Outline

- Purpose
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Purpose

- Long-term survival and maintenance of healthy San Joaquin River fall and spring-run Chinook salmon populations depend on sufficient suitable habitat (both quantity and quality) for each life stage and population.
- The goal of the ESHE model is to estimate the suitable habitat needs for spring-run and fall-run to support the range of production targets outlined in the Fisheries Management Plan (FMP).
- Variation in estimates of suitable habitat under varying flow conditions and habitat quality assumptions will be modeled to incorporate uncertainty in model output.
- These estimates will help inform the minimum 2B and 4B levee setbacks.

Conceptual Framework

- A fundamental concept in relating salmonid production to stream habitat is that stream-dwelling salmonids either defend or rely on food from a characteristic area of territory.
- We assume that the maximum number of individuals that a habitat area can support is limited by the territory size of the fish and the amount of available suitable habitat (ASH):

Capacity = ASH / Territory Size

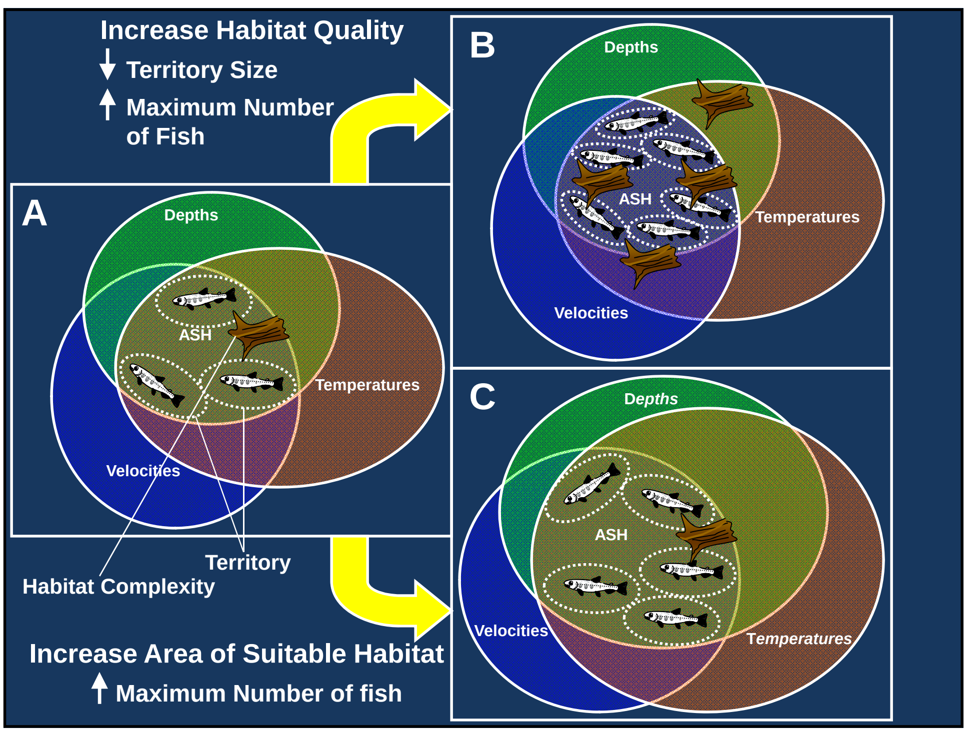
- We assume that juvenile salmon will only rear (and set-up territories) in habitat that meets their preferred range of non-consumable habitat conditions (Temperature, Depth, Velocity), defined as ASH.

***Important to note that water temperature modeling is being completed separate from ESHE and 2D estimates of suitable habitat needs.*

Conceptual Framework

Capacity = ASH / Territory Size

- The main driver of territory size requirements for juvenile salmon is fish size, with larger salmon requiring more space to attain energetic requirements and avoid competition.
- Secondarily, habitat quality influences territory size requirements, with juveniles requiring less space to meet their energetic requirements and avoid competition in high quality habitat (e.g high habitat complexity, food abundance).



Conceptual Framework

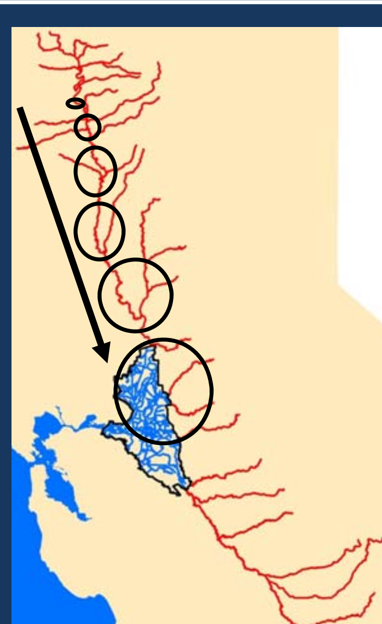
- The goal of ESHE is to enumerate the amount of rearing habitat required to support the Fisheries Management Plan production targets for fall and spring-run Chinook salmon. Therefore, we organize the equation to predict the required ASH to support production target abundance levels:

  ASH = Abundance • Territory Size

- In stationary systems, it is relatively easy to calculate territory size and population habitat needs.
- However, In dynamic systems emigration timing, initial size, growth, habitat quality, and mortality all act together to influence how much territory is needed for a cohort at a given location in the system at a given time.

Conceptual Framework

- Early in the year, juvenile Chinook salmon are relatively small and can be found in small numbers in upstream reaches
- As time (i.e., days) progress, juveniles increase in size and numbers and move through the system
- Required territory increases with increases in size



Conceptual Framework

- ESHE models the rearing and emigration of individual daily cohorts of juvenile Chinook salmon, and tracks their average growth, migration speed, territory size, and ultimately the amount of ASH required to sustain the number of juvenile salmon present within a model reach, on a given day throughout the rearing and emigration period.

- Important to remember that Available Suitable Habitat is a minor component of the amount of river channel, riparian vegetation, sediment input etc. needed to support that area of suitable habitat.

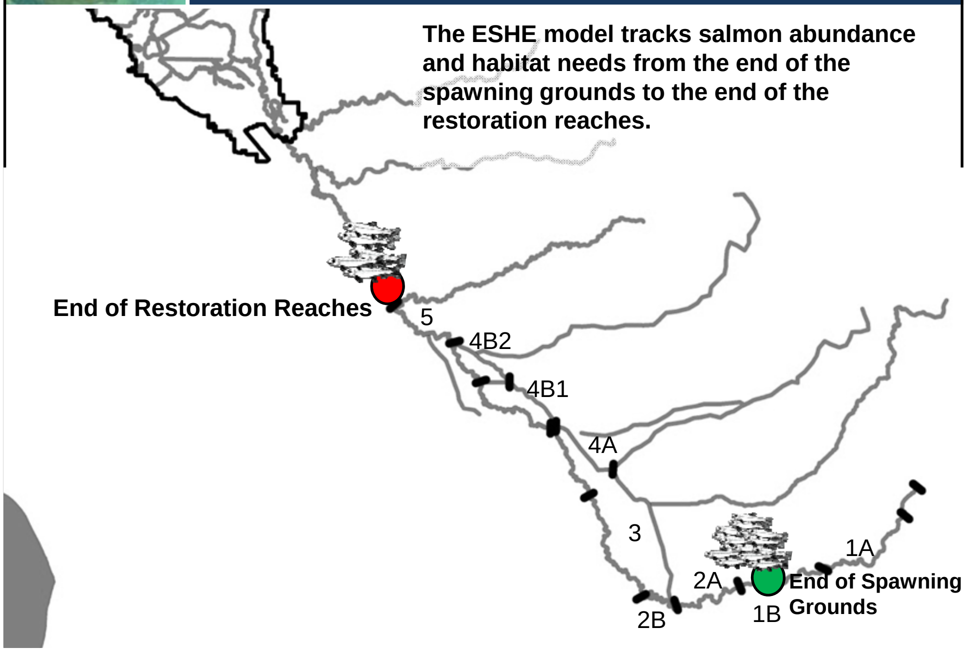
Model Functions

- The ESHE model has 7 major functions, 3 applied when juveniles first enter the model, and 4 applied daily as juveniles migrate through each successive model reach.

	Function	Data Source	Function of…
Model Entry	**Initial Abundance**	Production or Escapement Targets	
	Initial Size	Rotary Screw Trap	Time of Year, **Flow**
	Entry Timing	Rotary Screw Trap	**Flow**
Reaches	**Migration Speed**	Tagging Studies	Fish Length, **Flow**
	Survival	Tagging Studies	

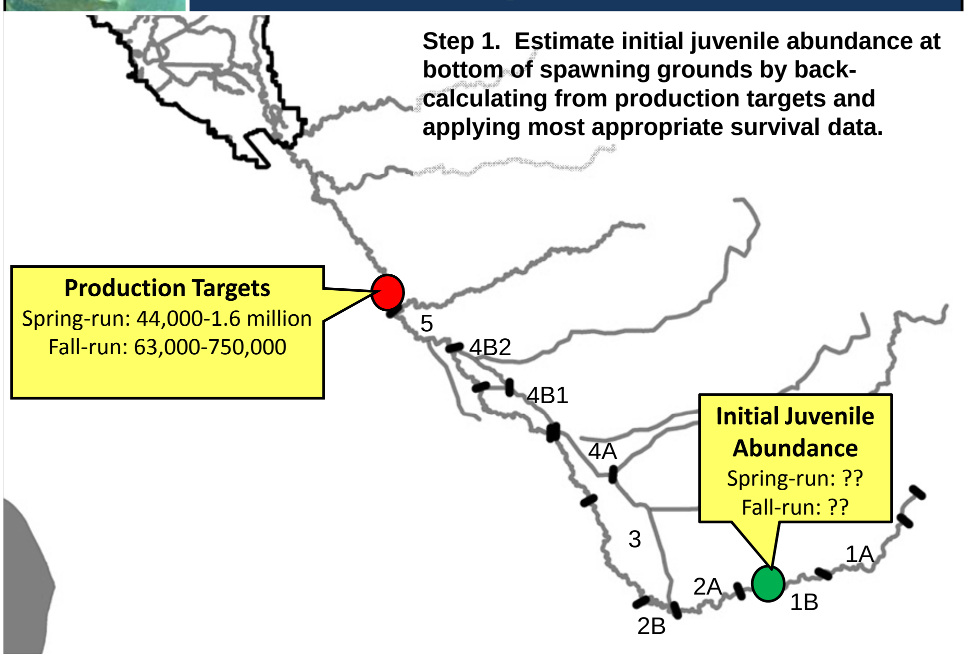
Model Description

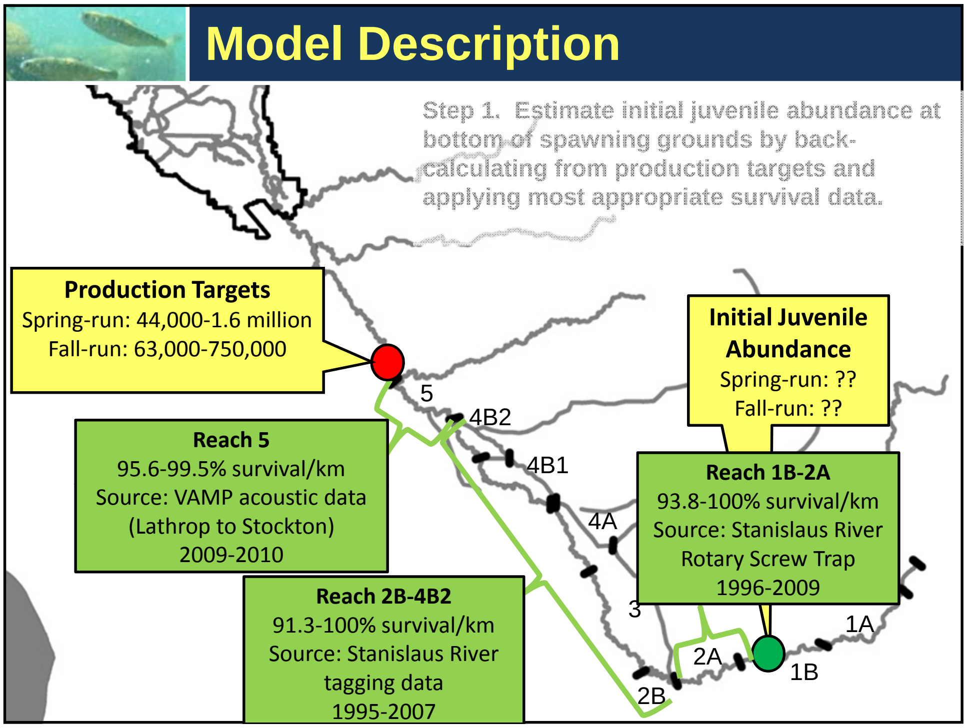
The ESHE model tracks salmon abundance and habitat needs from the end of the spawning grounds to the end of the restoration reaches.

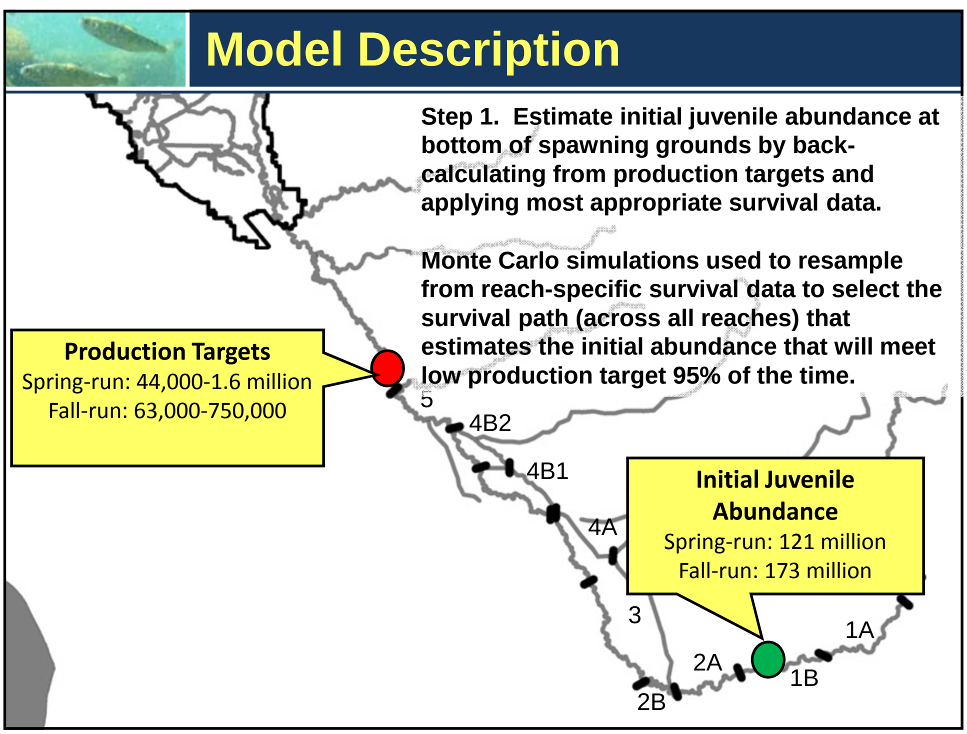


Model Description

Step 1. Estimate initial juvenile abundance at bottom of spawning grounds by back-calculating from production targets and applying most appropriate survival data.




Model Description
Step 1. Estimate initial juvenile abundance at bottom of spawning grounds by back-calculating from production targets and applying most appropriate survival data.
Production Targets
Spring-run: 44,000-1.6 million
Fall-run: 63,000-750,000
Initial Juvenile Abundance
Spring-run: ??
Fall-run: ??
Reach 5
95.6-99.5% survival/km
Source: VAMP acoustic data
(Lathrop to Stockton)
2009-2010
Reach 1B-2A
93.8-100% survival/km
Source: Stanislaus River
Rotary Screw Trap
1996-2009
Reach 2B-4B2
91.3-100% survival/km
Source: Stanislaus River
tagging data
1995-2007
5
4B2
4B1
4A
3
2A
2B
1A
1B


Model Description
Step 1. Estimate initial juvenile abundance at bottom of spawning grounds by back-calculating from production targets and applying most appropriate survival data.
Monte Carlo simulations used to resample from reach-specific survival data to select the survival path (across all reaches) that estimates the initial abundance that will meet low production target 95% of the time.
Production Targets
Spring-run: 44,000-1.6 million
Fall-run: 63,000-750,000
Initial Juvenile Abundance
Spring-run: 121 million
Fall-run: 173 million
5
4B2
4B1
4A
3
2A
2B
1A
1B

Model Description

The number of spring and fall-run juveniles needed to enter the ESHE model and exit each successive model reach in order to meet the low production targets (44,000 for spring-run, 63,000 for fall-run) leaving the last model reach 95% of the time.

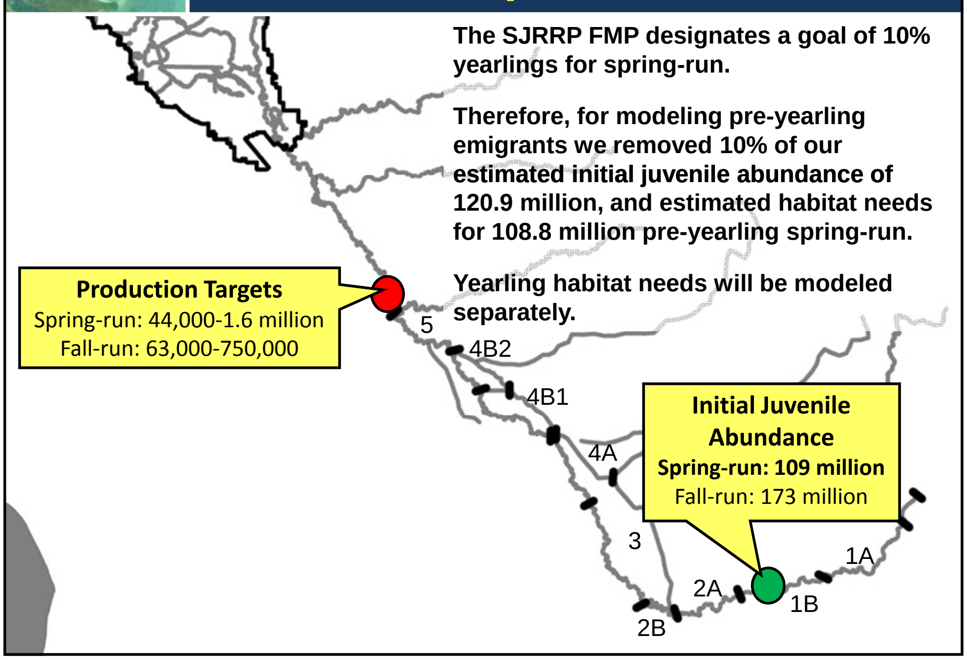
Location	Length (km)	survival per km	Survival	Number of Spring-run Emigrants	Number of Fall-run Emigrants
5	29	0.995	0.874	44,000	63,000
4B2	18	0.979	0.676	50,350	72,093
4B1	34	0.918	0.054	74,473	106,632
4A	22	0.922	0.170	1,387,424	1,986,539
3	37	0.979	0.454	8,159,358	11,682,717
2B	18	0.959	0.480	17,973,572	25,734,887
2A	21	0.964	0.469	37,408,023	53,561,488
Lower 1B	8	0.951	0.656	79,698,707	114,114,057
Entering Model	N/A	N/A	N/A	120,865,584	173,057,540

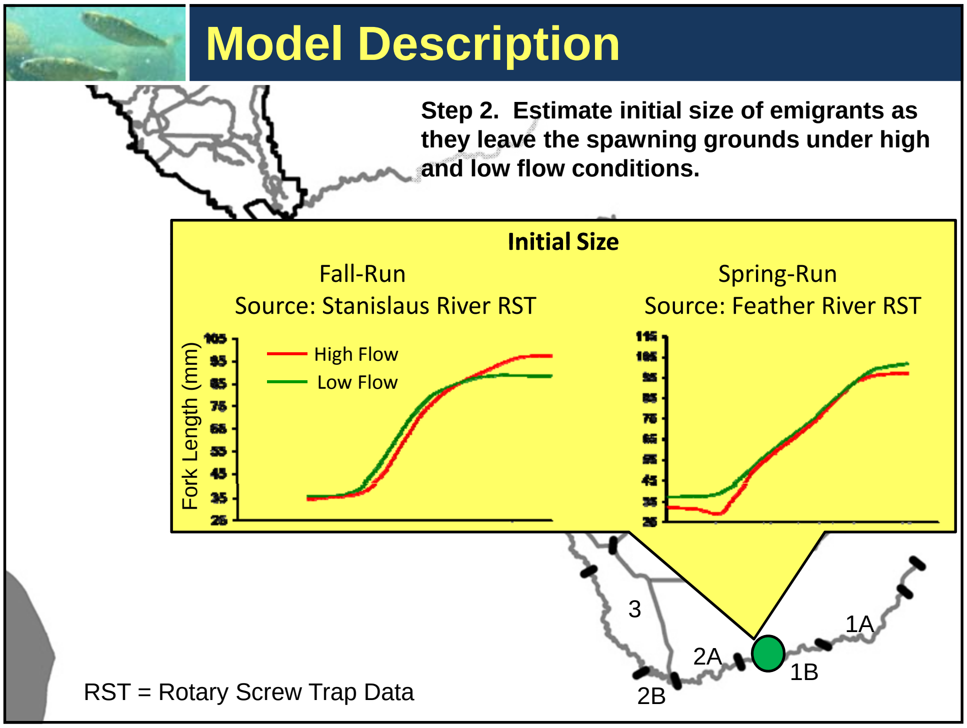
Model Description

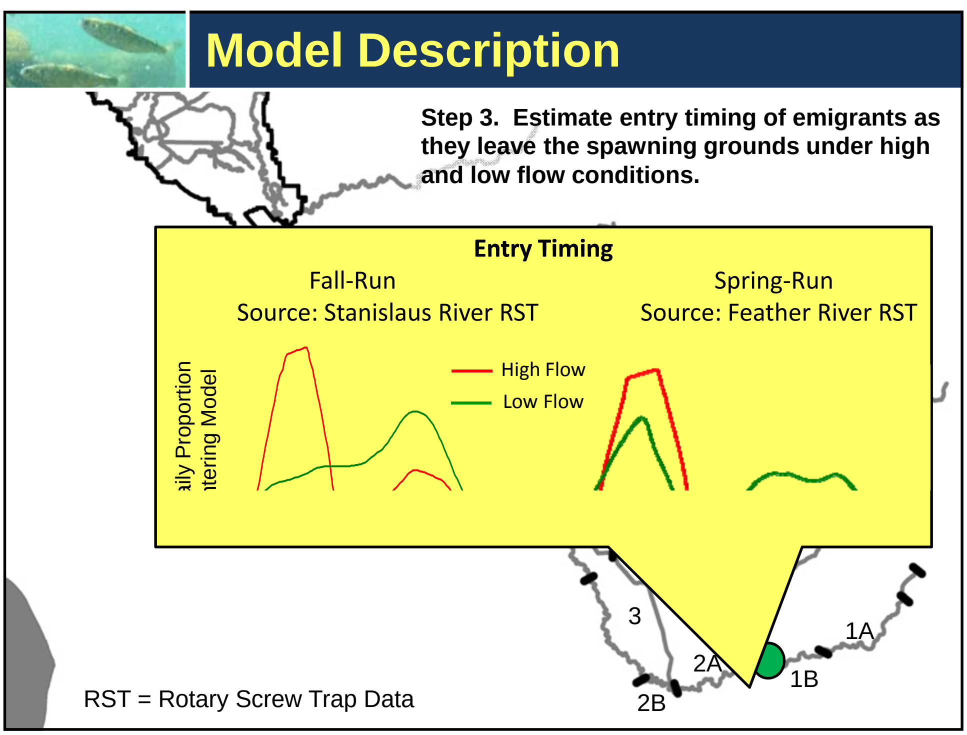
The SJRRP FMP designates a goal of 10% yearlings for spring-run.

Therefore, for modeling pre-yearling emigrants we removed 10% of our estimated initial juvenile abundance of 120.9 million, and estimated habitat needs for 108.8 million pre-yearling spring-run.

Yearling habitat needs will be modeled separately.

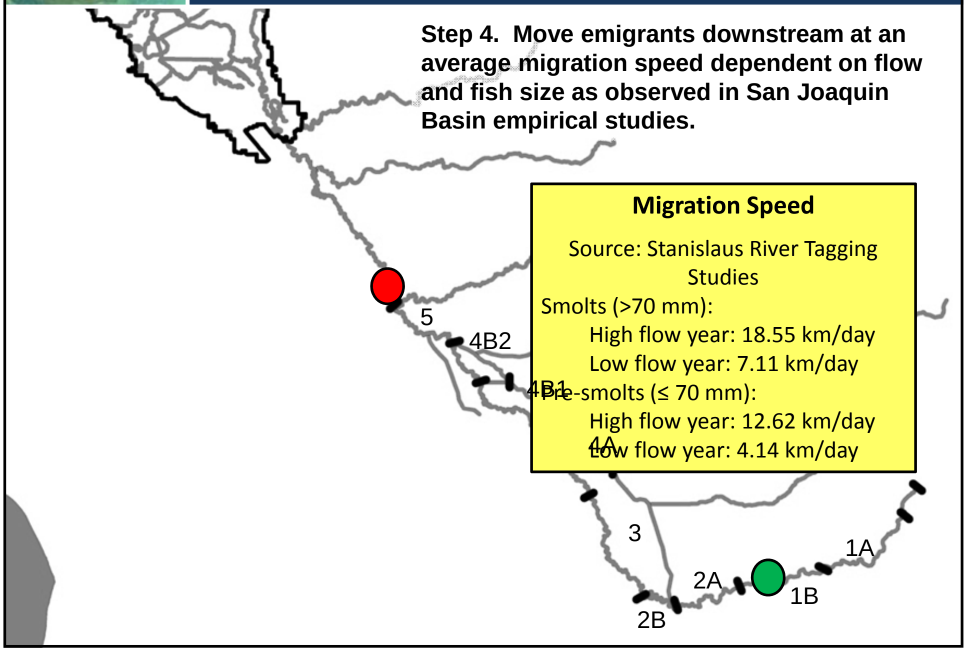



Model Description
Step 2. Estimate initial size of emigrants as they leave the spawning grounds under high and low flow conditions.
Initial Size
Fall-Run
Source: Stanislaus River RST
Spring-Run
Source: Feather River RST
Fork Length (mm)
High Flow
Low Flow
3
2A
2B
1A
1B
RST = Rotary Screw Trap Data


Model Description
Step 3. Estimate entry timing of emigrants as they leave the spawning grounds under high and low flow conditions.
Entry Timing
Fall-Run
Source: Stanislaus River RST
Spring-Run
Source: Feather River RST
High Flow
Low Flow
3
2A
2B
1A
1B
RST = Rotary Screw Trap Data

Model Description

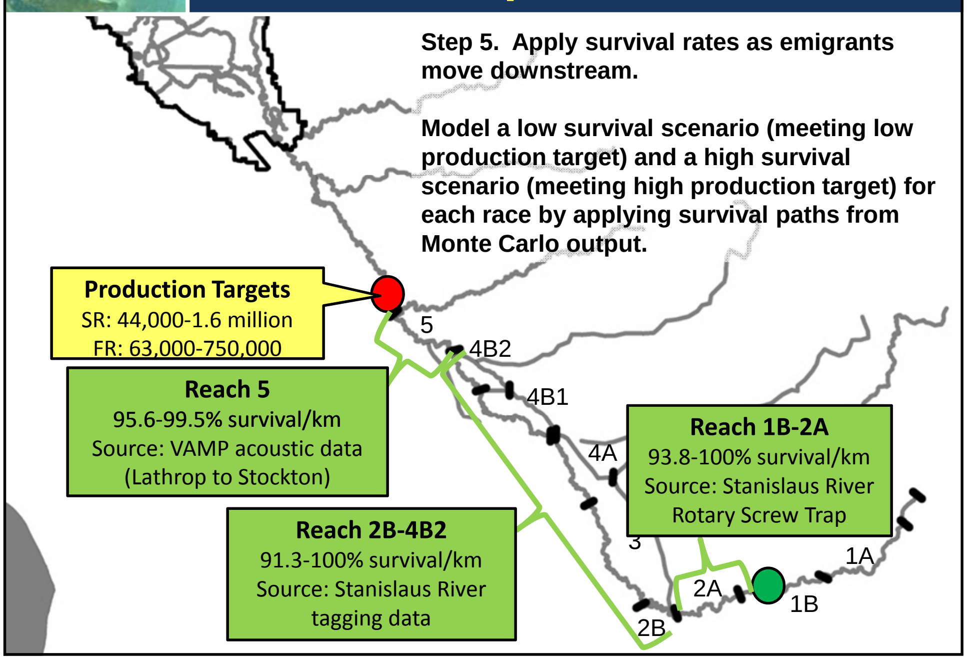
Step 4. Move emigrants downstream at an average migration speed dependent on flow and fish size as observed in San Joaquin Basin empirical studies.



Model Description

Step 5. Apply survival rates as emigrants move downstream.

Model a low survival scenario (meeting low production target) and a high survival scenario (meeting high production target) for each race by applying survival paths from Monte Carlo output.



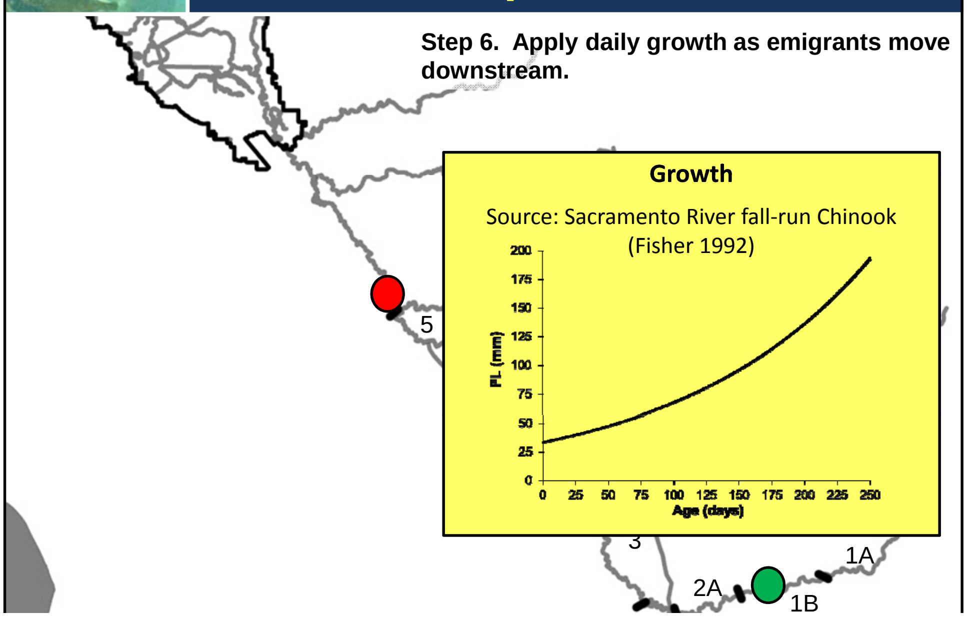
Model Description

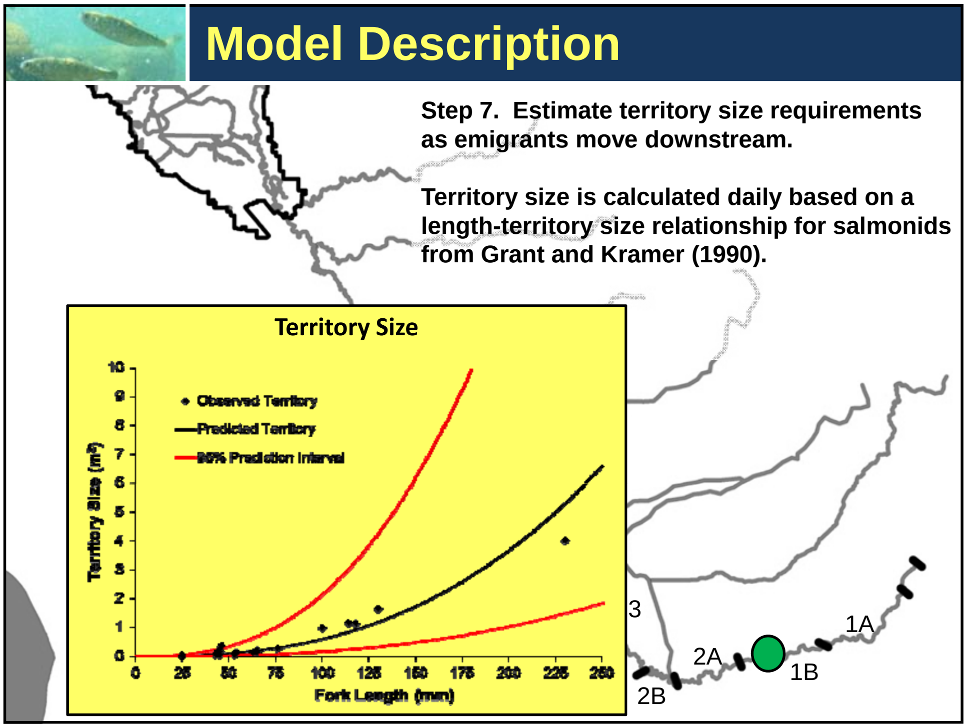
Lower Production Target					
Reach	Length	Survival per km	Survival	Spring-run Emigrants	Fall-run Emigrants
Entering Model	N/A	N/A	N/A	108,779,026	173,057,540
Lower 1B	8.46	0.95139	0.656	108,779,026	173,057,540
2A	20.92	0.96449	0.469	71,363,208	113,532,377
2B	17.70	0.95944	0.481	33,497,389	53,291,301
3	37.01	0.97889	0.454	16,096,471	25,608,021
4A	21.73	0.92169	0.170	7,307,987	11,626,343
4B1	34.28	0.91822	0.054	1,242,265	1,976,331
4B2	18.35	0.97889	0.676	66,676	106,076
5	28.65	0.99530	0.874	45,075	71,711
Leaving Model	N/A	N/A	N/A	40,000	63,000

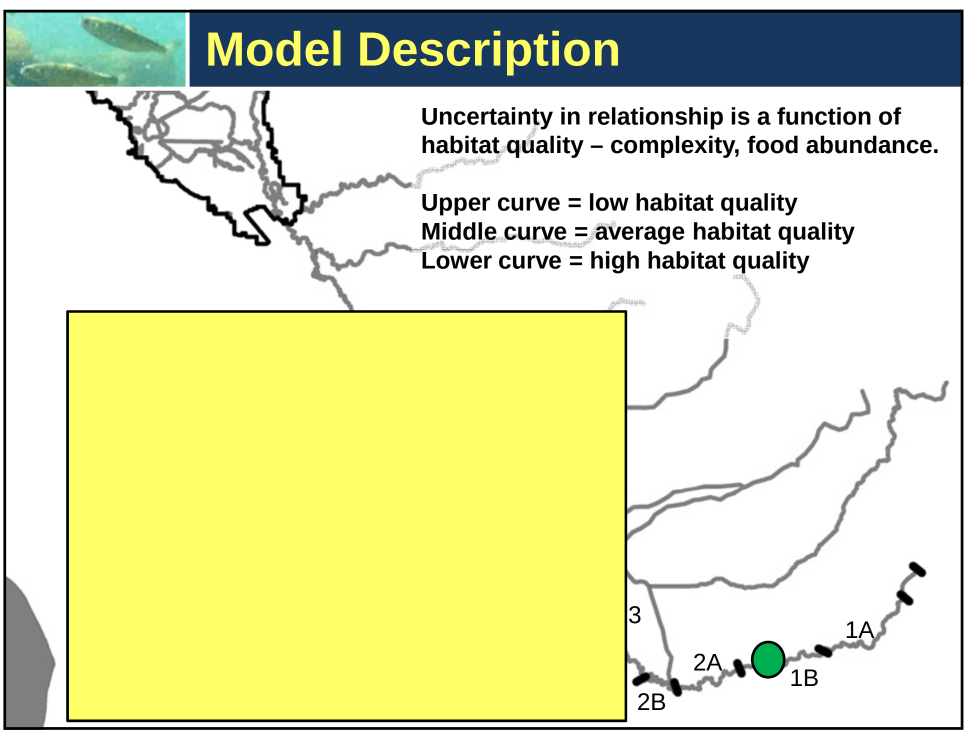
Upper Production Target							
		Spring-run			Fall-run		
Reach	Length	Survival per km	Survival	Emigrants	Survival per km	Survival	Emigrants
Entering Model	N/A	N/A	N/A	108,779,026	N/A	N/A	173,057,540
Lower 1B	8.46	0.96327	0.72861	108,779,026	0.98058	0.84710	173,057,540
2A	20.92	0.97520	0.59134	79,256,960	0.95361	0.37018	146,596,893
2B	17.70	0.97929	0.69042	46,868,057	0.97929	0.69042	54,266,993
3	37.01	0.95944	0.21602	32,358,492	0.98737	0.62471	37,466,842
4A	21.73	0.97929	0.63457	6,989,993	0.96876	0.50171	23,405,781
4B1	34.28	0.98737	0.64677	4,435,641	0.97123	0.36762	11,743,016
4B2	18.35	0.98264	0.72511	2,868,825	0.91557	0.19816	4,316,926
5	28.65	0.98721	0.68142	2,080,207	0.99530	0.87386	855,428
Leaving Model	N/A	N/A	N/A	1,417,000	N/A	N/A	750,000

Model Description

Step 6. Apply daily growth as emigrants move downstream.

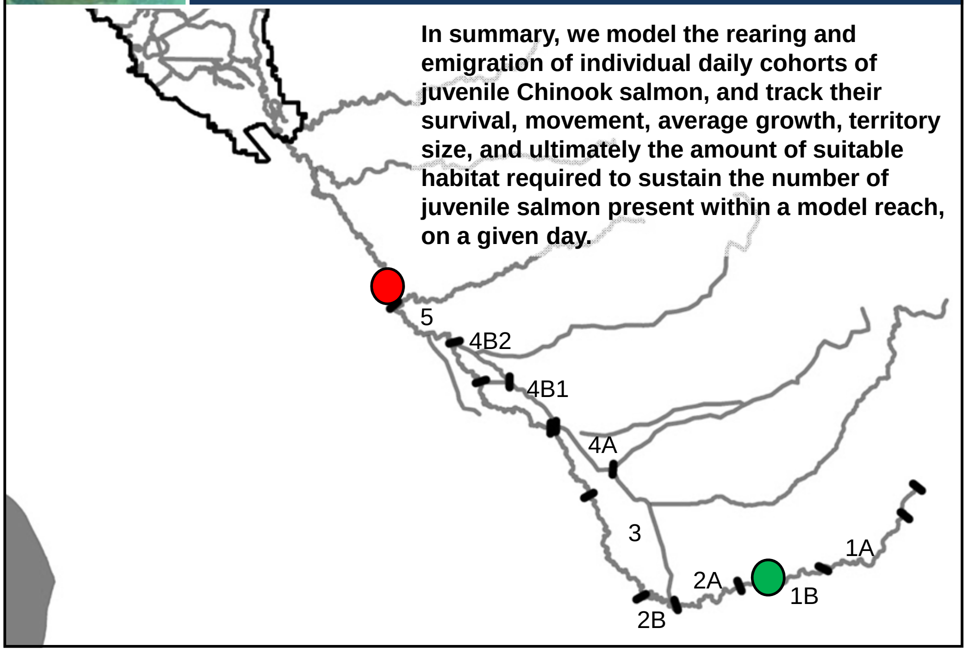



Model Description
Step 7. Estimate territory size requirements as emigrants move downstream.
Territory size is calculated daily based on a length-territory size relationship for salmonids from Grant and Kramer (1990).
Territory Size
Observed Territory
Predicted Territory
95% Prediction Interval
Territory Size (m²)
Fork Length (mm)
0
1
2
3
4
5
6
7
8
9
10
25
50
75
100
125
150
175
200
225
250
3
2A
2B
1A
1B

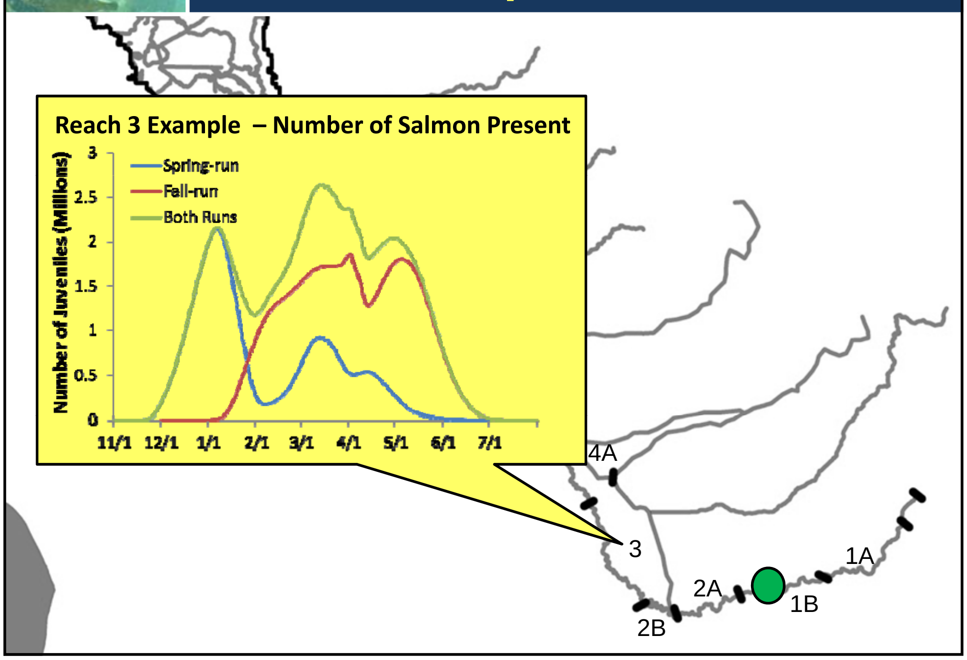

Model Description
Uncertainty in relationship is a function of habitat quality – complexity, food abundance.
Upper curve = low habitat quality
Middle curve = average habitat quality
Lower curve = high habitat quality
3
2A
2B
1A
1B

Model Description

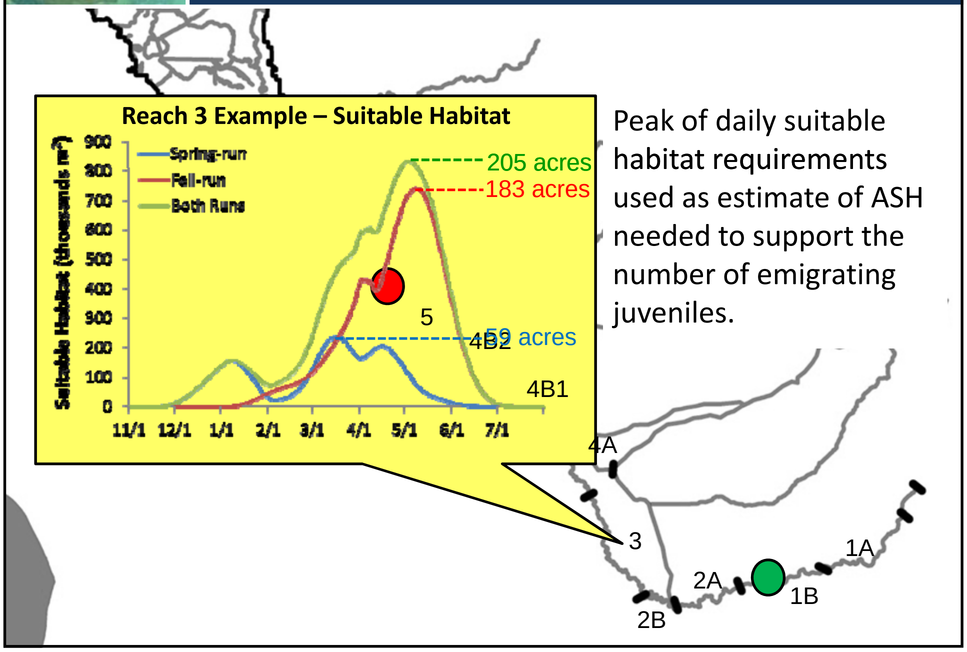
In summary, we model the rearing and emigration of individual daily cohorts of juvenile Chinook salmon, and track their survival, movement, average growth, territory size, and ultimately the amount of suitable habitat required to sustain the number of juvenile salmon present within a model reach, on a given day.



Model Description



Model Description



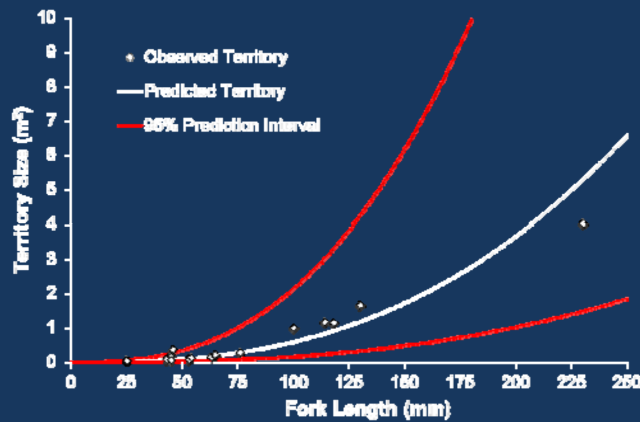
Peak of daily suitable habitat requirements used as estimate of ASH needed to support the number of emigrating juveniles.

Model Scenarios

- Present range of suitable habitat estimates across 12 scenarios.
  - 2 Production Targets X 2 Flow Years X 3 Habitat Quality Levels.
  - Low Production Targets: 44,000 spring, 63,000 fall.
  - High Production Targets: 1.6 million spring, 750,000 fall
  - Low flow and high flow conditions as defined from source data for each run (fall: Stanislaus, spring: Feather). Flow year affects entry timing, entry size, and migration speed.

Model Scenarios

- We model 3 habitat quality assumptions (indexed by habitat complexity and food abundance) by applying different territory size curves from Grant and Kramer (1990). Mean curve (white line) assumes average quality, upper curve assumes low quality, and lower curve assumes high quality.



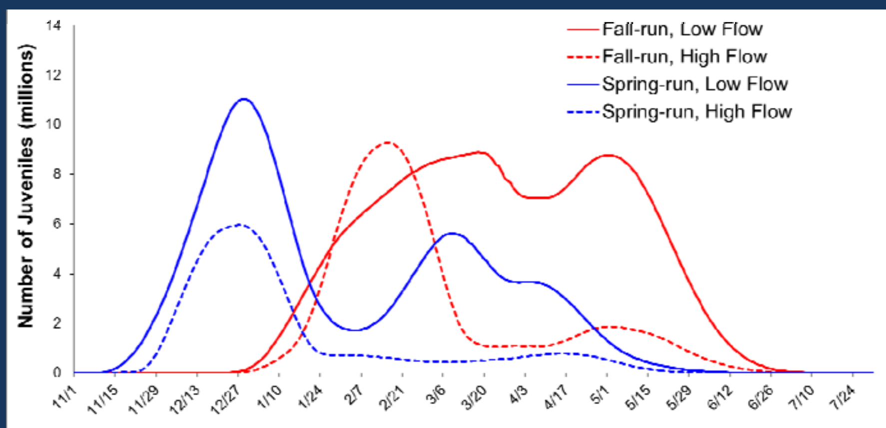
Model Scenarios

12 Modeled Scenarios

Low Production, Low Flow, Low Habitat Quality
Low Production, Low Flow, Average Habitat Quality
Low Production, Low Flow, High Habitat Quality
Low Production, High Flow, Low Habitat Quality
Low Production, High Flow, Average Habitat Quality
Low Production, High Flow, High Habitat Quality
High Production, Low Flow, Low Habitat Quality
High Production, Low Flow, Average Habitat Quality
High Production, Low Flow, High Habitat Quality
High Production, High Flow, Low Habitat Quality
High Production, High Flow, Average Habitat Quality
High Production, High Flow, High Habitat Quality

Preliminary Results

Timing of fish presence for each run across all restoration reaches, assuming high production target and average habitat quality



Preliminary Results

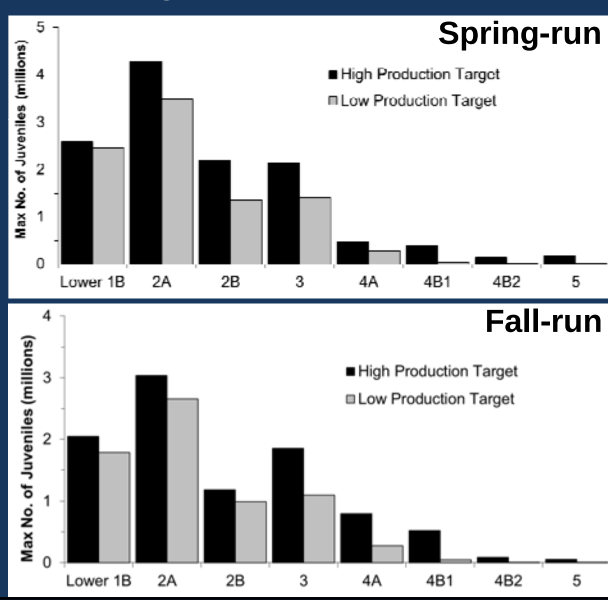
- Although it appears that fish production is higher in the low flow year than the high flow year, production is constant.
- However, in the low flow scenario fish are entering over a wider period of time and moving at a slower pace leading to fish residing in each reach (and in the entire restoration area) longer in the low flow versus the high flow year.
- Therefore, the number of fish present in the system is generally higher in the low flow versus the high flow year.
- Because we used data from 2 systems (Feather and Stanislaus) that do not have extensive floodplains, we don't have juveniles moving into floodplains and slowing down in high flow years. In fact they do the opposite, and move fast out of the system in conjunction with early flood pulses.

Preliminary Results

- Conversely, in low flow years fish move slower and a greater proportion rear in the river and emigrate out as smolts.
- Even though this pattern of movement will not likely mimic the movement of juveniles in a restored floodplain river system like the San Joaquin, we assume that ESHE output captures the range of emigration behaviors we might expect to see.
- We expect that a future version of the ESHE model will have the ability to predict the effects of habitat alteration (e.g., increased floodplain habitat) on emigration strategy of juvenile Chinook salmon.

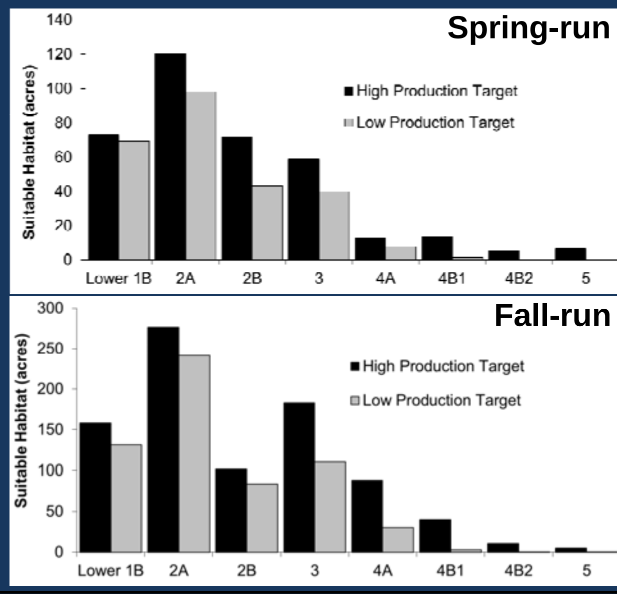
Preliminary Results

Production Targets – Maximum Numbers of Juveniles



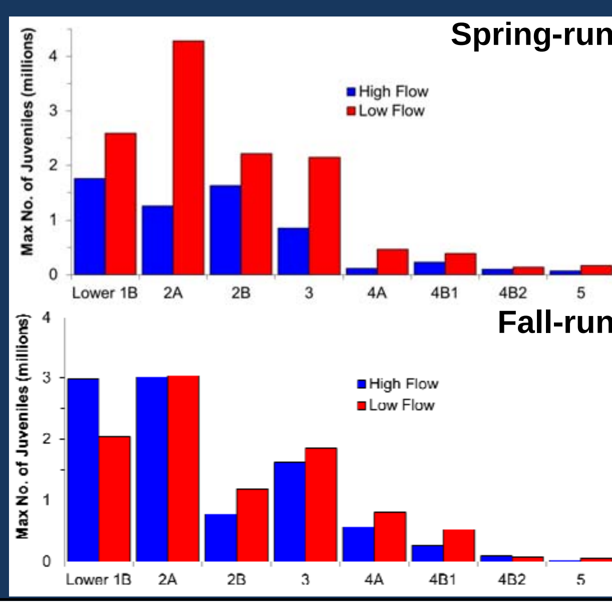
Preliminary Results

Production Targets – Suitable Habitat



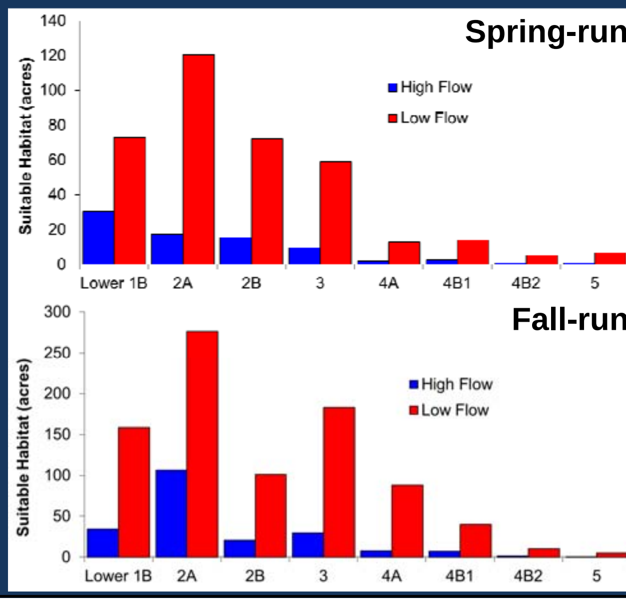
Preliminary Results

Flow Conditions – Maximum Numbers of Juveniles



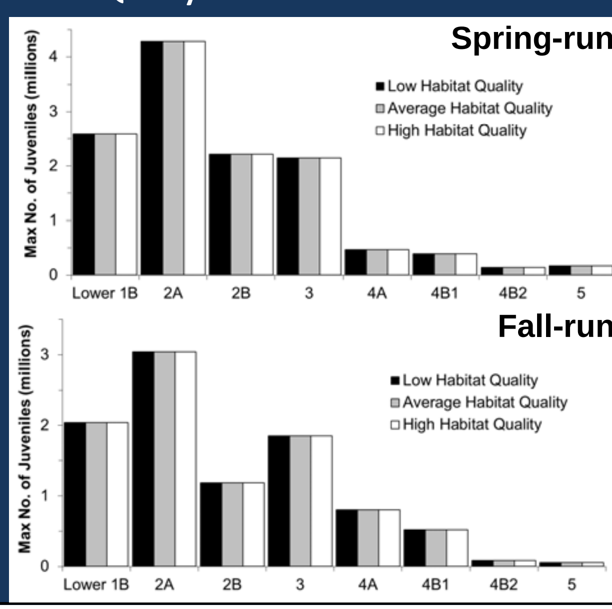
Preliminary Results

Flow Conditions – Suitable Habitat



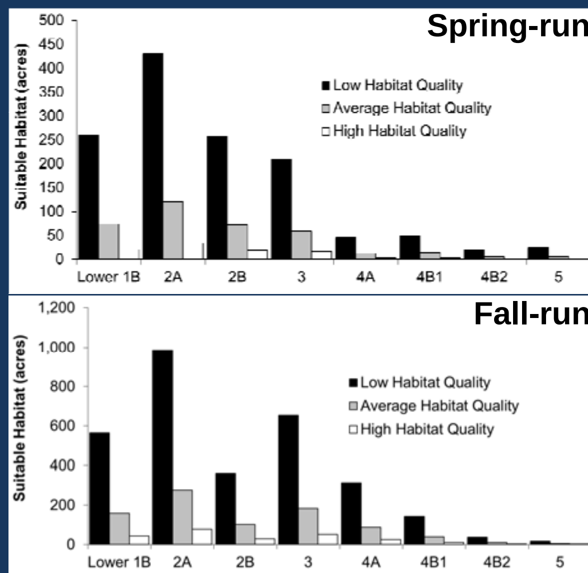
Preliminary Results

Habitat Quality– Maximum Numbers of Juveniles



Preliminary Results

Habitat Quality– Suitable Habitat



ESHE estimates of suitable habitat (acres) in each reach for spring and fall-run combined to meet the high and low FMP production targets and inform minimum reach 2B and 4B levee set-backs under all 12 different scenarios.

High Production Targets

	High Quality		Average Quality		Low Quality	
Reach	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**
Lower 1B	51	11	182	40	650	144
2A	92	33	329	118	1172	422
2B	40	8	142	29	507	105
3	58	10	205	37	733	131
4A	26	2	93	9	331	32
4B1	13	2	46	9	165	31
4B2	3	0	12	2	44	6
5	3	0	9	1	33	5
Total	**286**	**69**	**1019**	**245**	**3635**	**876**

Low Production Targets

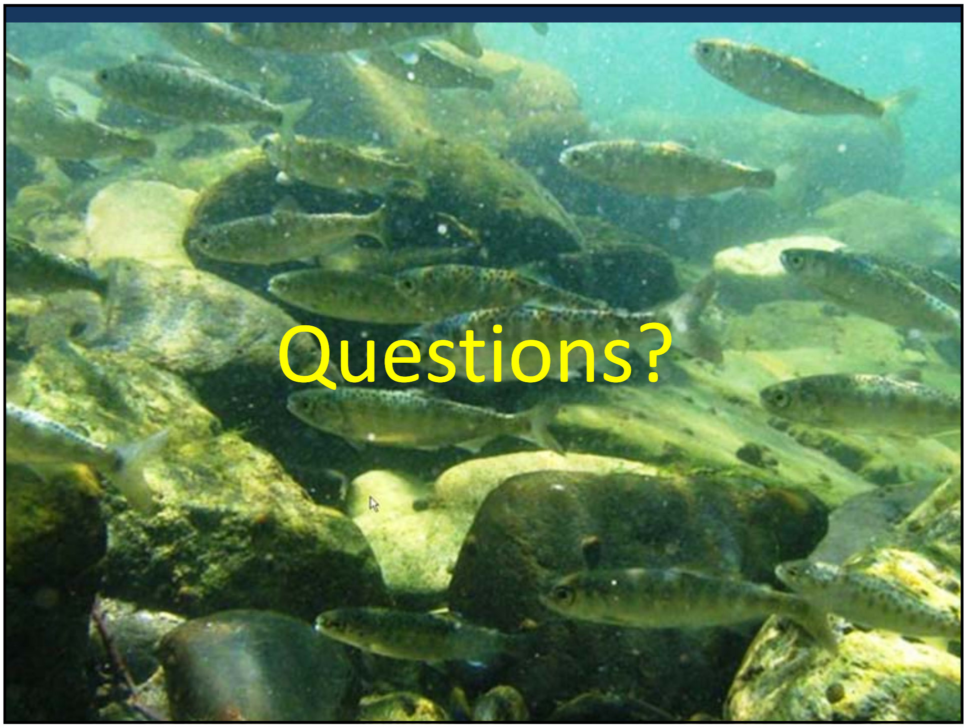
	High Quality		Average Quality		Low Quality	
Reach	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**
Lower 1B	44	11	156	38	55	
2A	79	27	283	98	101	
2B	30	6	106	20	37	
3	36	6	127	21	45	
4A	9	1	33	2	11	
4B1	1	0	4	1	14	
4B2	0	0	0	0	2	
5	0	0	0	0	2	
Total	**199**	**50**	**710**	**180**	**253**	

Discussion

- Important to remember that our model estimates “suitable” habitat that is only a fraction of the total habitat required to support it (2-D modeling addresses this).
- Also, we are modeling an “average” population, with average timing and migration speed.
- Therefore, our estimates of habitat in each particular reach should be assumed to be flexible – i.e. due to the unpredictable nature of fish populations, habitat could be available downstream or upstream and still meet the needs of the salmon population.

Discussion

- Lastly, nearly all ESHE model inputs can be altered (e.g. growth curve, production targets). Therefore, if better information is available to inform model functions, or if SJRRP management targets are changed, the ESHE model can easily be updated.



Suitable habitat (acres) in each reach for each run and both runs combined under 4 of the scenarios assuming average habitat quality: high production & high flow, high production & low flow, low production & low flow, low production & high flow

High Production Targets

	Spring-Run		Fall-Run		Both Runs	
Reach	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**
Lower 1B	73	30	158	34	182	40
2A	121	17	276	106	329	118
2B	72	16	101	21	142	29
3	59	10	183	30	205	37
4A	13	2	88	8	93	9
4B1	14	2	40	7	46	9
4B2	6	1	10	1	12	2
5	7	1	5	0	9	1
Total	**364**	**80**	**863**	**207**	**1,019**	**245**

Low Production Targets

	Spring-Run		Fall-Run		Both Runs	
Reach	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**	**Low Flow**	**High Flow**
Lower 1B	70	30	132	32	156	38
2A	98	14	241	88	283	98
2B	44	10	84	14	106	20
3	40	7	110	16	127	21
4A	8	1	30	2	33	2
4B1	2	0	3	0	4	1
4B2	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	**261**	**62**	**601**	**154**	**710**	**180**