

River flow:
a key ingredient in ecosystem-based management of the San
Francisco Bay estuary's imperiled fish species

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*Sample relevant literature available for download:
<https://tinyurl.com/NAS-Presentation-References>

River flow into, through, and out of the Delta

- Single most important variable affecting native fish populations
 - not a panacea
 - major improvements are necessary, even if not sufficient alone
- Affects most other important physical and water quality variables
 - not an “either/or” with other actions, but a “both/and”
- Volume and timing dramatically altered due to diversion and storage
- Necessary changes in flow volume and timing are possible
- Flow management is ecosystem management

Chinook Salmon

- Anadromous
- Semelparous (~3 year life cycle; range: 2-5)
- Four runs:
 - Two listed (winter-run; spring-run)
 - Two commercially harvested (fall-run; late-fall run)
 - Fishery closed 2008, 2009, 2023, 2024

Main Stressors

- River flow* (including Delta Channels; Old and Middle River)
 - *meaning flow-mediated variables
- Incubation temperatures
- Few and isolated populations



Illustrated by Fiorella Ikeue in collaboration with SF Baykeeper



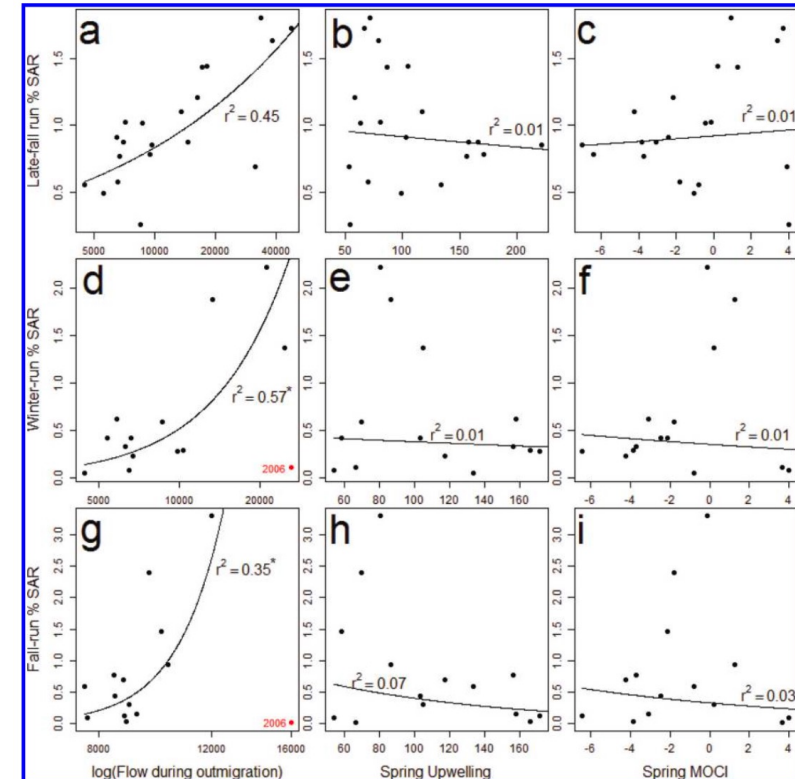
River flows affect juvenile Chinook Salmon survival

Research on Chinook Salmon flow-survival relationships has exploded since ~2015

- Mostly linear/linearizable relationships
 - but see Michel et al. 2021
- Throughout the migration corridor (river + Delta)
- Effect lasts through the life-cycle for all runs
- Mostly studied radio-tagged smolts



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Michel, C.J. 2019. Decoupling outmigration from marine survival indicates outsized influence of streamflow on cohort success for California's Chinook salmon populations. Canadian Journal of Fisheries and Aquatic Sciences. <https://doi.org/10.1139/cjfas-2018-0140>

Longfin Smelt

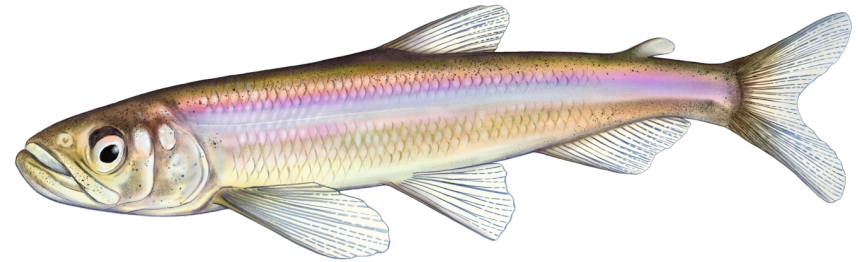
- Semi-anadromous
- Semelparous (~2-year life cycle)
- State-listed (2009); Federally listed (2024)

Main Stressors

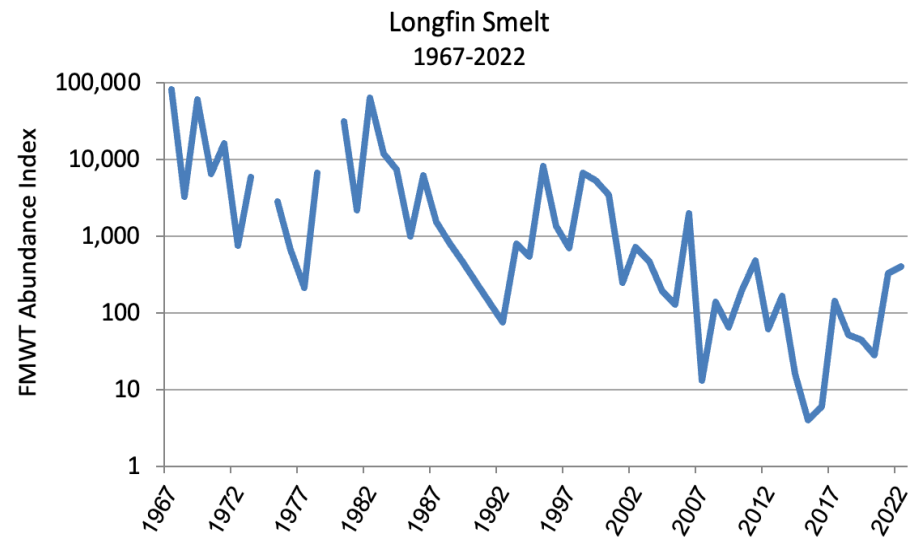
- Winter-spring Delta outflow
- Entrainment-related mortality (?) – episodically

“Based on the meta-analysis, the mean quasi-extinction value for the population is 33% (25%, 41%) over 20 years and rises to 50% (42%, 58%) in 30 years...”

USFWS 2024 at 115



Illustrated by Fiorella Ikeue in collaboration with SF Baykeeper



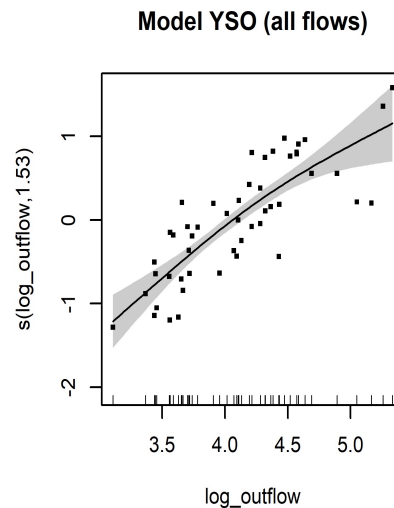
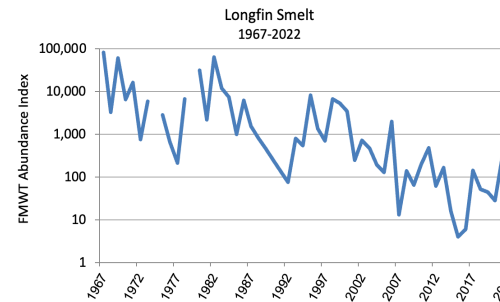
Longfin Smelt

Flow-abundance relationship

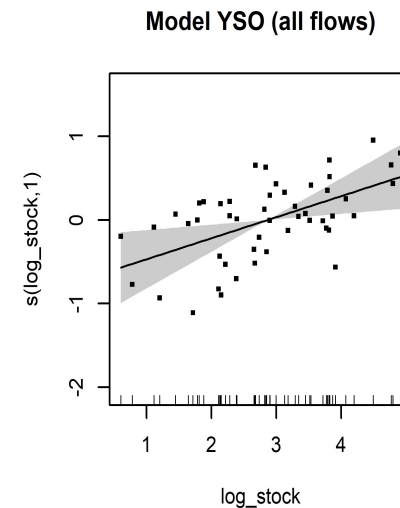
- Jassby et al. 1995
- Rosenfield & Baxter 2007
- Sommer et al. 2007
- Kimmerer et al. 2009
- Thomson et al. 2010
- Mac Nally et al. 2010
- and many more...

When & where is Delta outflow having its effect?

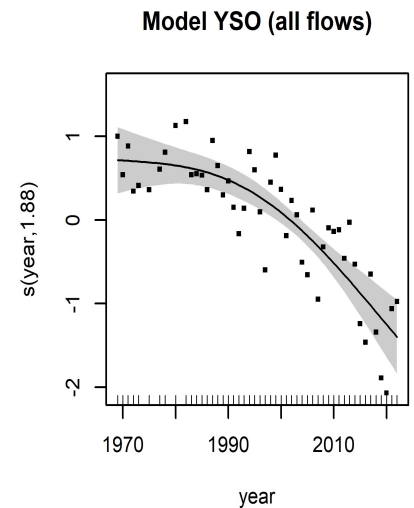
- Rosenfield & Baxter 2007
- Nobriga & Rosenfield 2016



Juvenile recruitment
(upstream)



Juvenile survival
(downstream)



Delta Smelt



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- Endemic estuarine resident
- Semelparous (1-year life cycle)
- State-listed & Federally listed (1993)

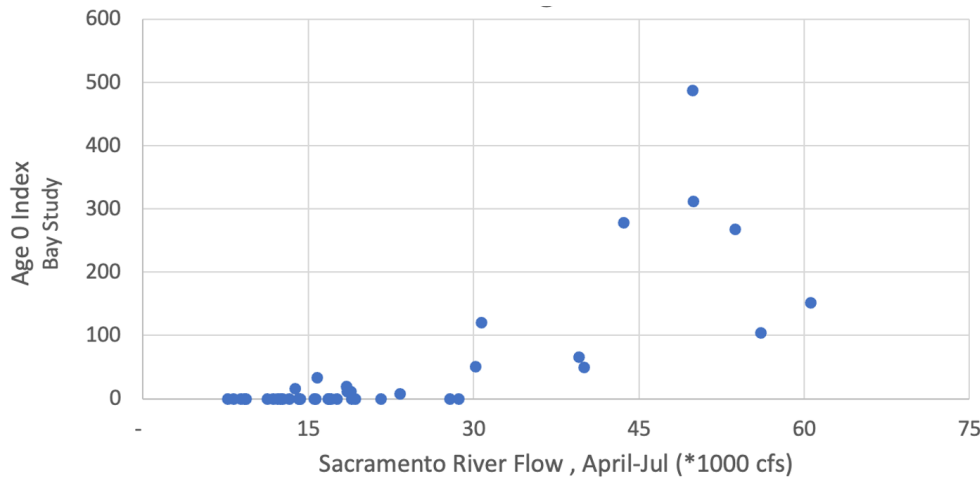
Main Stressors

- Summer Delta outflow (Polansky et al. 2021; CSAMP 2024)
- Entrainment-related mortality (Polansky et al. 2021; Smith et al. 2021), as indexed by OMR
- Temperature
- Foraging habitat (Hammock et al. 2019 and, on a massive scale CSAMP 2024)

White Sturgeon



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Baykeeper et al. 2023

- Amphidromous/estuarine resident
- Iteroparous (females mature at 12-16 years; 2-4 years between spawning)
- CESA-candidate (2024); Federal petition pending

Main Stressors:

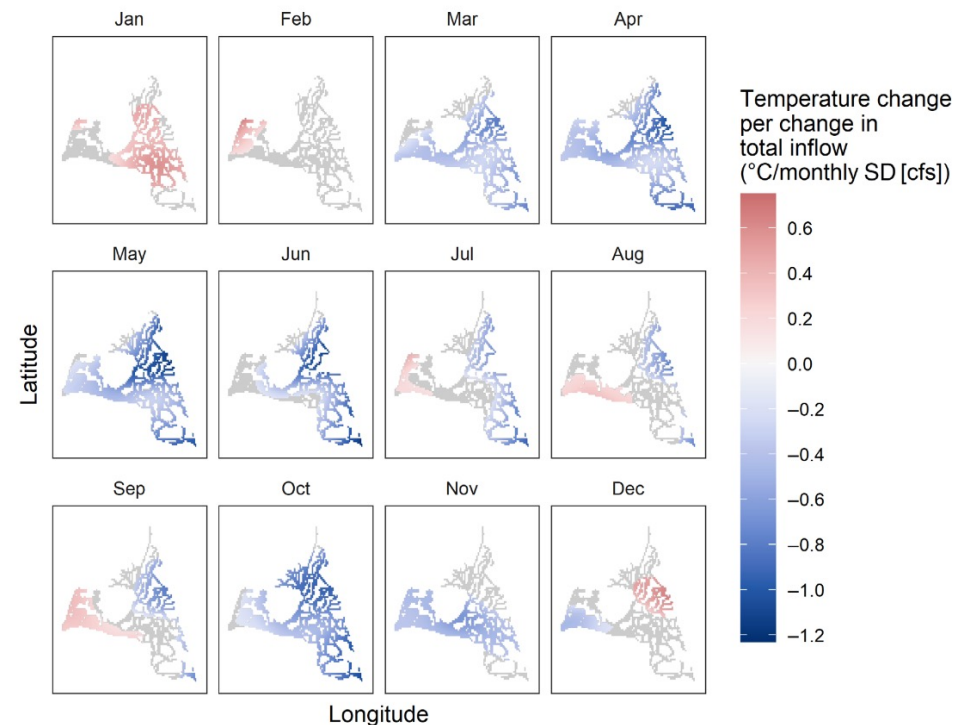
- reduced river & Delta flows
- overharvest
- harmful algae blooms

River flows affect other habitat variables

- Temperature
- Dissolved oxygen
- Habitat velocity/depth
- Habitat extent
- Turbidity
- Harmful algal bloom (HAB) development
- Hydrodynamics (tidal effects, gravitational circulation)
- etc.
- etc.

River flows affect other habitat variables e.g., water temperature

- Upstream (through the effect of reservoir storage)
 - Shasta release temperature more important than volume (Daniels & Danner 2020)
 - Shasta release temperatures essential for survival of listed runs and commercial, recreational, Tribal fisheries.
- Temperatures downstream (through the effect of river discharge)
 - Michele, Daniels, & Danner 2023
 - Bashevkin & Mahardja 2022
 - Nobriga et al. 2021
 - Munsch et al. 2019
 - Vroom et al. 2017



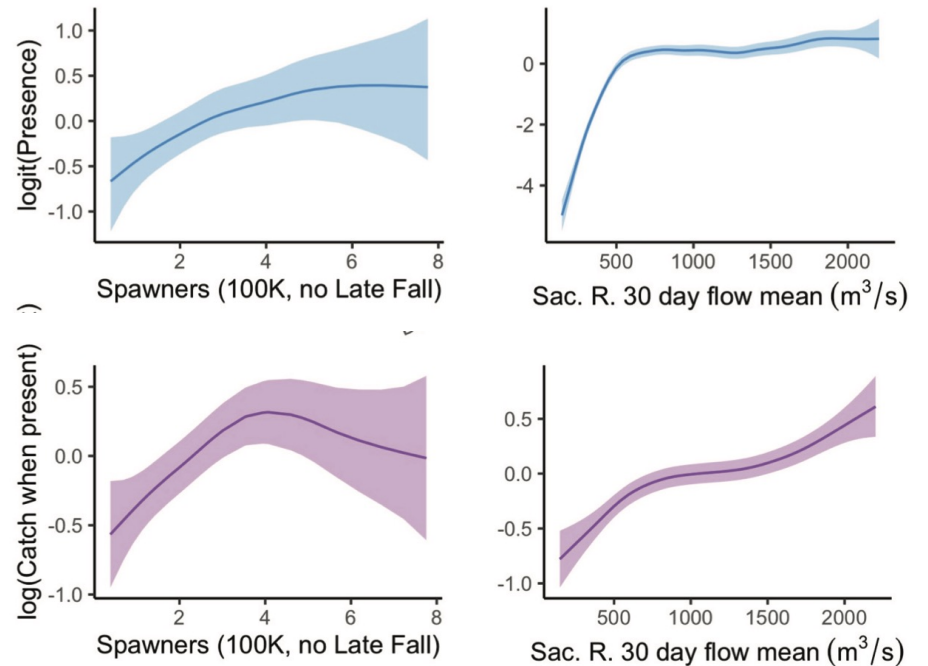
Bashevkin, S.M. and B. Mahardja. 2022. Seasonally variable relationships between surface water temperature and inflow in the upper San Francisco Estuary. *Limnology and Oceanography* 67(3) DOI: 10.1002/lno.12027

River flows affect habitat utilization

- Floodplain inundation makes habitat
- Fry/parr occupy & density of restored tidal marsh sites increases with flow



*Illustrated by Fiorella Ikeue in
collaboration with SF Baykeeper*

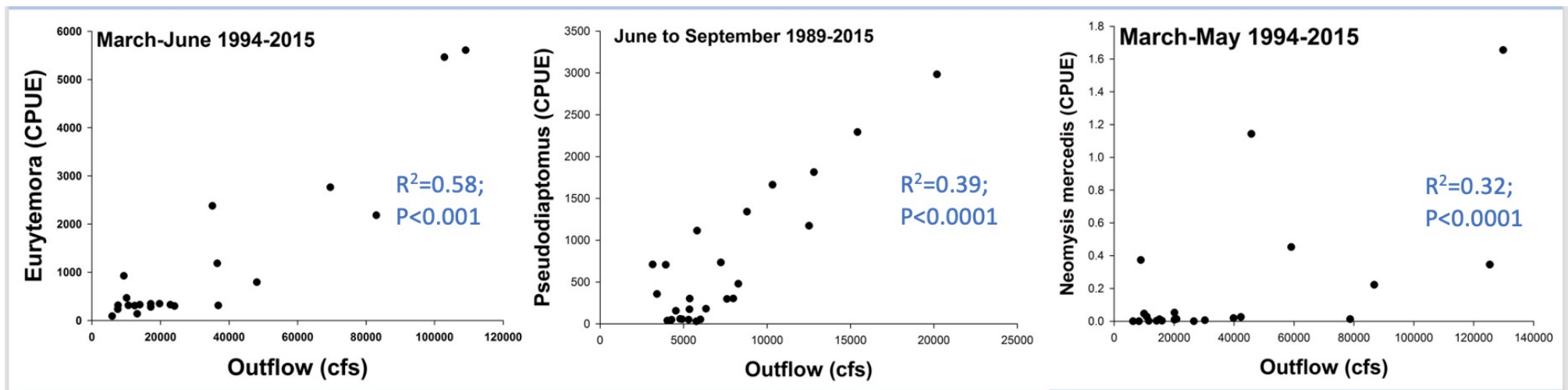


Munsch, S.H., C. M. Greene, R. C. Johnson, W. H. Satterthwaite, H. Imaki, P. L. Brandes, and M. R. O'Farrell. 2020. Science for integrative management of a diadromous fish stock: interdependencies of fisheries, flow, and habitat restoration. *Can. J. Fish. Aquat. Sci.* 77: 1487– 1504 (2020) [dx.doi.org/10.1139/cjfas-2020-0075](https://doi.org/10.1139/cjfas-2020-0075)

River flows affect prey availability

Transport of key zooplankton downstream (to important fish habitats) increases with increasing flow

- Hassrick et al. 2023
- Sturrock et al. 2022
- Kimmerer et al. 2017
- Hennessy and Burris. 2017



Hennessy, A. and Z. Burris. 2017a. Preliminary analysis of current relationships between zooplankton abundance and freshwater outflow in the upper San Francisco Estuary. California Department of Fish and Wildlife Memorandum to: Stephen Louie, Senior Environmental Scientist, CDFW. Dated: 2/21/2017.

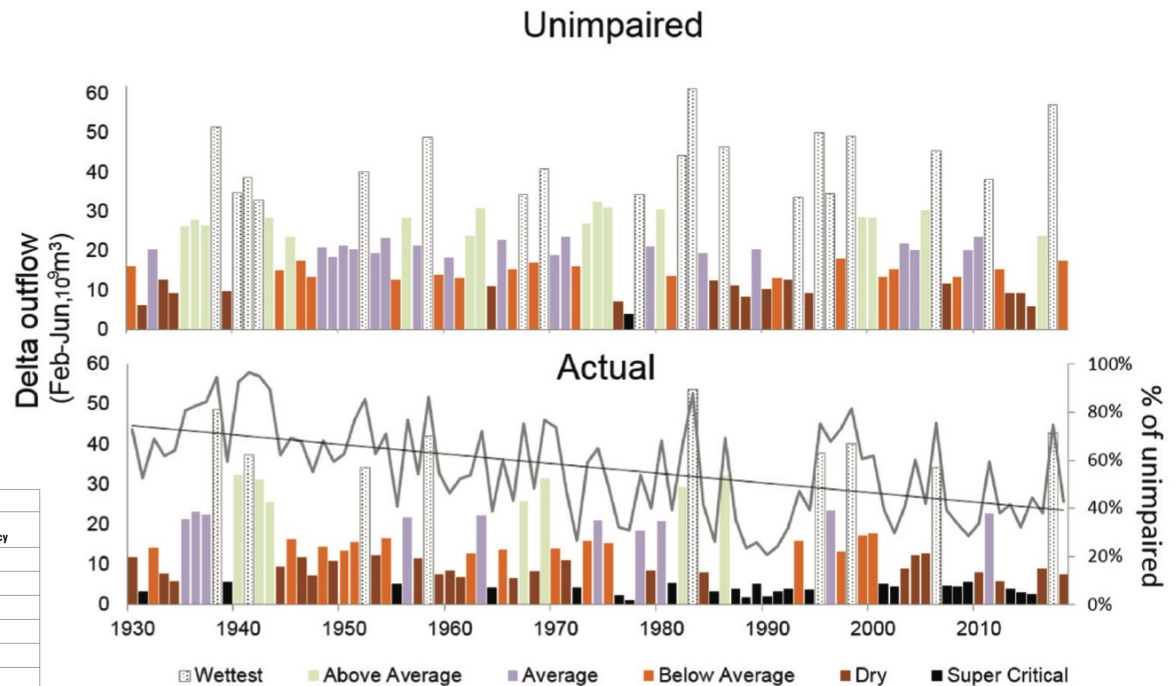
Flow volume and timing altered due to diversion and storage (CVP, SWP, and “non-project”)

Declining portion of Central Valley runoff reaches SF Bay

- “perpetual drought” for fish & wildlife

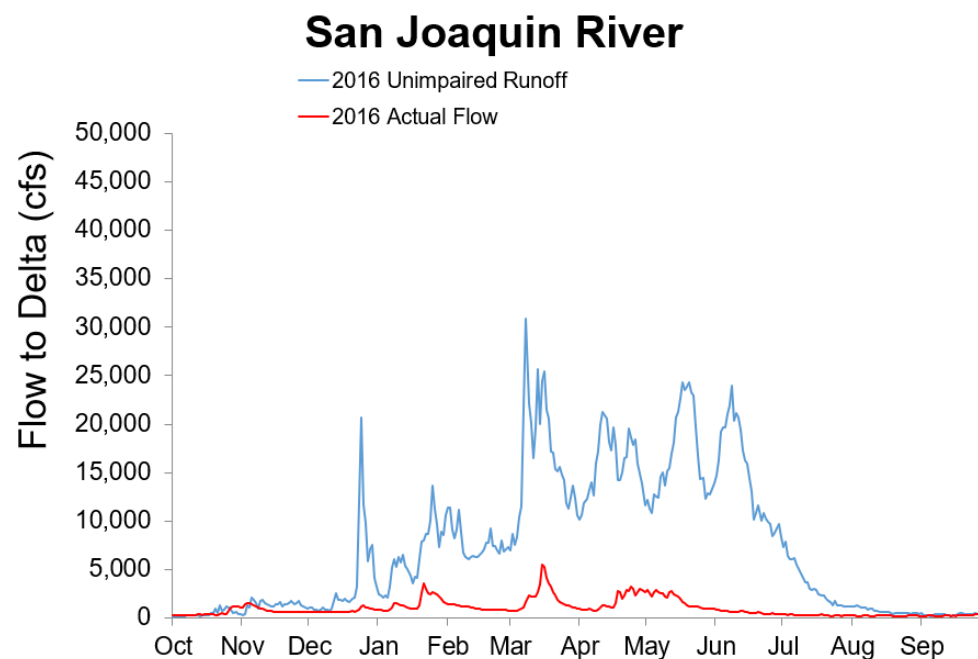
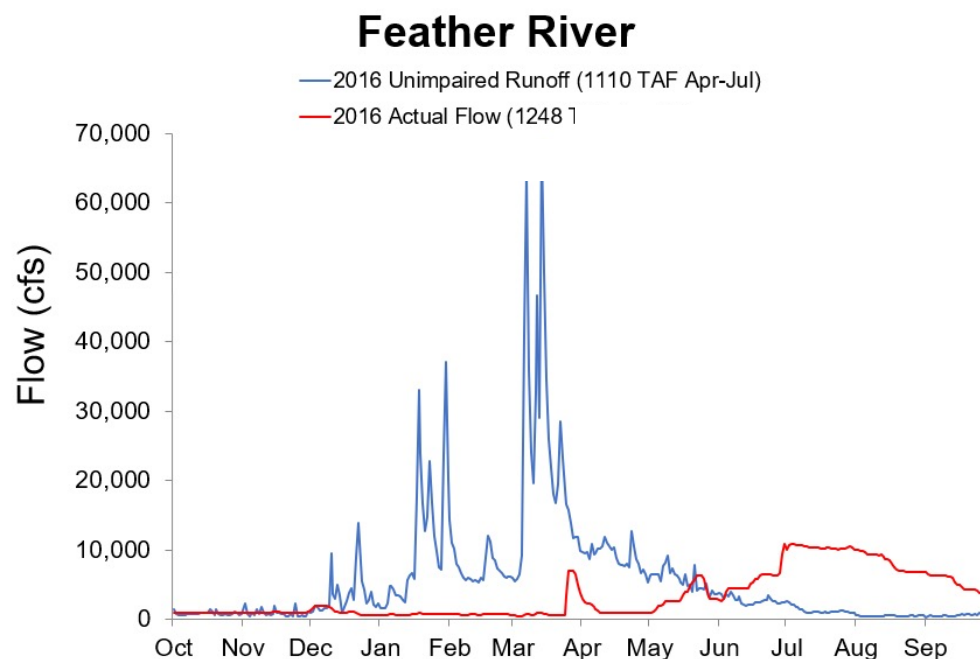
- Reis et al. 2019
- Hutton et al. 2017

		1930–1967		1968–1994		1995–2018	
Year type ^a	Unimpaired Delta outflow (10 ⁹ m ³)	Unimpaired frequency	Actual frequency	Unimpaired frequency	Actual frequency	Unimpaired frequency	Actual frequency
SC	<5.876	0%	13%	4%	44%	0%	38%
D	<12.838	13%	45%	30%	59%	17%	63%
BA	12.838–18.304	21%	21%	15%	15%	25%	13%
A	18.305–23.625	26%	13%	19%	11%	17%	8%
AA	23.626–32.798	21%	11%	15%	11%	17%	0%
W	>32.798	18%	11%	22%	4%	25%	17%



Reis, G.J., J.K. Howard, and J.A. Rosenfield. 2019. Clarifying Effects of Environmental Protections on Freshwater Flows to—and Water Exports from—the San Francisco Bay Estuary. San Francisco Estuary and Watershed Science, 17(1). Available at: <https://escholarship.org/uc/item/8mh3r97j>

Flow volume and timing altered due to diversion and storage (CVP, SWP, and “non-project”)



Necessary changes to flow are possible (if water deliveries are not sacrosanct)

CVP LTO DEIS -- Alternative 3 Modified Natural Hydrograph

- Described DEIS Chapter 3 at 3-60 to 3-66; modeling assumptions Appendix F at F.1-1-51 to F.1-1-60
- Simple prioritization scheme of CVP operations produces benefits upstream and downstream
 - Human health and safety supplies
 - Shasta coldwater pool
 - Delta inflow & outflow
 - Water deliveries

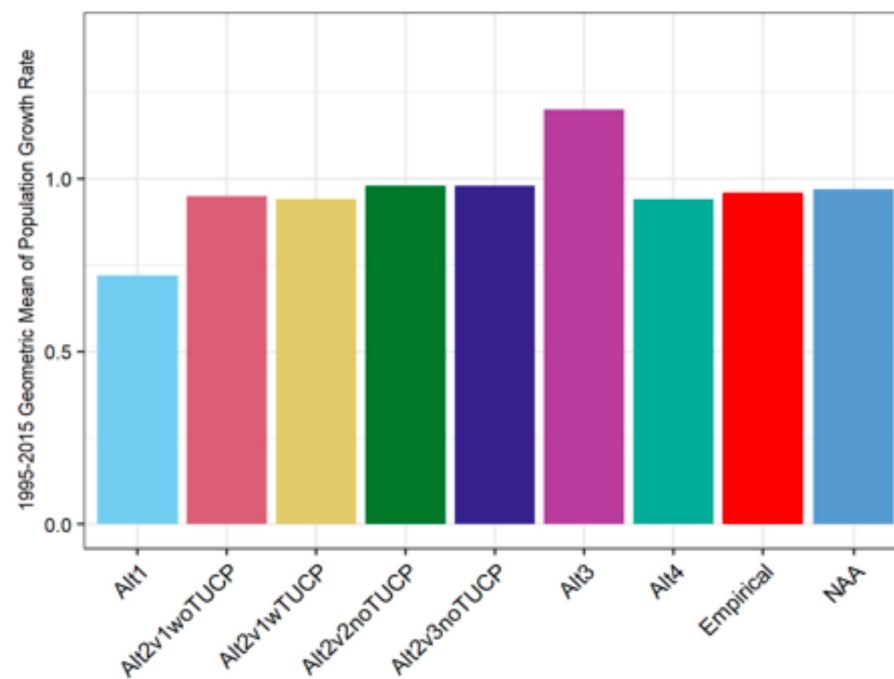


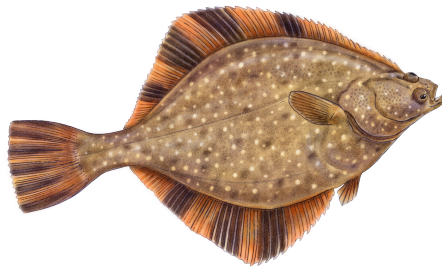
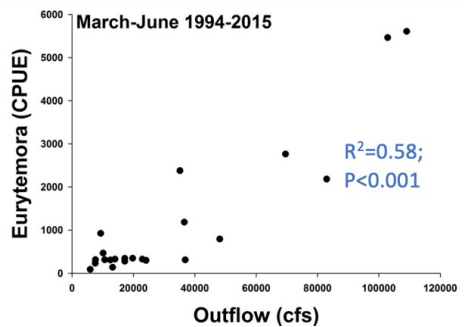
Figure 12-4. Mean population growth rates aggregated across the years. Bar plot demonstrating the geometric mean of population growth rate (λ) from 1995 to 2015 for the various alternatives.

Federal DEIS at 12-55

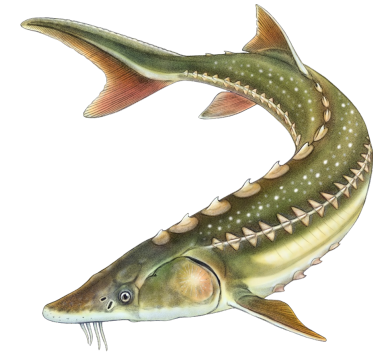
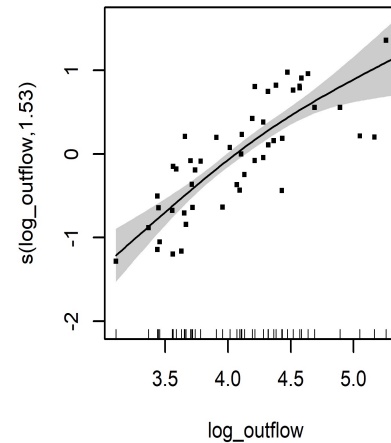
Flow management is ecosystem management



Southern Resident Killer Whale



Starry Flounder



Green Sturgeon



Central Valley Steelhead



Microcystis HAB in Stockton, CA