The Natural Flow Regime: A paradigm for river conservation and restoration

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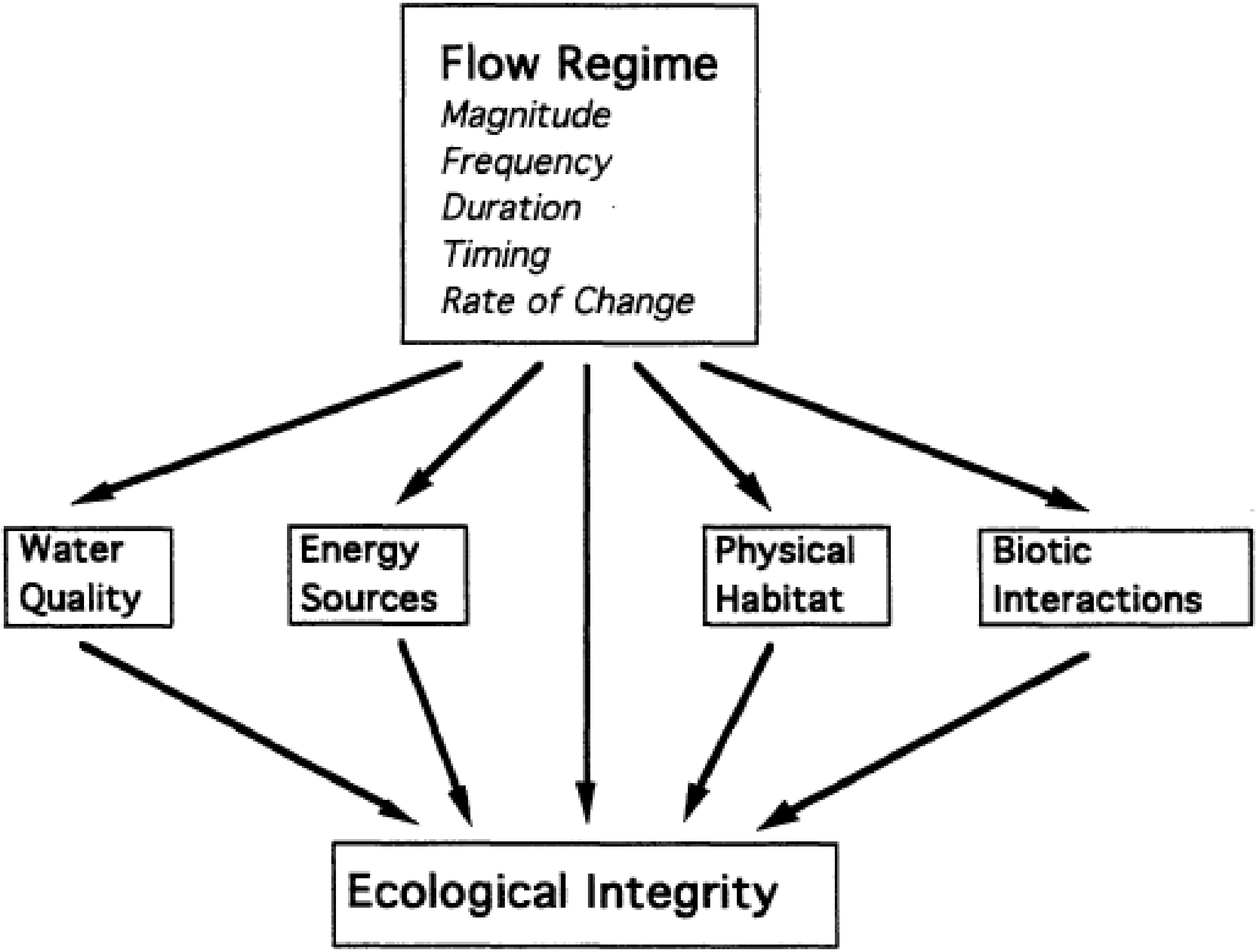
Figure 1. Flow regime is of central importance in sustaining the ecological integrity of flowing water systems. The five components of the flow regime—magnitude, frequency, duration, timing, and rate of change—influence integrity both directly and indirectly, through their effects on other primary regulators of integrity. Modification of flow thus has cascading effects on the ecological integrity of rivers. After Karr 1991.



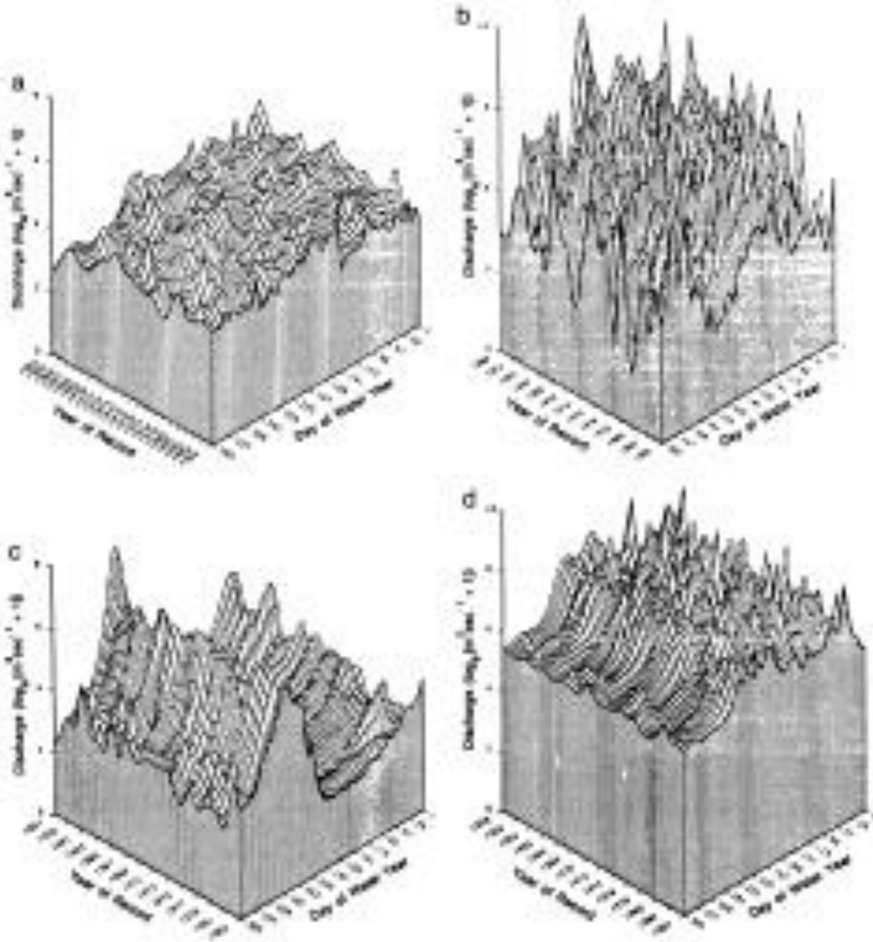
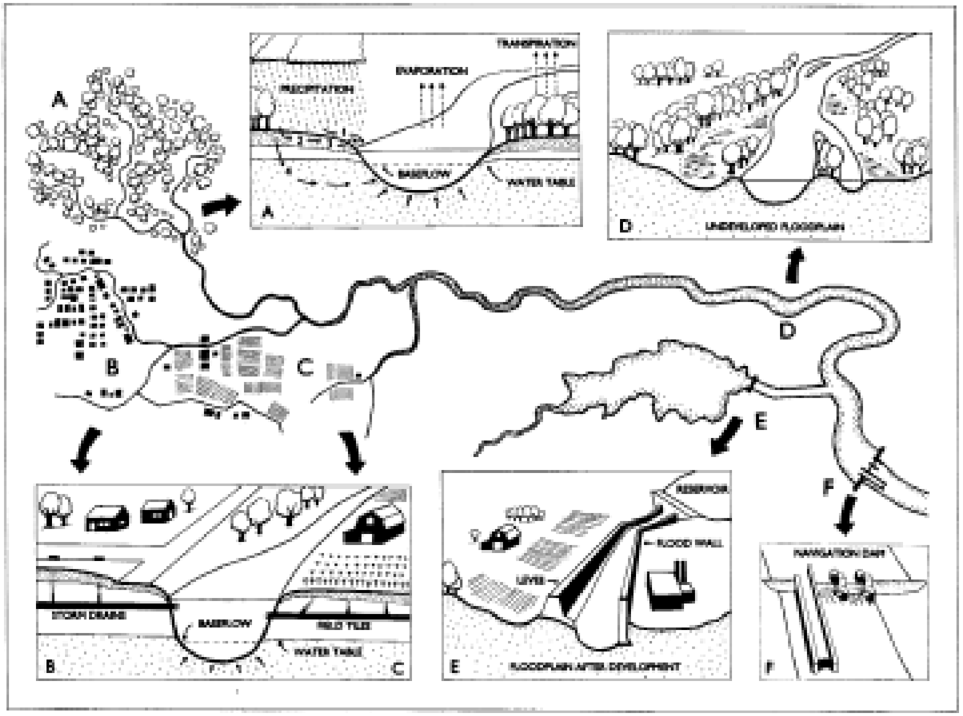


Figure 2. Flow histories based on long-term, daily mean discharge records. These histories show within- and among-year variation for (a) Augusta Creek, MI, (b) Satilla River, GA, (c) upper Colorado River, CO, and (d) South Fork of the McKenzie River, OR. Each water year begins on October 1 and ends on September 30. Adapted from Poff and Ward 1990.

- Take note of the different scales of variability (seasonal and inter-annual)
- Some rivers are naturally more flashy
- The dominant flow components and sources of runoff can be seen
    - CO- spring pulse caused by snow melt
    - GA- rain fed, highly variable
    - MI- spring fed?
    - OR- rain fed, but more consistent



Runoff components

- Overland flow
- Shallow subsurface stormflow
- Saturated overland flow
- Groundwater flow

Storm peaks in hydrograph = overland + shallow subsurface flows

Baseflow = deeper groundwater pathways

Urban & agricultural LUs = ↑ surface flow

- ↑ impermeable surfaces, ↓ vegetation cover, ↑ drainage systems
- ↑ depth, ↓ water table, ↓ baseflow

Levees & flood walls on main channel = loss of floodplain habitats

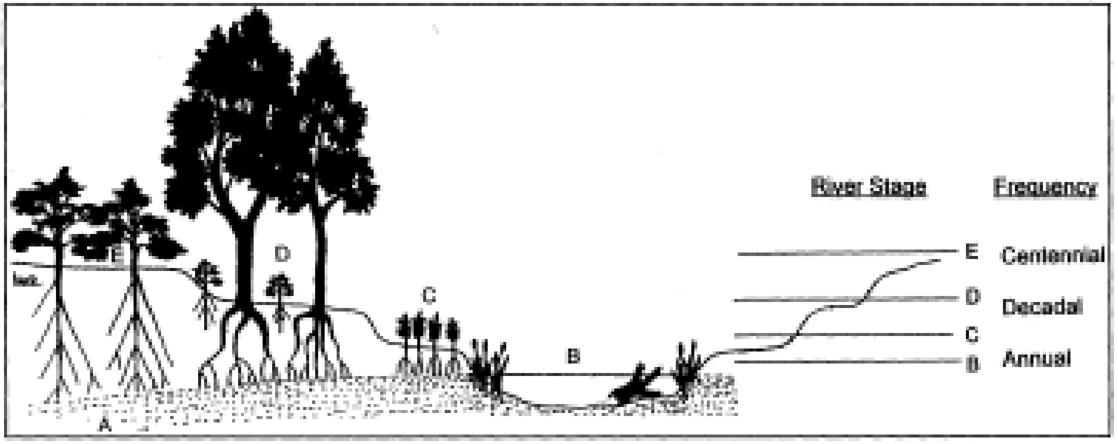
- Floodplain habitats
  - Side-channels, Wetlands, Episodically flooded lowlands

Dams = ↓ downstream movement of water, Δ flow regime

- Effects depend on type: run-of-river or storage

Table 1. Physical responses to altered flow regimes.

Source(s) of alteration	Hydrologic change(s)	Geomorphic response(s)
Dam	Capture sediment moving downstream	Downstream channel erosion and tributary headcutting
		Bed armoring (coarsening)
Dam, diversion	Reduce magnitude and frequency of high flows	Deposition of fines in gravel
		Channel stabilization and narrowing
		Reduced formation of point bars, secondary channels, oxbows, and changes in channel planform
Urbanization, tiling, drainage	Increase magnitude and frequency of high flows	Bank erosion and channel widening
		Downward incision and floodplain disconnection
	Reduced infiltration into soil	Reduced baseflows
Levees and channelization	Reduce overbank flows	Channel restriction causing downcutting
		Floodplain deposition and erosion prevented
		Reduced channel migration and formation of secondary channels
Groundwater pumping	Lowered water table levels	Streambank erosion and channel downcutting after loss of vegetation stability



E) Rare large floods (centennial)

Uproot mature riparian trees = creates high quality CWD habitat

D) Larger floods (decadal)

Inundate aggraded floodplain terraces = prevent channel encroachment of later successional species)

C) Intermediate-size floods (annual to decadal)

Inundate low-lying floodplains

Deposit entrained sediment = pioneer species establishment

Import organic matter into channel

Help maintain form of active stream channel

B) Small floods (frequent, annual)

Transport fine sediments = high benthic productivity maintained

Create fish spawning habitat

A) Water tables

Sustain riparian vegetation & delineate in-channel baseflow habitat

Maintained by groundwater inflow & flood recharge

Table 2. Ecological responses to alterations in components of natural flow regime.[a]

Flow component	Specific alteration	Ecological response
Magnitude and frequency	Increased variation	Wash-out and/or stranding Loss of sensitive species
		Increased algal scour and wash-out of organic matter
		Life cycle disruption
		Altered energy flow
	Flow stabilization	Invasion or establishment of exotic species, leading to: Local extinction Threat to native commercial species Altered communities
		Reduced water and nutrients to floodplain plant species, causing: Seedling desiccation Ineffective seed dispersal Loss of scoured habitat patches and secondary channels needed for plant establishment
		Encroachment of vegetation into channels
Timing	Loss of seasonal flow peaks	Disrupt cues for fish: Spawning
		Egg hatching Migration Loss of fish access to wetlands or backwaters Modification of aquatic food web structure Reduction or elimination of riparian plant recruitment Invasion of exotic riparian species Reduced plant growth rates

Table 2. Ecological responses to alterations in components of natural flow regime.[a]

Flow component	Specific alteration	Ecological response
Duration	Prolonged low flows	Concentration of aquatic organisms Reduction or elimination of plant cover Diminished plant species diversity Desertification of riparian species composition Physiological stress leading to reduced plant growth rate, morphological change, or mortality
	Prolonged baseflow "spikes"	Downstream loss of floating eggs
	Altered inundation duration	Altered plant cover types
	Prolonged inundation	Change in vegetation functional type Tree mortality Loss of riffle habitat for aquatic species
Rate of change	Rapid changes in river stage	Wash-out and stranding of aquatic species
	Accelerated flood recession	Failure of seedling establishment

Ecological Limits of Hydrologic Alteration (ELOHA)

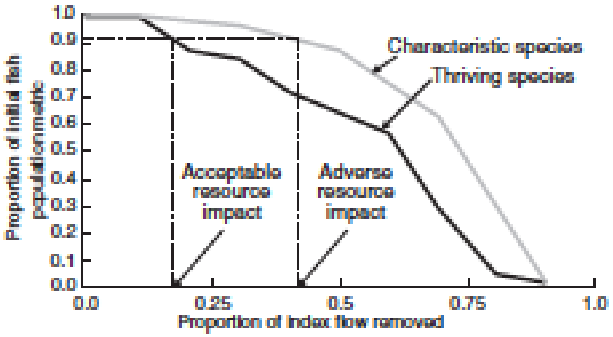
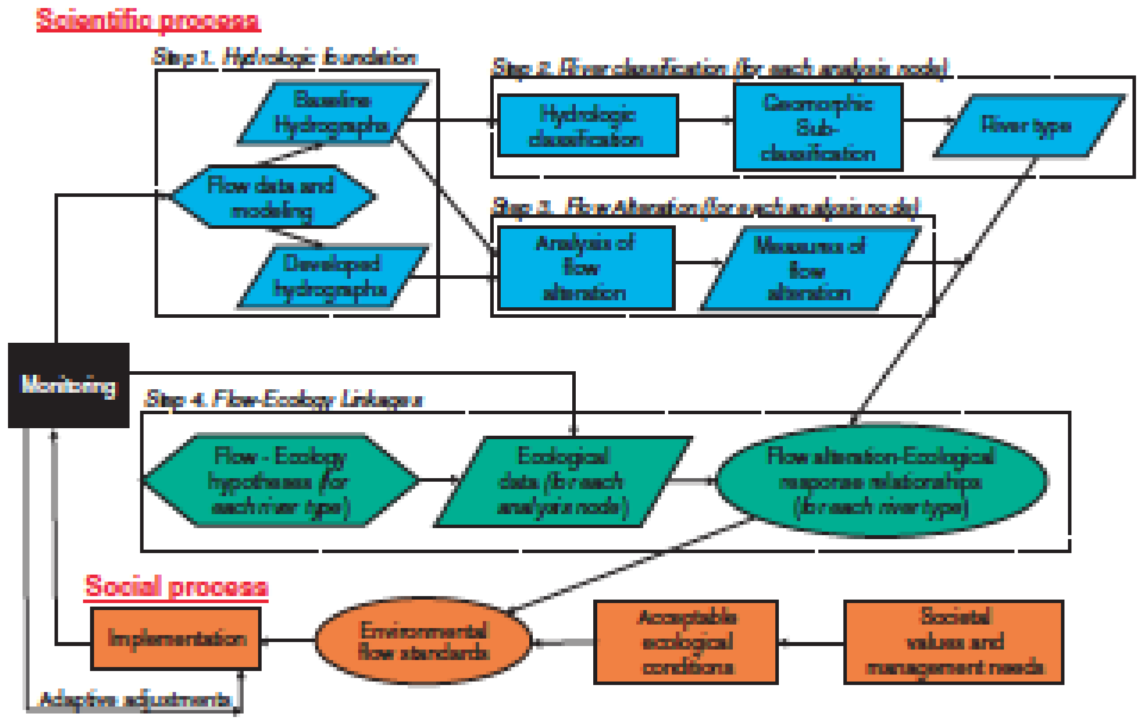


Fig. 1 The ELOHA framework comprises both a scientific and social process. Hydrologic analysis and classification (blue) are developed in parallel with flow alteration–ecological response relationships (green), which provide scientific input into a social process (orange) that balances this information with societal values and goals to set environmental flow standards. This paper describes the hydrologic and ecological processes in detail, and outlines the scientist's role in the social process.



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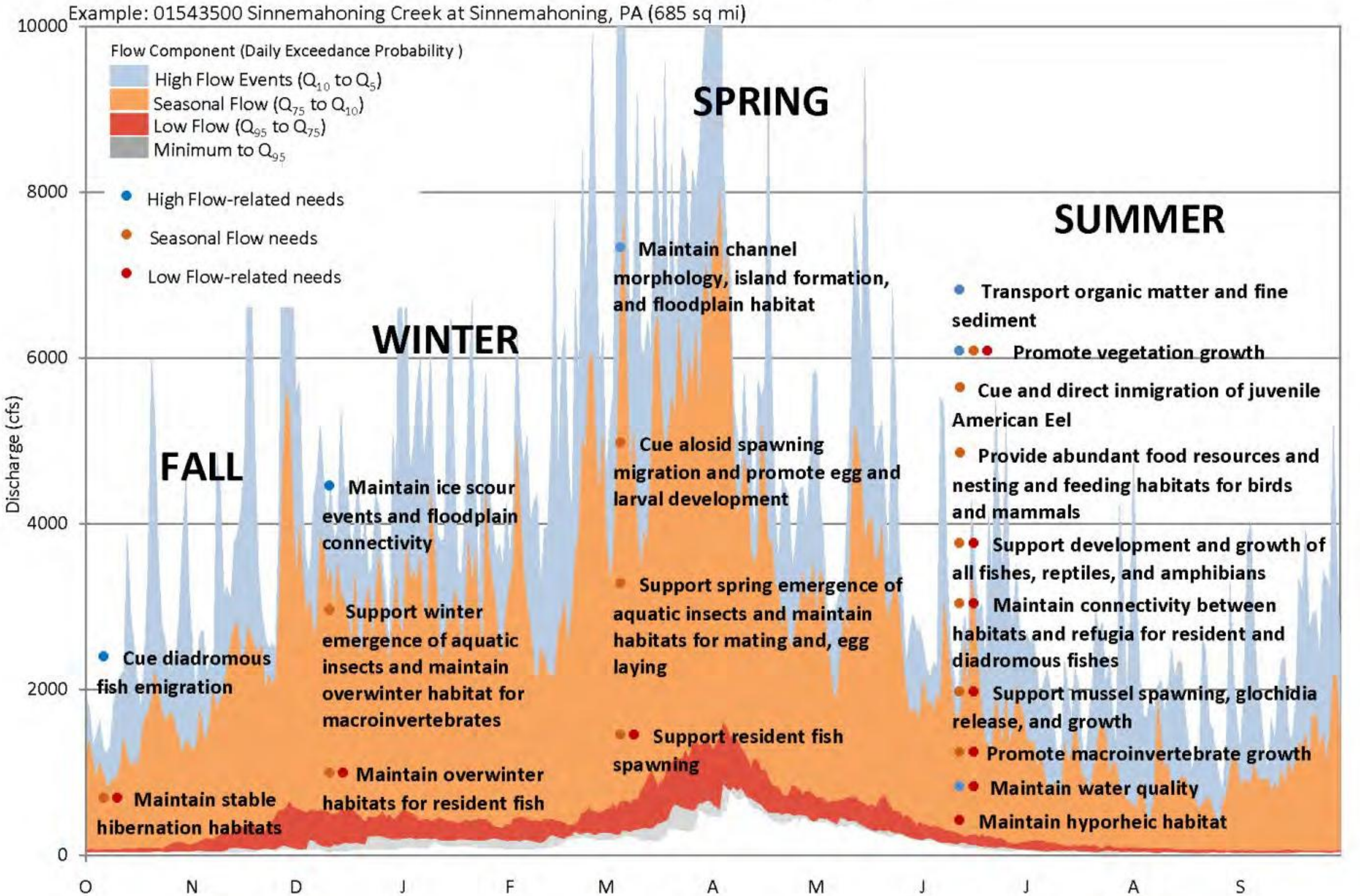
Flow Components and Needs: Major Tributaries



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Restoring native fish assemblages to a regulated California stream using the natural flow regime concept

JOSEPH KIERNAN, PETER MOYLE, PATRICK CRAIN

Study Area

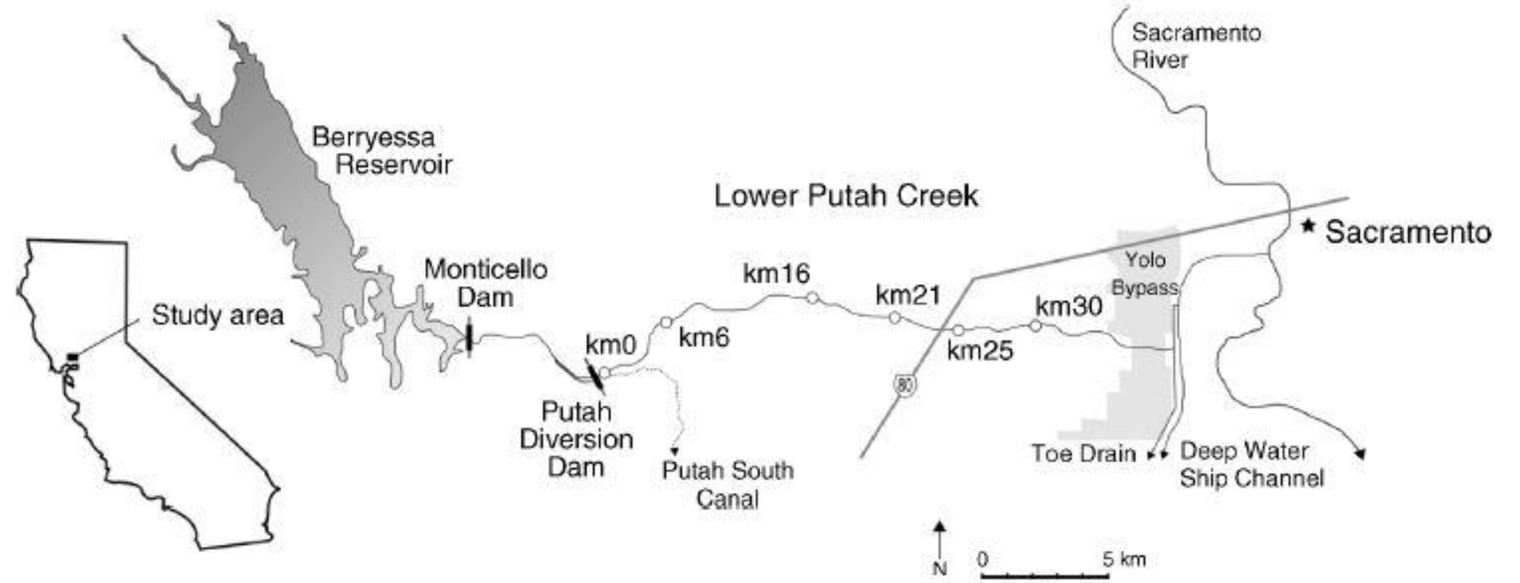

FIG. 1. Map of lower Putah Creek, Yolo and Solano counties, California, USA. Sample sites (open circles) are coded to reflect their approximate distance (in kilometers) downstream of the Putah Diversion Dam (e.g., km16 = 16.2 km below the diversion).

Putah Creek Accord

1989: Putah Creek goes dry

1996: Court order to increase minimum release by 50%

2000: Signing of Putah Creek Accord

1) Native fish flows
2) Anadromous fish flows
3) Schedule for extended droughts
4) New forum for management
5) Restoration and monitoring funds
6) Landowner water rights

Release Schedule

Feb 15-March 31: Three day pulse, followed by a month-long release of elevated flows

Fall: Supplemental pulse flows

November or December: Five day pulse for adult chinook migration

Year-round: Permanent stream flow from Putah Diversion Dam to I-80 at all times, even during drought years

Objectives

Determine whether the more natural streamflow patterns put in place by the Putah Creek Accord would:

1) Reestablish native fishes

2) Reduce alien fish

IHA Model

1) Flow magnitude
2) Magnitude and duration of annual extreme conditions
3) Timing of annual extreme conditions
4) Frequency and duration of high and low pulses
5) Rate and frequency of changes

Streamflow Variations

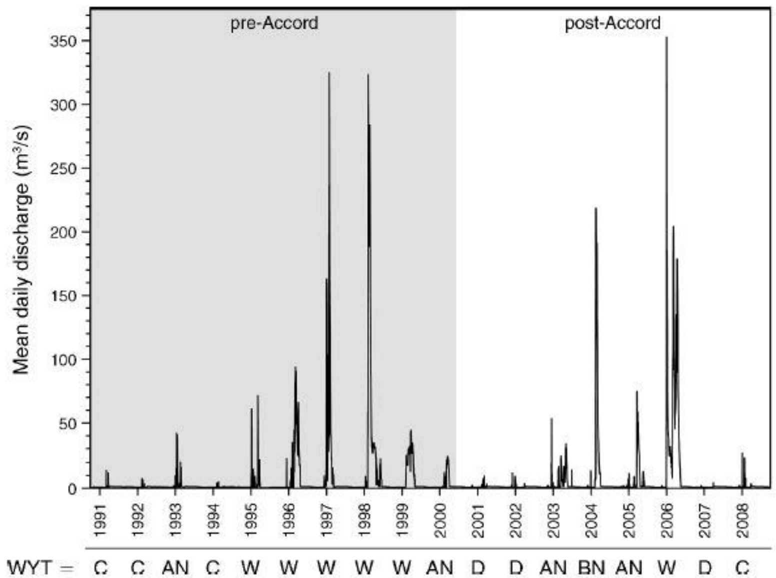

FIG. 2. Time series of mean daily discharge from the Putah Diversion Dam before (pre-Accord; shaded) and after (post-Accord; unshaded) implementation of a new flow regime. Water year types (WYT) appear below each year on the abscissa and are classified as wet (W), above normal (AN), below normal (BN), dry (D), and critically dry (C). See the *Introduction* for a description of the Accord.

Streamflow Variations

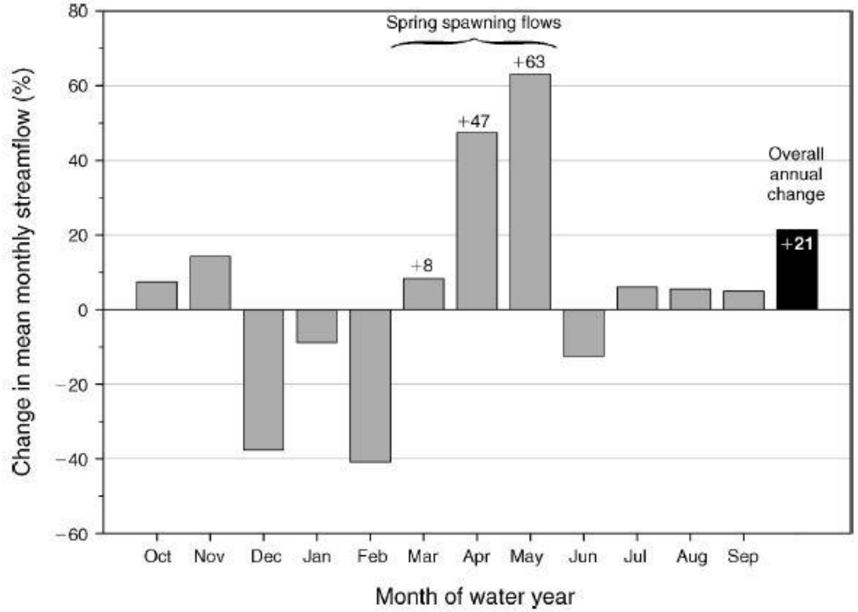

FIG. 3. Percentage change in mean monthly stream flow following implementation of the new flow regime. The pre-Accord period includes the water years 1979–1999, whereas the post-Accord period includes water years 2000–2008.

Fish Assemblages

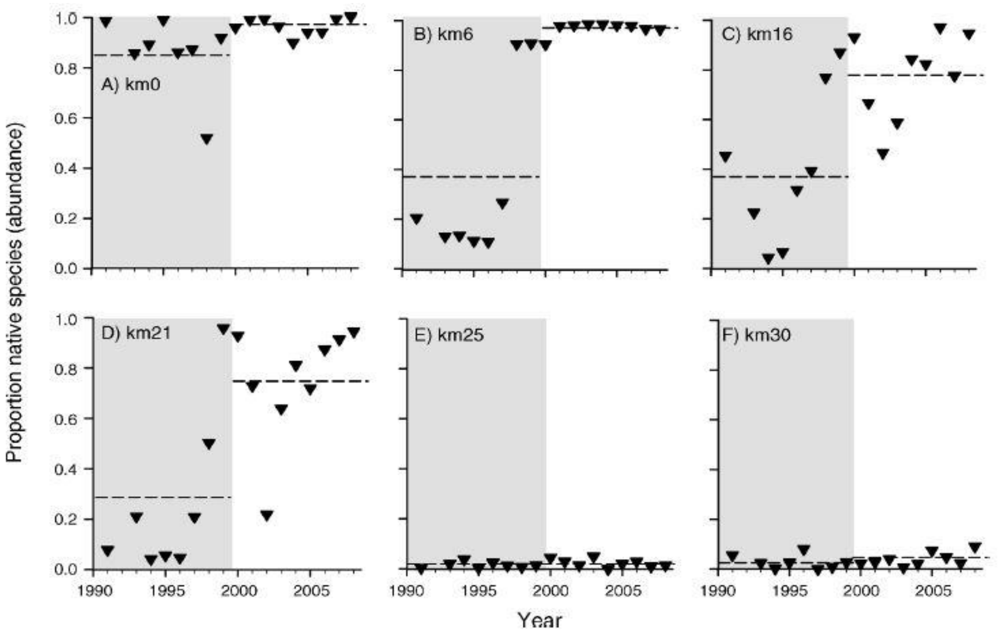

Fig. 5. Time series (1991–2008) of the proportion of the total fish assemblage composed of native species at six permanent sample sites. Sites are presented from upstream to downstream, and site codes (e.g., km0) reflect approximate distances downstream of the Putah Diversion Dam. The gray shaded region in each plot identifies the pre-Accord period (1991–1999). Horizontal dashed lines indicate the mean proportion of native species during each time period.

Questions

Why no data collected on chemicals/food sources/geomorphology?

Is this an effective way to satisfy landowner and wildlife needs?