Simplified WRLCM Runs Workshop I

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Objectives

Obtain a better understanding of the WRLCM model

- Run WRLCM under simplified conditions to gain insight into the mechanics

- Change model parameters one at a time to understand how the model responds to those changes

Base Case

Physical drivers

- Temperature at Keswick
  - Egg to Fry Survival (Apr – Oct) constant 13C
  - Spawn timing (Apr)
- Fremont Weir Spill
  - Yolo entrance probability constant 4005 cfs
- Flow at Bend Bridge
  - Smolt survival constant at 14,593 cfs (historical average)
- South Delta Exports
  - Smolt survival – constant by habitat
- Flow at Wilkins Slough
  - Movement Lower River to Delta no flow trigger

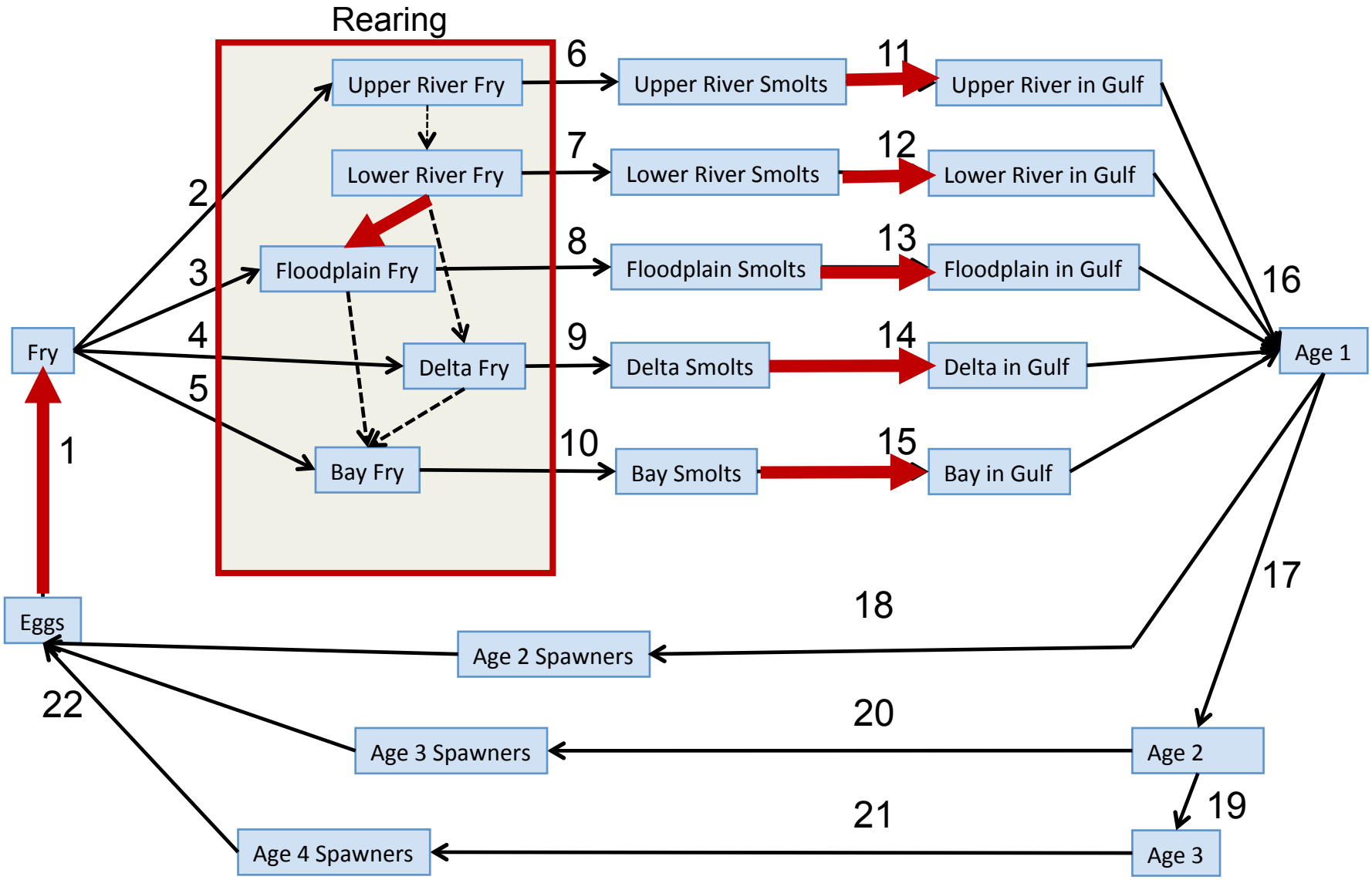
Some caveats to these model runs

think of it more like a Franken-model … in silica

- For demonstration purposes only
- Abundance is used for comparison purposes only, and should not represent actual fish…anywhere
- Results should not be used for management

Illustration by Kate Sheppard, with photo "http://www.flickr.com /photos/soggydan/4041050503

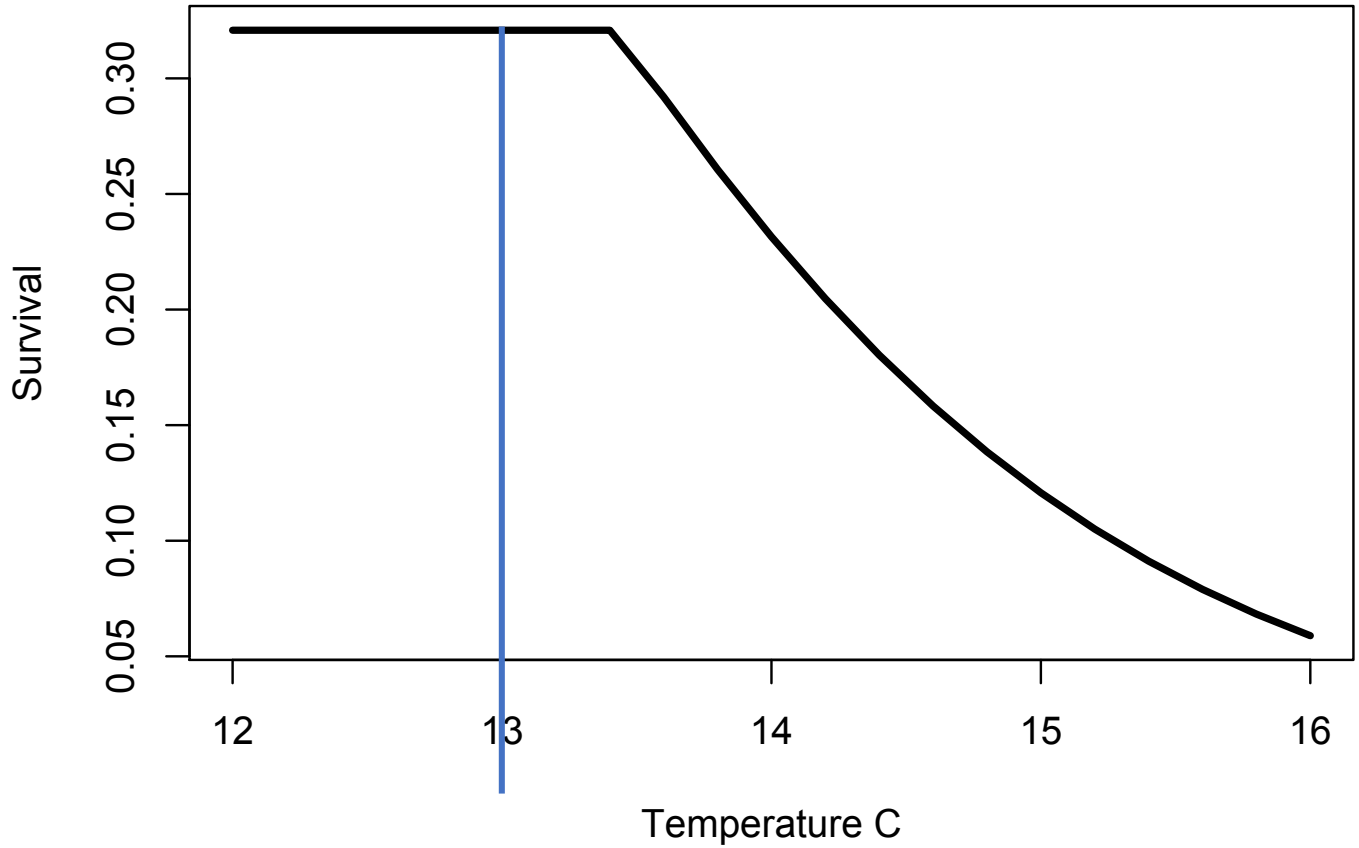
WRLCM Diagram – Base Case



Egg to fry survival relationship

Redd temperature = 13.0 C

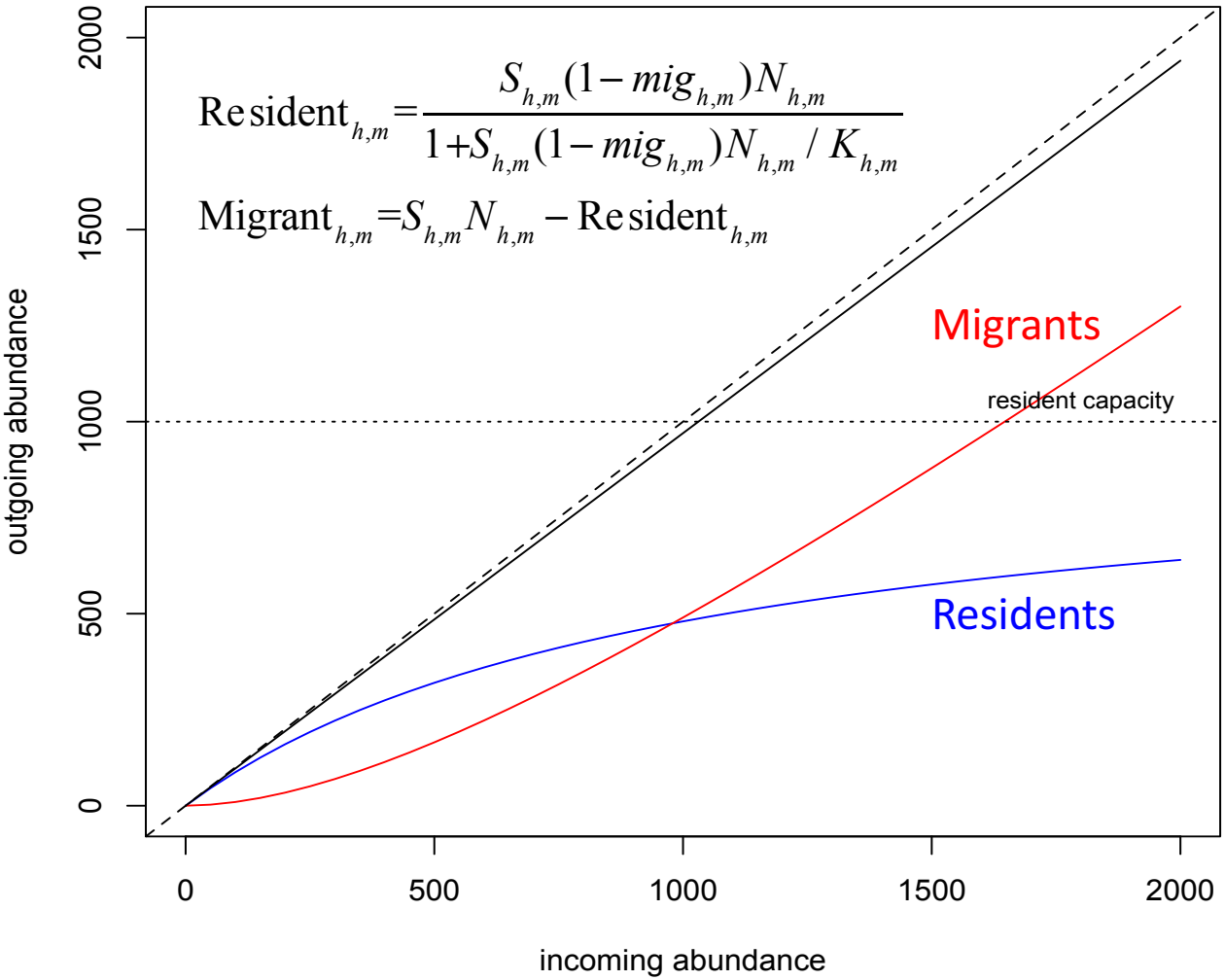
Survival = 0.321

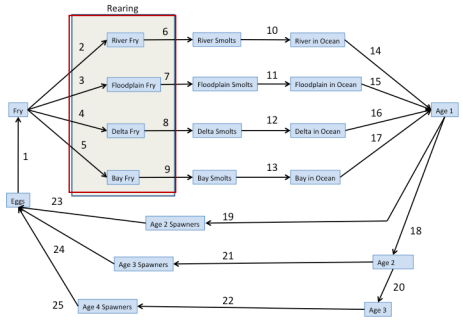


Fry Rearing
survival and movement function

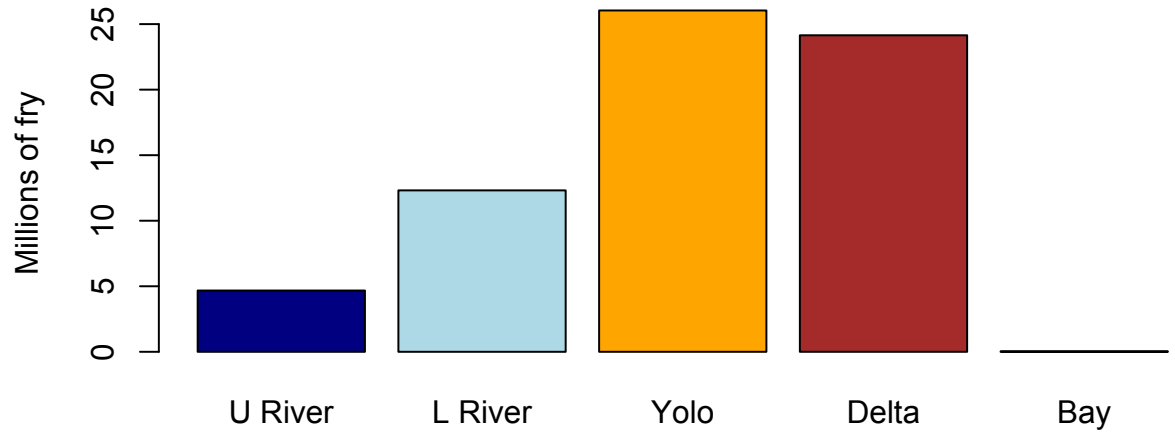
$$\text{Resident}_{h,m} = \frac{S_{h,m}(1-mig_{h,m})N_{h,m}}{1+S_{h,m}(1-mig_{h,m})N_{h,m}/K_{h,m}}$$

$$\text{Migrant}_{h,m} = S_{h,m}N_{h,m} - \text{Resident}_{h,m}$$





Fry capacity of each habitat

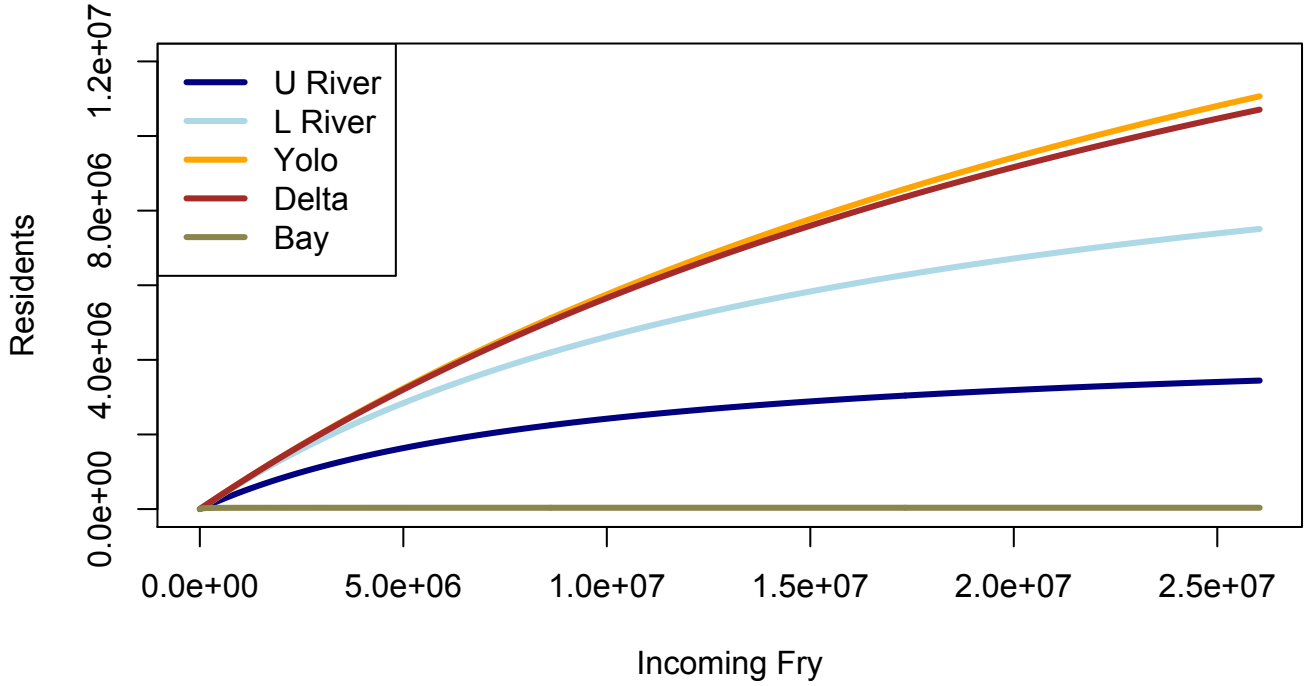


Fry movement in the absence of density dependence

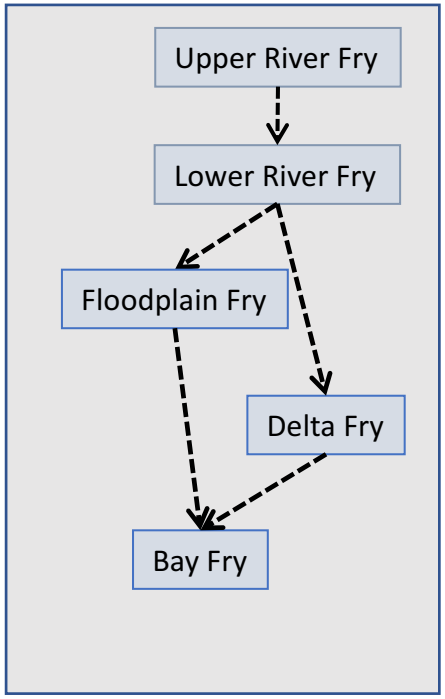
- Fry movement out of the Upper River to the Lower River occurs at higher rate than other habitats
  - Approximately 32% of fry move in the absence of density dependence
  - Based on fitting to the monthly juvenile abundance index at Red Bluff Diversion Dam

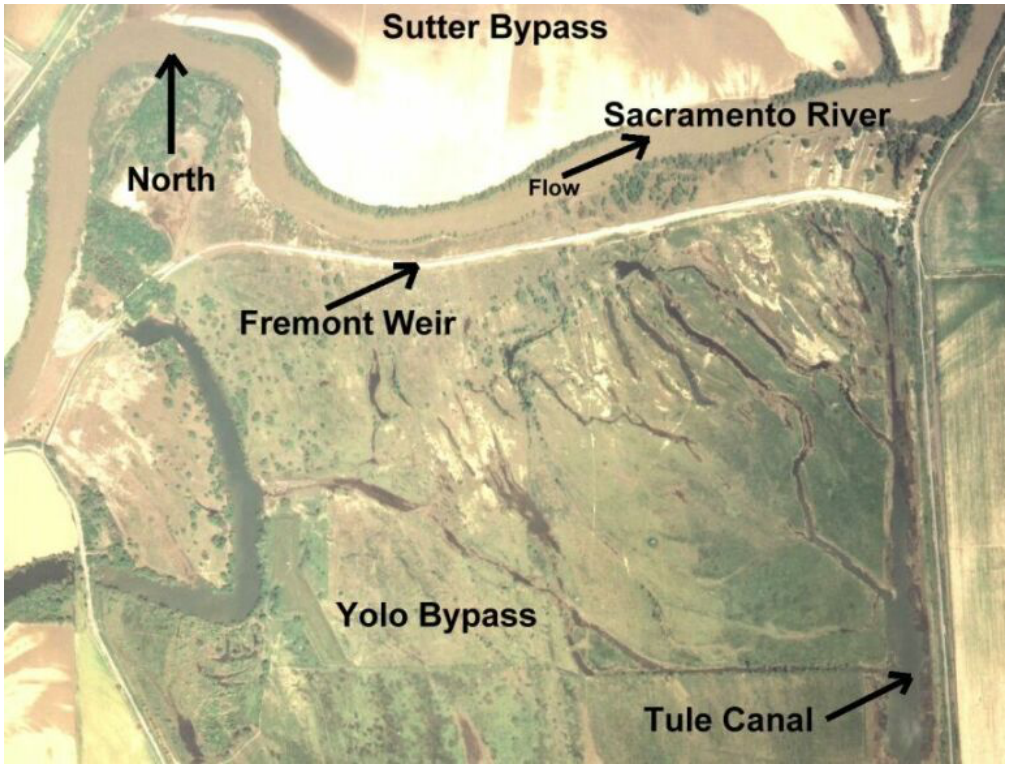
- Fry movement out of the other habitats occurs at a lower rate
  - Approximately 5% in the absence of density dependence
  - Model assumption that fry like to stay in habitats to rear

Beverton-Holt function for fry residents



Spatial Linkages



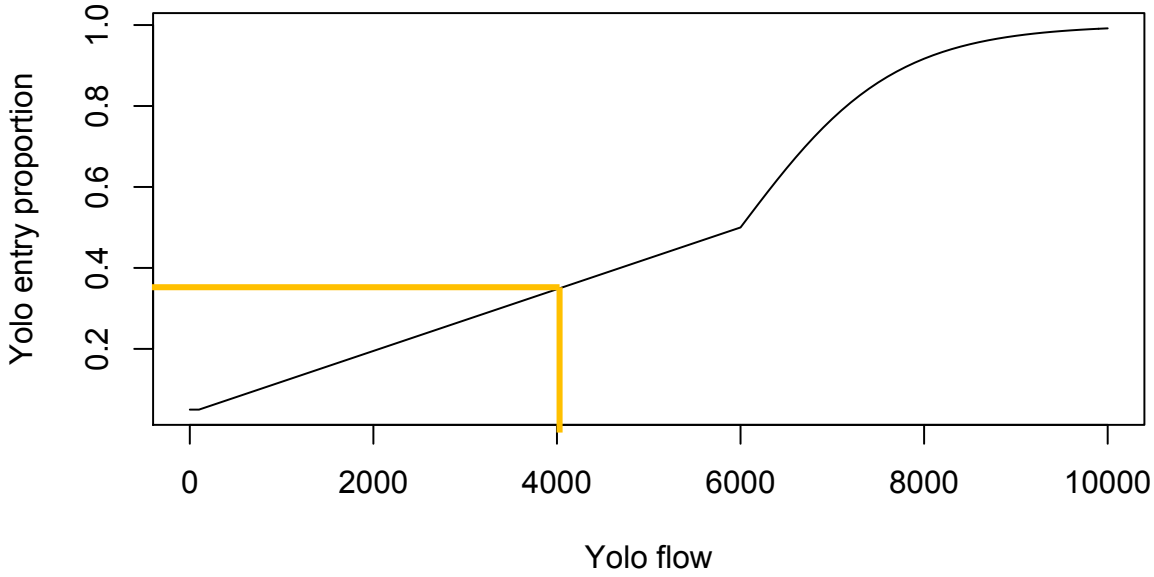


Credit: T. Endreny SUNY

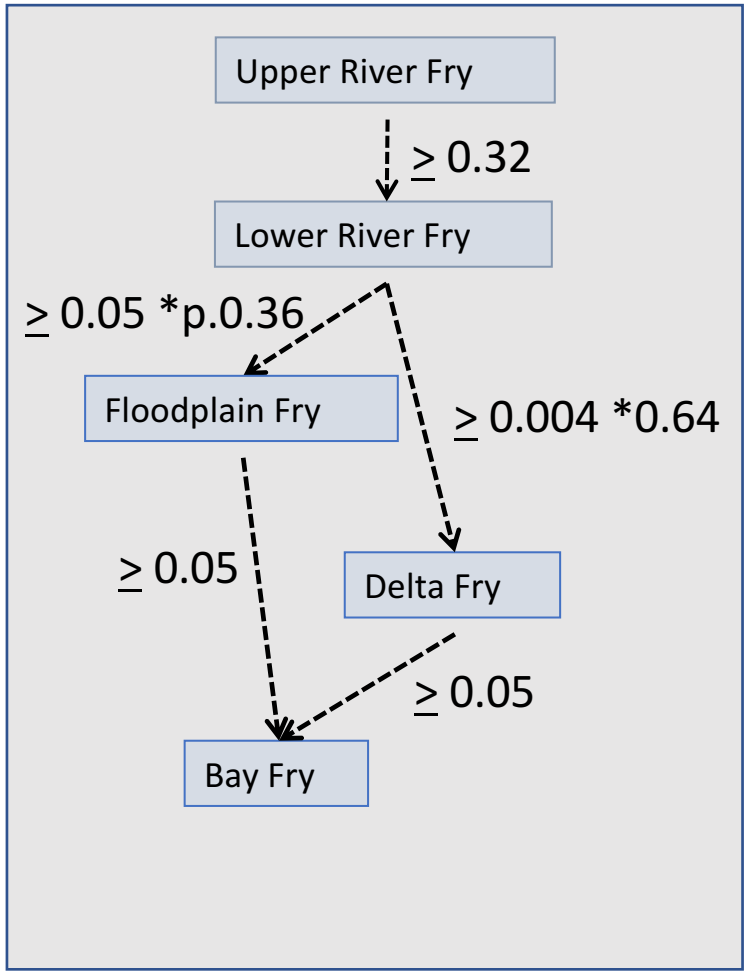
Fry can enter into Floodplain habitat only when there is flow into Yolo Bypass

Access to Yolo bypass

Yolo flow = 4005 cfs
Proportion = 0.348



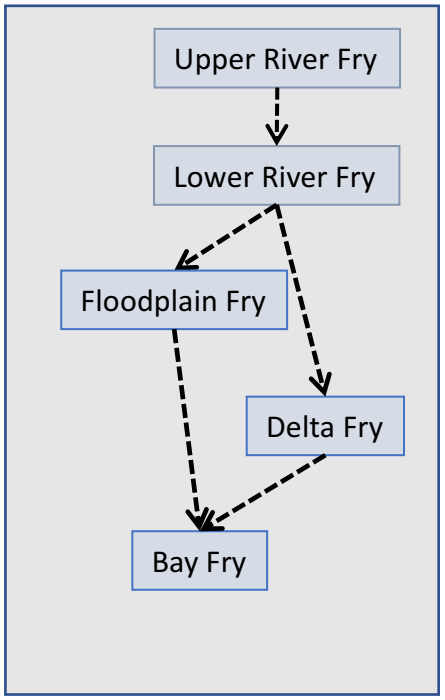
Movement of fry



- Movement rates in absence of density dependence set lower bound on monthly proportions moving among habitats
- Density dependence causes fry to move from Lower River to other habitats*

*Wilkins slough flow trigger also causes fry to move out of Lower River , but we are not implementing it here

Spatial dynamics during fry rearing*



Initial abundance – 1 million

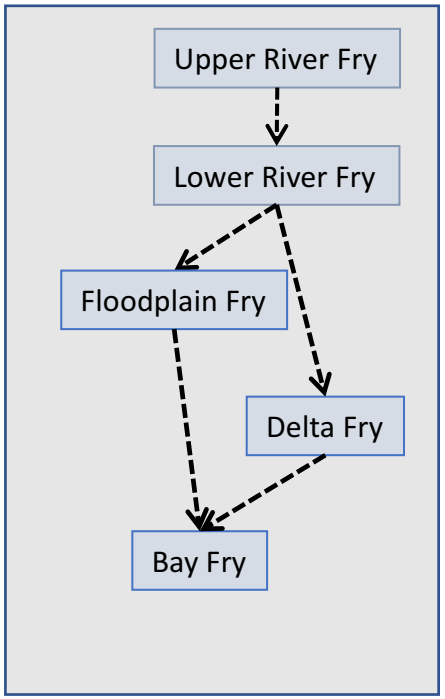
	URiver	LRiver	Yolo	Delta	Bay
Sept	1.00E+06	0	0	0	0
Oct	593643	406357	0	0	0
Nov	371588	613976	5022	9414	0
Dec	239721	714556	15666	29368	689

Initial abundance – 5 million

	URiver	LRiver	Yolo	Delta	Bay
Sept	5.00E+06	0	0	0	0
Oct	1968331	3031669	0	0	0
Nov	1040527	3353117	210929	395427	0
Dec	614538	3053590	451767	844024	36081

* Calculations assume no mortality of fry

Spatial dynamics during fry rearing* – percentages



Initial abundance – 1 million

	URiver	LRiver	Yolo	Delta	Bay
Sept	100.0%	0.0%	0.0%	0.0%	0.0%
Oct	59.4%	40.6%	0.0%	0.0%	0.0%
Nov	37.2%	61.4%	0.5%	0.9%	0.0%
Dec	24.0%	71.5%	1.6%	2.9%	0.1%

Initial abundance – 5 million

	URiver	LRiver	Yolo	Delta	Bay
Sept	100.0%	0.0%	0.0%	0.0%	0.0%
Oct	39.4%	60.6%	0.0%	0.0%	0.0%
Nov	20.8%	67.1%	4.2%	7.9%	0.0%
Dec	12.3%	61.1%	9.0%	16.9%	0.7%

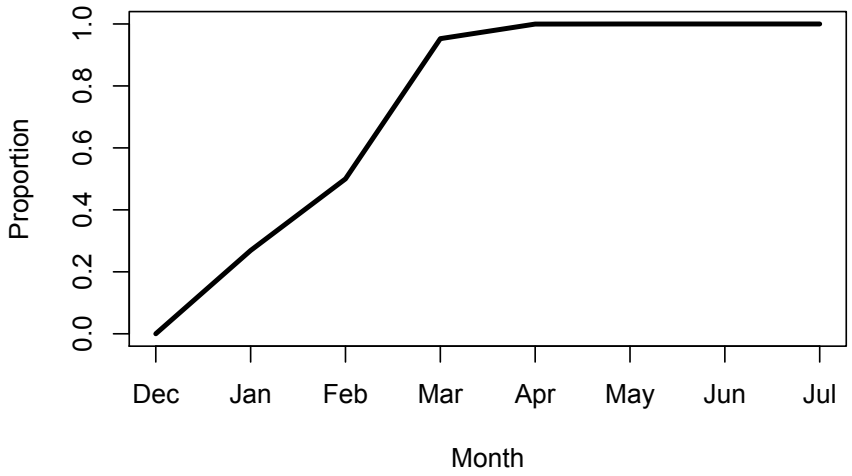
* Calculations assume no mortality of fry

Smoltification

Probability of smolting P_{smolt} is modeled as a proportion ordered logistic regression

$$\text{logit}(P_{smolt,\ m}) = Z_k$$

where $-\infty < Z_1 < Z_2 \ldots < Z_k < \infty$ are the monthly rates of smoltification based on photoperiod (k = 1, …, 7 encompassing January to July).



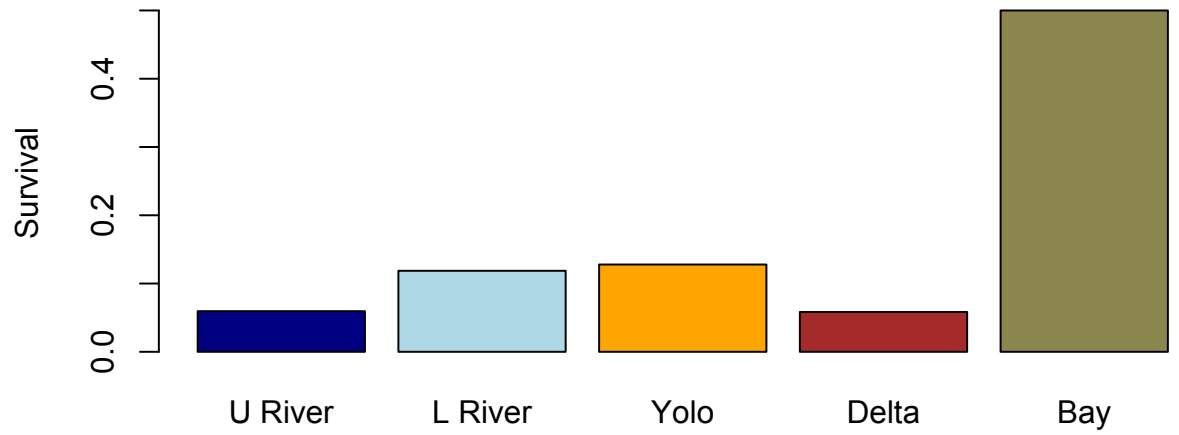
Credit: salmonguy.org

WRLCM steps during smoltification

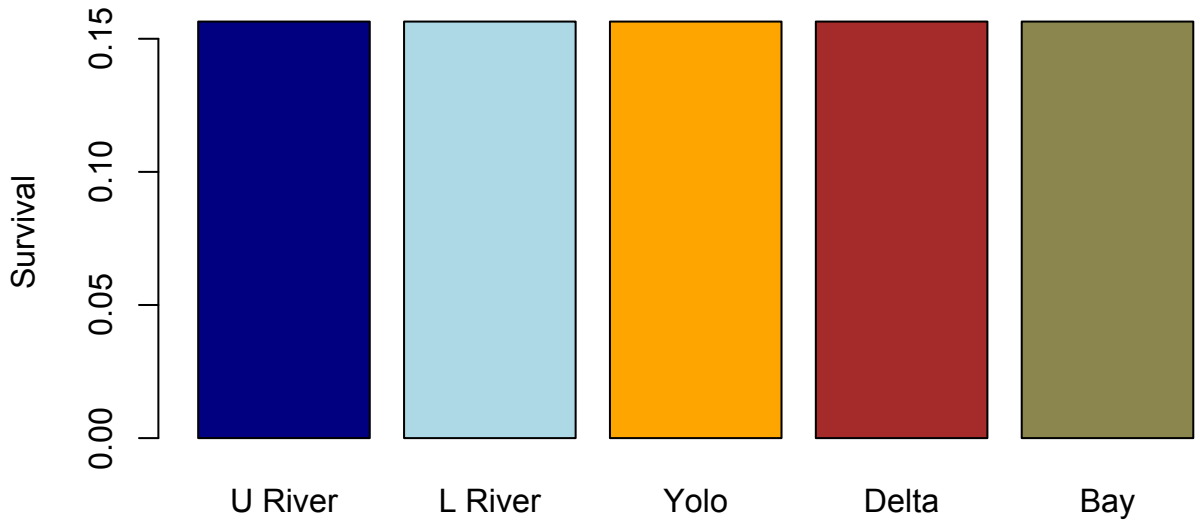
Pseudocode for monthly steps during smolting:

1. Smoltification of *Resident fry,* which are removed from habitat
2. *Migrant fry* from the upstream habitats are added to
3. *Resident fry* that did not smolt
4. Calculate *Resident* and *Migrant fry* from Beverton-Holt movement function

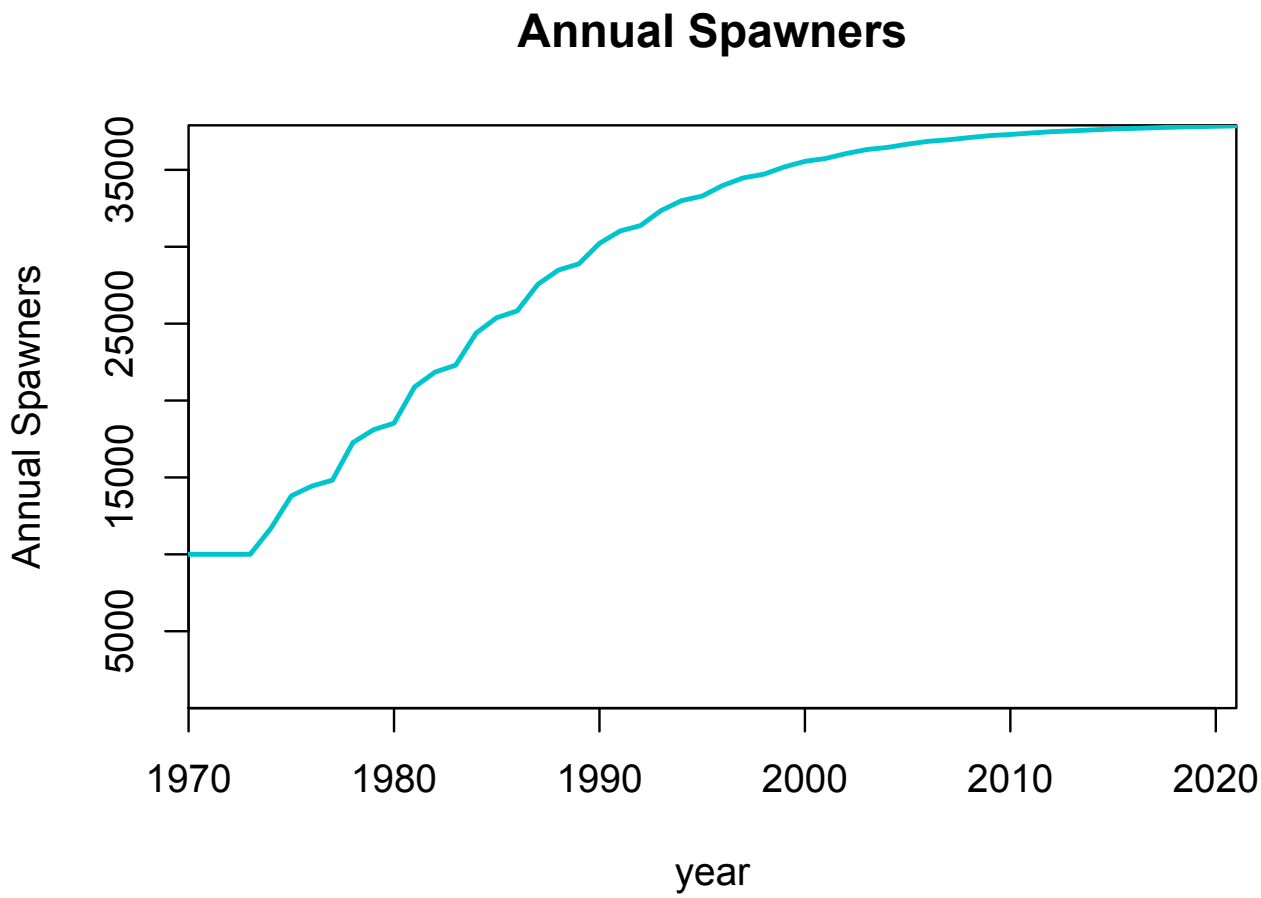
Survival of smolts from rearing habitat to Golden Gate



Early ocean survival by habitat



Base model - abundance



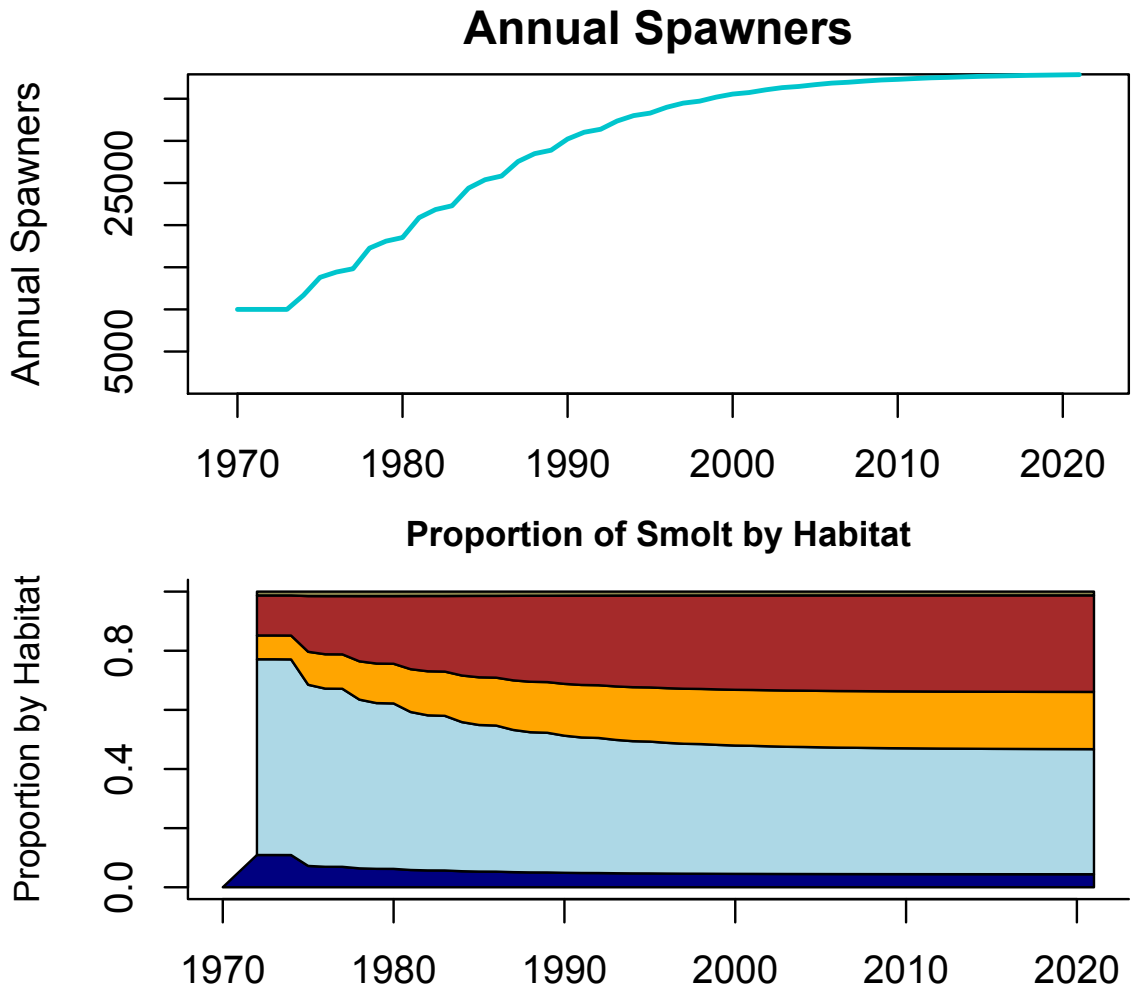
What leads to equilibrium abundance?

Short answer: density dependence

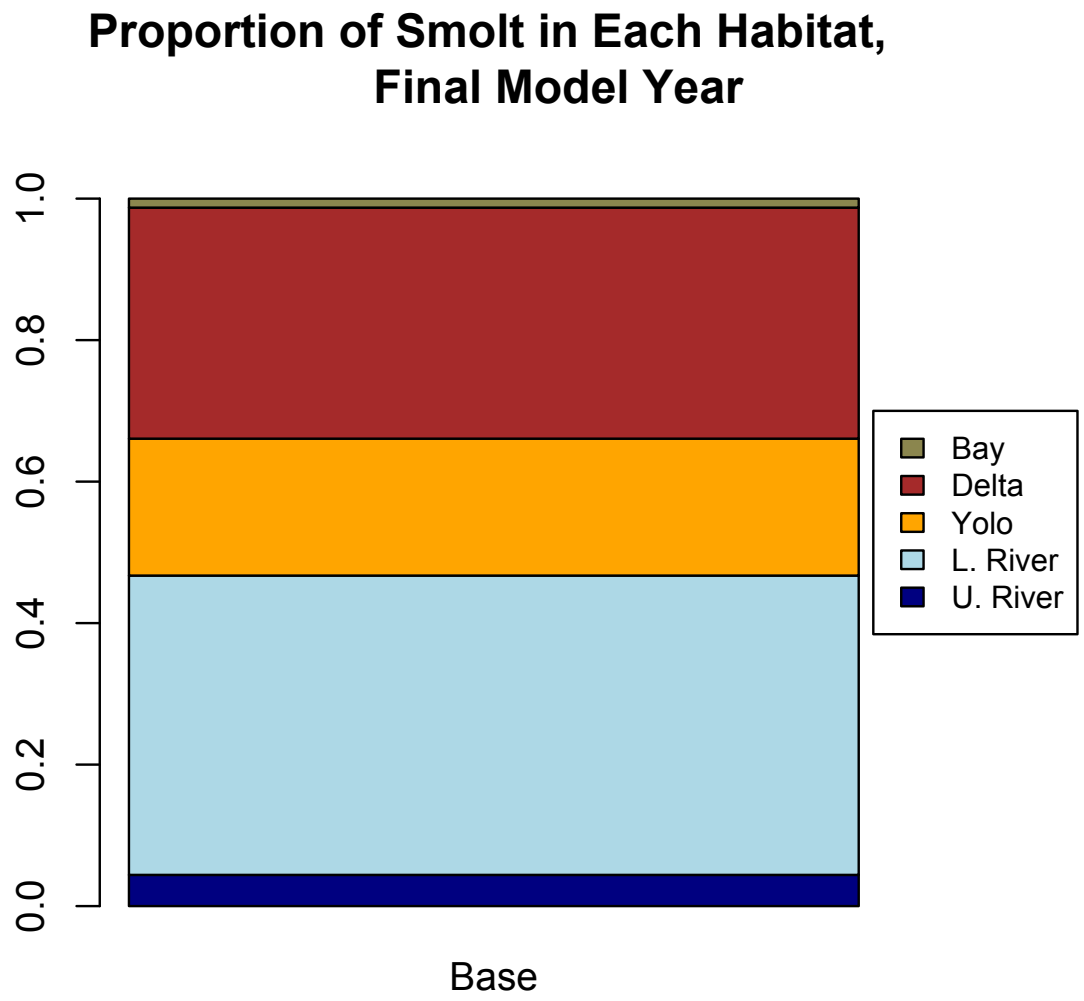
Long answer:

- Fry are distributed across multiple habitats
- Smolt survival rates vary by habitat
- Total smolt survival is a weighted average of the habitat-specific survivals
- Weights are the proportion of fry that reared in that habitat

Spatial dynamics affecting equilibrium abundance



Equilibrium habitat of origination



Alt vs Base

An interactive modeling exercise

An active approach

- Some psychological research suggests that learning is augmented by an active approach as opposed to a passive one
- We have a series of alternatives to the base model
- For each alternative:
  1. Predict how it affects equilibrium abundance
  2. Predict how it affects equilibrium habitat of origination
  3. Describe the mechanism

A worksheet

Alternative	Description	Prediction			WRLCM Response			Notes
		Abundance	Distribution	Mechanism	Abundance	Distribution	Mechanism	
Baseline	Baseline physical driver and coefficient values							
T13.5	Egg incubation temp is 13.5 C							
T14.0	Egg incubation temp is 14.0 C							
T14.5	Egg incubation temp is 14.5 C							
S Delta	Reduce survival of smolts originating from delta by 20%							
S River	Reduce survival of smolts originating from river habitats by 20%							
C URiver	Increase fry rearing capacity in the Upper River by 20%							
C LRiver	Increase fry rearing capacity in the Lower River by 20%							
C Delta	Increase fry rearing capacity in the Delta by 20%							
S River & C URiver	Reduce survival of smolts originating from River habitats by 20% & Increase fry rearing capacity in the Upper River by 20%							
S River & C LRiver	Reduce survival of smolts originating from River habitats by 20% & Increase fry rearing capacity in the Lower River by 20%							
S River & C Delta	Reduce survival of smolts originating from River habitats by 20% & Increase fry rearing capacity in the Delta by 20%							

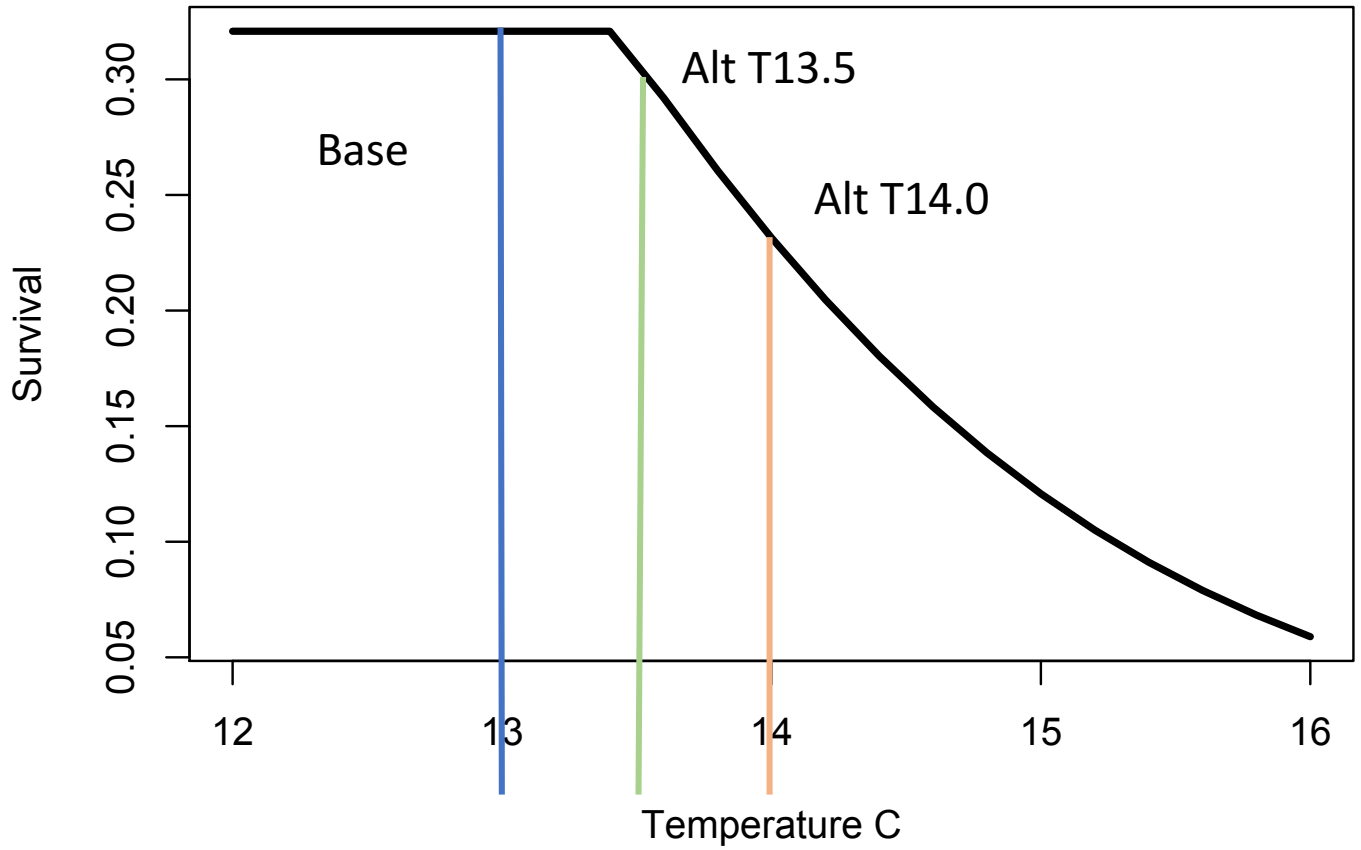
Alternatives – temperature

In the Base model run, temperature is 13.0 C

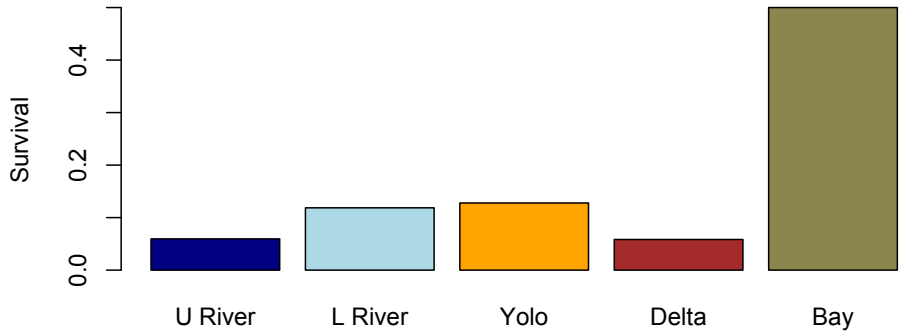
Alternatives: Temperature during incubation in egg to fry survival is:

1. Temperature = 13.5 C
2. Temperature = 14.0 C

Egg to fry survival relationship



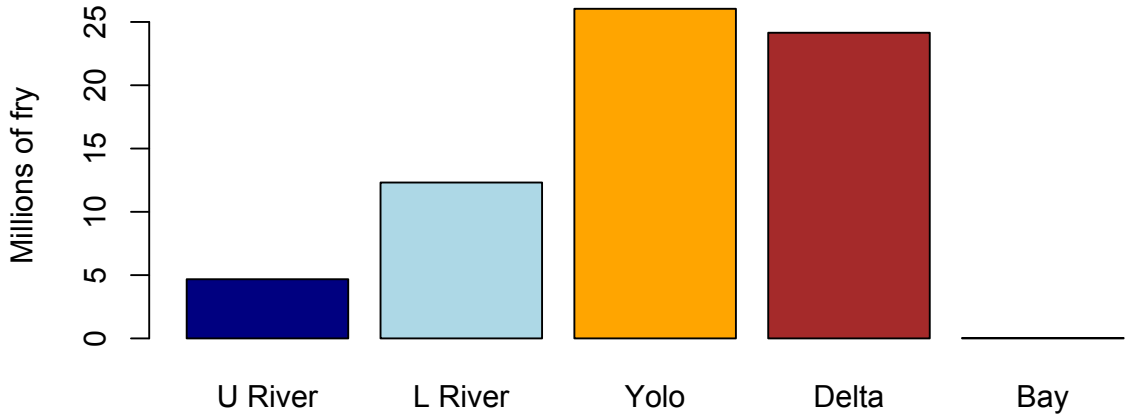
Alternatives – reduce smolt survival



Smolt Survival

1. Reduce Delta smolt survival by 20%
2. Reduce Upper and Lower River smolt survival by 20% (these rates are linked in the WRLCM)

Alternatives – increase fry capacity



Capacity

1. Increase Upper River capacity by 20%
2. Increase Lower River capacity by 20%
3. Increase Delta capacity by 20%

Alternatives – combination of smolt survival and fry habitat

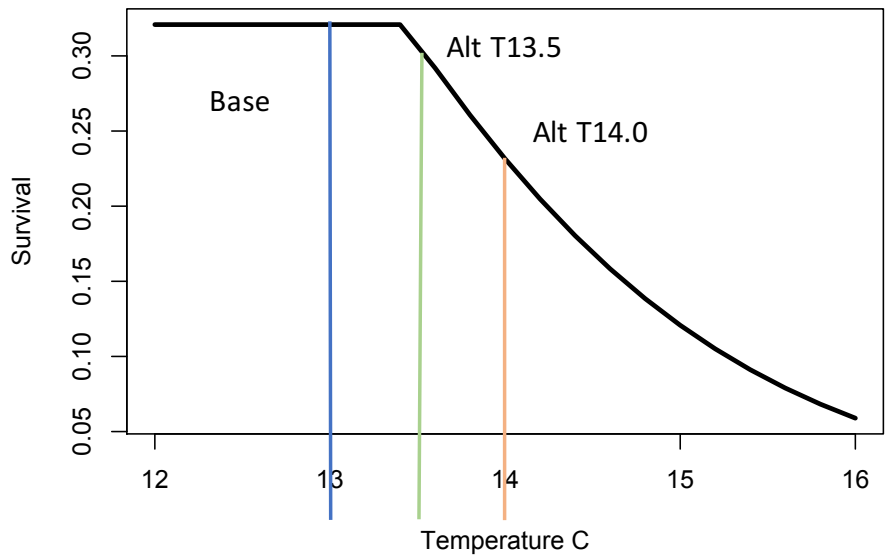
Combination of survival and capacity

1. Reduce Upper and Lower River survival by 20% and increase Upper River habitat by 20%
2. Reduce Upper and Lower River survival by 20% and increase Lower River habitat by 20%
3. Reduce Upper and Lower River survival by 20% and increase Delta habitat by 20%

Temperature Alternatives

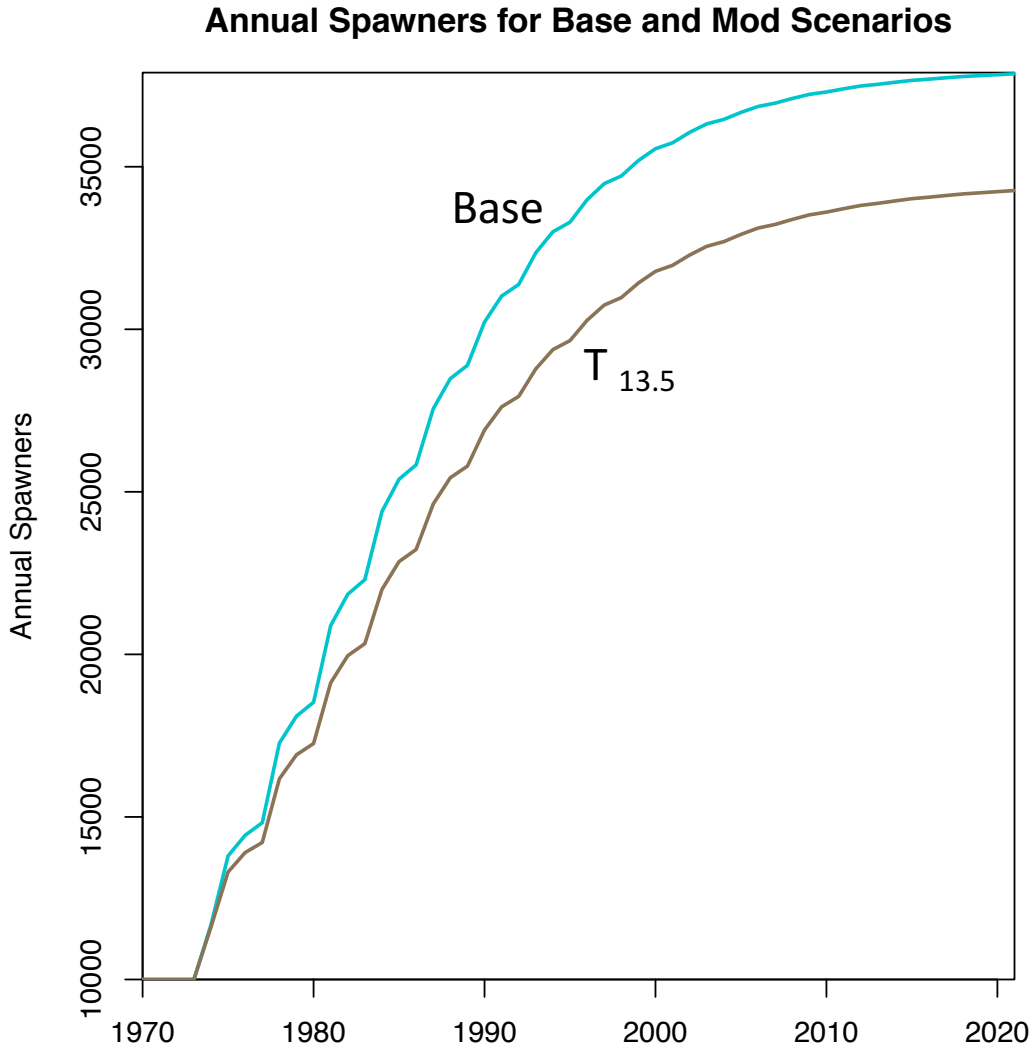
Alternative $T_{13.5}$
egg incubation temperature is 13.5 C

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



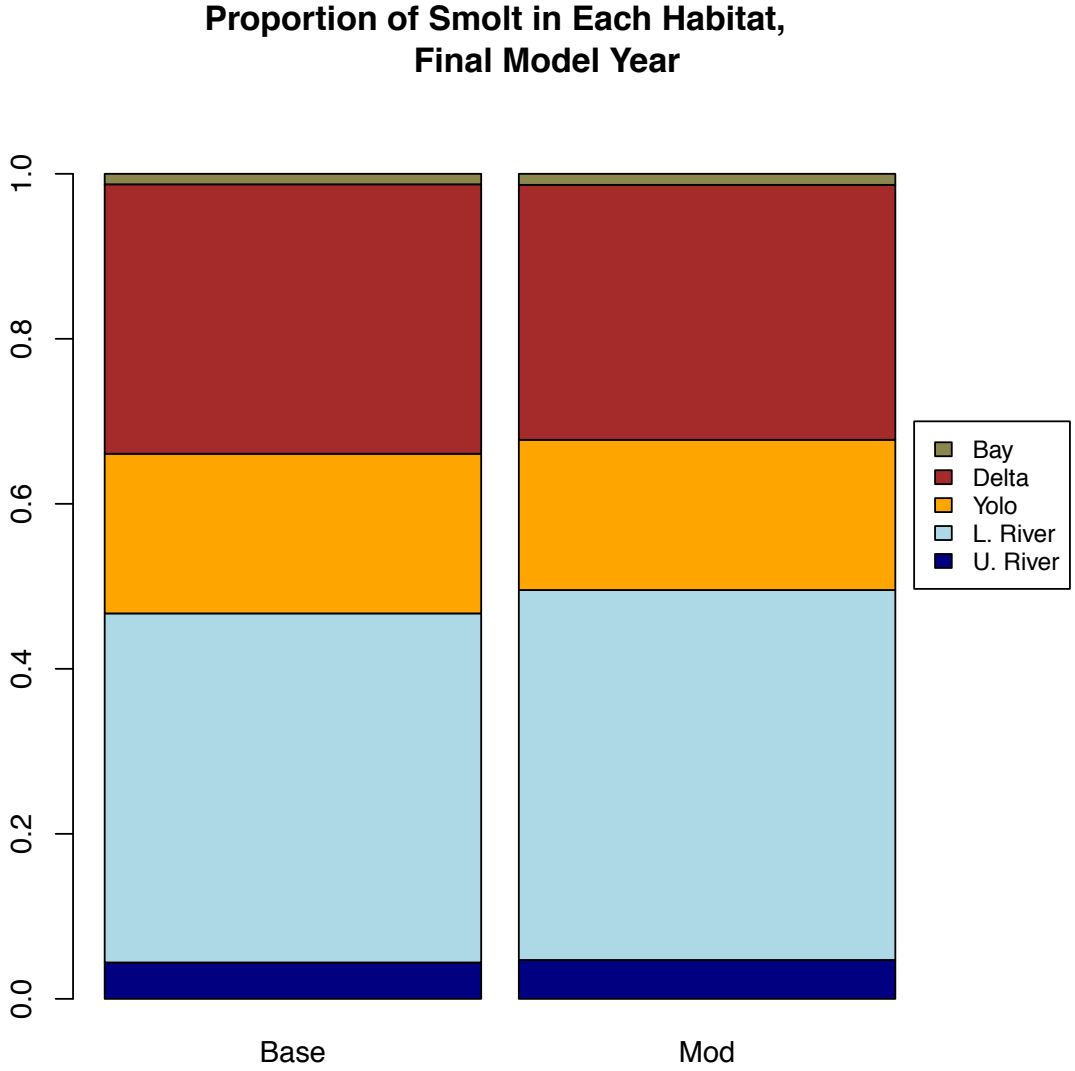
$T_{13.5}$ vs Base – abundance

egg incubation temperature is 13.5 C



$T_{13.5}$ vs Base – distribution

egg incubation temperature is 13.5 C



Alternative $T_{13.5}$

egg incubation temperature is 13.5 C

- What is your prediction for equilibrium abundance?

Abundance is lower - 9.5%

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River slightly

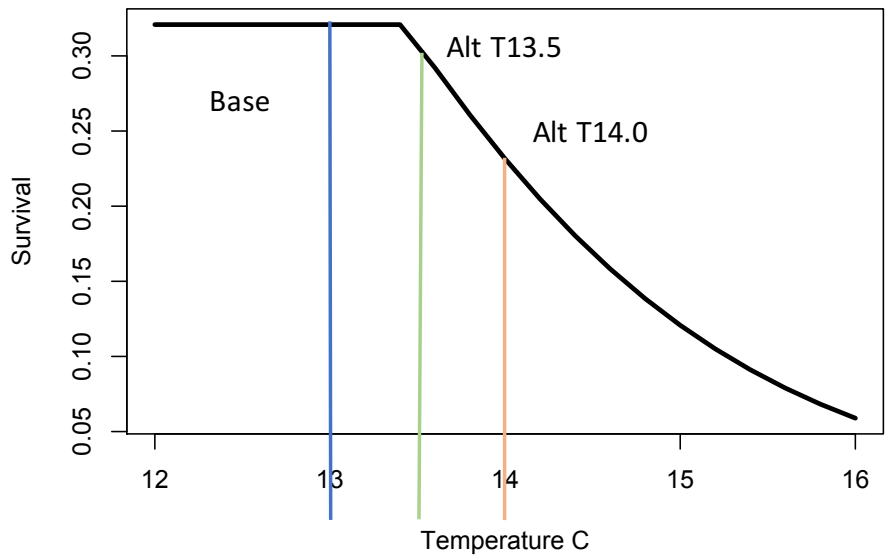
- What is the mechanism?

Reduced survival in egg to fry leads to lower fry abundance, less density dependence in Lower River, and more smolts originating from the Lower River

Alternative $T_{14.0}$

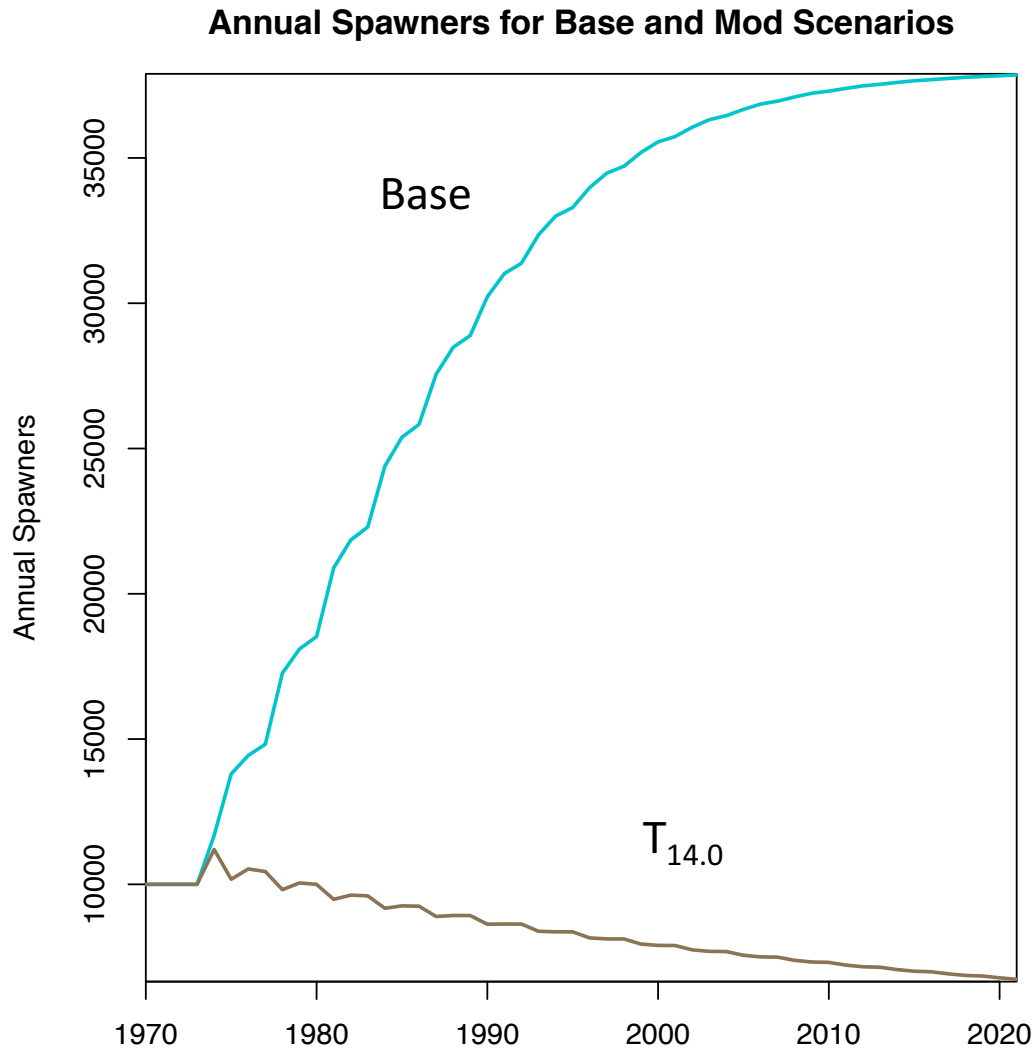
egg incubation temperature is 14.0 C

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



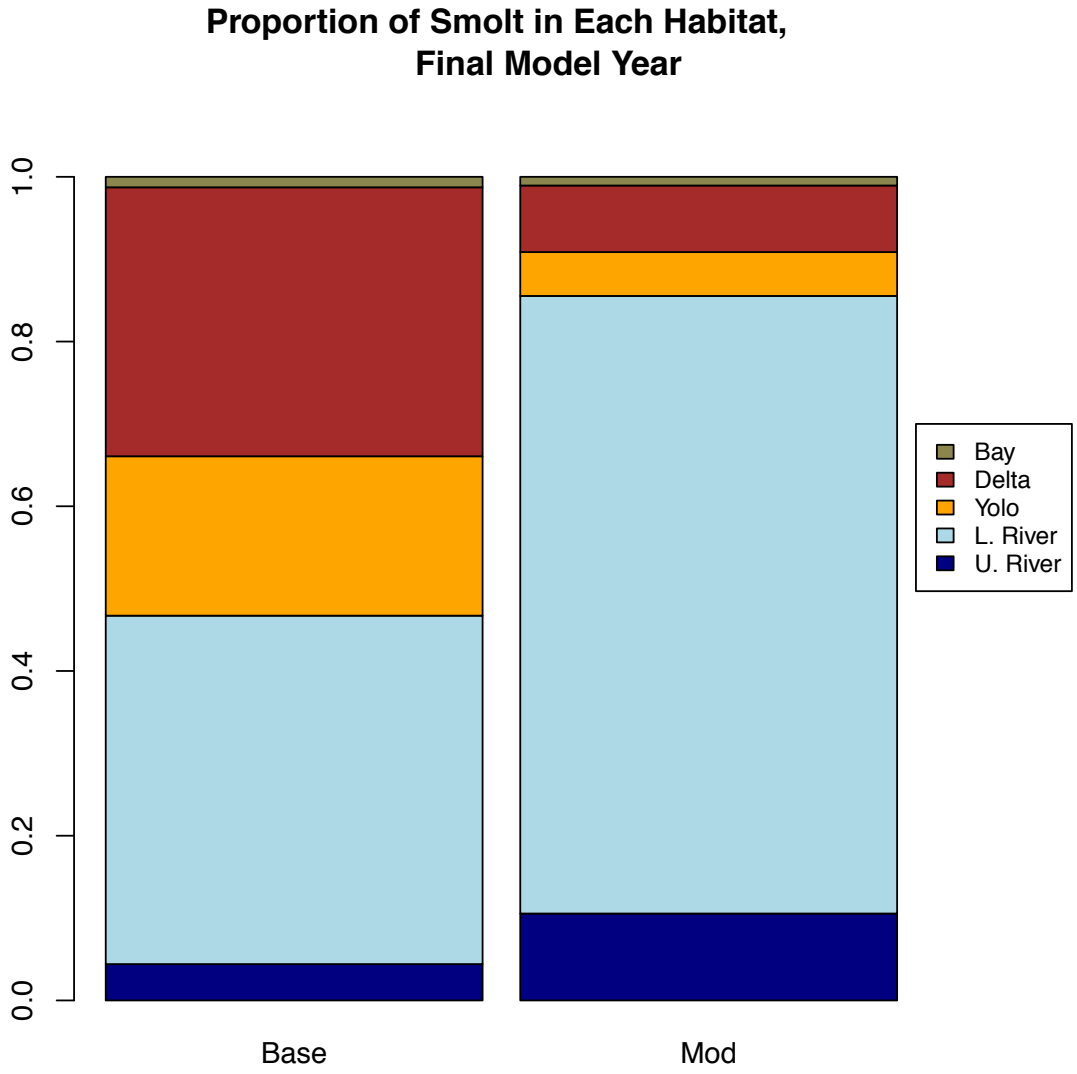
$T_{14.0}$ vs Base – abundance

egg incubation temperature is 14.0 C



$T_{14.0}$ vs Base – distribution

egg incubation temperature is 14.0 C



Alternative $T_{14.0}$

egg incubation temperature is 14.0 C

- What is your prediction for equilibrium abundance?

Abundance is lower ~ - 82%

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River strongly

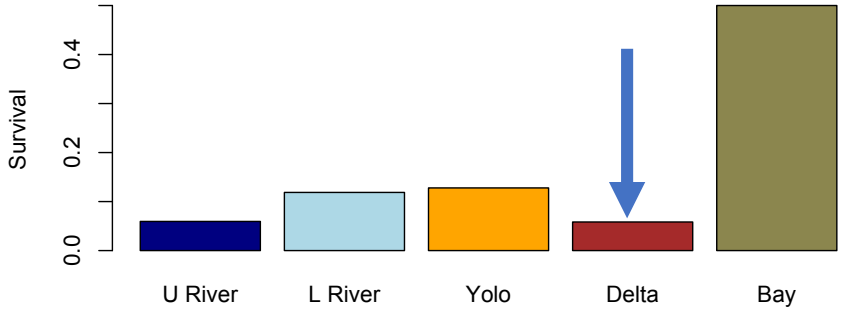
- What is the mechanism?

Reduced survival in egg to fry leads to lower fry abundance, and thus less density dependence in Lower River so more fry remain there

Smolt survival Alternatives

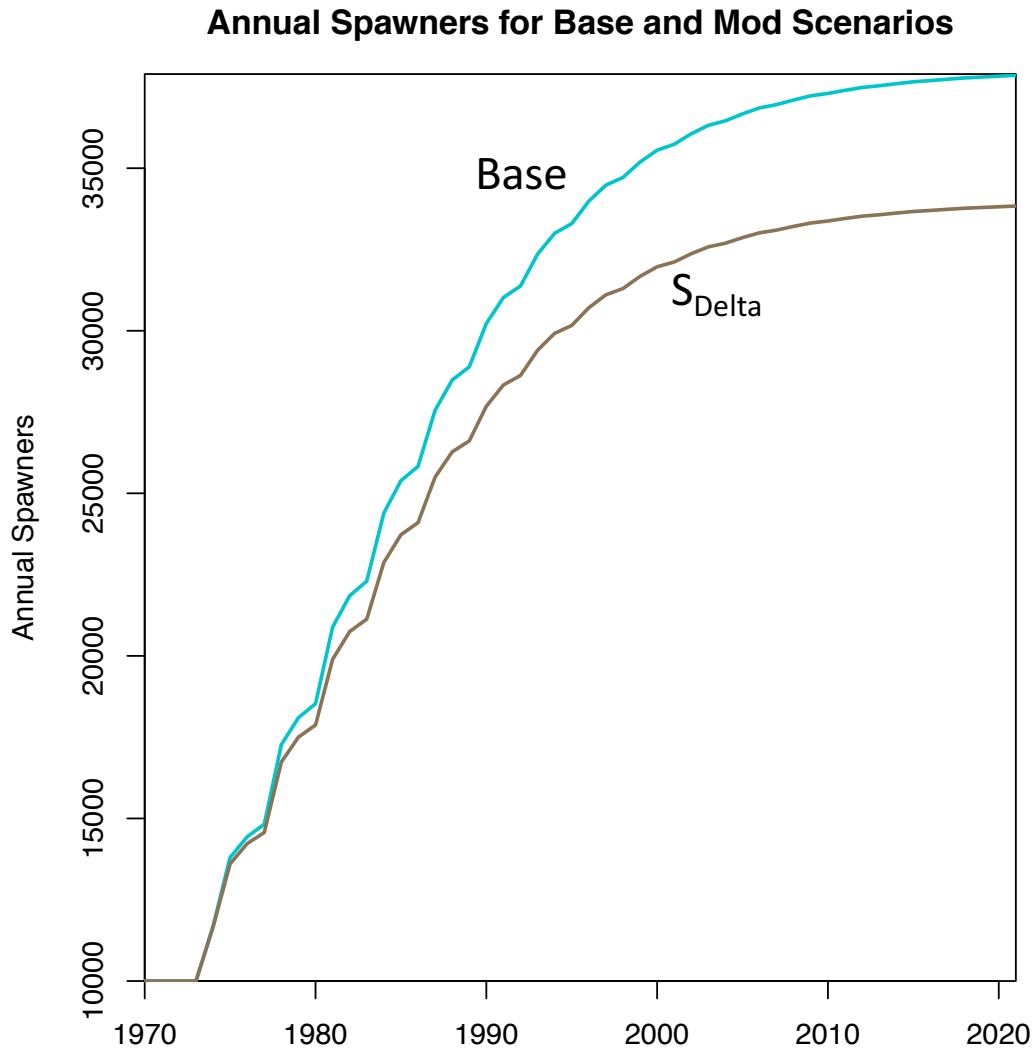
Alternative S_{Delta}
reduce Delta survival by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



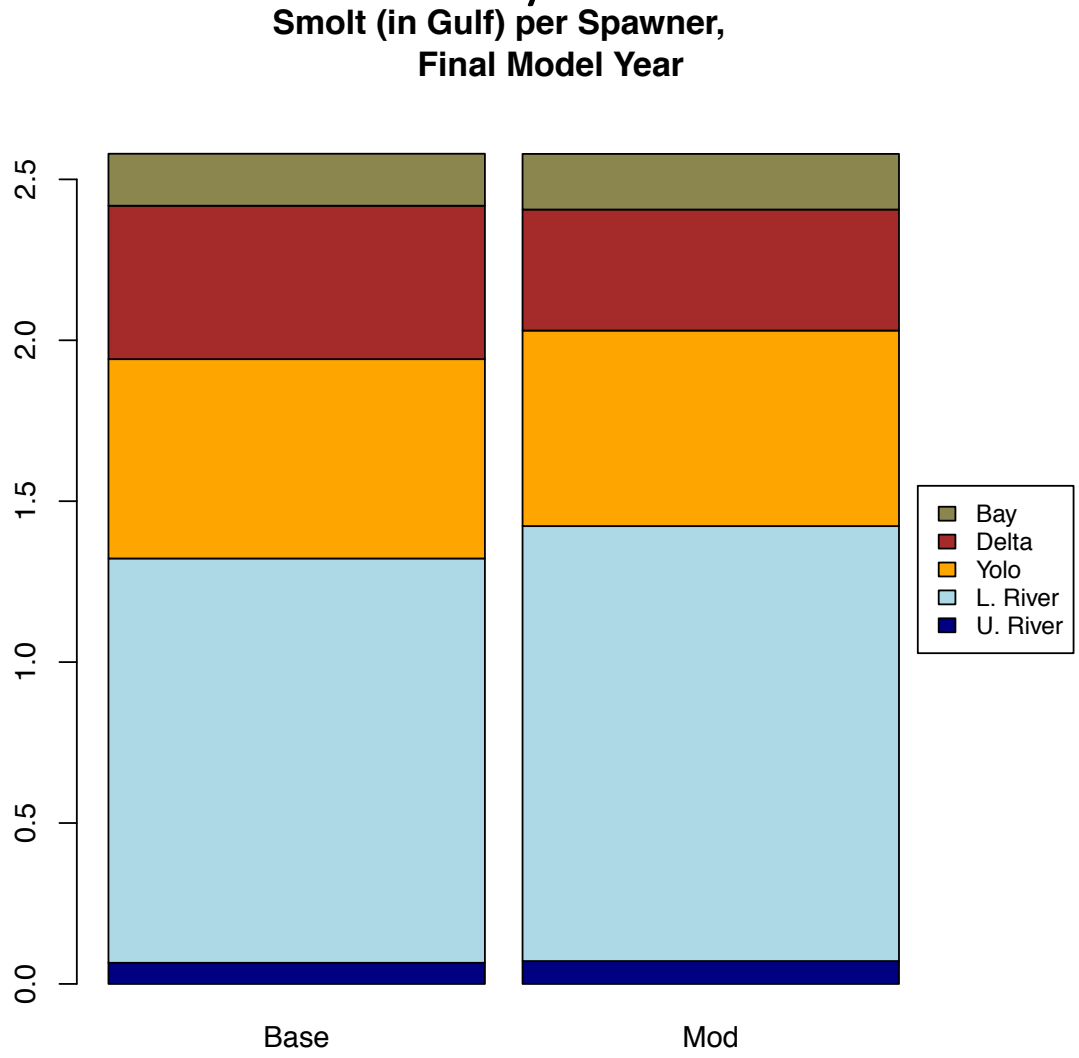
S_{Delta} vs Base – abundance

reduce Delta survival by 20%



S_{Delta} vs Base – distribution

reduce Delta survival by 20%



Alternative S_{Delta}
reduce Delta survival by 20%

- What is your prediction for equilibrium abundance?

Abundance is slightly lower -10.6%

- What is your prediction for smolt origin of distribution?

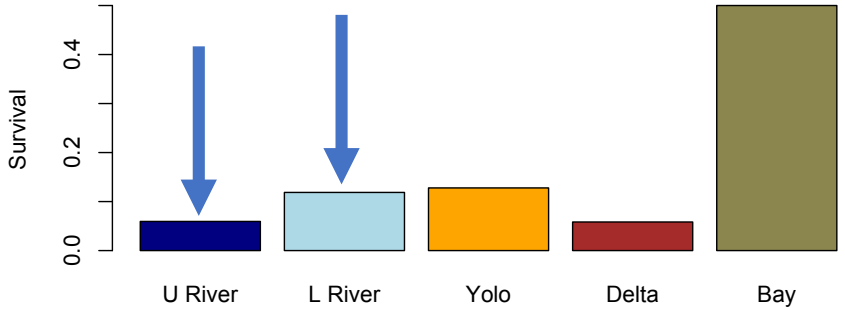
Distribution shifts to Lower River slightly

What is the mechanism?

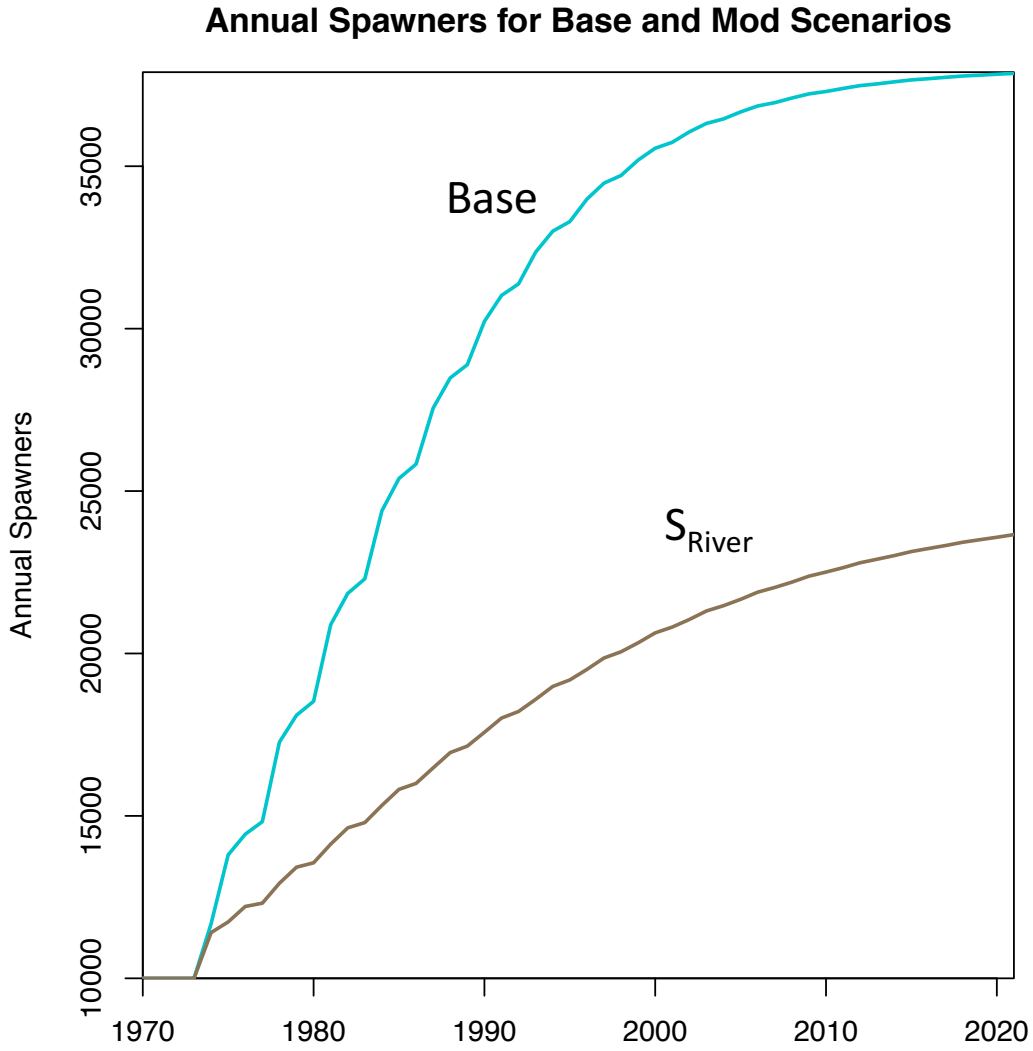
Reduced survival in smolt abundance leads to lower adult abundance, leading to lower fry abundance, and a slightly higher proportion remain in the Lower River

Alternative S_{River}
reduce Upper and Lower River survival by 20%

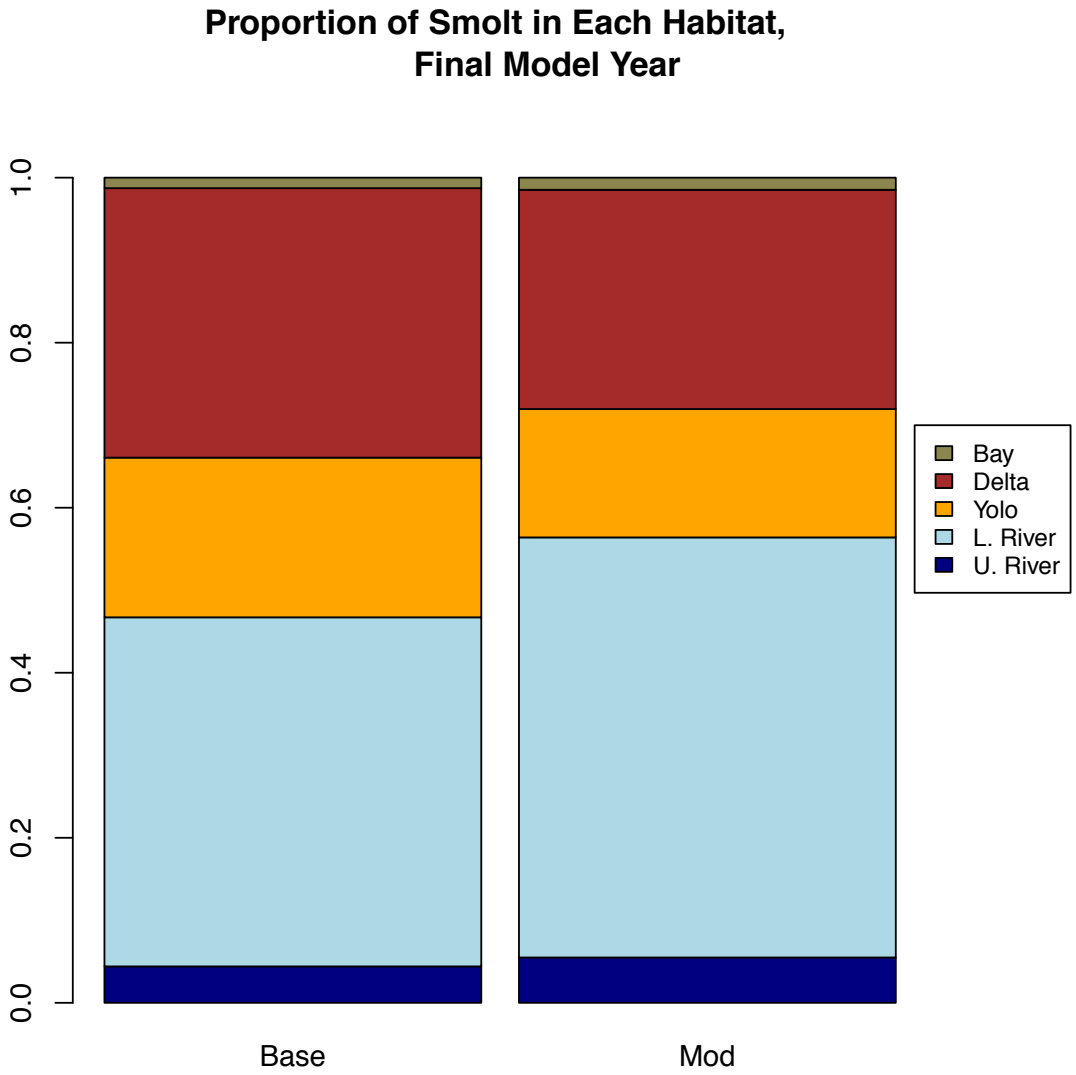
- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



S_{River} vs Base – abundance
reduce Upper and Lower River survival by 20%



S_{River} vs Base – distribution
reduce Upper and Lower River survival by 20%



Alternative S_{River}
reduce Upper and Lower River survival by 20%

- What is your prediction for equilibrium abundance?

Abundance is lower -37.5%

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River instead of Delta and Yolo

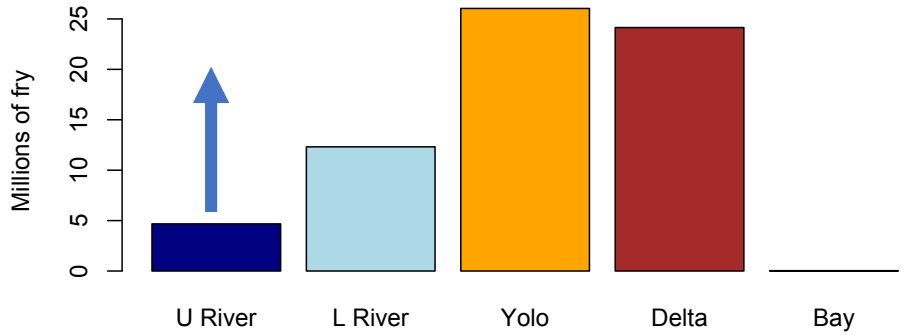
What is the mechanism?

Reduced survival in smolt abundance leads to lower adult abundance, leading to lower fry abundance, and a higher proportion are residents in the Lower River rather than being pushed as migrants to Yolo and Delta

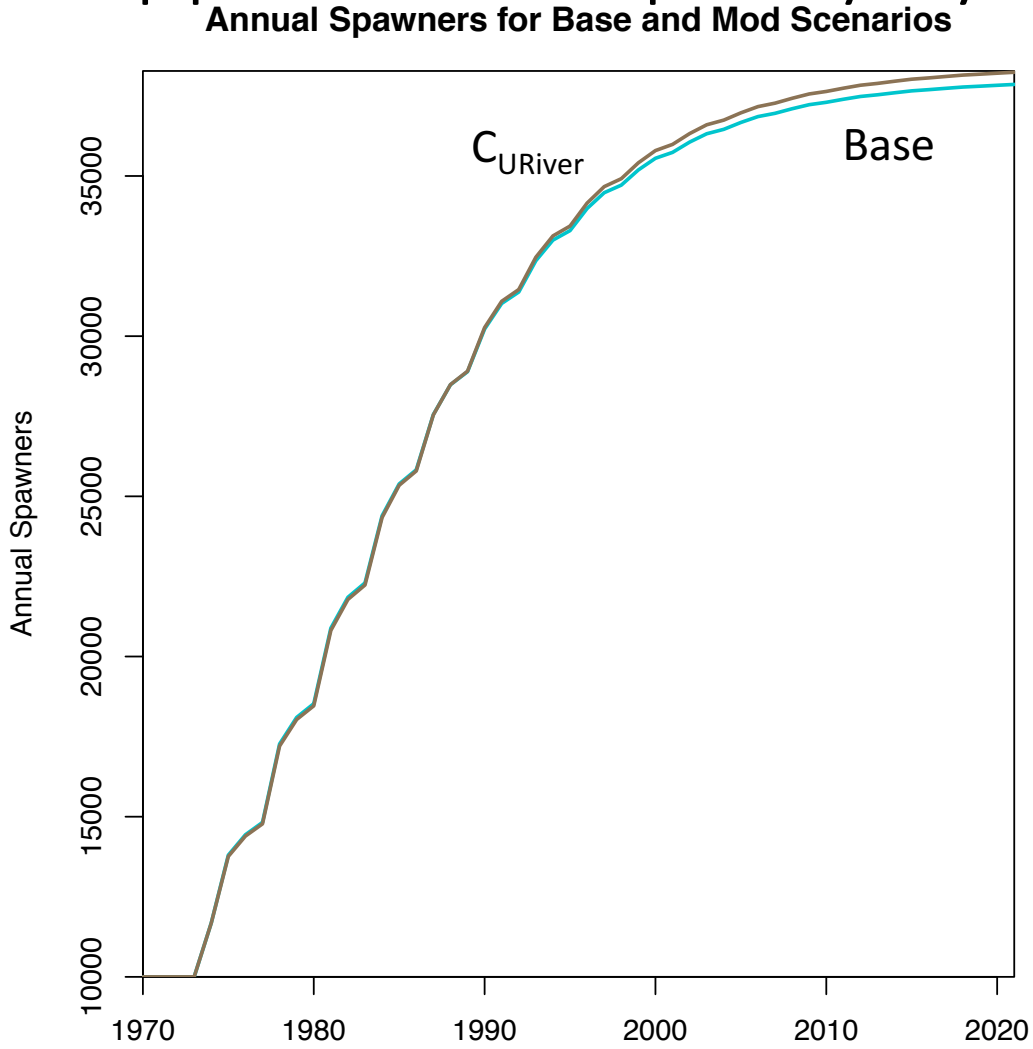
Capacity Alternatives

Alternative C_{URiver} – increase Upper River capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?

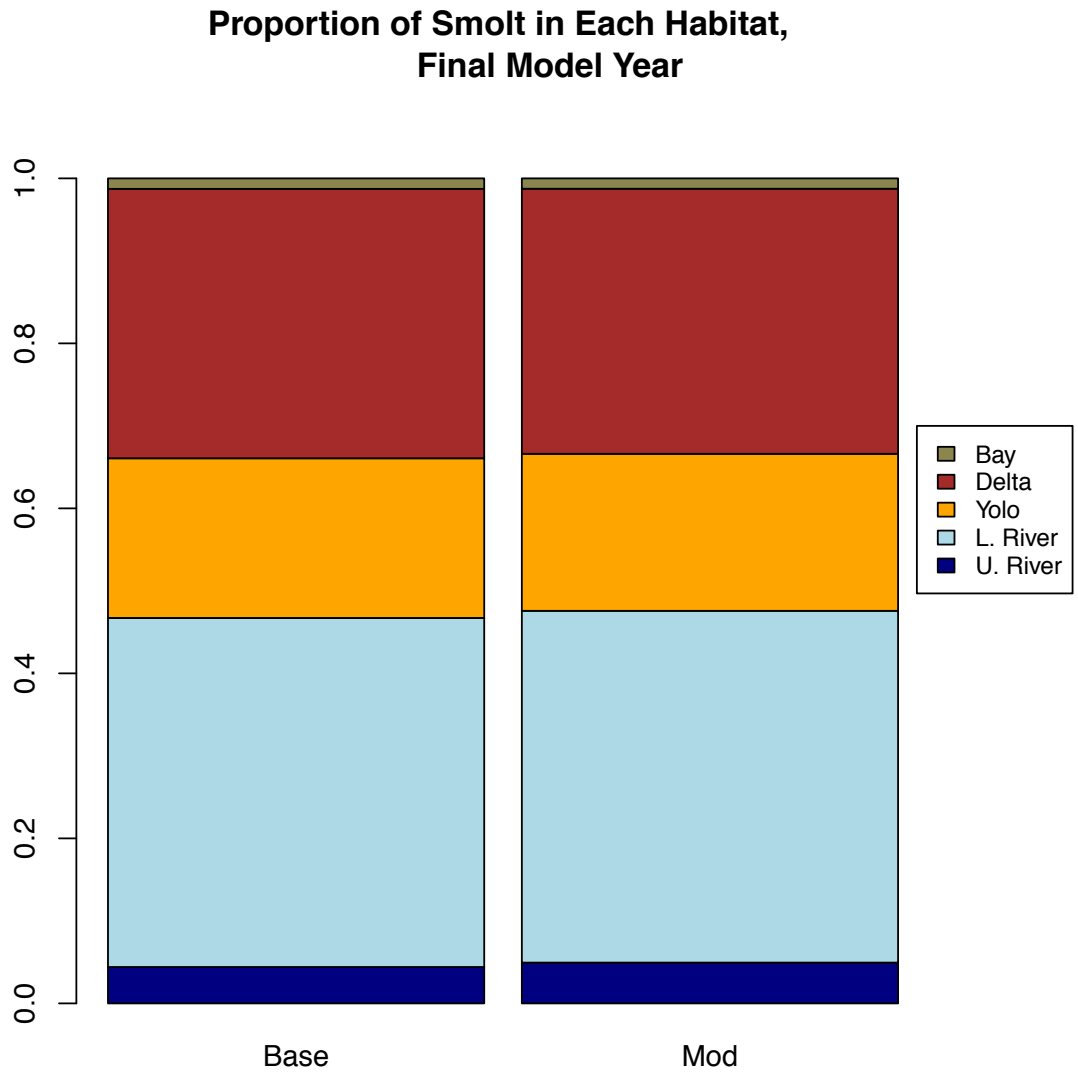


C_{URiver} vs Base – abundance increase Upper River capacity by 20%



C_{URiver} vs Base – distribution

increase Upper River capacity by 20%



Alternative C_{URiver}
increase Upper River capacity by 20%

- What is your prediction for equilibrium abundance?

Abundance is slightly higher ~ 1.0 %

- What is your prediction for smolt origin of distribution?

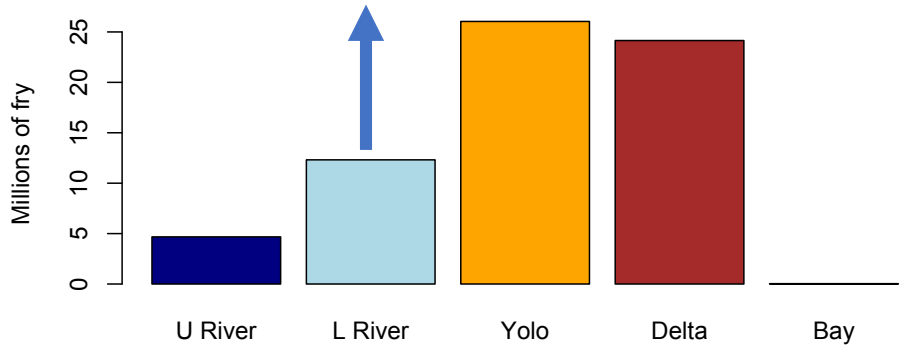
Distribution does not change

What is the mechanism?

Most fry moving out of the Upper River habitat to rear and smolt elsewhere

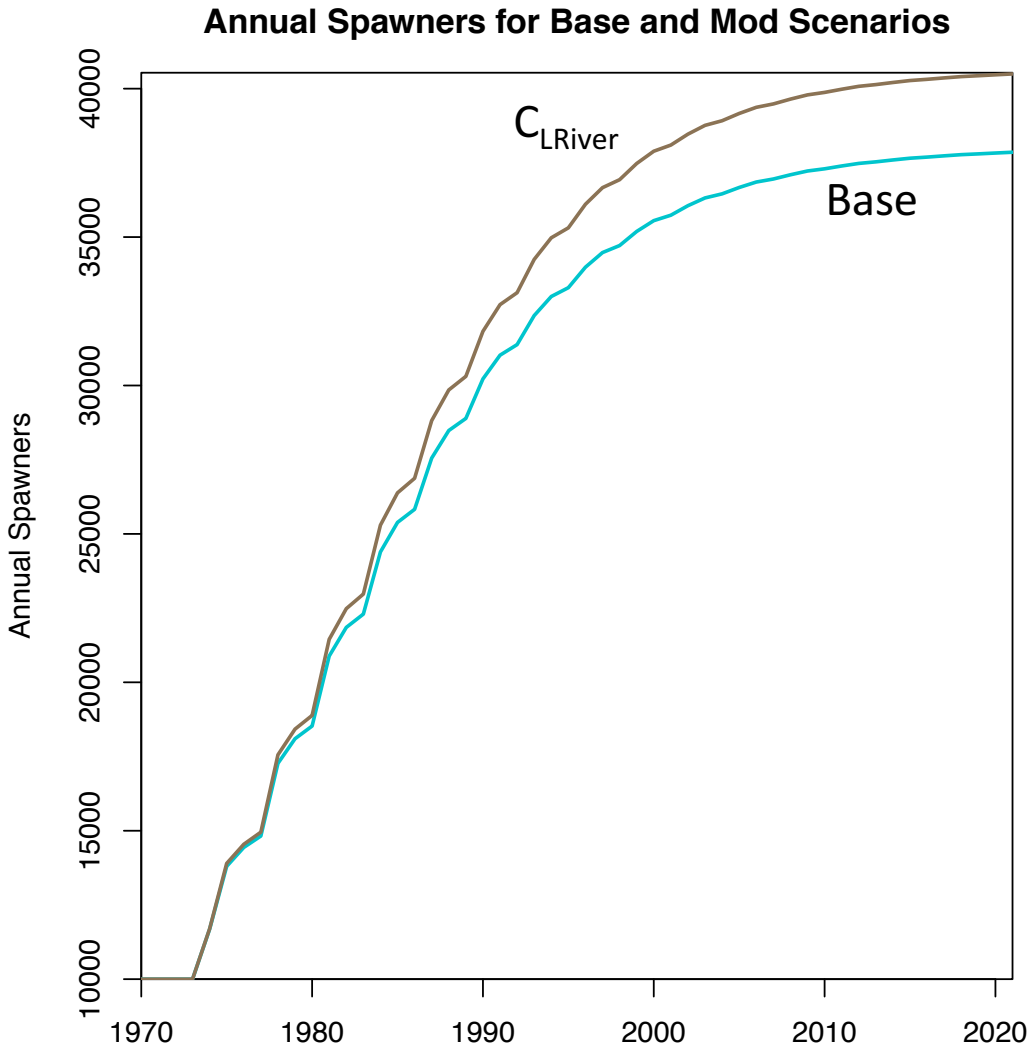
Alternative C_{LRiver} – increase Lower River capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



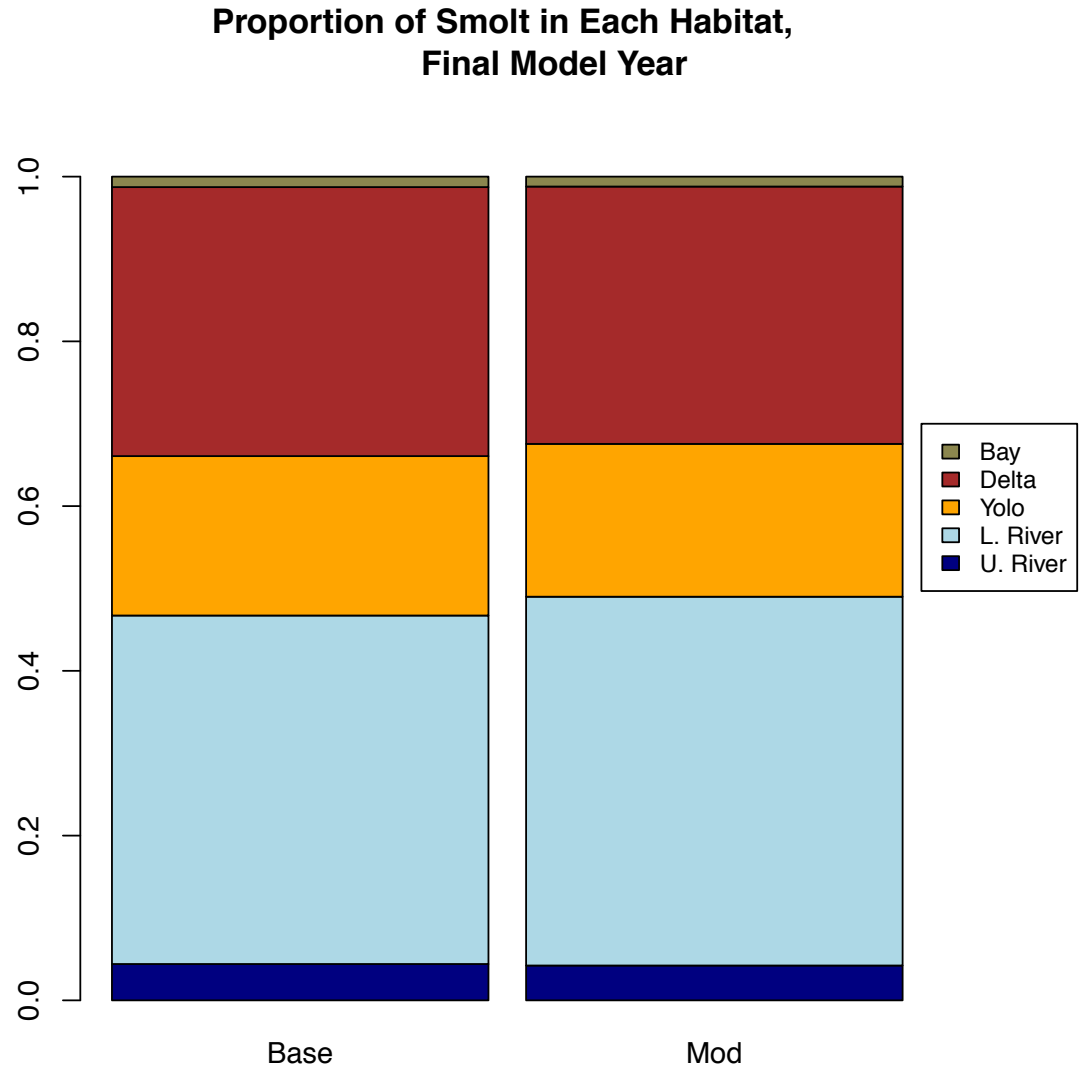
C_{LRiver} vs Base – abundance

increase Lower River capacity by 20%



C_{LRiver} vs Base – distribution

increase Lower River capacity by 20%



Alternative C_{LRiver}
increase Lower River capacity by 20%

- What is your prediction for equilibrium abundance?

Abundance is higher ~ 7.0 %

- What is your prediction for smolt origin of distribution?

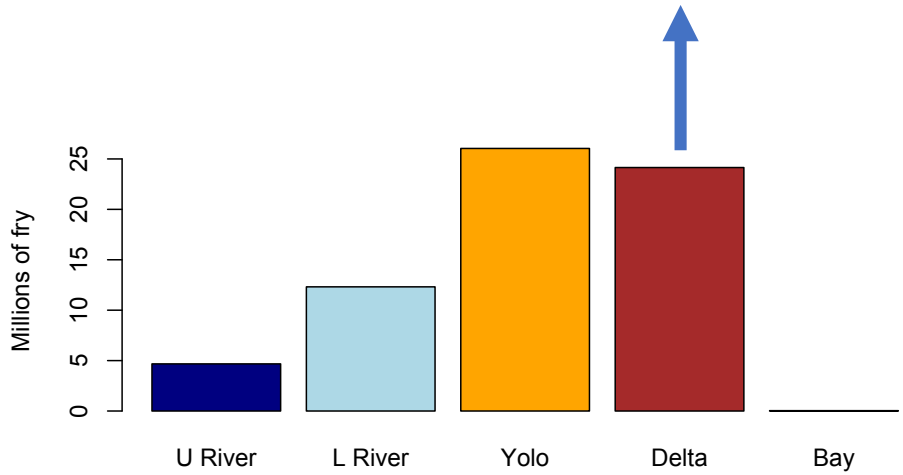
Distribution increases in Lower River

What is the mechanism?

Additional capacity in Lower River allows fry to rear there, as opposed to the Delta; subsequent survival is higher for smolts that stayed in the Lower River

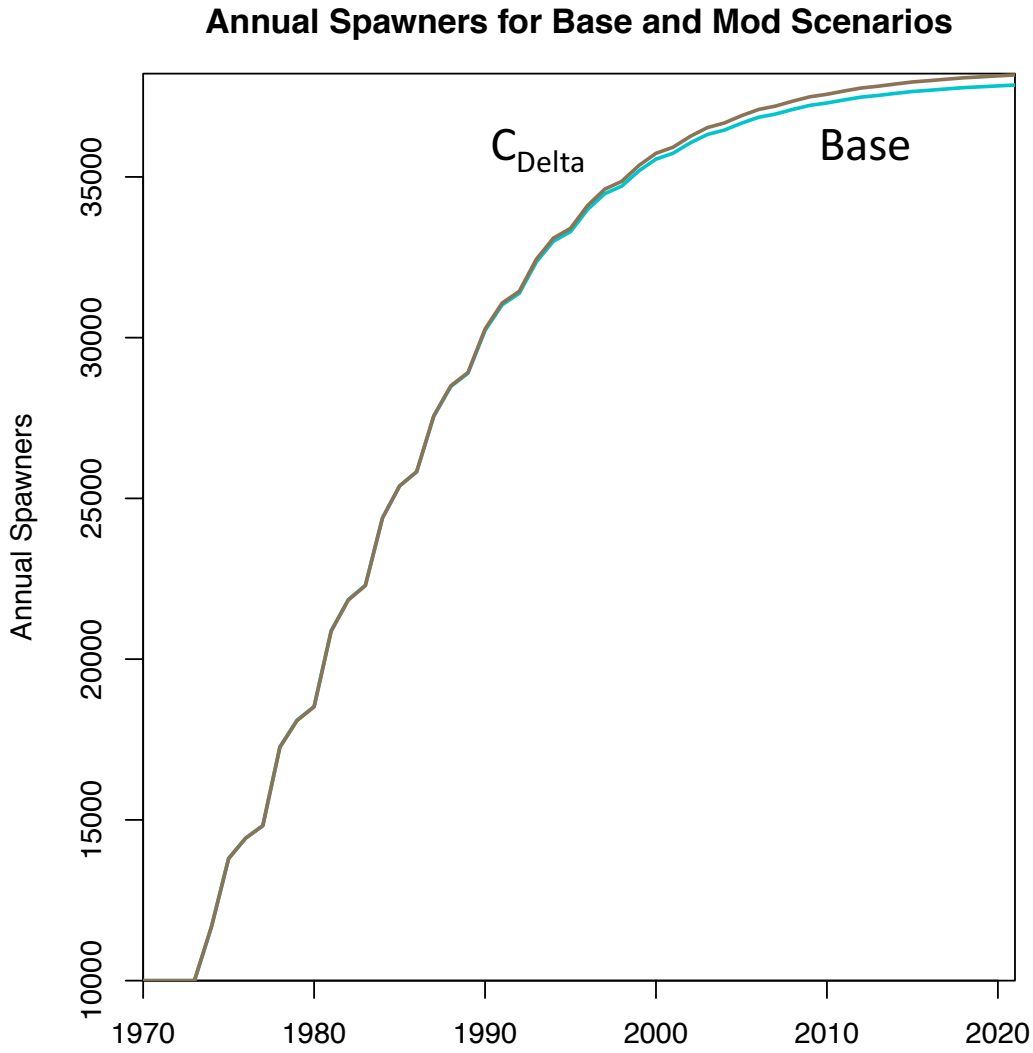
Alternative C_{Delta} – increase Delta capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



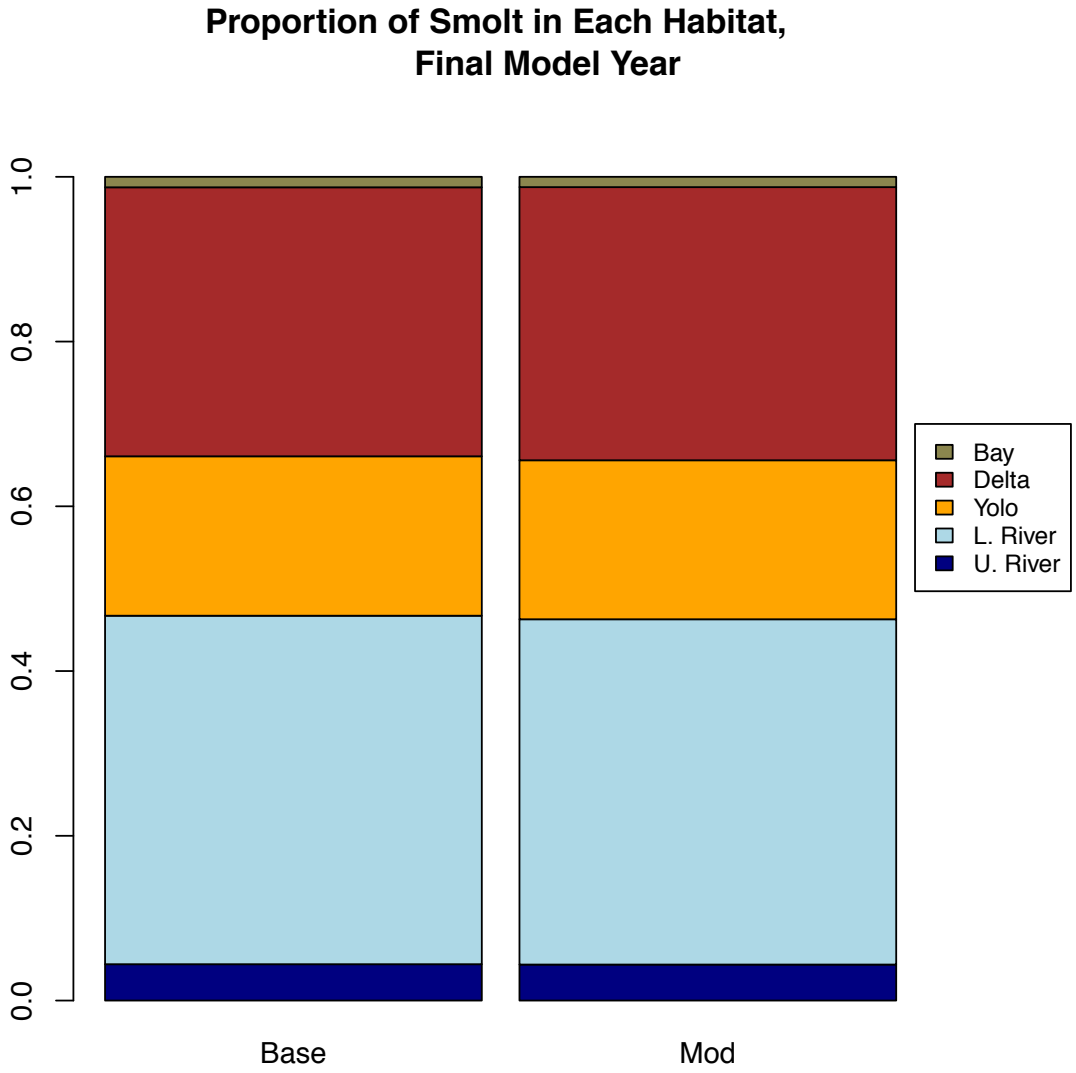
C_{Delta} vs Base – abundance

increase Delta capacity by 20%



C_{Delta} vs Base – distribution

increase Delta capacity by 20%



Alternative C_{Delta}
increase Delta capacity by 20%

- What is your prediction for equilibrium abundance?

Abundance is slightly higher 0.8 %

- What is your prediction for smolt origin of distribution?

Distribution does not change

What is the mechanism?

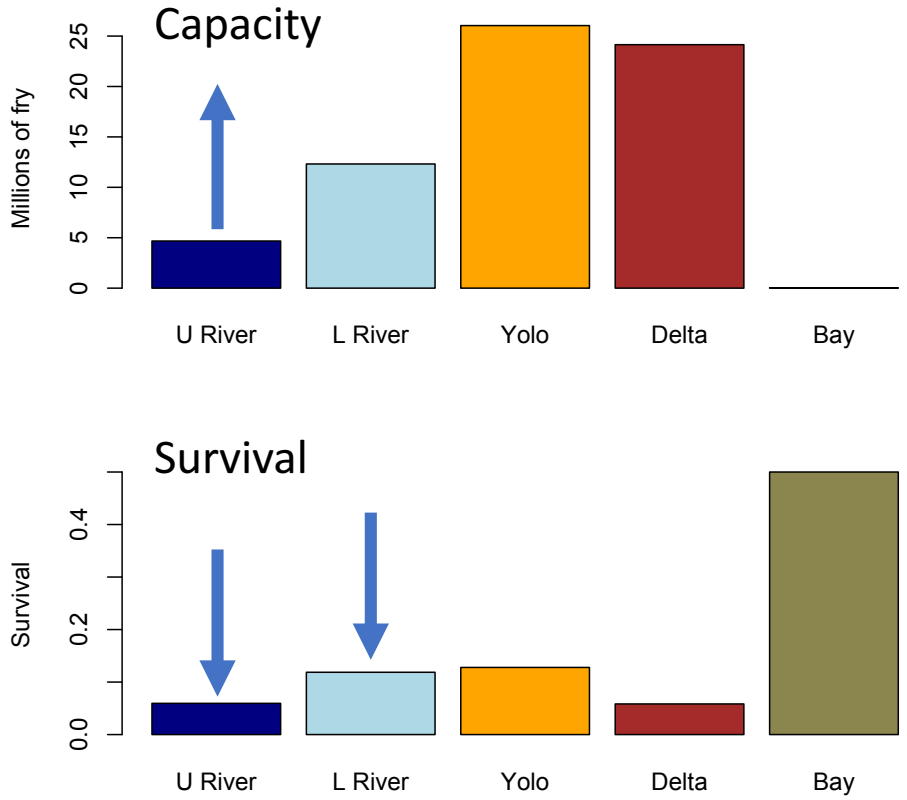
Additional capacity in the Delta has little effect because there is already plenty of Delta habitat

Fry capacity and smolt survival alternatives

Alternative S_{River} & C_{URiver}

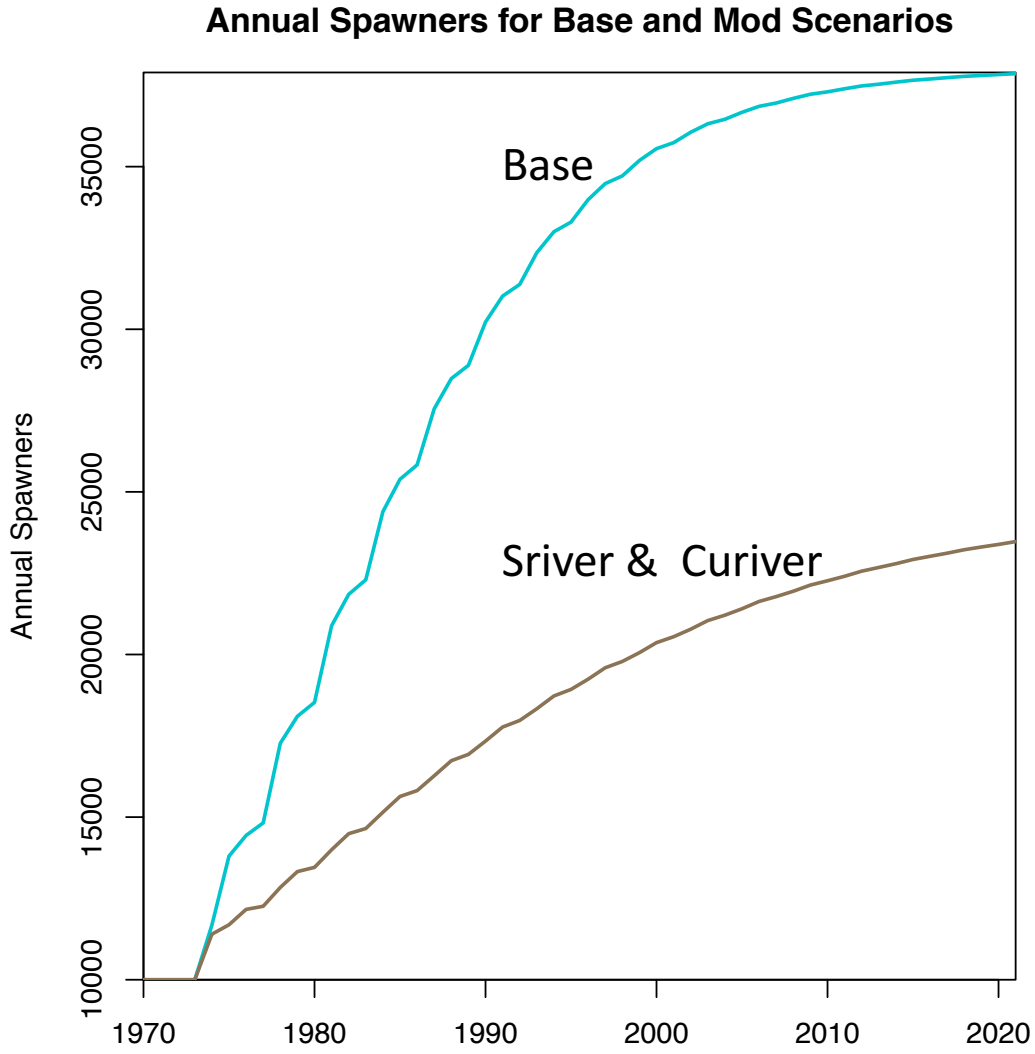
decrease Upper and Lower River smolt survival by 20%, increase Upper River capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



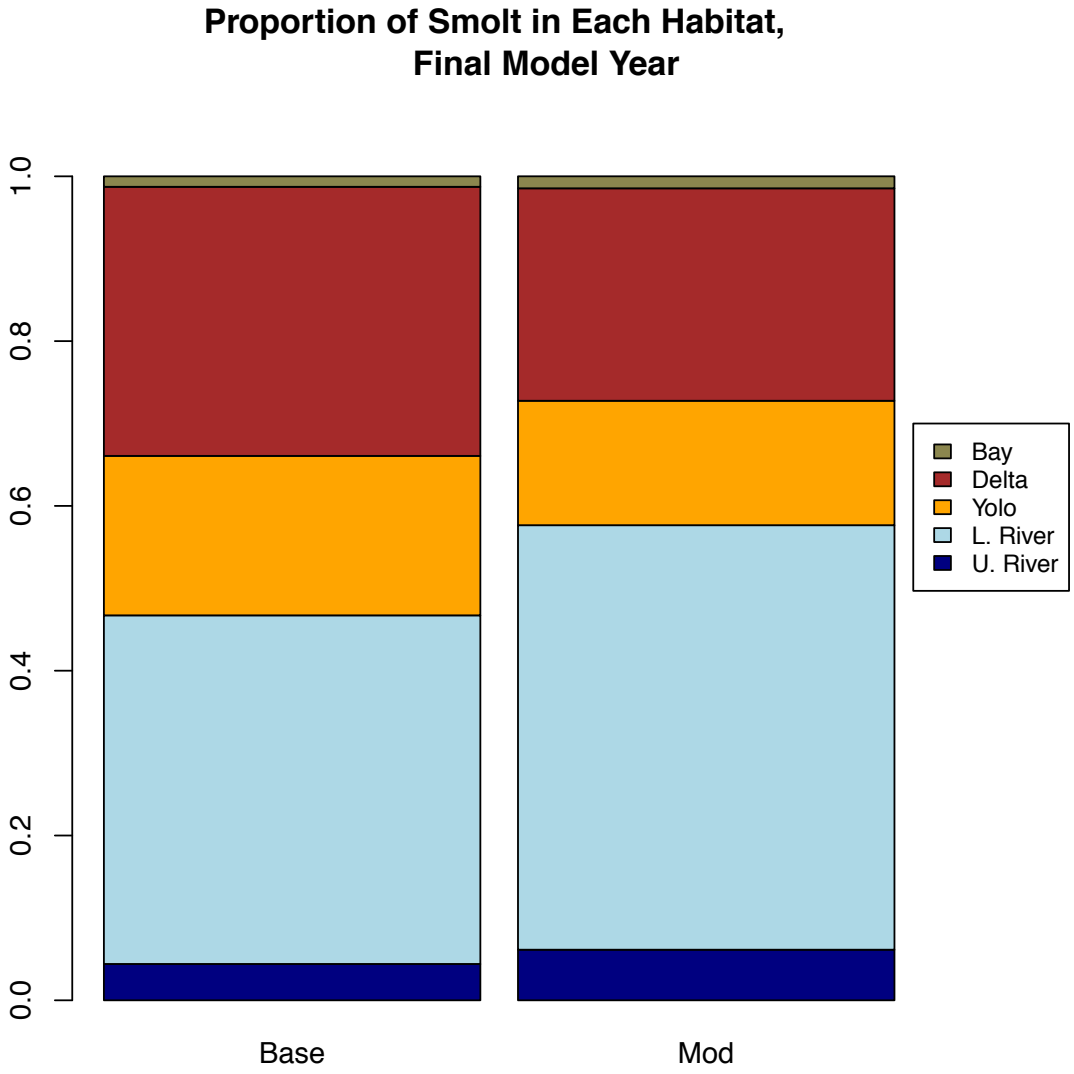
S_{river} & C_{URiver} vs Base – abundance

decrease Upper and Lower River smolt survival by 20%, increase Upper River capacity by 20%



S_{river} & C_{URiver} vs Base – distribution

decrease Upper and Lower River smolt survival by 20%, increase Upper River capacity by 20%



Alternative S_{river} & C_{URiver}

- What is your prediction for equilibrium abundance?

Abundance is lower - 38 %,

and note that S_{River} alone is – 37.5%

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River as abundance of fry decreases

What is the mechanism?

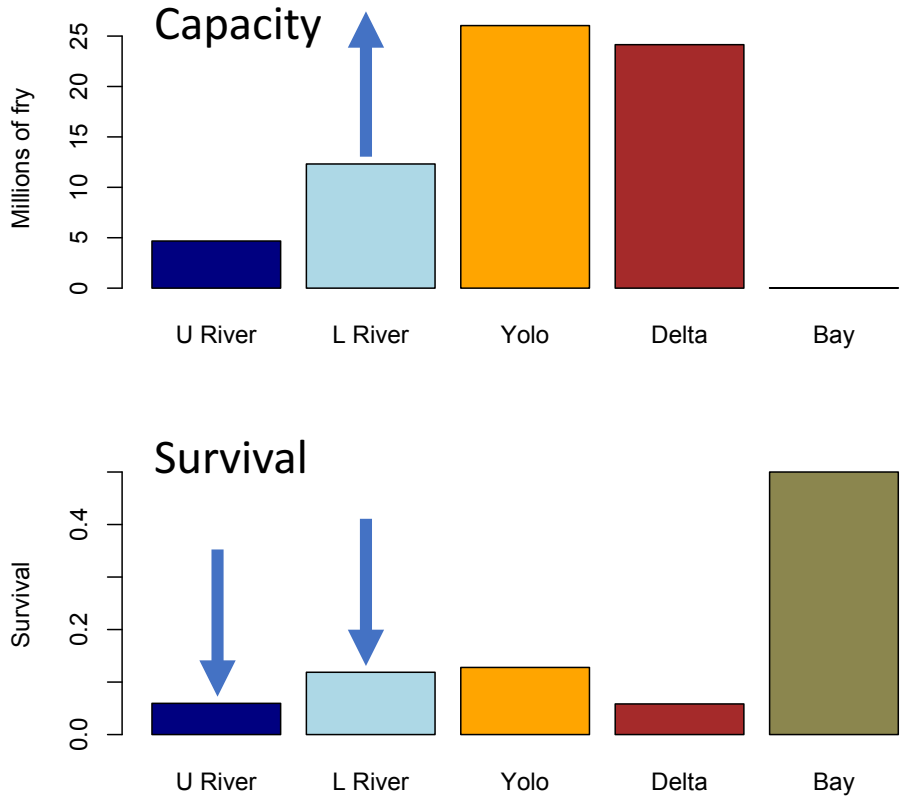
1) Reduced survival in smolt abundance leads to lower adult abundance, leading to lower fry abundance, and a higher proportion are residents in the Lower River rather than being pushed as migrants to Yolo and Delta.

2) Additional Upper River capacity allows more fry to remain there and be affected by reduced smolt survival rate relative to Lower River

Alternative S_{River} & C_{LRiver}

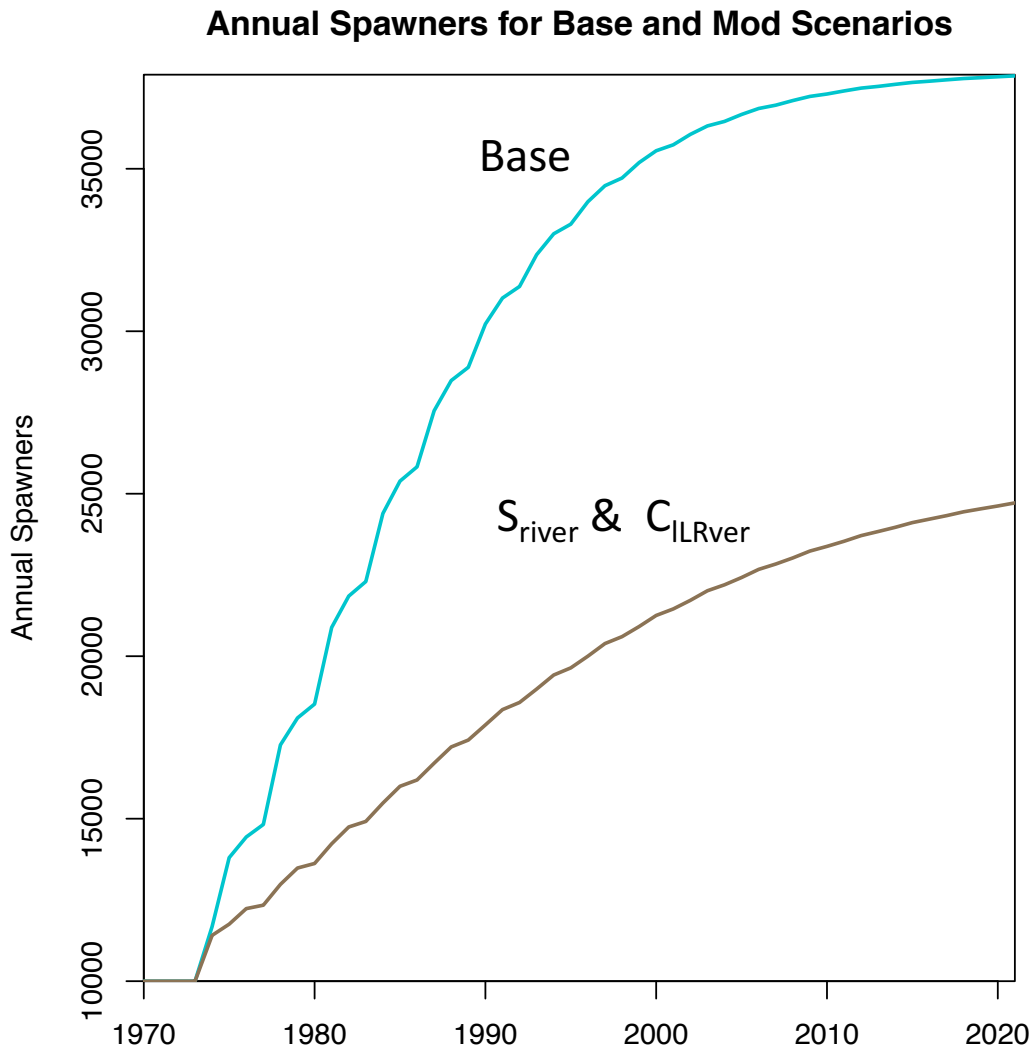
decrease Upper and Lower River smolt survival by 20%, increase Lower River capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



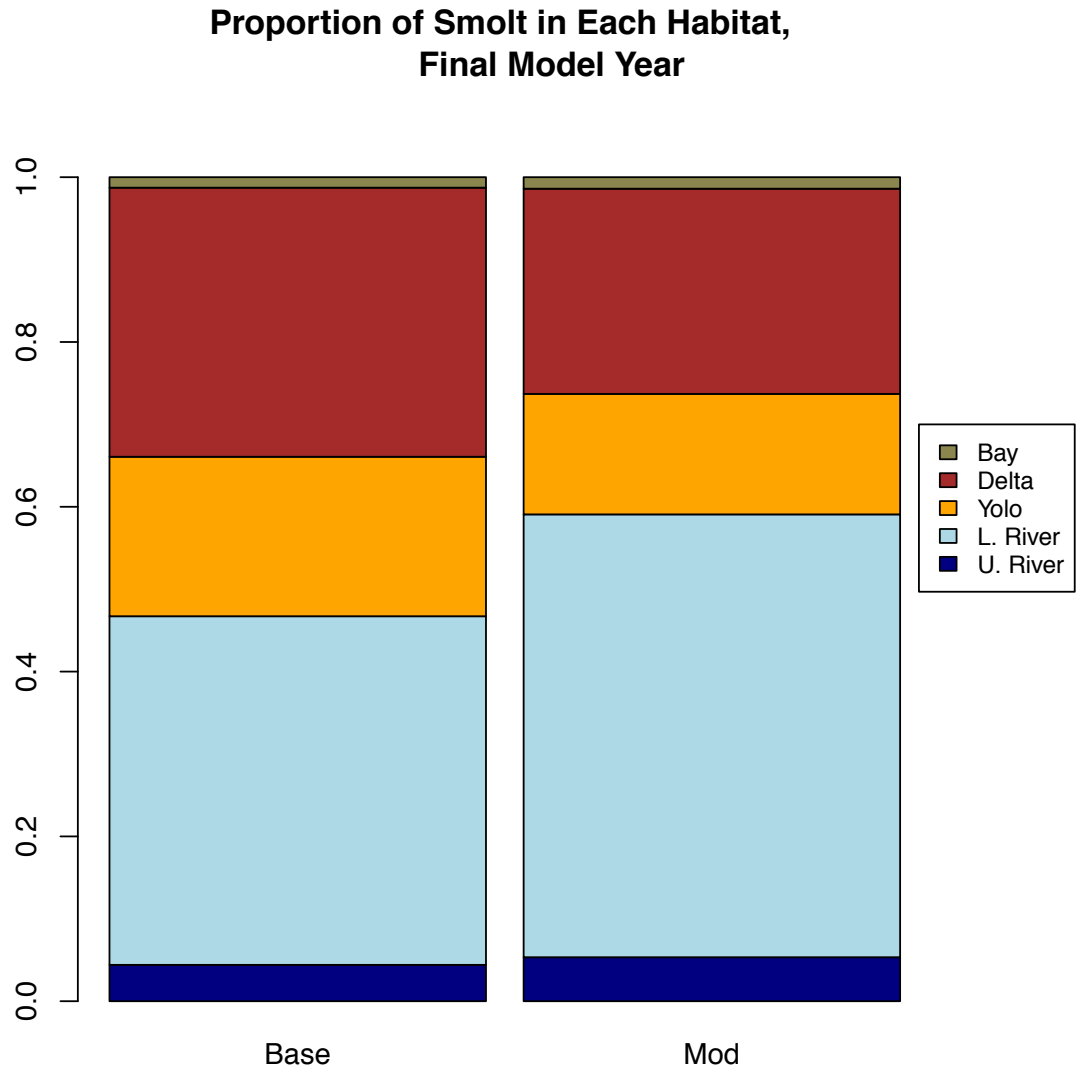
S_{river} & C_{LRiver} vs Base – abundance

decrease Upper and Lower River smolt survival by 20%, increase Lower River capacity by 20%



S_{river} & C_{LRiver} vs Base – distribution

decrease Upper and Lower River smolt survival by 20%, increase Lower River capacity by 20%



Alternative S_{River} & C_{LRiver}

decrease Upper and Lower River smolt survival by 20%, increase Lower River capacity by 20%

- What is your prediction for equilibrium abundance?

Abundance is lower - 35 %

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River as abundance of fry decreases and capacity there increases

What is the mechanism?

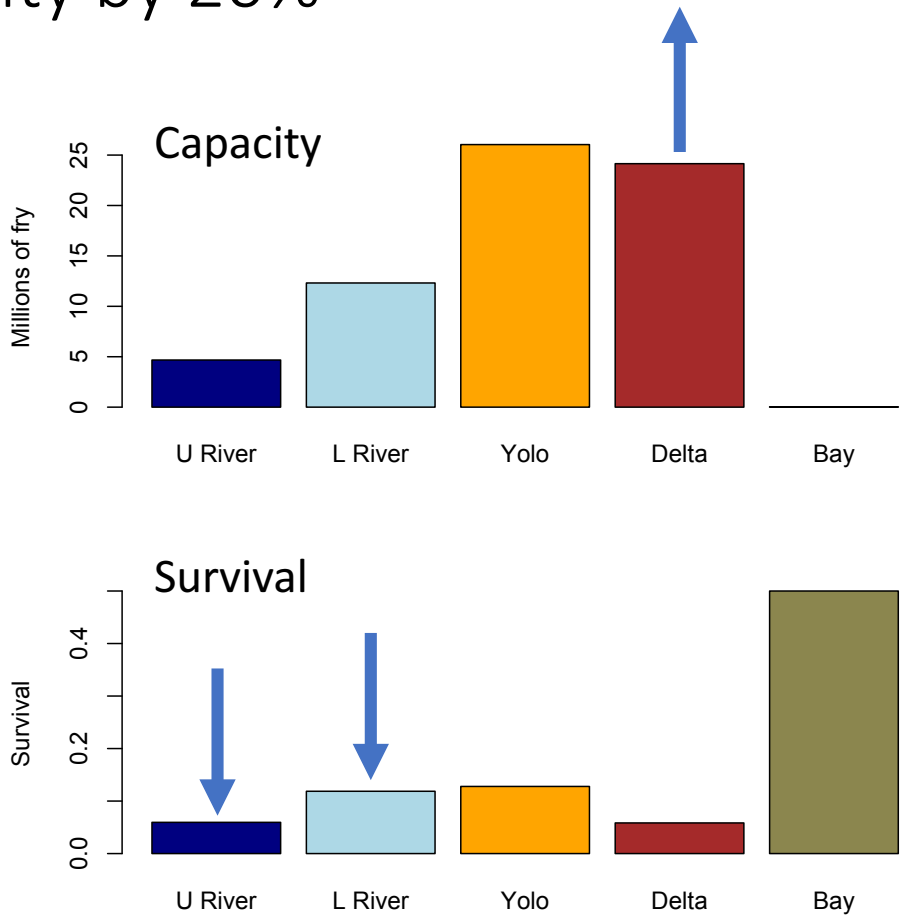
1) Reduced survival in smolt abundance leads to lower adult abundance, leading to lower fry abundance, and a higher proportion are residents in the Lower River rather than being pushed as migrants to Yolo and Delta

2) Additional Lower River capacity allows more fry to remain and outmigrate with a better smolt survival rate relative to Delta

Alternative S_{River} & C_{Delta}

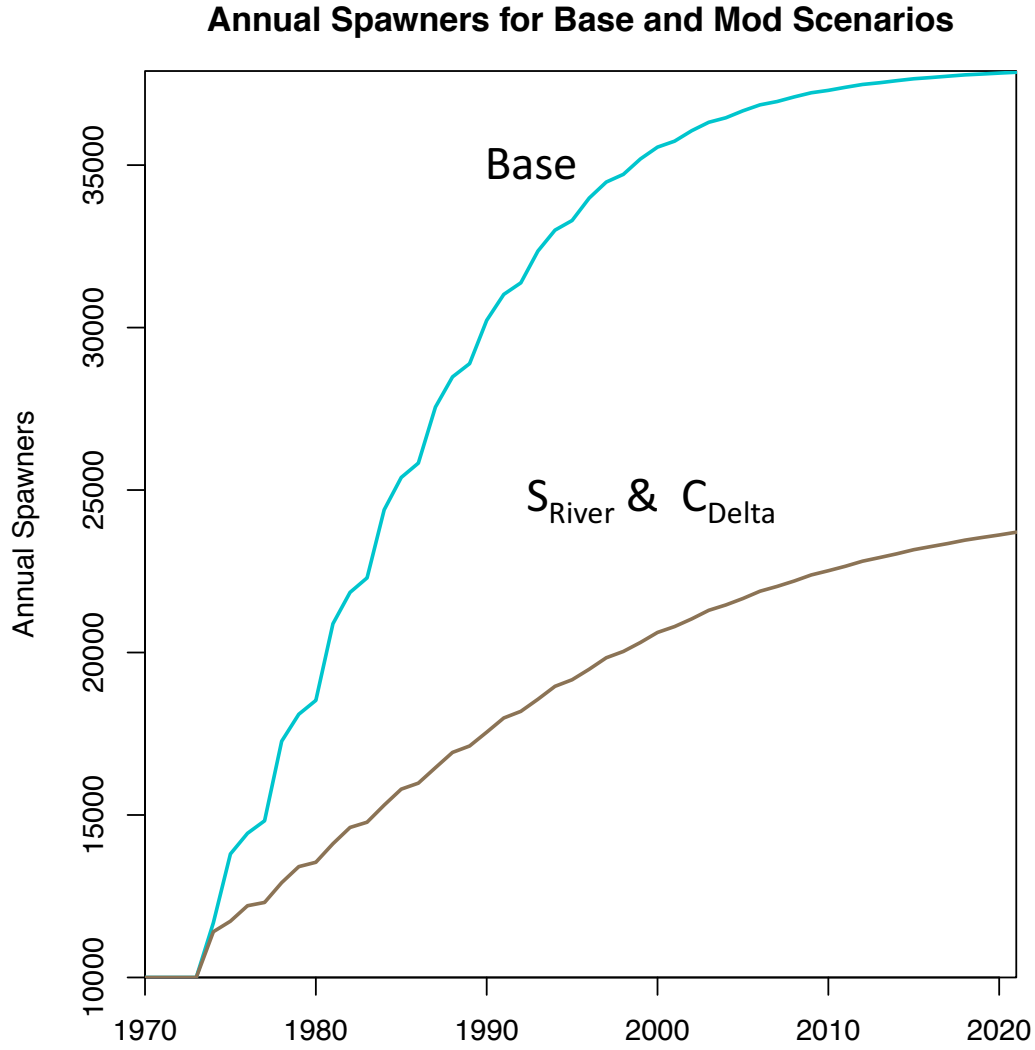
decrease Upper and Lower River smolt survival by 20%, increase Delta capacity by 20%

- What is your prediction for abundance?
- What is your prediction for smolt origin of distribution?
- What is the mechanism?



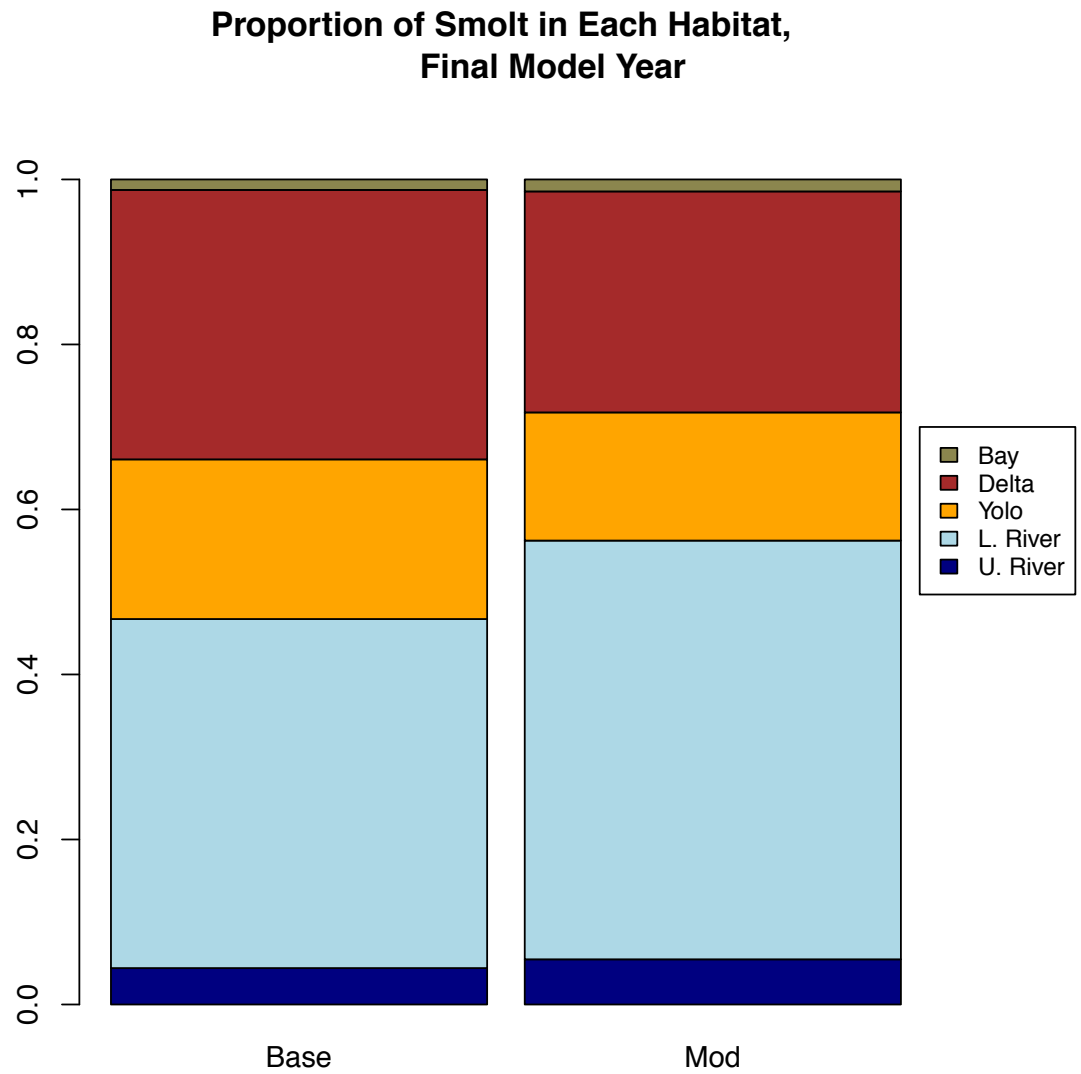
S_{River} & C_{Delta} vs Base – abundance

decrease Upper and Lower River smolt survival by 20%, increase Delta capacity by 20%



S_{River} & C_{Delta} vs Base – distribution

decrease Upper and Lower River smolt survival by 20%, increase Delta capacity by 20%



Alternative S_{River} & C_{Delta}

decrease Upper and Lower River smolt survival by 20%, increase Delta capacity by 20%

- What is your prediction for equilibrium abundance?

Abundance is lower - 37.4 %

- What is your prediction for smolt origin of distribution?

Distribution shifts to Lower River as abundance of fry decreases and capacity there increases

What is the mechanism?

1) Reduced survival in smolt abundance leads to lower adult abundance, leading to lower fry abundance, and a higher proportion are residents in the Lower River rather than being pushed as migrants to Yolo and Delta

2) Additional Delta capacity provides little benefit as it is not limiting

Summary of the little exercise

- Alts that improved equilibrium abundance
  - Increasing Lower River habitat
- Alts that had little effect on equilibrium abundance
  - Increasing Upper River habitat - due to low survival rates of smolts from this habitat
  - Increasing Delta habitat - due to not being limiting and low survival rate of smolts
- Alts that had a negative effect on equilibrium abundance
  - Increasing temperature during incubation
  - Decreasing Upper and Lower River smolt survival
  - Decreasing Delta smolt survival

Conclusions

- Spatial arrangement important for dynamics
  - All rearing fry initiate at Upper River
  - Move out to Lower River and Yolo predominantly
  - Delta provides rearing capacity as “overflow” from upstream habitats (in this scenario due to no Wilkins flow trigger)
- Smolt survival reductions
  - Have a larger impact in habitats where fry rear in high proportions
- Capacity additions
  - Increases equilibrium abundance if increase fry in habitats with good smolt survival
  - Decreases equilibrium abundance if increase fry in habitats with poor smolt survival

Questions?

noblehendrix@gmail.com

Credit www.azrainman.com

… a true Franken - fish