Biological Effects of Flows Proposed Water Quality Standards for the Lower San Joaquin River & Tributaries

Jon Rosenfield, Ph.D.

November 29, 2016

The Bay Institute

Main Points

- No evidence that flows <50% UIF will achieve salmon doubling targets or ensure a functioning south Delta ecosystem
- Even at higher flows, salmon doubling is possible ***only if*** accompanied by very precise manipulation of flow (aka "shaping") & massive investments in physical restoration of habitat
- Rearing habitat restoration is necessary, but at flows <50% UIF, restoration acreage & costs skyrocket
- High temperatures limit egg incubation and juvenile rearing habitat at flows <50% UIF – this constrains tributary carrying capacity and the ability to shape flows without producing negative effects

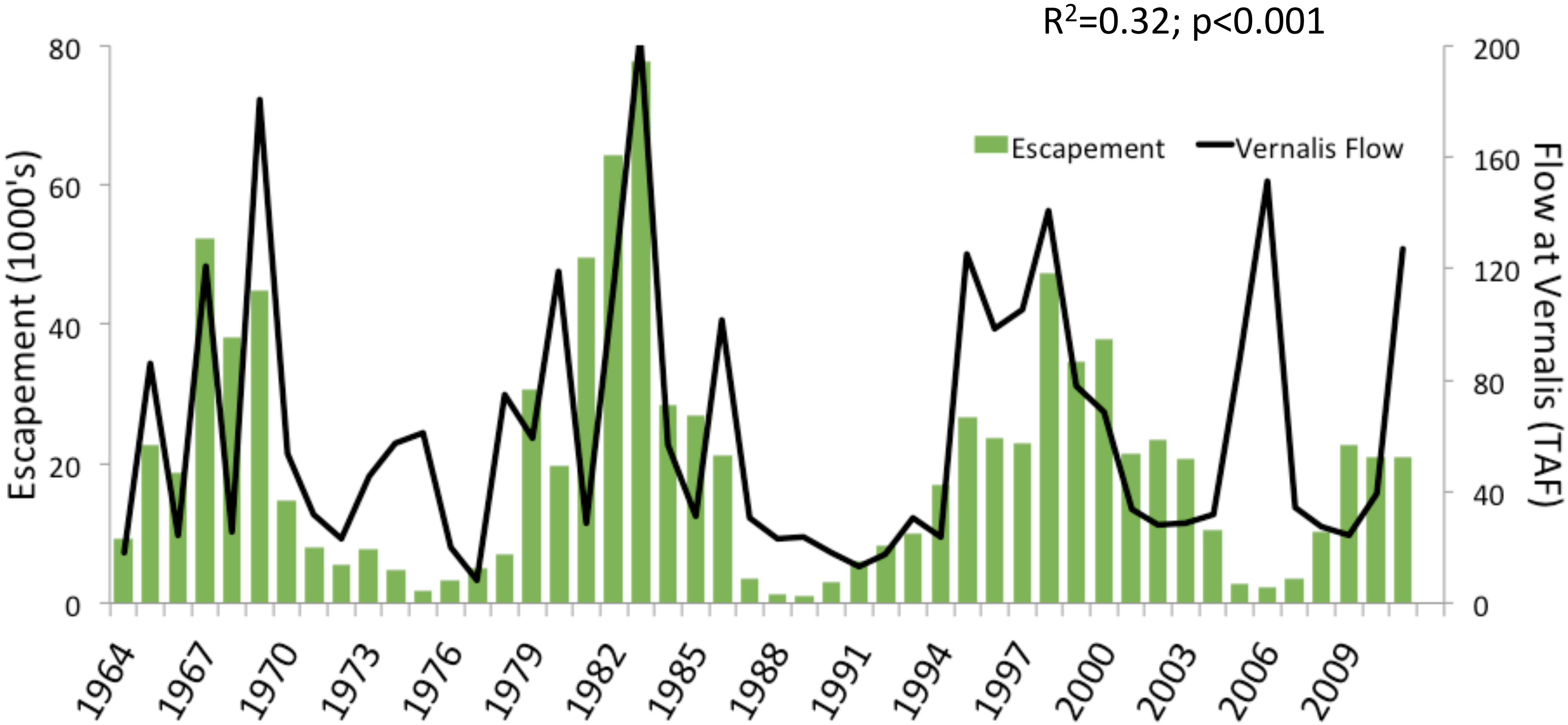
Analyses

Numerous lines of evidence demonstrate that 40% UIF is inadequate.

- Strong correlations between winter-spring flows and:
  - Adult escapement
  - Juvenile survival on tributaries
- Strong functional connections between flow and carrying capacity via:
  - Temperature
  - Inundated off-channel habitat

San Joaquin Salmon Escapement

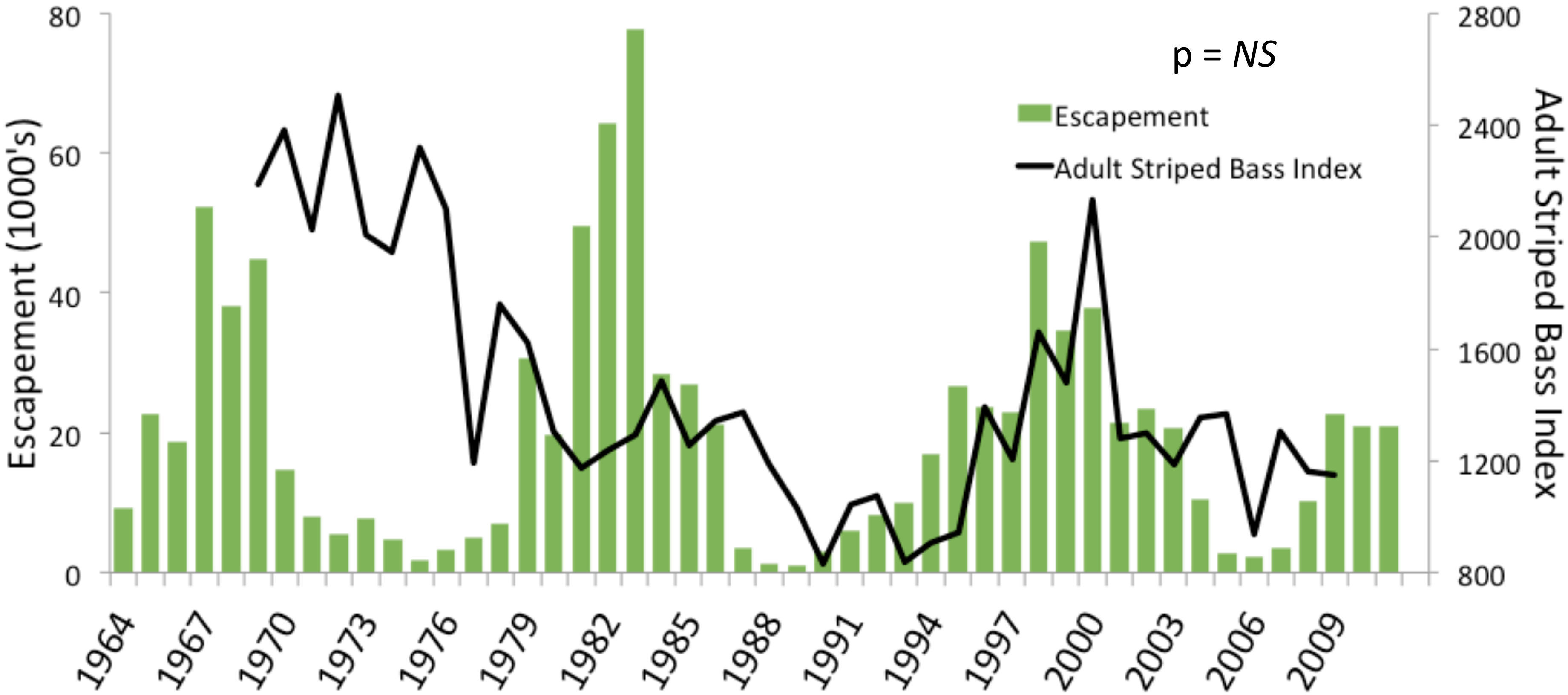
strongly correlated with winter-spring flows



Redrawn from Sturrock et al. 2015

San Joaquin Salmon Escapement

not strongly correlated with striped bass abundance



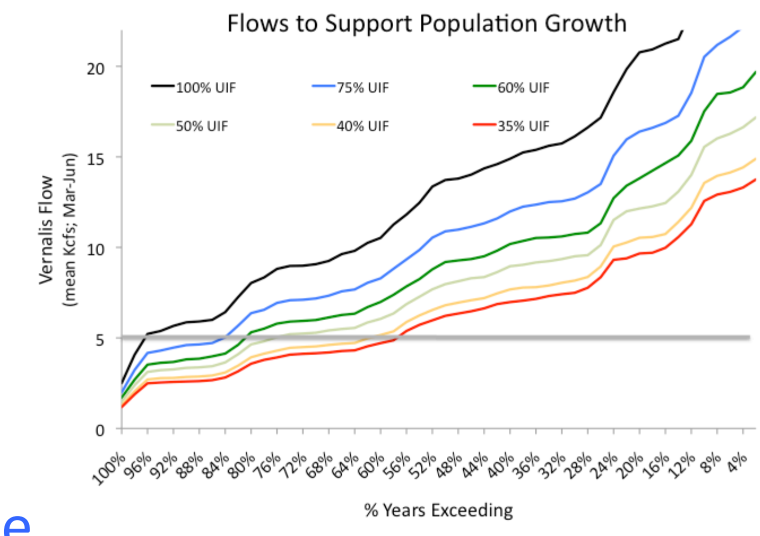
Also, not correlated with

- "Ocean conditions" (North Pacific Gyre Oscillation or NPDO)
- Hatchery releases (Merced or Mokelumne hatcheries)

Seasonal Flows Correlate with Escapement

Average Spring flows at Vernalis of:

- 5 Kcfs → Population growth
  - (desired recurrence occurs @ 50-60% UIF)
- 10 Kcfs → AFRP Production Target
  - (desired recurrence occurs @ >60% UIF)



TBI presentation to SWRCB March 2013

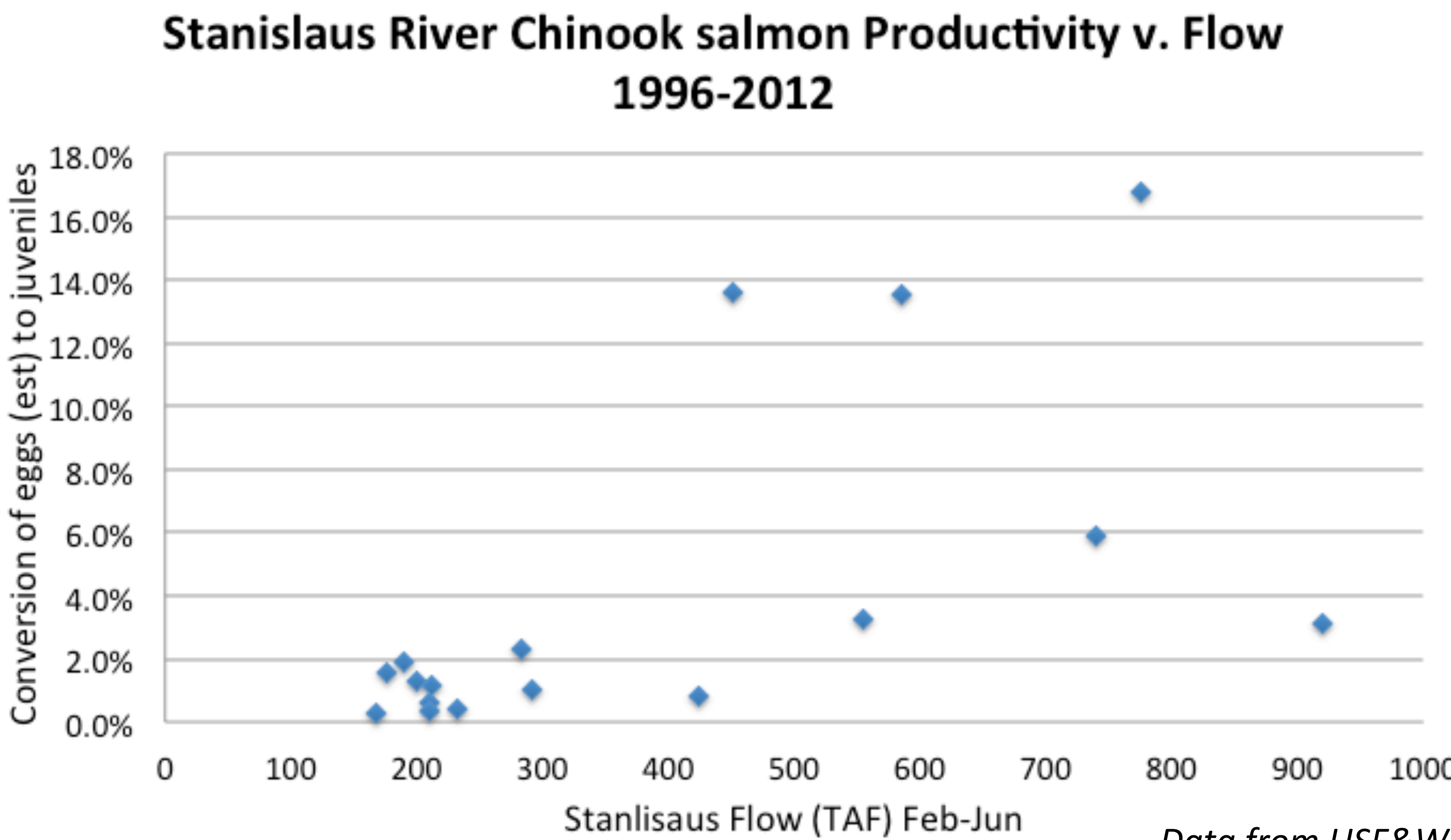
Flow shaping will not change *seasonal average* flows

"Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow…."

SWRCB, 2010, p. 119

Juvenile Salmon Productivity (Survival)

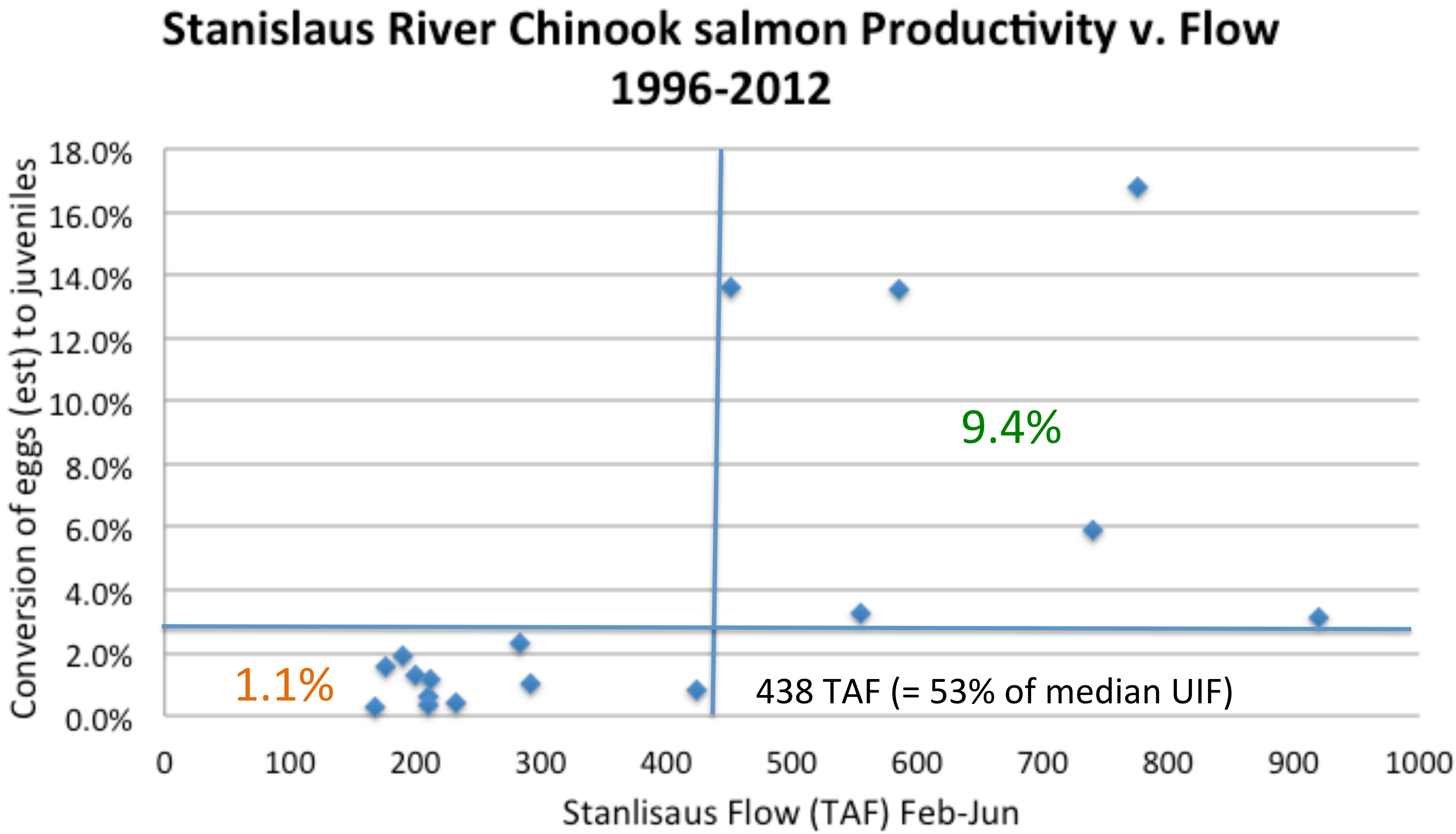
strongly correlated with winter-spring flows



Data from USF&WS

Juvenile Salmon Productivity (Survival)

strongly correlated with winter-spring flows



Data from USF&WS

Juvenile Salmon Productivity (Survival)

strongly correlated with winter-spring flows

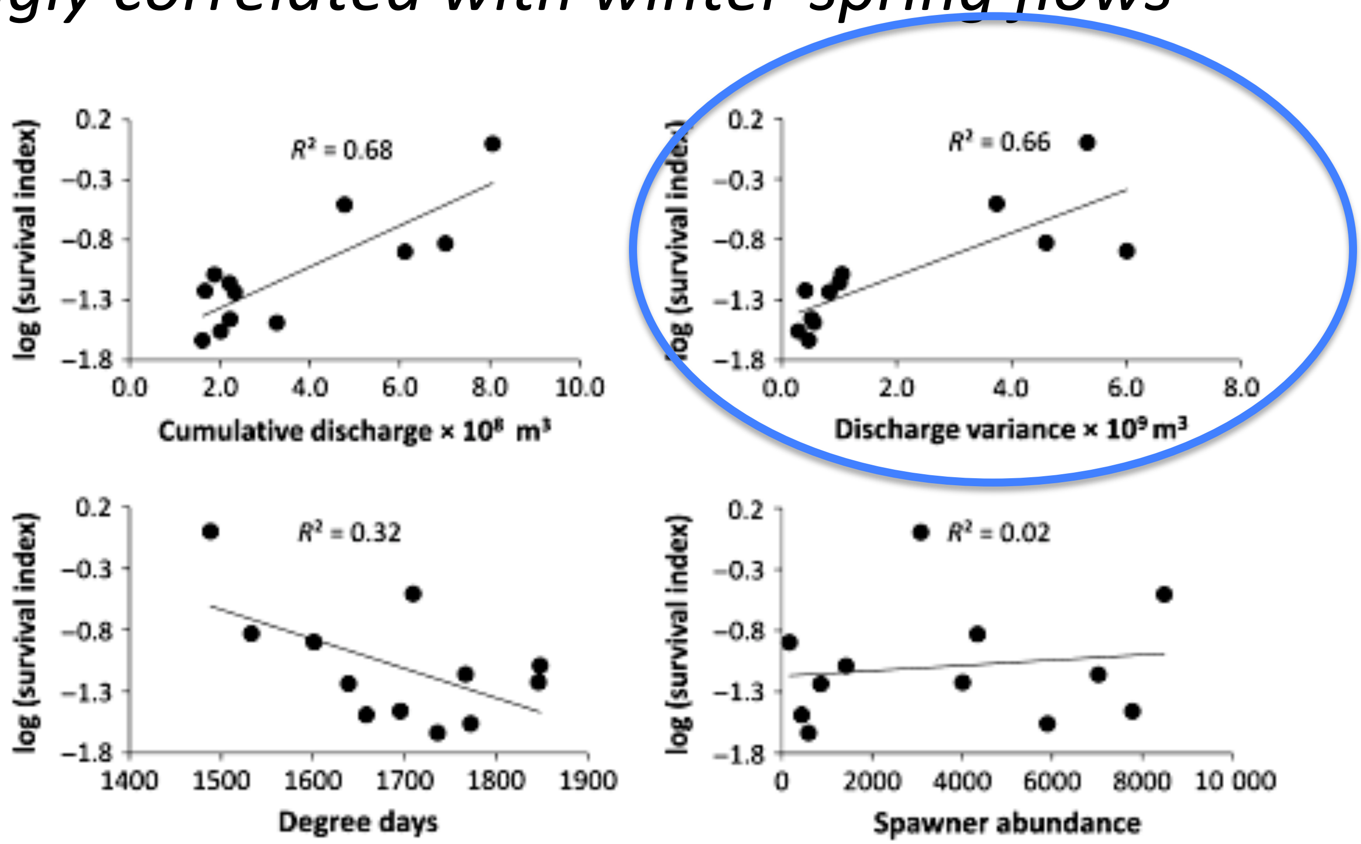


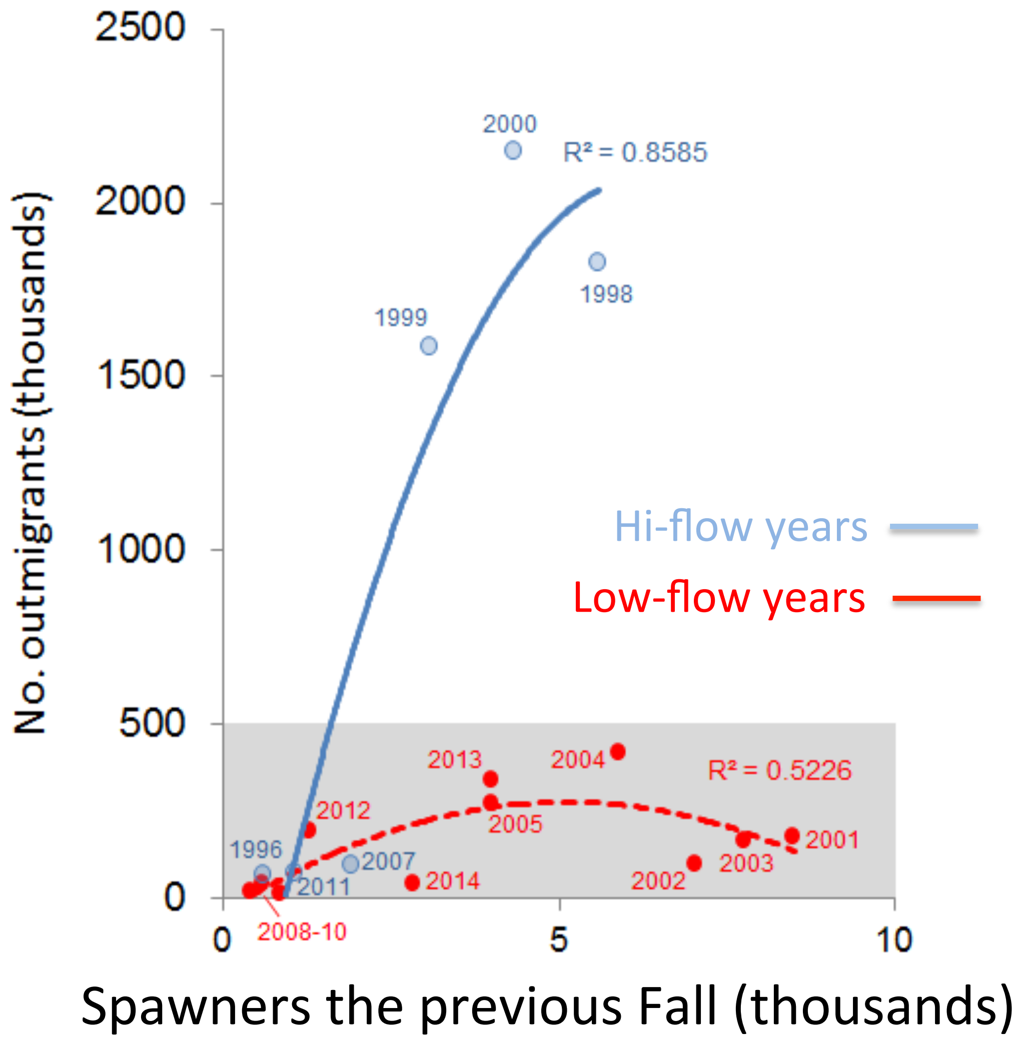
Figure 3. Relationships between the juvenile Chinook salmon survival index and four predictor variables.

Flow Shaping Tends to Reduce Flow Variation

Zeug et al. 2014. *Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America.* Fisheries Management and Ecology. 21: 155–168.

Juvenile Salmon Productivity (Survival)

Mechanism: flow-mediated carrying capacity



Sturrock et al., *in preparation*

Flow and Carrying Capacity
Mechanistic Relationships

Carrying Capacity = Habitat Suitability * Space * Time

- **Limited inundated off-channel habitat** limits capacity for:
  - Juvenile migration and rearing

Rearing Habitat Area

Analysis of changes in inundated acreage must link to biological outcomes

Minimum habitat acreage required to support "doubled" salmon populations

- Estimated for Conservation Strategy of DWR's Central Valley Flood Protection Plan (Available at: http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf)

"Habitat" ≠ "wetted acre days"

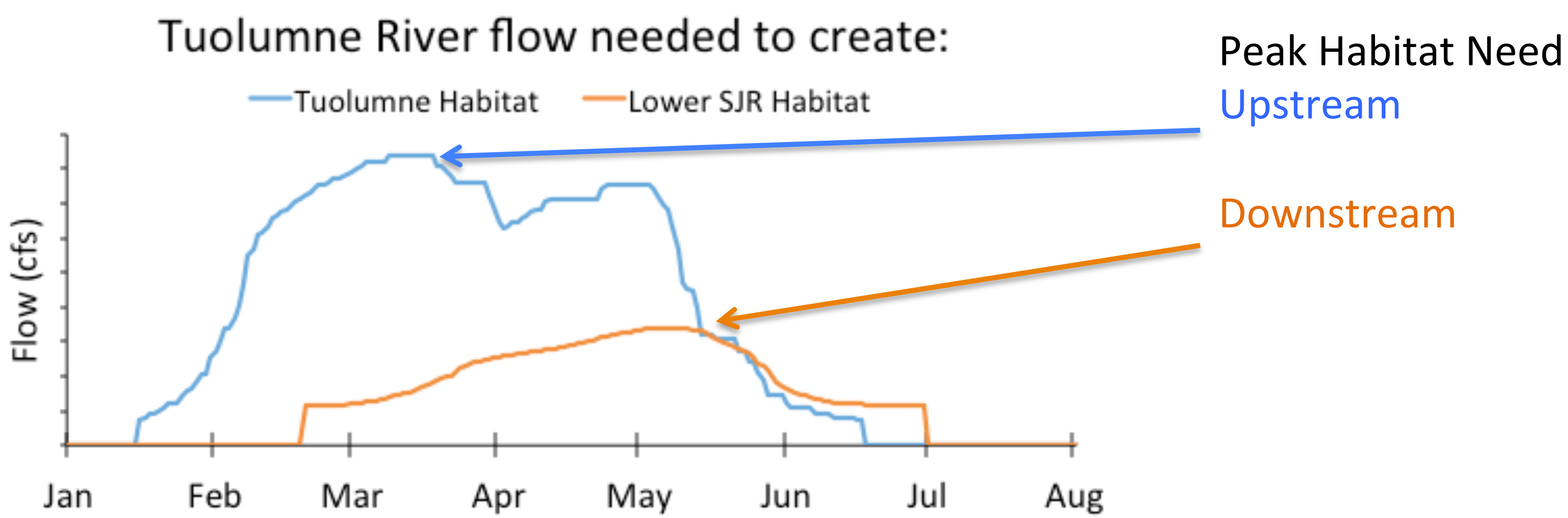
- The acreage required to support "doubled" salmon population must inundate:
  - at least 10 consecutive days (for low-gradient habitat)
  - at least 1/2 of years (i.e., in the median year)
- We assumed habitat suitability was at the high end of that currently available (HSI = 30%)
  - Field studies indicate HSI range from 7-30% (SJRRP 2012)

Rearing Habitat Area

Analysis of changes in inundated acreage must link to biological outcomes

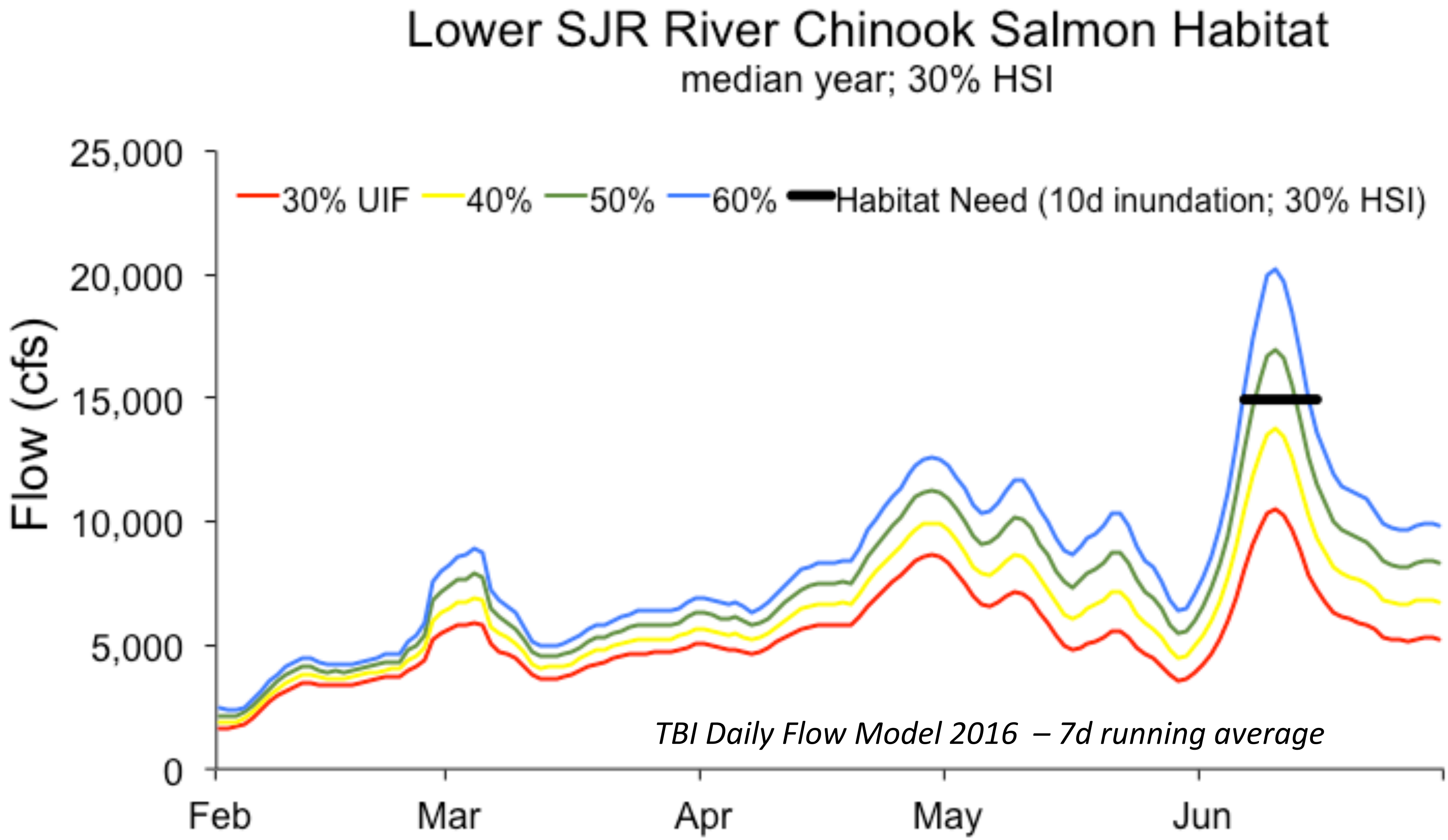
Inundated habitat is required along the migration route (tributaries and lower San Joaquin River) throughout the migration period

- Habitat required upstream must inundate before habitat required downstream (~1.5 month lag)



Flow and Habitat are Linked

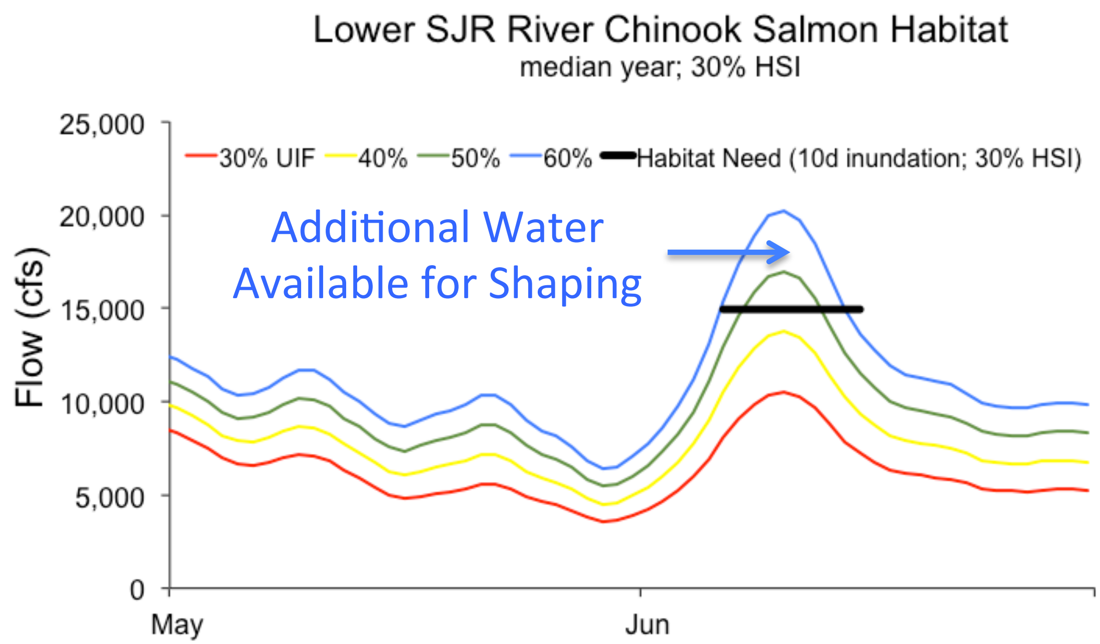
Trade-off between physical restoration and required in-stream flows



TBI Daily Flow Model 2016 – 7d running average

Flow and Habitat are Linked

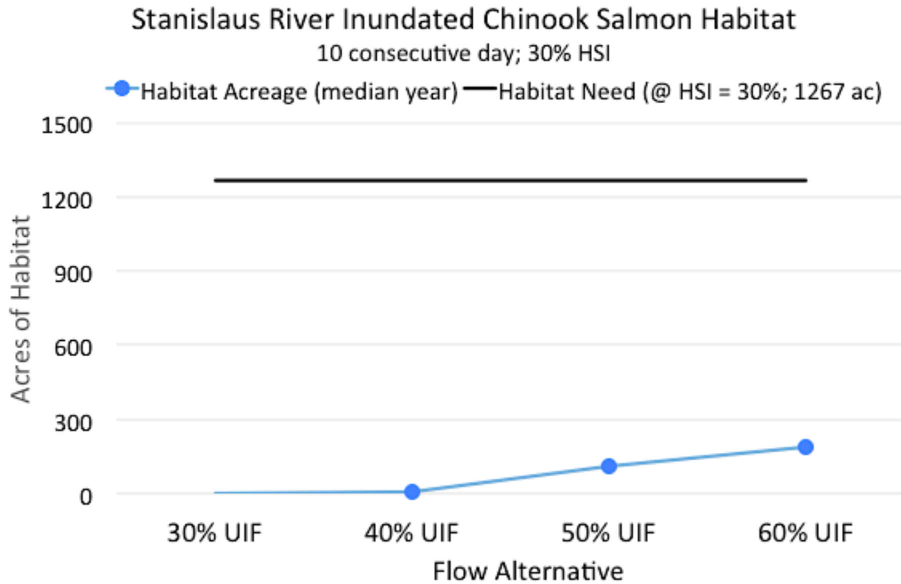
Lower flows require more habitat restoration & limit opportunities



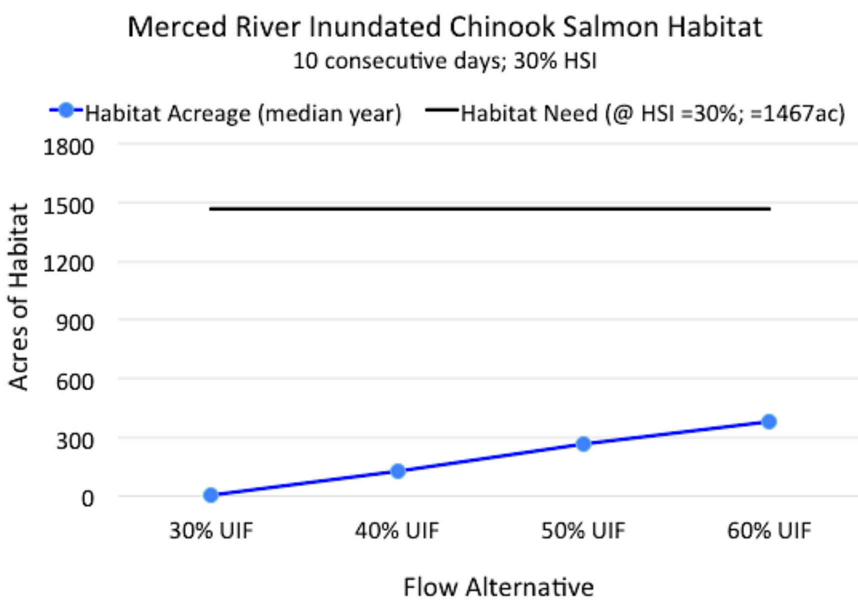
Alternative	Days of Inundation	Additional AF water needed w/o shaping	Additional AF water available for shaping	Acreage shortfall w/o shaping	Acreage shortfall with shaping
60%	8	2,547	54,291	996	0
50%	5	17,534	14,011	3,201	1,766
40%	0	58,791	0	5,131	5,131
30%	0	114,059	0	6,787	6,787

Flow and Habitat are Linked

Lower flows require more habitat restoration & limit opportunities



Alternative	Acreage shortfall (@ 30% HSI)
60%	1,080
50%	1,160
40%	1,258
30%	1,267



Alternative	Acreage shortfall (@ 30% HSI)
60%	1,088
50%	1,203
40%	1,344
30%	1,467

Flow and Carrying Capacity
Mechanistic Relationships

Carrying Capacity = Habitat Suitability * Space * Time

Limited inundated off-channel habitat limits capacity for:

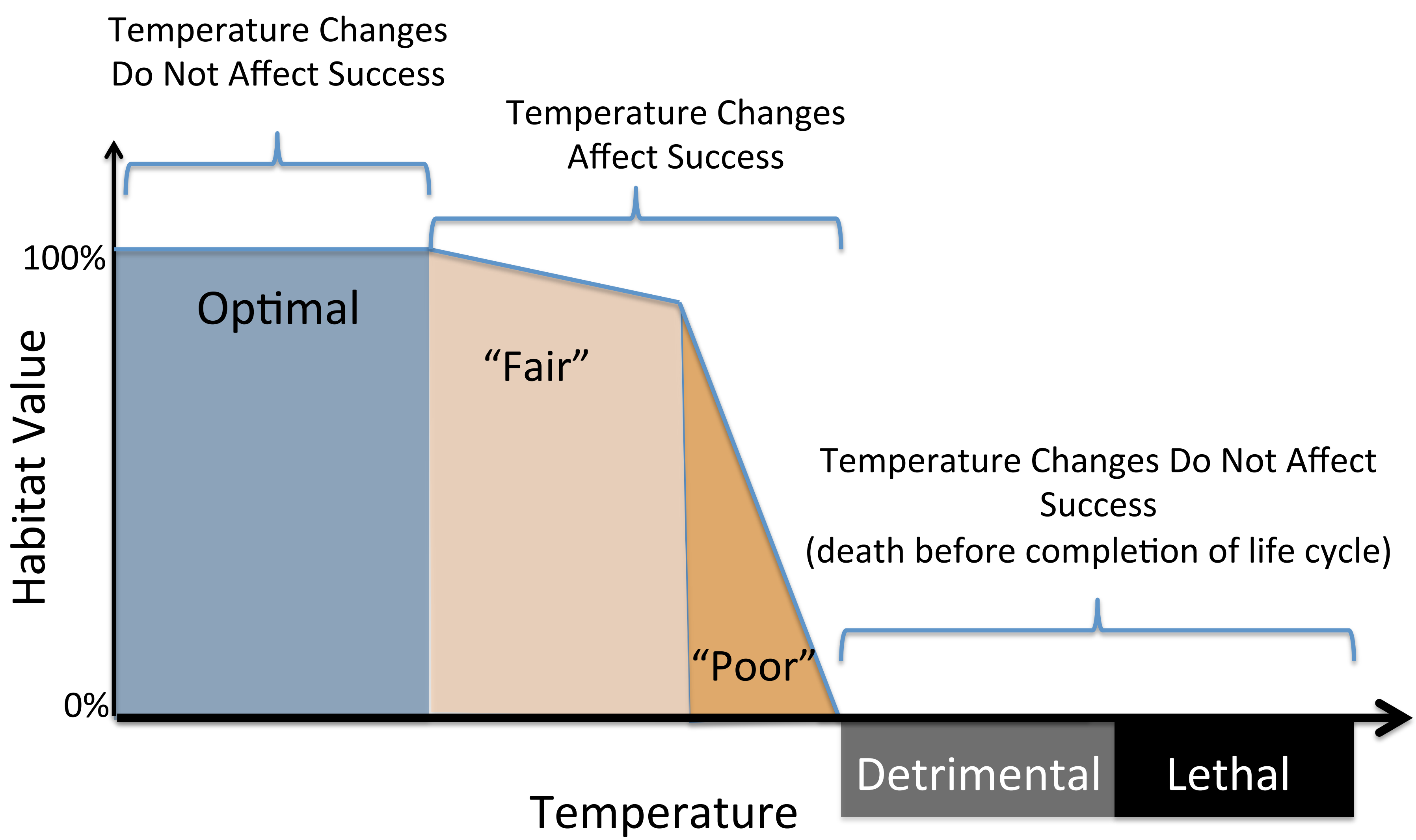
- Juvenile migration and rearing

➢ **High Temperatures** limit capacity for:

- Spawning & incubation
- Juvenile migration and rearing

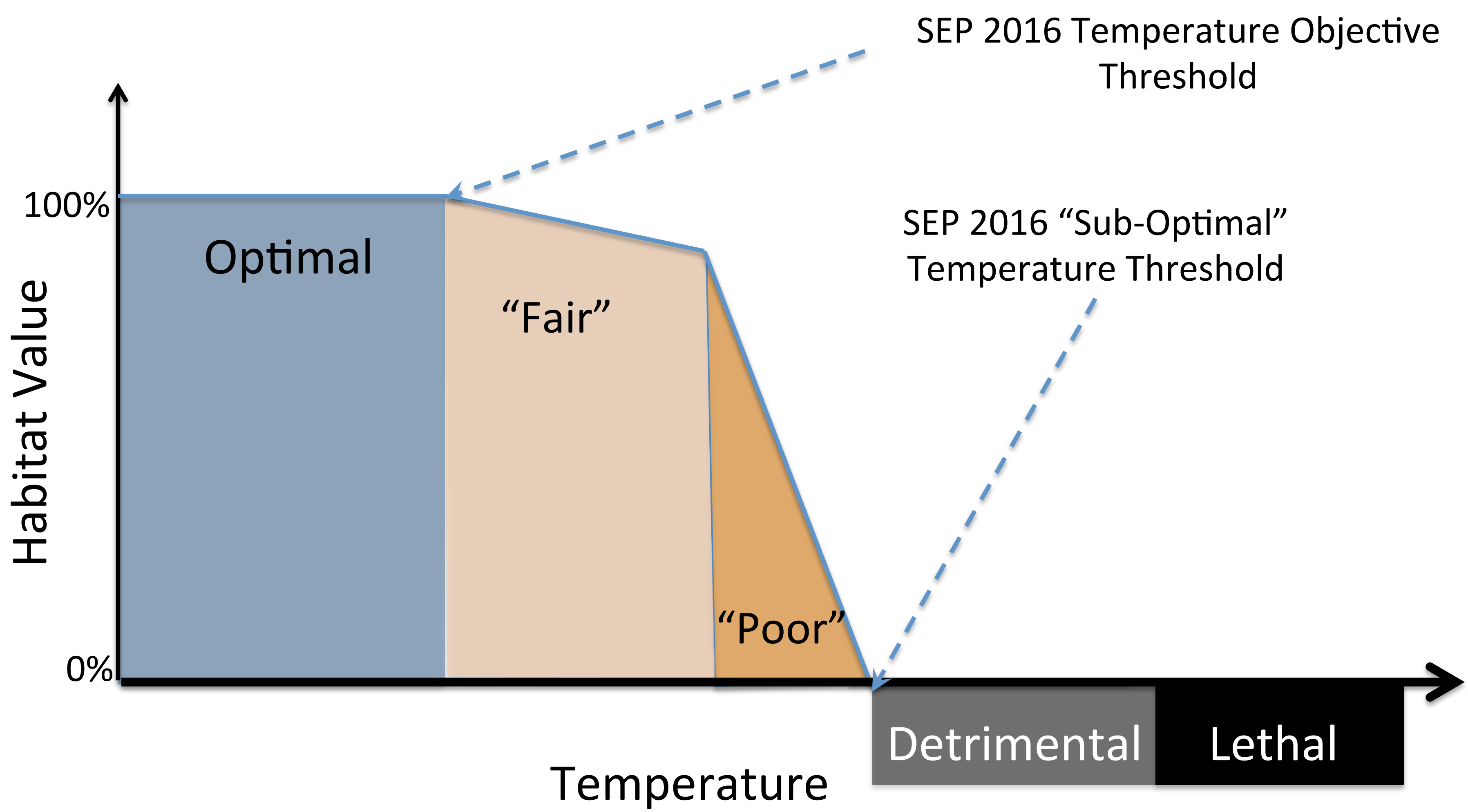
Temperature: Thresholds v. Continuous Effects

Analysis of temperature changes must link to biological outcomes



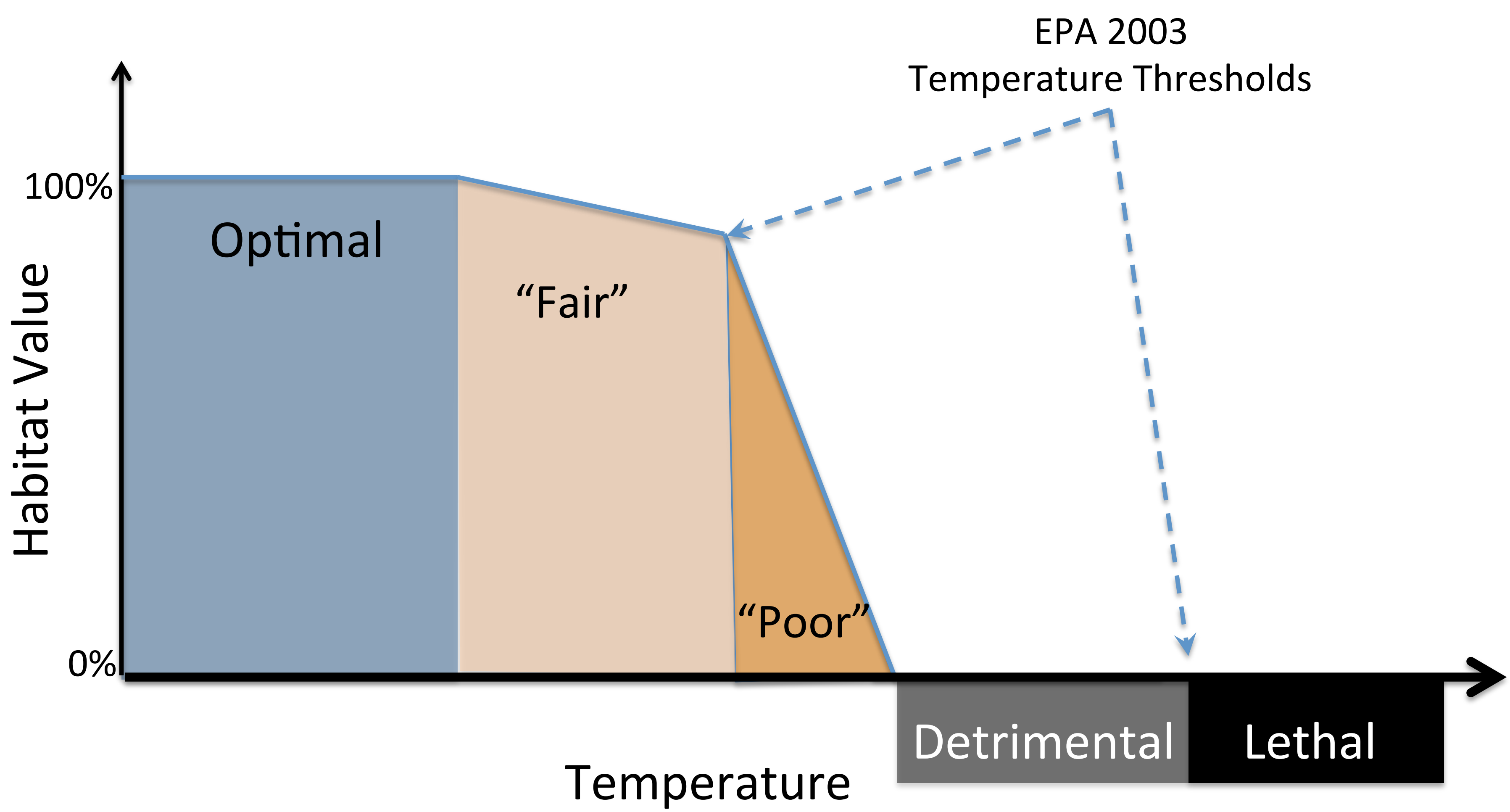
Temperature: Thresholds v. Continuous Effects

Analysis of temperature changes must link to biological outcomes

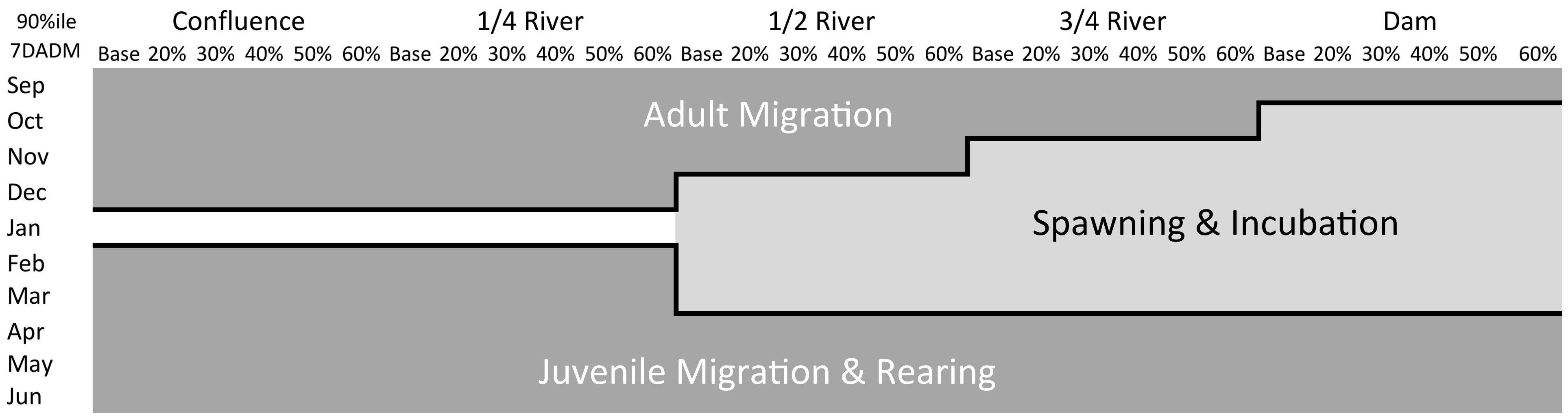


Temperature: Thresholds v. Continuous Effects

Analysis of temperature changes must link to biological outcomes



Temperature: Life Stage-specific Temperature Thresholds



Tuolumne River

Temperature

90%ile 7DADM	Confluence (RM0)						1/4 River (RM13.2)						1/2 River (RM28.1)						3/4 River (RM38.29)						Below La Grange (RM53.5)					
	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base ('	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8	1.8	1.3	1.3	1.4	1.2	1.4
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6	1.5	1.2	1.1	1	0.9	1.4
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9	0.1	-0.2	-0.2	0	0.4	0.5
Jan													-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	-5.6	-6	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	2.4	0.9	-0.3	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	20.4	17.9	16.7	14.7	12.7	11	20.2	17.3	15.5	12.9	10.7	8.7	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal | Detrimental | Poor | Fair | Optimal

= Modeled Temperature (SED 2016) *minus* Optimal Temperature (SEP 2016)

Tuolumne River

Temperature

90%ile 7DADM	Confluence (RM0) Base	20%	30%	40%	50%	60%	1/4 River (RM13.2) Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3
Jan												
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	2.4	0.9	-0.3
Jun	20.4	17.9	16.7	14.7	12.7	11	20.2	17.3	15.5	12.9	10.7	8.7

90%ile 7DADM	1/2 River (RM28.1) Base	20%	30%	40%	50%	60%	3/4 River (RM38.29) Base	20%	30%	40%	50%	60%	Below La Grange (RM53.5) Base	20%	30%	40%	50%	60%
Sep	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8	1.8	1.3	1.3	1.4	1.2	1.4
Nov	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6	1.5	1.2	1.1	1	0.9	1.4
Dec	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9	0.1	-0.2	-0.2	0	0.4	0.5
Jan	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	[illegible]	-6	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal | Detrimental | Poor | Fair | Optimal

Gain miles of incubation habitat in Feb & March @ 50% UIF

Source data from Phase I SED, 2016

Tuolumne River

Temperature

90%ile 7DADM

Month	Confluence (RM0) Base	20%	30%	40%	50%	60%	1/4 River (RM13.2) Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3
Jan												
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	[illegible]	0.9	-0.3
Jun	20.4	17.9	16.7	14.7	12.7	11	20.2	17.3	15.5	[illegible]	10.7	8.7

Month	1/2 River (RM28.1) Base (	20%	30%	40%	50%	60%	3/4 River (RM38.29) Base	20%	30%	40%	50%	60%
Sep	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9
Oct	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8
Nov	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6
Dec	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9
Jan	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1
Feb	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5
Mar	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8
Apr	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	-5.6	-6
May	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9
Jun	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8

Month	Below La Grange (RM53.5) Base	20%	30%	40%	50%	60%
Sep	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	1.8	1.3	1.3	1.4	1.2	1.4
Nov	1.5	1.2	1.1	1	0.9	1.4
Dec	0.1	-0.2	-0.2	0	0.4	0.5
Jan	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal | Detrimental | Poor | Fair | Optimal

Substantially better rearing conditions over miles of habitat during April @ 50% UIF

Source data from Phase I SED, 2016

Tuolumne River

Temperature

90%ile 7DADM	Confluence (RM0)						1/4 River (RM13.2)					
	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3
Jan												
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	2.4	0.9	-0.3
Jun	20.4	17.9	16.7	14.7	[illegible]	11	20.2	17.3	15.5	12.9	10.7	8.7

90%ile 7DADM	1/2 River (RM28.1)						3/4 River (RM38.29)						Below La Grange (RM53.5)					
	Base ('	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%
Sep	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8	1.8	1.3	1.3	1.4	1.2	1.4
Nov	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6	1.5	1.2	1.1	1	0.9	1.4
Dec	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9	0.1	-0.2	-0.2	0	0.4	0.5
Jan	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	-5.6	-6	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal | Detrimental | Poor | Fair | Optimal

Successful juvenile rearing/ migration extended for a month @ 50% UIF

Source data from Phase I SED, 2016

Tuolumne River

Temperature

90%ile 7DADM	Confluence (RM0)						1/4 River (RM13.2)						1/2 River (RM28.1)						3/4 River (RM38.29)						Below La Grange (RM53.5)					
	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8	1.8	1.3	1.3	1.4	1.2	1.4
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6	1.5	1.2	1.1	1	0.9	1.4
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9	0.1	-0.2	-0.2	0	0.4	0.5
Jan													-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	-5.6	-6	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	2.4	0.9	-0.3	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	20.4	17.9	16.7	14.7	12.7	11	20.2	17.3	15.5	12.9	10.7	8.7	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal	Detrimental	Poor	Fair	Optimal

Month(s)	Life stage	Result @ 40% UIF	Result @ 50% UIF
Sept-Oct	Adult Migration	Not possible – no difference among alternatives	
Oct-Nov	Spawning/Incubation	Largely inhospitable -- no difference among alternatives	
Dec-Jan	Spawning/Incubation	Largely good conditions – no difference among alternatives	
Feb-Mar	**Incubation**	**Poor incubation @ ¼ river**	**Good incubation @ ¼ river**
Apr	**Rearing/Outmigration**	**Low-stress @ ¼ river; Stressful @ confluence**	**Optimal @ ¼ river; Low-stress @ confluence**
May	**Rearing/Outmigration**	**Stressful @ ¼ river; Poor survival @ confluence**	**Low-stress @ ¼ river Stressful @ confluence;**

Merced River

Temperature

90%ile 7DADM	Confluence (RM2.52) Base	20%	30%	40%	50%	60%	1/4 River (RM13.41) Base	20%	30%	40%	50%	60%
Sep	16.9	16.9	16.9	16.9	16.9	16.9	18.4	18.3	18.4	18.3	18.4	18.5
Oct	11	10.3	10.6	10.4	10.5	11	11.8	10.9	11.1	10.8	11	11.7
Nov	2.8	2.1	2.1	1.7	1.7	2.1	3.4	2.3	2.4	2	2.1	2.6
Dec	-5.6	-6	-6	-6	-5.9	-5.8	-4.9	-5.6	-5.6	-5.6	-5.5	-5.2
Jan												
Feb	-3	-2.9	-3	-3	-3.2	-3.4	-2.8	-2.8	-2.8	-2.8	-3.1	-3.3
Mar	2.6	2.4	2	1.4	0.9	0.5	2.6	2.5	2	1.4	0.7	0.3
Apr	8.8	6.8	5.2	4.1	3.4	2.8	9.5	6.7	4.8	3.6	2.8	2.2
May	13.5	9.8	8.6	7.7	6.8	6.2	14.7	9.9	8.2	7.3	6.4	5.6
Jun	18.1	16.6	15.8	15.1	14.5	13.9	19.1	17.2	16.4	15.4	14.3	13.6

90%ile 7DADM	1/2 River (RM27.07) Base	20%	30%	40%	50%	60%	3/4 River (RM37.79) Base	20%	30%	40%	50%	60%
Sep	18.4	18.2	18.2	18.3	18.4	18.6	20.3	19.9	19.9	20	20.2	20.5
Oct	10.9	9.3	9.5	9.2	9.5	10.6	10.9	8.4	8.7	8.3	8.7	10.6
Nov	3.3	1.6	1.6	1.4	1.6	2.1	9.9	7.5	7.5	7.2	7.4	7.9
Dec	0.9	-0.1	-0.1	-0.1	0.1	0.4	2.2	0.9	1	1	1.2	1.3
Jan	-1.6	-1.6	-1.6	-1.6	-1.6	-1.7	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Feb	2.4	2.5	2.5	2.4	2.1	1.9	2.9	3	3	3	2.6	2.5
Mar	6.9	7	6.7	6	5.5	5.1	6.5	6.7	6.4	5.8	5.2	4.9
Apr	6.8	4.3	2.7	1.8	1.2	0.7	6.4	3.6	1.9	1.2	0.7	0.3
May	12	7.6	6.1	5.2	4.7	4	10.9	6.8	5	4.2	3.8	3.2
Jun	17.3	15.3	14.3	13.2	12	11.3	16.6	14.6	13.3	11.6	10.5	10

90%ile 7DADM	Below Crocker Huffman (RM Base	20%	30%	40%	50%	60%
Sep	7.8	3.8	4	4.2	4.9	7.3
Oct	12.9	6.9	6.6	6.7	7.5	10.5
Nov	9	4.3	4.2	4.1	4.6	5.5
Dec	1.6	0	0	0.1	0.2	0.5
Jan	-2.5	-2.8	-2.7	-2.8	-2.8	-2.9
Feb	-1.9	-1.5	-1.5	-1.6	-1.7	-1.8
Mar	0	0.6	0.4	0.4	0.2	0.1
Apr	-4.7	-4.7	-5.3	-5.5	-5.3	-5.4
May	-3.4	-3.4	-3.8	-3.9	-3.8	-3.9
Jun	-0.3	-1.9	-1.7	-1.2	-0.9	-0.4

Lethal | Detrimental | Poor | Fair | Optimal

Month(s)	Life stage	Result @ 40% UIF	Result @ 50% UIF
Sept-Nov	Adult Migration	Not possible – no difference among alternatives	
Oct-Nov	Spawning/Incubation	Largely inhospitable -- no difference among alternatives	
Dec-Mar	Spawning/Incubation	Largely good conditions – no difference among alternatives	
Apr	**Rearing/Outmigration**	**Poor survival throughout lower river**	**Fair conditions throughout lower river**
May	**Rearing/Outmigration**	**No juveniles**	**Some juveniles survive** ***(probably early in month)***

Analysis of Habitat Effects Must be ***Integrated***

Aggressive "Flow Shaping" Will Produce Temperature Impacts; Likely Harmful @ <50% UIF

90%ile 7DADM	Confluence (RM0)						1/4 River (RM13.2)						1/2 River (RM28.1)						3/4 River (RM38.29)						Below La Grange (RM53.5)					
	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base (	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%	Base	20%	30%	40%	50%	60%
Sep	20.2	20.2	20.2	20.2	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.3	17.8	17.8	17.8	17.8	17.8	17.8	15.9	15.9	15.9	15.9	15.9	15.9	-4.3	-4.6	-4.4	-4.4	-4.6	-4.6
Oct	13.6	13.6	13.6	13	13	13	12.7	12.7	12.7	12.4	12.5	12.5	9.8	9.7	9.7	9.7	9.7	9.7	7	6.8	6.8	6.8	6.7	6.8	1.8	1.3	1.3	1.4	1.2	1.4
Nov	2.9	2.9	3	2.8	2.8	2.8	2	2	2.1	1.9	1.9	1.8	0.8	0.8	0.8	0.7	0.5	0.5	5.2	5	5	4.7	4.7	4.6	1.5	1.2	1.1	1	0.9	1.4
Dec	-6	-6	-5.9	-6	-5.9	-5.9	-6.5	-6.5	-6.4	-6.4	-6.3	-6.3	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.7	0.9	0.9	0.1	-0.2	-0.2	0	0.4	0.5
Jan													-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4	-0.2	-0.1	-0.1	-2.3	-2.3	-2.2	-1.9	-1.7	-1.5
Feb	-1.7	-1.9	-2.2	-2.5	-2.9	-3.4	-2.3	-2.6	-3	-3.4	-3.8	-4.3	3.3	3.4	2.6	1.9	1.5	1	2.2	2.3	1.6	1	0.7	0.5	-2.8	-2.8	-2.8	-2.8	-2.7	-2.6
Mar	4.7	3.2	2.2	0.9	0.1	-0.8	3.8	2.3	1	-0.3	-1.2	-1.9	8.1	6	4.5	3.7	2.8	2.1	6.1	4.1	2.8	2	1.3	0.8	-3.2	-3.3	-3.2	-3.3	-3.2	-3.2
Apr	8.2	5.7	3.7	2.1	0.7	-0.3	6.6	4	2.1	0.4	-0.8	-1.7	2.6	0.1	-1.6	-3	-3.9	-4.5	-0.2	-2.3	-3.6	-4.8	-5.6	-6	-9.7	-9.7	-9.8	-9.8	-9.7	-9.7
May	12.4	9.4	6.7	4.4	2.8	2.4	10.7	7.9	4.7	2.4	0.9	-0.3	5.4	3.3	0.2	-1.4	-2.3	-3	2	0.1	-2.5	-3.7	-4.5	-4.9	-9.3	-9.4	-9.4	-9.3	-9.3	-9.2
Jun	20.4	17.9	16.7	14.7	12.7	11	20.2	17.3	15.5	12.9	10.7	8.7	18.2	13.3	9.7	6.7	4.9	3.5	16.2	10.1	5.4	3.1	1.8	0.8	-8.2	-8.4	-8.4	-8.3	-8.2	-8

Lethal | Detrimental | Poor | Fair | Optimal