Analysis and Model Evaluation of Long-Term Data Collected at the Willow Creek Outmigrant Trap

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Science Symposium
“Brownbag Sessions”

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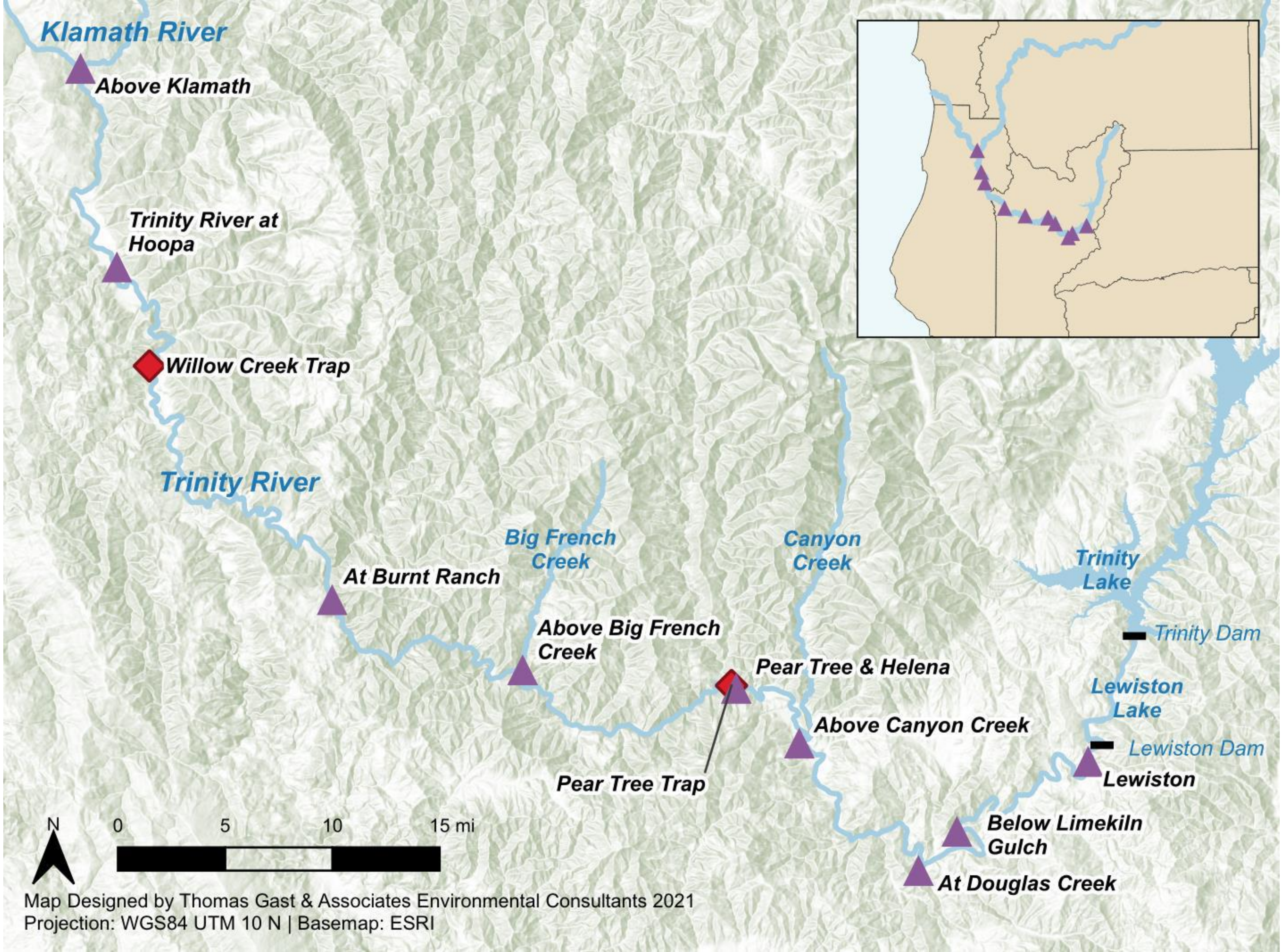
Photo: Max Ramos

Background

- Outmigrant traps first installed in the late 1980s
  - Operated annually since 1989
  - Used to assess population, outmigration timing and duration of salmonid species
- Several models developed to enumerate population estimates and passage
  - Flow-based → expands the count of fish caught in trap by proportion of river that was sampled
  - Mark-recapture → expands the count of fish caught in the trap by the recapture of a known amount of marked individuals
  - HDAT → relates smolt emigration timing with accumulated daily average water temperatures in Hoopa
- In 2016, YTFP published a request for assistance to further develop existing statistical analyses and statistical models to synthesize long-term Trinity River data sets
- In 2017, YTFP selected Thomas Gast & Associates Environmental Consultants to evaluate project objectives

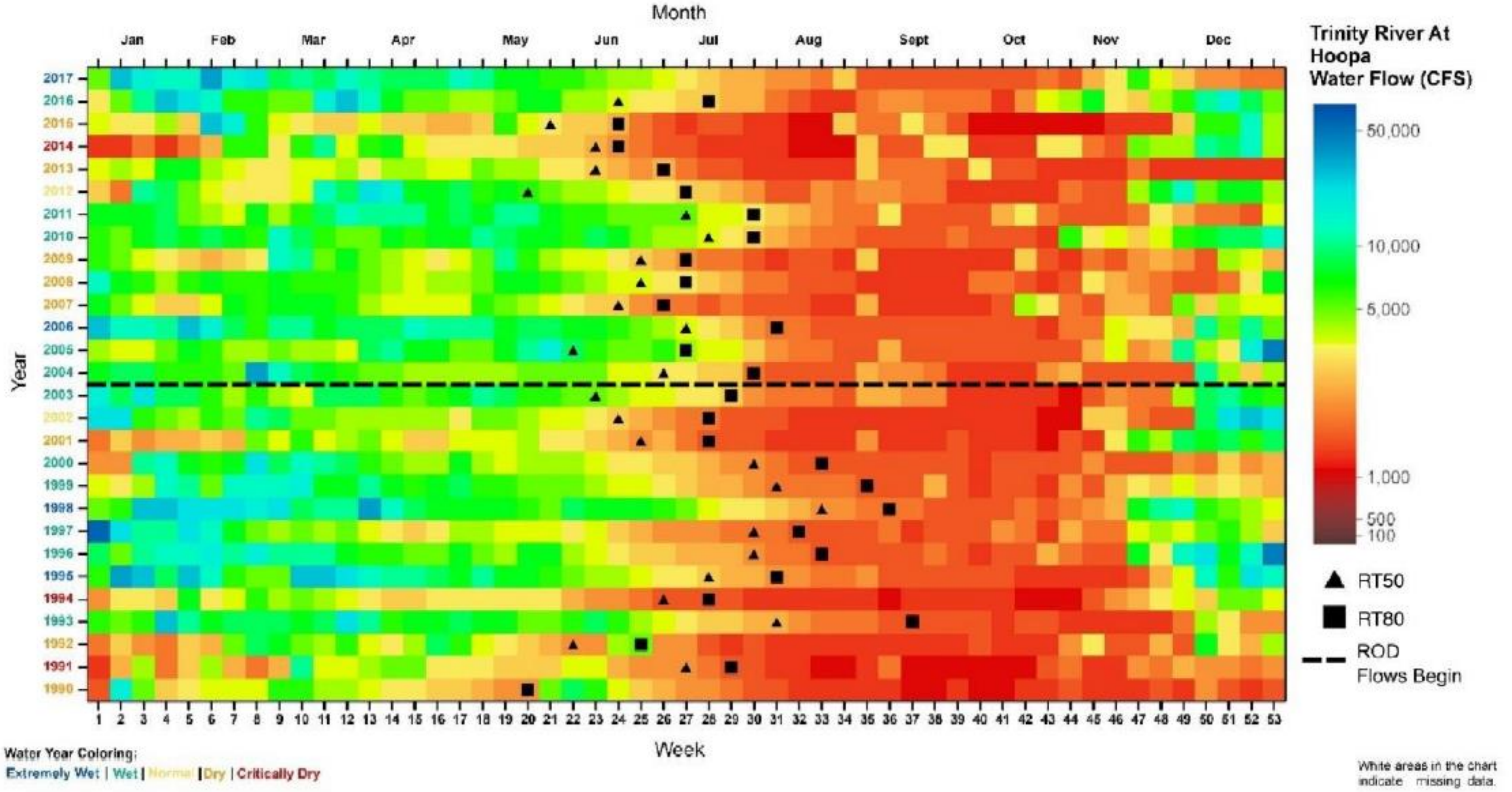


Klamath River
Above Klamath
Trinity River at Hoopa
Willow Creek Trap
Trinity River
At Burnt Ranch
Big French Creek
Above Big French Creek
Pear Tree & Helena
Pear Tree Trap
Canyon Creek
Above Canyon Creek
Trinity Lake
Trinity Dam
Lewiston Lake
Lewiston Dam
Lewiston
Below Limekiln Gulch
At Douglas Creek
N
0
5
10
15 mi
Map Designed by Thomas Gast & Associates Environmental Consultants 2021
Projection: WGS84 UTM 10 N | Basemap: ESRI

Objectives

- 1) Evaluate influence of water temperature on the outmigration timing of Trinity River Chinook Salmon
- 2) Evaluate flow-based and mark-recapture population estimates as predictors of RT50 and RT80
- 3) Quantify the predictive ability of the HDAT model proposed by Hayden and Heacock
- 4) Evaluate the historical differences between Chinook salmon outmigrant abundance/population on the Trinity River pre and post implementation of the Record of Decision (ROD) flows

Objective 1 → Evaluate influence of water temperature on the outmigration timing of Trinity River Chinook Salmon



Objective 1 (cont.)

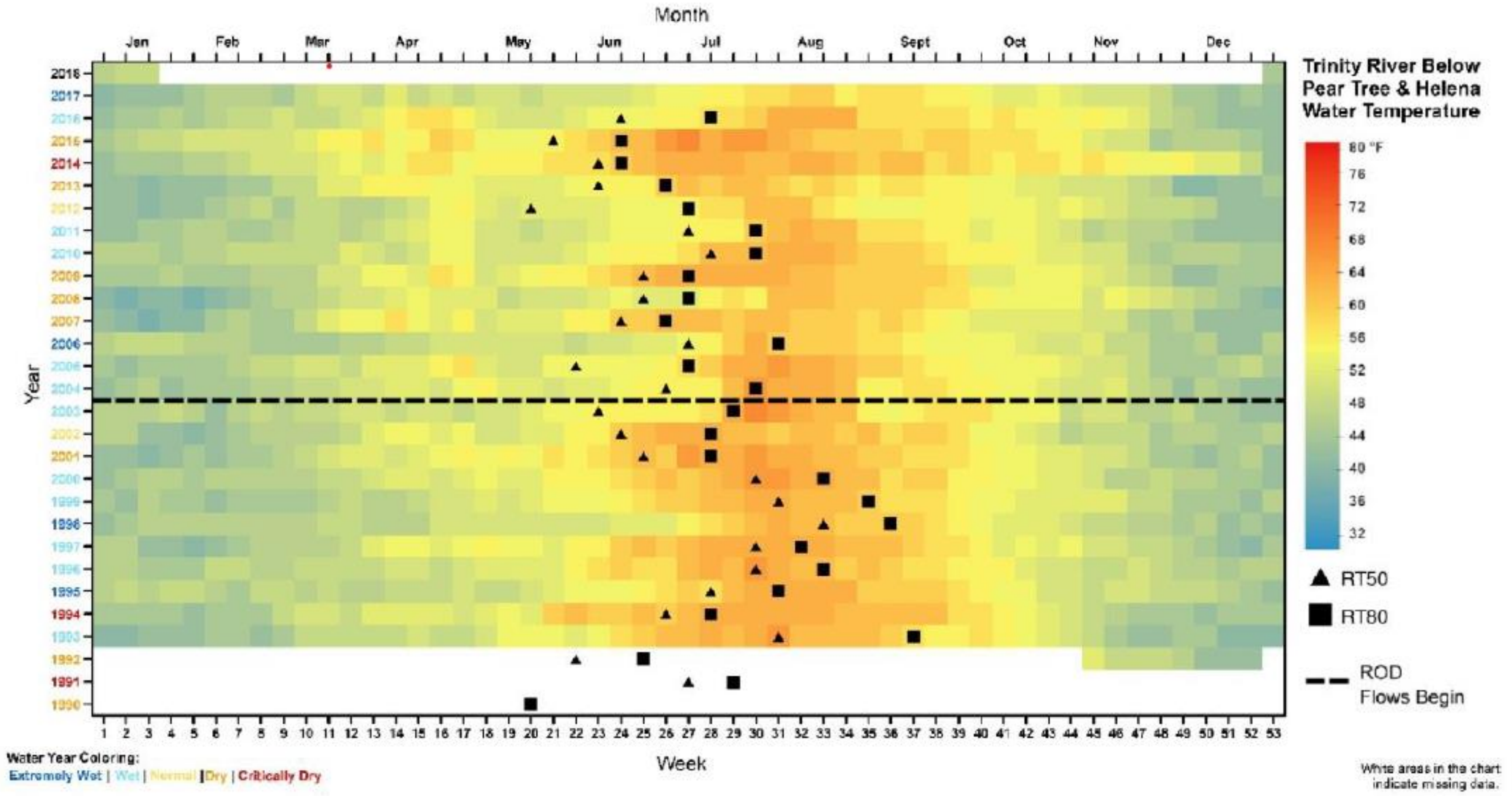


Figure 9. Water temperature at Helena/Pear Tree, 1992-2017. The years on the y-axis are formatted to show different colors for water year types.

Objective 1 (cont.)

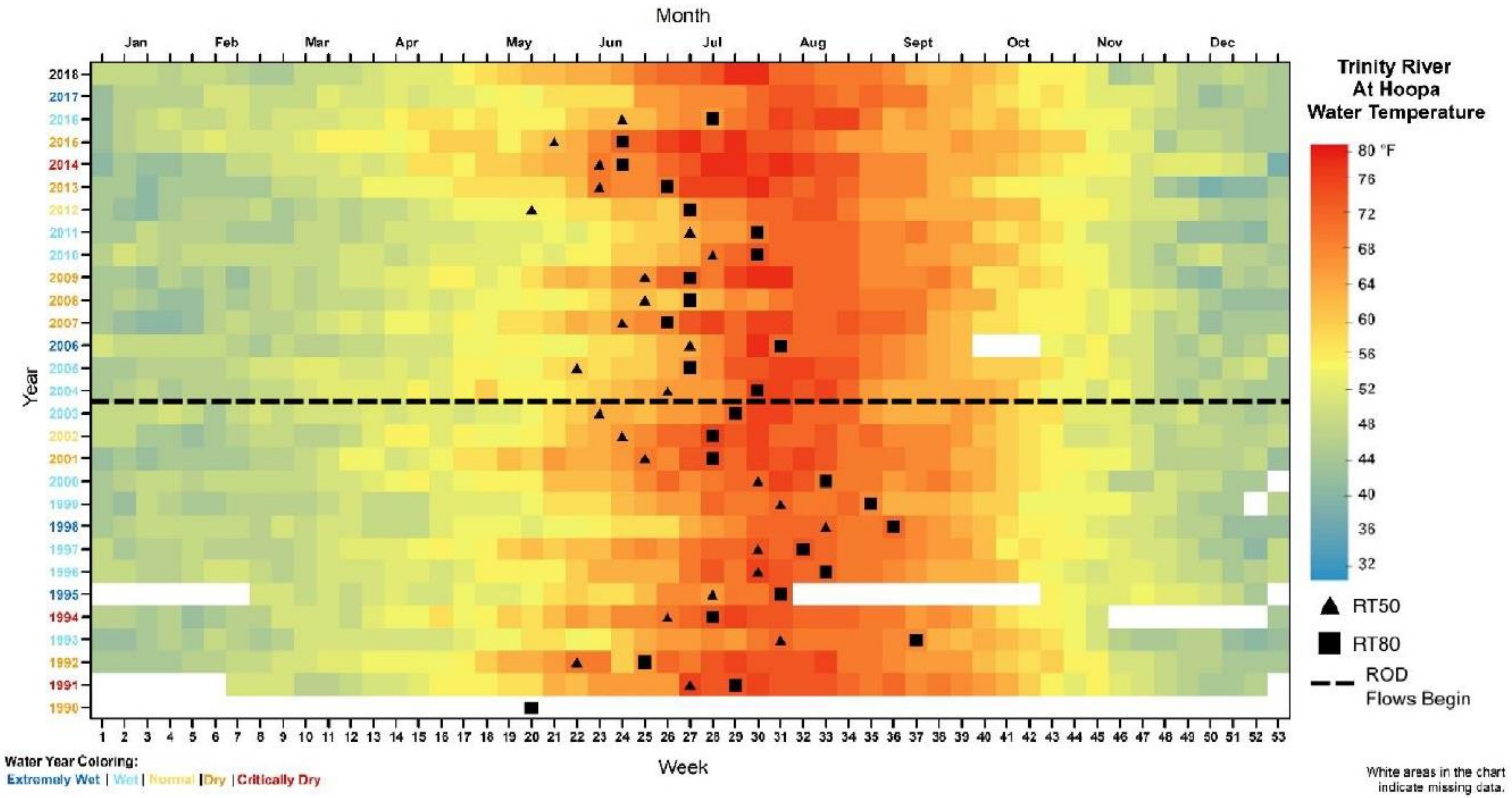


Figure 8. Water temperature at Hoopa, USGS Gage 11530000, 1999-2017. The years on the y-axis are formatted to show different colors for water year types. Eli Asarian filled gaps in the Hoopa temperature time series using single variable regressions based on adjacent temperature monitoring stations when available.

Objective 1 (cont.)

- Used Wisconsin Bioenergetics Model 4.0 to simulate daily growth and consumption of Chinook juveniles
- Consumption generally declined sharply in late April during the spring ROD flow releases
- Model developed to link consumption with discharge and density
  - Higher discharge Feb-April (+)
  - # of redds and discharge in May (-)

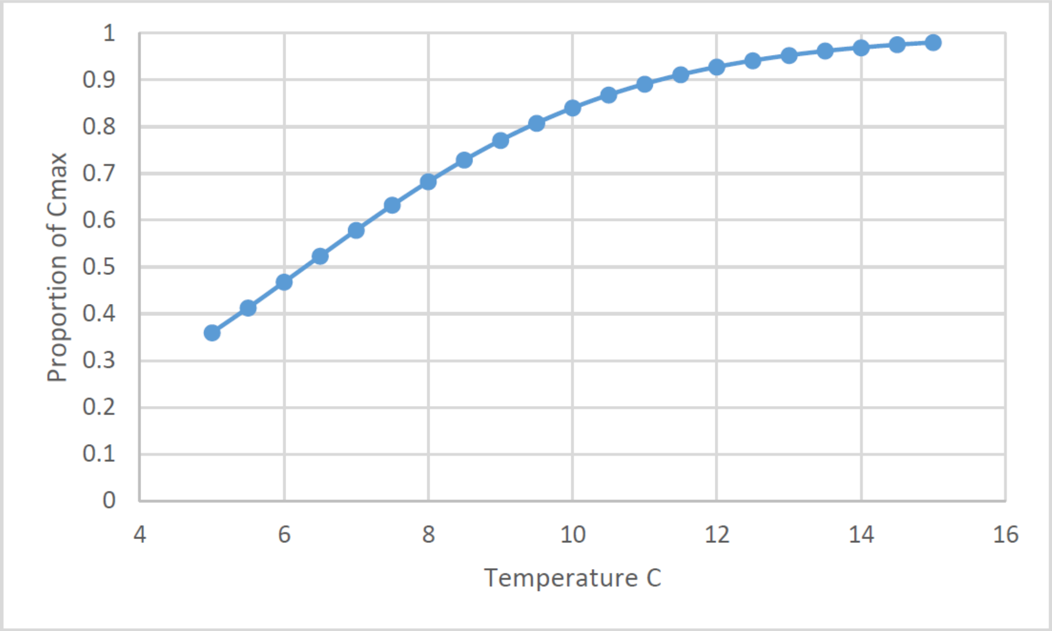


Figure 11. Temperature dependence function for Chinook for the normal range of temperature recorded at the Pear Tree/Helena station during the modeling period.

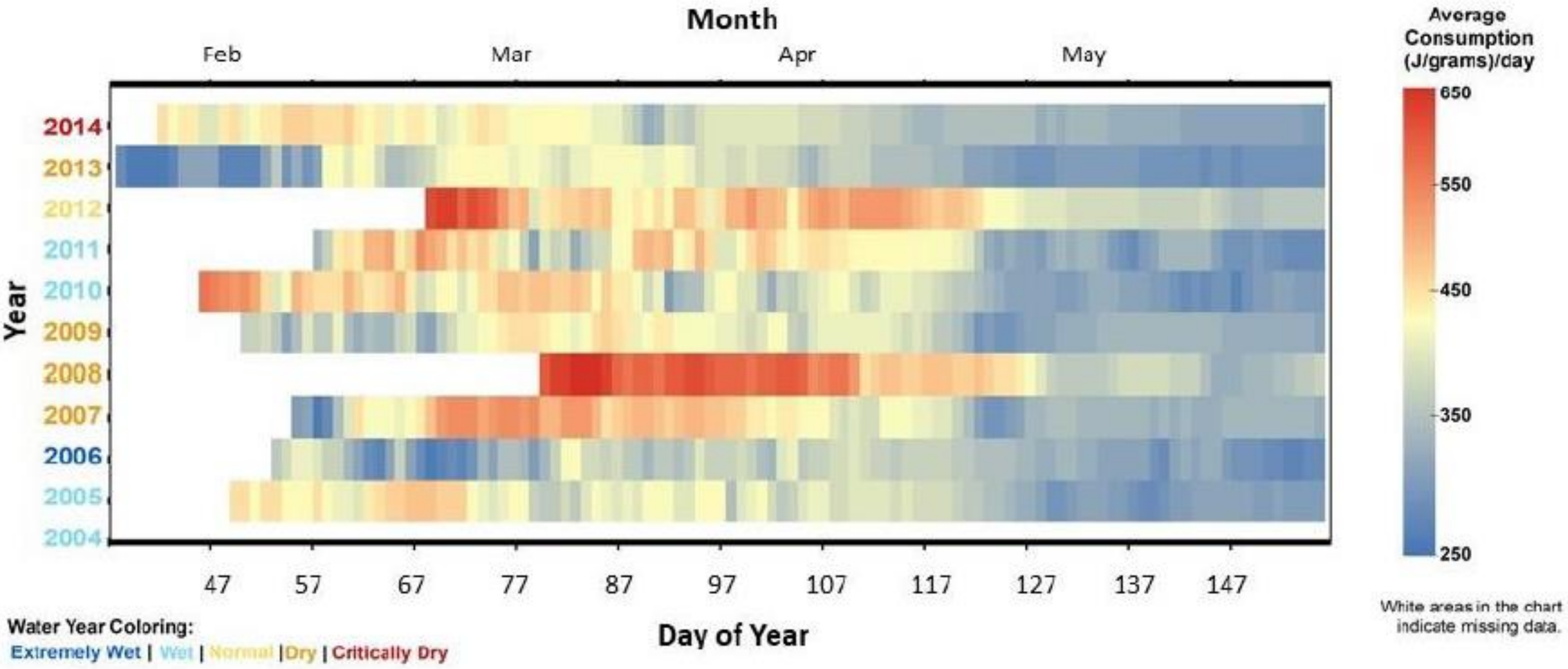


Figure 13. Inter-annual comparison of modelled average daily consumption (J/g/d) of juvenile > 55mm from median date of fry emergence until June 4th from 2005 to 2014. 2015 and 2016 are not depicted because the emergence date was not known (it was estimated as February 1 for Figures 12, 14, 16, and 17).

Objective 2 → Evaluate flow-based and mark-recapture population estimates as predictors of RT80 and RT50

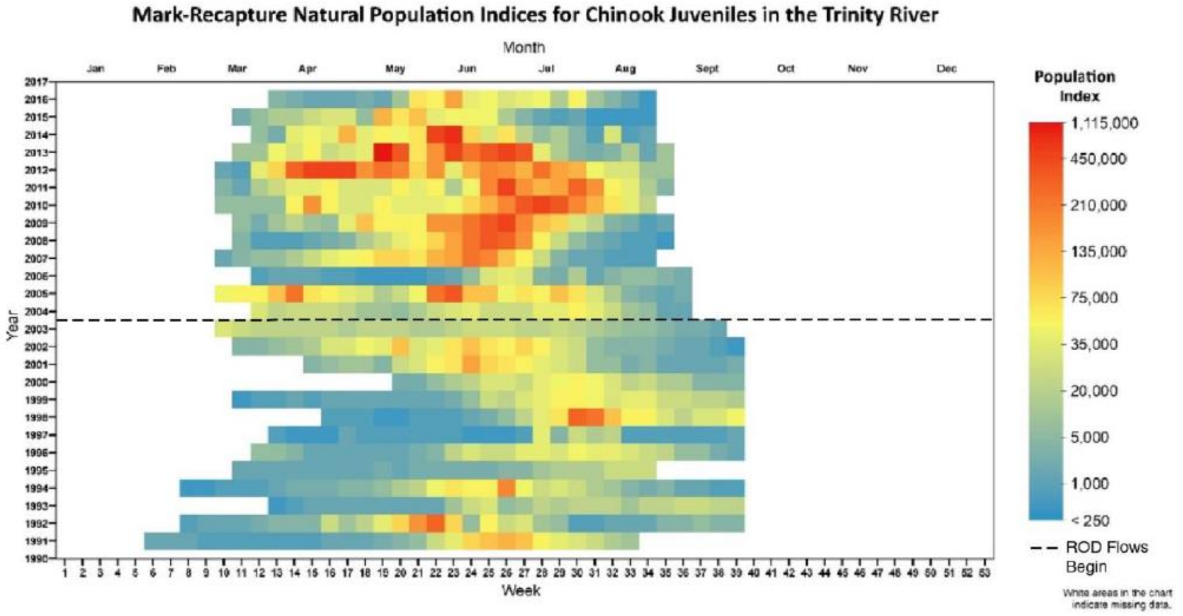


Figure 25, Mark recapture population estimates for the Willow Creek Trap.

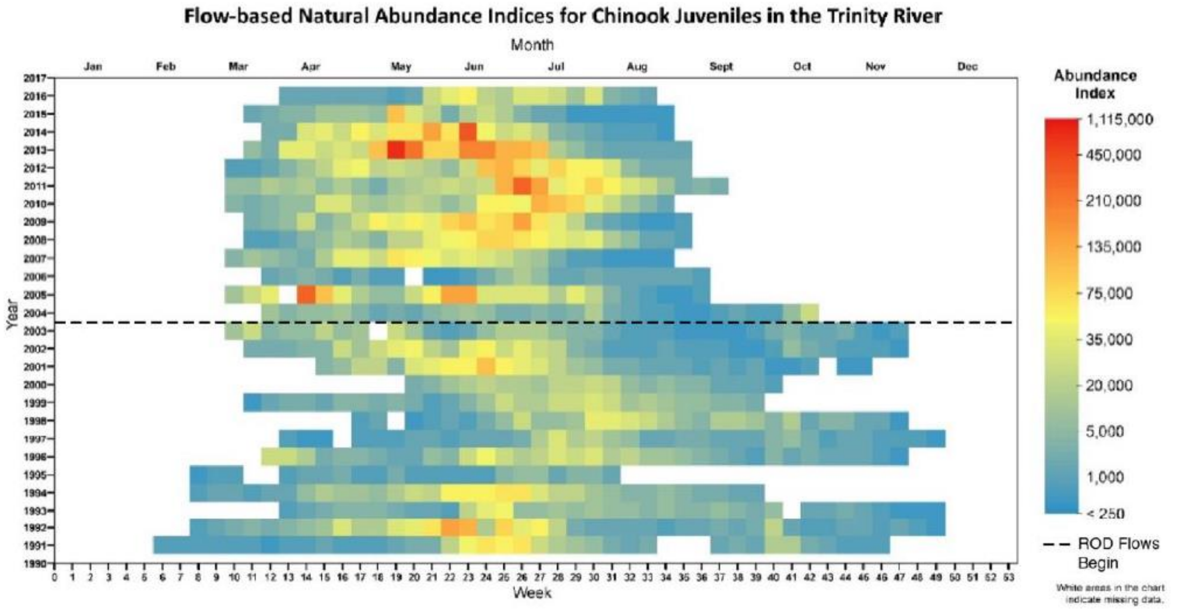


Figure 26. Flow-based abundance estimates for the Willow Creek Trap.

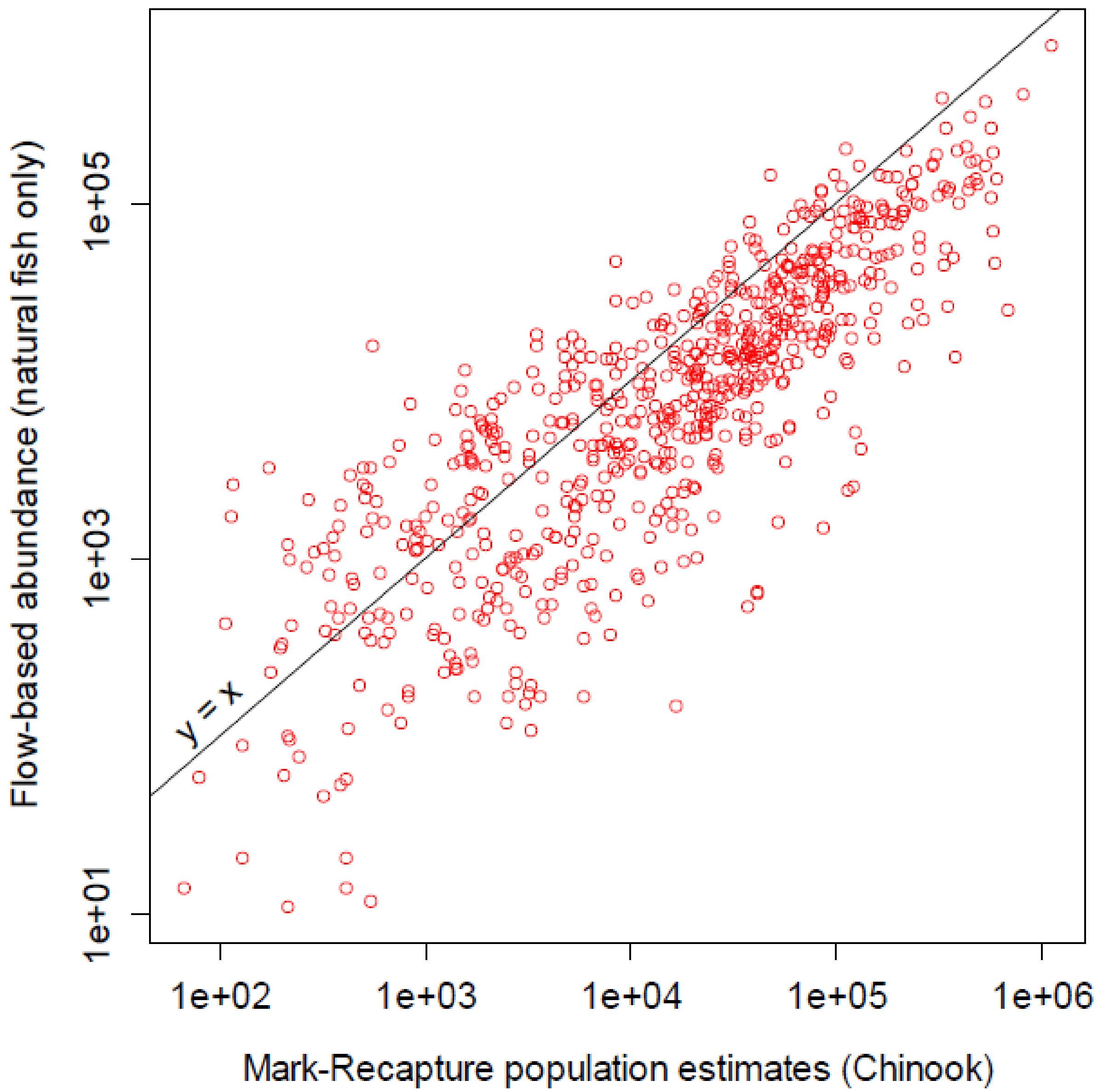


Figure 27. The Flow-based abundance estimates are plotted against the mark-recapture estimates for natural Chinook juveniles. Equal estimates would lie on the y=x line. Most of the mark-recapture estimates are higher than the flow-based estimates.

Objective 2 (cont.)

- Mark-recapture consistently has higher estimates compared to flow-based
- Both methods rely on sets of assumptions
- Which is better?
- Acoustic tracking or three-dimensional tracking could help address assumptions

Objective 3 → Quantify the predictive ability of the HDAT model

- 2013 → Hayden and Heacock develop HDAT model
  - Linear regression used to estimate outmigration timing based on water temperatures
- HDAT model had large discrepancies when applied to longer time series
- Better fit for flow-based estimates than mark-recapture

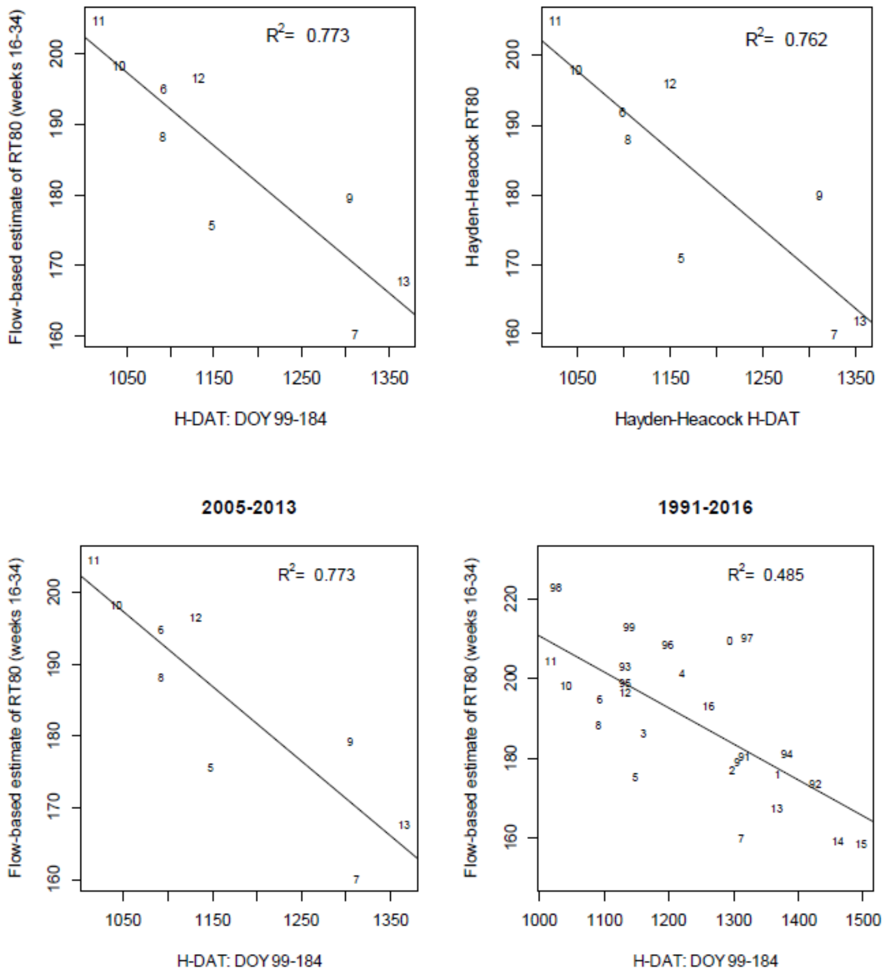


Figure 30. Comparisons of the regressions of the flow-based abundance estimates and accumulated thermal units.

Objective 3 (cont.)

- Explored several new models
  - PDAT
  - Temperature thresholds
  - ATU thresholds
- Models fit flow-based estimates better than mark-recapture

Table 2. Coefficient of determination (R2) for simple regression models for RT50 and RT80.

Location	Predictor	RT window (weeks)	F-B RT50	F-B RT80	M-R RT50	M-R RT80
Hoopa	HDAT to DOY 184	16-34		0.540		0.496
Hoopa	HDAT to DOY 184	15-34		0.514		0.476
Hoopa	HDAT to DOY 184	14-34		0.462		0.454
Hoopa	HDAT to DOY 184	13-34		0.463		0.447
Hoopa	HDAT to min RTxx	16-34		0.480		0.511
Hoopa	HDAT to mean RTxx	16-34		0.546		0.489
Hoopa	HDAT to max RTxx	16-34	0.469	0.556		0.468
Hoopa	Temp thresh 59F	16-34	0.391	0.319		
Hoopa	Temp thresh 67F	16-34		0.462		
Hoopa	Temp thresh 55F	16-34	0.479			
Hoopa	ATU thresh (160,1500)	16-34	0.516	0.601		
Hoopa	ATU thresh (110, 800)	16-34			0.318	0.490
Pear Tree	PDAT to DOY 184	16-34	0.392	0.512	0.260	0.454
Pear Tree	PDAT to min RTxx	16-34	0.418	0.535		
Pear Tree	PDAT to mean RTxx	16-34	0.415	0.448	0.297	0.400
Pear Tree	PDAT to max RTxx	16-34	0.314	0.398		
Pear Tree	Temp thresh 59F	16-34	0.261	0.278		
Pear Tree	Temp thresh 53F	16-34	0.559	0.598		
Pear Tree	Temp thresh 50F	16-34	0.623	0.615		
Pear Tree	ATU thresh (61,500)	16-34	0.711	0.738		
Pear Tree	ATU thresh (60,500)	16-34	0.721	0.735		

Objective 3 (cont.)

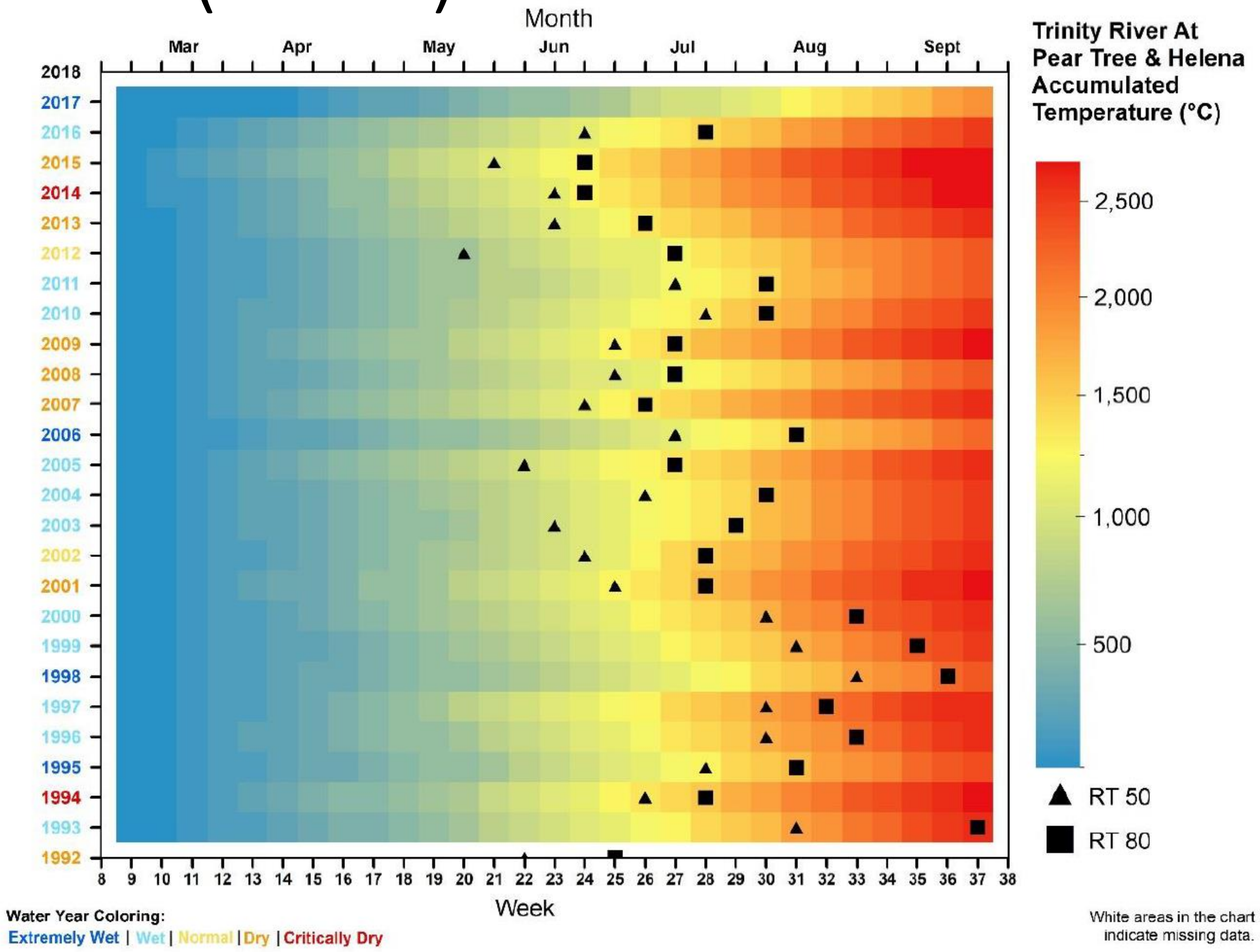


Figure 33. Accumulated Temperature Units at Pear Tree starting week 9 with mark recapture RT50 and RT80 dates.

Objective 3 (cont.)

- Also explored multiple regression models
  - Temperature
  - Redd counts
  - Median emergence date
- One model stood out using 3 variables
  - Lowest AIC and highest R^2
  - Only based off 12 years of record
  - Re-examine after more data points

$$RT80 = 4.851\, D_{60,500} + 0.0041\, E - 0.0040\, R - 391.3, \quad adjusted\ R^2 = 0.798 \ (n = 12)$$

Where:

$D_{60,500}$ = DOY accumulated temperature starting on DOY 60 reaches 500 (Pear Tree temperature).

E = Emergence date

R = Redd count

Objective 4 → Evaluate the historical differences between Chinook salmon outmigrant abundance/population pre and post ROD

- Differences between pre-ROD and post-ROD were tested using non-parametric methods
- Mark-recapture and flow-based highly significant ($p < 0.01$)
  - Number of post-ROD juveniles more abundant
- Other GLM also highly significant
- Explored relationship between redd counts and outmigrants
  - No significant relationships and low R^2

Table 3. p-values for tests of outmigration abundance before and after ROD.

	Flow-based abundance	Mark-recapture abundance
Mann-Whitney	0.0256	0.0029
Permutation test	0.0112	0.0006
GLM: change in mean	0.0016	0.0000
GLM: change in slope	0.1724	0.883
GLM: continuous trend	0.2144	0.671
GLM: change in mean, 2015-16 omitted	0.0001	0.0000
GLM: change in slope, 2015-16 omitted	0.0101	0.2022
GLM: continuous trend, 2015-2016 omitted	0.0081	0.0416

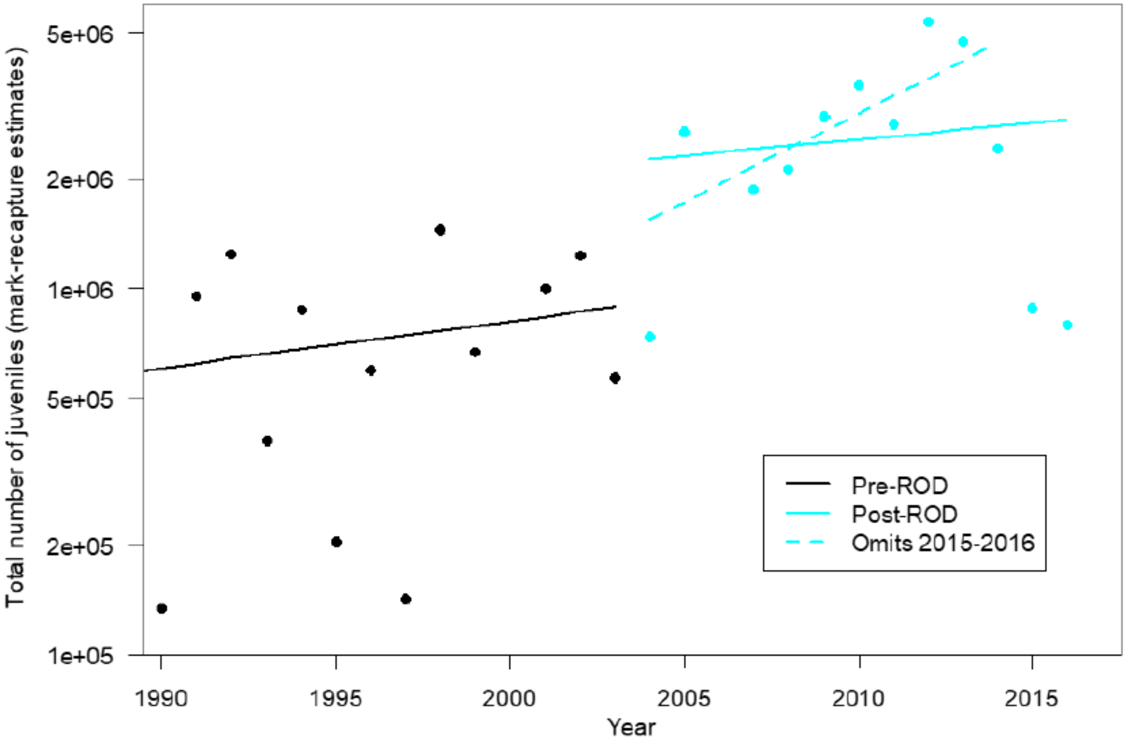


Figure 34. Annual total number of juveniles as computed by mark-recapture techniques from 1991 to 2016 (data from 2000 and 2006 were not included). Lines were fit to data before (black) and after (cyan) 2004; dotted cyan line was fitted without the 2015 and 2016 estimates.

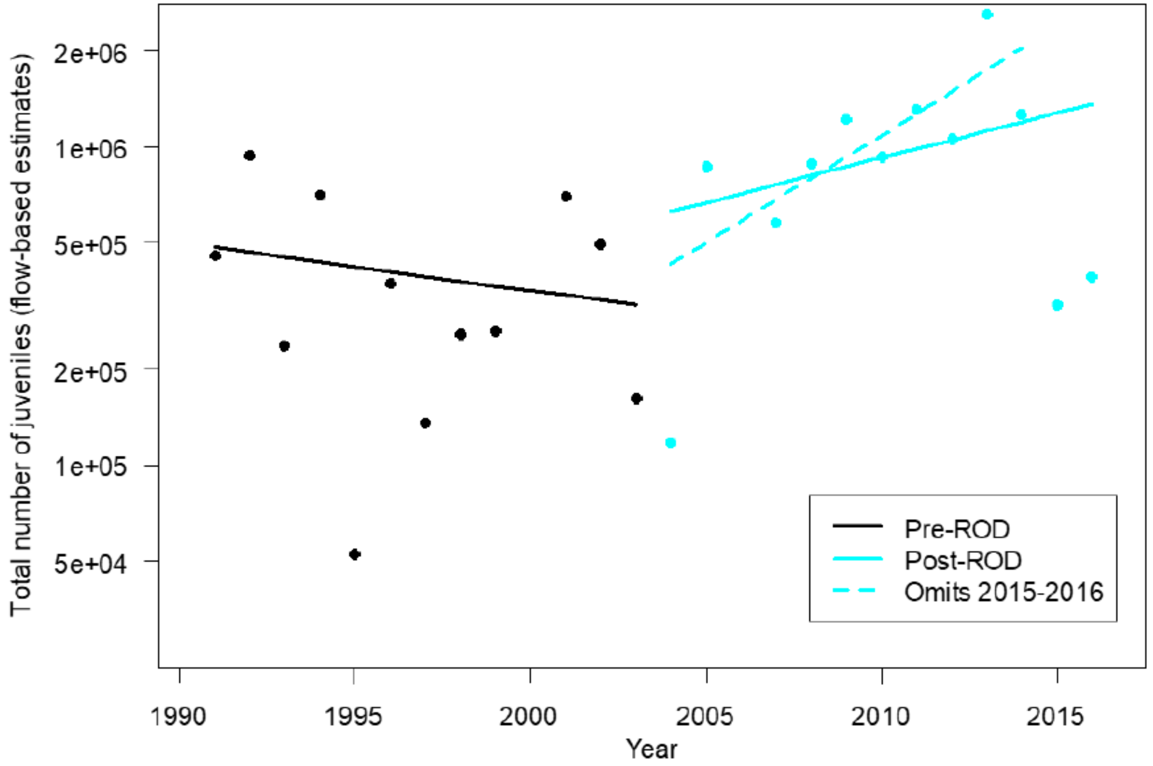


Figure 35. Flow-based estimate of annual total number of natural juveniles (weeks 16-34) caught from 1991 to 2016 (data from 2000 and 2006 were not included). Lines were fit to data before (black) and after (cyan) 2004; dotted cyan line was fitted without the 2013 estimate (which was very high).

Conclusions

- Juvenile Chinook abundance significantly increased post-ROD
- Warmer water temperatures during the initial ROD flows could increase the potential for growth and could encourage earlier outmigration
- Bioenergetics shows potential consumption rate variable from February-April then a lower consistent level during ROD flows.
- HDAT performed worse with longer time-series
- Best explanatory model to describe outmigration timing includes PT ATU and PT temperature thresholds
- Multivariate models for outmigration also explored but not enough time series data for practical use
- Flow-based estimates consistently lower than mark-recapture estimates