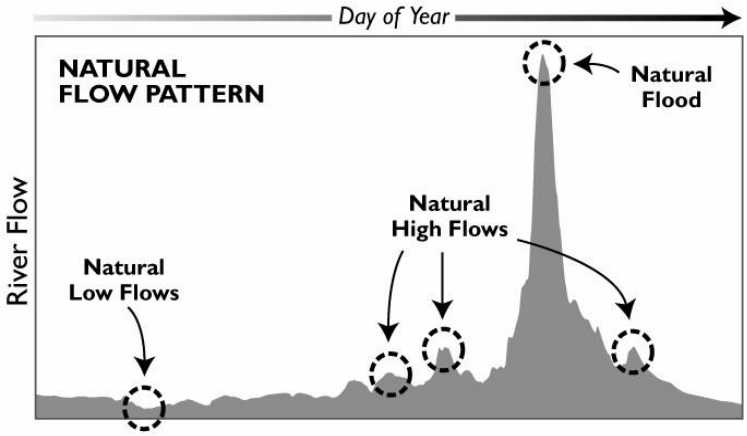

Riverine/Riparian Ecosystem Structure
Biogeographic Context
(climate, lithology, topography)
Processes
• Precipitation & flow regimes
• Sediment supply & transport
• Channel morphodynamics
• Temperature regimes
• Energy inputs & nutrient cycling
Principle drivers
Secondary feedbacks
Natural disturbance
(fire, floods, wind, ice storms, insect/pest outbreaks)
Habitats
• Instream aquatic habitat
• Riparian floodplain habitat
• Abandoned/secondary channels
• Seasonally flooded wetlands
Human land use, climate change, resource extraction
(energy, water, agriculture, forestry, grazing, mining)
Biotic Response
• Foodweb structure
• Species richness
• Population density
• Community dynamics
• Species invasions

3


Flow Regime
(lows, highs, floods)
Physical Habitat
Water Quality
Energy Supply
Biotic Interactions
Ecological Integrity
Poff et al. 1997

4

Flow Events (lows, highs, floods)



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Ecological Functions of Flow Events

Sockeye salmon migration © Maclean

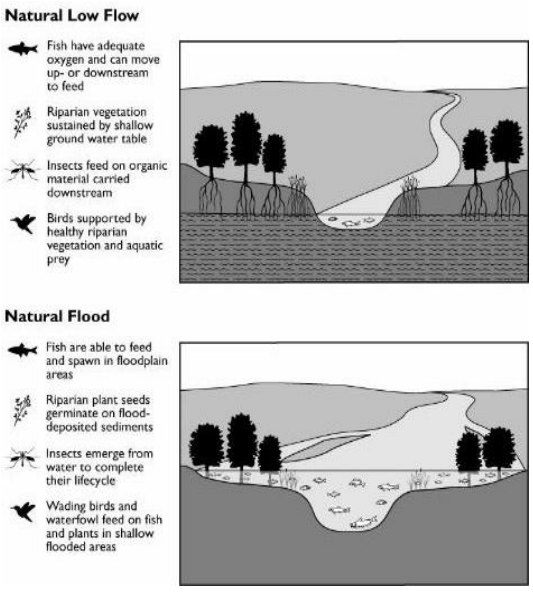
6

Ecological Functions of Flow Events

Cypress in South Carolina © Kirkendall

7

Ecological Functions of Flow Events



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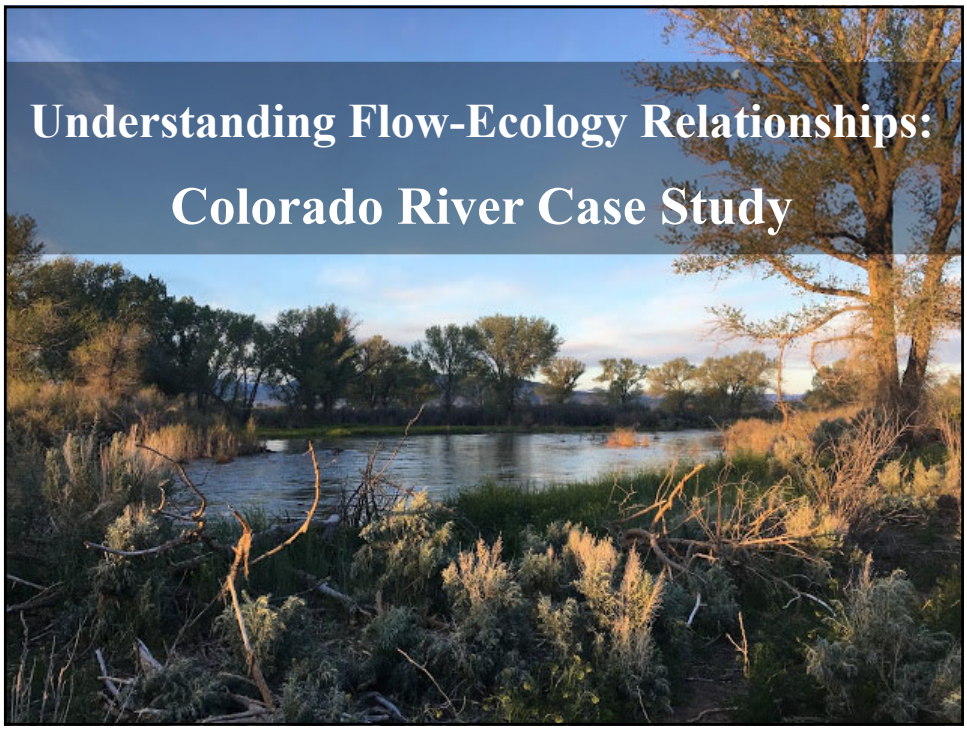

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Colorado Pikeminnow

A Life History

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- Ancient fish
- Endemic to the Colorado River
- Largest minnow in North America
- Lifespan 40+ years
- Potamodromous
- Predatory
- Important food source historically for humans

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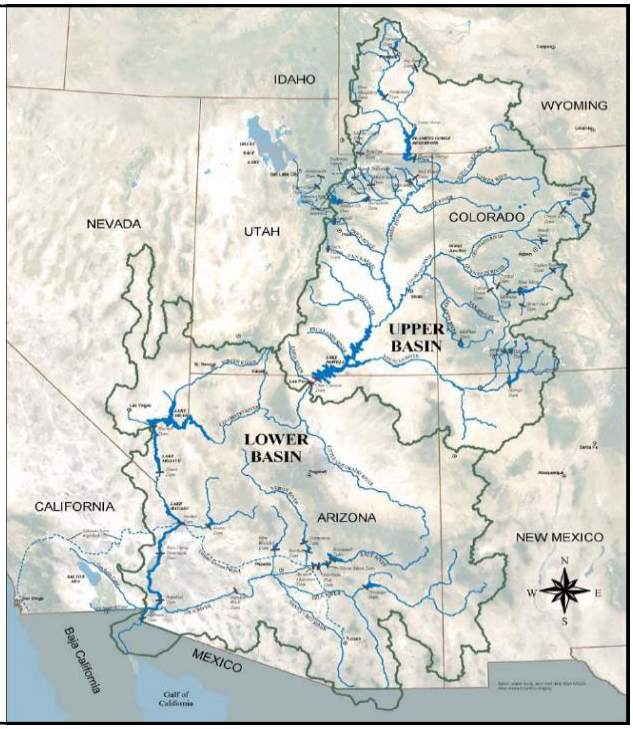
Colorado River Basin

Area:
244K mi^2
(632K km^2)

Length:
1.44K mi.
(2.32K km.)

Annual Flow:
14.5M ac.ft./yr
(17.89B m^3/yr)



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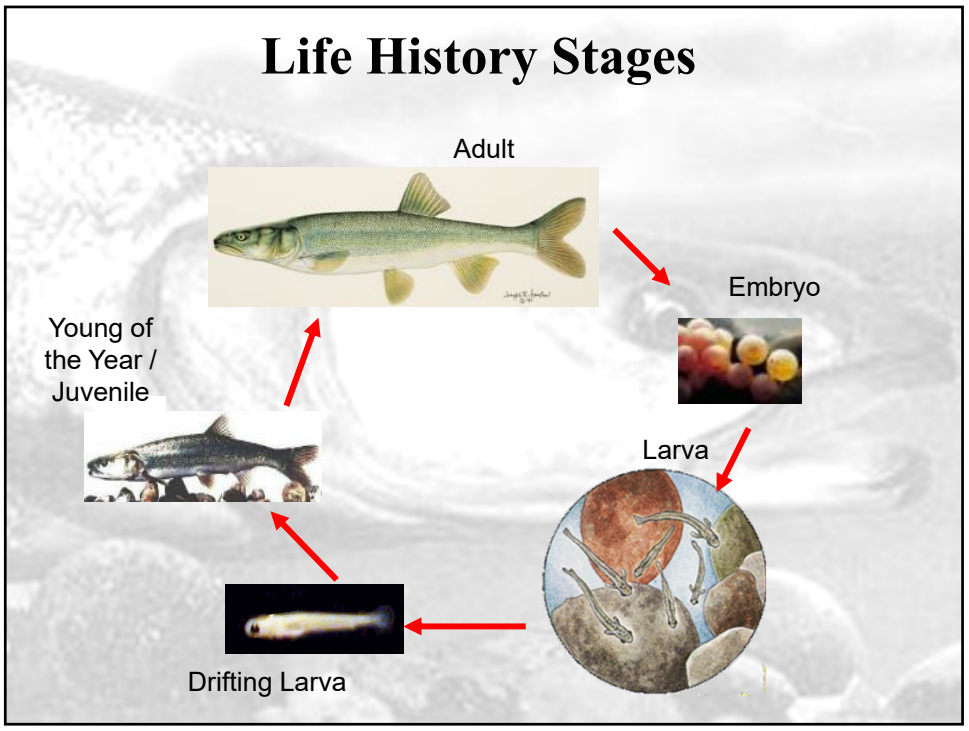
Life History Stages
Adult
Embryo
Larva
Drifting Larva
Young of the Year / Juvenile

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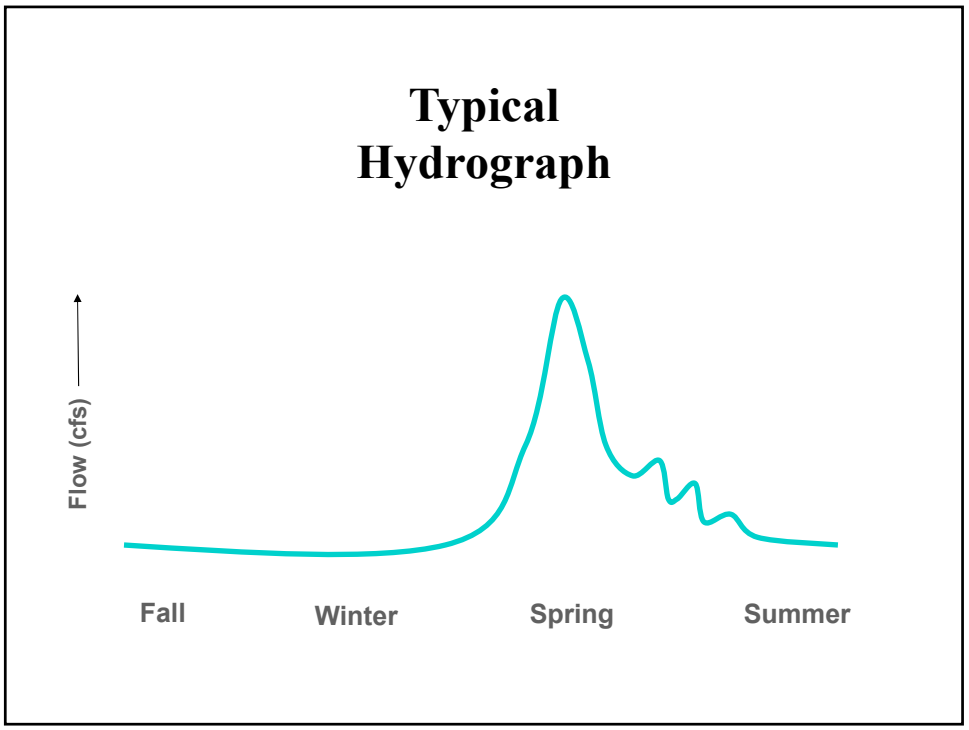
Typical Hydrograph
Flow (cfs)
Fall
Winter
Spring
Summer

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Fall (Sept-Oct)

- Young of the year remain in nursery habitats, to grow and mature
- Adults occupy a variety of habitats prior to overwintering
- Both require stable flows

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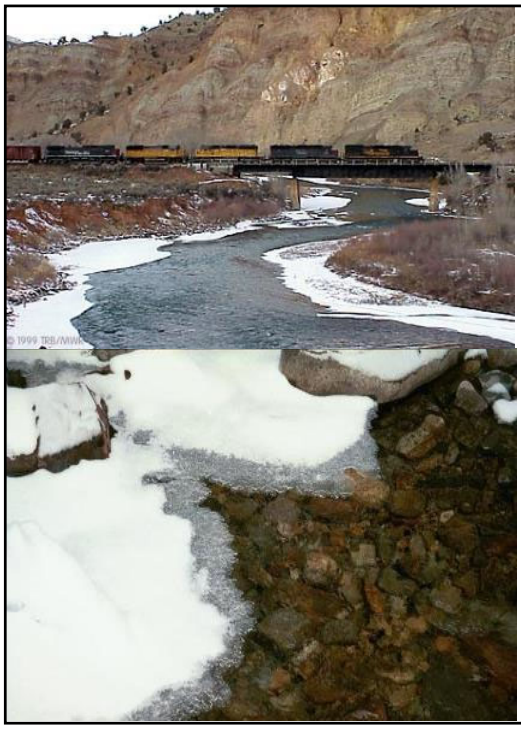

Winter (Nov-Mar)

- Season with the greatest stress on aquatic biota
- Flows are generally low and relatively stable
- Overwinter in slow runs and deep pools, including backwater habitats

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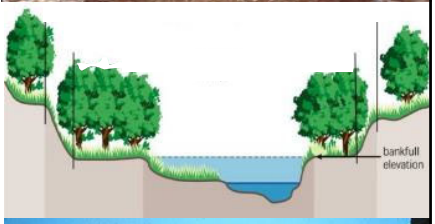
Early Spring (April-May)

- Utilize floodplain habitat created from rising spring flows (snowmelt runoff)
- Warm, food-rich, off-channel habitat for juveniles and adults
- Consume warm water fish adapted to backwater environments



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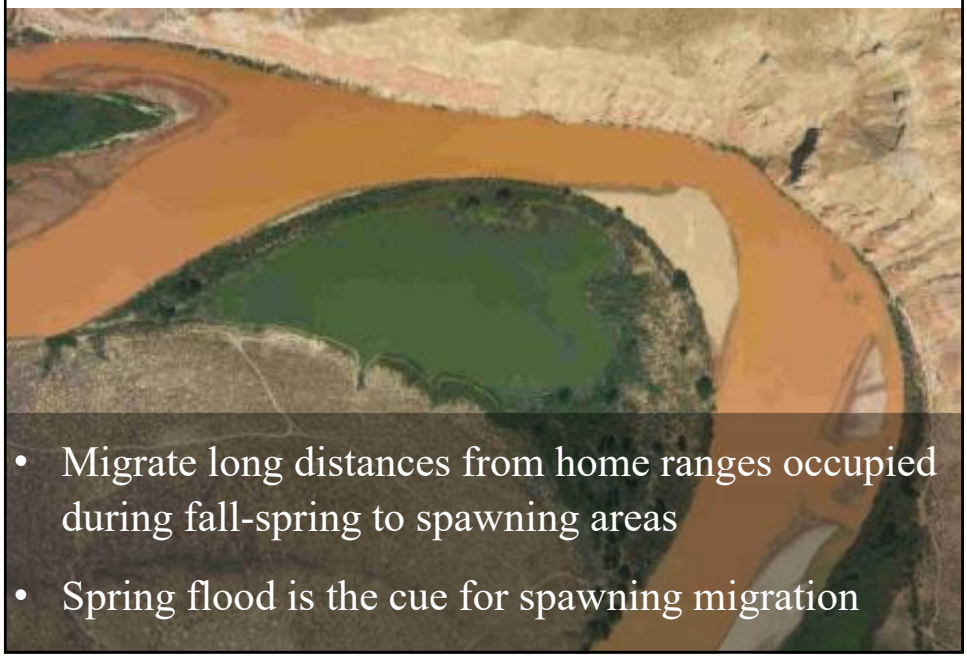
Spring (June)



- Migrate long distances from home ranges occupied during fall-spring to spawning areas
- Spring flood is the cue for spawning migration

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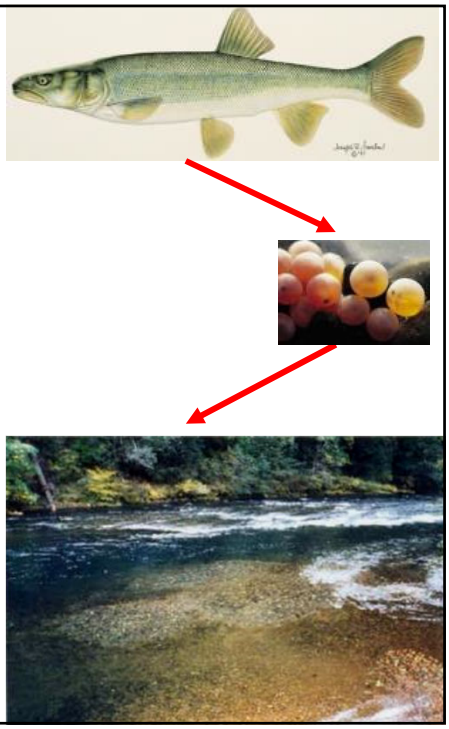
Summer (July-Aug)

- Spawning occurs when spring flood flows subside & water temperatures reach 18-23°C
- Broadcast spawners
- Summer high flow pulses are important in maintaining spawning bars
- After hatching and emerging from substrate, larvae drift downstream



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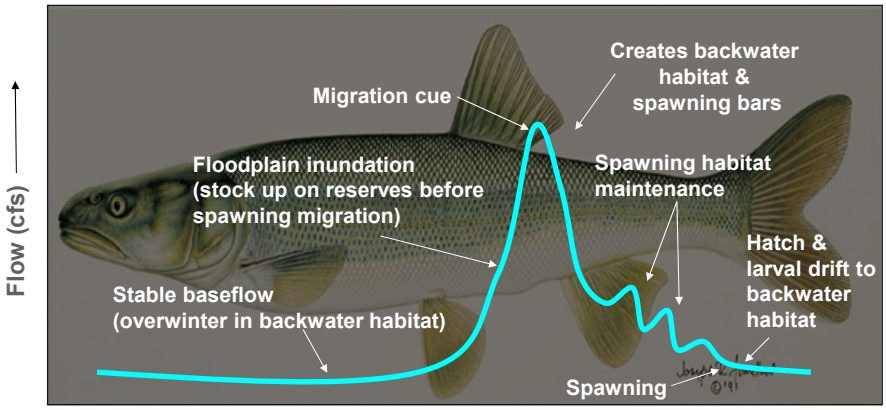
Colorado Pikeminnow

summary of flow-ecology relationships



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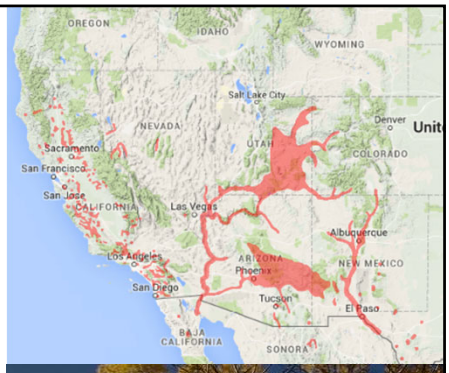
Fremont Cottonwood
(Populus fremontii)

- Iconic, widespread tree in western riparian zones
- Fast growing, high biomass
- High structural complexity, high habitat value



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A *Ribbon of Green* along Southwestern rivers

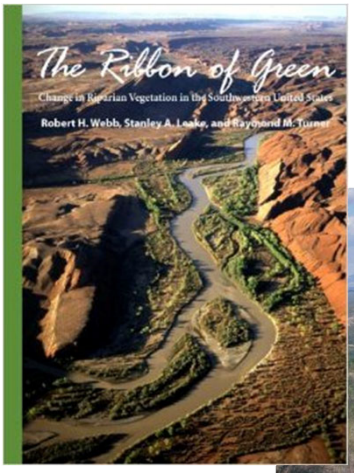

Photo of San Pedro Ripairan National Conservation Area: Arizona State University

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Riparian forest stands depend on dynamic river processes

Point bars migrate Riparian trees colonize

Forest stands colonize new floodplains and abandoned channels

(e.g., Stella et al. Ecosystems 14:776-790.)

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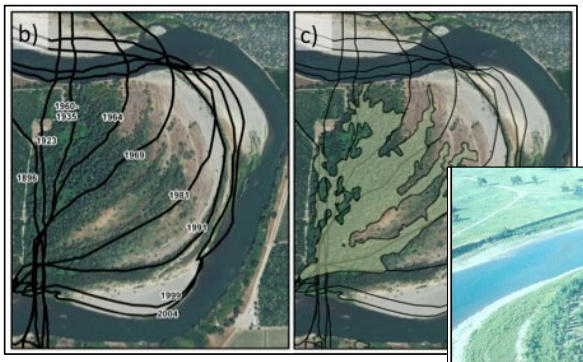
Riparian forest stands depend on dynamic river processes

Point bars migrate Riparian trees colonize

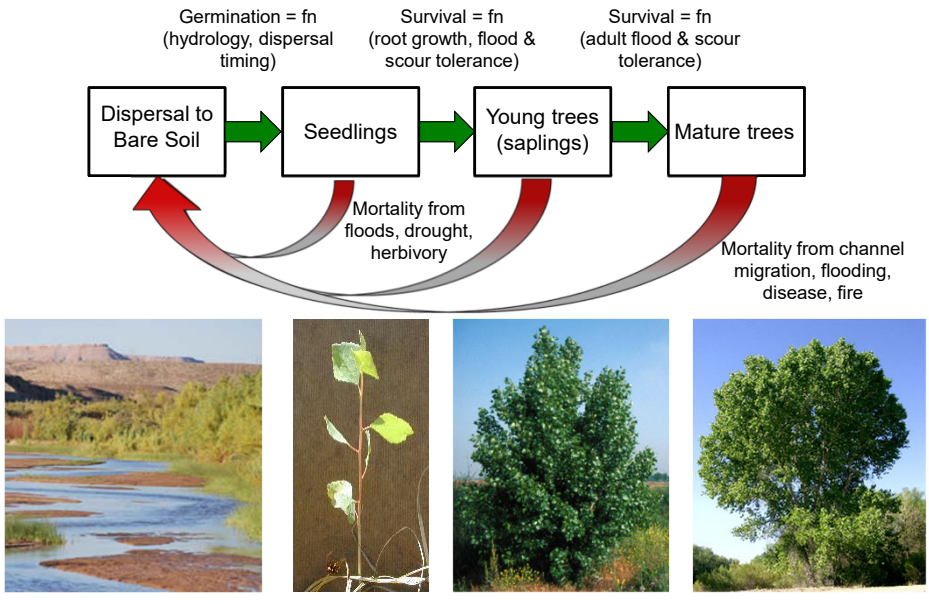


Forest stands colonize new floo
and abandoned channels

(e.g., Stella et al. Ecosystems 14:776-790.)

25

Cottonwood life history stages



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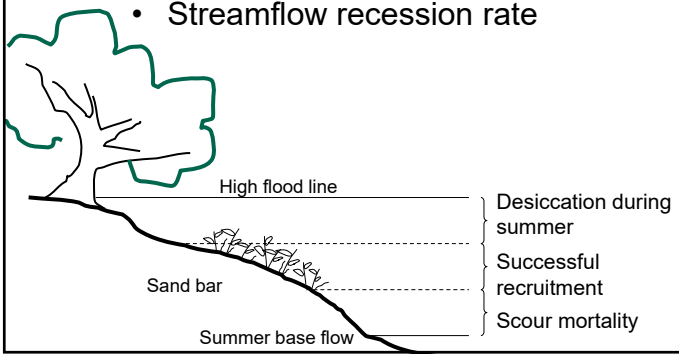
Fluvial influences on cottonwood recruitment and survival

- Seed availability
- Flow timing and magnitude
- Sediment depth and texture
- Intensity of scour and flooding
- Streamflow recession rate



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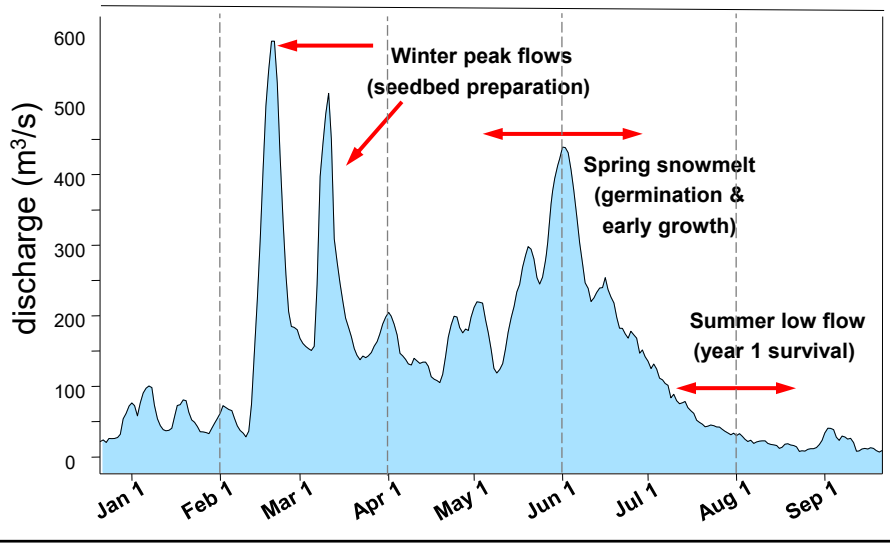
Flow-ecology relationships



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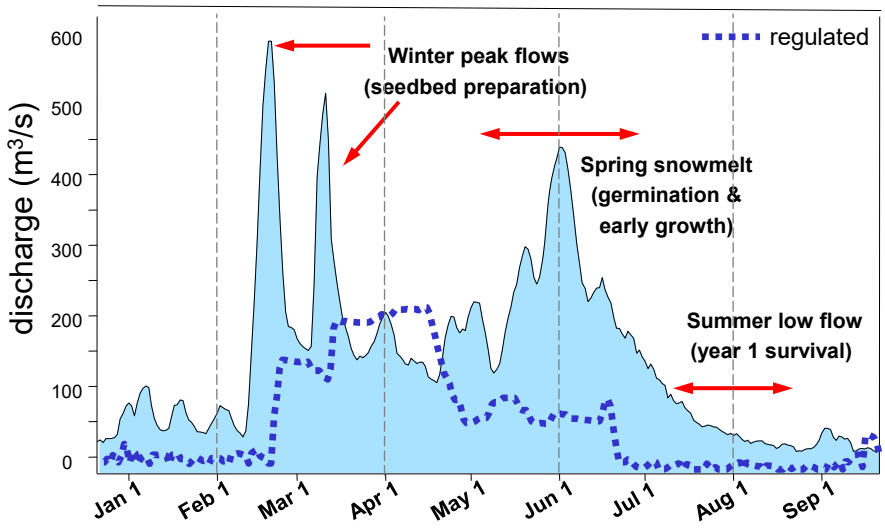
Flow-ecology relationships



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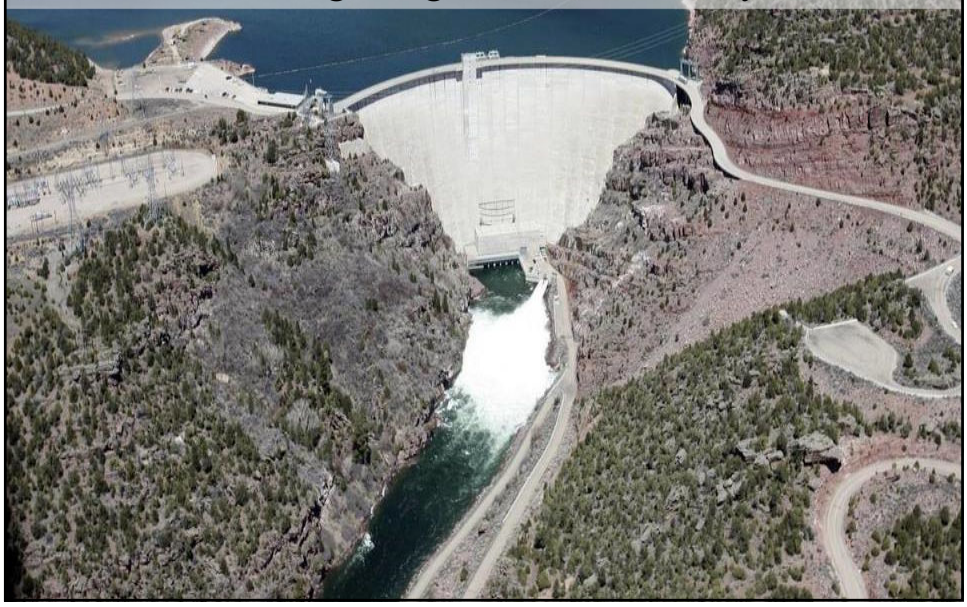
Ecological Impacts of Flow Alteration

Flaming Gorge Dam Case Study



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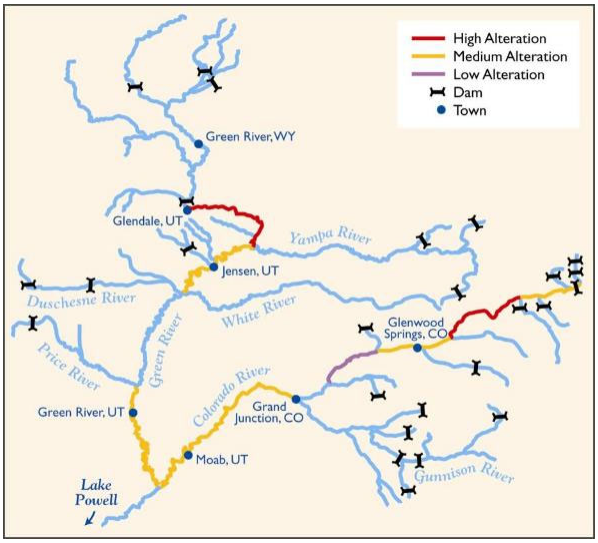
Hydrologic Alteration in the Upper Colorado River Basin



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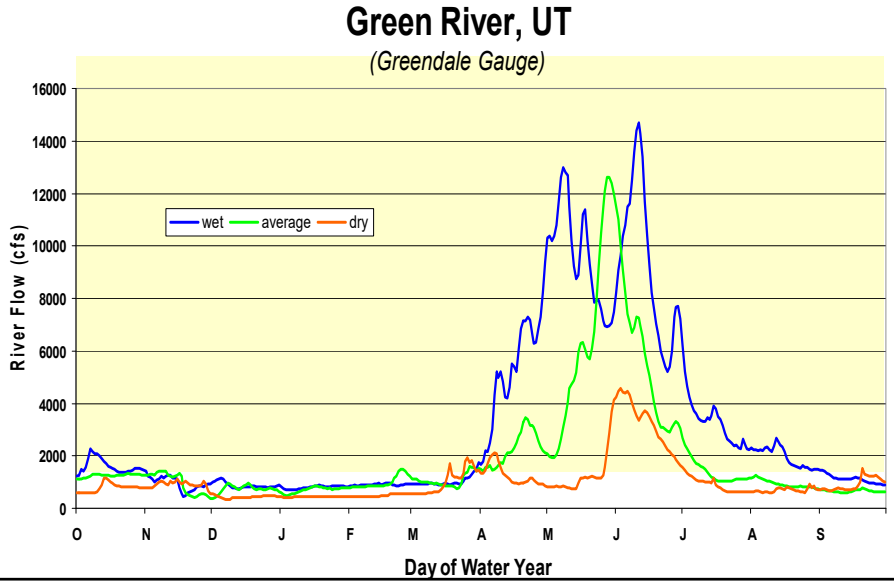
Inter-annual Variability



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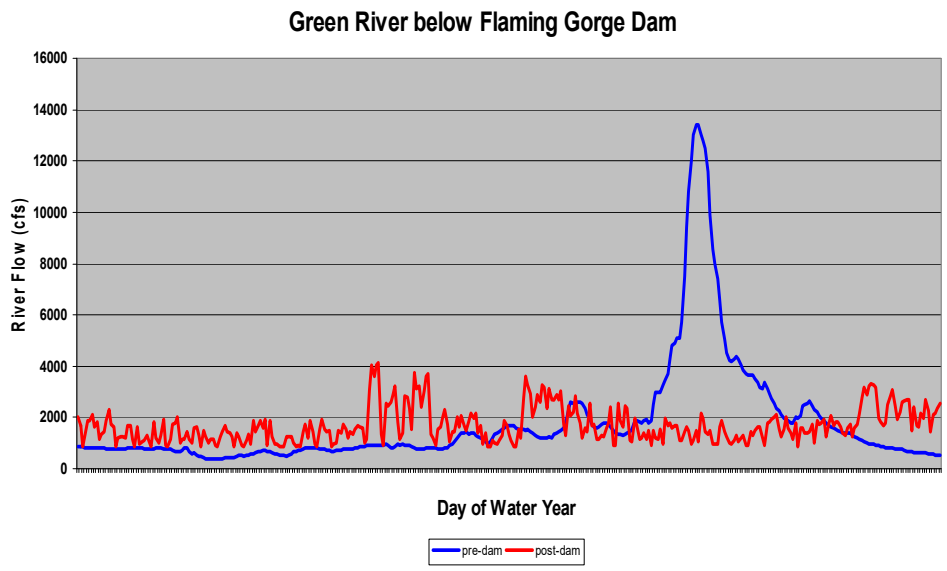
Impacts on Annual Hydrograph



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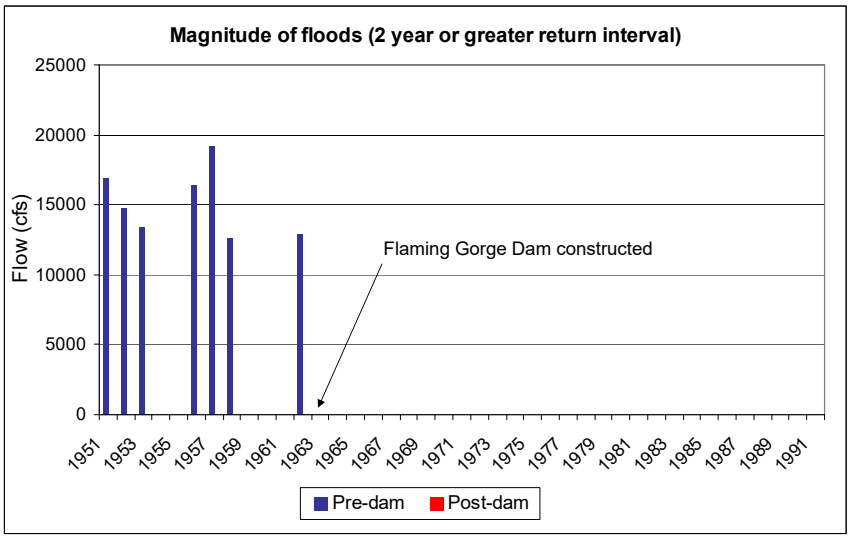
Impacts on Spring Floods



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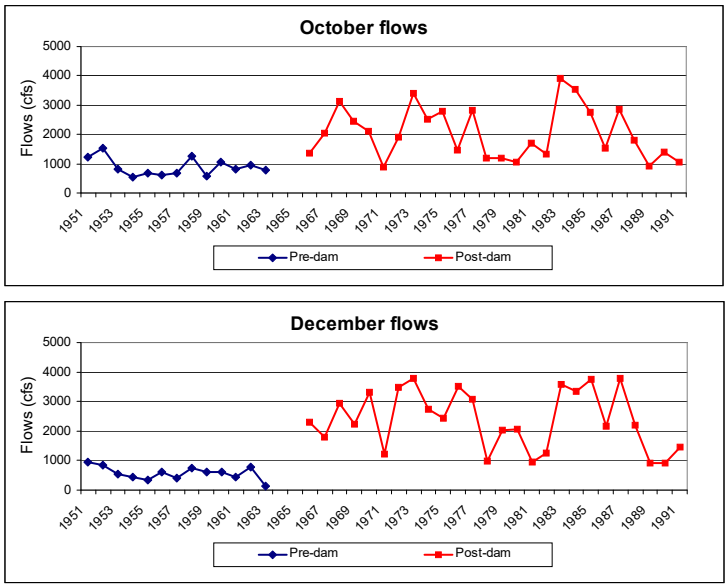
Impacts on Low Flows



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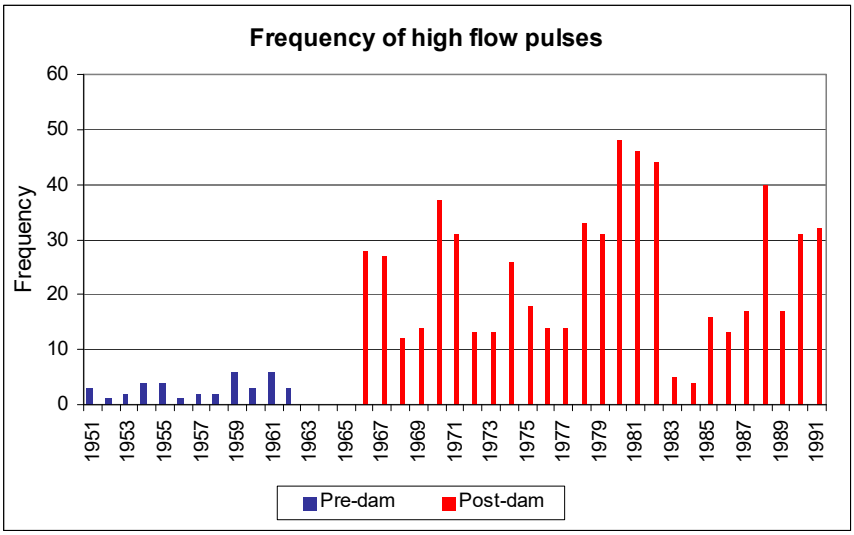
Impacts on High Flows



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Environmental Flow Recommendations for the Re-Operation of Flaming Gorge

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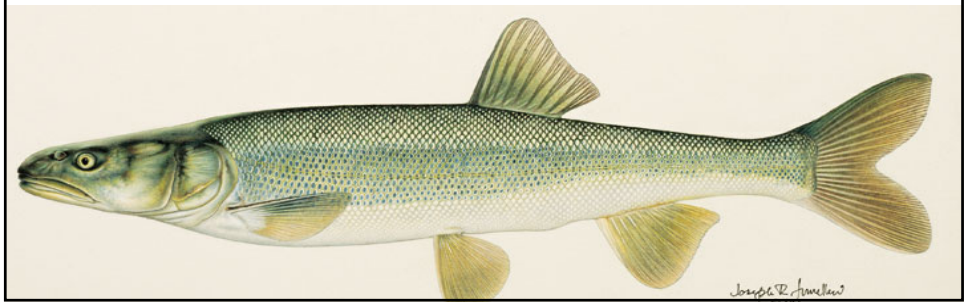
NEPA and Section 7 History

- Section 7 consultation began in 1980
- Biological Opinion issued in 1992
- Flaming Gorge Flow recommendations report (2000)
- Final EIS and Biological Opinion on proposed action, September 2005
- Record of Decision signed on February 16, 2006



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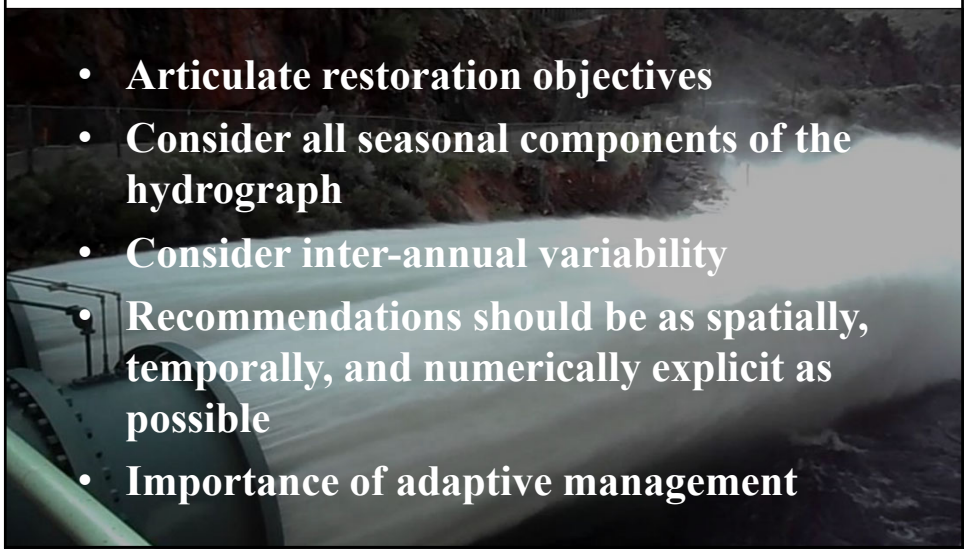
Developing Environmental Flow Recommendations



- Articulate restoration objectives
- Consider all seasonal components of the hydrograph
- Consider inter-annual variability
- Recommendations should be as spatially, temporally, and numerically explicit as possible
- Importance of adaptive management

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Goal of 2000 Flaming Gorge Recommendations

from USFWS

Provide the annual and seasonal patterns of flow and temperature in the Green River that enhance populations of endangered fishes

1. ***Provide increased within-year and between-year variability in flows***
2. ***Variability critical to support in-channel and floodplain geomorphic processes that maintain ecosystem dynamics***
3. ***Higher peak and base flows in wetter years; lower peak and base flows in drier years***

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Flow magnitude and temperature recommendations

TABLE 1 Recommended Magnitudes and Duration of Maximum Spring Peak and Summer-to-Winter Base Flows and Temperatures for Endangered Fishes in the Green River Downstream From Flaming Gorge Dam as Identified in the 2000 Flow and Temperature Recommendations

Location	Flow and Temperature Characteristics	Hydrologic Conditions and 2000 Flow and Temperature Recommendations[a]				
		Wet (0–10% Exceedance)	Moderately Wet (10–30% Exceedance)	Average (30–70% Exceedance)	Moderately Dry (70–90% Exceedance)	Dry (90–100% Exceedance)
Reach 1 Flaming Gorge Dam to Yampa River	Maximum Spring Peak Flow	≥8,600 cfs (244 cubic meters per second [m3/s])	≥4,600 cfs (130 m3/s)	≥4,600 cfs (130 m3/s)	≥4,600 cfs (130 m3/s)	≥4,600 cfs (130 m3/s)
	Peak flow duration is dependent upon the amount of unregulated inflows into the Green River and the flows needed to achieve the recommended flows in Reaches 2 and 3.					
	Summer-to-Winter Base Flow	1,800–2,700 cfs (50–60 m^3/s)	1,500–2,600 cfs (42–72 m^3/s)	800–2,200 cfs (23–62 m^3/s)	800–1,300 cfs (23–37 m^3/s)	800–1,000 cfs (23–28 m^3/s)
Above Yampa River Confluence	Water Temperature Target	≥ 64 °F (18 °C) for 3-5 weeks from mid-August to March1	≥ 64 °F (18 °C) for 3-5 weeks from mid-August to March 1	≥ 64 °F (18 °C) for 3-5 weeks from mid-July to March 1	≥ 64 °F (18 °C) for 3-5 weeks from June to March 1	≥ 64 °F (18 °C) for 3-5 weeks from mid-June to March 1

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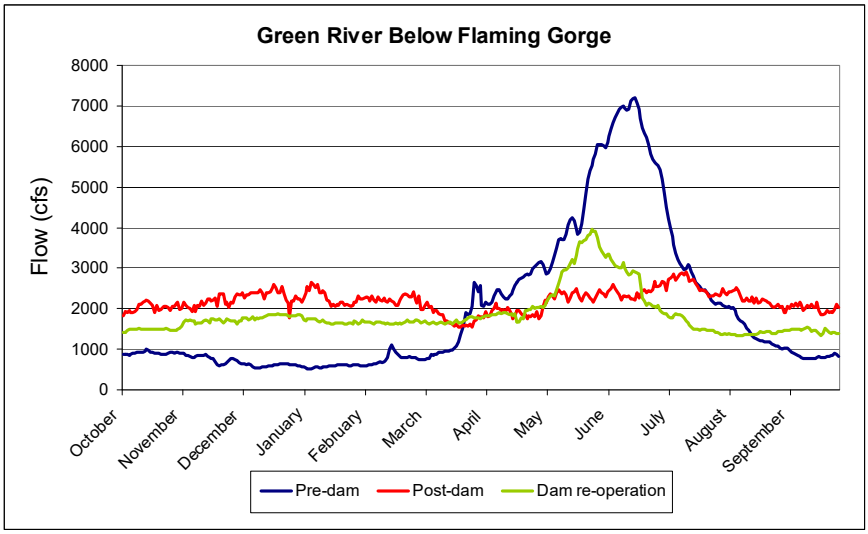
Impacts of Re-Operation



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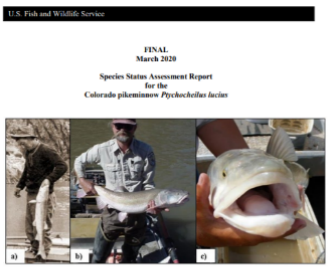
Status?



March 2020

Species Status Assessment

- Monitoring: habitat & populations
- Overall "high" habitat condition
- Peak flows maximize backwater habitat, maintain instream habitat
- Modified summer baseflows to favor greater YOY survival
- Flow recs have been/are being developed/improved for downstream tributaries (White, Price, Duschene)
- High reproduction, BUT abundance in decline!
- Challenge: Nonnative species

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Lecture 2.1 Summary

Hydrology is a "Master Variable" and altered hydrology is a leading cause of ecosystem degradation *river flows, lake, groundwater, and wetland levels*

Science and methods necessary to define "environmental flows" are available

Restoring key components of natural river flows can significantly restore the health and productivity of river systems

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