Physiological and Behavioral Approaches to the Conservation of California's Native Fishes

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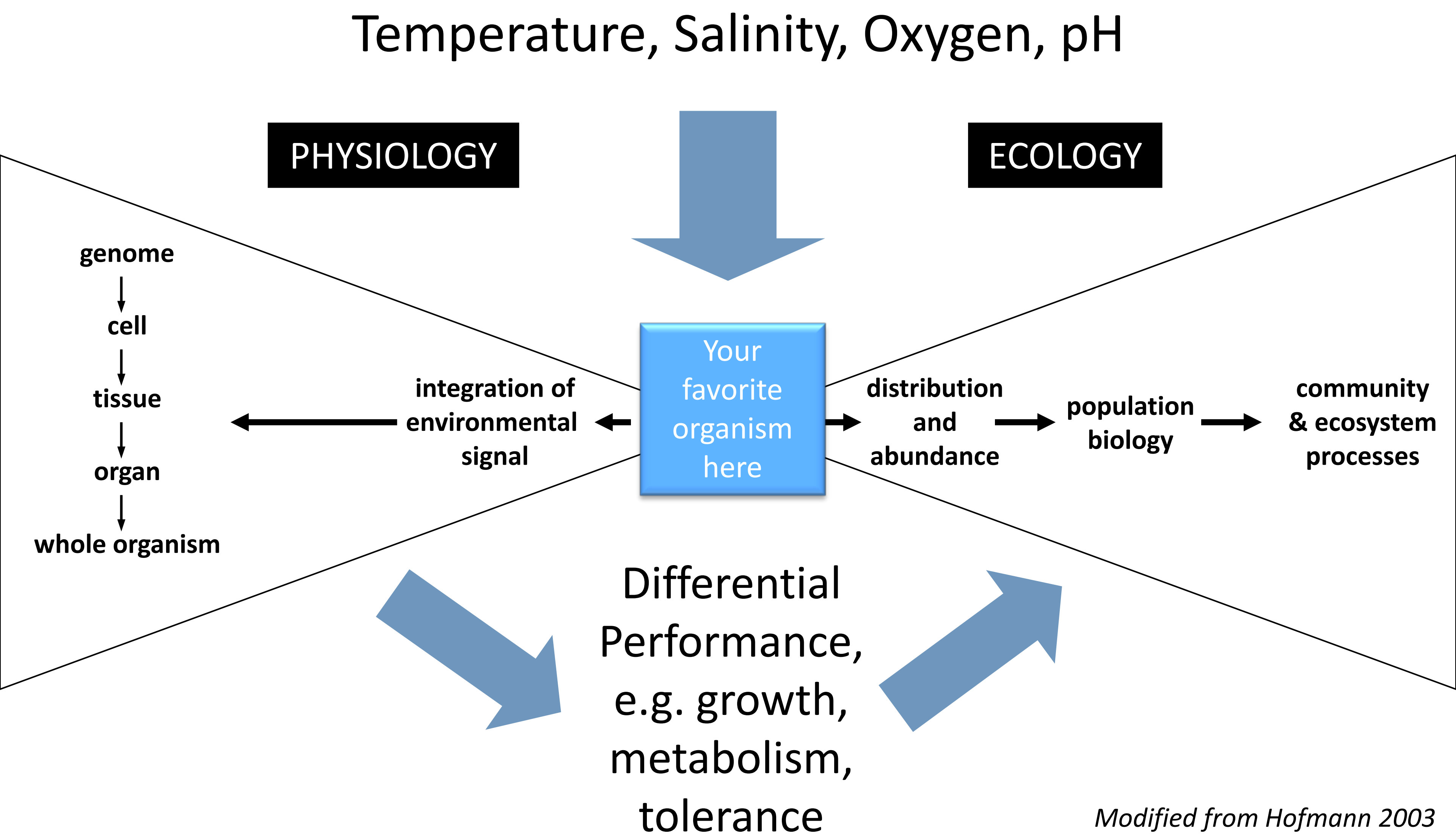
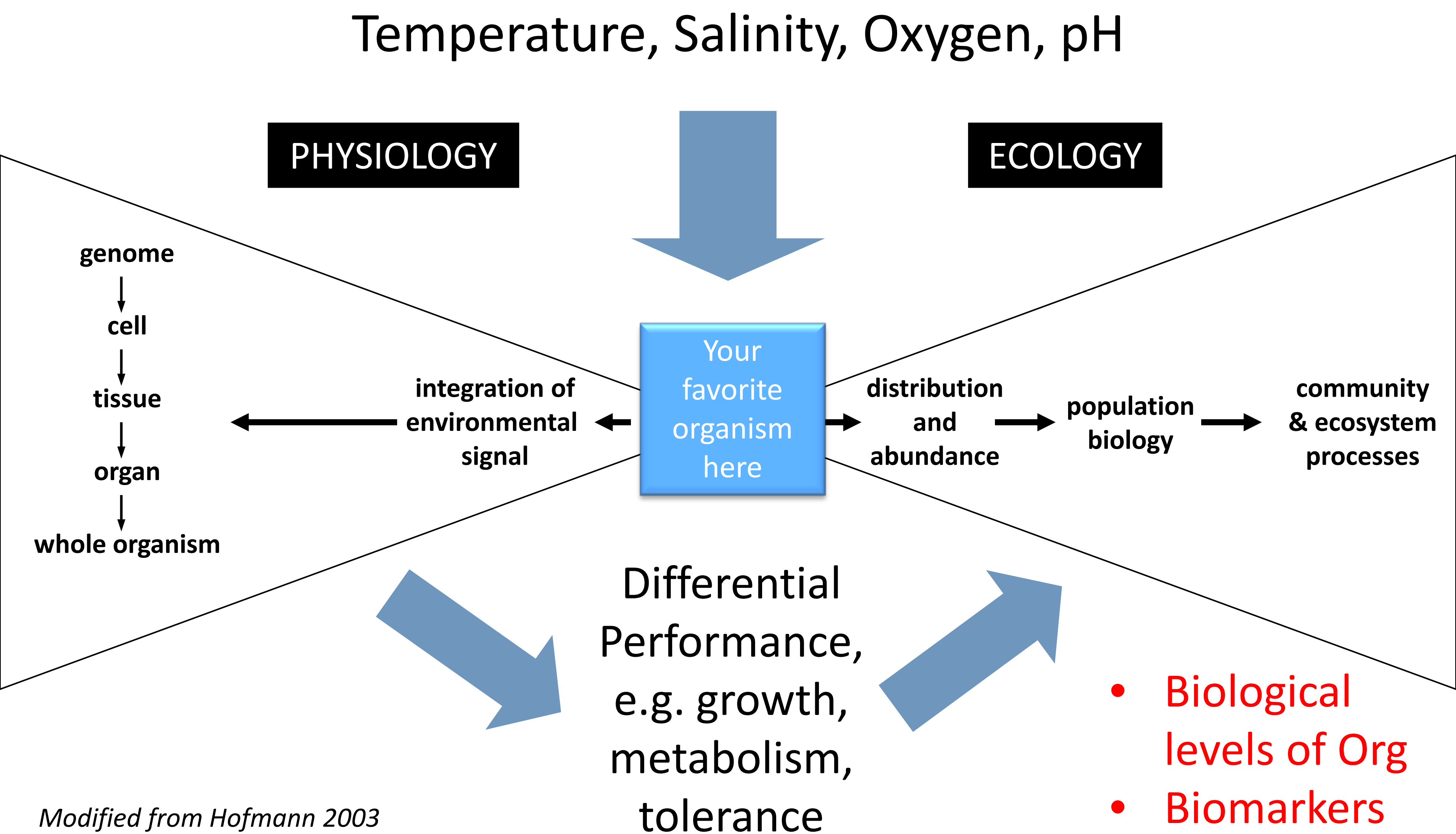
Native Fish Conservation: linking mechanisms to outcomes



Modified from Hofmann 2003

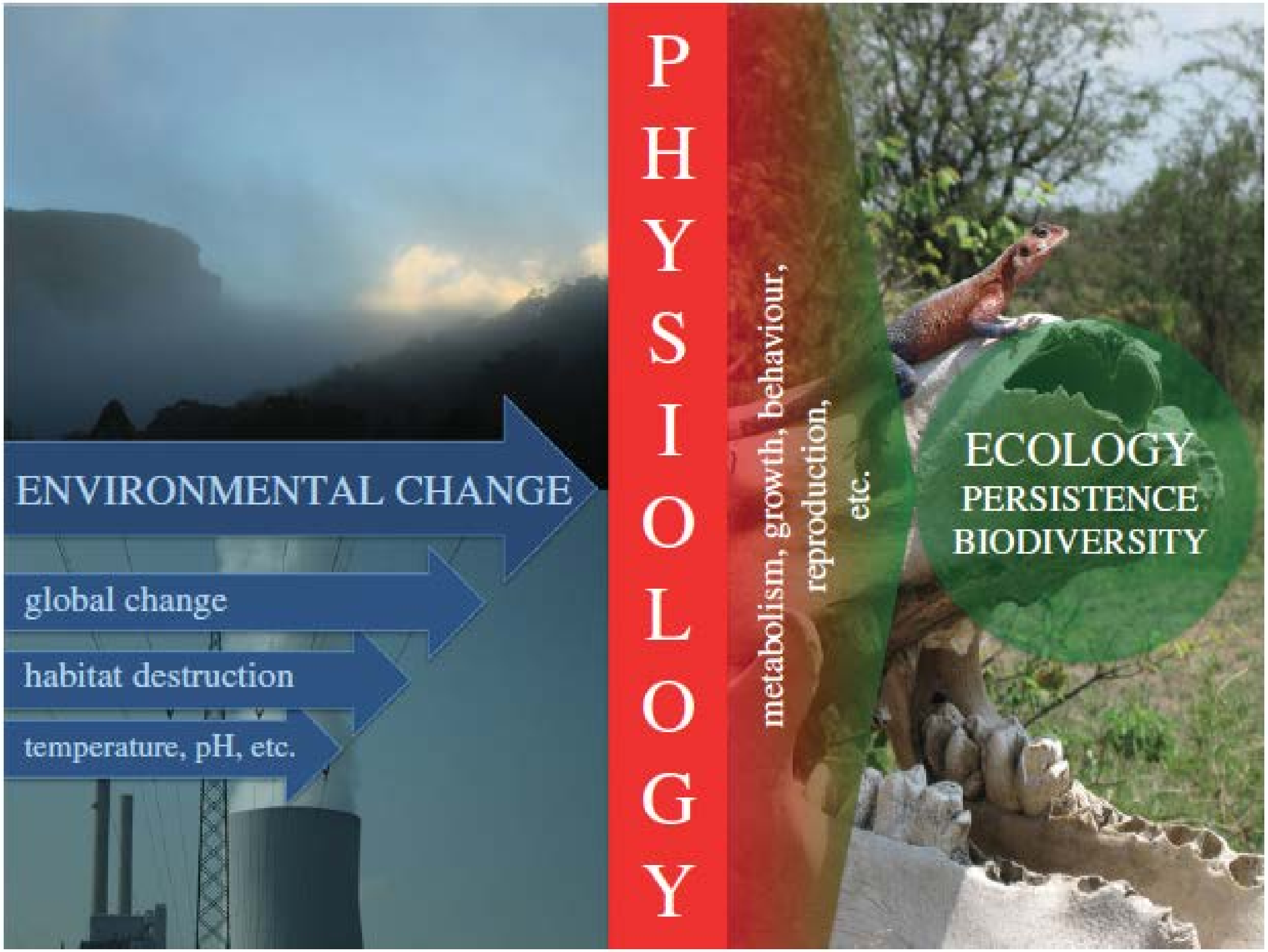
Native Fish Conservation: linking mechanisms to outcomes



- Biological levels of Org
- Biomarkers

Modified from Hofmann 2003

Conservation Physiology: An emerging discipline

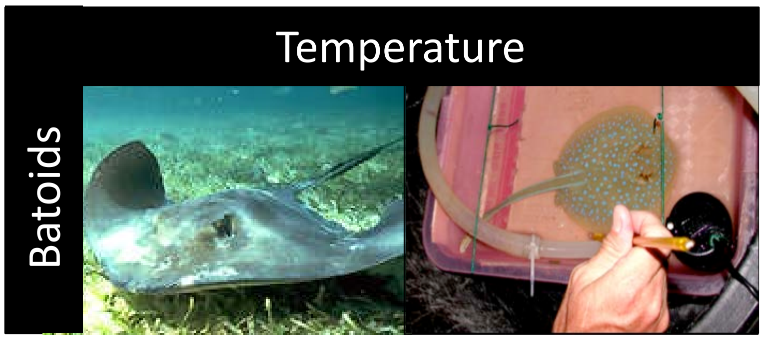


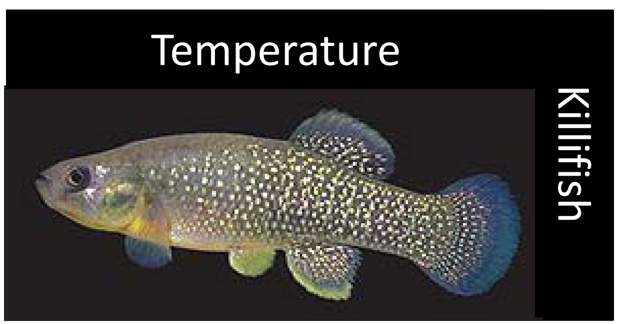
Seebacher and Franklin 2012

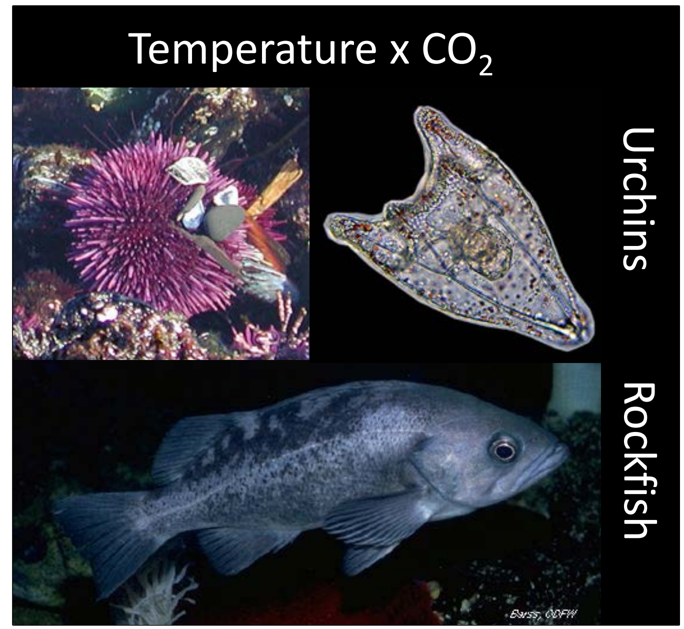
Fitness fncs. Including behavior

Overarching Research Themes

- Fundamental mechanisms of acclimatization (plasticity) and adaptation







- Integrating physiological and behavioral studies with conservation and

Overarching Research Themes

- Fundamental mechanisms of acclimatization (plasticity) and adaptation
- Integrating physiological and behavioral studies with conservation and management
- Recurring themes: biological levels of org., timescales (exposures & experiments), multiple & diverse stressors, behavior & physiology, interdisciplinary partnerships

Current Project Highlights

Temperature x Salinity x Turbidity

Delta Smelt

DSP# 201015533
USBR# R12AP20018
USBR# 201012973

Environmental Stress

Nutrition x Temp x Salinity

White Sturgeon

Green Sturgeon

CDFW ERP# E1183017

Water Exports

Chinook Salmon

Green Sturgeon

AFSP#R09AC20048
USBR#R10AC20012

CEC# PIR-08-029

Temperature

Hardhead

DSP# 201119725

Temperature x Salinity

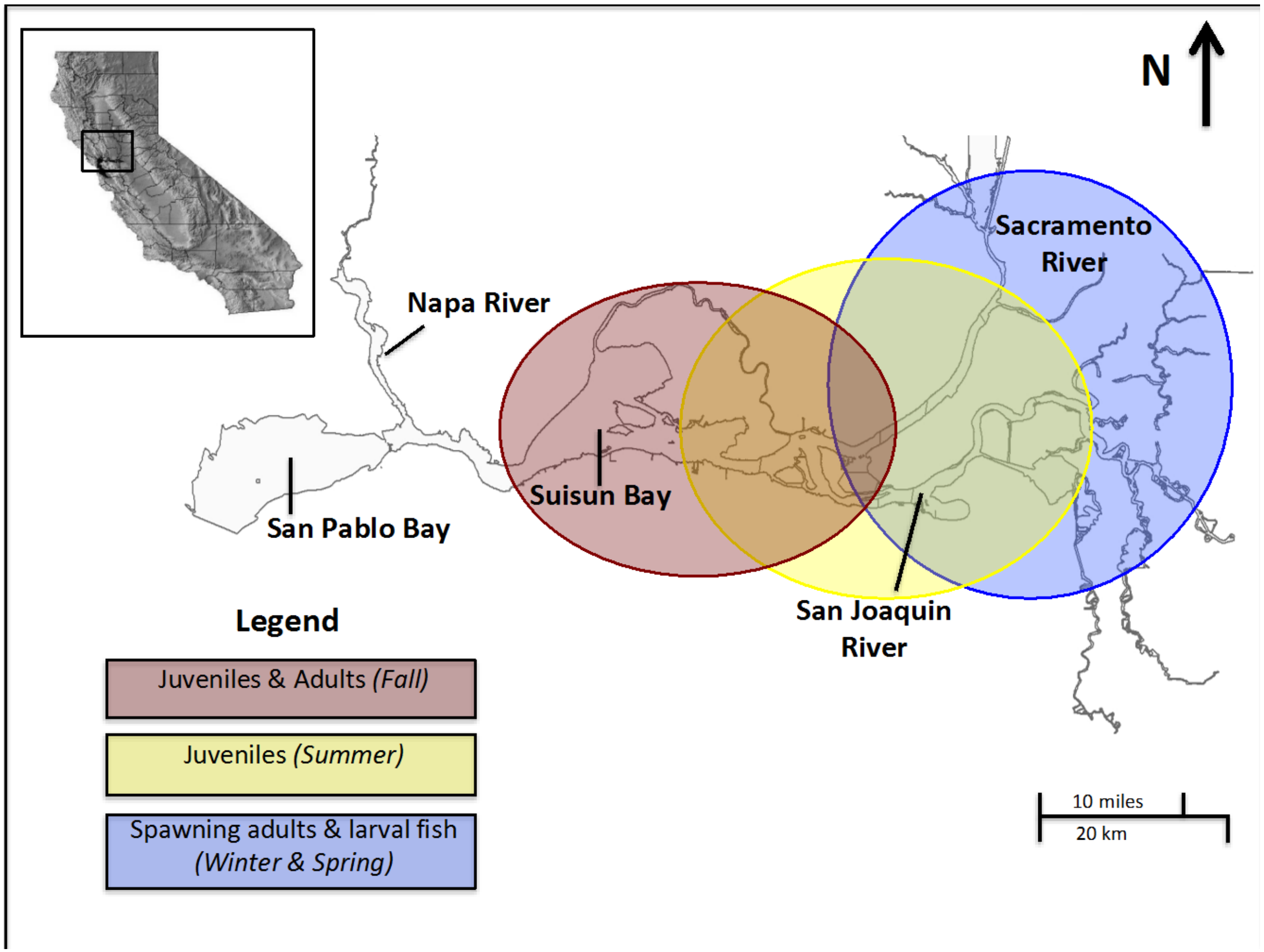
Splittail

The Delta smelt

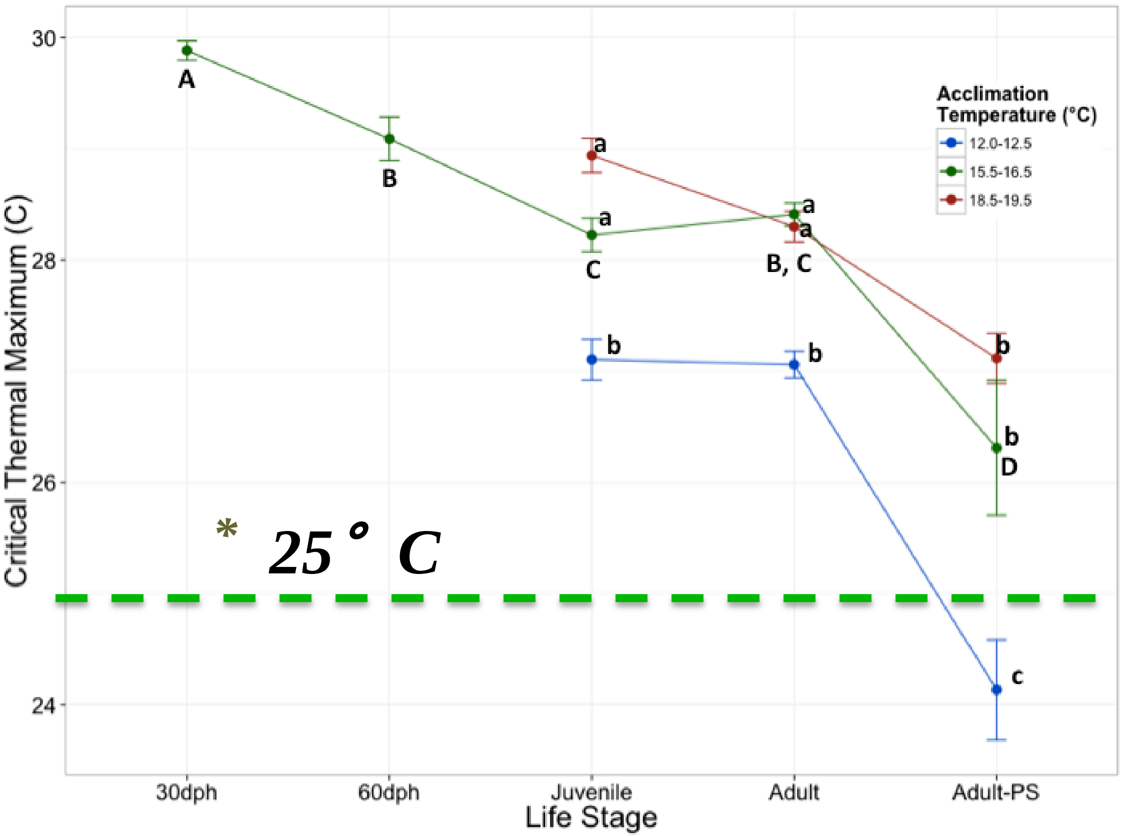
Integrating physiological and behavioral studies with delta smelt conservation

- Temperature, Salinity, and Turbidity effects on feeding (Hasenbein, Connon, Lindberg)
  - Feeding performance, biochemical stress markers, molecular markers (gene expression)
- Ontogeny of temperature and salinity tolerance (Komoroske, Connon, Lindberg)
  - Whole organismal tolerance, behavioral preferences, molecular markers (gene expression)
- Individual based bioenergetics model (Eder, Cocherell, Loge)
  - Feeding performance and metabolism of delta smelt across lifestages and temperatures

Integrating physiological and behavioral studies with delta smelt conservation



Delta smelt – Thermal Tolerance



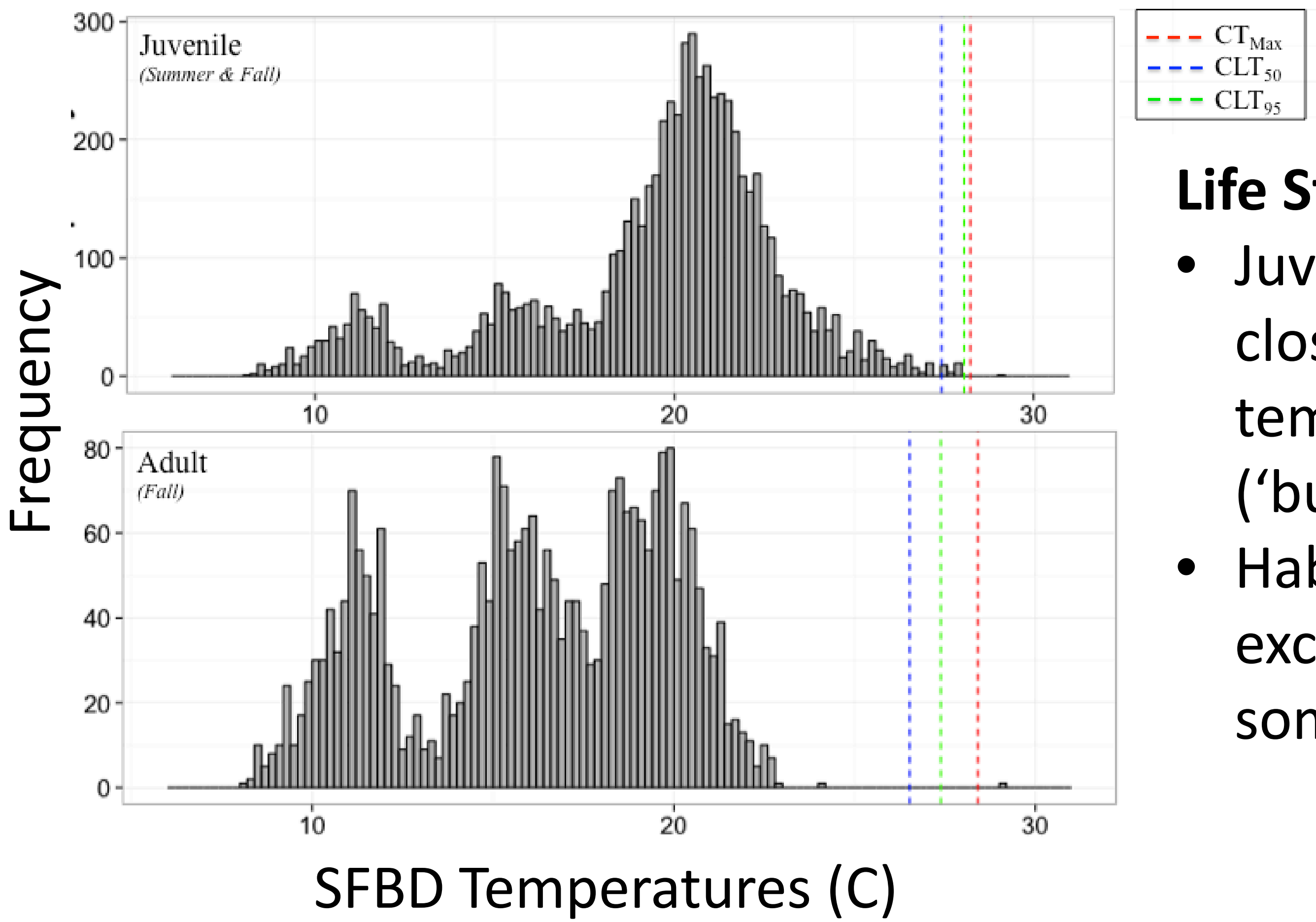
Fish photos: US Bureau of Reclamation

Life Stage differences:

- Larvae most tolerant
- Post-spawners most sensitive
- CTmax values exceed those of Swanson et al. 2000*

Komoroske et al., in prep

Delta smelt – Thermal Tolerance

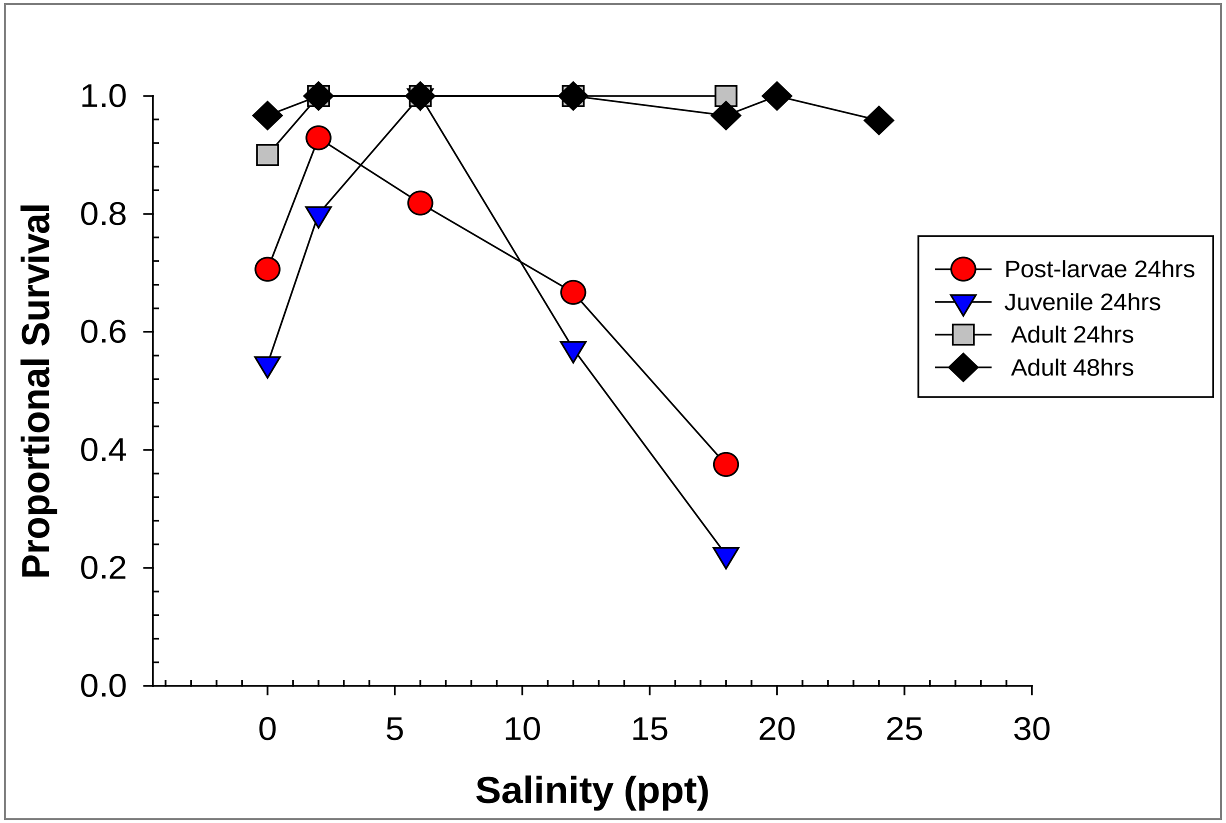


Life Stage differences:

- Juvenile tolerance closest to current temperatures ('buffer')
- Habitat temperatures exceed tolerances in some locations

Komoroske et al., in prep

Delta smelt – Salinity Tolerance

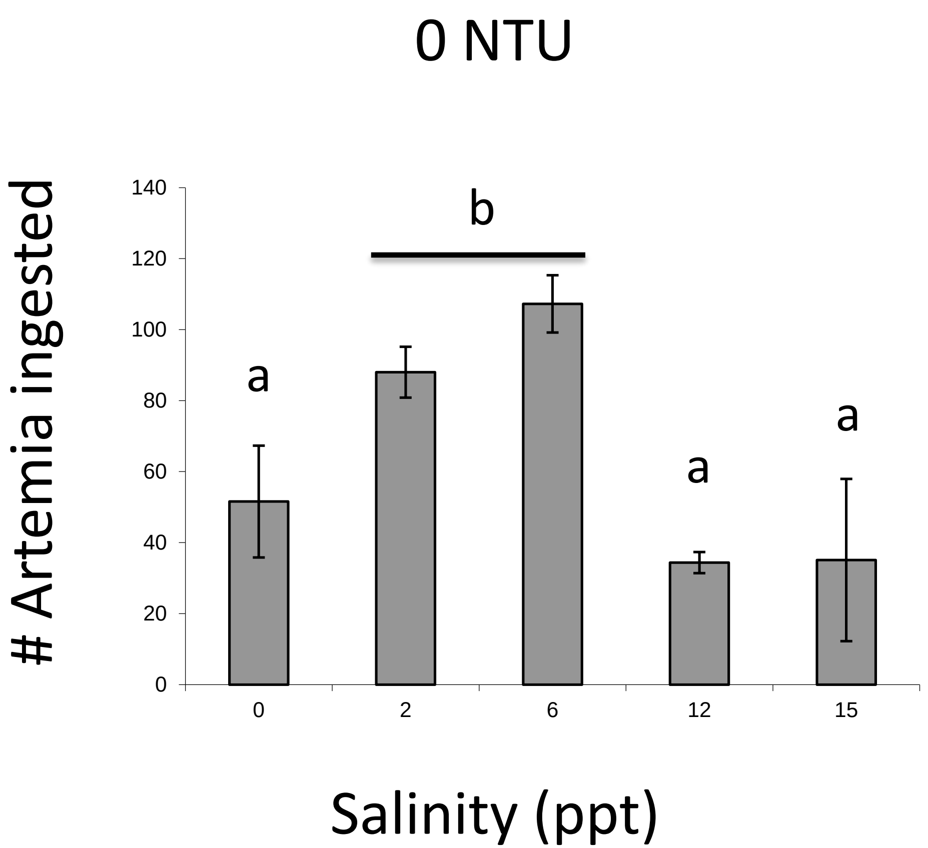


Life Stage differences:

- Post-Larvae & Juveniles more sensitive
- Adults handle high salinities

Komoroske et al., in prep

Delta smelt – Feeding Performance

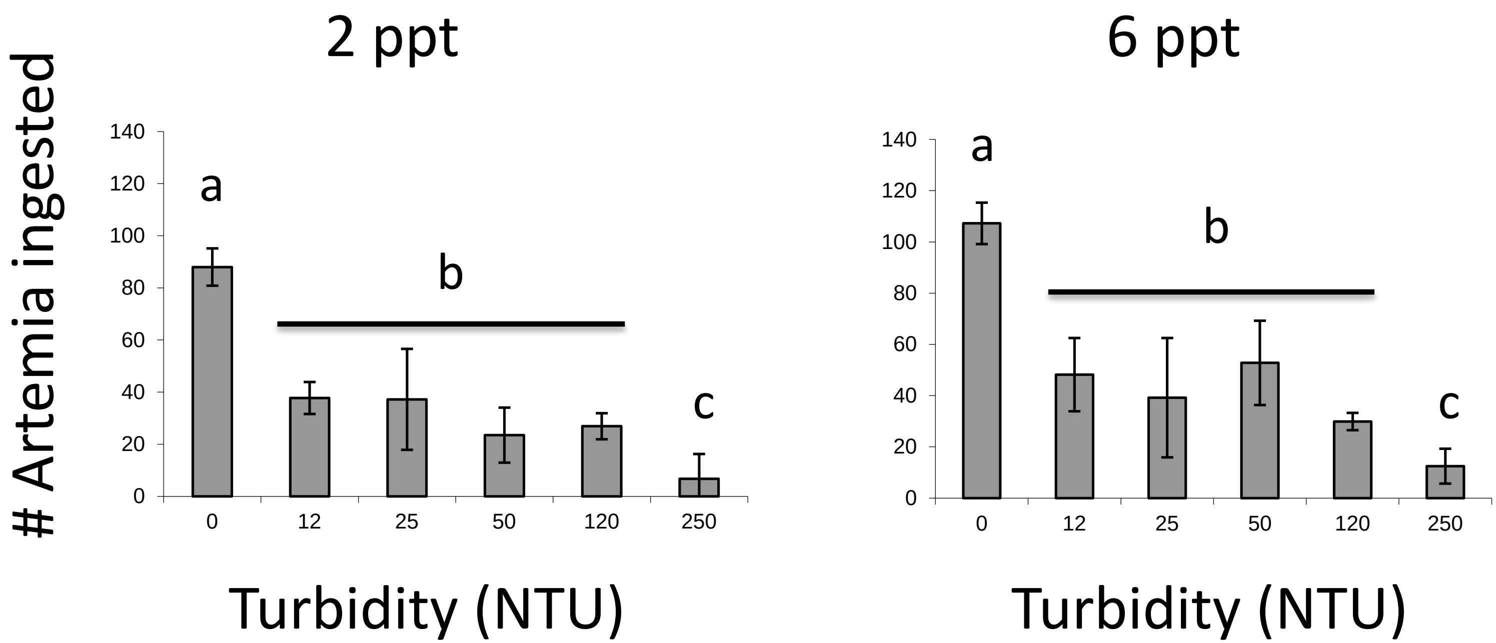


Salinity affects feeding

- Juveniles feed best at salinities conducive to high survival
- Consistent with salinity habitat associations
- Clear water (0 NTU)

Hasenbein et al., 2013

Delta smelt – Feeding Performance

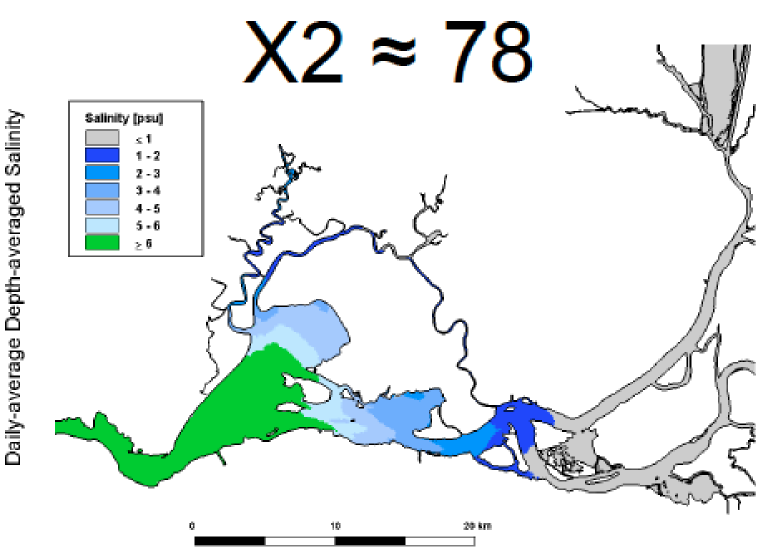


Turbidity also affects feeding:

- Juveniles feed best at 2-6 ppt and in clear water
- Feeding declines ca. 2 fold as turbidity increases

Hasenbein et al., 2013

Takehome Messages



- Stage specific thermal & salinity tolerance
- Optimal feeding at 2-6 ppt, in clear water, low light
- 2 fold reduction in feeding at all SFBD turbidities
- Biochemical and transcriptomic indices consistent with temperature, salinity and turbidity 'optima', (Hasenbein et al. 2013)
- Management implications:
  - Juveniles may be most susceptible to lethal temperatures
  - Fall low salinity habitat (X2) may be critical for feeding (0.5-6 ppt, 0-120 NTU)

Delta smelt bioenergetics

Delta smelt, swimming respirometer
photo: Dennis Cocherel

Delta smelt facility on the UC Davis campus

Metabolism (resting and active) &
Maximum Food Consumption Estimates

Intraspecific variation in Splittail (SPT) Populations

Genetically distinct SPT populations:

1. Petaluma/Napa (0-13 ppt)
2. Central Valley (0 ppt)

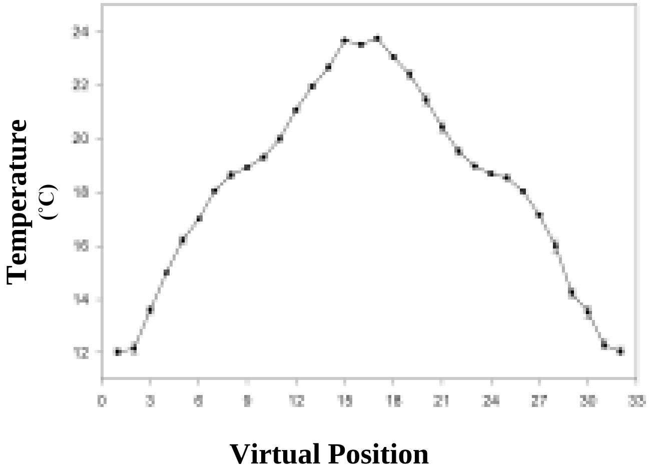
Baerwald et al., 2011

Correlation between population structure and environmental features unclear

Do genetic differences between translate to intraspecific physiological responses (to temperature, salinity)?

Approach: physiological tolerances, lab crosses, molecular mechanisms (transcriptome seq in development), and behavioral preference

Behavioral Preferences: Annular Flumes

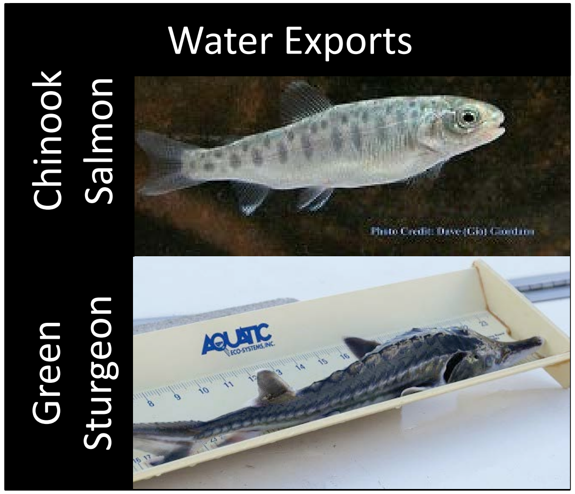


Sacramento splittail

Sturgeon, delta smelt, hardhead, rainbow trout…temperature and salinity

‘Flumes’ of all shapes and sizes to address water exports

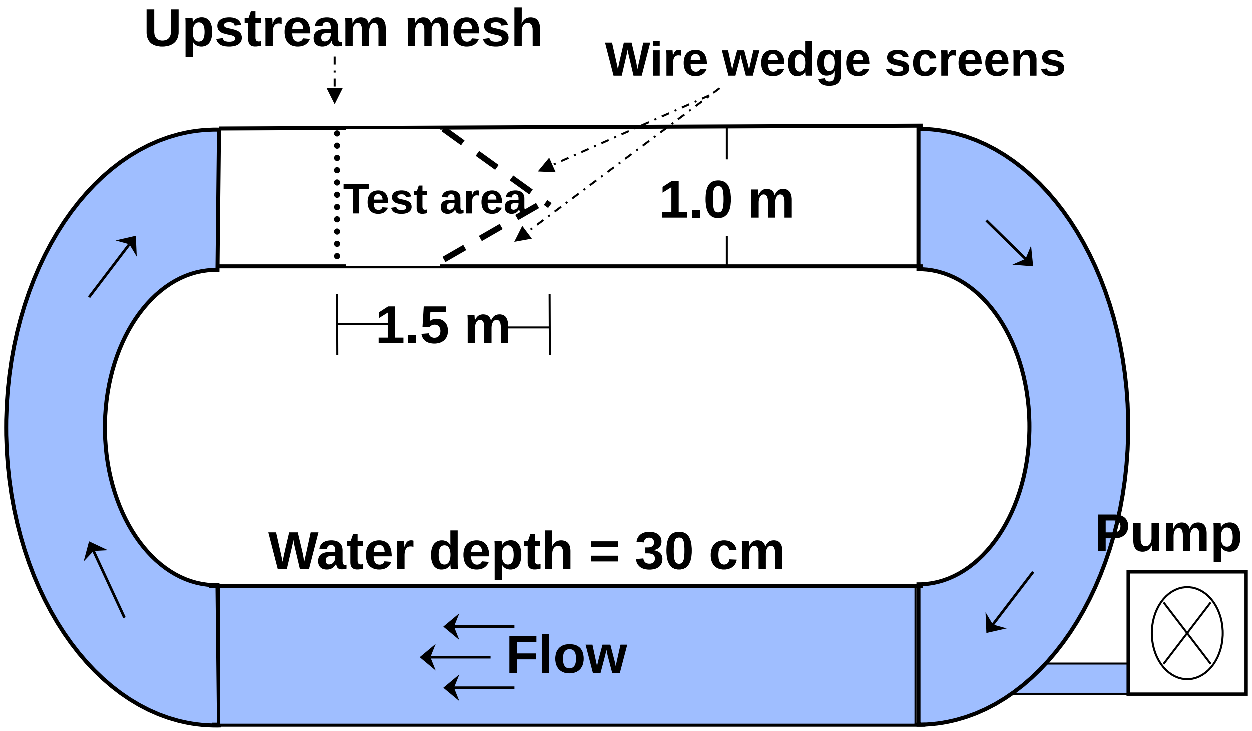
- Avg year, 40% inflow water to SFBD diverted
- Mechanism of export
  - Direct impacts, e.g. entrainment
  - Interaction of fishes with structures

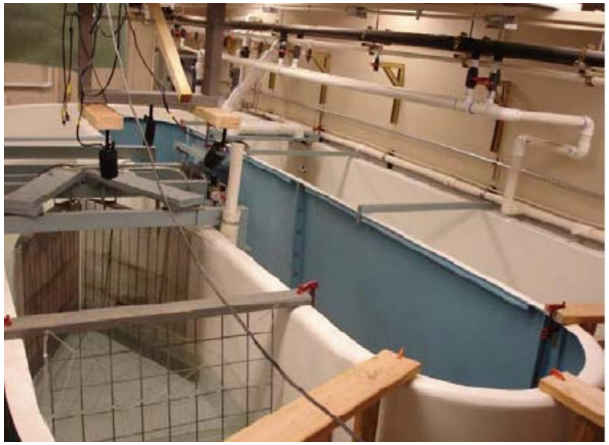


Wilkins Slough Pumping Plant, Sac River

Lund et al. 2010

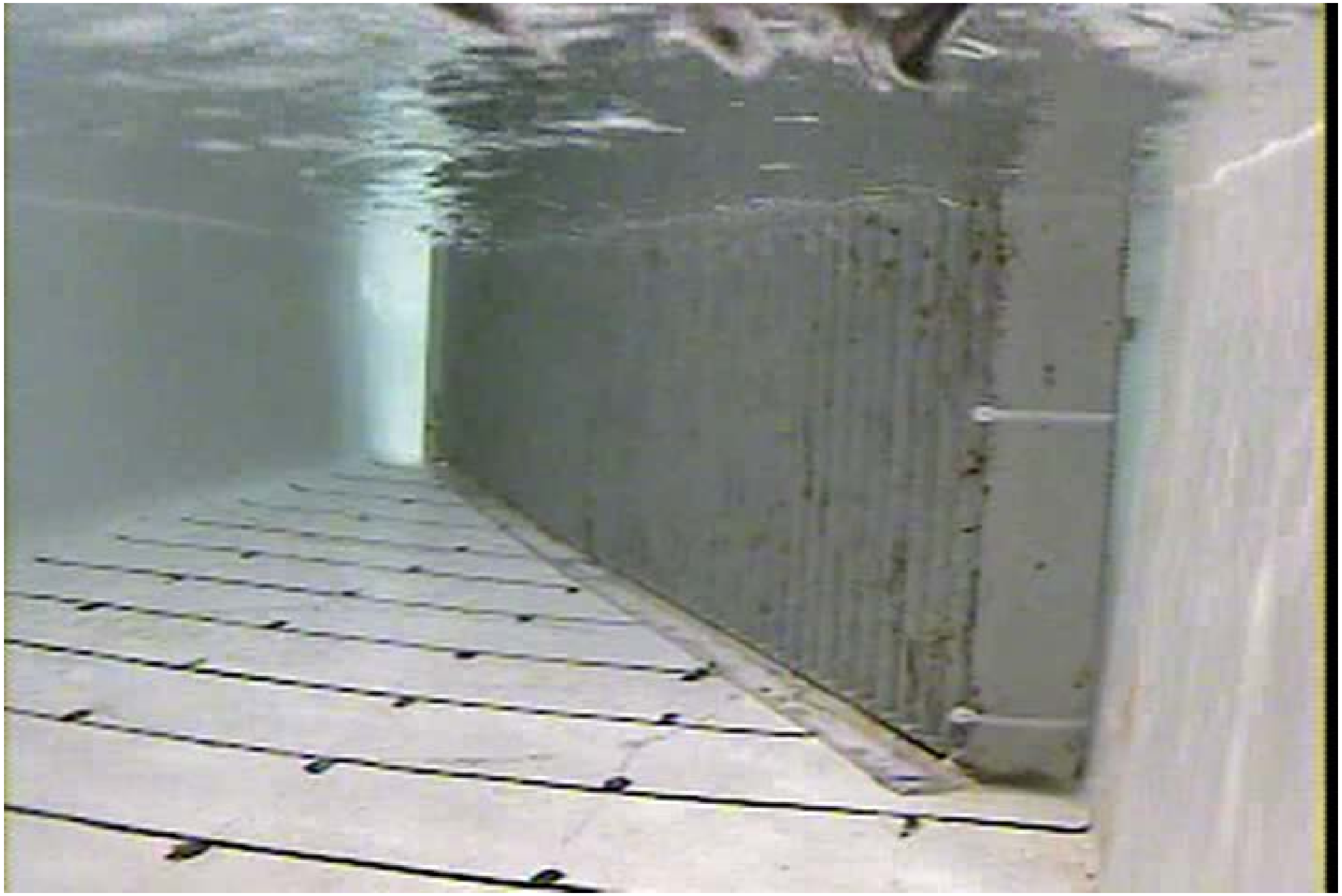
‘Small’ Swimming Flume





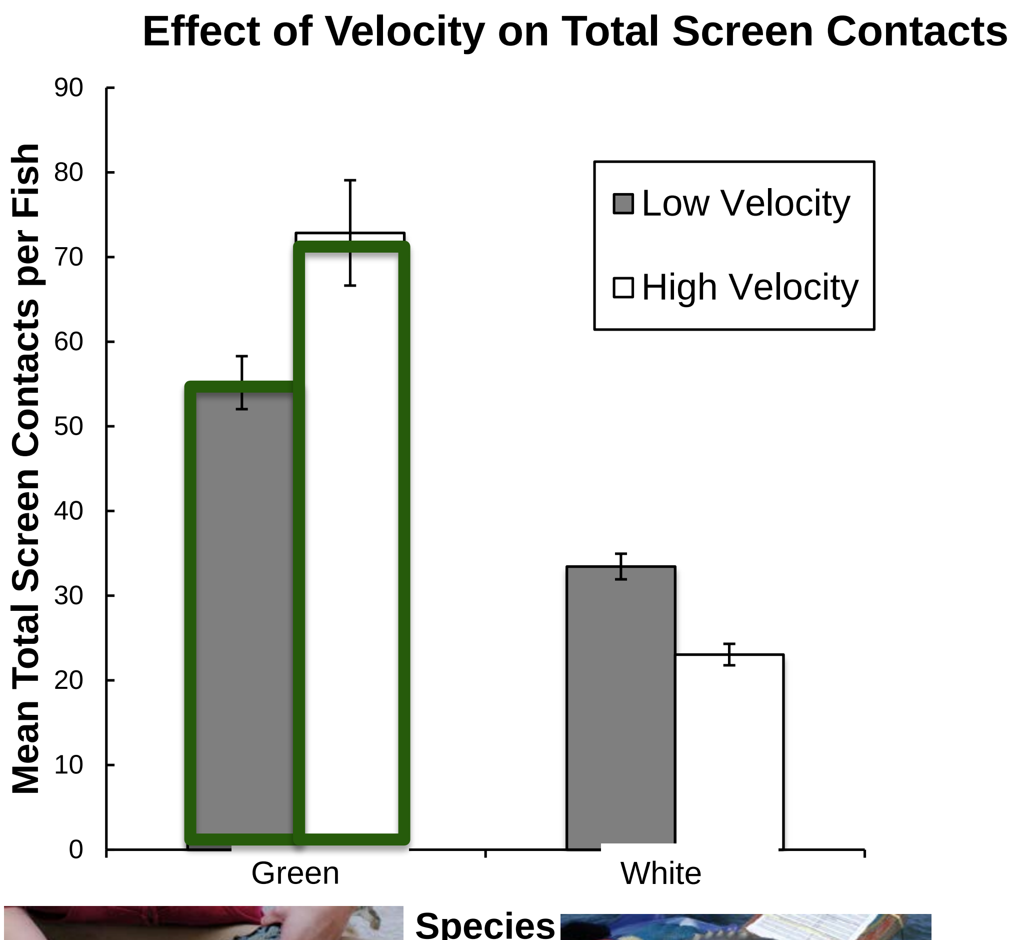
Jamilynn Poletto, Dennis Cocherell, Timothy Mussen

Green sturgeon moving downstream



Jamilynn Poletto, Dennis Cocherell

Total Screen Contacts: Velocity



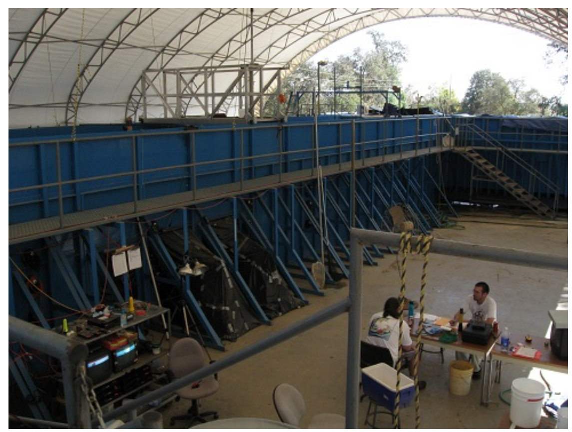
- **Velocity impacted the behavior of both species ($z = 3.7$, $p = 0.0002$).**

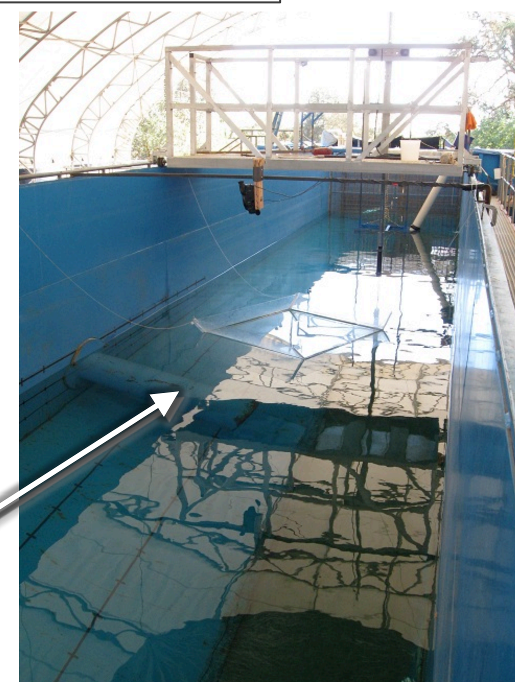
- **Interaction between velocity and species significant ($z = 5.1$, $p < 5.2e\text{-}07$).**

Poletto et al., In review

Water diversion pipes in the California Delta Photo by Dennis Cocherell

‘Large’ River-Simulation Flume



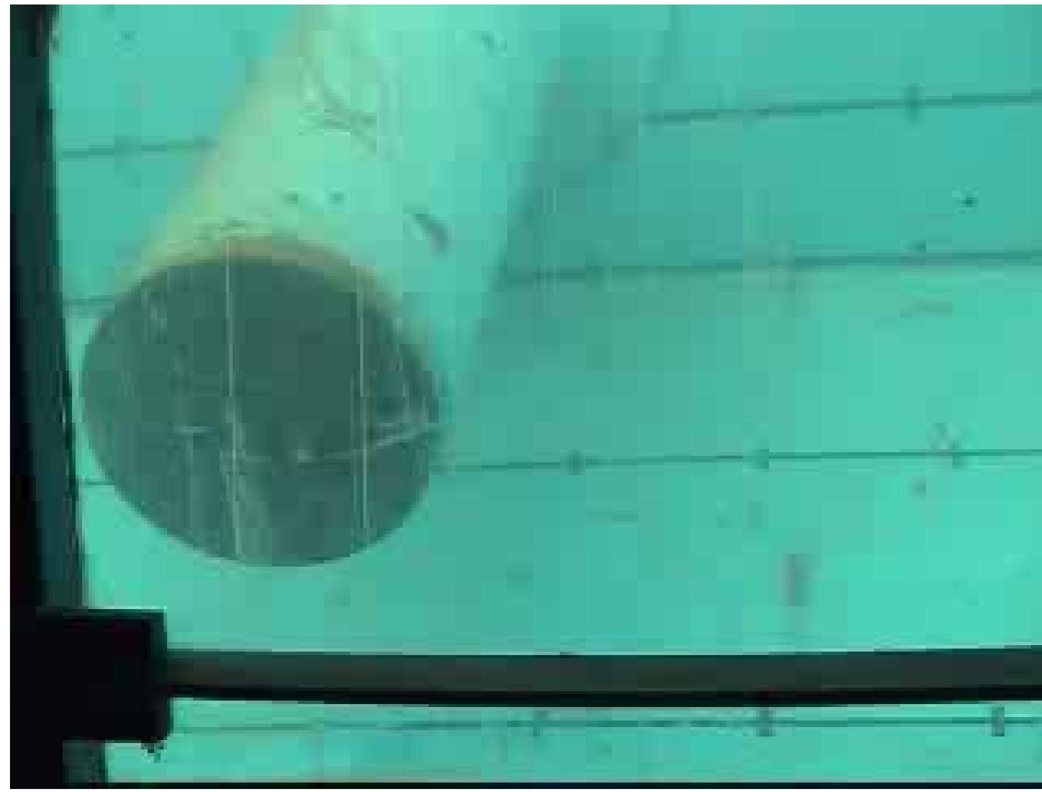


Diversion Pipe Location

What conditions are most likely to entrain native fishes? Can we limit entrainment?

Experimental Measurements

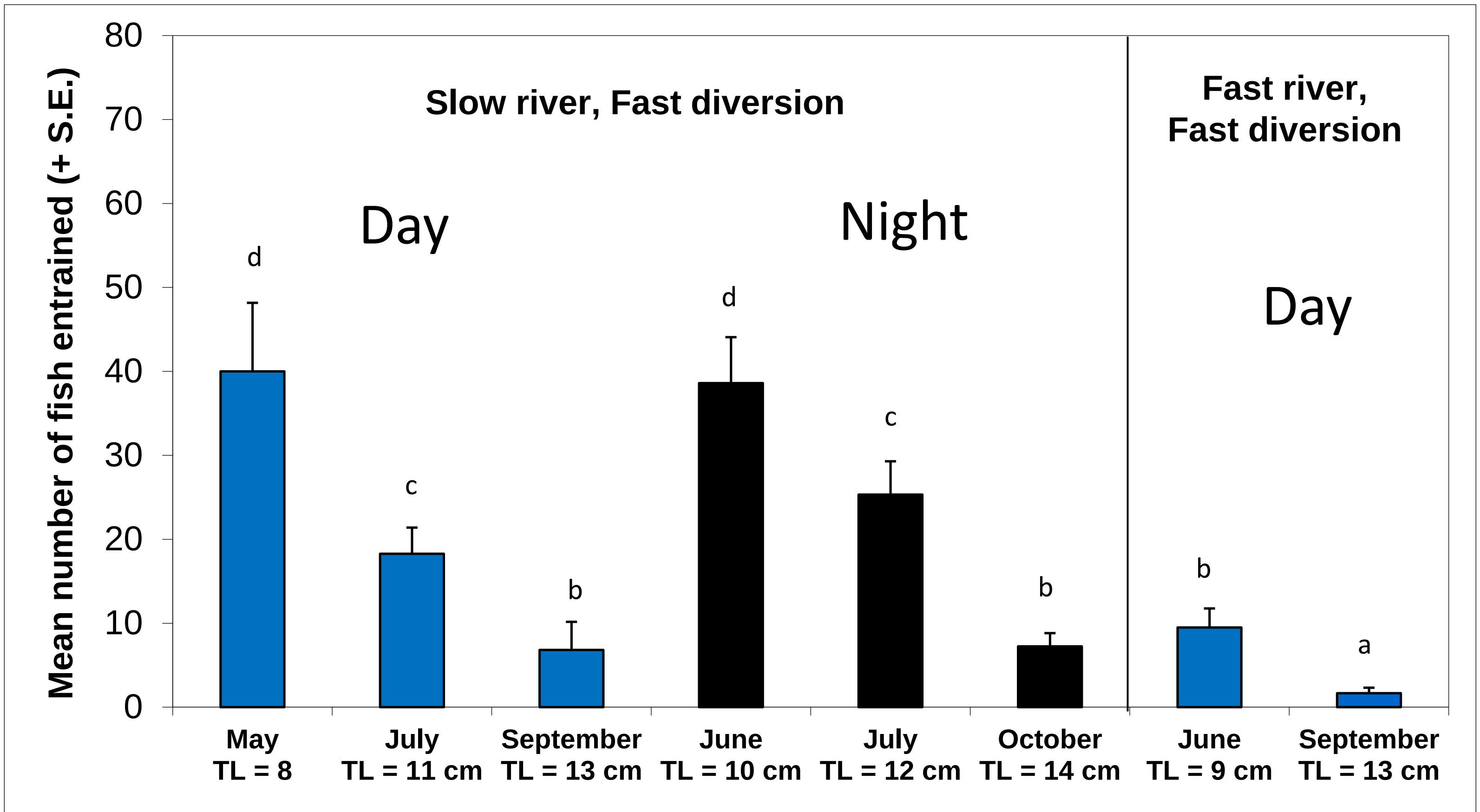
- Number of fish entrained
  - Flow regimes
  - Day, night, turbid
  - Deterrents
- Entrainment starting locations
- Fish orientation when passing or entraining
- Fish pipe passage rates
- Critical entrainment velocities



- Co-PI's: Levent Kavvas (UC Davis Civil and Environmental Engineering), Joseph Cech
- Timothy Mussen & Dennis Cocherell

Entrainment

- Chinook entrainment decreased as fish aged, day and night
- Highest Chinook entrainment at slower river velocities (below) and high diversion pump rates (not shown)
- Green sturgeon: same patterns, but higher overall entrainment



(Mussen et al., 2012)

Green Sturgeon Entrainment

- Entrainment rates of outmigrating green sturgeon are higher than those of Chinook salmon

(Mussen et al., in review)

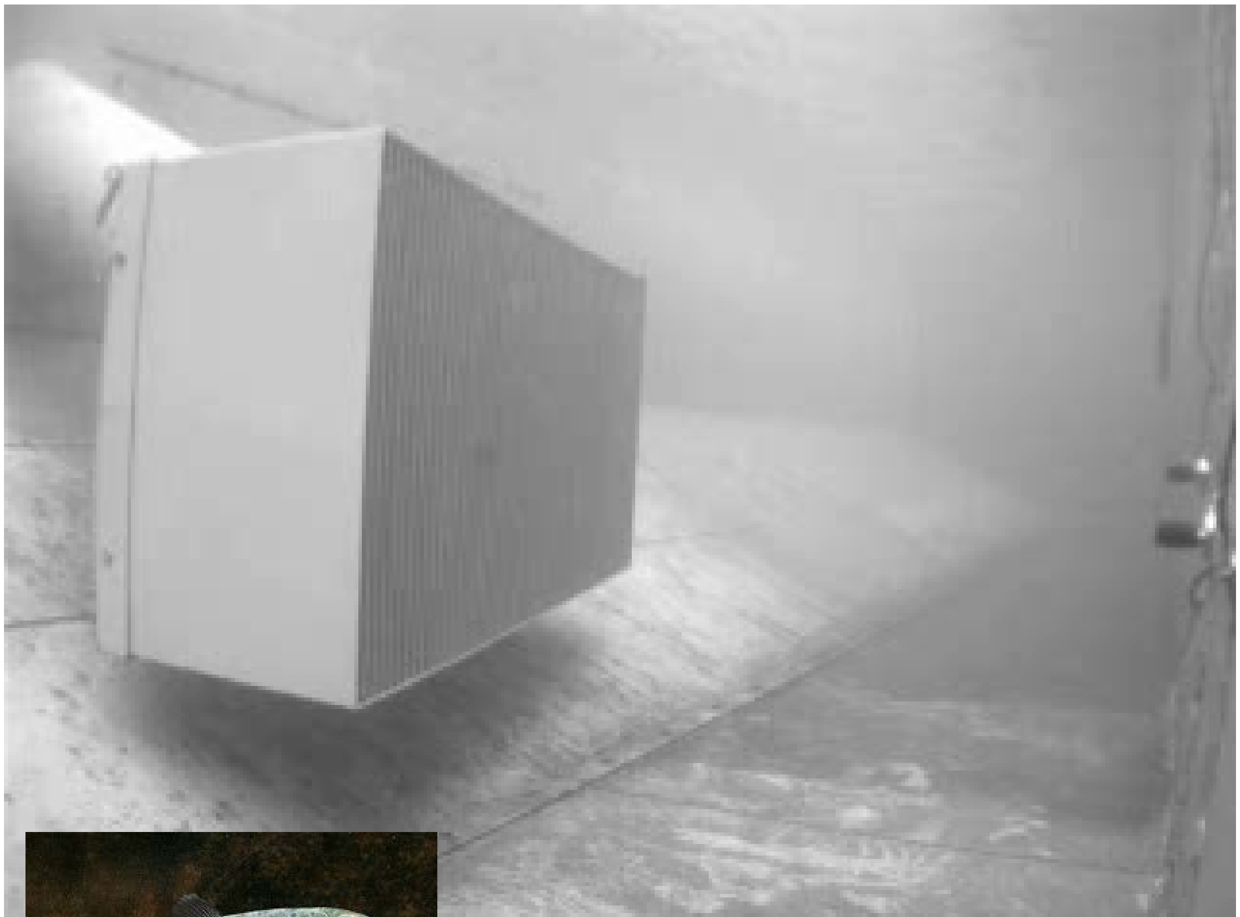
Mechanism of entrainment: passage rate

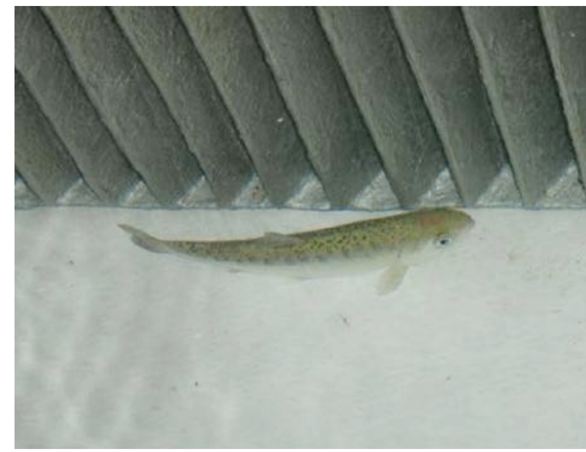
Slow river speeds increase passage rates (pipe encounters), and entrainment is proportional to encounter rate

(Mussen et al., in review)

Widened Inlet Box with Louver-Array

96% reduction in fish entrainment





Reduced velocity, improved visual cues

Linking physiological and behavioral ecology with water policy

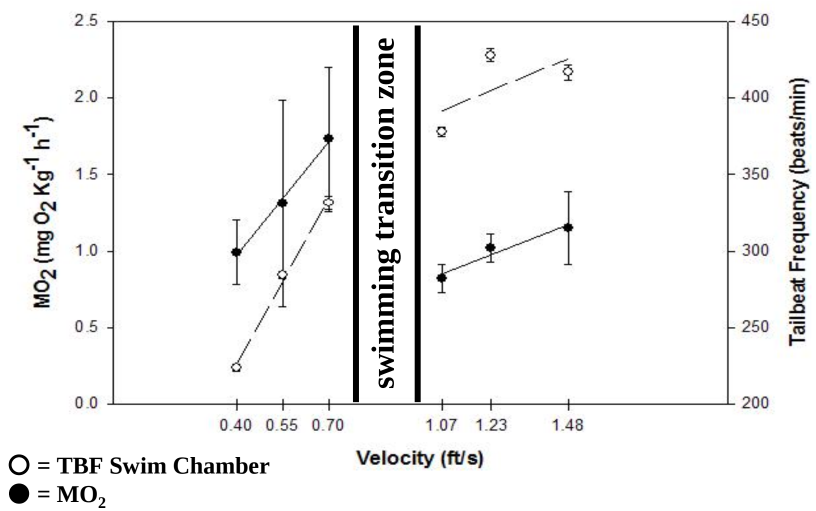
Entrainment-related mortality may be high for endangered fishes in SFBD

Management Recommendations:

- Pump from fast-flowing areas, and later in the season when fish are older
- Prioritize screening for diversions operating under high entrainment conditions
- Pipe modifications may decrease entrainment risk without reducing water diversion rate

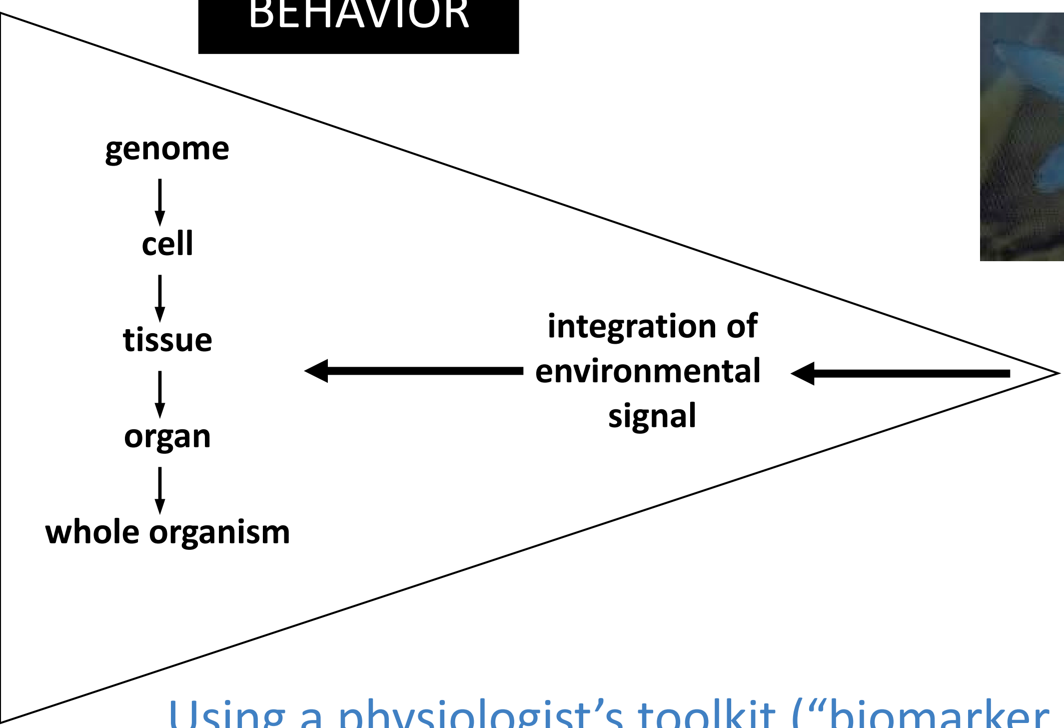
Linking laboratory experiments to "The Field"

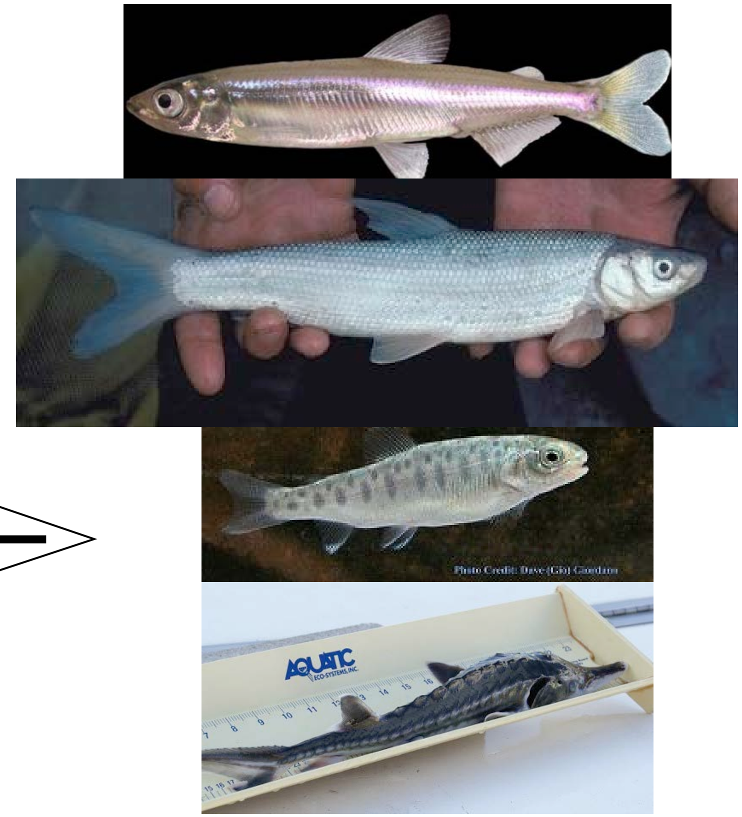
- Lab: Isolation & control, mechanism, predictions
- Molecular & biochemical signatures Ex: non-lethal gill biopsies
- Entrainment Ex: management recommendations & conditions for focused field testing
- Swimming metabolism an TBF & hydraulic cover use paired with field observations, telemetry, &restoration



Native Fish Conservation: linking mechanisms to outcomes

PHYSIOLOGY
&
BEHAVIOR





Using a physiologist's toolkit ("biomarker discovery") to address a problem of immediate conservation concern.

Multiple stressors, timescales, levels of biological organization, ecological context

Thank You!!

- Fangue lab
- Key Collaborators:
  - Richard Connon
  - Joseph J. Cech, Jr.

NSF

ECOSYSTEM RESTORATION PROGRAM

California Department of Fish & Wildlife
National Oceanic & Atmospheric Administration
US Fish & Wildlife Service

USBR • USFWS • SWRCB • DFG • USGS • NMFS • USACE • USEPA • DWR

U.S. FISH & WILDLIFE SERVICE

AFSP Program

Delta Stewardship Council

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

RECLAMATION

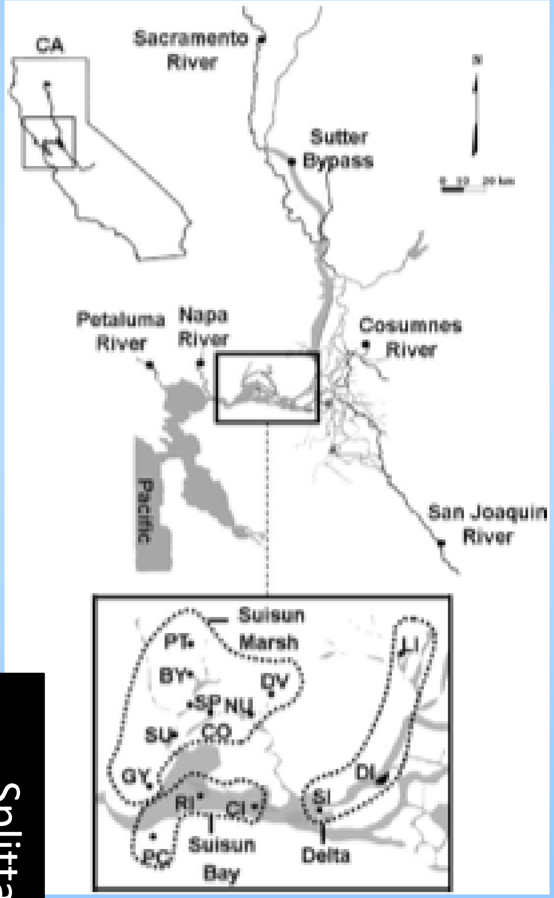
Managing Water in the West

Intraspecific variation in Splittail (SPT) Populations

Genetically distinct SPT populations:

1. Petaluma/Napa (0-13 ppt)
2. Central Valley (0 ppt)

Correlation between population structure and environmental features unclear



Baerwald et al., 2011

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(USBR), and Te

Research Questions

Are environmental factors (e.g., temperature, salinity) critical in determining SPT foraging/spawning site preferences?

Do genetic differences between Petaluma/Napa and Central Valley SPT populations translate to differences in physiological adaptation?

Approach: physiological tolerances, lab crosses, molecular mechanisms (transcriptome seq in development), and behavioral preference