Trade-Offs and Synergies in Floodplain Management: A Historical-Ecological Approach

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What is floodplain restoration?

- Floodplains are lands adjacent to rivers that are periodically flooded during high flows. They are among the most productive, diverse, and threatened ecosystems in the world.
- Intact floodplain-river systems provide important ecological benefits: spawning habitat for native fish, feeding grounds for migratory birds, and primary productivity that supports downstream food webs.
- In the U.S. over 90% of floodplains have been converted to agriculture or developed. Floodplains have been disconnected from rivers by dredging, damming, and construction of levees.
- In 2002, the US Army Corps of Engineers determined California's aging flood protection infrastructure desperately needs to be revamped. The status quo approach to improving flood protection has been to build taller, stronger levees.
- Floodplain restoration projects remove levees, move them farther from the river, or change floodplain topography to allow floods on selected lands, which relieves stress from nearby levees that are protecting critical lands. In this way, **floodplain restoration provides flood protection in addition to ecological benefits.**

Obstacles to Implementation

Floodplain restoration is a promising alternative to traditional flood protection approaches, but we lack ecological tools and historical context necessary to evaluate proposed projects.

- It is hard to measure, predict, and compare the multiple ecological and social benefits of floodplain restoration. These measures are needed to evaluate trade-offs when planning restoration projects.
- Floodplain management is politically complex and projects must account for competing interests among many stakeholders.
- Little is known about the historical and social conditions that lead to successful river management projects.

Geese in Yolo bypass near Sacramento. Photo by Dave Feliz.

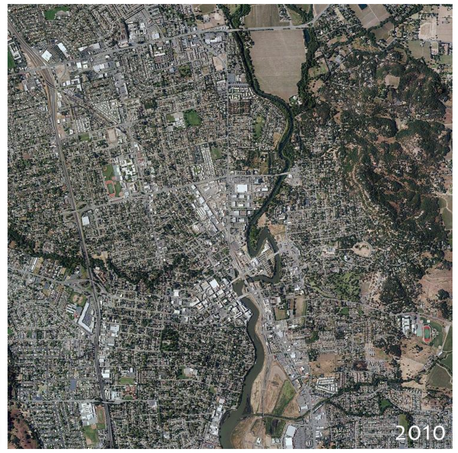
Our Interdisciplinary Approach

Identify social and ecological sources of conflict and synergy

- Combine hydraulic and ecological models to forecast how floodplain restoration will change the provisioning of multiple benefits and identify tradeoffs and synergies between them. Benefits include:
  - Native fish species habitat
  - Riparian tree establishment
  - Organic nutrient export to downstream ecosystems
  - Agricultural production
  - Flood damage reduction
- Examine historical instances of conflict and cooperation among floodplain stakeholders to gain insight into the social conditions that facilitate floodplain restoration.
- Compare historical research with ecological analyses to reveal where social conflicts and cooperation match ecological tradeoffs and synergies, and where these patterns diverge. This will help illuminate the root causes of conflict and how they can be overcome.

Historical Context: Conflict in an Era of Increasing Development

- Napa experienced a series of dramatic floods in the 20th century. Increased development during this period made floods more economically damaging, causing the community to call for increased flood protection.
- In the 1970's and again in the 1980's, conflict arose over **how** to provide flood protection. Should the Army Corps of Engineers raise floodwalls and deepen the river channel - the lowest cost approach? Or should Napa's citizens pay more and sacrifice strategic parcels of riverside land to reconnect the river to its floodplain? The Army Corps advocated the channel-deepening approach, while natural resource agencies argued for modification of the approach to meet environmental standards (such as improved water quality), and community groups pushed their vision of a "living river" with intact natural processes and recreational opportunities.



Aerial photos of the Napa River through the city of Napa taken in 1948 (left) and 2010 (right) document a dramatic increase in development. Photos from Aerial Archives.

- The Napa County Flood Control and Water Conservation District tried to balance these competing desires by funding a collaborative planning process in the 1990's.
- In the end, a plan that combined elements from the different alternatives was developed, but there were costs. Houses and businesses had to be moved from the floodplain, and sales tax was increased by county vote to fund the project.

How much does floodplain restoration improve chances of native fish survival?

Fish survival is one of several benefits we model and compare to assess the outcomes of restoration. This requires a new approach linking hydraulic and biological processes. The following example demonstrates our method on simulated data:

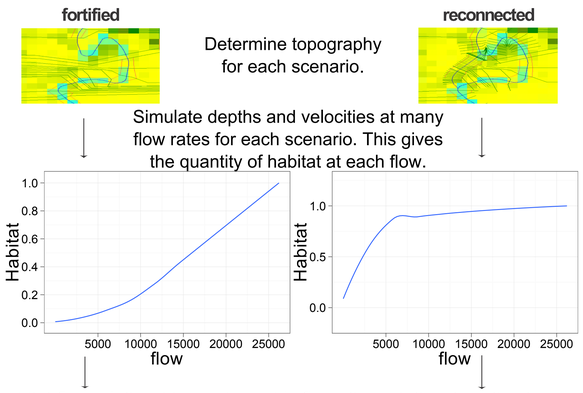
1. Identify habitat requirement for native fish species.

Sacramento splittail (*Pogonichthys macrolepidotus*) spawn in floodplains

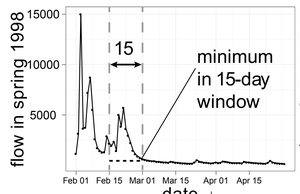
Water of specific depth, velocity, and duration is required for successful spawning and rearing.

2. Use hydraulic models to relate habitat to river flow rates.

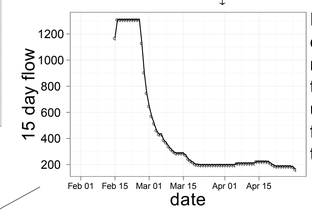
a. Estimate the amount of habitat available at different river flows under **different management scenarios** (fortifying the riverbank with levees vs. reconnecting the floodplain to the river).



b. Estimate habitat available through **time** using historic river flows.

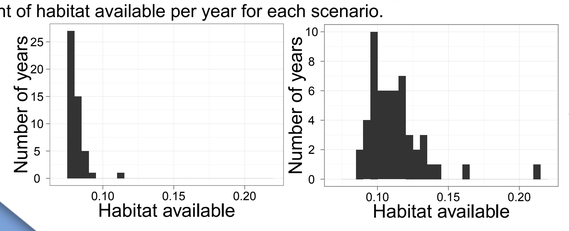


Identify periods that meet minimum duration requirements for fish reproduction.

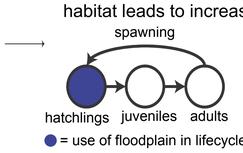


Filter by this duration requirement to estimate useable river flows over time.

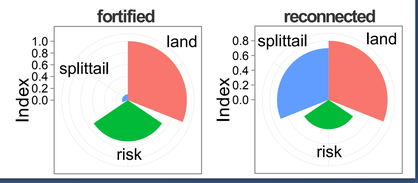
3. Combine habitat-flow relationships and useable flows through time to estimate the amount of habitat available per year for each scenario.



4. Use quantity of available habitat as input to a simple fish population model. More floodplain habitat leads to increased spawning success and hatchling survival. Output is chance of population survival.



5. Compare fish populaton survival across management scenarios (riverbank fortified with levees vs. floodplain reconnected to river) and compare to other benefits (e.g. land for agriculture and flood risk reduction).



Outputs and Outreach

- **New Methods:**
  - Link hydraulic and population models to quantitatively predict the effects of floodplain restoration on plant and animal populations.
  - Evaluate multiple ecological benefits concurrently with flood risk and agricultural benefits and analyze tradeoffs and synergies.
- **Identify Barriers:** By examining ecology and history together, we can identify barriers to and preconditions for success of floodplain restoration projects.
- **Policy Uptake:** Through a multi-stakeholder workshop and ongoing communication with policy-makers, we are working to incorporate our findings into future flood protection planning and policy in California.

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