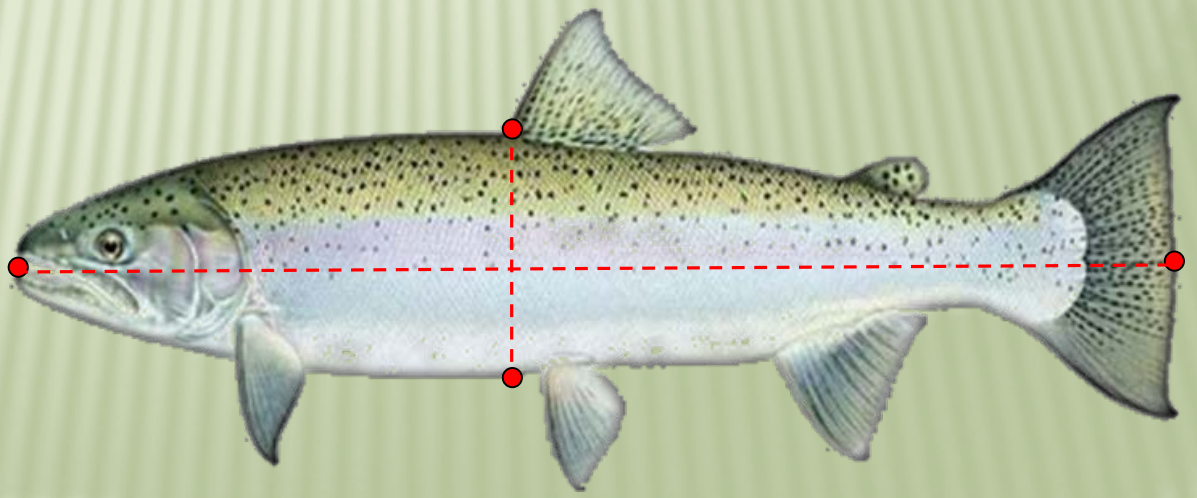
Morphometric Variation Among Four Distinct Population Segments of California Steelhead Trout

Authors:

Farhat S. Bajjaliya, Robert G. Titus, Joe R. Ferreira, and Ronald M. Coleman

Background

- Morphology
  - Quantitative description, analysis, and interpretation of shape and shape variation
- Describe and compare body shape within and among populations
- Can vary
  - Geographic origin
  - Sexual dimorphism
  - Artificial propagation
- Heritable



Natal Homing

- Minimizes genetic interchange
- Maintains heritable adaptations to local environment
- Encourages differentiation between isolated populations
  - Including body morphology

Difficulty and Distance of Migration

- Previous observations
  - Shorter migration – larger, deeper bodies
  - Longer migration – smaller, narrower bodies
- Steelhead morphometric variation undocumented
  - Coastal adult steelhead would be larger
  - Inland adult steelhead would be smaller

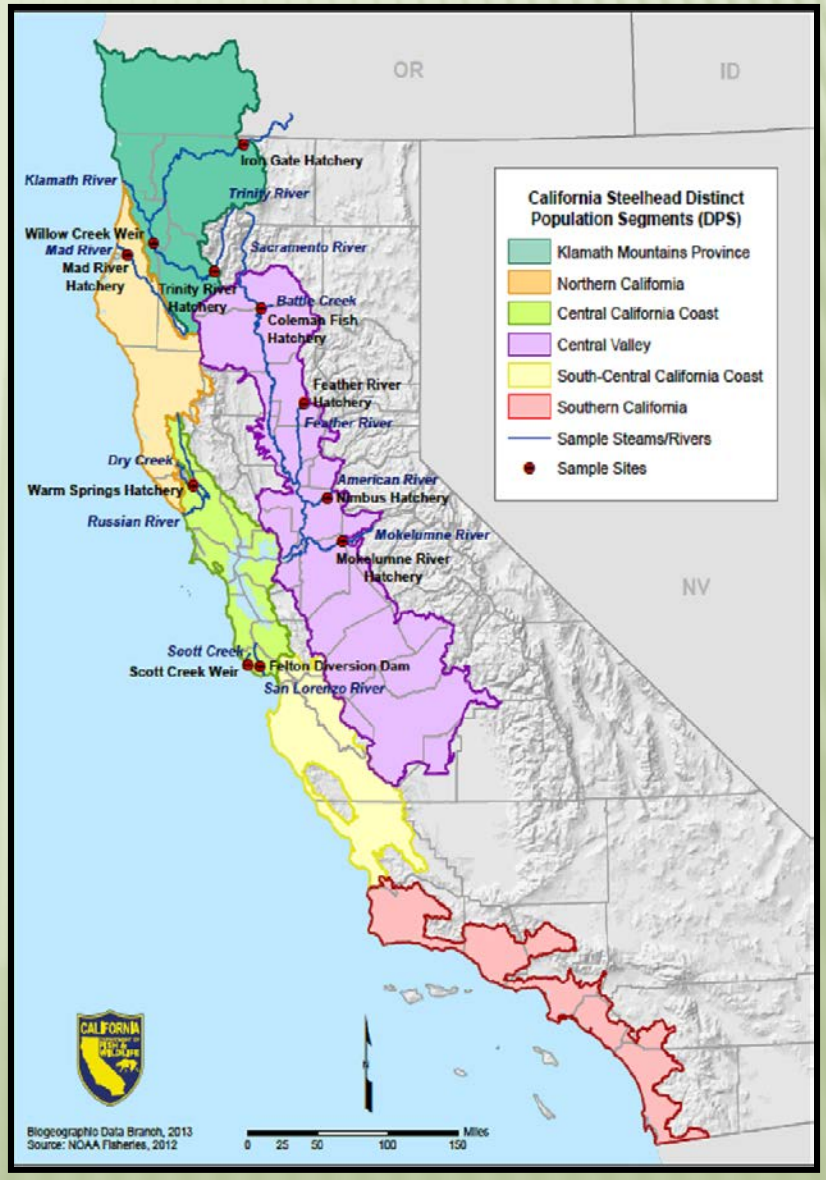
Steelhead Require Adequate Flows

- Steelhead are dependent on adequate instream flow
  - Migration
  - Spawning
  - Juvenile rearing
- Historical hydrological regimes
  - Timing and abundance of returning adults
  - Morphology
- Reoccurring low instream flow
  - Impeding largest individuals
  - Directional selection over time
  - Decrease segregation between origins

Photo Credit: The Bay Institute

Distinct Population Segments

- Widespread, but in decline
- NMFS – 6 CA DPSs
  - Evolutionary sig. unit
  - Reproductively isolated
  - Contribute to evo. legacy of spp.
- Undocumented among DPSs
- May contribute to species management and recovery



Artificial Propagation

- Conservation, mitigation, and sport fishing enhancement
- Broodstock typically established within basin
- Some through inter-basin transfers
- Nimbus Hatchery, Lower American River

Nimbus Hatchery

- Mitigation for Folsom Dam Project
- Amalgamation of many stocks
- Clusters with winter-run Eel River stock
- Nimbus vs CV DPS

Study Objective

To compare adult steelhead morphometrics between four Distinct Population Segments

Three key factors

- DPS
- Sex (male, female)
- Origin (natural, hatchery)

Morphometric response variables

- Fork length (mm)
- Weight (Kg)
- Body depth (mm)


Photo Credit: Gena Lasko

Hypotheses

1. Distinct Population Segment
   H1: Significant difference in morphometric response variables among DPSs

2. Sex
   H1: Significant difference in morphometric response variables between sex

3. Origin
   H1: Significant difference in morphometric response variables between origin

4. Interactions
   H1: Significant interactions between the factors, with regards to the mean of each morphometric response variable

Sampling

- 11 sampling locations, 4 DPSs
- Hatcheries and weirs
- 2 field seasons
- Total: 4,973 adult steelhead

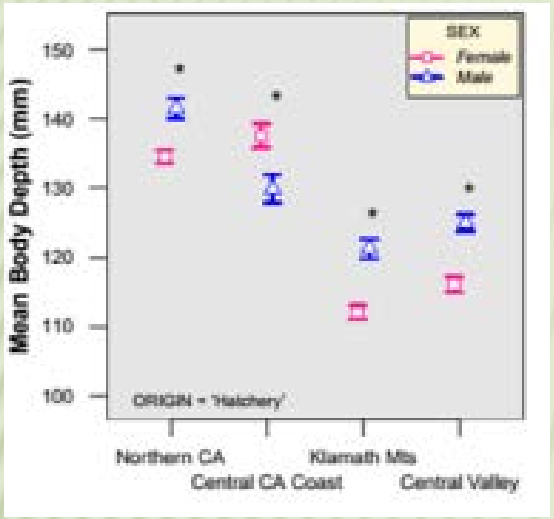
Statistical Analysis

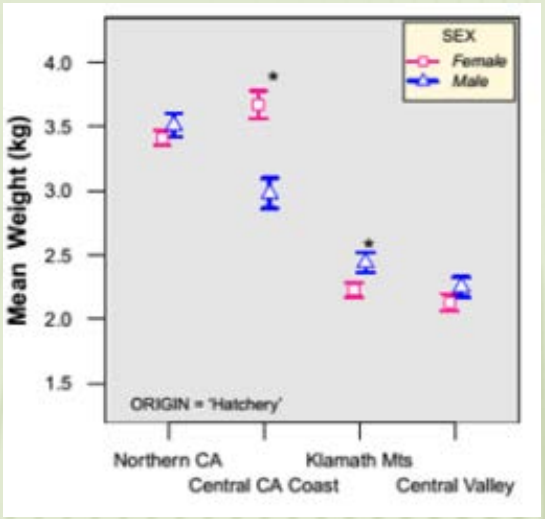
- Factorial Analysis of Variance
  - Main factor effects and factor interactions
- Tested assumptions
  - Normality and homogeneity of variances not always met
- Factorial ANOVA
  - Robust
  - Adequately address departures from assumptions when sample size is large
- Significant interactions between factor and response variables
- Pairwise t-tests to identify where significant differences exist

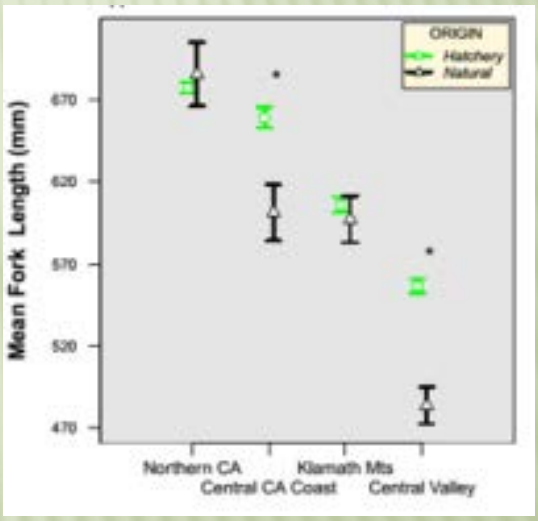
Nimbus Hatchery Analysis

- Series of One-Way ANOVAs
  - Compare Nimbus, Central Valley, and Northern DPSs
  - Null rejected - Means of response variables not equal among groups
  - Post-hoc t-tests used to determine where differences existed

Results and Discussion



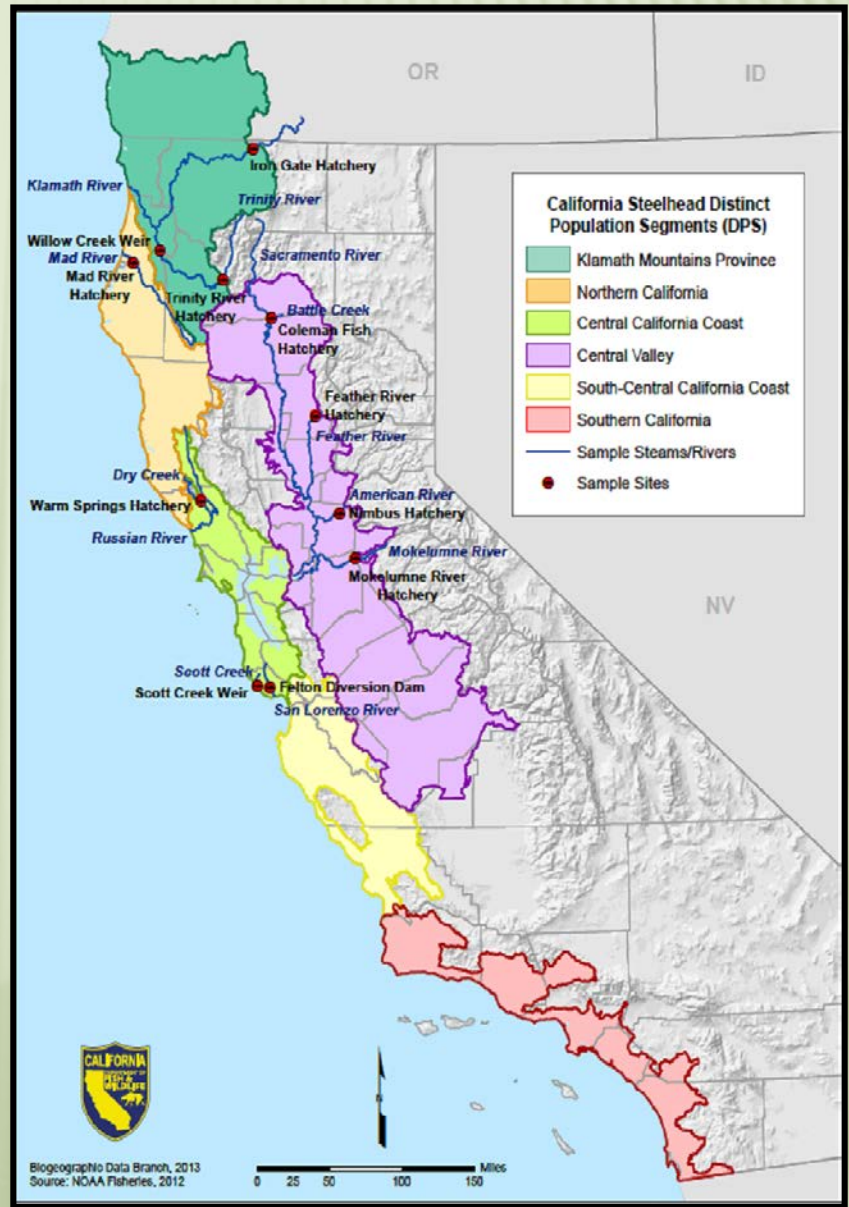




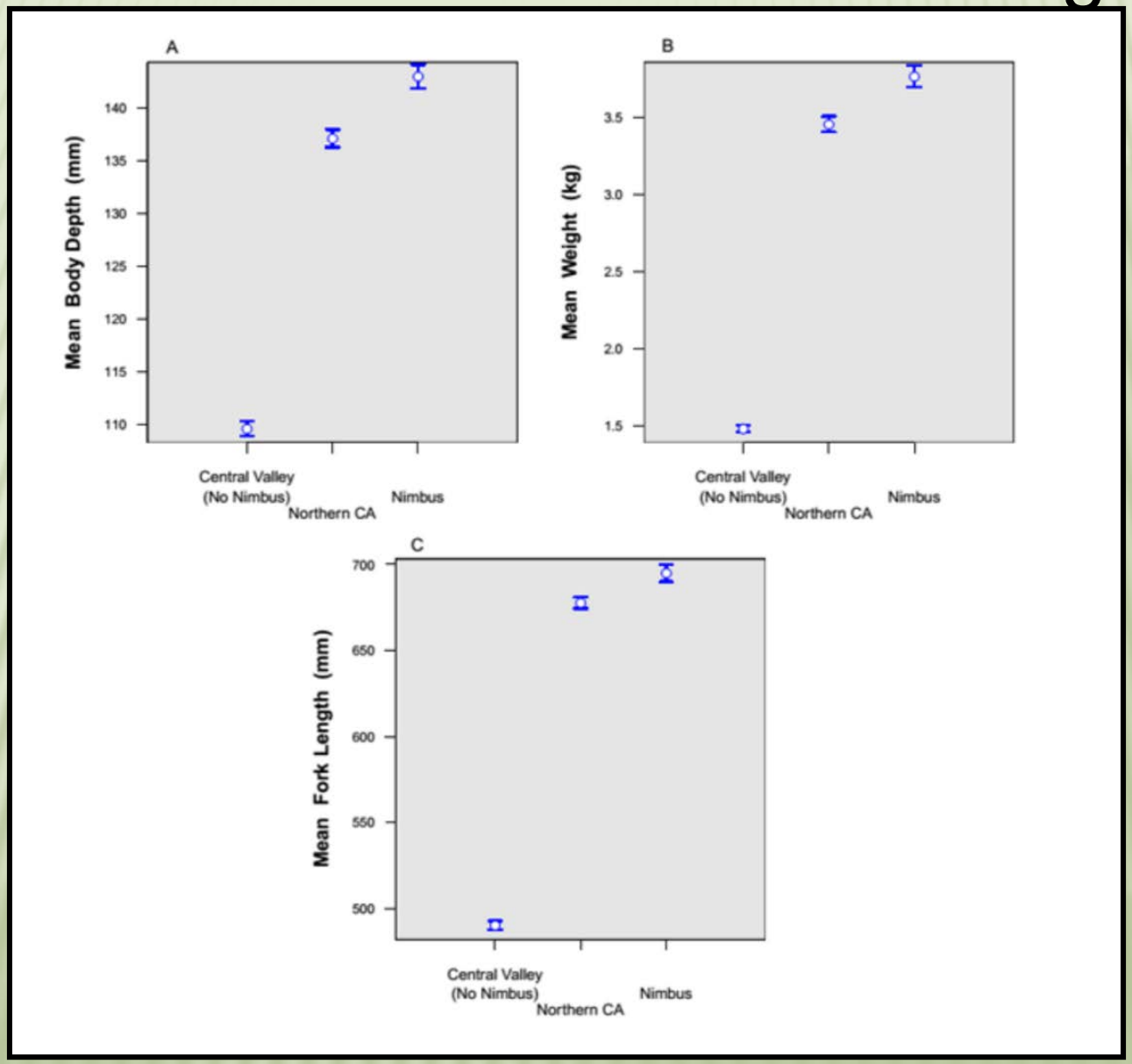
- Morphometric features can be used to distinguish isolated populations
- Largest adult steelhead – NC, CCC, KMP, and CV
- Hatchery-origin adult steelhead longer on average than natural-origin
- Significant trends between coastal and inland groups
- Coastal – Larger across all response variables

Coastal vs Inland

- 10-fold mean difference
  - Coastal < 160km
  - Inland> 160km
  - 160km ~ mid point
- Migration Distance
  - Shortest:1km to Scott Creek
  - Longest: 529km to Coleman Hatchery
- Coastal DPSs:
  - Northern CA
  - Central CA Coast
- Inland DPSs:
  - Klamath Mountains Province
  - Central Valley



Nimbus Steelhead are the Largest



Nimbus: A Successful Anomaly

- Largest Fish Sampled:
  - Artificial selection?
- Eel River Winter-Run Stock
  - Continues to perform where others failed
  - Rapid growth
  - Early emigration
  - Highly anadromous
- Possible explanations:
  - Adapted well to engineered/altered environment
  - Preadapted from Eel work well in Lower American

Photo Credit: westernrivers.org

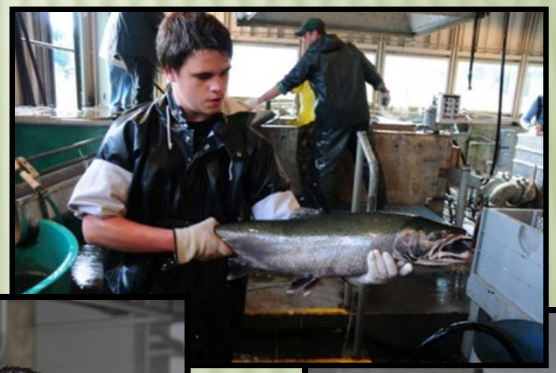
Morphometrics and Instream Flow Prescriptions

- Body morphology differs within and among DPSs
  - Coastal and inland populations
  - Nimbus vs Central Valley DPS
- Specific criteria for DPS and/or stream may be appropriate
  - SWRCB state-wide standard based on Thompson method
  - Minimum flow standards may only protect average and smaller

Future Work

- Current study - broad brush assessment
- Assessment of morphometric variation within KMP
- South Central CA Coast and Southern CA DPSs
- Refine coastal vs inland types
  - Hydrology, water temp, elevation gain
- More inclusive of natural-origin steelhead

Thank You



Questions