Chignik watershed sockeye salmon run reconstruction and escapement goals

Oral report to the Alaska Board of Fisheries, February 2023

By

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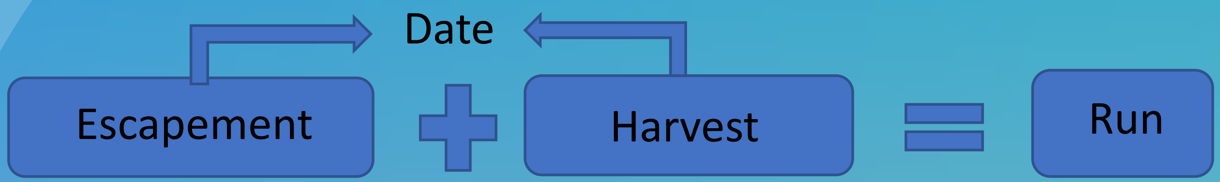
Oral report: RC 3 Tab 2

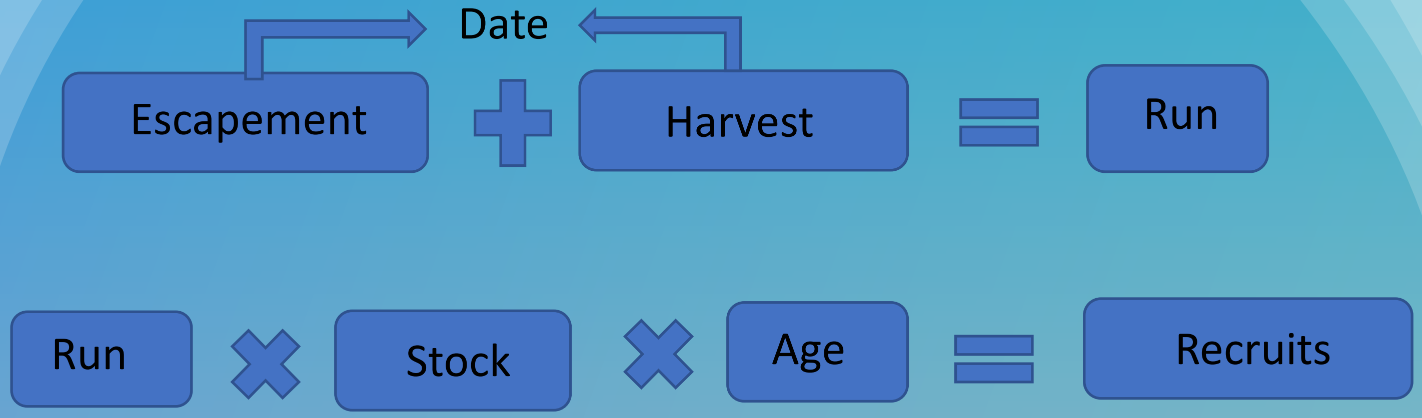
Overview

- Changes to the run reconstruction
- Methods of escapement goal analysis
- Results

Run reconstruction
What is it?



Run reconstruction
What is it?



Run reconstruction
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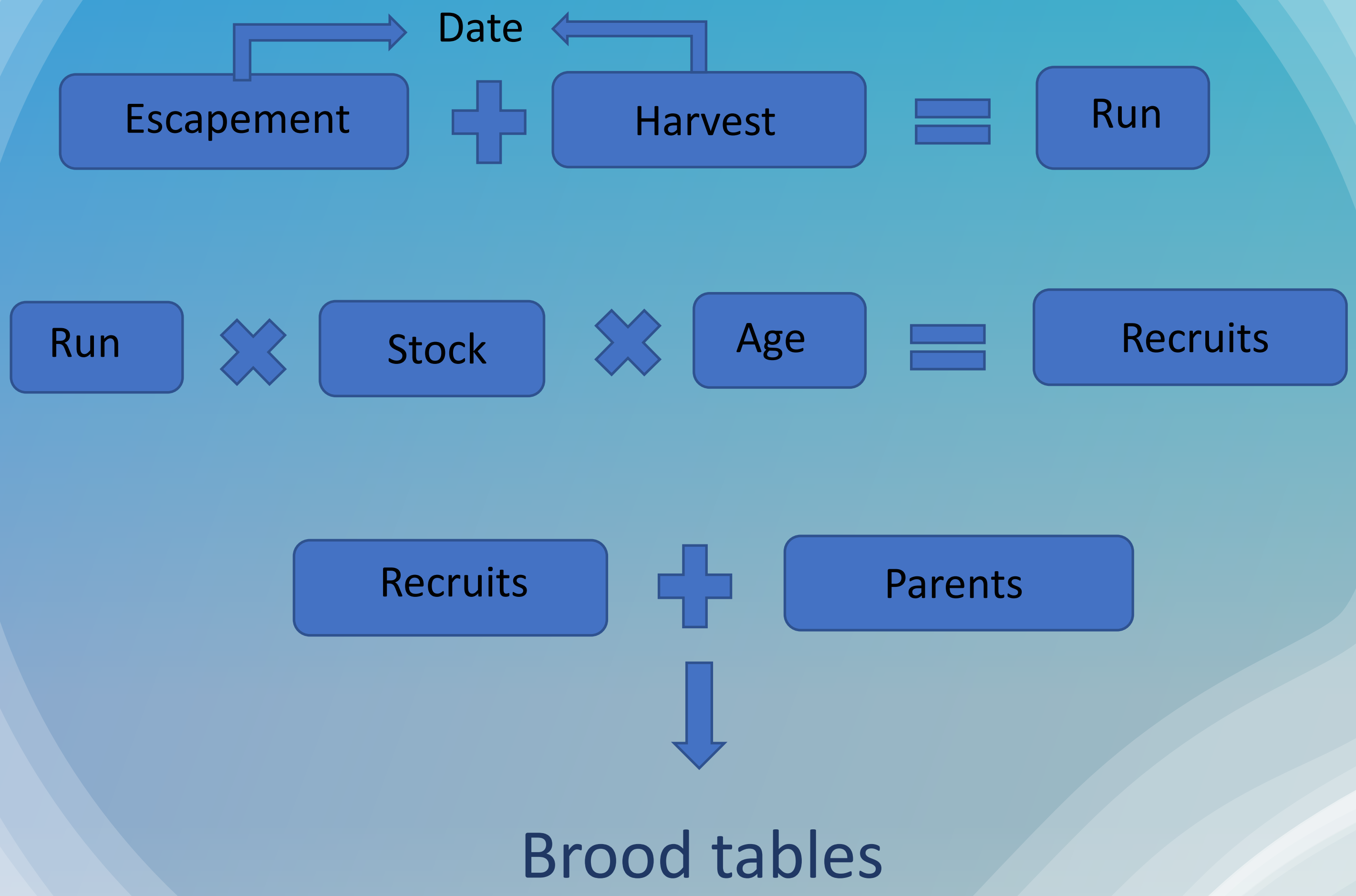


Historical method

Organize data

- Assumes all fish caught in the CMA are Chignik-bound fish
- Assumes 90% of Igvak harvest is Chignik bound from June 1 thru July 5
- Assumes 80% of select SEDM harvest is Chignik bound (SEDM thru June 30 and SEDM less Northwest Stepovak from July 1 to July 25)
- All harvest lagged to arrival day at weir
  - All swim times to weir based on Conrad 1983

Historical method

After catch and escapement have been temporally aligned to weir date

⬇

Stock apportionment: multiple past methods

- Time of entry curves (1967 to 1982)
- Scale pattern analysis (1983 to 2003)
- July 4 cut-off date (2004 to 2011)
- Genetics (2012 to 2021, prior genetics data applied retroactively)

⬇

Apply weekly age compositions

Run reconstruction
Why a new approach?

Availability of better data to inform run reconstruction

Development of a method that is easily reproduced and applied to historical data

Run reconstruction
Why a new approach?

- Chignik harvest has been overestimated
  - Genetic data indicate mixed stocks in CMA
  - Regulations for Igvak and SEDM do not match genetic information

- Stock apportionment is inconsistent over time
  - Minimize the amount of error imparted by using multiple methods
  - Needs consistency and reproducibility

New method – Organize data

Determine number of Chignik-bound fish based on genetic study results

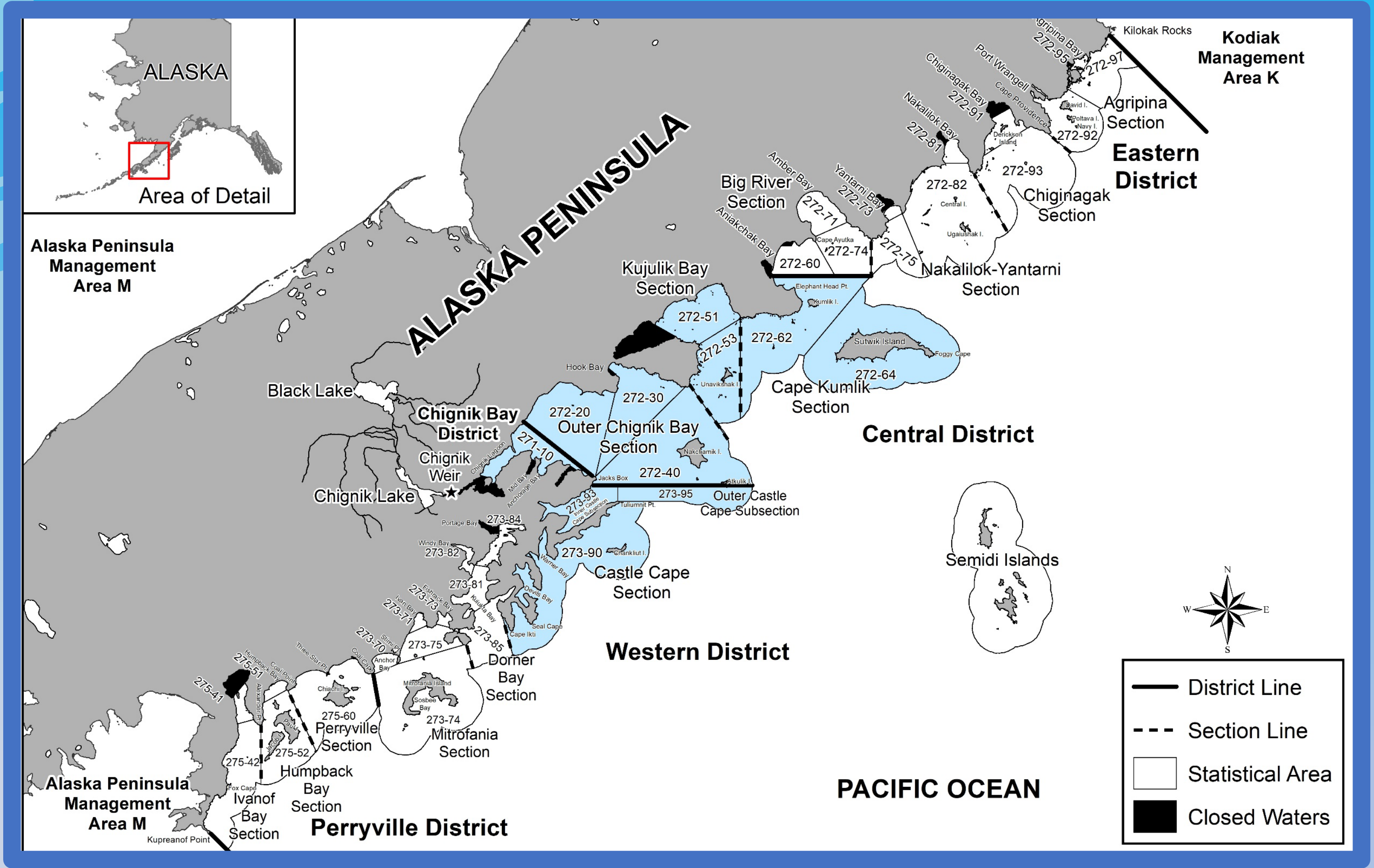
(Dann et al. 2012, Shedd et al. 2016)

- Chignik Bay District: 100%
- Central District: 95%
- Western, Perryville, Eastern District :   80% through June; 50% through July and August
- Igvak: 75% through July 5
- SEDM: 80% through July 5 ; 50% post July 5

Organize data

Subset run data for stock apportionment

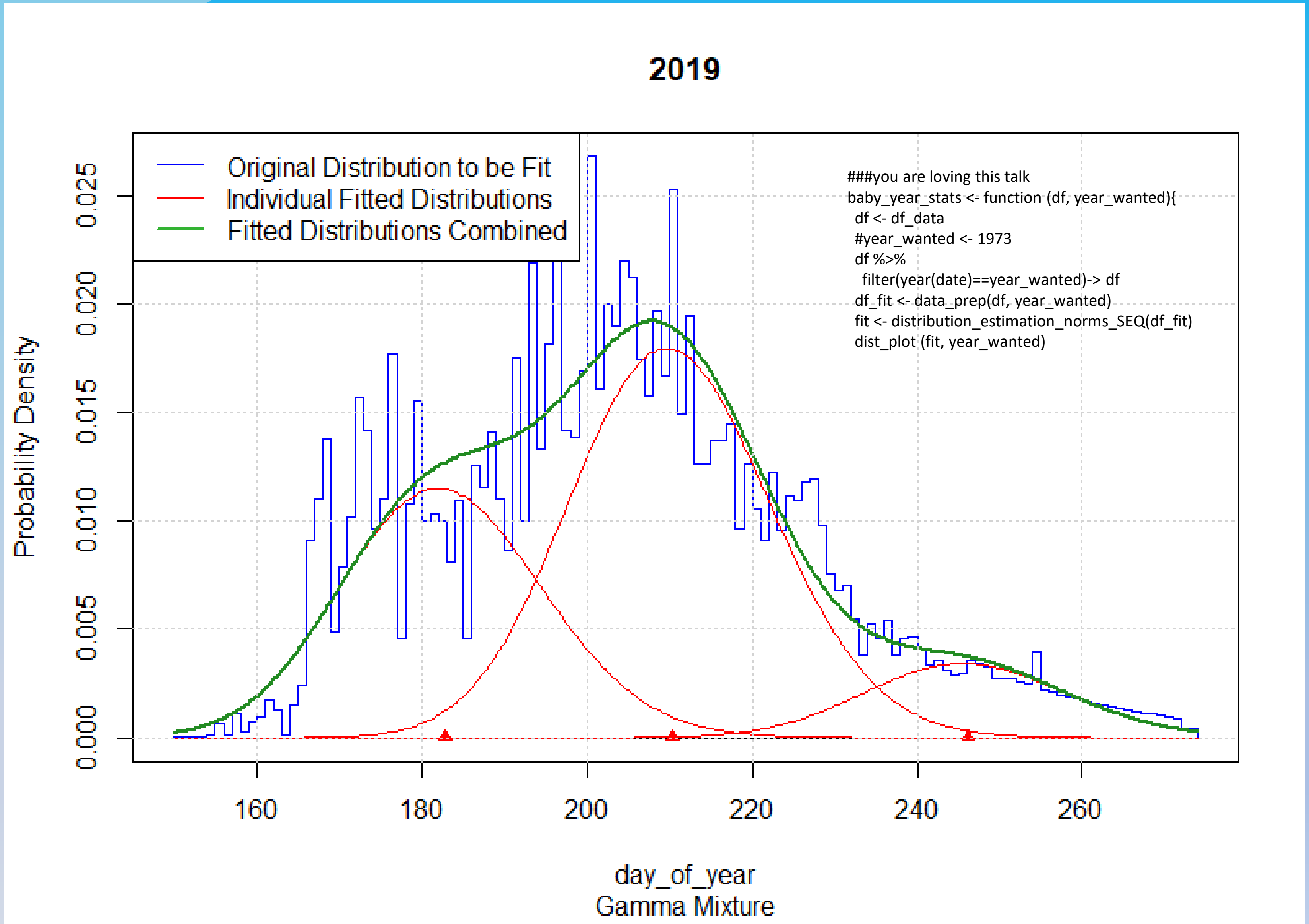
- Determine stock percentages by day using escapement and harvest from 11 stat areas within 90 km of the weir
- Harvest data are predominantly (≥80%) Chignik-bound fish to represent the probability density function of each run



Determine stock proportions

R package mixDist

- Expectation-Maximization (EM) algorithm to determine probability density functions (pdf) of daily run timing
- Assumes 3 distributions: 1 early, 2 late (Creelman et al. 2011)
- Model will estimate a pdf for each day and each stock

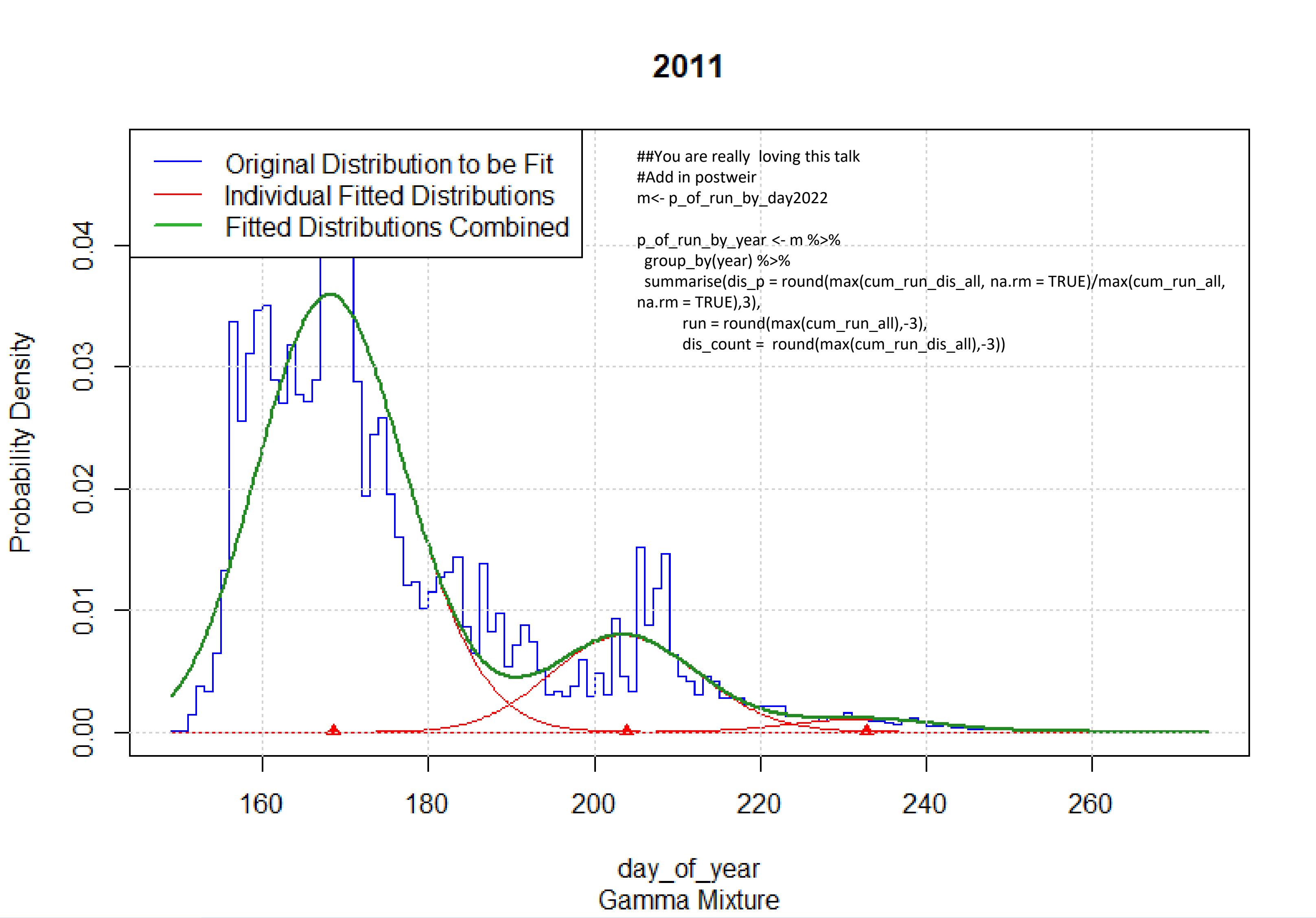


Determine stock proportions

The proportion of early run fish is estimated by dividing the early run pdf on a given day by the sum of all pdfs on that same day.

$$P_{day} = \frac{pdf_1\,(day)}{\sum_{i=1}^{3} pdf_i(day)}$$

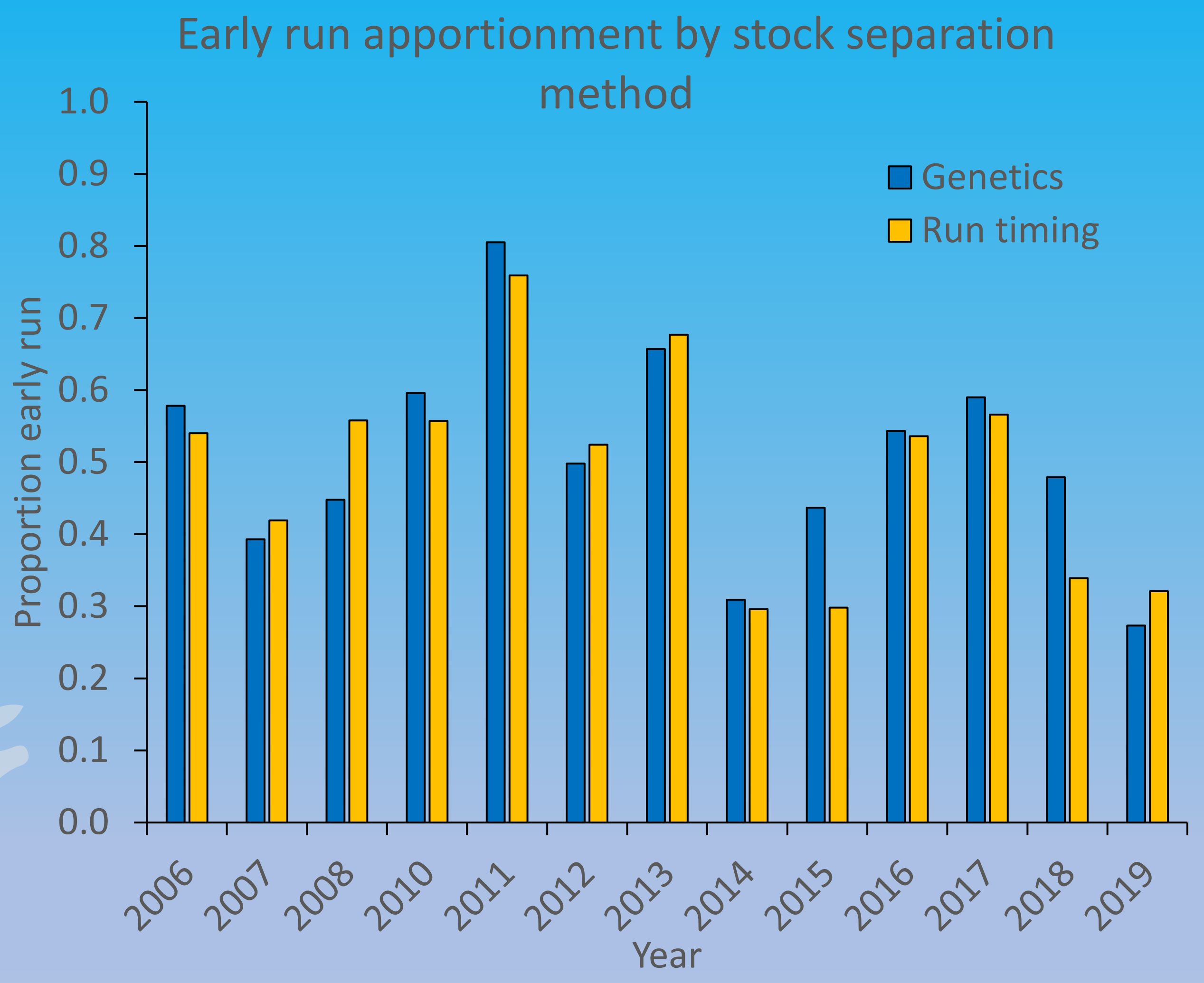
Daily proportion of early run fish X total daily run = early run



Compared to genetics collected from escapement

Daily proportions not significantly different from genetic proportions (paired Student T-test $p > 0.24$)

5% average difference between models



Results of new approach

	Summary of method differences	
Steps of the run reconstruction	Historical	New method
Assign harvest as Chignik bound	Based on past tagging studies	Based on WASSIP/KMA genetics
Align harvest to weir date	Same - Conrad 1984	Same - Conrad 1984
Stock apportionment	Multiple methods with different variances Weekly data	One method applicable to historical data Daily data
Age composition	Weekly average	Interpolated daily

Results of new approach

Brood tables will differ because of

- Corrections to harvest numbers
- Differences in stock proportions between methods
- Changes to the percentages of harvest considered Chignik-bound fish (~10% less in the CMA)

Results of new approach

- More accurate harvest numbers
- Reproducible and consistent method of stock apportionment
- Provides a better index for stock assessment

Escapement goal review for Chignik sockeye salmon

General Approach

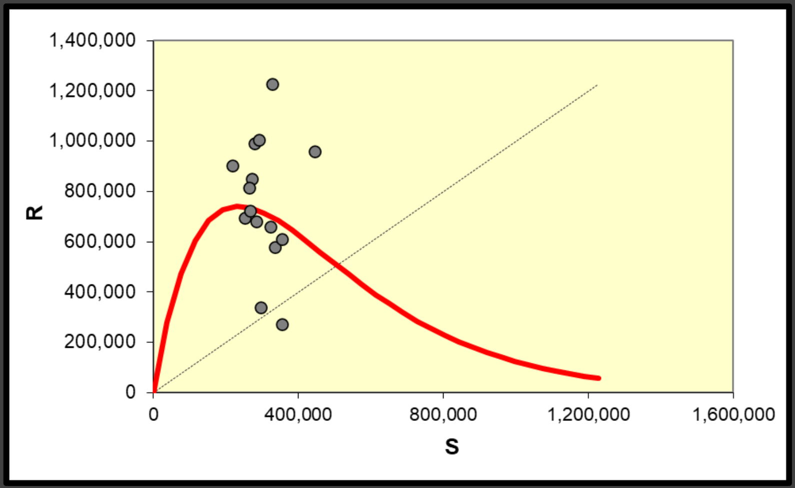
Identify and assess periods of changing productivity to estimate the most biologically representative value of S_{MSY}

Account for early- and late-run stock interactions of rearing fry in Chignik Lake to facilitate restoring Black Lake productivity

Dahlberg took the same approach in the 1960s

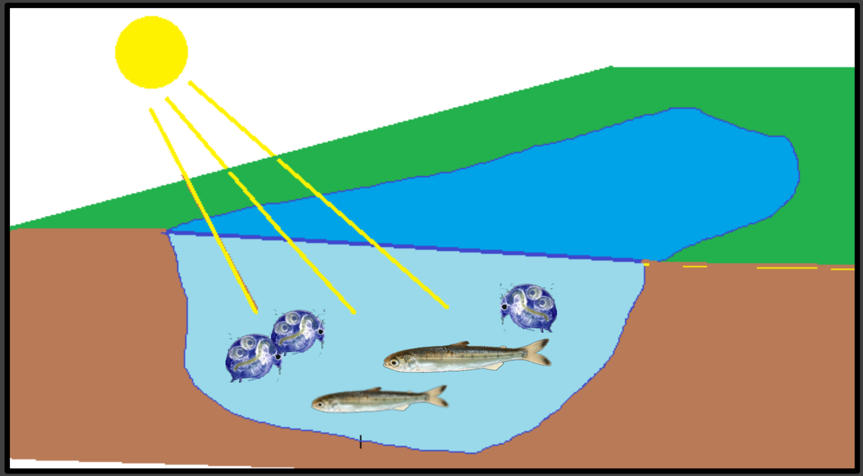
Analyses

Spawner-recruit models



Habitat-based models

- Euphotic volume
- Zooplankton biomass



S-R Analyses

Spawner-recruit models

- All S-R models run in the Pacific Salmon Escapement Goal Analysis app (Hamazaki 2022)

- Data from 1983 to 2013
  - Limited by what daily age comp data we could audit

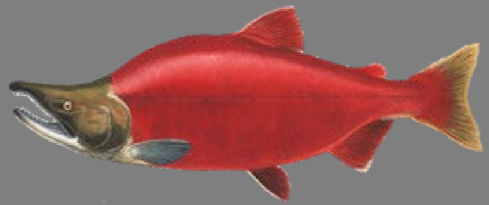
Image: Freshwaters Illustrated

S-R Analyses

Spawner-recruit models

- Time-varying α Ricker
  - $ln(R)=ln(\alpha)-\beta s+ln(S)+\varepsilon$
  - $ln(\alpha)_t=ln(\alpha)_{t-1}+\omega_t$
- Bayesian simple Ricker
  - $ln(R)=ln(\alpha)-\beta s+ln(S)+\varepsilon$
- Parameters
  - α - productivity
  - β - density dependence

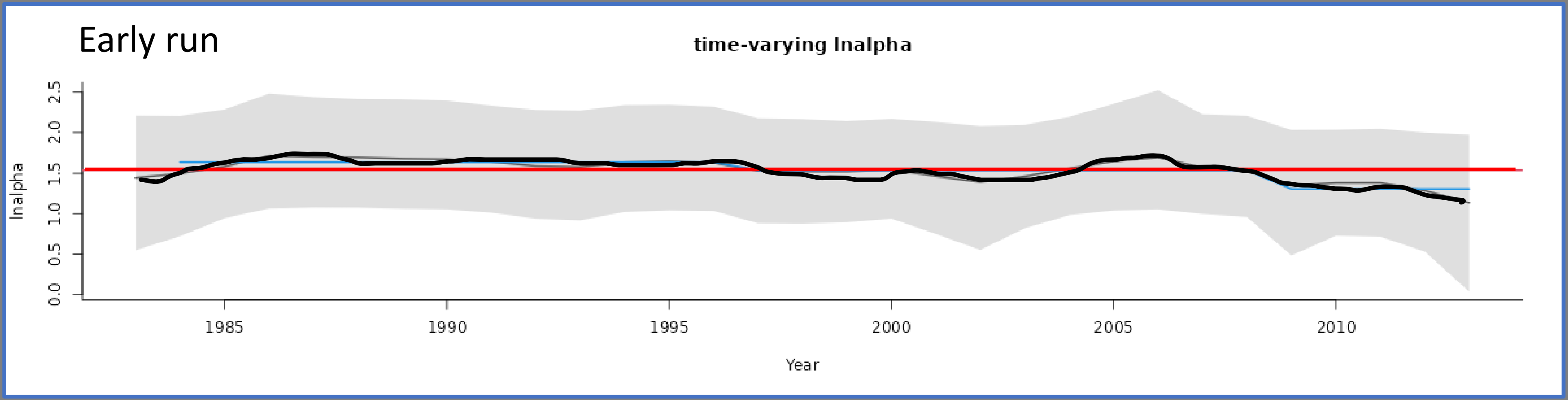
Image: NOAA Fisheries

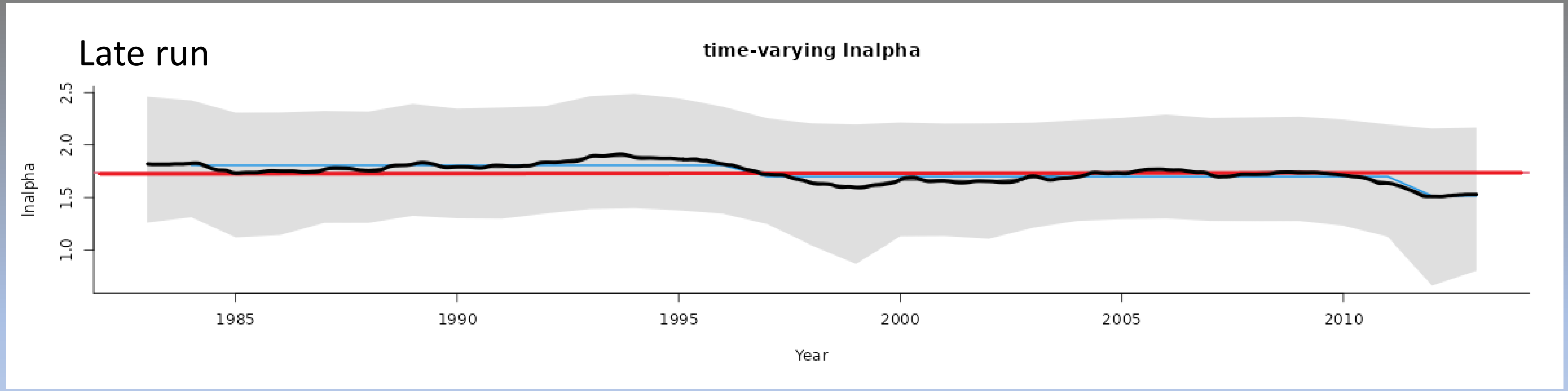


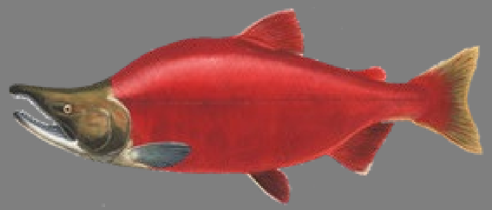
S-R Analyses

Time-varying α

- Estimates S_{MSY} for each year
- Indicated lower productivity for both runs







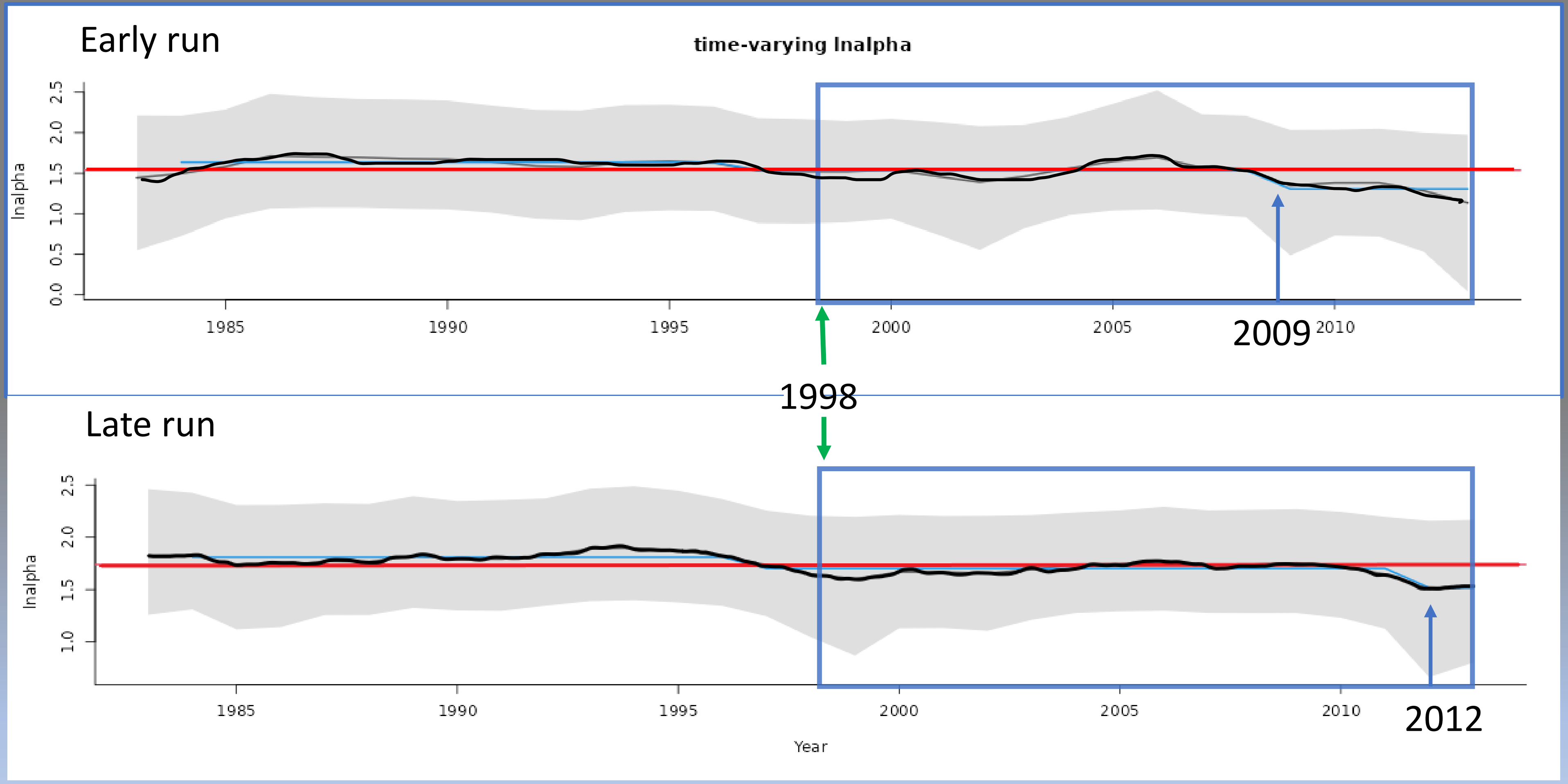
S-R Analyses

Time-varying α

- More variable S_{MSY} starting around 1998
- Productivity declines

  ER: 2009

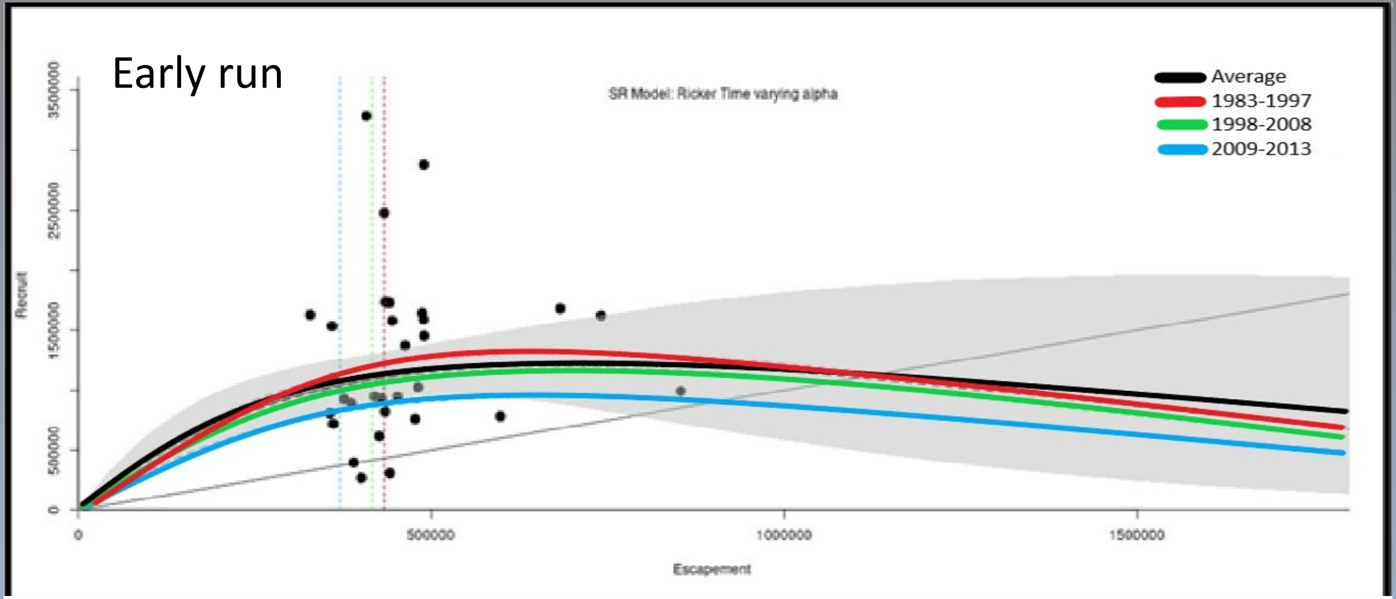
  LR: 2012

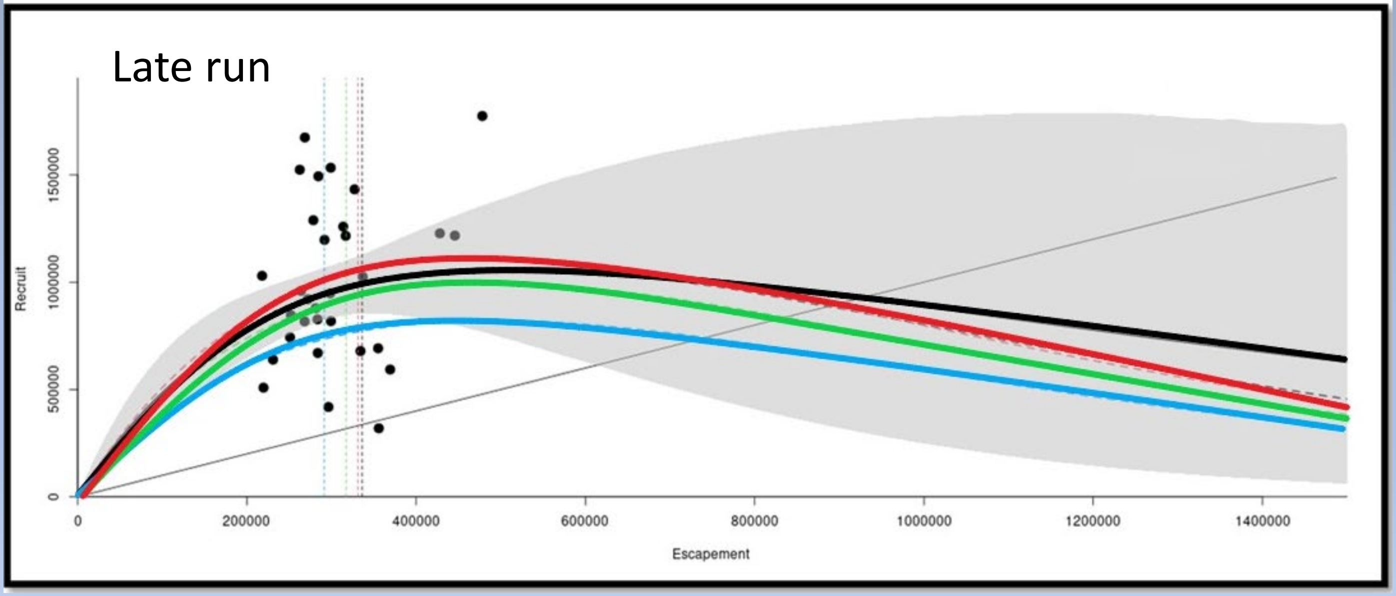


S-R Analyses

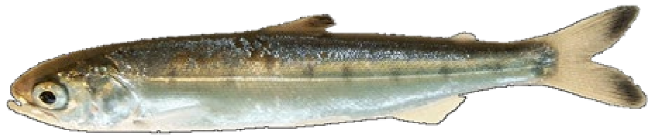
Time-varying α

- Production declines for both stocks starting in the late 1990s coincided with watershed stabilization (USACOE Nov 3-4, 2021 Black Lake Workshop)
- Indicates S-R data are suitable for truncating into higher and lower periods of productivity around 1998.





S-R Analyses

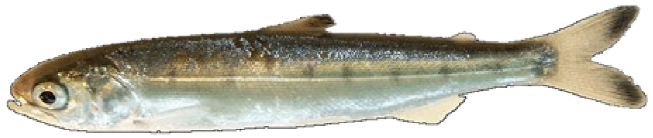


Bayesian Simple Ricker

- TV α was not used to estimate S_{MSY} because of uncertainty in interpreting model output, but it did inform data trends
- Data sets used
  - Higher productivity: 1983 to 2013
  - Lower productivity: 1998 to 2013

Stock	Data set and analysis	Data range	ln α	β	Midpoint	Lower	Upper
Early							
	Current goal				***400,000***	***350,000***	***450,000***
	Simple Ricker	1983 to 2013	1.548	0.141	427,272	284,768	787,477
		1998 to 2013	1.722	0.208	309,642	204,371	564,870
Late							
	Current goal				***300,000***	***200,000***	***400,000***
	Simple Ricker	1983 to 2013	1.794	0.215	311,507	205,635	582,558
		1998 to 2013	2.059	0.349	208,634	143,371	356,442
Total run							
	Simple Ricker	1983 to 2013	1.651	0.081	782,087	496,126	1,564,447
		1998 to 2013	1.982	0.142	500,668	333,300	900,651

S-R Analyses



Bayesian Simple Ricker

Early + Late S_{MSY} from the full data sets comparable to current goals

Stock	Data set and analysis	Data range	ln α	β	Midpoint	Lower	Upper
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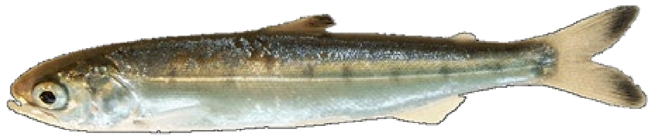

Bayesian Simple Ricker

S_{MSY} correspondingly lower during period of lower productivity.

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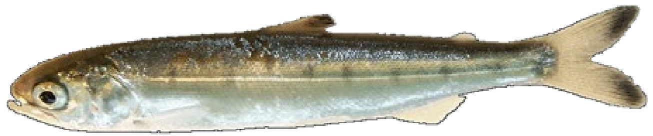

Bayesian Simple Ricker

Early + Late S_{MSY}

- 1983 to 2013: 738,799
- 1998 to 2013: 518,276

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	Current goal				***400,000***	***350,000***	***450,000***
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S-R Analyses

Bayesian Simple Ricker

- β increased during periods of lower productivity
- Consider total run

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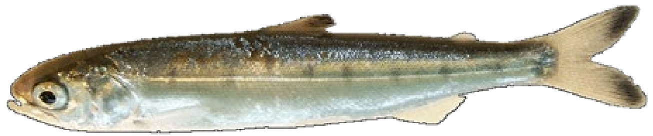


Habitat-based models

- Euphotic volume model
  - $EV = EZD \cdot SA \cdot e$

    EZD = depth of 1% light penetration

    SA = lake surface area

    e = constant

- Zooplankton biomass model
  - $S_G = \frac{2.11\ ZB \cdot SA}{G}$

    ZB = zooplankton biomass

    SA = lake surface area

    G = smolt weight (g)

Habitat-based models

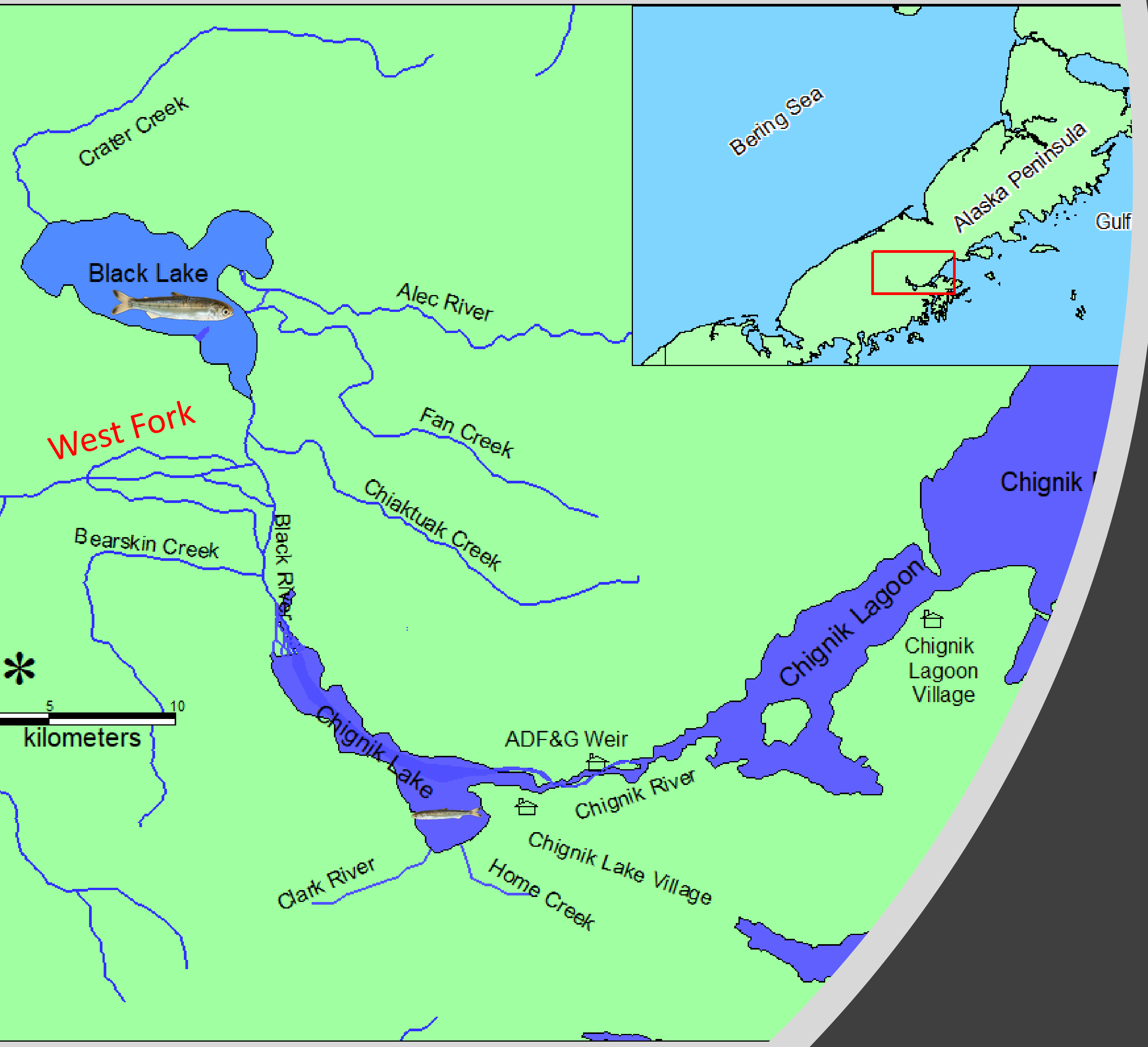
- Chignik Lake data: 2000 to 2020
- EV model: 396,000 to 594,000 fish
- Zooplankton biomass model: 450,000 to 674,000 fish

Image: NY Times

Image: Salmon facts

Results

- Discontinue early- and late-run goals
- Total run BEG
- 450,000 to 800,000 sockeye salmon



Results

Single goal

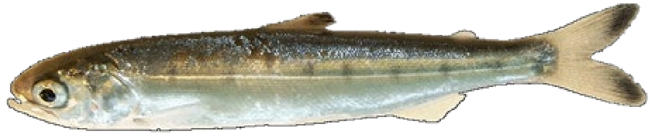
Prior to noticeable changes in Black Lake, both stocks of sockeye salmon interacted as juveniles in Chignik Lake (Dahlberg 1968, Narver 1966, Parr 1972)

Results

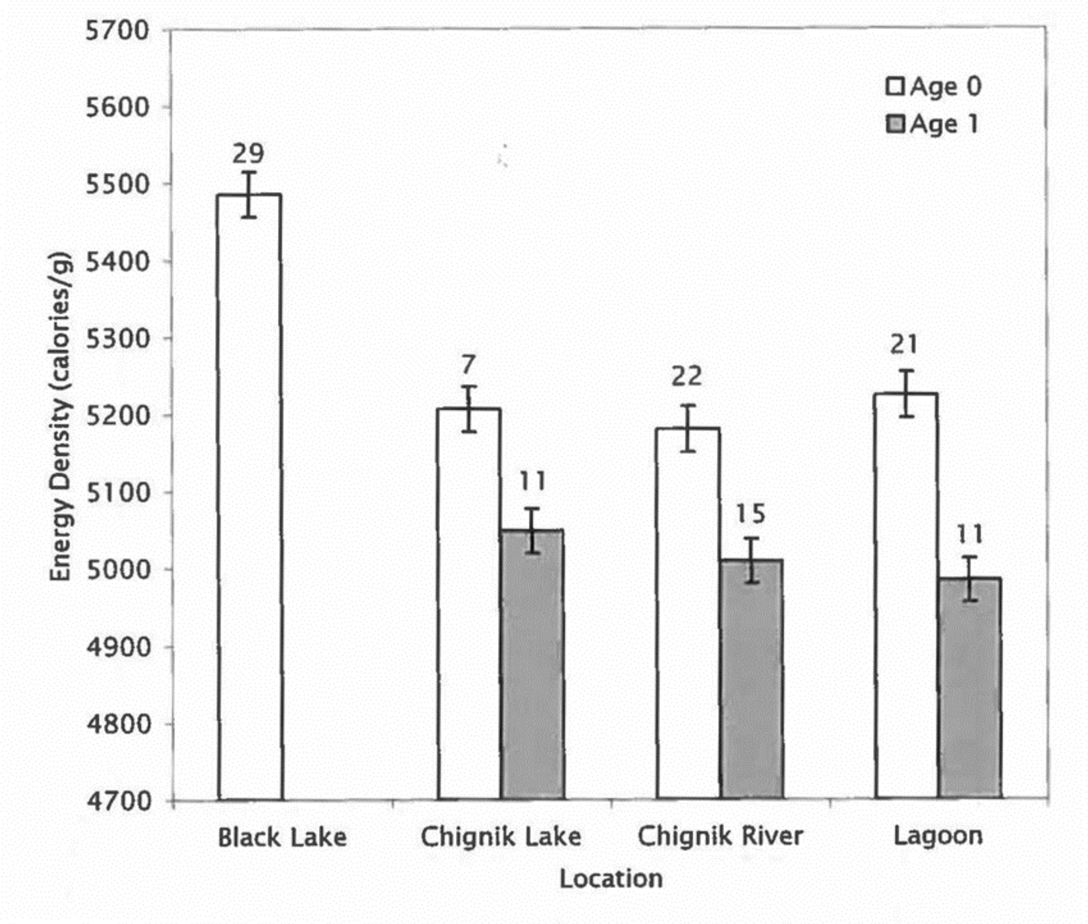
Single run

- Black Lake can still be excellent rearing habitat as evidenced by high caloric content of its rearing juvenile sockeye salmon (Finkle 2004)

- But once in Chignik Lake, Black Lake fish are outgrown by Chignik Lake fish (Simmons et al. 2013, Griffiths et al. 2014)



Mean energy density by age and area for Chignik watershed sockeye salmon, 2002.



Results

Single goal

- With physical changes to the upper portion of watershed and greater climatic variability, density independent factors play a larger role.
- Temperature influences growth and migration

2008

2020

Black Lake

Results

Single goal

- With current watershed stability and increasing climatic variability, juvenile Black Lake sockeye salmon are likely to continue adaptive rearing strategies and utilize the entire watershed

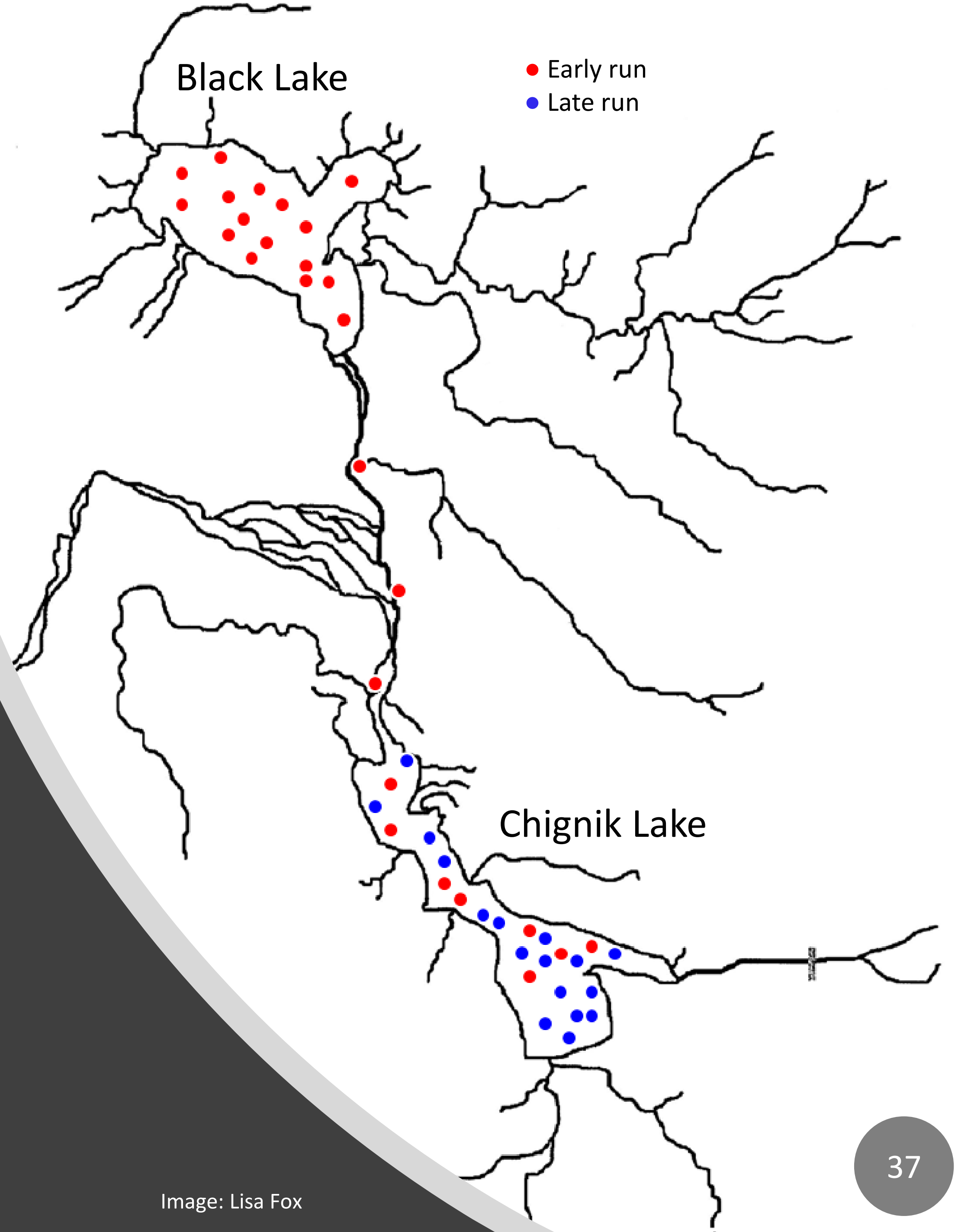
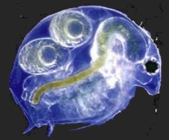


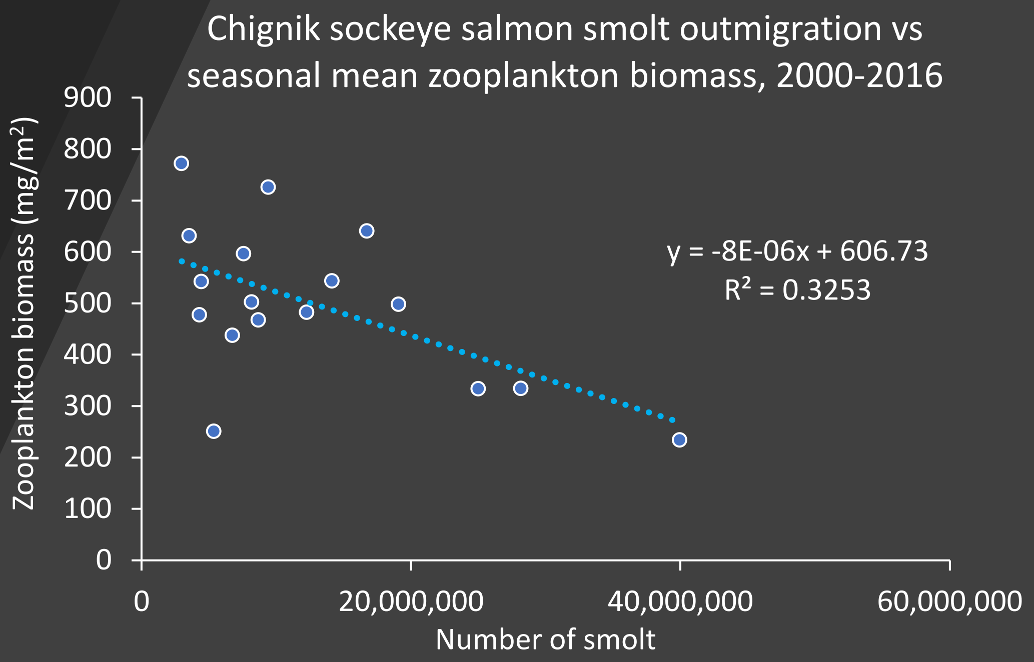
Image: Lisa Fox

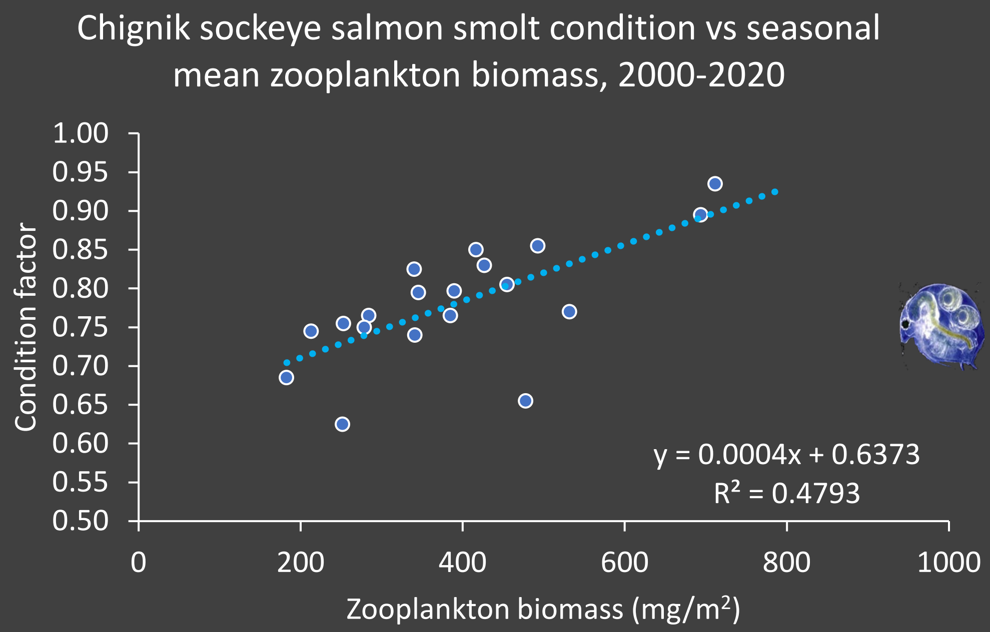
Results



Single goal

- Density dependence in Chignik Lake may create a bottleneck when a large juvenile population rears in the lake
  - Large outmigrations crop Chignik Lake zooplankton
  - Condition has a positive relationship with zooplankton biomass ∴ Low zooplankton = poor condition





Results

Single goal

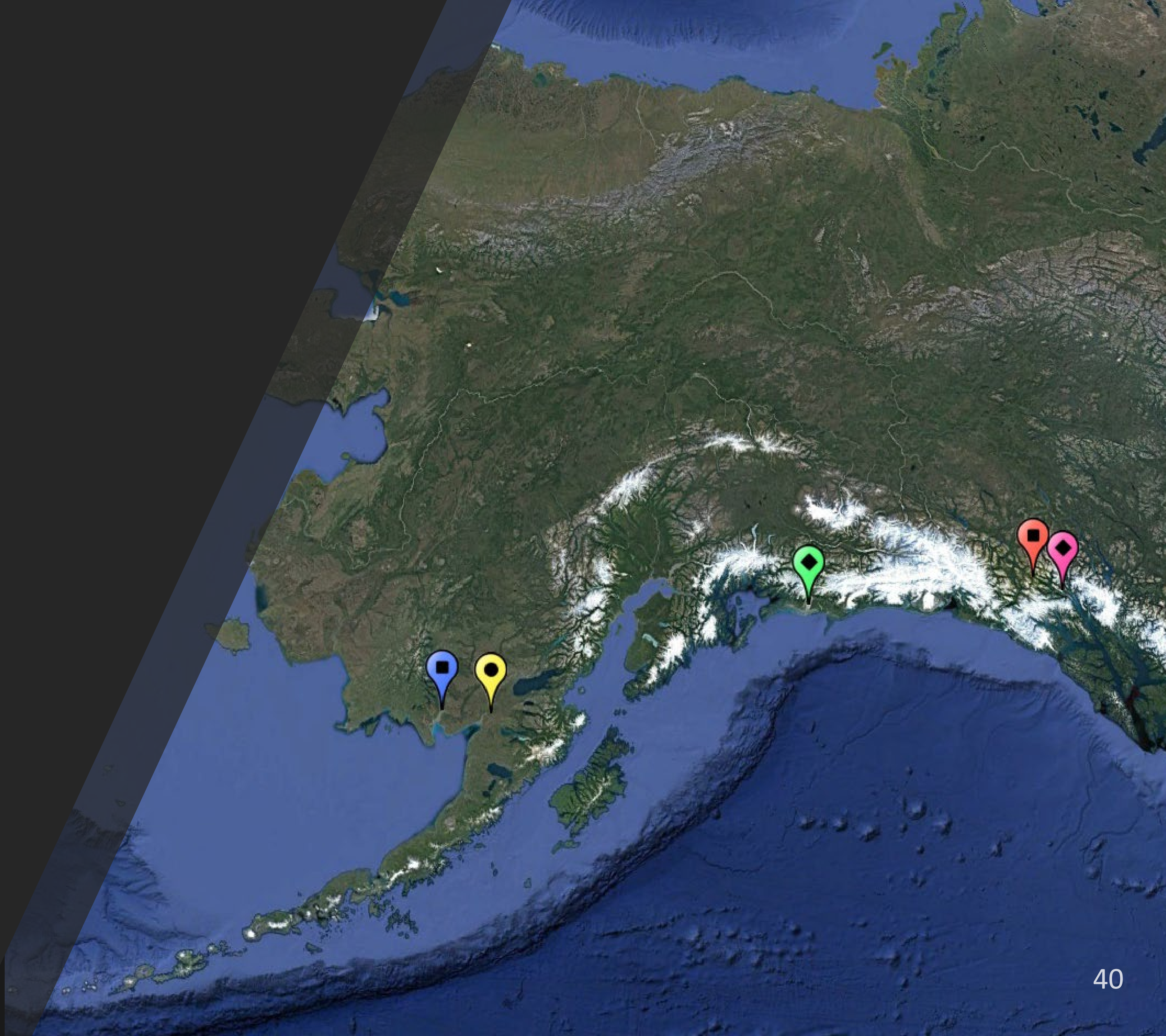
- Density dependence parameter β will not accurately reflect S-R relationships if mixed stock interactions are not considered
- S_{MSY} estimated from the total run accounts for freshwater mixed stock interactions.

Results

Single goal

- Other sockeye salmon systems with multiple stocks have one goal

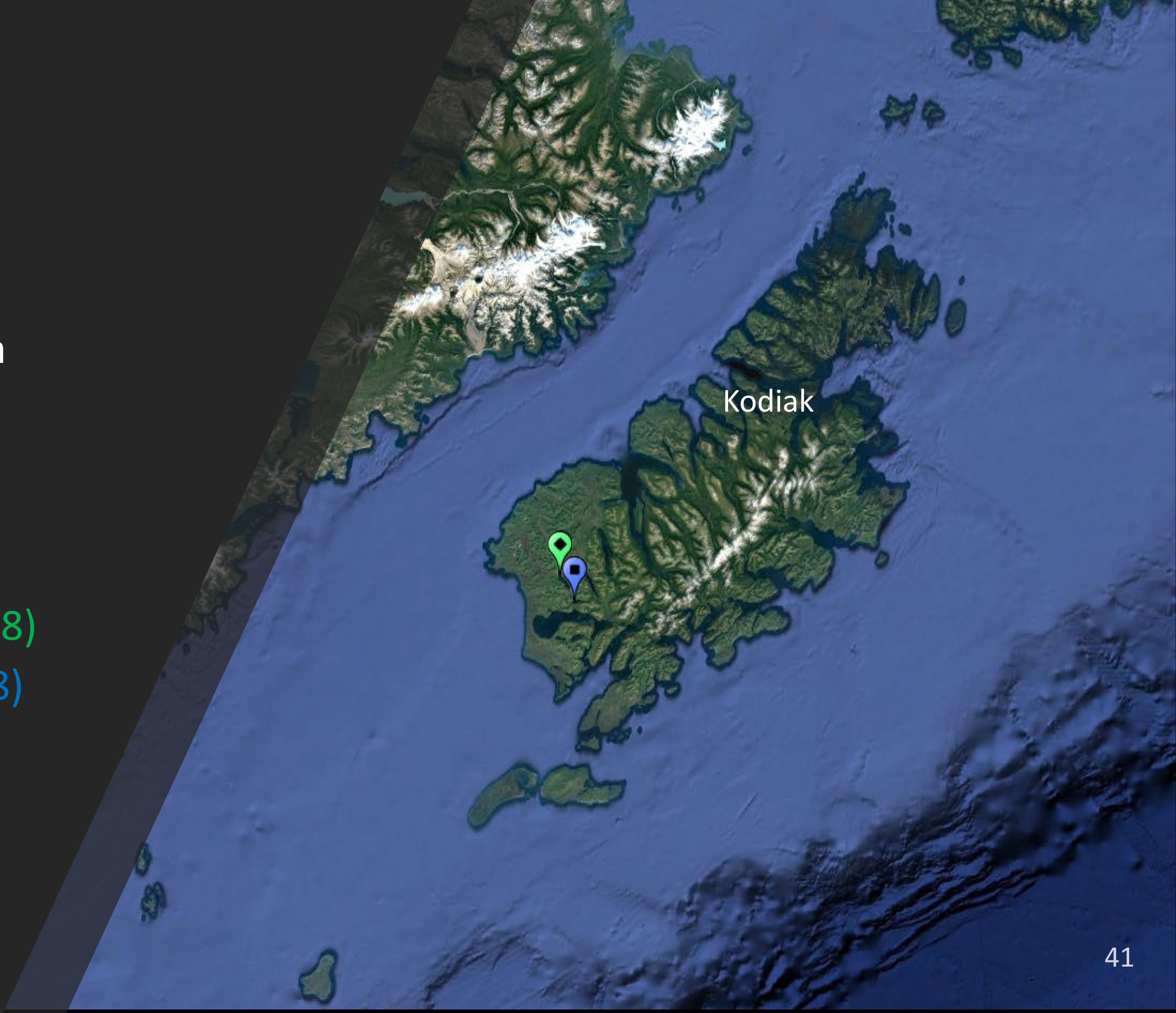
- A few examples:
  - Wood River - Bristol Bay
  - Alagnak River - Bristol Bay
  - Copper River - PWS
  - Chilkoot Lake Haines
  - Chilkat Lake - Haines



Results

Single goal

- Going from two goals to a single goal is not unprecedented:
- A few examples:
  - Ayakulik sockeye (1988)
  - Akalura sockeye (1988)

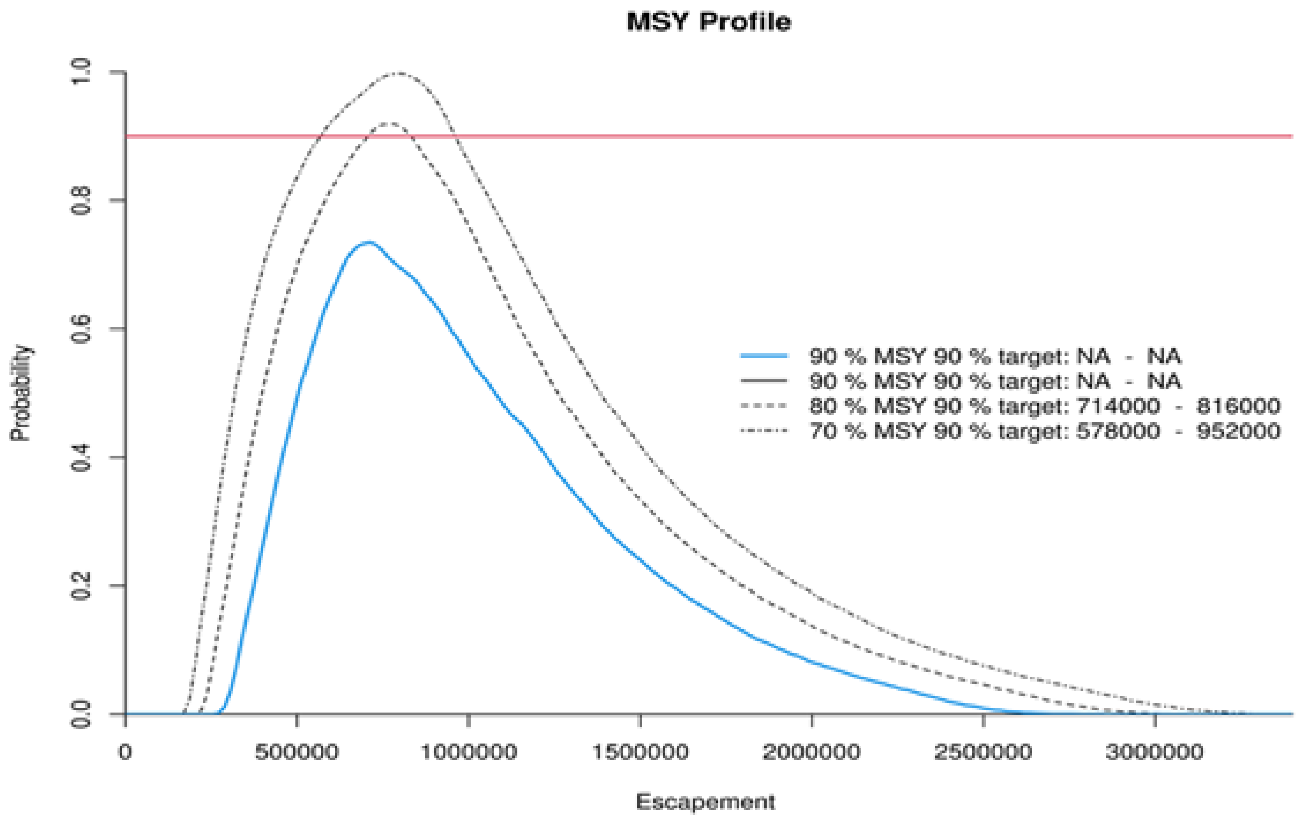


Results

Upper bound

- The upper bound of 800,000 fish was estimated to provide a 90% probability of achieving 80% of MSY for the Chignik-bound run

Total run 1983 to 2013



Results

Upper bound

- Escapements observed up to the upper bound of 800,000 fish have reliably produce replacement

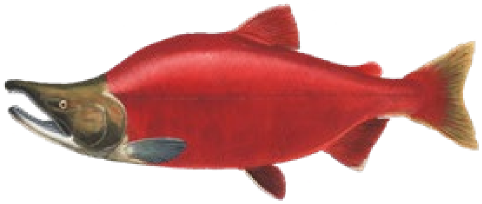
Image: Salmon facts

Results

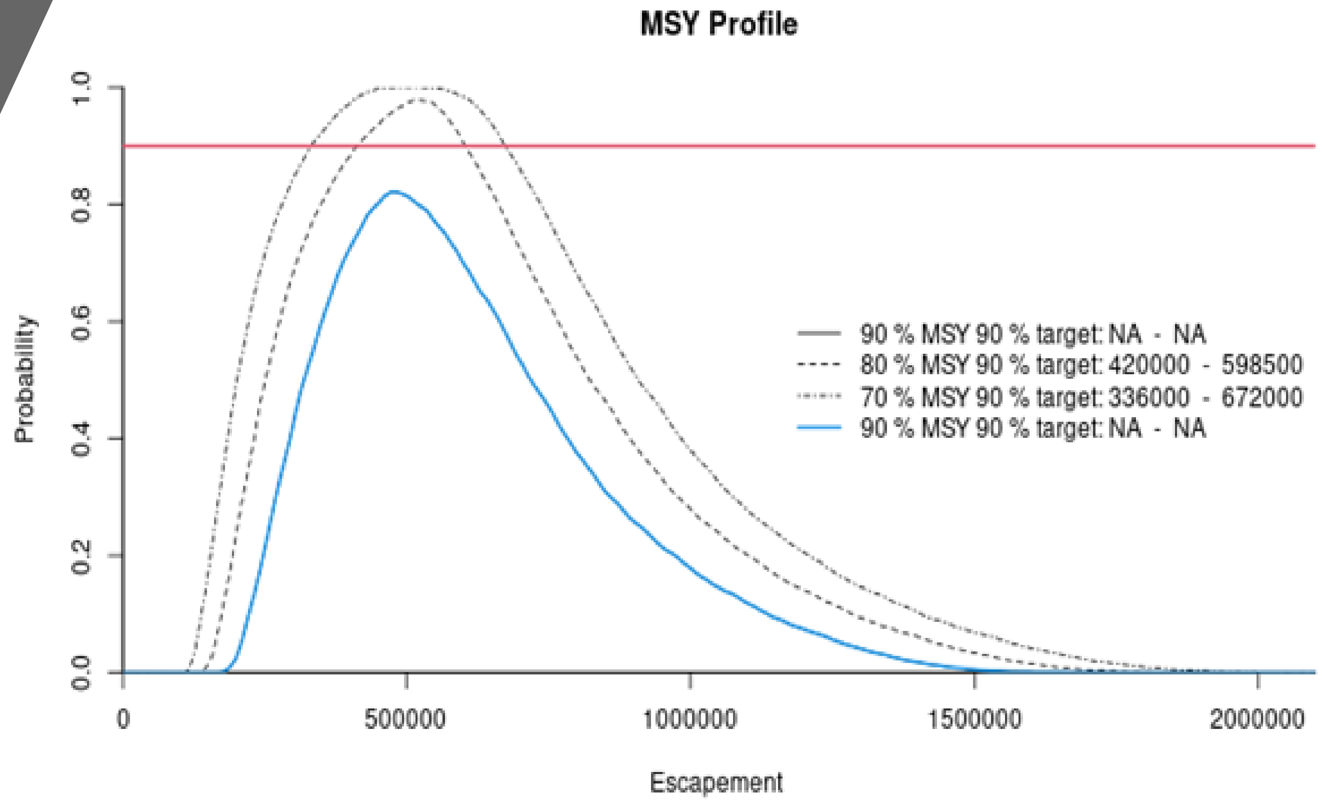
Lower bound

- ZB model lower bound supports S-R model lower bound

- Lower bound of 450,000 fish is estimated to provide a 90% probability of achieving 80% of MSY for the Chignik-bound run



Total run 1998 to 2013



Results

Chignik-bound yield

- Yield is similar during periods of average productivity
- Single-run goal provides greater yield during periods of low productivity

Estimated yields relative to escapement and productivity

Data range and productivity	Goal type	Goal range	Median yield
1983 to 2013	Total run-new	450,000 to 800,000	1,336,250
Average	Early + Late	550,000 to 850,000	1,284,077
		Difference	52,173
1998 to 2013	Total run-new	450,000 to 800,000	1,202,269
Low	Early + Late	550,000 to 850,000	1,039,895
		Difference	162,374

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		Difference	162,374

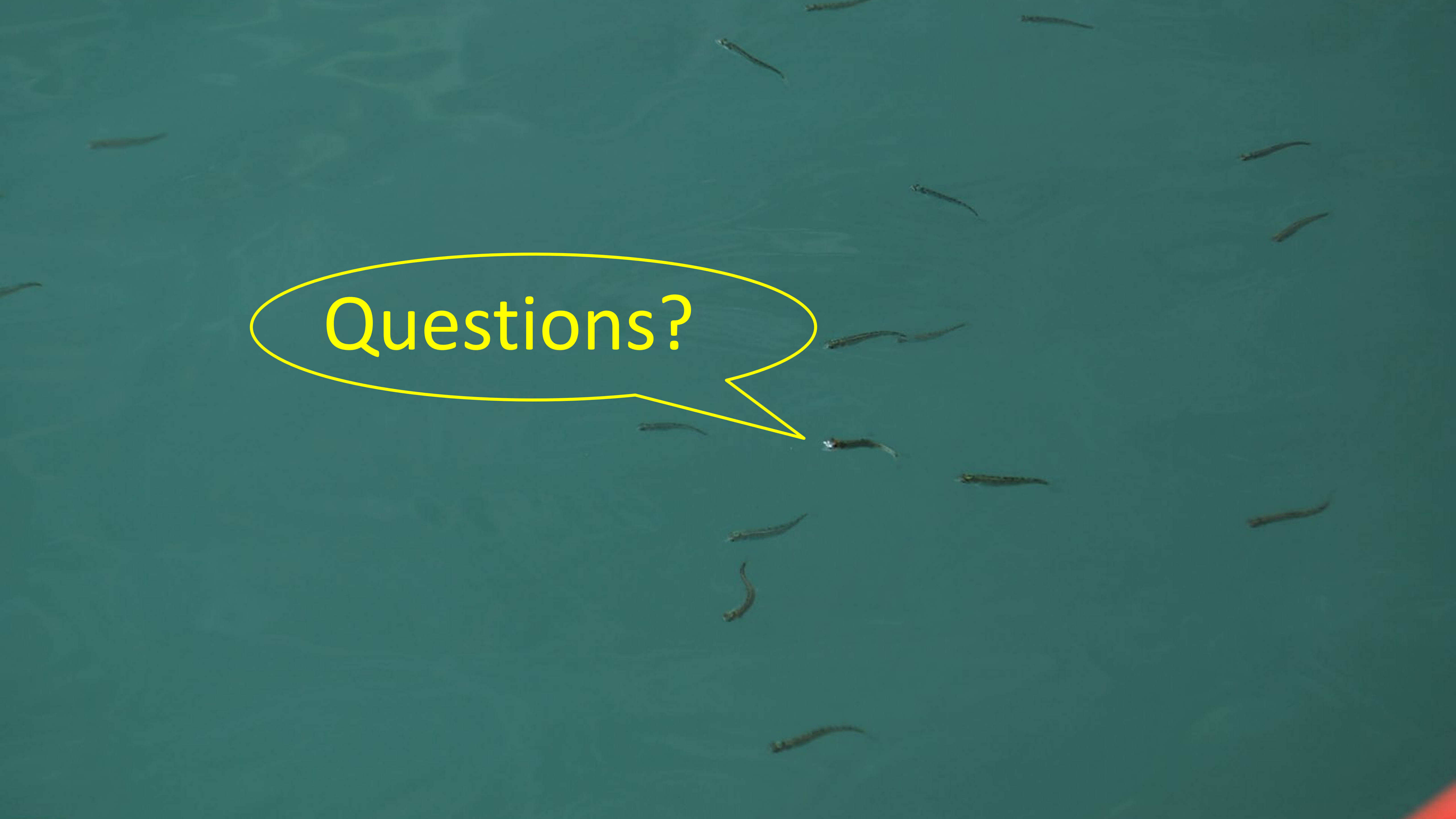
Considerations

Management

- Objectives based on historical run timing from years with genetic stock ID (2006 -2008, 2010-2021)

- Same management tools (ASL data, aerial surveys, observed abundance, etc..)


Thanks to
Sarah Power
Birch Foster
Michelle Wattum
Annie Looman
Kyle Shedd
Bobby Hsu
The review team


Questions?