CVPIA SIT Chinook Salmon Annotated Decision Support Models (DSMs)

September 2024

Model Purposes

Integrate knowledge from across the Central Valley

Coarse resolution

Track fish metrics at different scales (i.e., adult escapement, juvenile production, population viability)

Evaluate management alternatives and sequence of actions over 20 years:

- Eliminate predator contact points
- Reduce water diversions
- Increase spawning, floodplain, or in-channel habitat
- Manipulate flows
- Remove barriers

Chinook Model Grain and Extent

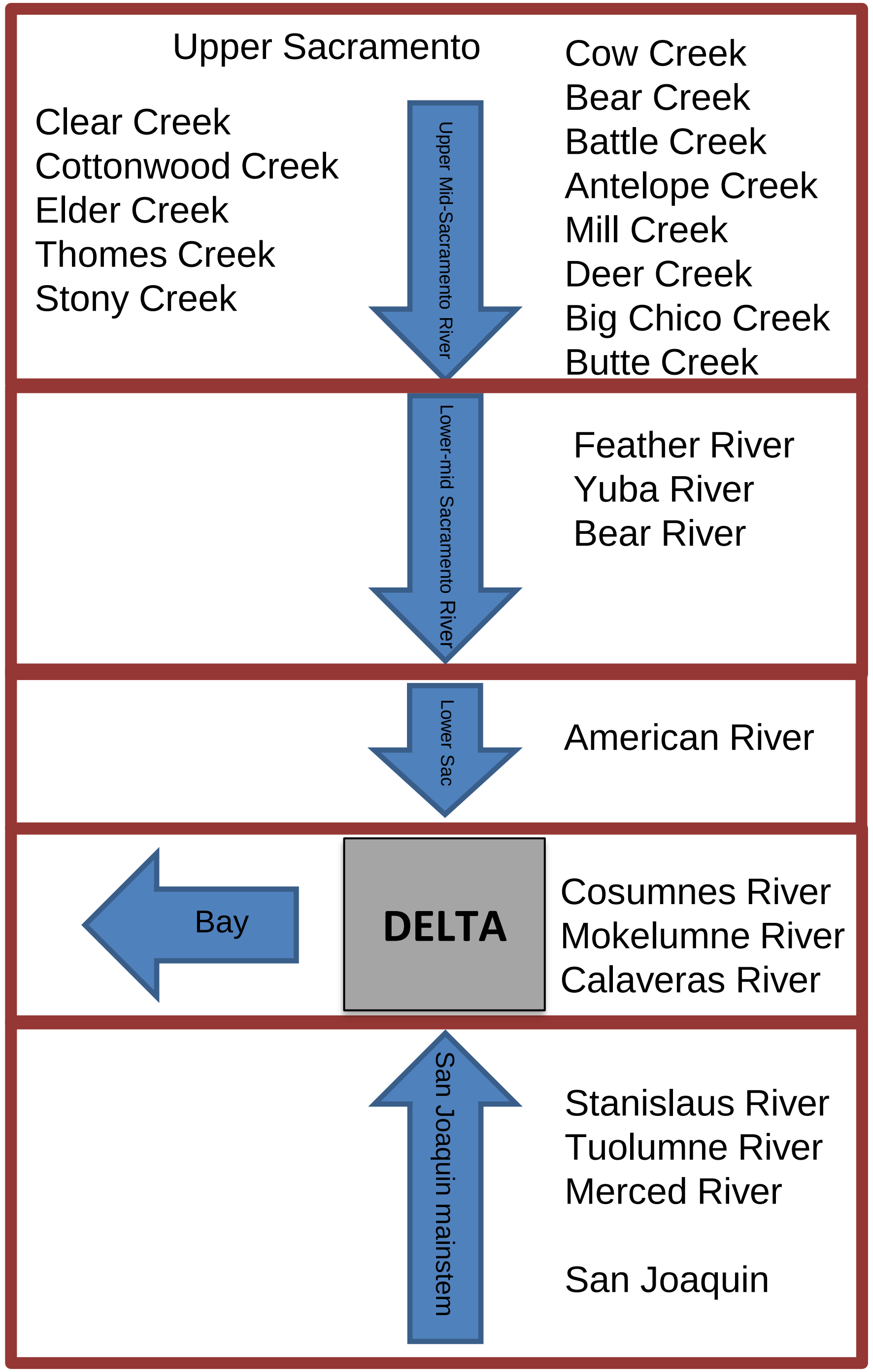
Spatial grain (Movement and Rearing Watershed Groups) – see next slides

Size groups:

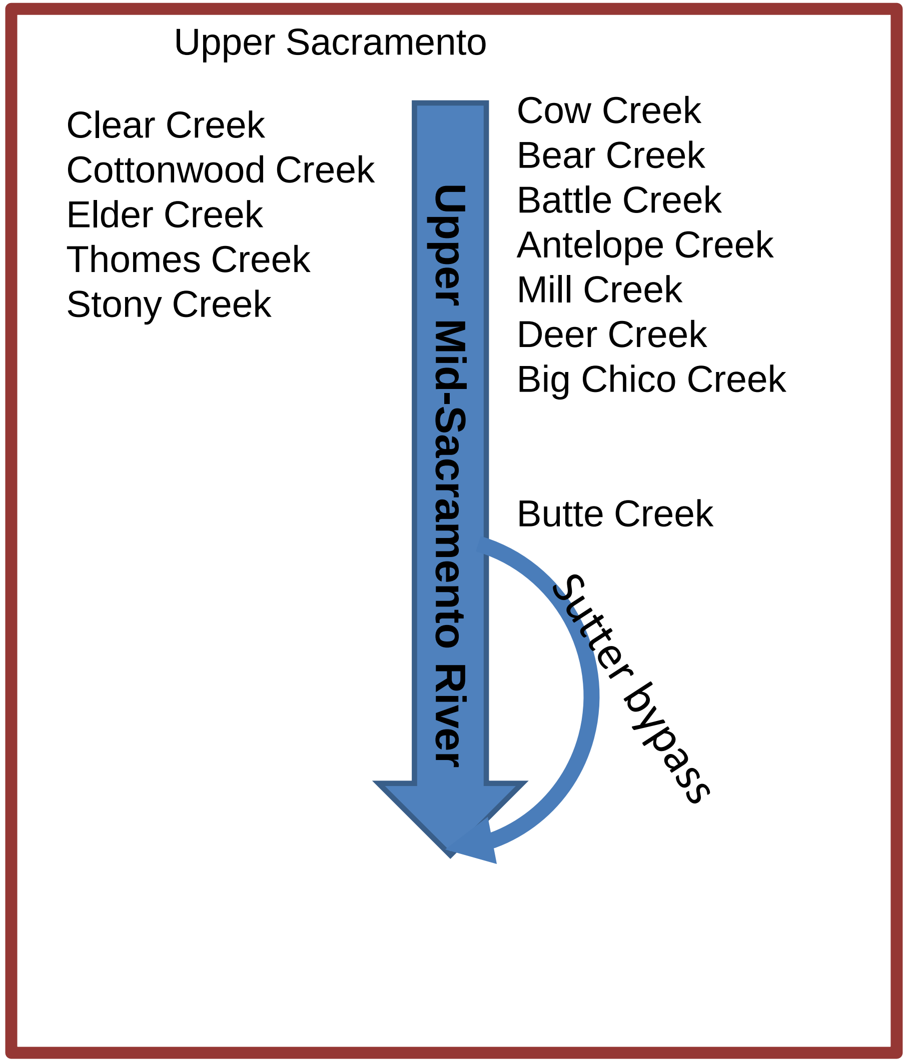
< 42 mm, 42-72 mm, 72 – 110 mm, > 110 mm

Monthly time step

Movement and Rearing Watershed Groups



Movement and Rearing Watershed Groups



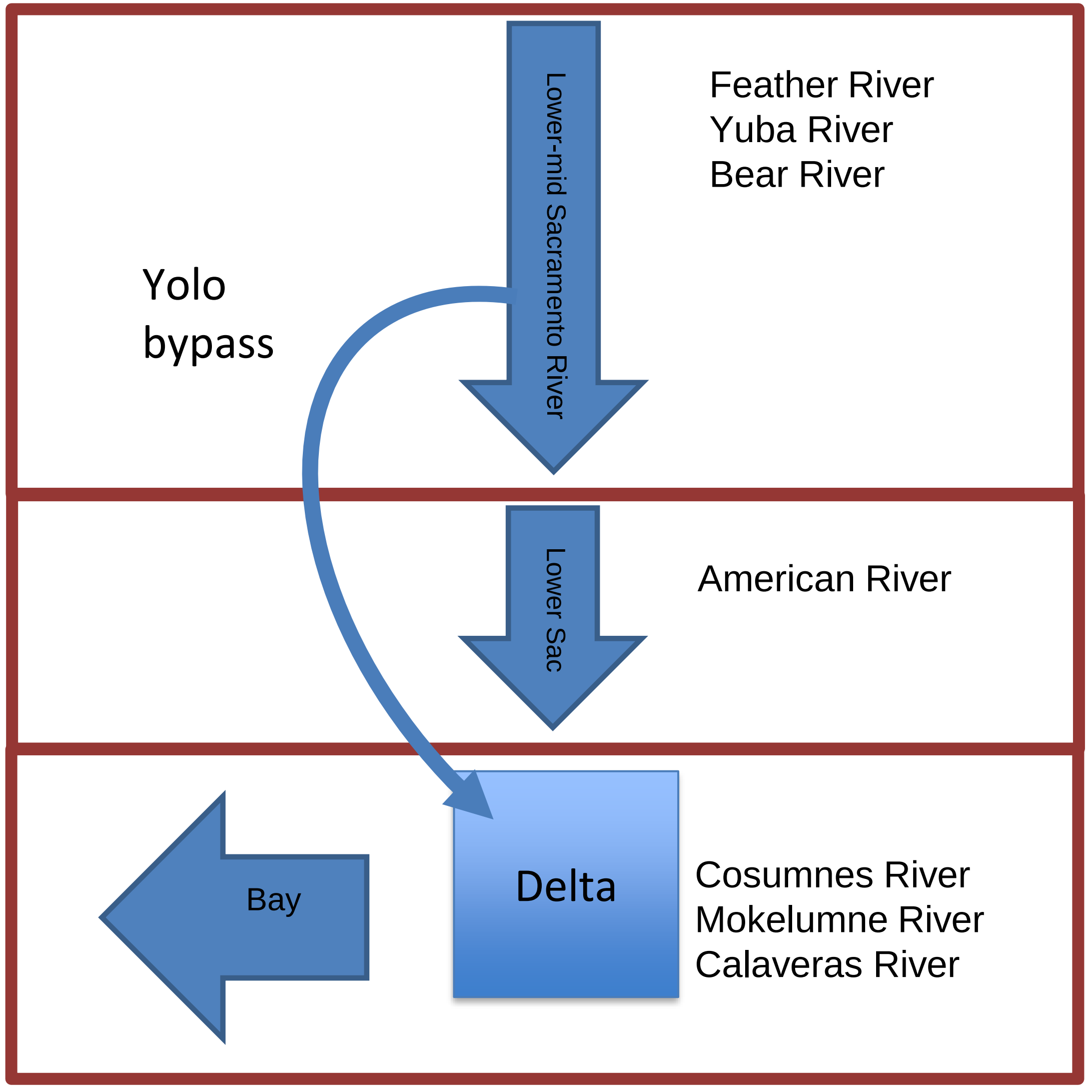
Sutter Bypass Routing ruleset:

100% Butte Creek fish through Sutter BP

% fish from upstream tributaries enter as equal to % flow being diverted

Allow use by Feather, Yuba, and Bear Rivers as possible management action

Movement and Rearing Watershed Groups



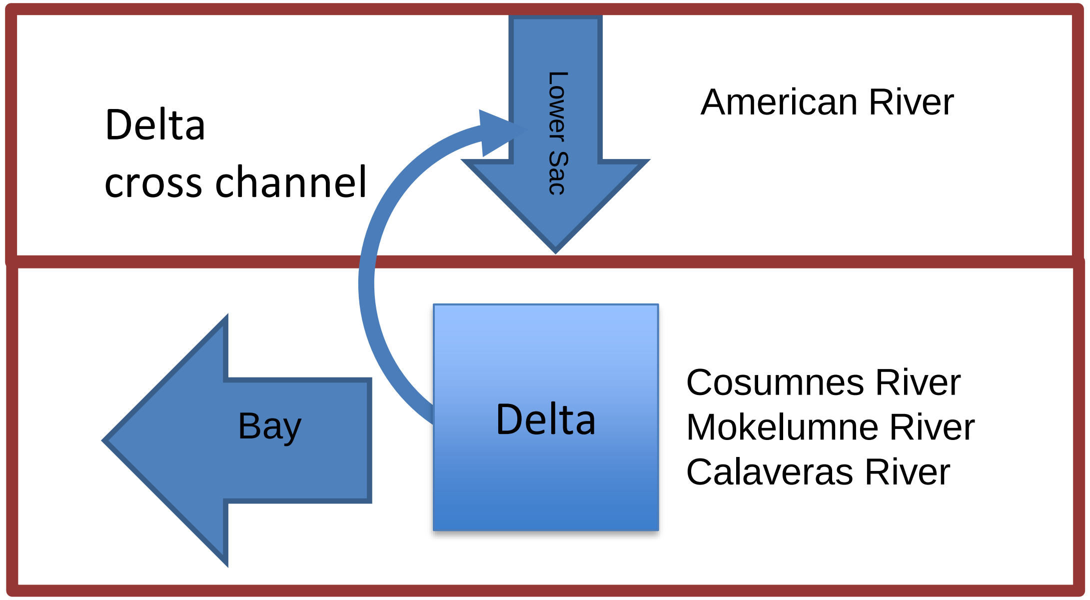
Yolo Bypass Routing Ruleset:

% fish entering from upstream tributaries enter as % flow being diverted

All entrained fish to delta with slightly higher survival than fish entering delta from Sacramento River

Allow for possible American River fish to use bypass

Adult Returns



Central Delta tributary adults can be attracted to delta cross channel to Sacramento River

Straying Central Delta adults different based on distance from DCC

Delta

Separated Delta into 13 zones

North Delta


NRC Research Press

ARTICLE

Flow-mediated effects on travel time, routing, and survival of juvenile Chinook salmon in a spatially complex, tidally forced river delta

Russell W. Perry, Adam C. Pope, Jason G. Romine, Patricia L. Brandes, Jon R. Burau, Aaron R. Blake, Arnold J. Ammann, and Cyril J. Michel

South Delta (2008-2015)


U.S. Fish & Wildlife Service

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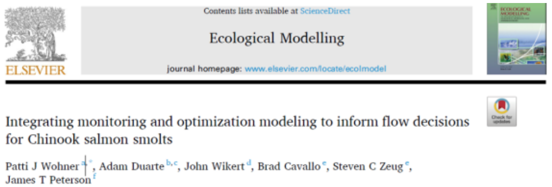
Home | AFRP | Aquatic Invasive Species | Juvenile Fish Monitoring | Juvenile Salmon Survival Studies | San Joaquin River Restoration Program

Juvenile Salmonid Survival Studies


Contents lists available at ScienceDirect

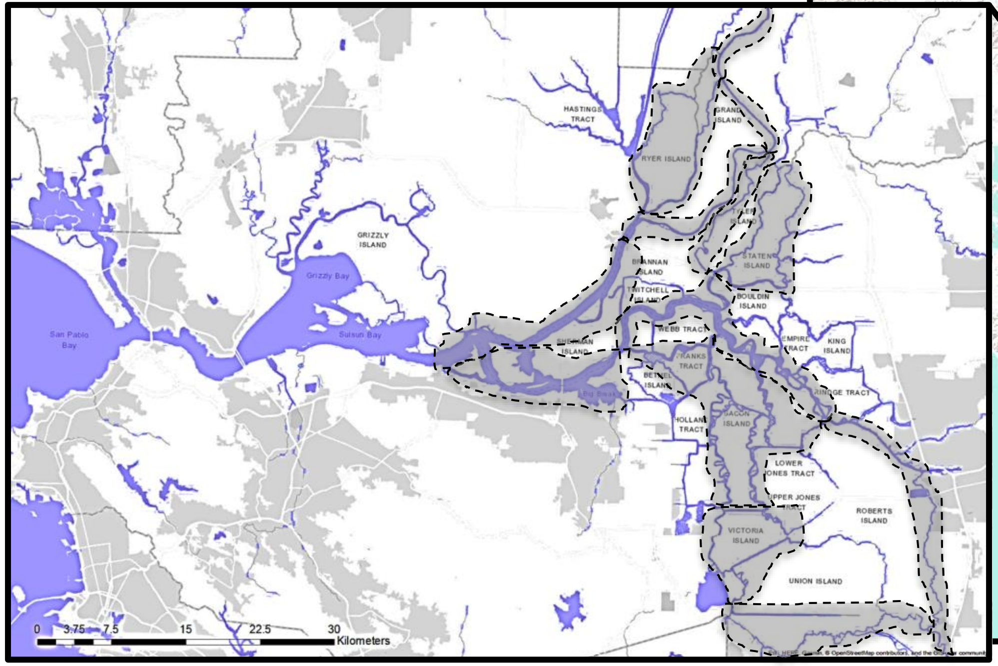
Ecological Modelling

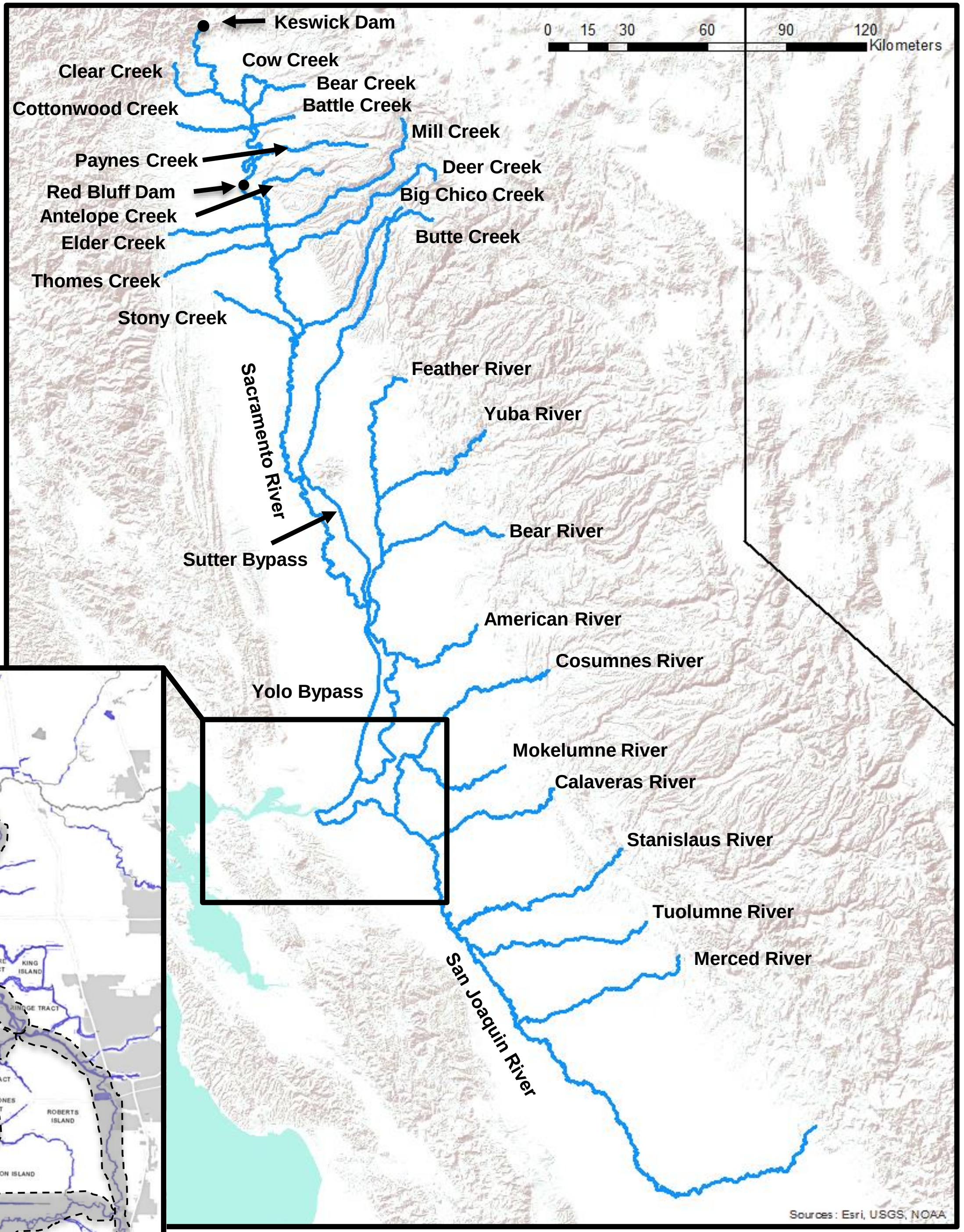
journal homepage: www.elsevier.com/locate/ecolmodel

ELSEVIER

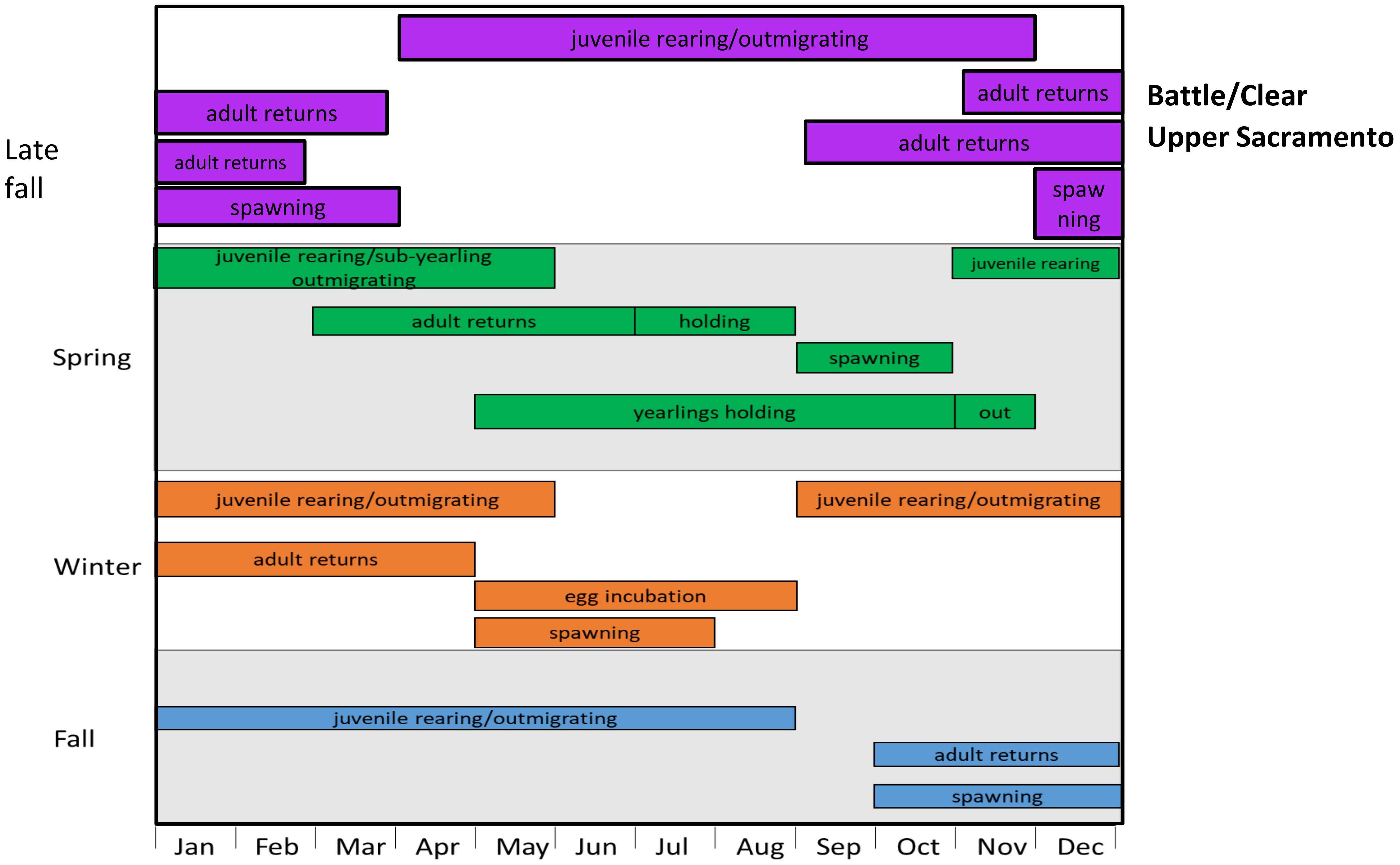
Integrating monitoring and optimization modeling to inform flow decisions for Chinook salmon smolts

Patti J Wohner, Adam Duarte[b,c], John Wikert[d], Brad Cavallo[e], Steven C Zeug[e], James T Peterson





Timing Chinook Salmon



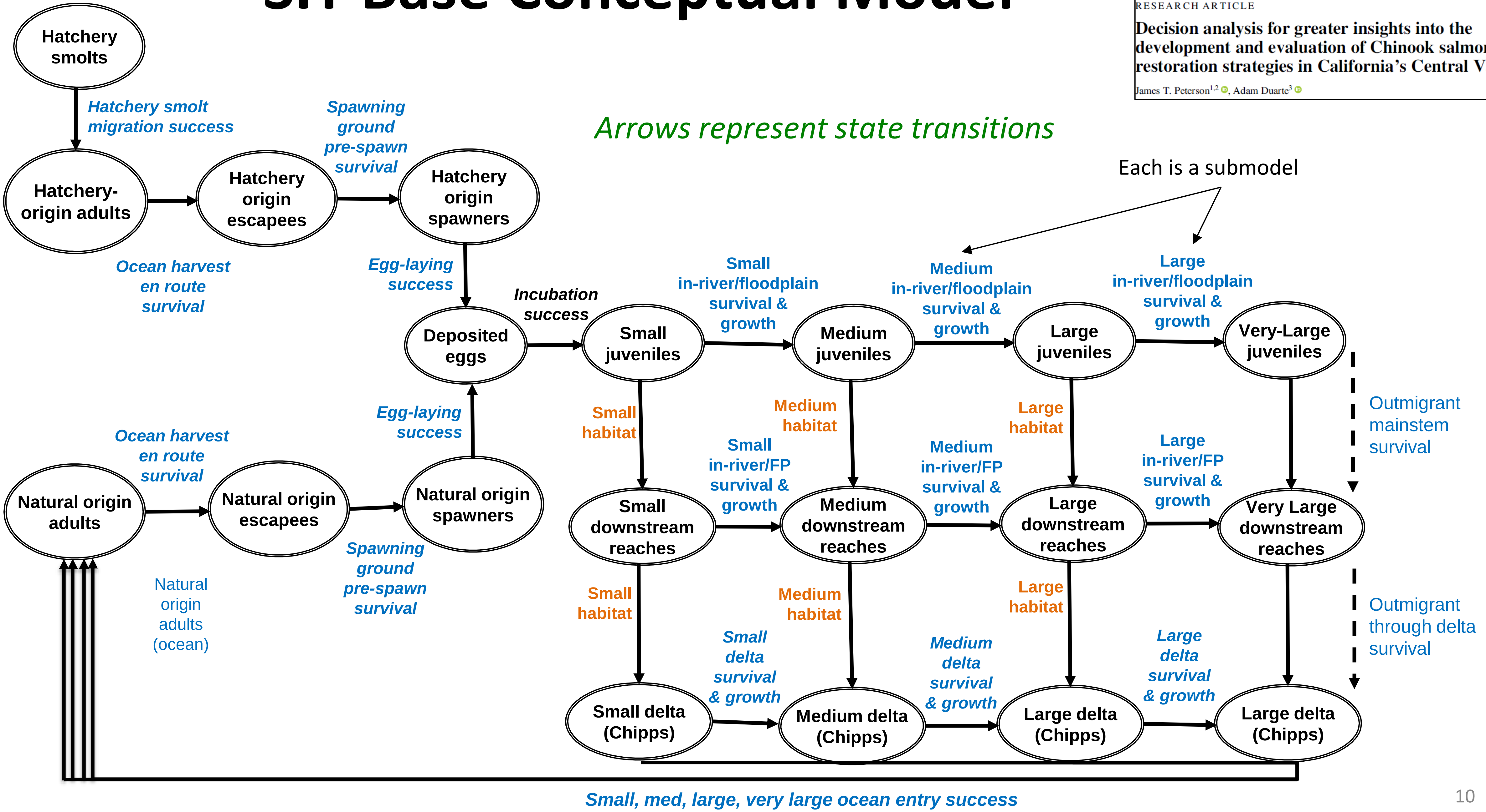
SIT Base Conceptual Model

RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration
SER

RESEARCH ARTICLE

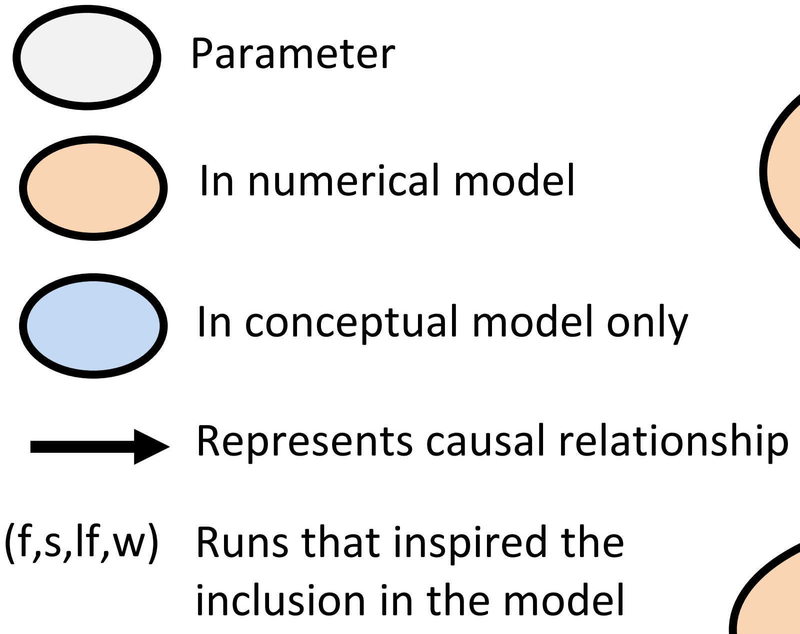
Decision analysis for greater insights into the development and evaluation of Chinook salmon restoration strategies in California's Central Valley

James T. Peterson[1,2], Adam Duarte[3]

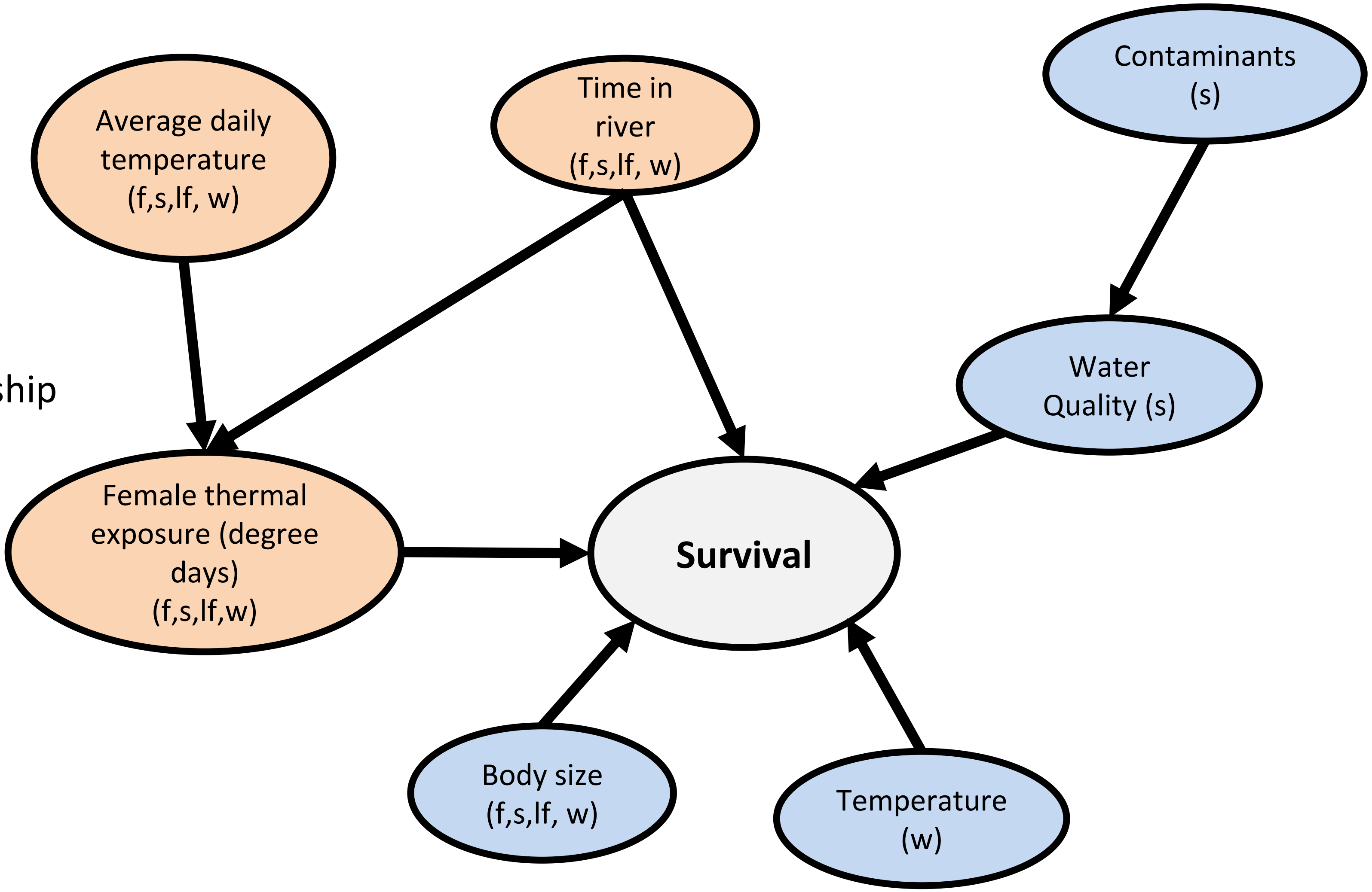


Key to Conceptual Model Slides

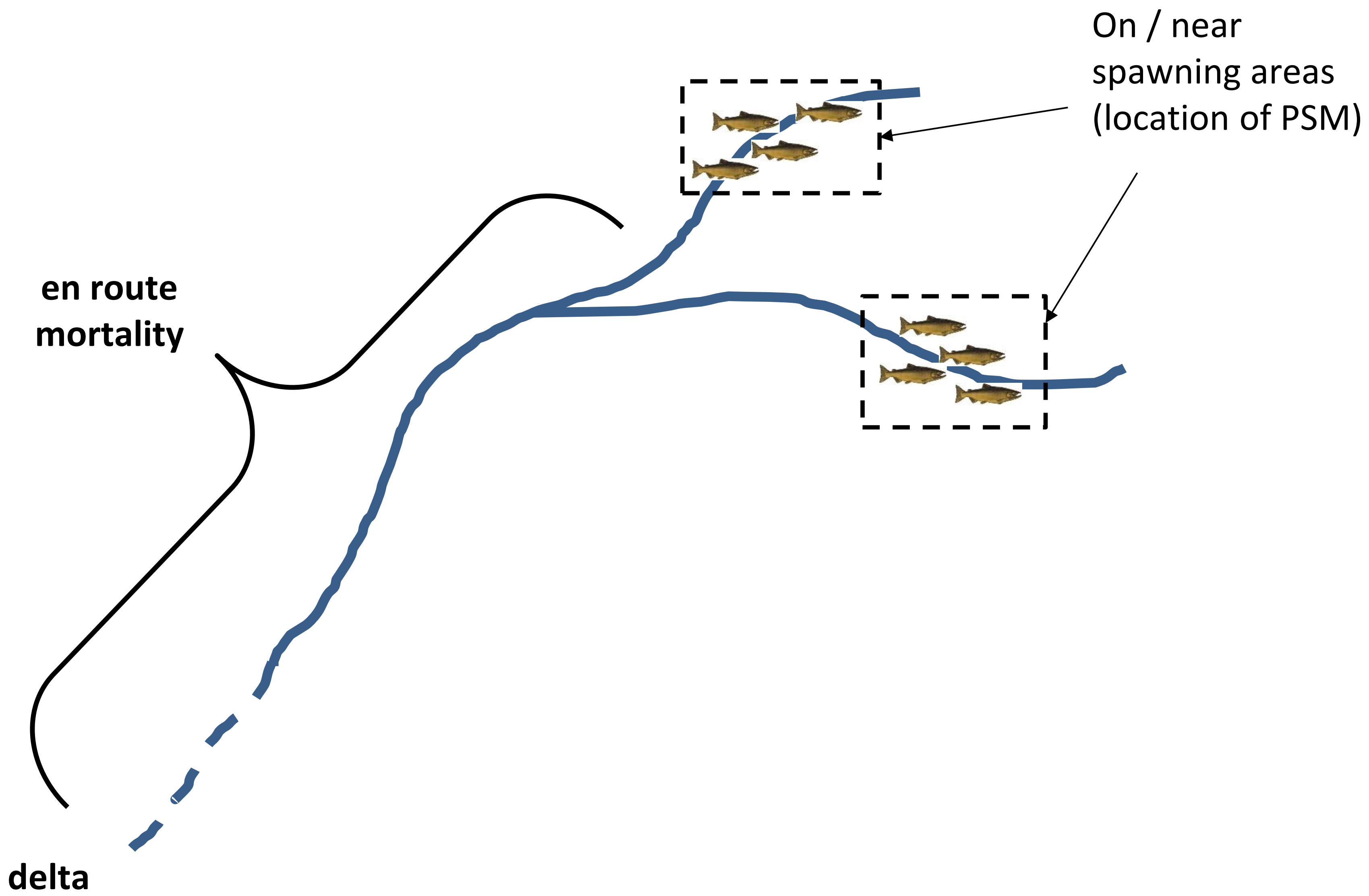
Key



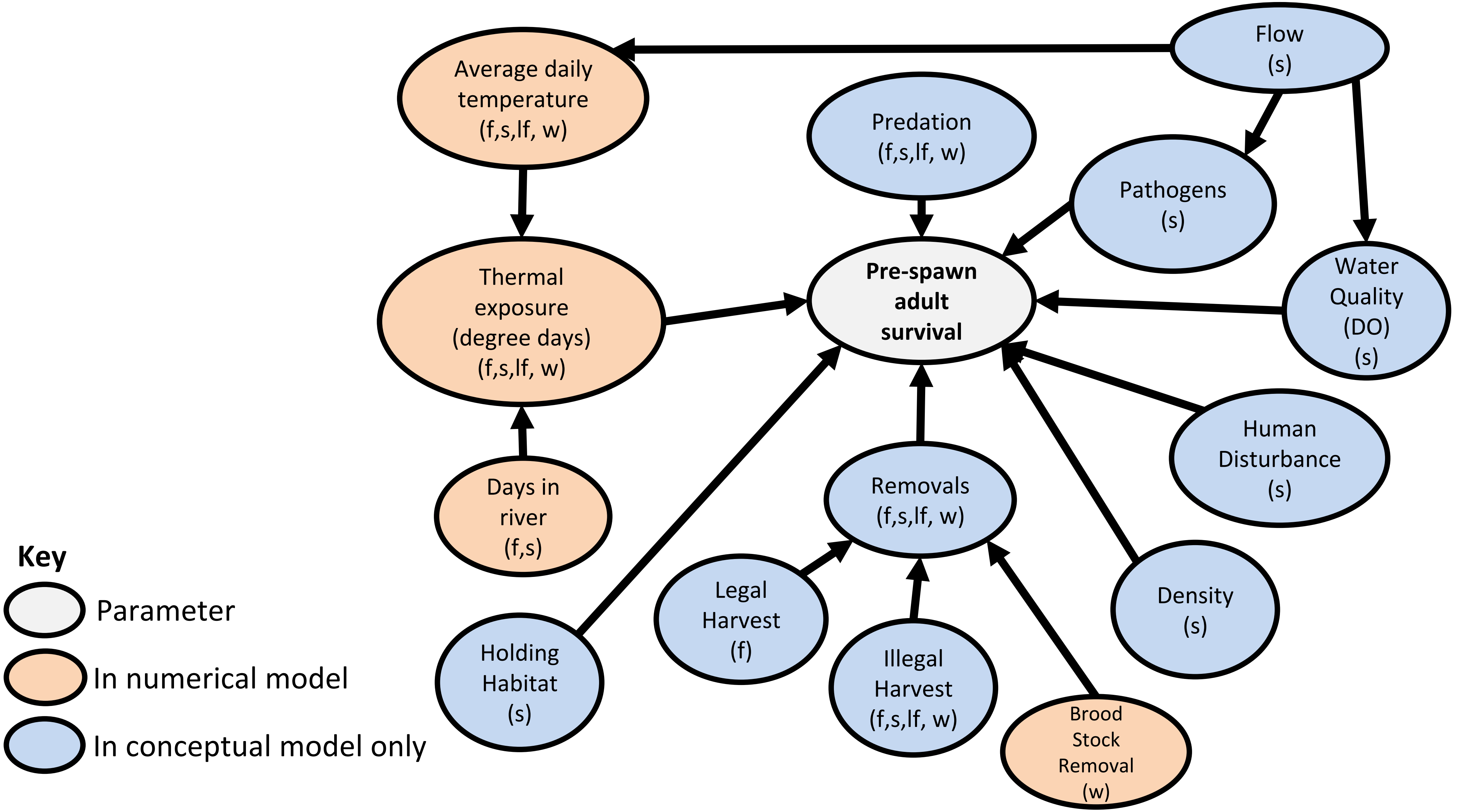
Example Conceptual Model



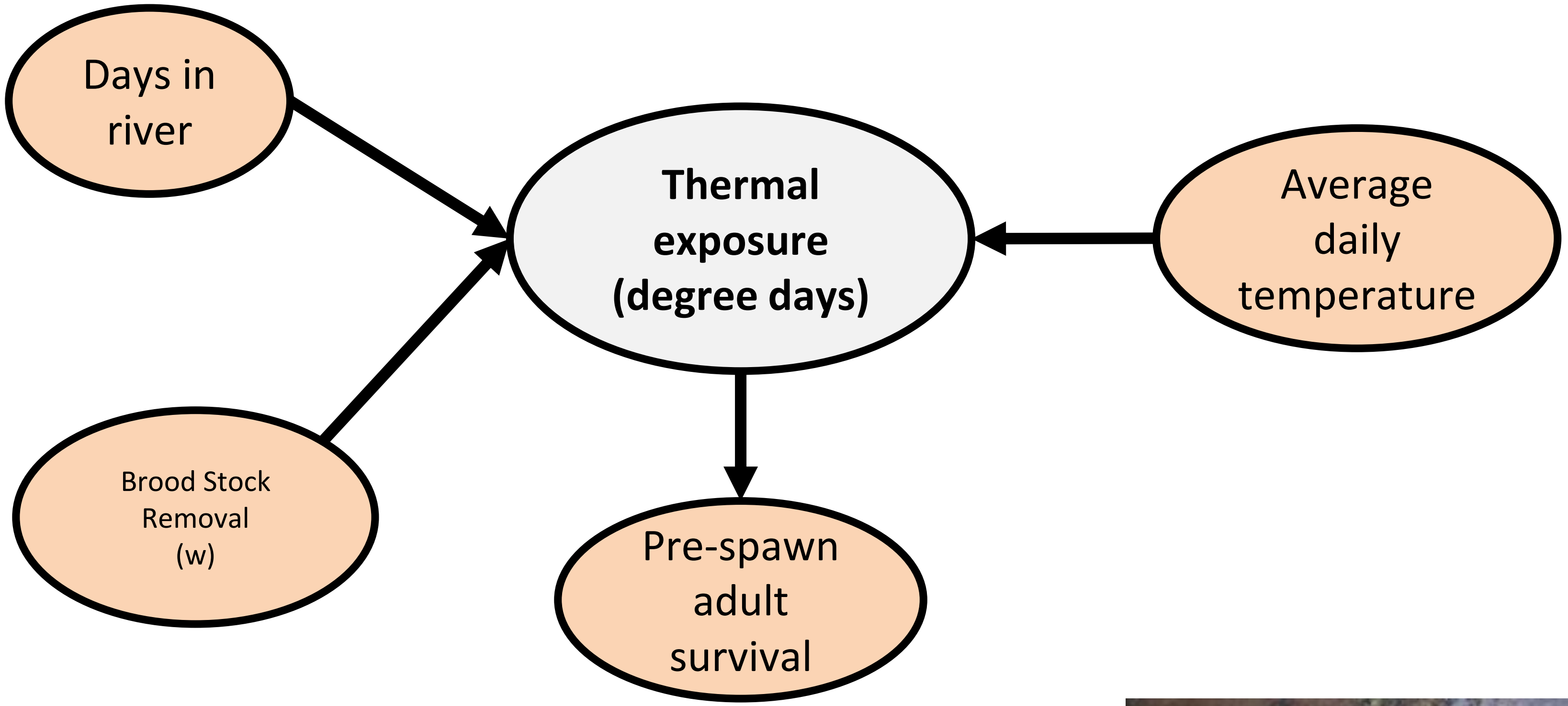
Pre-spawn Mortality (PSM) Definition



Adult Pre-spawn Survival Conceptual Submodel

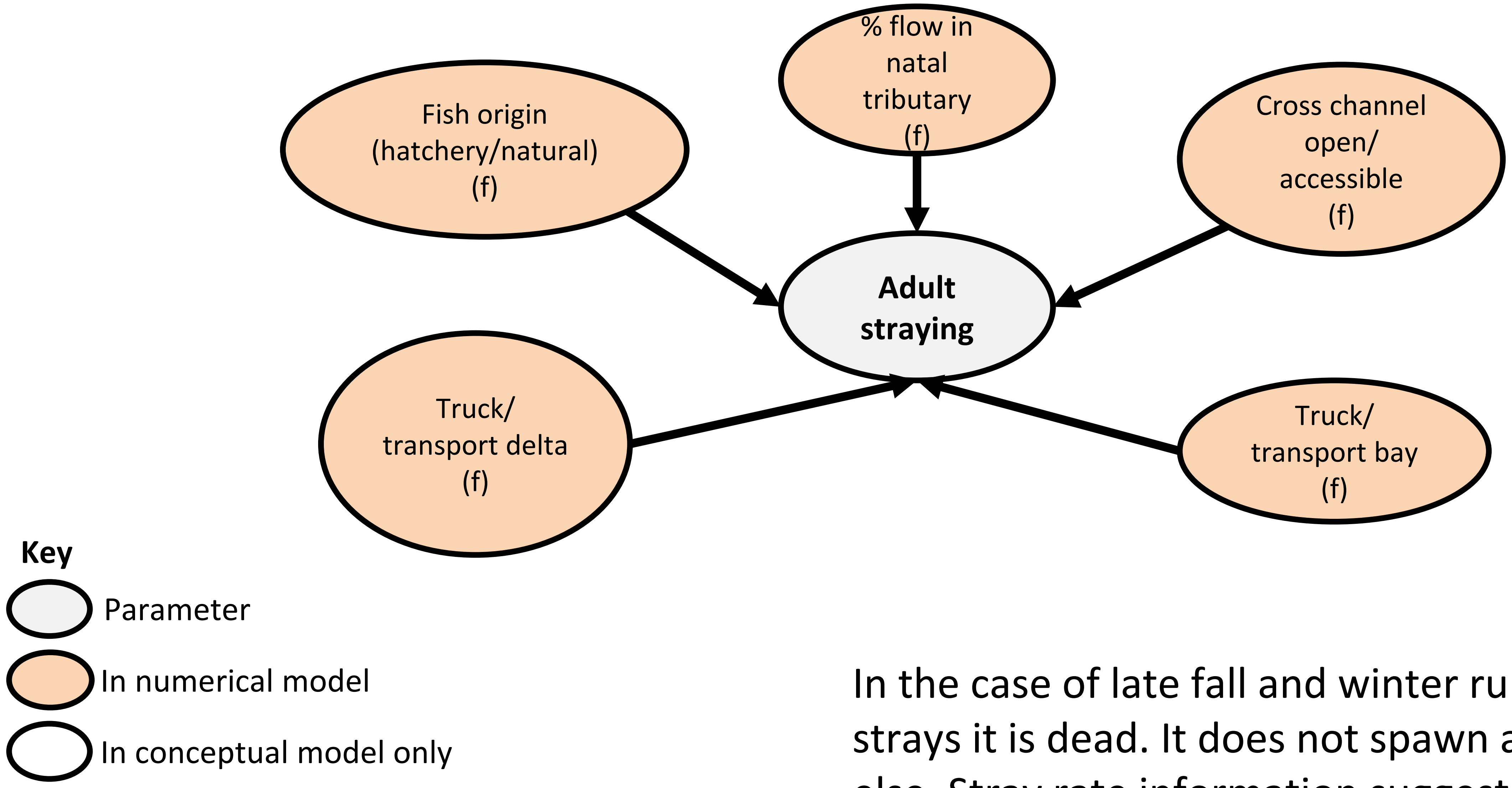


Adult Pre-spawn Survival Numerical Submodel



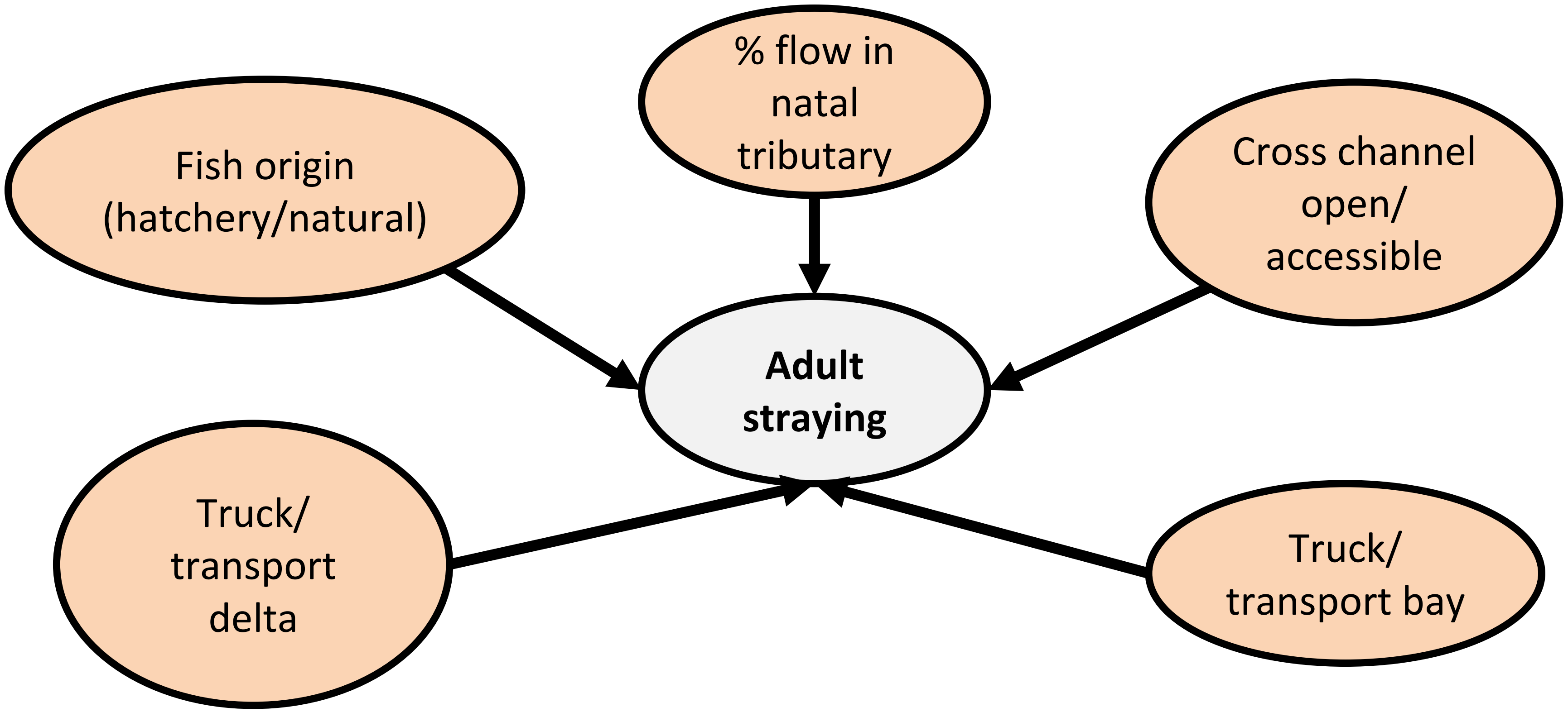
- Parameter estimates from published sources and 2010-2019 CWT analyses

Adult Straying Conceptual Submodel



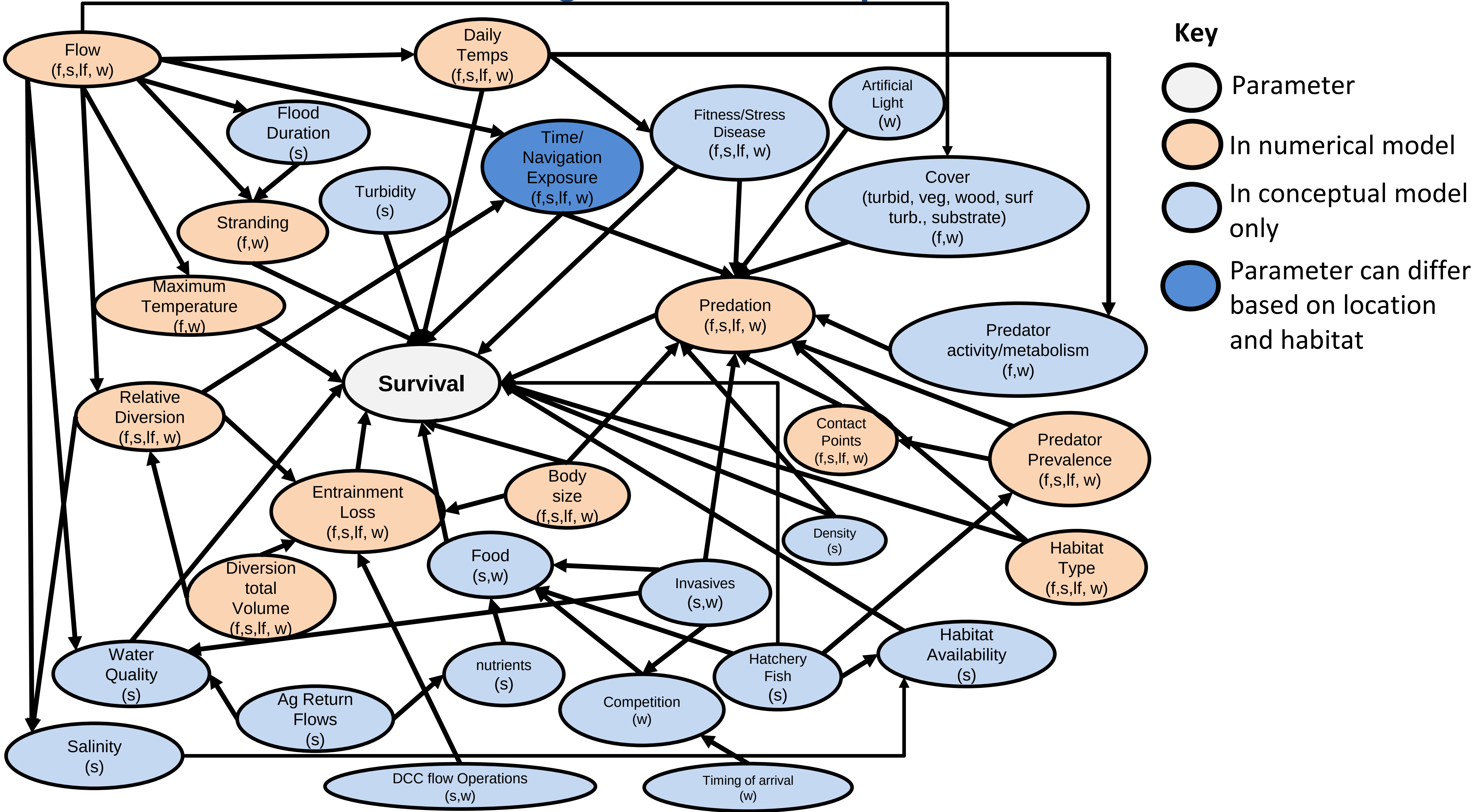
In the case of late fall and winter run, if a fish strays it is dead. It does not spawn anywhere else. Stray rate information suggests it is very very low.

Adult Straying Numerical Submodel

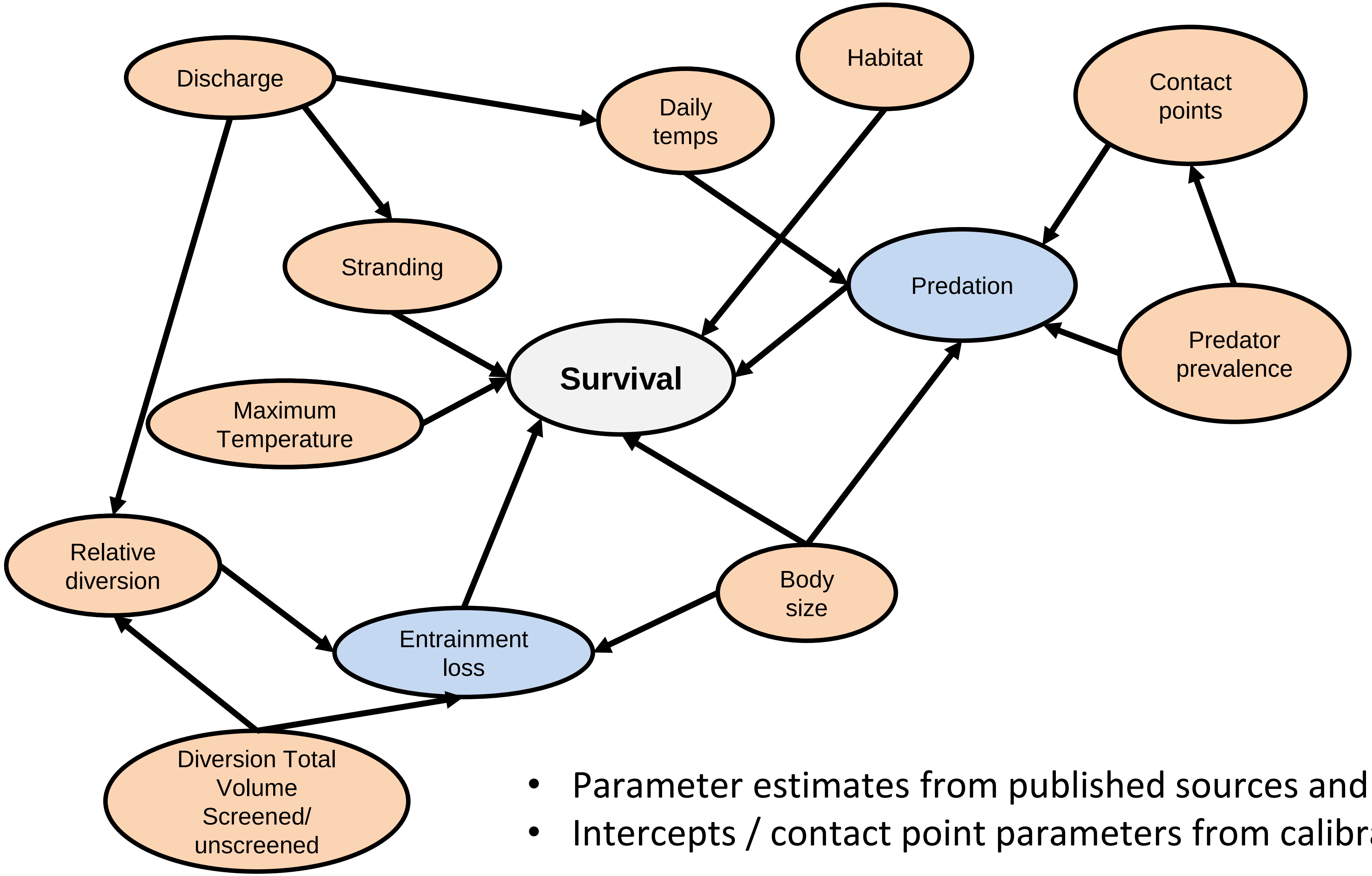


- Hatchery origin adults assigned to watersheds based on average proportion from 2010 – 2019 coded wire tag data used in the Constant Fractional Marking Program.
  - If CWT data were not available for a watershed, the assumed AFRP hatchery proportion was used.
- Remaining parameters estimated using data provided by M. Workman (EBMUD)

Juvenile Rearing Survival Conceptual Submodel



Juvenile Rearing Survival Numerical Submodel

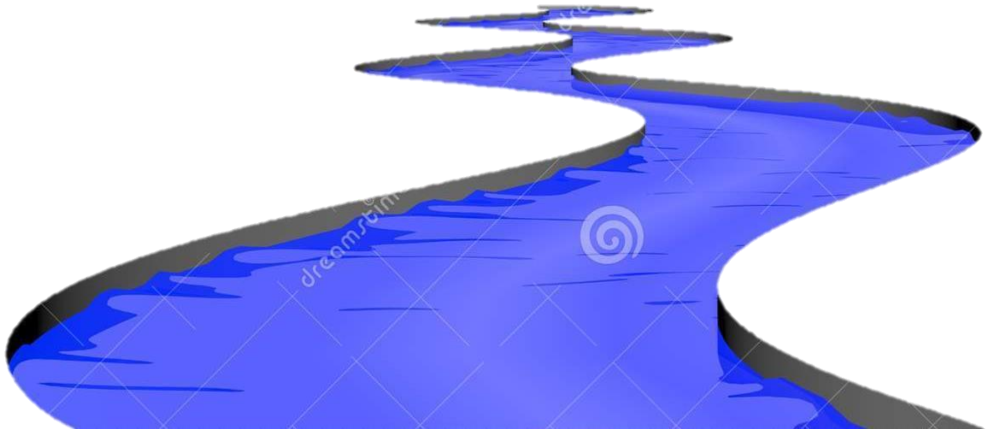


- Parameter estimates from published sources and data analyses
- Intercepts / contact point parameters from calibration

Fish Habitat Use and Movement Out of Tributaries, Reaches, Bypasses, and Delta

Rule set used (defined as base fill, see next slide)

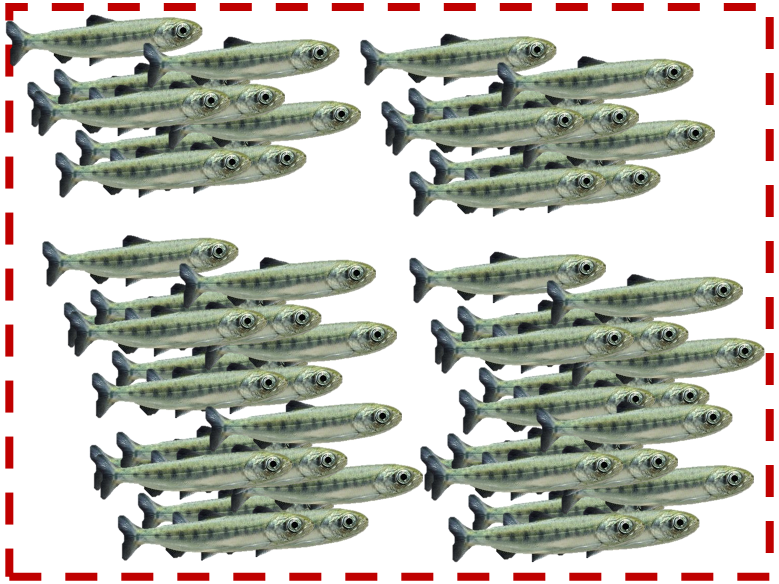
- Once a fish (assigned to floodplain habitat) grows to size class 3: Move out of area
- Once a fish (assigned to in-channel habitat) reaches size class 2: Move out of area (except for low elevation tribs. leave at size 3)
- No Habitat: Send out of location
- Bypass rules: % fish movement into = % discharge entering bypass



How fish currently move under the <u>Base fill</u> ruleset

<u>What does this all mean?</u>

- If we grow fish fast, fish leave earlier due to habitat capacity regardless of other environmental conditions
- Fish fill habitats regardless of other environmental conditions
- It is using a ceiling model for density dependence



Snow Globe Movement

NRC Research Press

ARTICLE

Science for integrative management of a diadromous fish stock: interdependencies of fisheries, flow, and habitat restoration

Stuart H. Munsch, Correigh M. Greene, Rachel C. Johnson, William H. Satterthwaite, Hiroo Imaki, Patricia L. Brandes, and Michael R. O'Farrell

Fry sized fish

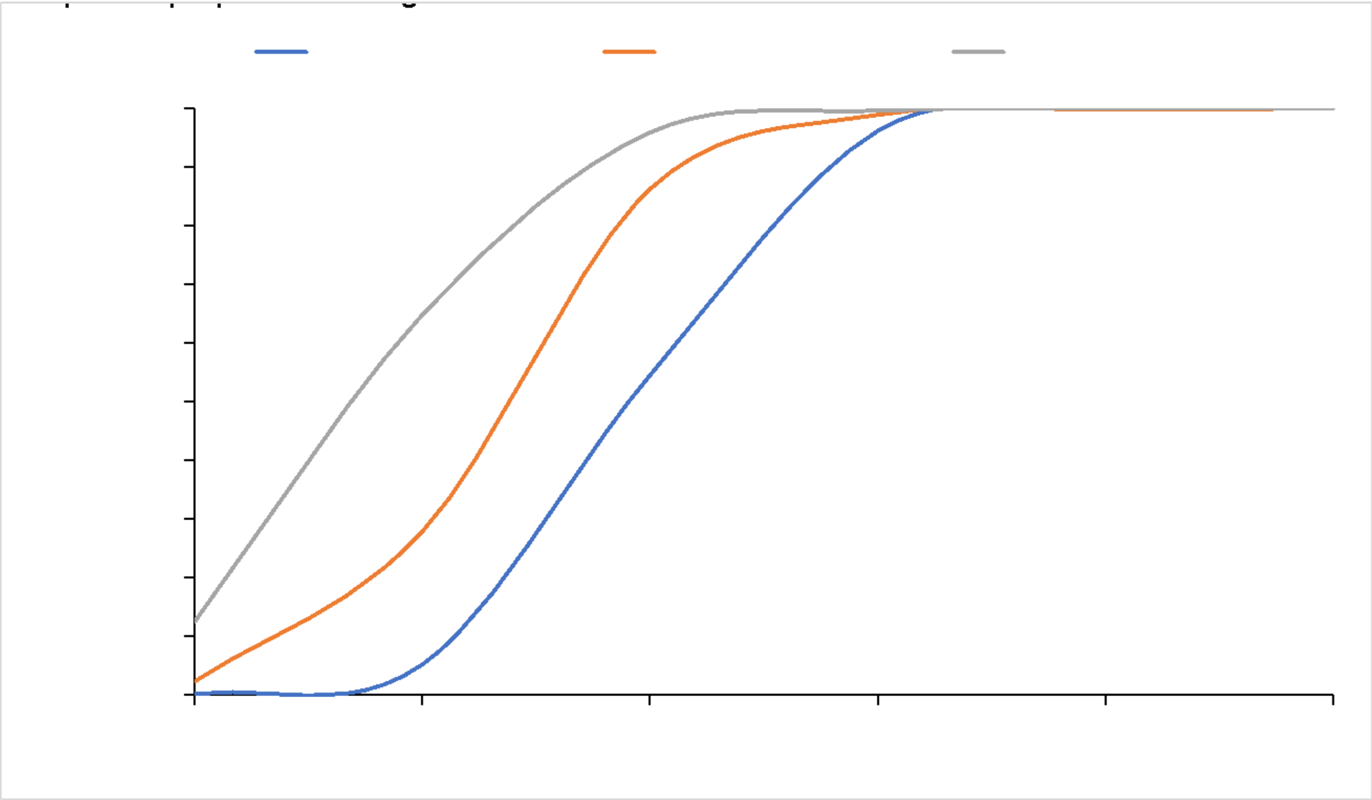
Flow-based

Freeport + Vernalis discharge > 1000 cms⍰ 30% fish distribute downstream reach

Vary threshold and % fish during sensitivity analysis

Temperature Movement

Chipps Island Trawl cumulative fall-run catch 2002-2018
Mean monthly temperature @ Freeport
Pr(leave) ~ Month + Temperature + Month*Temperature



Fall Run: Habitat use/ movement combinations

- Weight each equally and combine

- Hypothesis 1: Base fill + No Additional Movement
- Hypothesis 2: Base fill + Snow Globe Movement
- Hypothesis 3: Base fill + Temperature Movement
- Hypothesis 4: Density fill + No Additional Movement
- Hypothesis 5: Density fill + Snow Globe Movement
- Hypothesis 6: Density fill + Temperature Movement

Spring Run: Yearling life History

Fry leave natal tributaries and rear in the Sacramento and delta using habitat filling rules identical to fall run, with some notable exceptions:

- Small- and medium-sized fish that are rearing in their natal tributary in the last month exhibit a yearling life history strategy.
- Yearling fish continue to experience habitat-specific mortality over the summer, but growth does not resume until September.
- In November, yearling fish immediately migrated to the ocean.

Late fall Run: Timing and life history

Hypotheses

1) Majority leave as fry. Stick around upper Sacramento down to GCID
2) Evidence of majority holding above RBDD
3) Movement could be genetic where a certain portion juveniles holding
4) Water temp influences movement
   - Could be related to thermal block ~18-20 C [might compare GCID fish to temps]
   - Unnatural cold water upstream hold fish

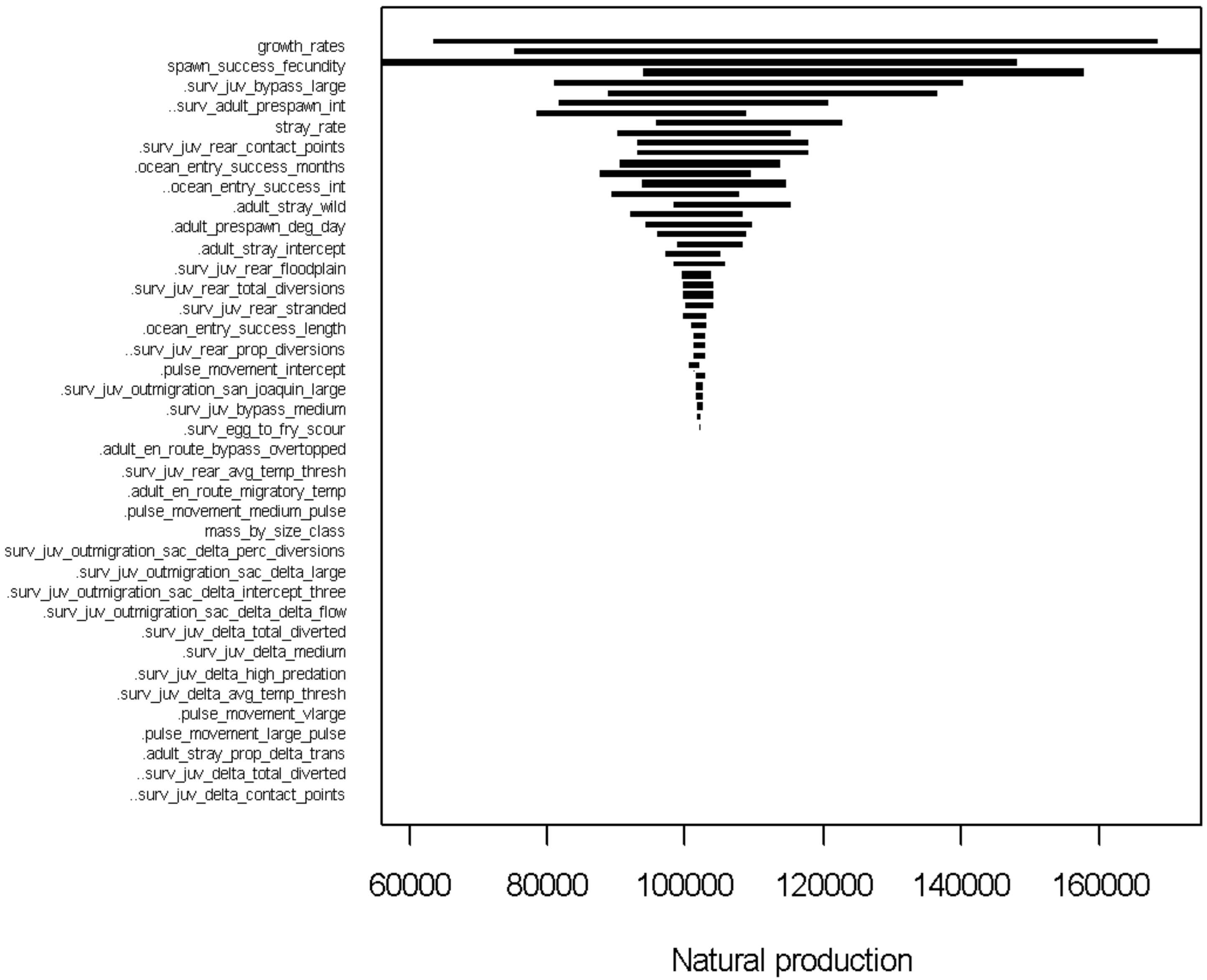
Late Fall Run: alternative movement hypotheses

Alternative juvenile dynamics

1) Fry leave natal tributaries and rear in the Sacramento and delta using habitat filling rules identical to fall run.
2) Fry leave natal tributaries and rear in the Sacramento with 25% migrating below RBBD rear in Sacramento and delta.
3) Fry leave natal tributaries and rear in the Sacramento and delta but they do not pass an downstream segment is temperatures > 18 C.

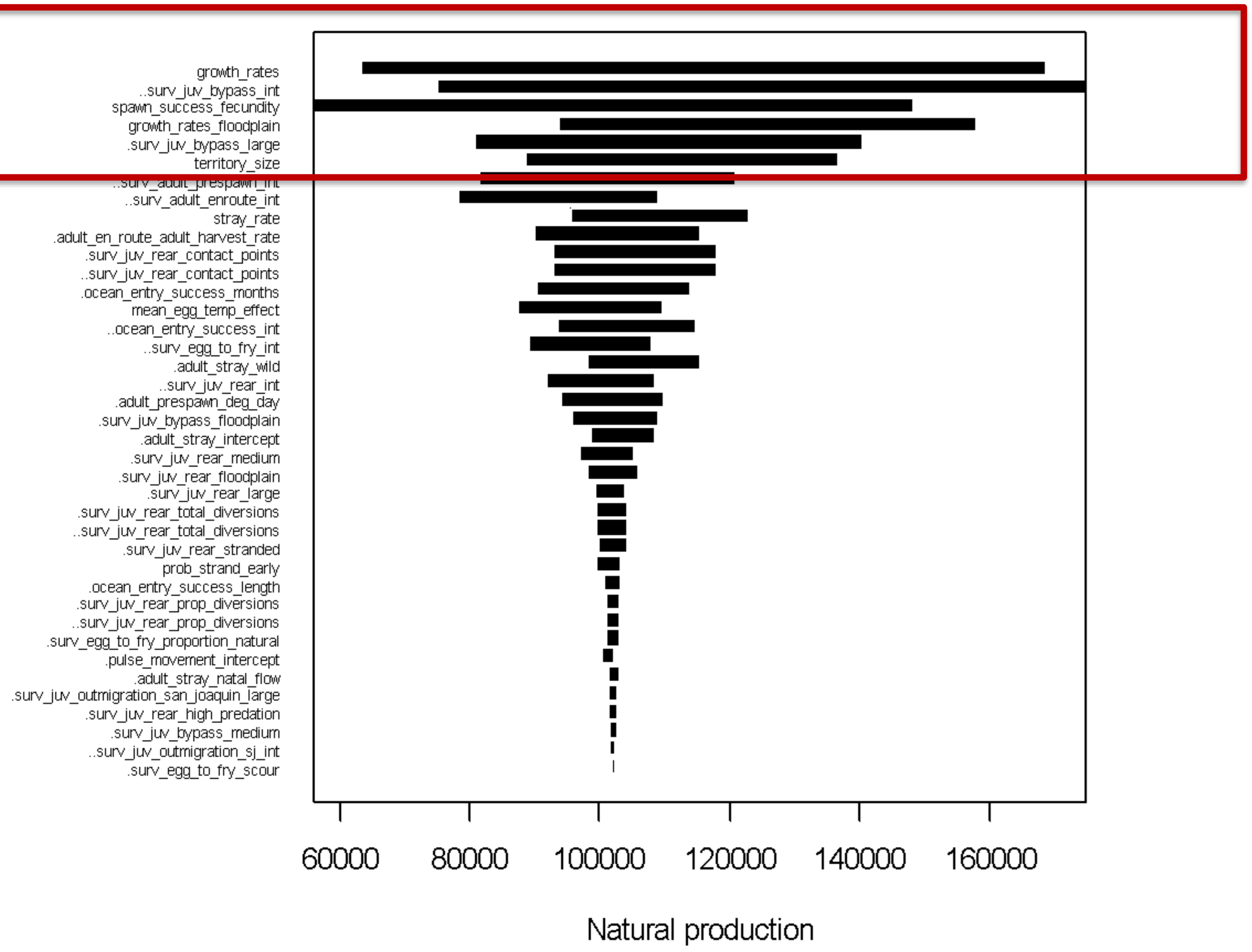
- Give each equal weight and average
- Sensitivity analysis

Fall-run Parameter Sensitivity Analysis



Fall-run Parameter Sensitivity Analysis

Reduced version



Inputs to Chinook Models

All inputs to the Chinook salmon models are documented and available online via these links:

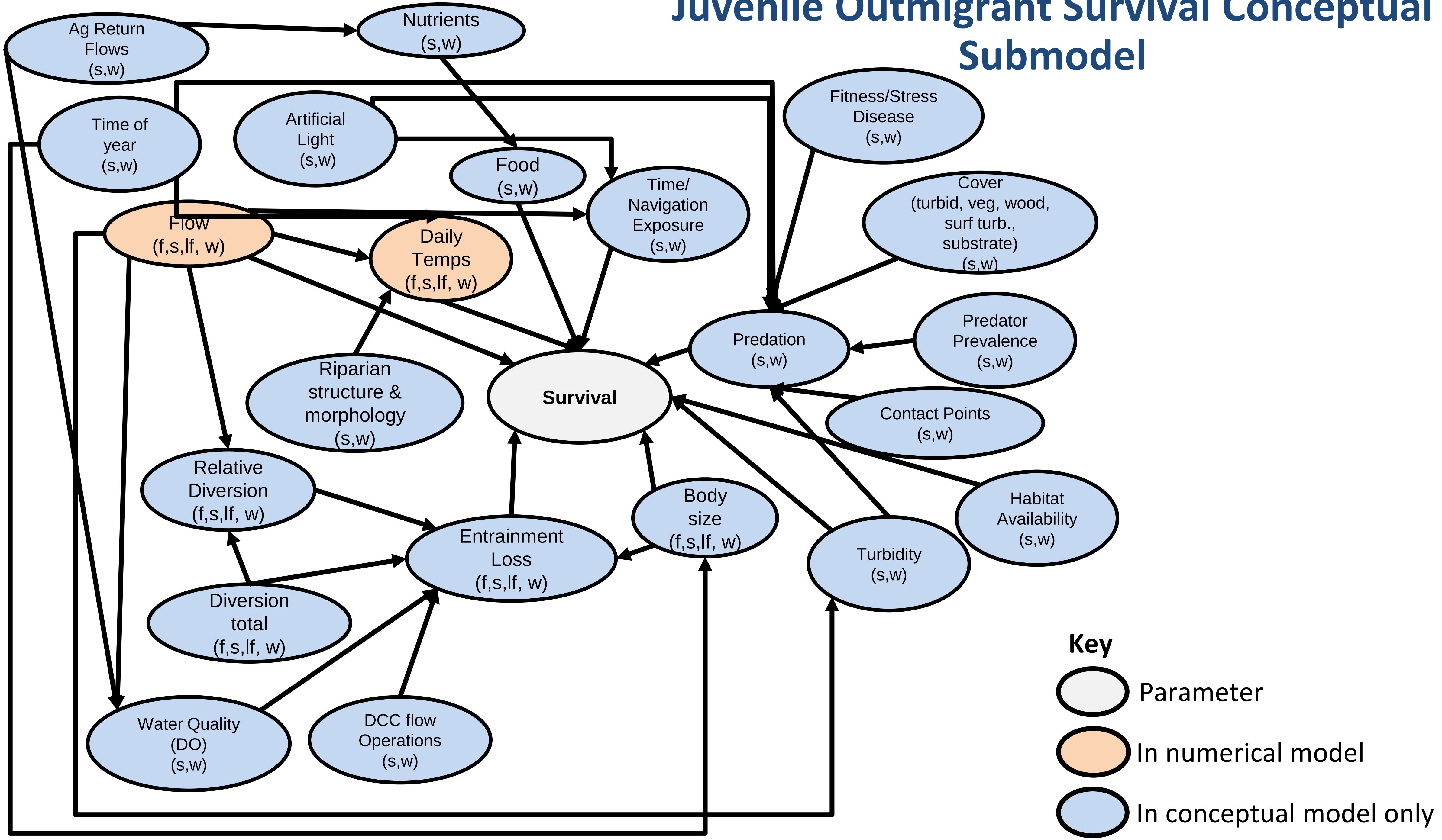
Source information and visualization of model inputs
https://flowwest.shinyapps.io/cvpia-model-inputs/

Modeled water temperatures
https://cvpia-osc.github.io/DSMtemperature/

Habitat availability linked with discharge from IFIM and other studies
https://cvpia-osc.github.io/DSMhabitat/ and details

Water diversion and discharge from empirical databases (CalSim, CalLite)
https://cvpia-osc.github.io/DSMflow

Juvenile Outmigrant Survival Conceptual Submodel

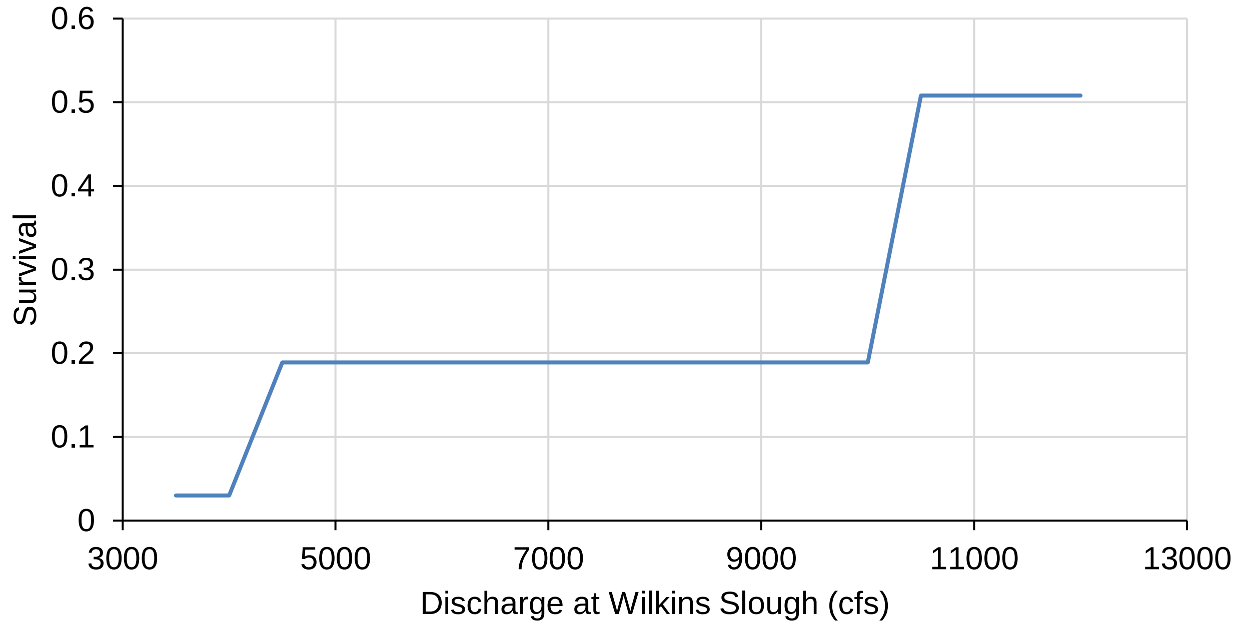


Juvenile Outmigrant Survival Numerical Submodel

Parameter estimates from data analyses by C. Michel.

Survival should vary in response to flow in the Sacramento River, with a step function. Specifically, survival for acoustic tagged spring-outmigrating (i.e., fall-run and spring-run) salmon smolts in the upper Sacramento (Deer Ck confluence to Verona):

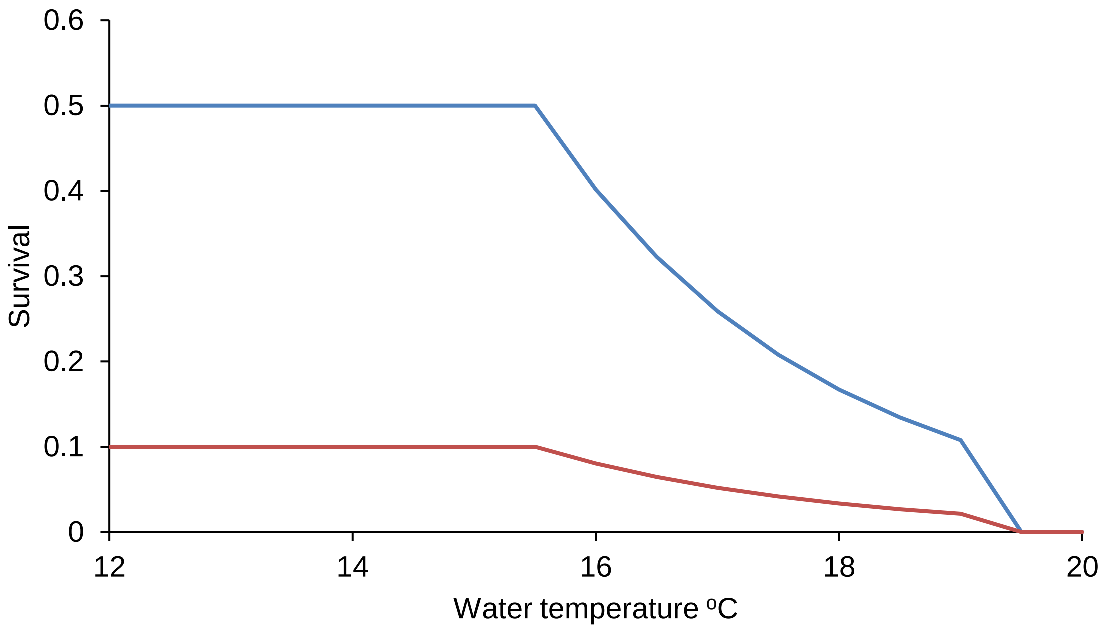
- 3.0% for flows below 4,259 cfs as measured at Wilkins
- 18.9% for flows between 4,259 and 10,712 cfs
- 50.8% for flows above 10,712 cfs.



Temperature vs. survival relationship for the Delta Rearing

Change temperature: survival relationship for juvenile salmon Delta survival:

- 50% survival below 15.5 degrees C for Sacramento basin fish, 10% survival for San Joaquin basin fish (based on telemetry estimates)
- decreasing by a factor of 1.55 per degree Celsius increase up to 19.5C, at which point survival goes to zero above 19.5.



Chinook Delta Routing and Survival (actively migrating smolts)

Movement and survival parameters

North Delta

NRC Research Press

1

ARTICLE

Flow-mediated effects on travel time, routing, and survival of juvenile Chinook salmon in a spatially complex, tidally forced river delta

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South Delta (2008-2015)

ELSEVIER

Ecological Modelling

Volume 471, September 2022, 110058

Integrating monitoring and optimization modeling to inform flow decisions for Chinook salmon smolts

Patti J Wohner [a], Adam Duarte [b c], John Wikert [d], Brad Cavallo [e], Steven C Zeug [e], James T Peterson [f]

Chinook Delta Routing and Survival

North Delta Routing & Survival

North delta
- Yolo entrainment
- Sutter/steamboat
- Delta Cross Channel*
- Georgiana Slough

} *f*(discharge Freeport)

* DCC open/closed

Chinook Delta Routing and Survival

South Delta Routing

Head of old river ~ f(physical barrier, discharge Vernalis)

Turner cut ~ f(discharge at Stockton)

SWP entrainment ~ f(exports)

CVP entrainment ~ f(pumps operating)

South Delta Survival

Varied by region

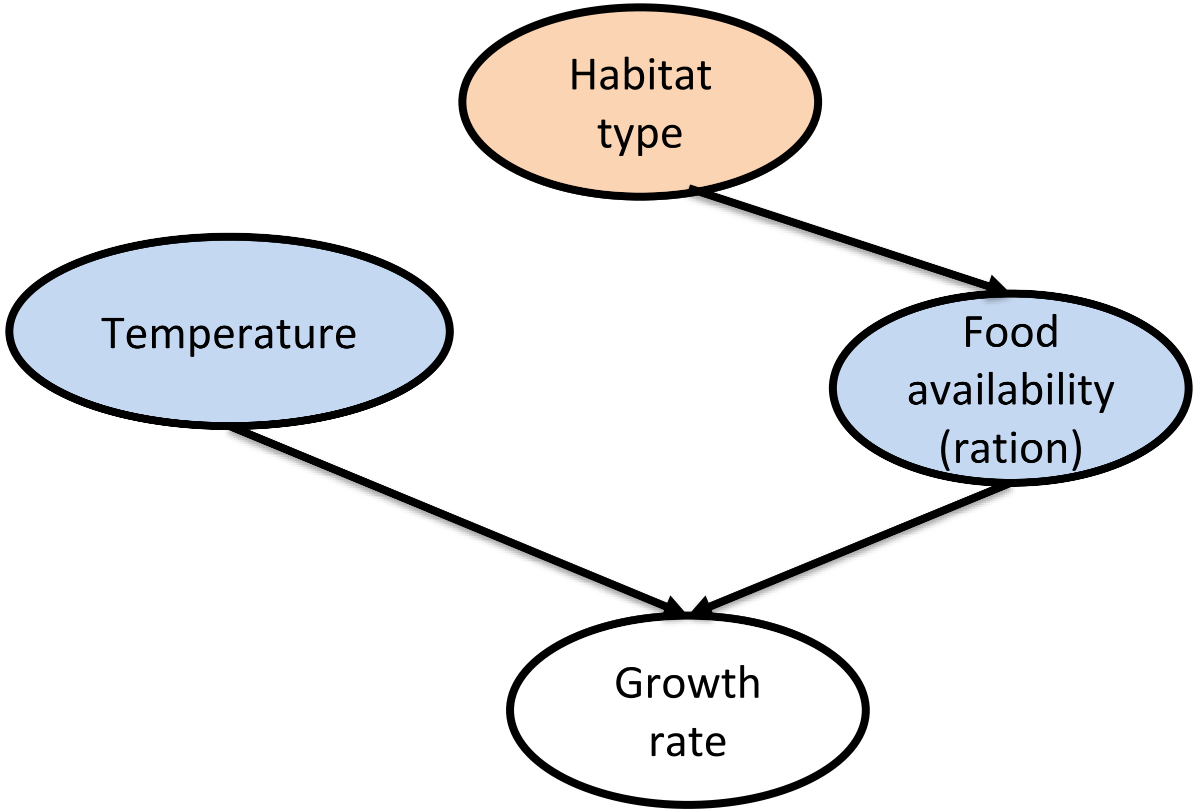
Q Vernalis, Temperature Vernalis & Prisoners Point

(meta-analysis of tagging data)

Water project specific estimates published studies

Juvenile growth numerical submodel

- Phillis, et al. Bioenergetics model



In-channel, 10 degrees C

Median prey density

	s	m	l	vl
s	0.953	0.047	0.000	0.000
m	0.000	0.982	0.018	0.000
l	0.000	0.000	0.980	0.020
vl	0.000	0.000	0.000	1.000

High prey density

	s	m	l	vl
s	0.582	0.418	0.000	0.000
m	0.000	0.863	0.137	0.000
l	0.000	0.000	0.866	0.134
vl	0.000	0.000	0.000	1.000

Max prey density

	s	m	l	vl
s	0.052	0.946	0.002	0.000
m	0.000	0.565	0.435	0.000
l	0.000	0.000	0.719	0.281
vl	0.000	0.000	0.000	1.000

Floodplain, 10 degrees C

Median prey density

	s	m	l	vl
s	0.582	0.418	0.000	0.000
m	0.000	0.863	0.137	0.000
l	0.000	0.000	0.866	0.134
vl	0.000	0.000	0.000	1.000

High prey density

	s	m	l	vl
s	0.050	0.949	0.001	0.000
m	0.000	0.569	0.431	0.000
l	0.000	0.000	0.709	0.291
vl	0.000	0.000	0.000	1.000

Max prey density

	s	m	l	vl
s	0.056	0.940	0.004	0.000
m	0.000	0.561	0.439	0.000
l	0.000	0.000	0.717	0.283
vl	0.000	0.000	0.000	1.000

Chinook Salmon DSM Calibration and Model Results

as of August 2024

Candidate Restoration Strategies Summary

Strategy	Description
0	Implement no restoration
1	Juvenile perrennial habitat restoration focused in upper and lower-mid Sacremento River; Butte, Deer and Battle Creeks; and the Stanislaus and Feather Rivers
2	Juvenile perrennial habitat restoration focused in upper and lower-mid Sacremento River; Butte, Deer and Clear Creeks; and the Stanislaus and Feather Rivers
3	Juvenile perrennial habitat restoration focused in upper and lower-mid Sacremento River; Butte and Clear Creeks; and the Stanislaus, Mokelumne, and Feather Rivers
4	Juvenile perennial habitat restoration focused in the mainstem Sacramento and San Joaquin Rivers
5	Juvenile perennial habitat restoration focused in the upper, upper-mid, and lower-mid Sacramento River and Cow and Clear Creeks
6	Juvenile perennial habitat restoration focused in the upper and lower-mid Sacramento River; American River; and Clear Creeks with maintaining existing habitat in Clear and Butte Creeks and the Upper Sacramento River.
7	Juvenile seasonally-inundated habitat restoration focused in the mainstem Sacramento and San Joaquin Rivers
8	Optimal habitat restoration actions for winter run in the mainstem Sacramento with an emphasis on the the Sacramento River below Red Bluff
9	Optimal habitat restoration actions for spring run in the upper-mid and lower Sacramento River; Battle, Butte, Clear, Deer, Mill, and Antelope Creeks; and the Feather River with an emphasis on the Sacramento River and Battle, Butte, and Clear Creeks
10	Optimal habitat restoration actions for spring run in the upper-mid Sacramento River and Battle, Butte, Clear, Deer, Mill, and Antelope Creeks; and the Feather River equally allocated across tributaries
11	Optimal habitat restoration actions for fall run with at least one action per year in a tributary in each diversity group
12	Optimal habitat restoration actions for fall run in the upper and lower Sacramento River and the American, Stanislaus, and Calaveras Rivers equally allocated across tributaries
13	Optimal habitat restoration actions for fall run in the upper and lower Sacramento River and the American, Stanislaus, and Mokelumne Rivers equally allocated across tributaries

Review Revised Chinook Model Calibration/Sensitivity

Calibrated using empirical escapement estimates (GrandTab) from 1998–2017 plus adjusted Yuba estimates

Parameters estimated using a genetic algorithm

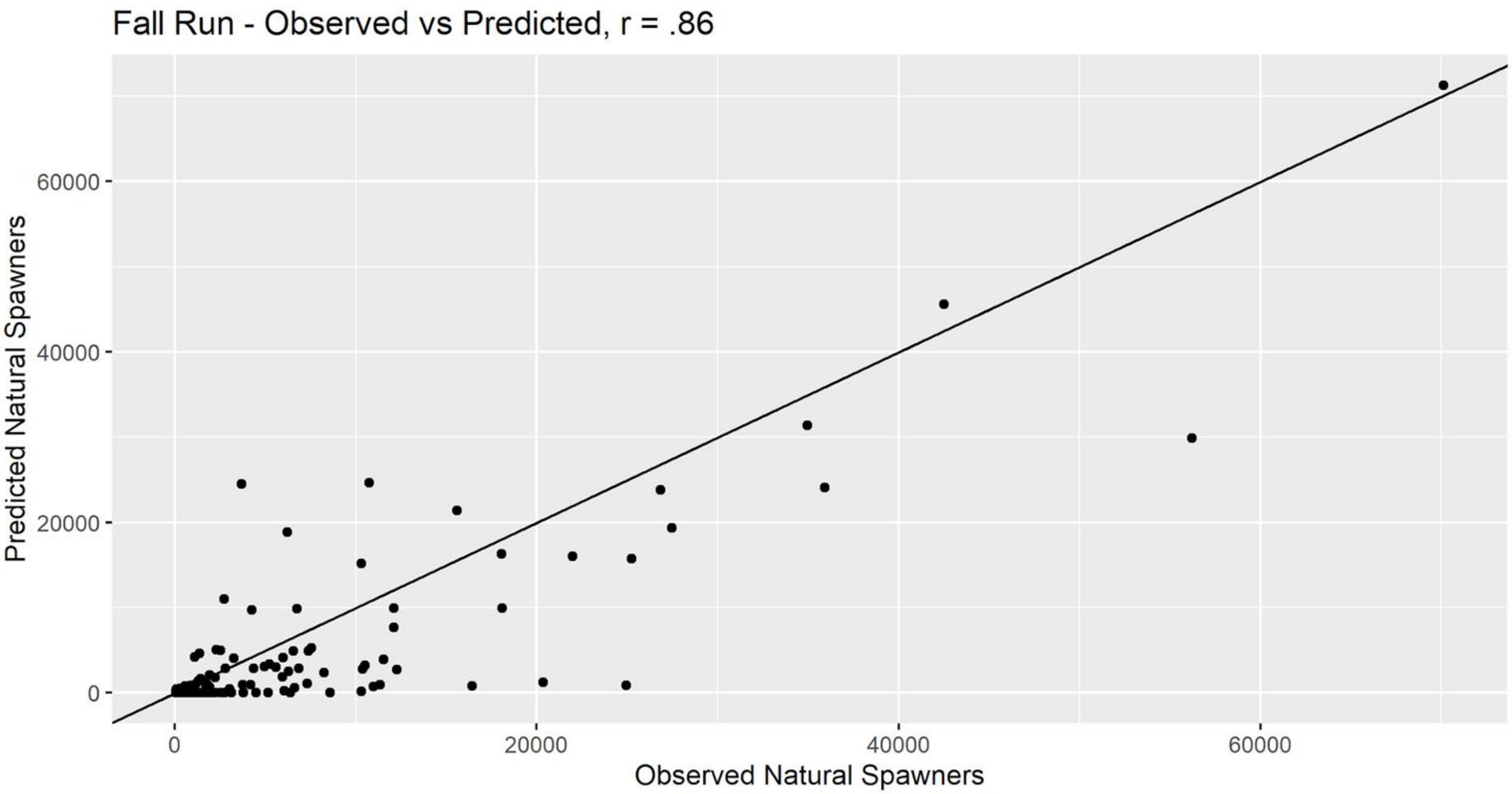
Examined predicted and observed adult escapement

- Minimized the sum of squared differences

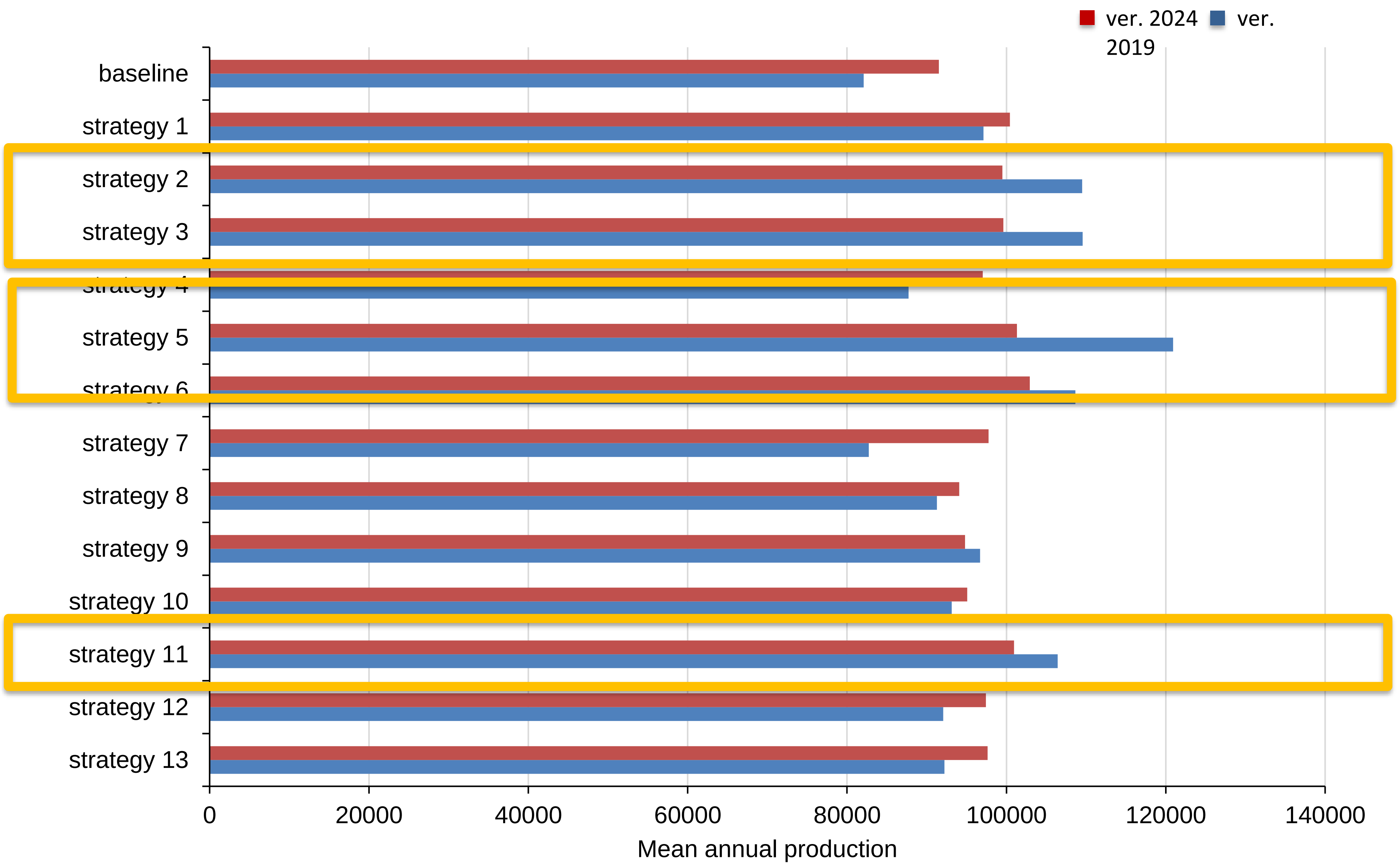
Calibration of Chinook DSM

- Parameters estimated: Intercepts for
  - juvenile rearing survival in tributaries (each separately where data exist)
  - juvenile rearing survival the delta
  - juvenile outmigrant survival mainstem (Sac. and SJ separately)
  - juvenile outmigrant survival through delta
  - adult en route survival
  - ocean entry survival
  - contact points vs juvenile survival (due to predation),
  - proportion water diverted vs juvenile rearing survival (trib)
  - total amount of water diverted vs juvenile rearing survival (trib),
  - the effect of total amount of water diverted on juvenile delta rearing survival.

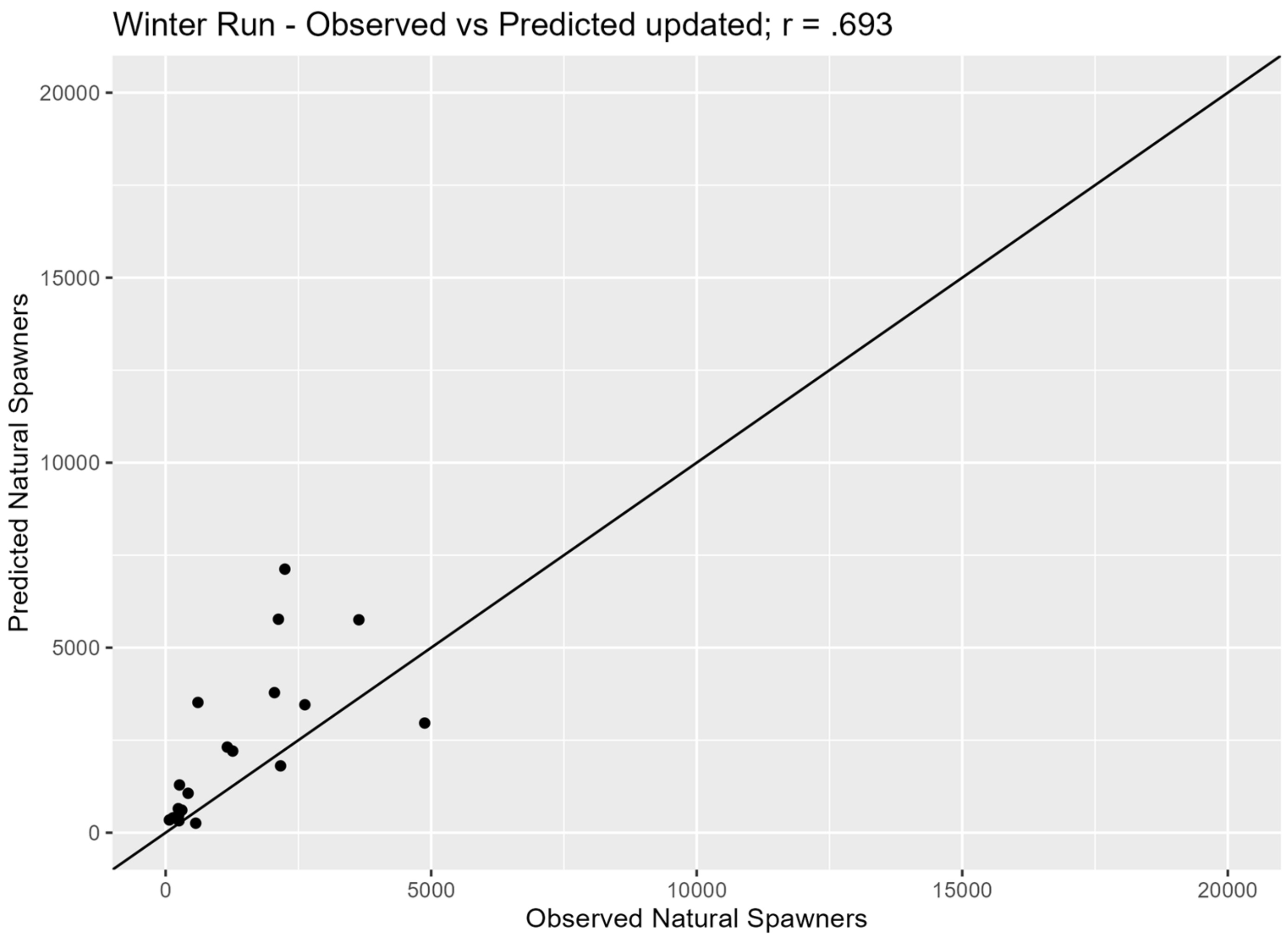
Fall Run Calibration Results



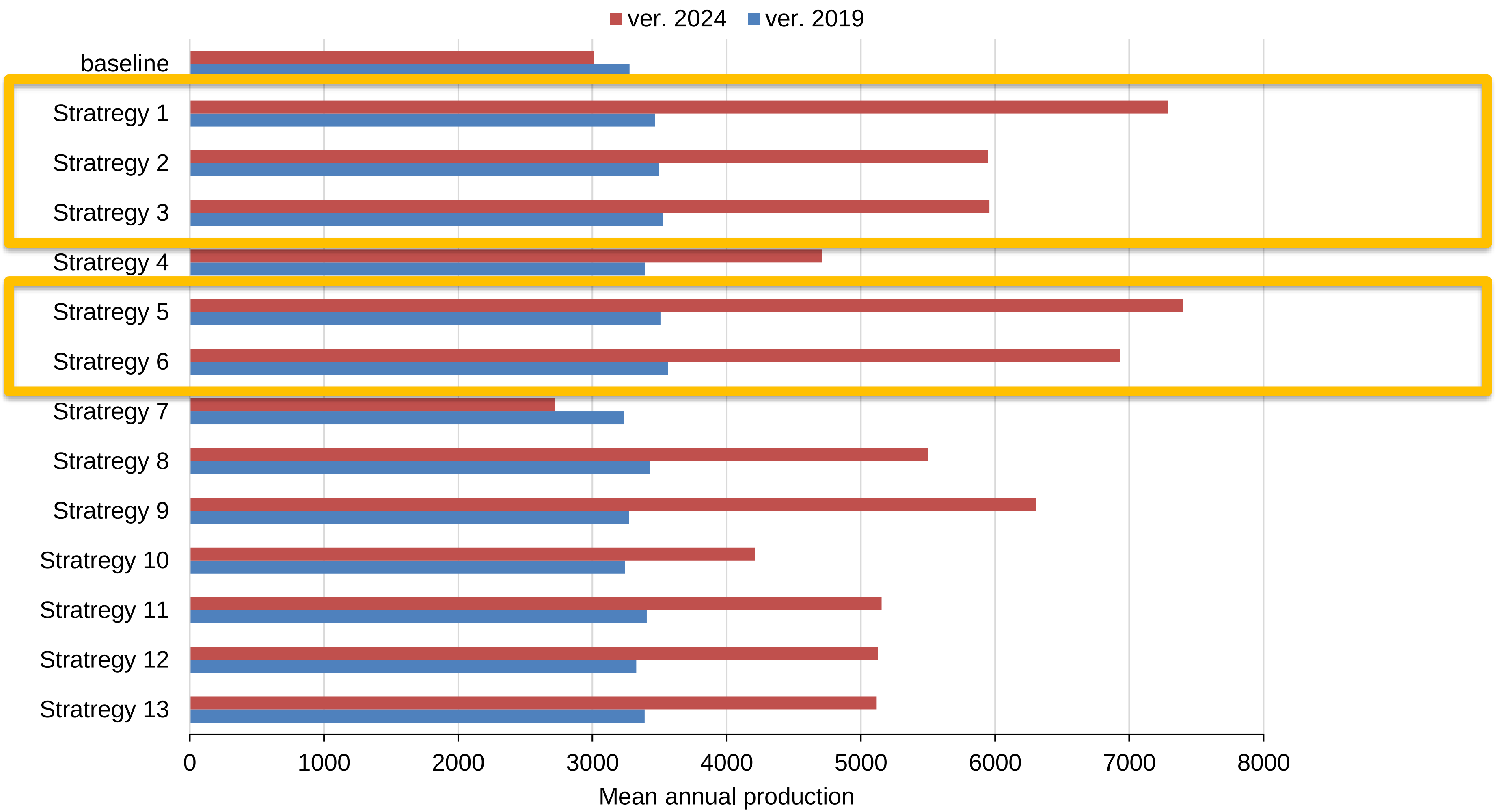
Fall Run Simulation Results



Winter Run Calibration Results

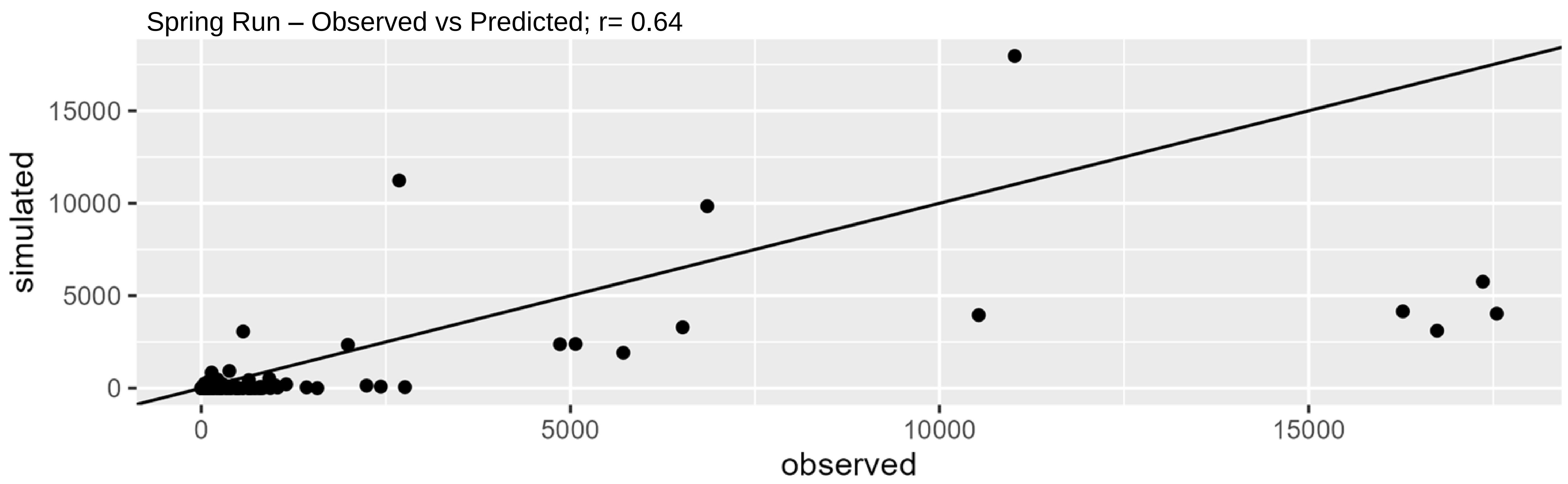


Winter Run Simulation Results

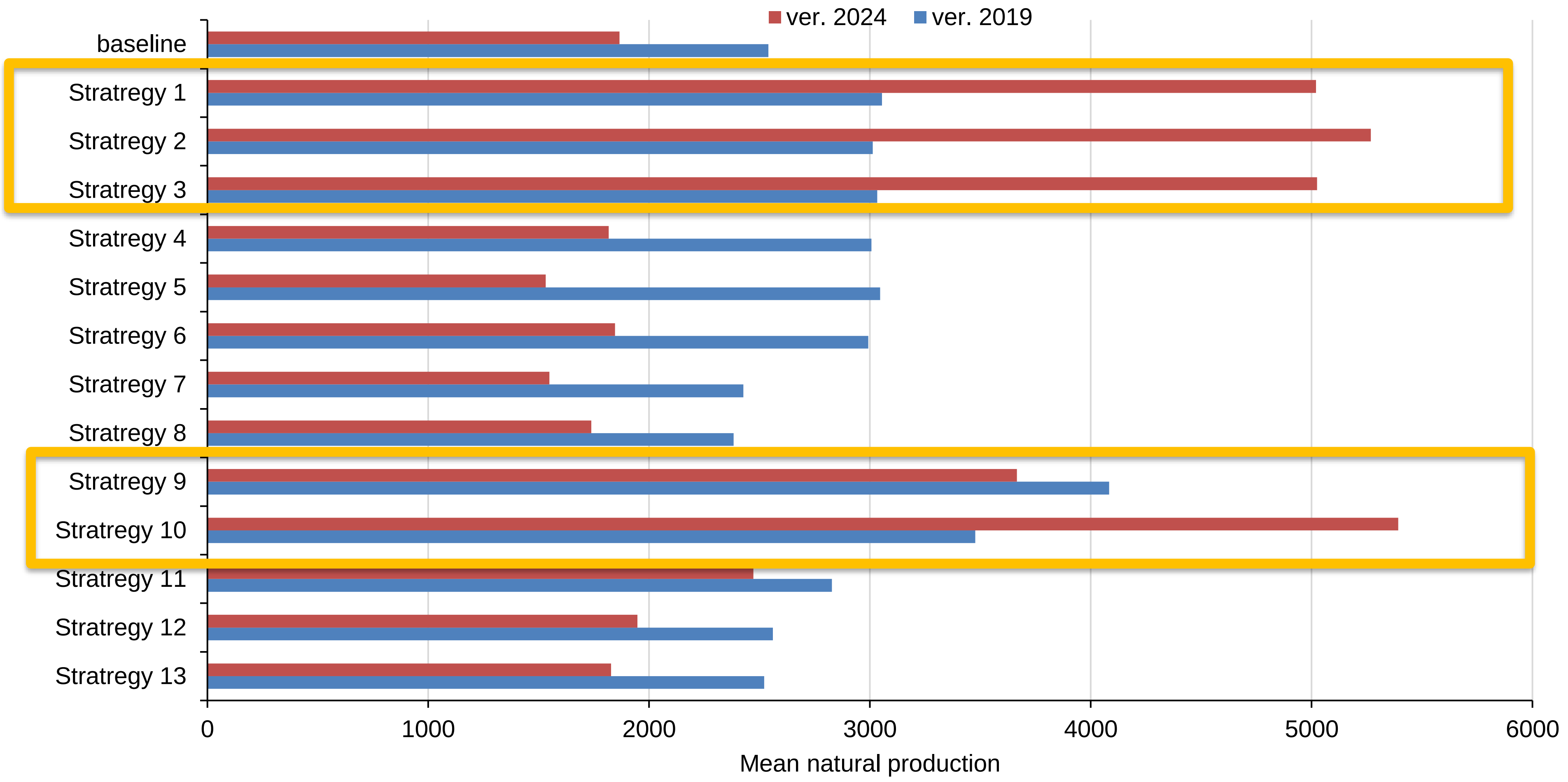


Note: 2019 Does NOT include Battle Creek

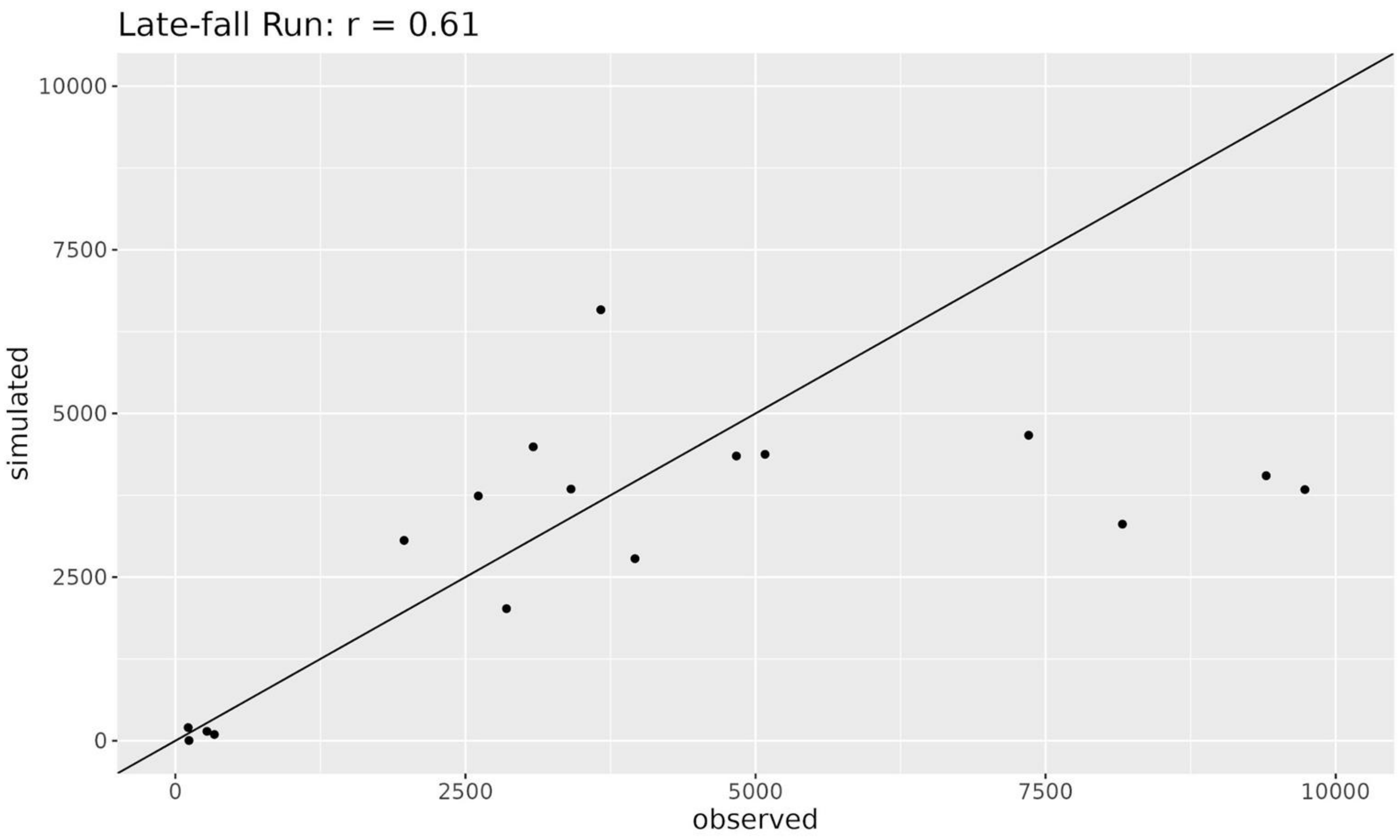
Spring Run Calibration Results



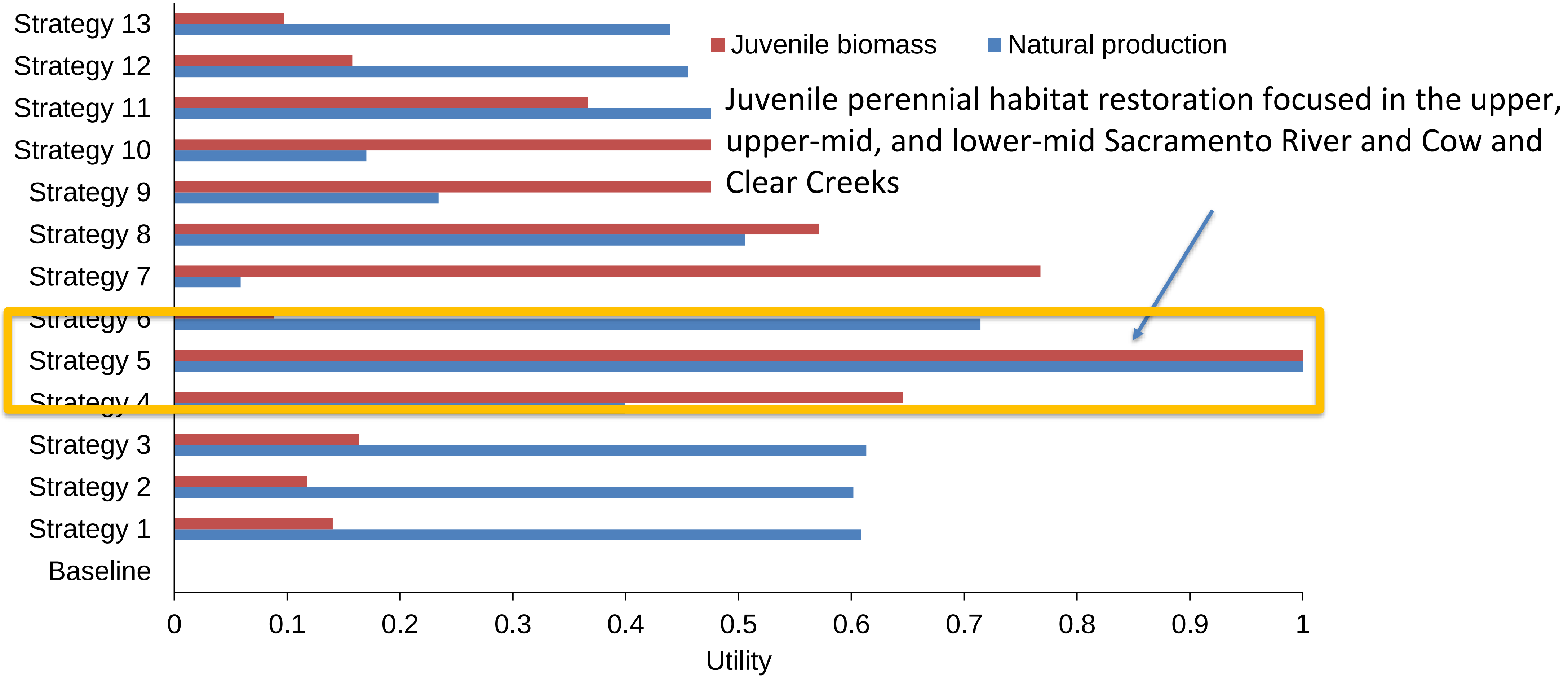
Spring Run Simulation Results



Late-Fall Run Calibration Results



Late-fall-run Simulation Results

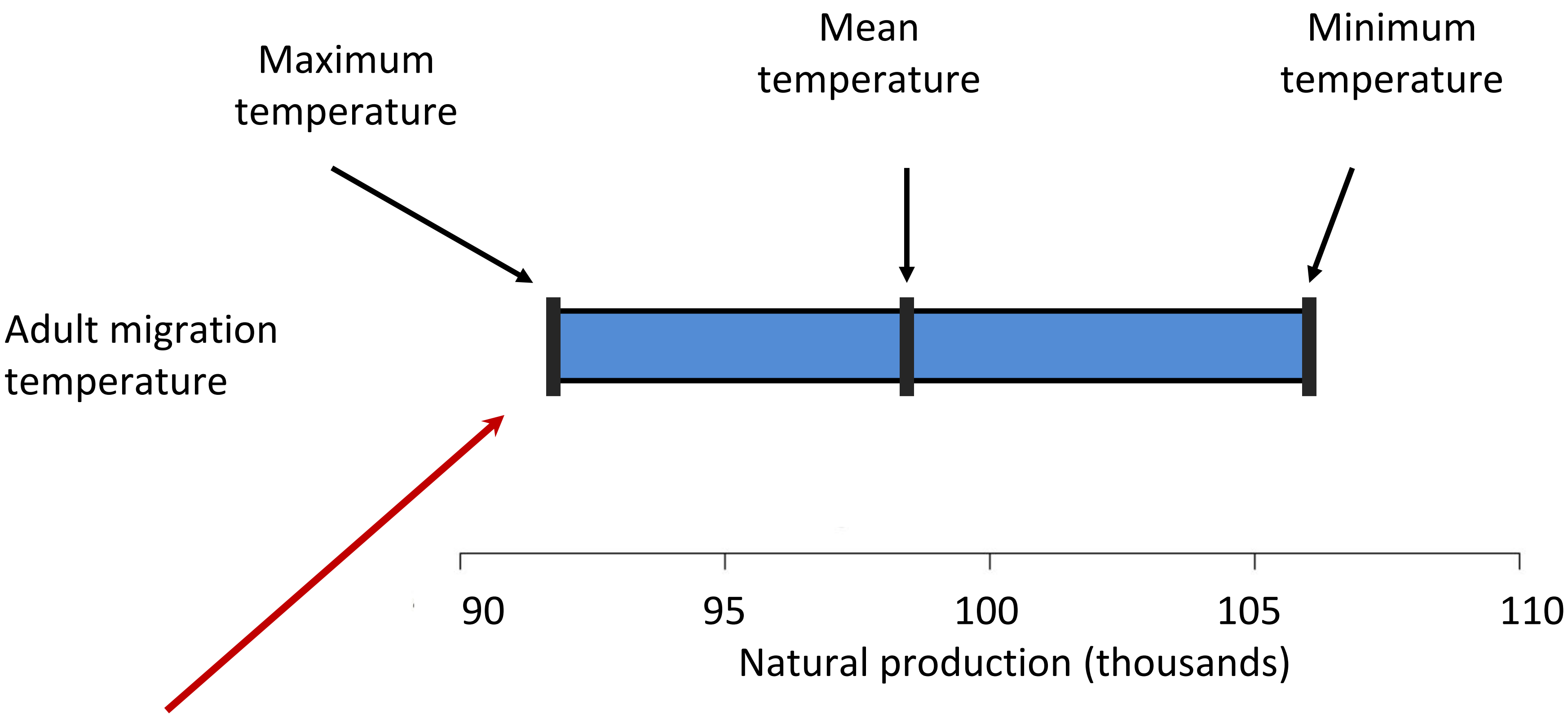


NTRS Priority Restoration Actions for Chinook Salmon

Type of Restoration Action	Locations and Runs Benefitting
Juvenile habitat restoration	• Mainstem Sac River above the American River confluence (all runs) • Battle Creek in winter-run juvenile rearing locations (winter) • American River (fall) • Stanislaus River downstream to San Joaquin River at Vernalis (fall) • Clear Creek (spring, fall) • Lower Feather River below confluence with Yuba River (fall, spring)
Reconnect ephemeral non-natal tributaries	• Mainstem Sac River (winter)
Improve survival	• Butte Creek in downstream areas (spring, fall)
Maintain existing spawning habitats	• Upper Sac, American, and Stanislaus Rivers • Clear and Butte Creeks (all runs)

One-way Sensitivity Analysis (interpretation)

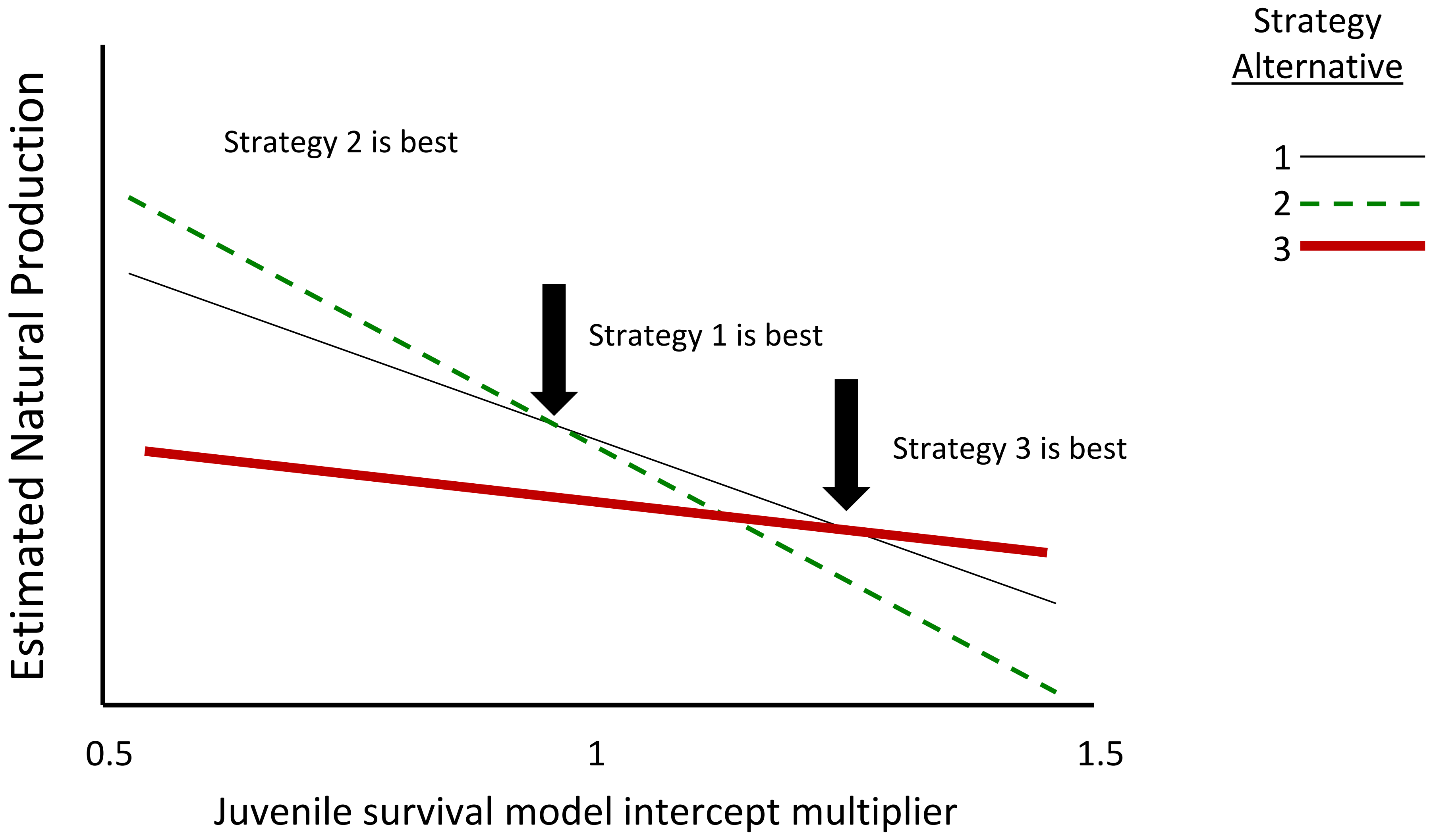
Temperature during outmigration allowed to vary +/- 50% of the mean value



Width of bar represents how much the estimated natural production varies

Response Profile Sensitivity

Does the parameter value affect the strategy rankings?



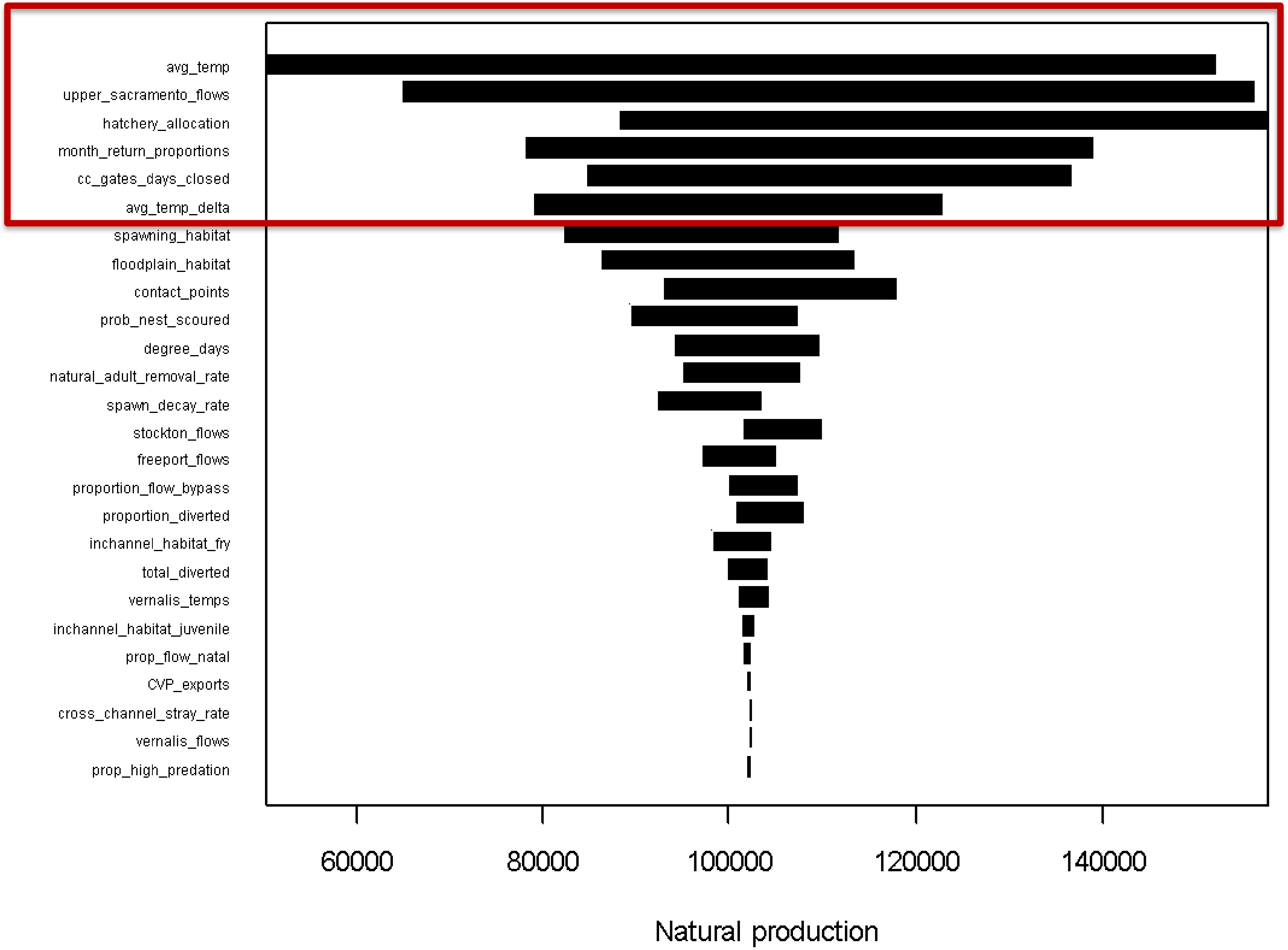
Fall-run Parameters Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
3	..surv_juv_rear_int
3	..surv_juv_bypass_int
3	territory_size
2	.adult_prespawn_deg_day
2	.surv_juv_rear_contact_points
2	.surv_juv_rear_total_diversions
2	.surv_juv_bypass_large
2	..surv_adult_prespawn_int
2	..surv_juv_rear_contact_points
2	..surv_juv_rear_total_diversions
2	..ocean_entry_success_int
2	growth_rates_floodplain
2	spawn_success_fecundity
2	spawn_success_redd_size

Fall-run Input Sensitivity Analysis

Reduced version



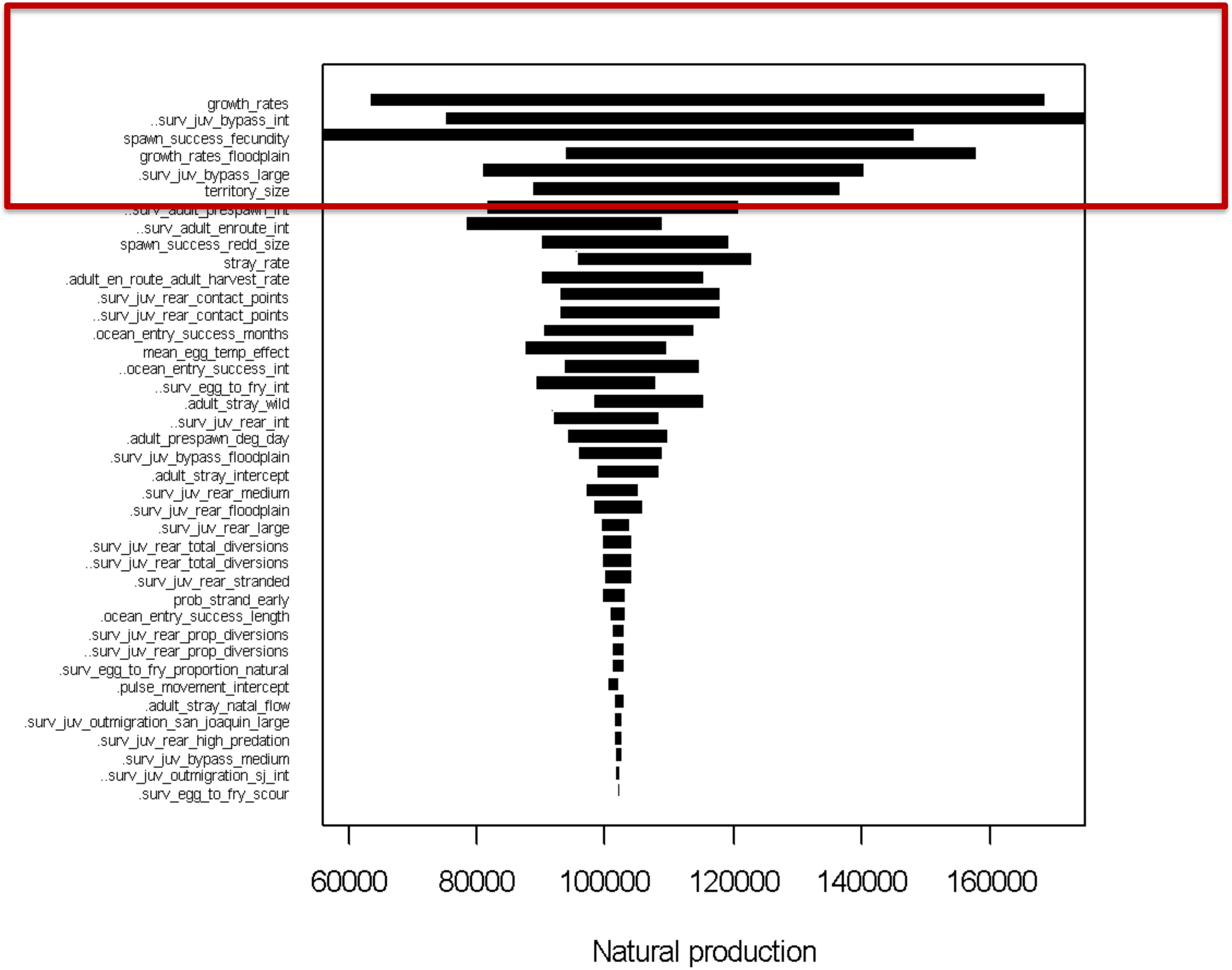
Fall-run Input Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
6	cc_gates_days_closed
2	avg_temp
2	floodplain_habitat
2	hatchery_allocation
2	inchannel_habitat_fry

Winter-run parameter sensitivity analysis

Reduced version



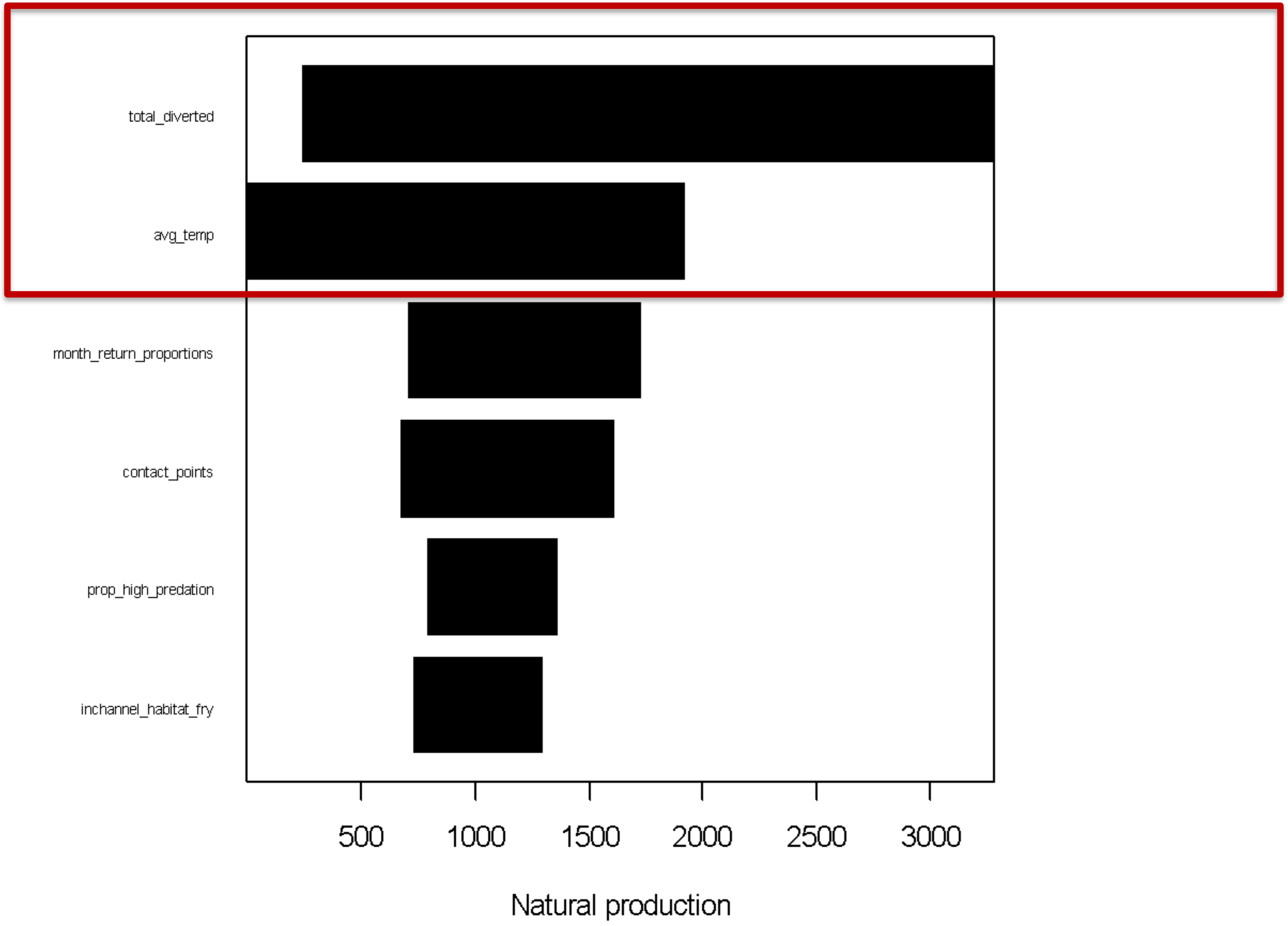
Winter-run parameters response profile

Number of times top 3 ranked strategies changed

times	Parameter
3	spawn_success_fecundity
2	..surv_juv_rear_int
2	..surv_juv_bypass_int
2	growth_rates
2	growth_rates_floodplain
2	mean_egg_temp_effect
2	prob_strand_early
2	spawn_success_redd_size
2	spawn_success_sex_ratio
2	stray_rate
2	territory_size

Winter-run Input Sensitivity Analysis

Reduced version



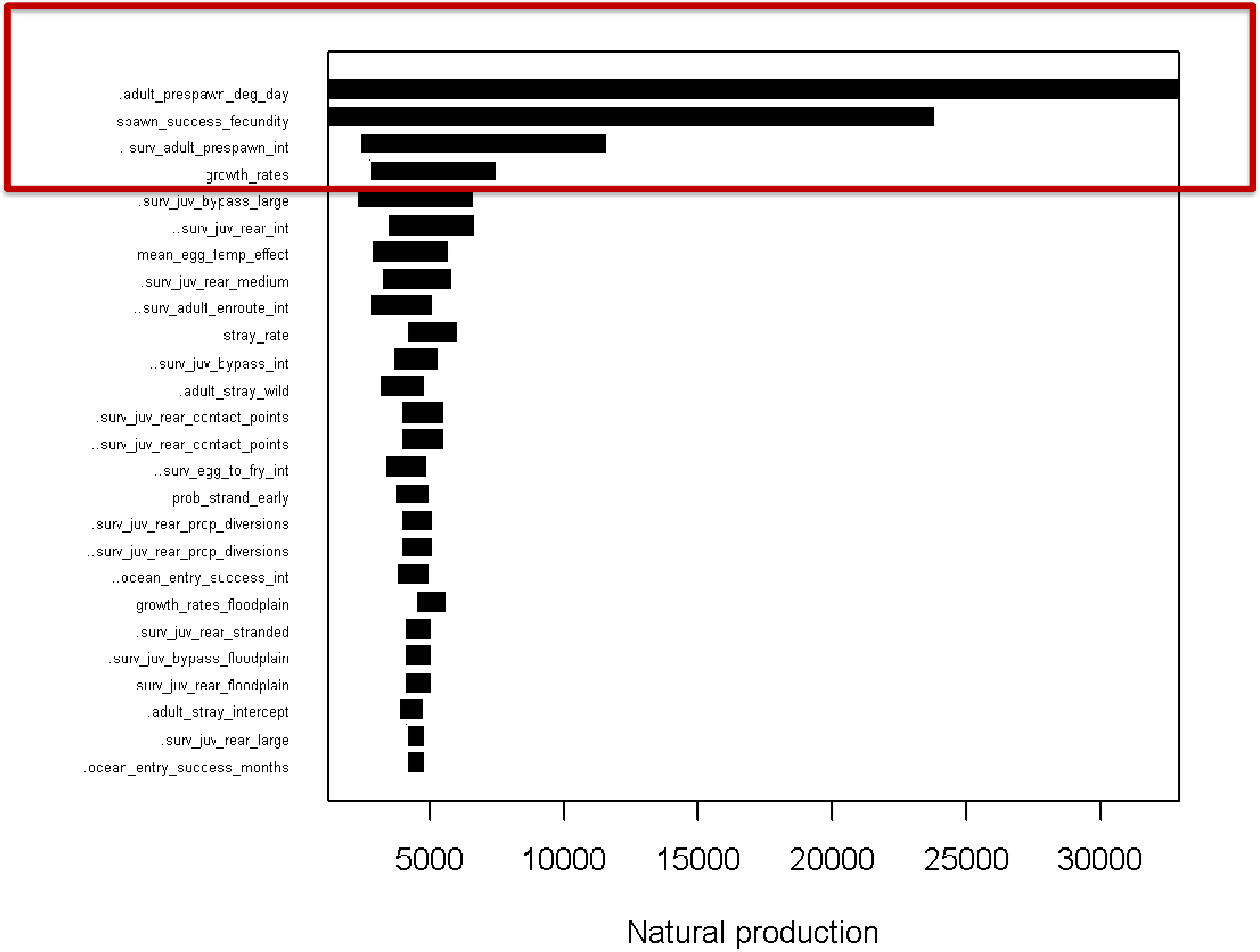
Winter-run Input Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
3	avg_temp
2	cc_gates_days_closed
2	contact_points
2	floodplain_habitat
2	freeport_flows
2	inchannel_habitat_fry
2	min_survival_rate
2	month_return_proportions
2	natural_adult_removal_rate
2	prob_nest_scoured
2	prob_strand_late
2	prop_high_predation

Spring-run Parameter Sensitivity Analysis

Reduced version



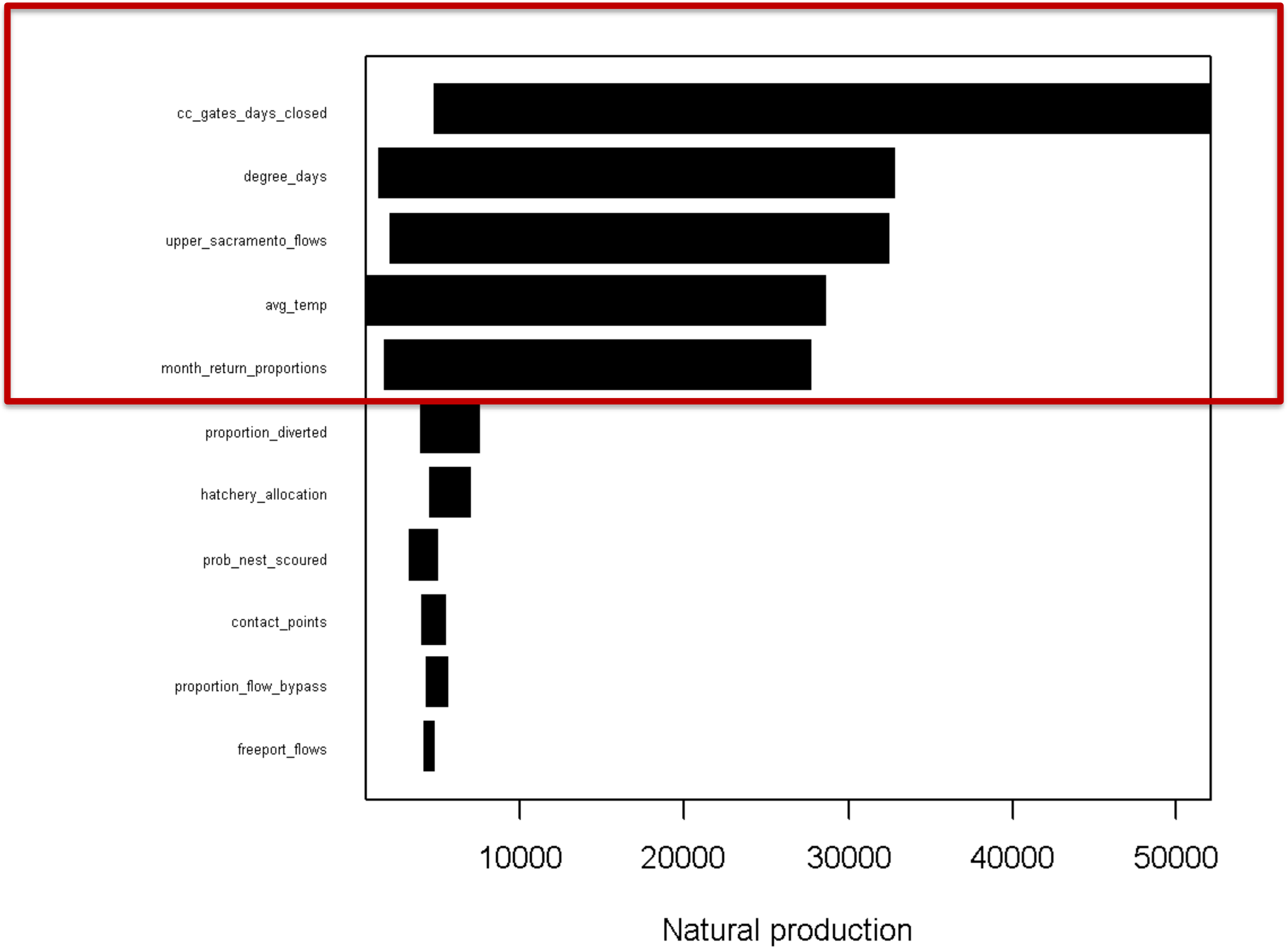
Spring-run Parameters Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
5	.adult_prespawn_deg_day
5	..surv_adult_enroute_int
5	..surv_juv_rear_int
5	spawn_success_fecundity
4	.surv_juv_bypass_large
4	..surv_juv_bypass_int
4	spawn_success_redd_size
4	territory_size
3	.adult_stray_intercept
3	.adult_stray_wild
3	.surv_juv_rear_medium
3	..surv_adult_prespawn_int
3	..surv_egg_to_fry_int
3	..ocean_entry_success_int
3	growth_rates
3	growth_rates_floodplain
3	mean_egg_temp_effect
3	stray_rate

Spring-run Input Sensitivity Analysis

Reduced version



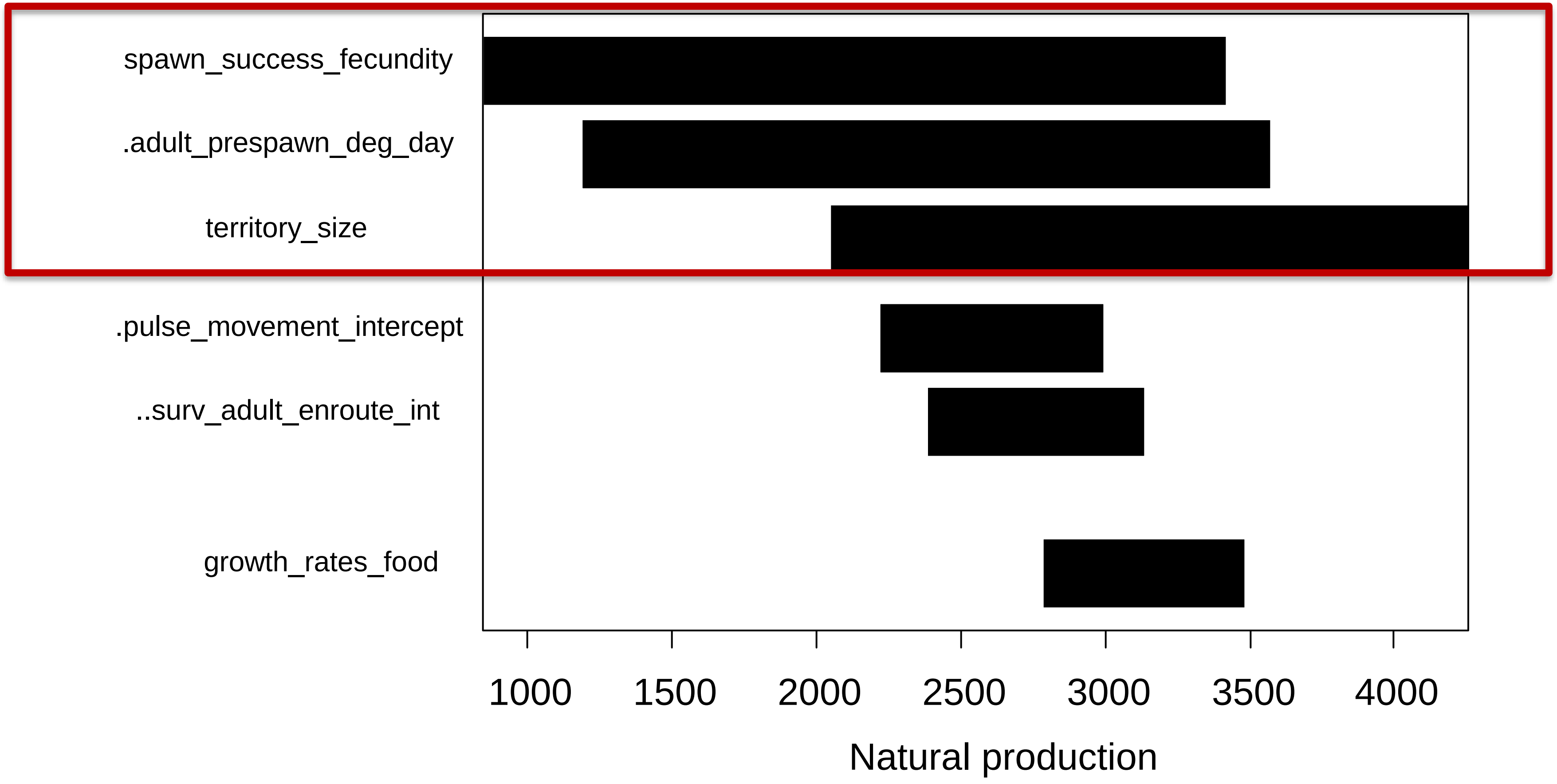
Spring-run input response profile

Number of times top 3 ranked strategies changed

times	Parameter
3	avg_temp
3	degree_days
2	cc_gates_days_closed
2	prob_nest_scoured
1	hatchery_allocation
1	inchannel_habitat_fry
1	month_return_proportions

Late Fall Run Parameter Sensitivity Analysis

Reduced version



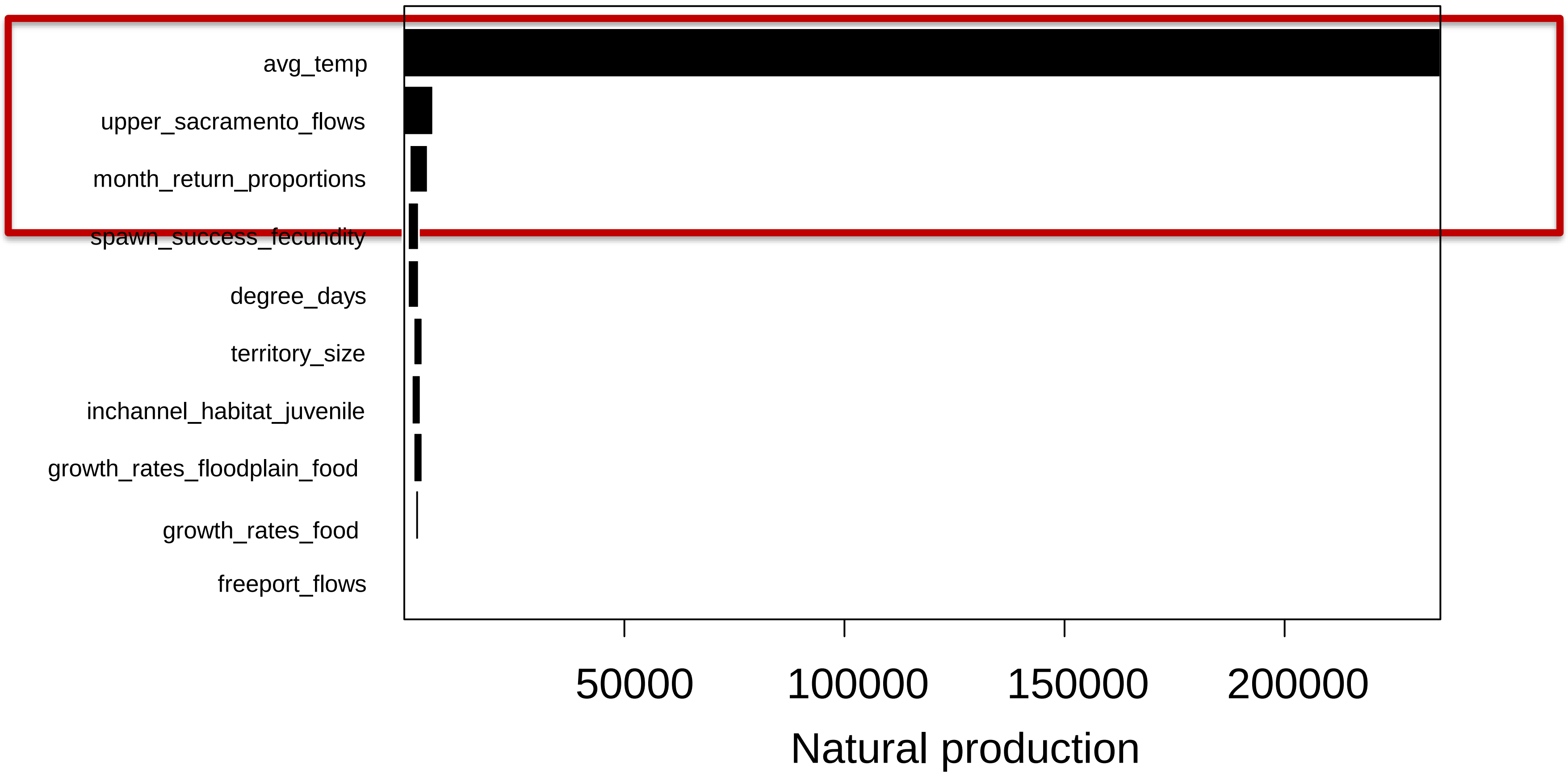
Late Fall Run Parameters Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
4	.adult_prespawn_deg_day
4	spawn_success_fecundity
1	.adult_stray_intercept
1	.adult_stray_wild
1	territory_size

Late Fall Run Input Sensitivity Analysis

Reduced version



Late Fall Run Input Response Profile

Number of times top 3 ranked strategies changed

times	Parameter
7	avg_temp
6	upper_sacramento_flows

How do SIT members request changes?

Proposal Process

1. **Describe change to conceptual model**
   – Identify gap/modification needed, gather subgroup, describe data needed
   – New template for this "pre-proposal" forthcoming
2. **Present initial idea to SIT**
   – Get comments, feedback, direction from SIT
3. **Develop full model change proposal**
   – Describe needed modification and data to support change, get SIT thumbs up
4. **Prototype model change**
5. **Discuss results of model change with SIT**
6. **Based on SIT input, finalize model change**