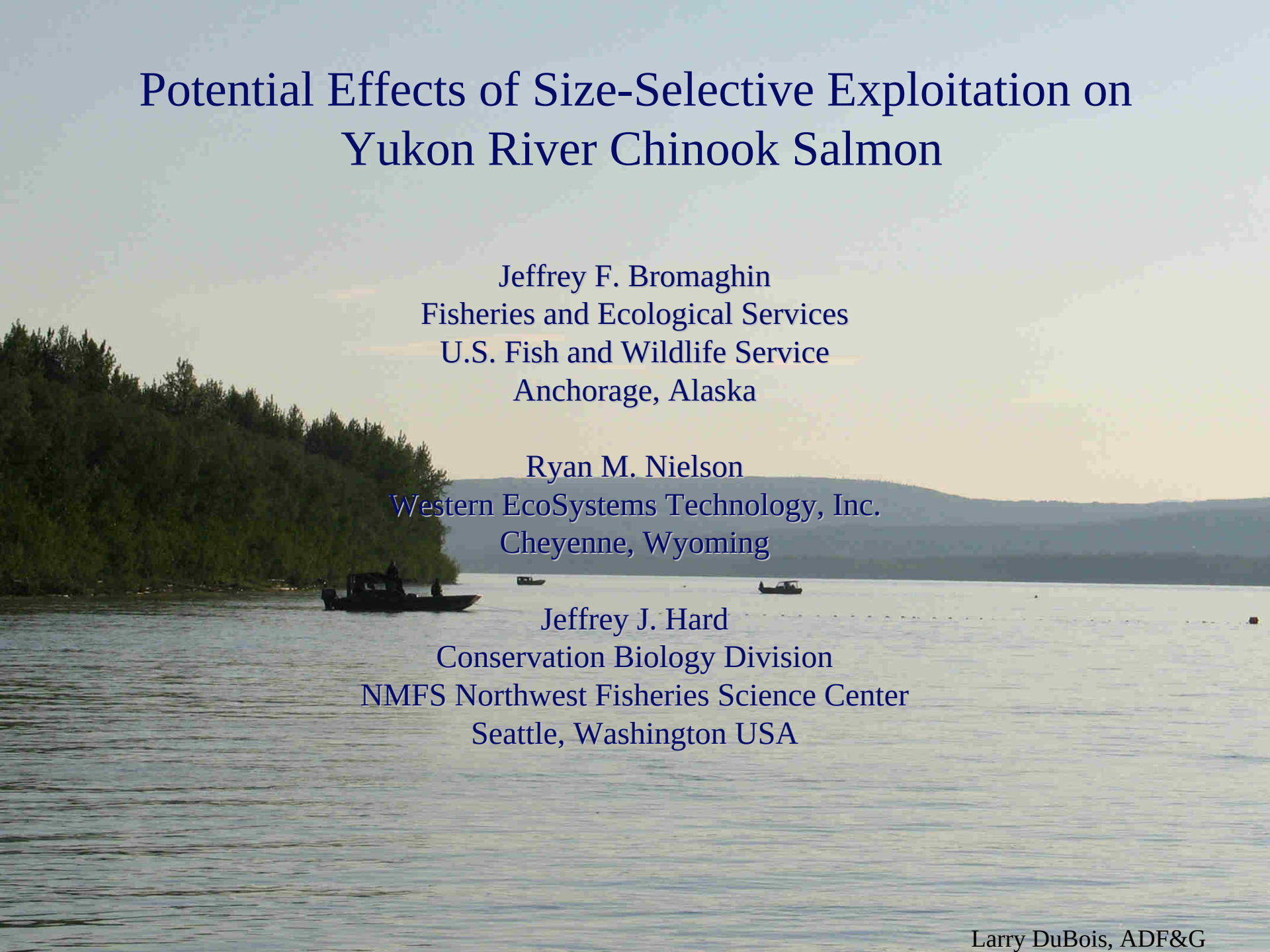
Potential Effects of Size-Selective Exploitation on Yukon River Chinook Salmon

Jeffrey F. Bromaghin
Fisheries and Ecological Services
U.S. Fish and Wildlife Service
Anchorage, Alaska

Ryan M. Nielson
Western EcoSystems Technology, Inc.
Cheyenne, Wyoming

Jeffrey J. Hard
Conservation Biology Division
NMFS Northwest Fisheries Science Center
Seattle, Washington USA



Larry DuBois, ADF&G

Evidence for Fishery-Induced Adaptation

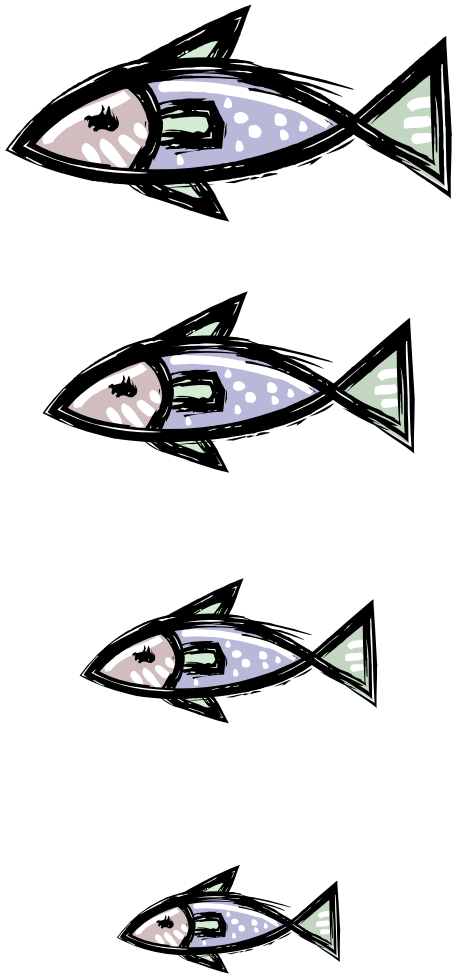
- Many observational studies of marine fisheries link harvest with changes in fish populations.
  - Especially reductions in size and age at maturation.
  - Prominent examples:
    - Abundance, reduced size and age-at-maturation of northwest Atlantic cod.
    - Size decline and shifts in the species composition of demersal fish along the Pacific coast of the United States.
    - Altered reproductive strategy of North Sea plaice.
    - Near collapse of western Atlantic bluefin tuna.
- Tank experiments with short-lived species documented substantial reductions in fish size and population productivity in as little as 3 generations.

Evidence for Fishery-Induced Adaptation

- Information of Pacific salmon is slowly accumulating.
- Changes in body morphology.
  - Trends in weight, length, age.
  - Increase in length after marine fishing halted.
- Life-history strategies.
  - Changes to run-timing.
  - Reduced age at maturation.
- Heritability of traits documented.
  - Body size, shape, flesh color.
  - Age at maturation, propensity to jack.
  - Return rate (survival), homing ability.
  - Disease resistance.

Are Yukon River Chinook Salmon Changing?

- Concern regarding potential fishery effects has been growing in recent years.
  - Is selection for large fish altering genetics?
- Regulatory proposals before the Board of Fisheries since (at least) early 1990s.
- Similar proposals before the Federal Subsistence Board in recent years.



Yukon River Chinook Salmon Trends

- Bigler et al., 1996.

Fig. 7. Mean weight of chinook salmon sampled from nine North American commercial fisheries.

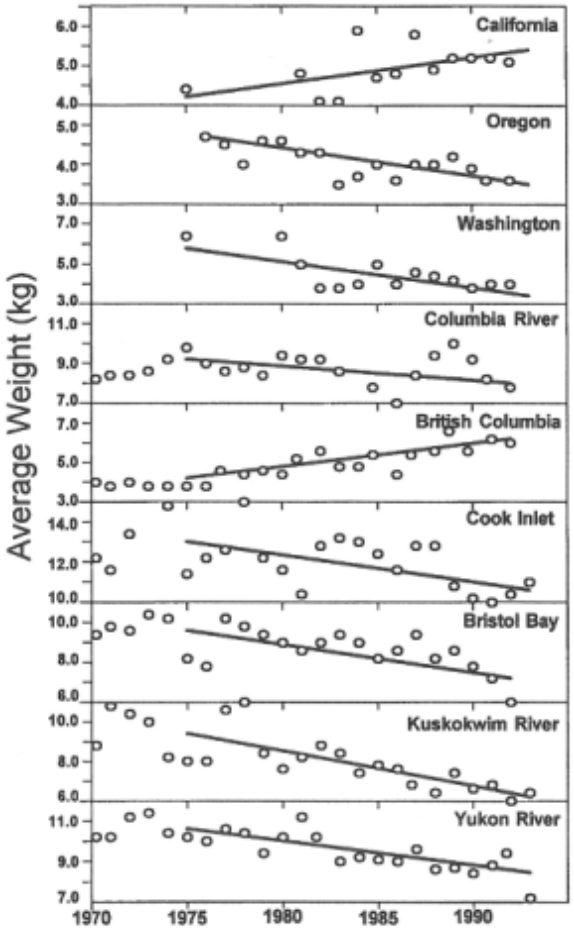
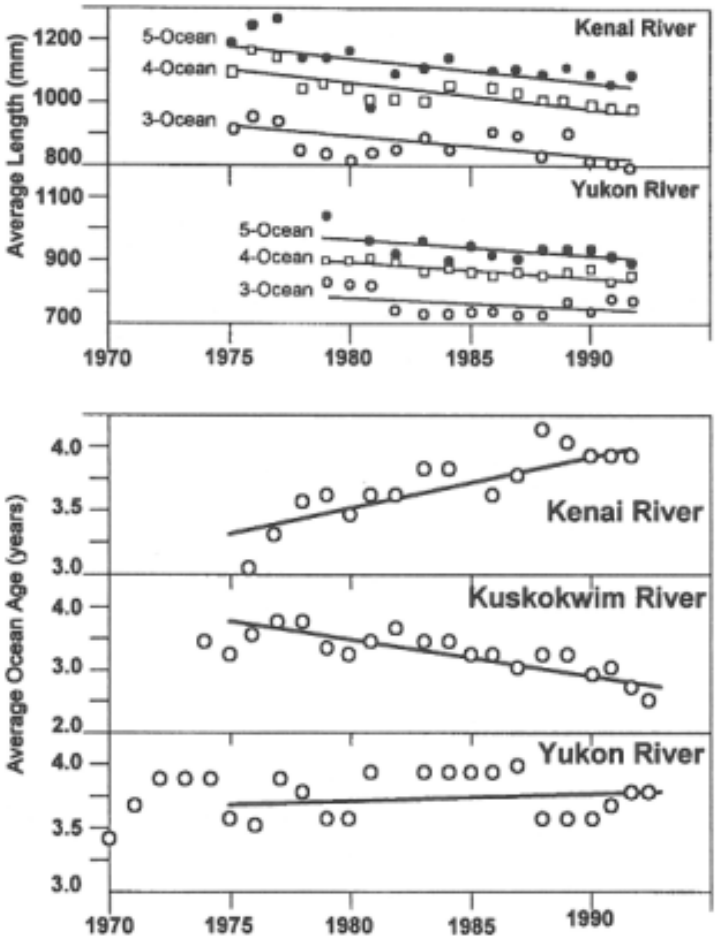
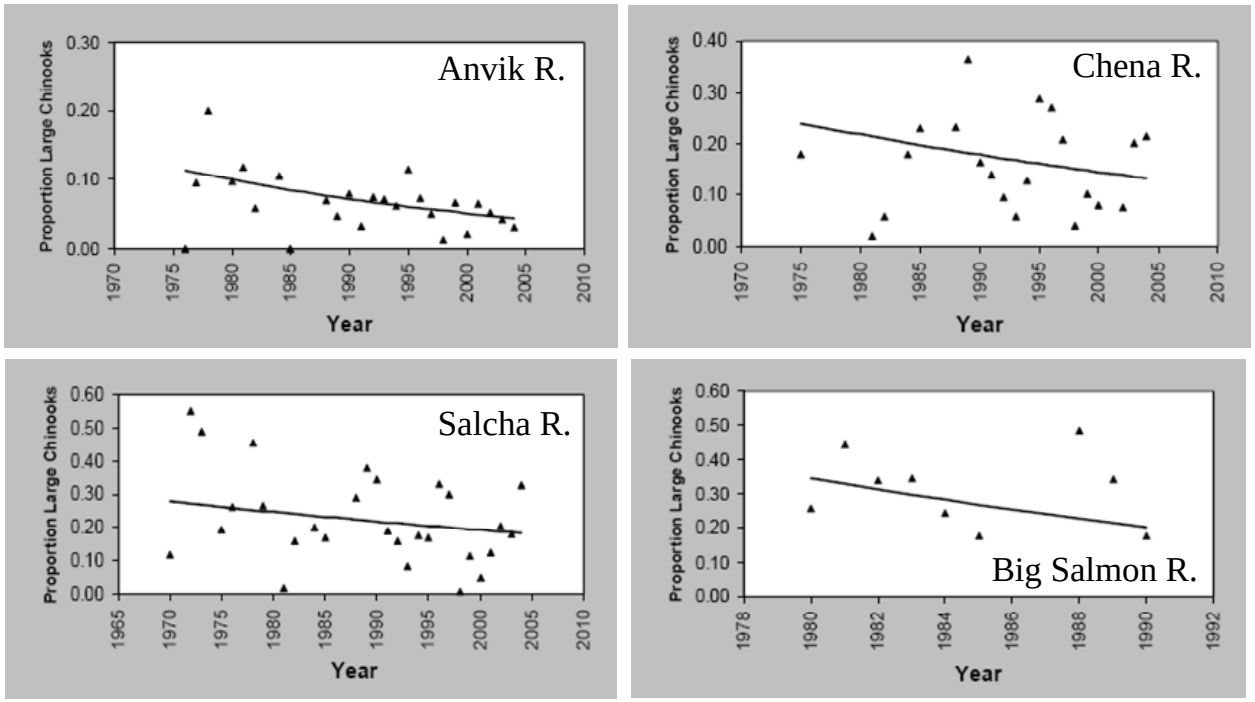


Fig. 8. Change in average length and age among chinook salmon from the Kuskokwim, Yukon, and Kenai rivers.



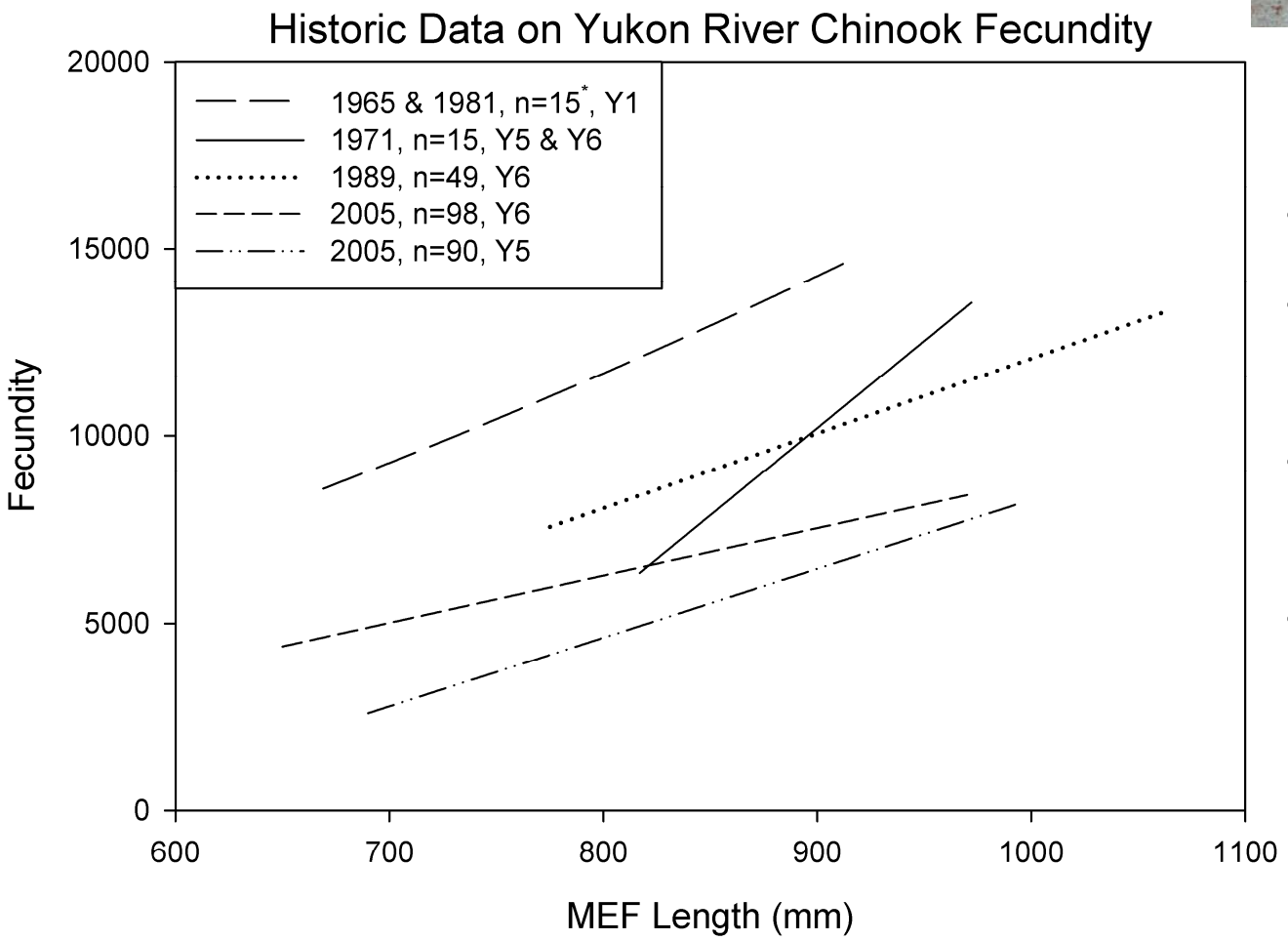
Yukon River Chinook Salmon Trends

- Hyer and Schleusner, 2005.
- Proportion of fish >900 mm declined from 2-7% annually in some tributaries.



- No trend was observed in the data from other tributaries.
- Other variables they examined did not display trends.

Yukon River Chinook Salmon Trends



- Weidner, 1972.
- Healey and Heard, 1984.
- Skaugstad and McCracken, 1991.
- Jasper and Evenson, 2006.

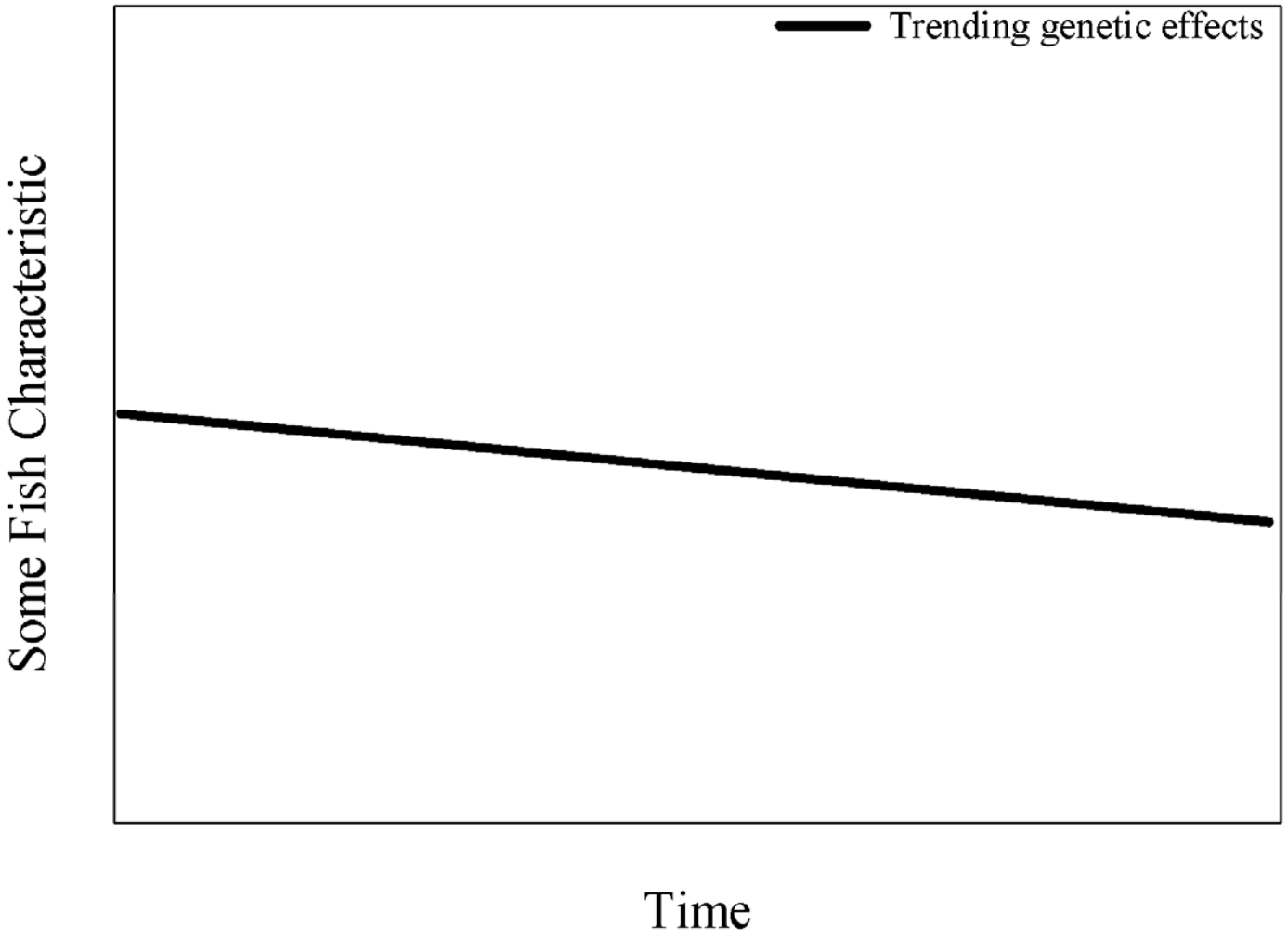
Investigative Questions

- Is the genetic effect of long-term, harvest of large fish likely to alter the size and age composition and productivity of Yukon River Chinook salmon?

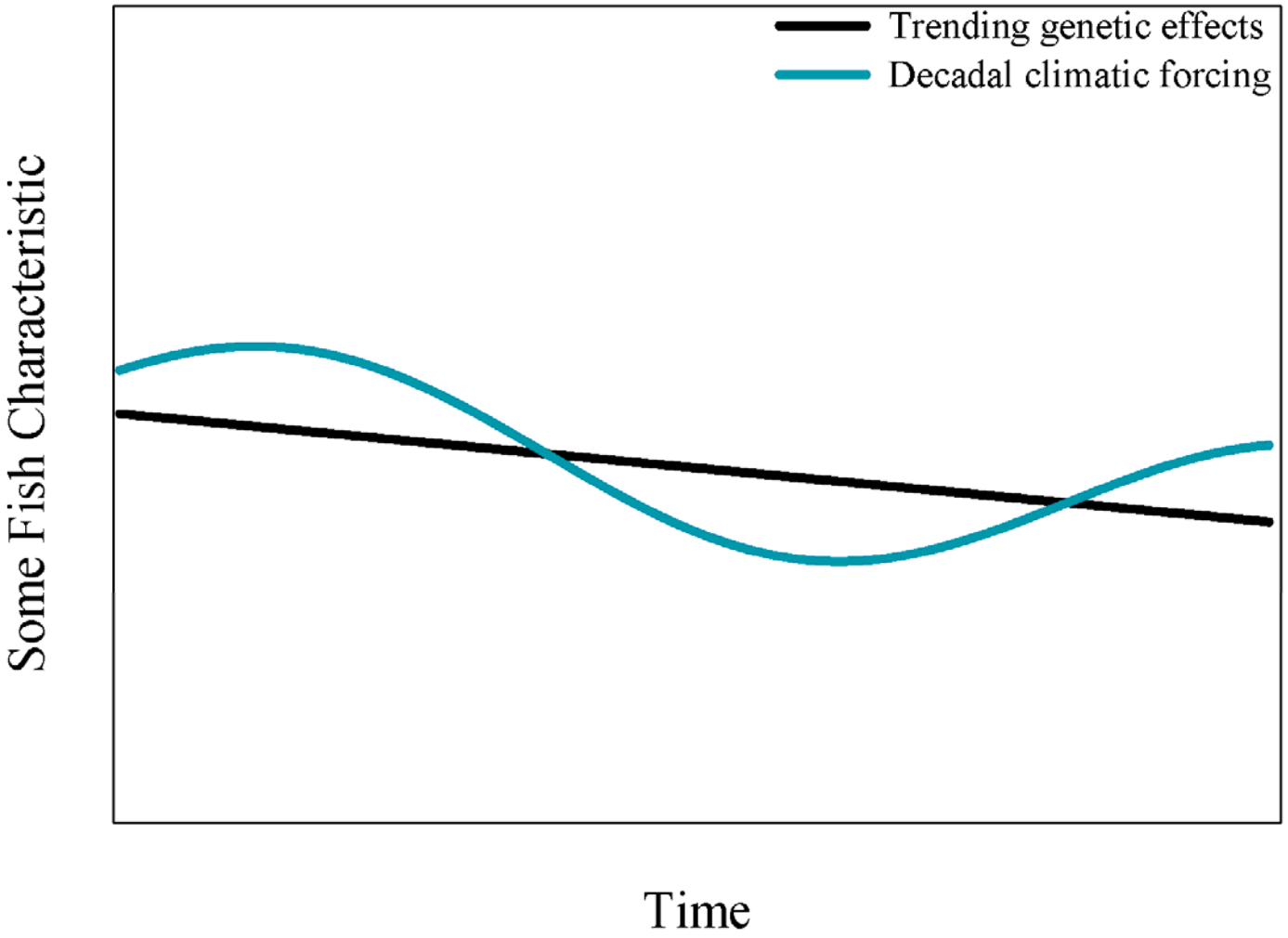
Wennona Brown, USFWS

- If yes:
  - What aspects of a fishery are most likely to cause adaptation?
  - Can fishery-induced adaptation be reversed?

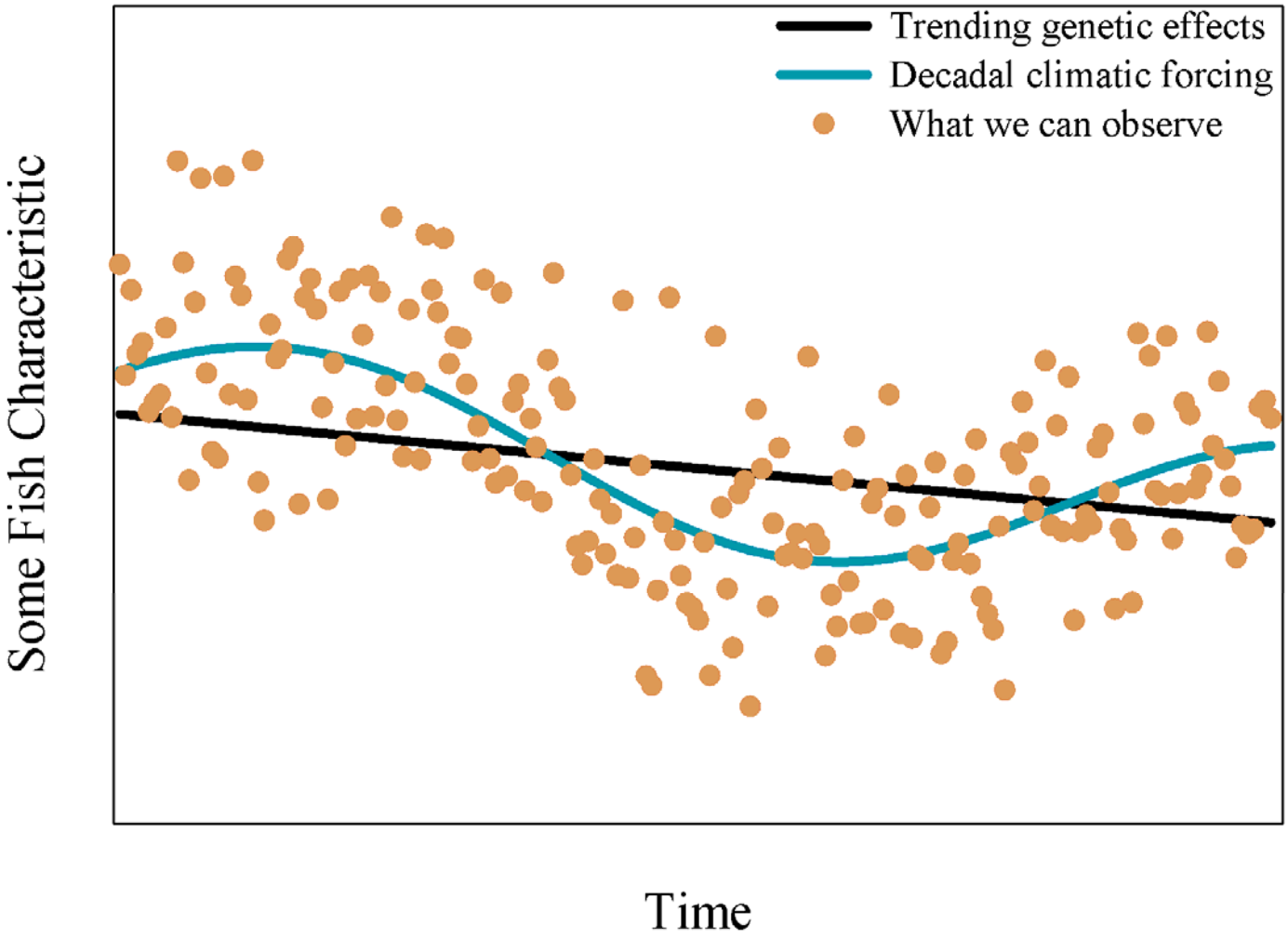
Components of Fish Characteristics



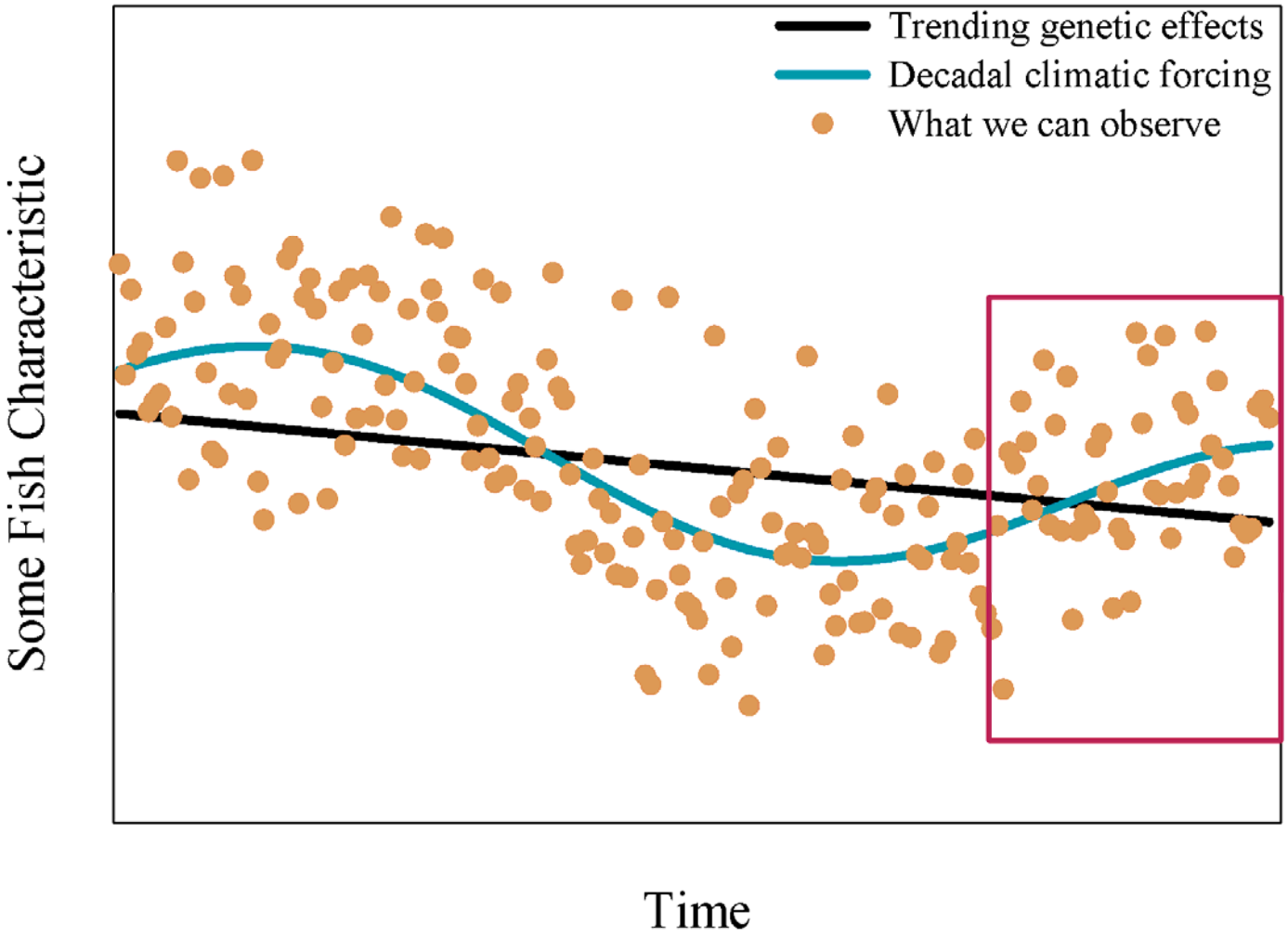
Components of Fish Characteristics



Components of Fish Characteristics



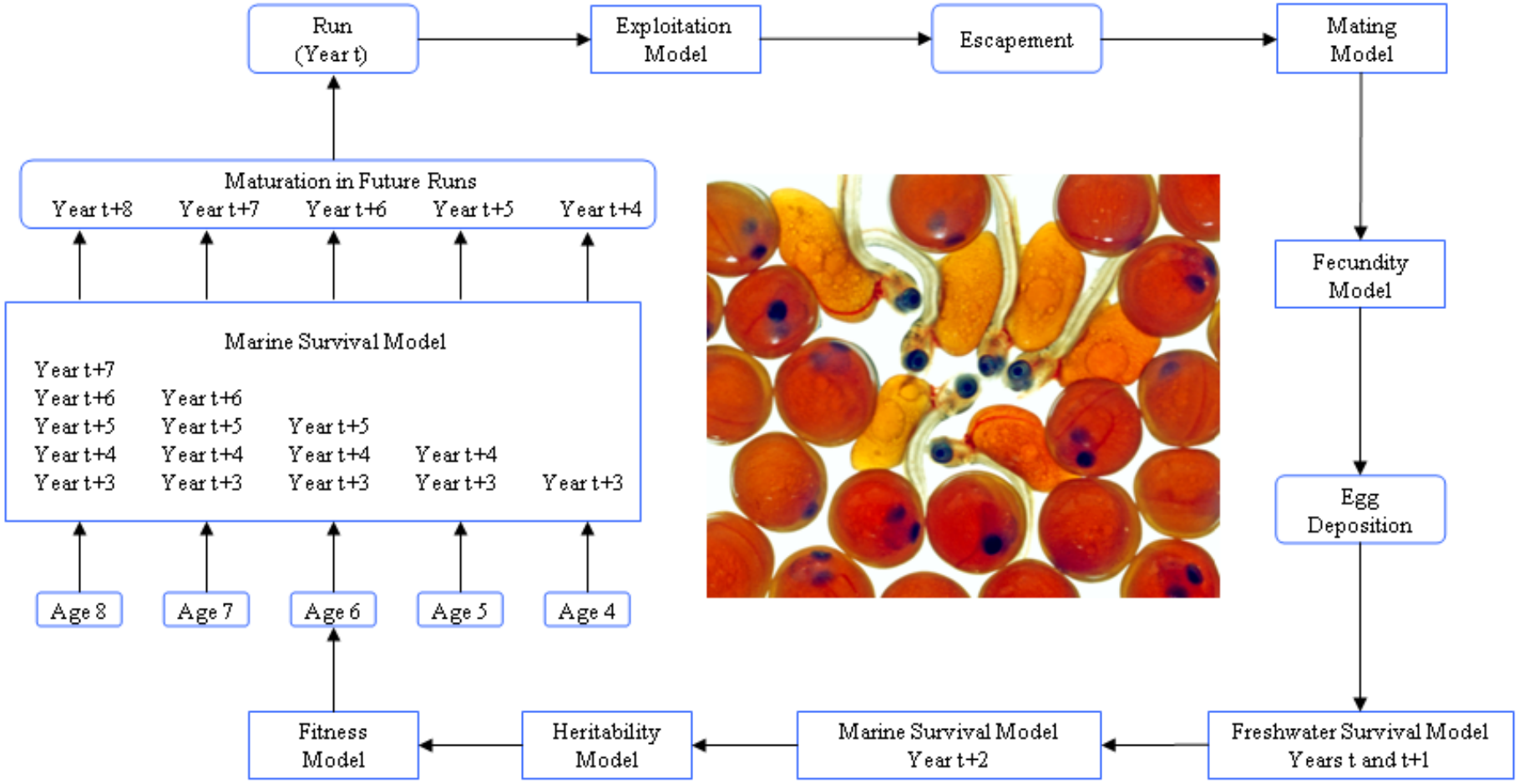
Components of Fish Characteristics



Reasons for Computer Simulation

- Expected fishing-induced adaptation to occur slowly over many generations.
- No pre-fishery data to provide a true baseline.
- Environmental conditions known to be influential.
- High levels of natural variation can mask trends.
- Often have short time series of data collected with biased gear.
- Observational studies cannot confirm cause.
- Computer models provide more controlled experimentation.

Model Structure



Initial Simulations

- 26 scenarios simulated, each for 200 years
  - 24 combinations of 4 productivity/harvest variables (table below)
  - 2 no-harvest “controls”, one for each productivity level
  - 250 replicates per scenario
- Equilibrium abundance: 10,000 adults
- All initial simulations used 8.5” gillnet

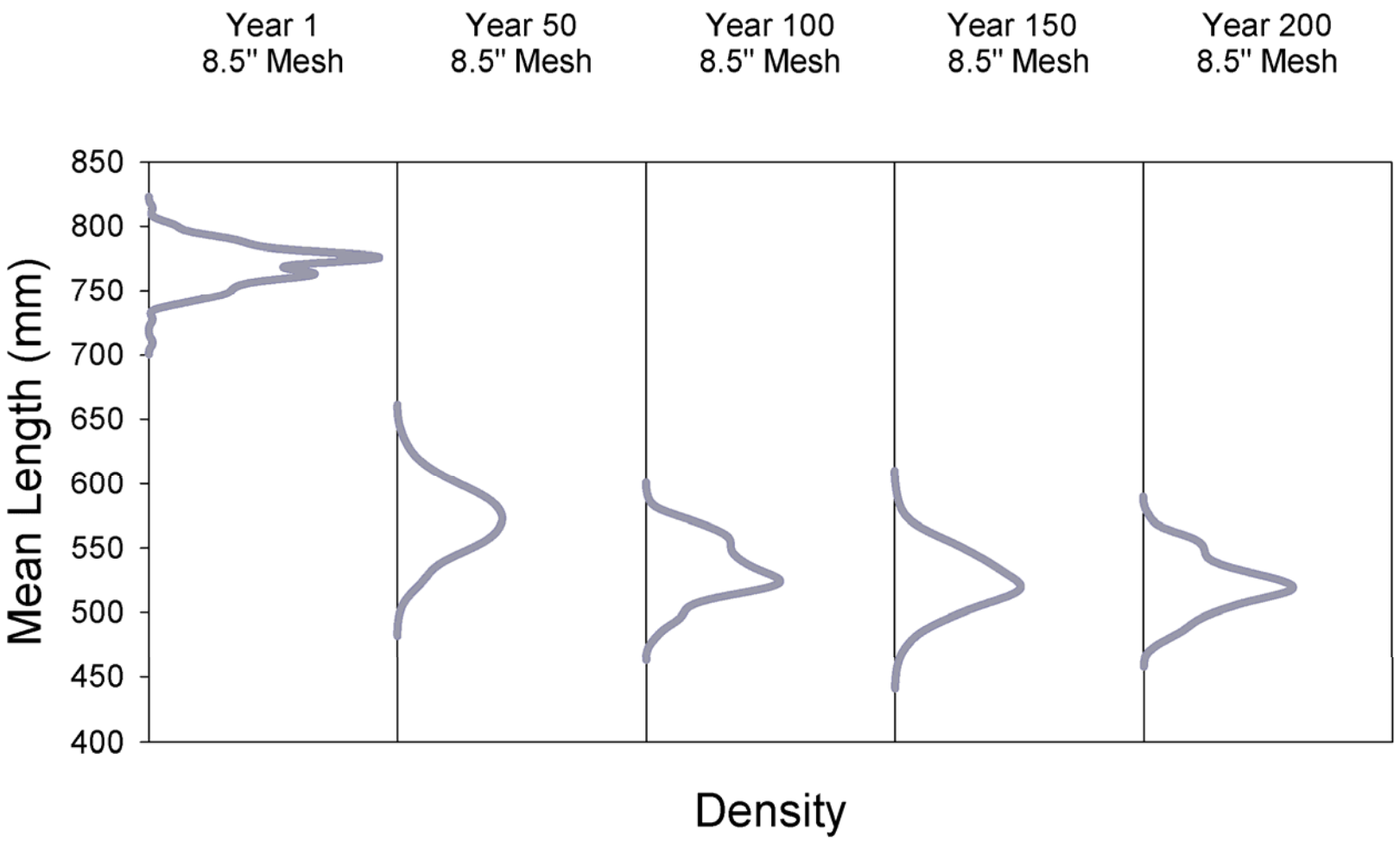
Productivity (Ricker α)	Exploitation Parameter (γ)	Management Precision	Escapement Goal (k*Smsy)
Low (1.5)	Low (0.50)	Low (± 30%)	Low (k=0.5)
High (2.25)	High (0.85)	High (± 15%)	Medium (k=1.0)
			High (k=1.5)

Initial Simulation Results

- **Simulation 21**
  - **Exploitation - high**
  - **Escapement goal – low**
  - **Results typical of most simulations**
- **Simulation 26**
  - **Exploitation - low**
  - **Escapement goal – high**

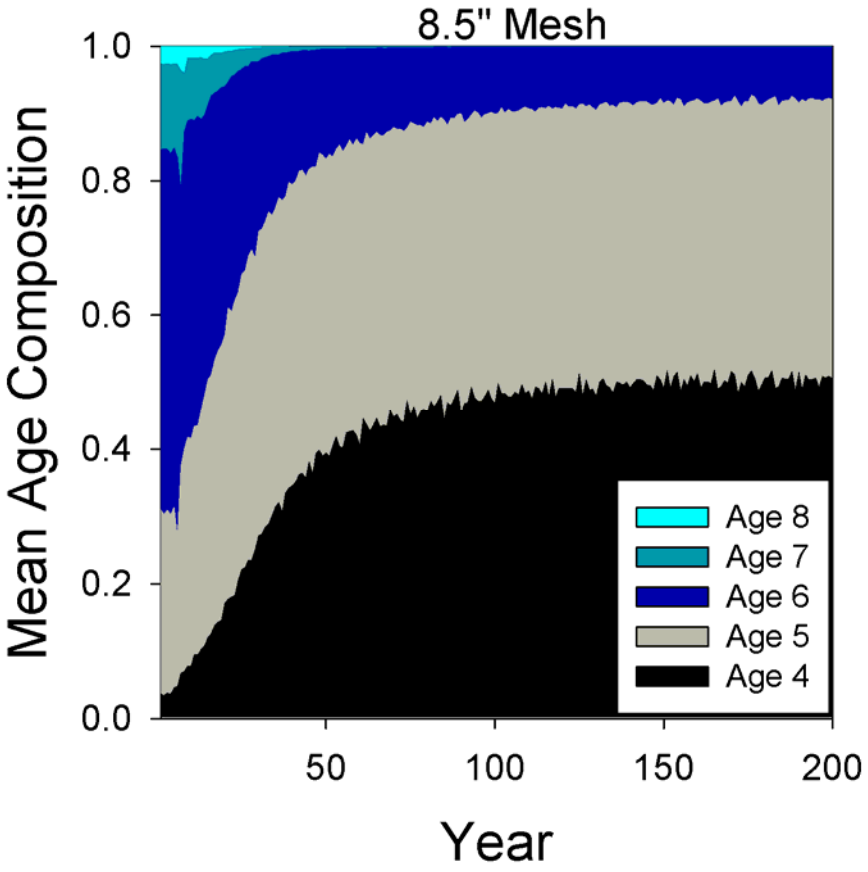
Initial Simulations

- Simulation 21 – high exploitation, low escapement goal



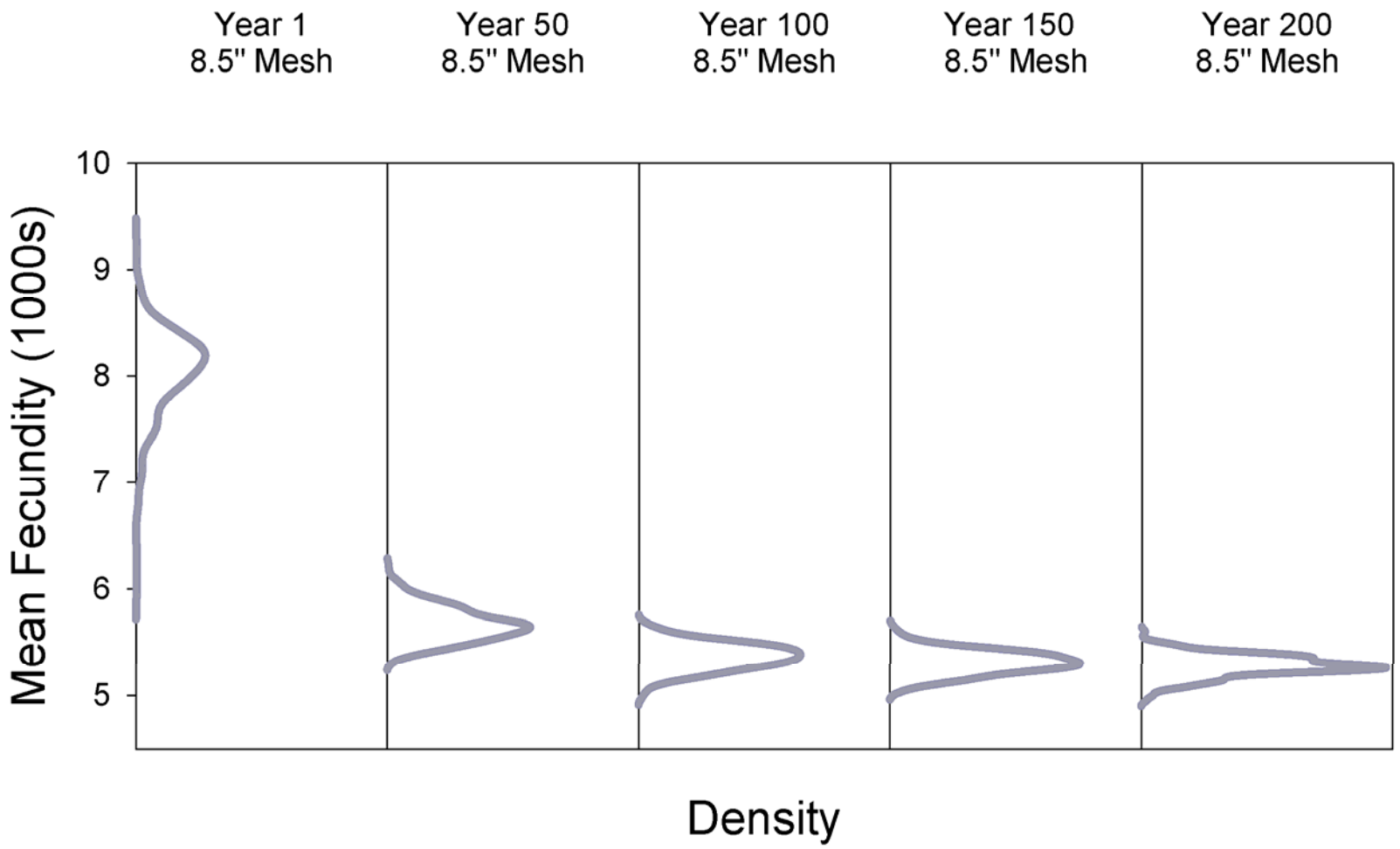
Initial Simulations

- Simulation 21 – high exploitation, low escapement goal



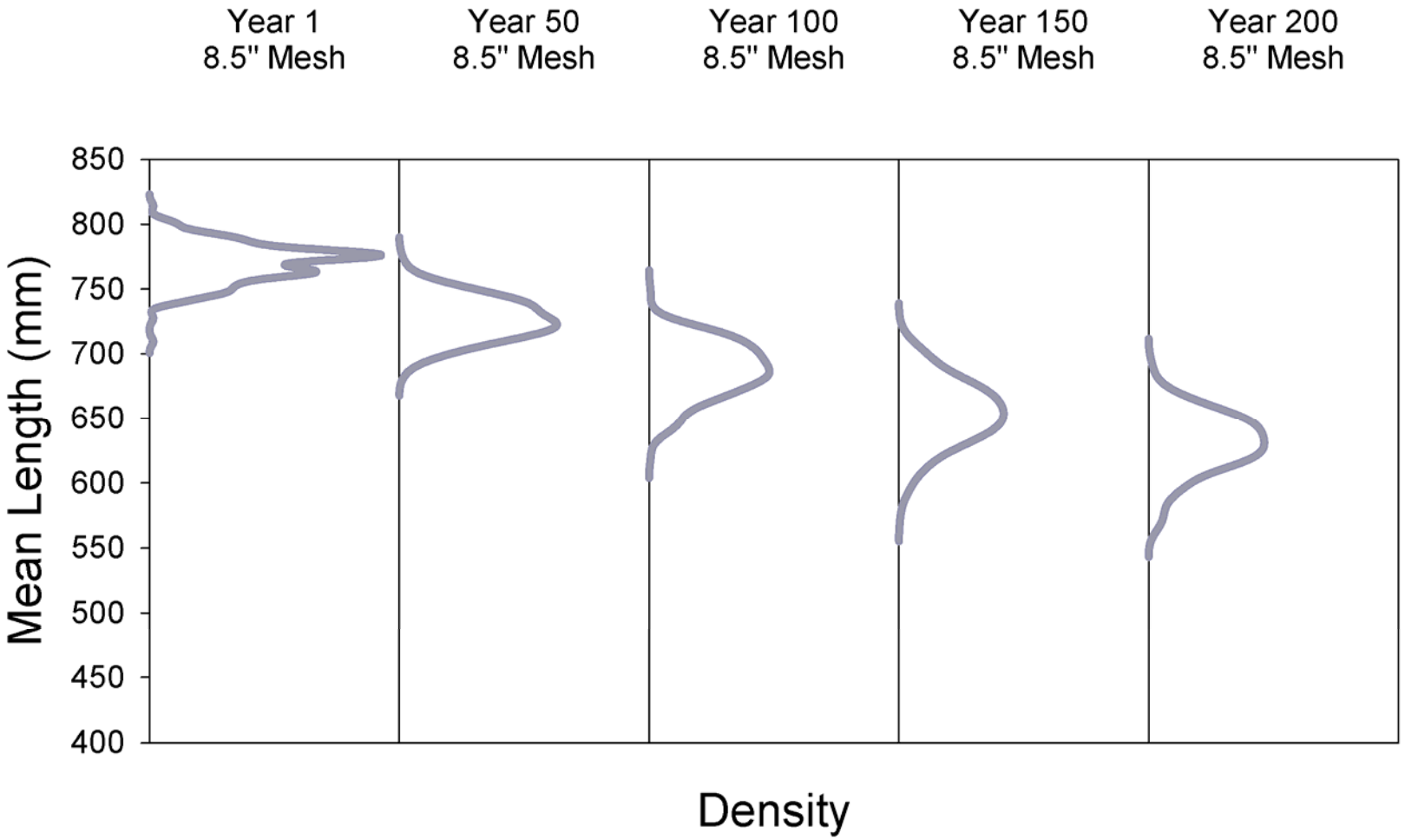
Initial Simulations

- Simulation 21 – high exploitation, low escapement goal



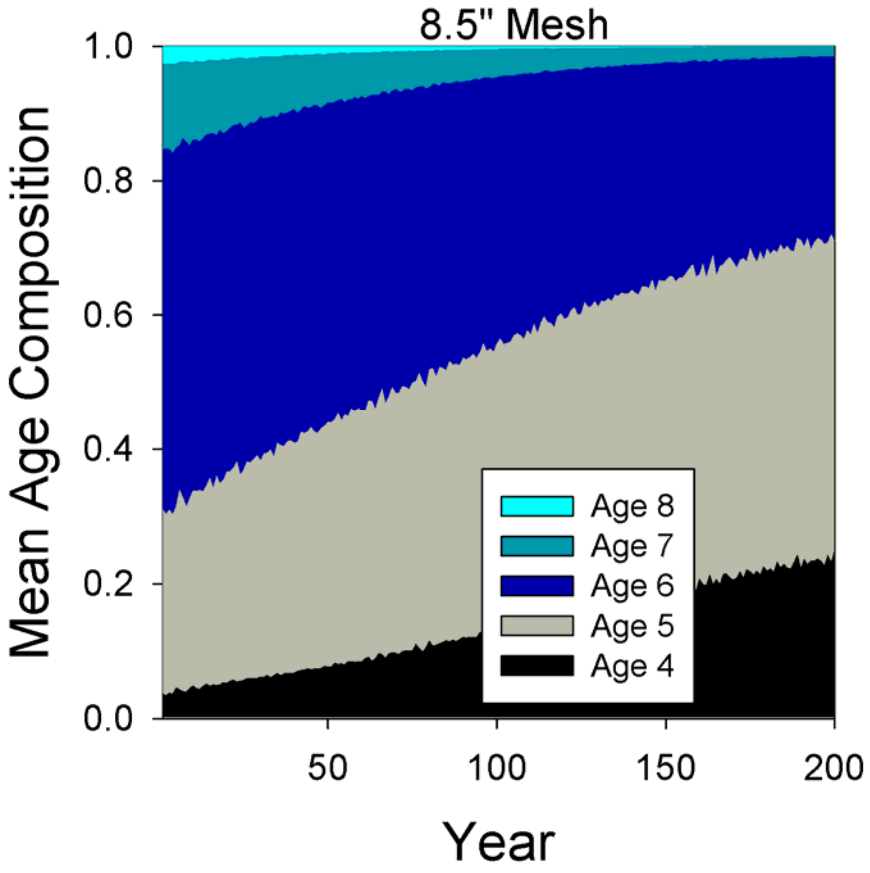
Initial Simulations

- Simulation 26 – low exploitation, high escapement goal



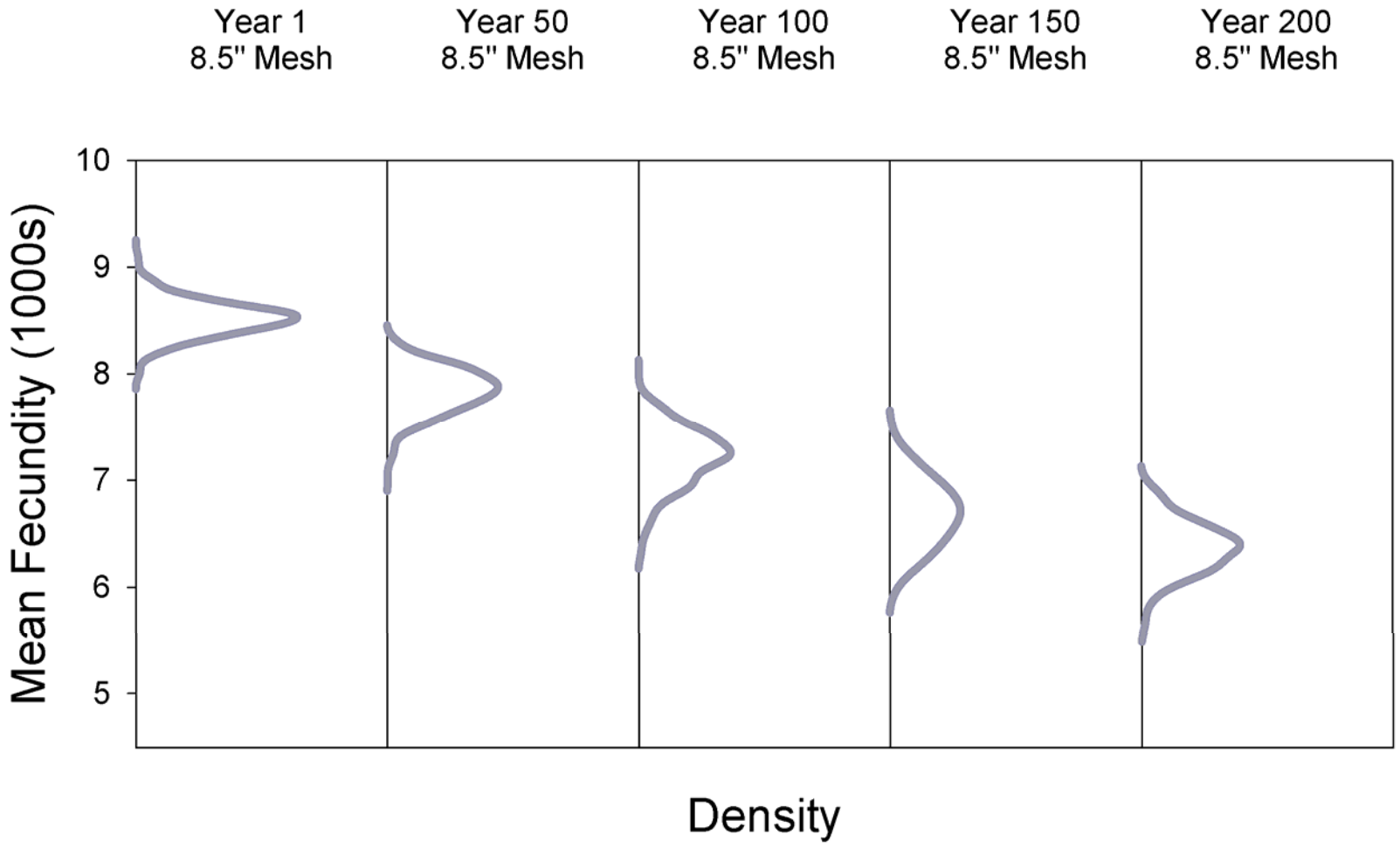
Initial Simulations

- Simulation 26 – low exploitation, high escapement goal

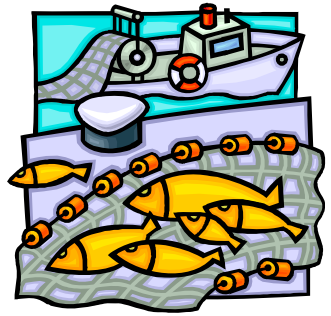


Initial Simulations

- Simulation 26 – low exploitation, high escapement goal



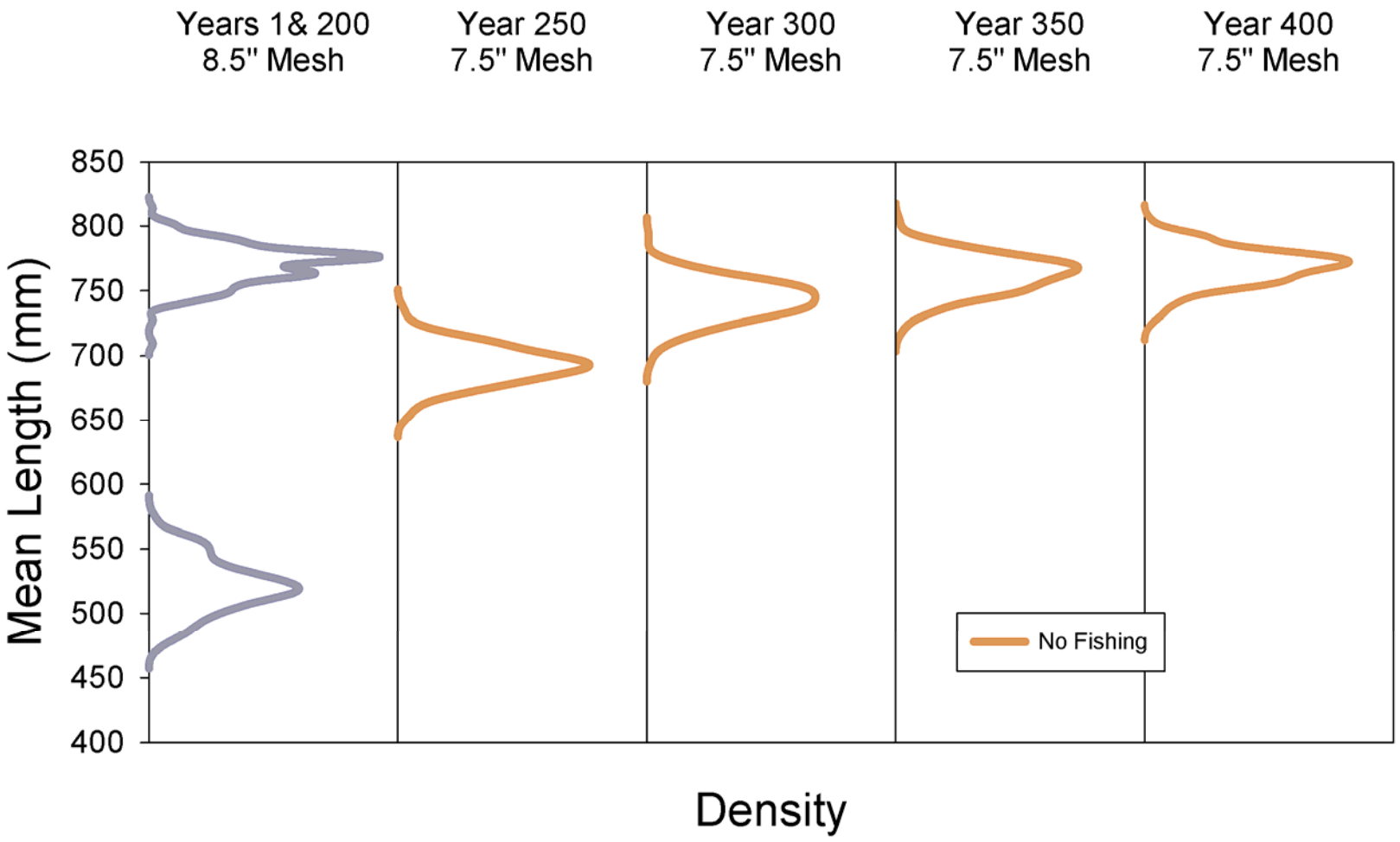
Alternative Fishing Simulations



- Selected 4 scenarios bracketing range of results.
- Implemented alternative management strategies to explore resiliency.
  - One case in which fishing was stopped completely.
  - Mesh size reduced from 8.5” to 7.5”.
  - Exploitation parameter:
    - Used original value (low or high).
    - High values also change to low.
  - Increased escapement goal in increments of $0.5(S_{MSY})$.
- Simulated population dynamics additional 200 years.

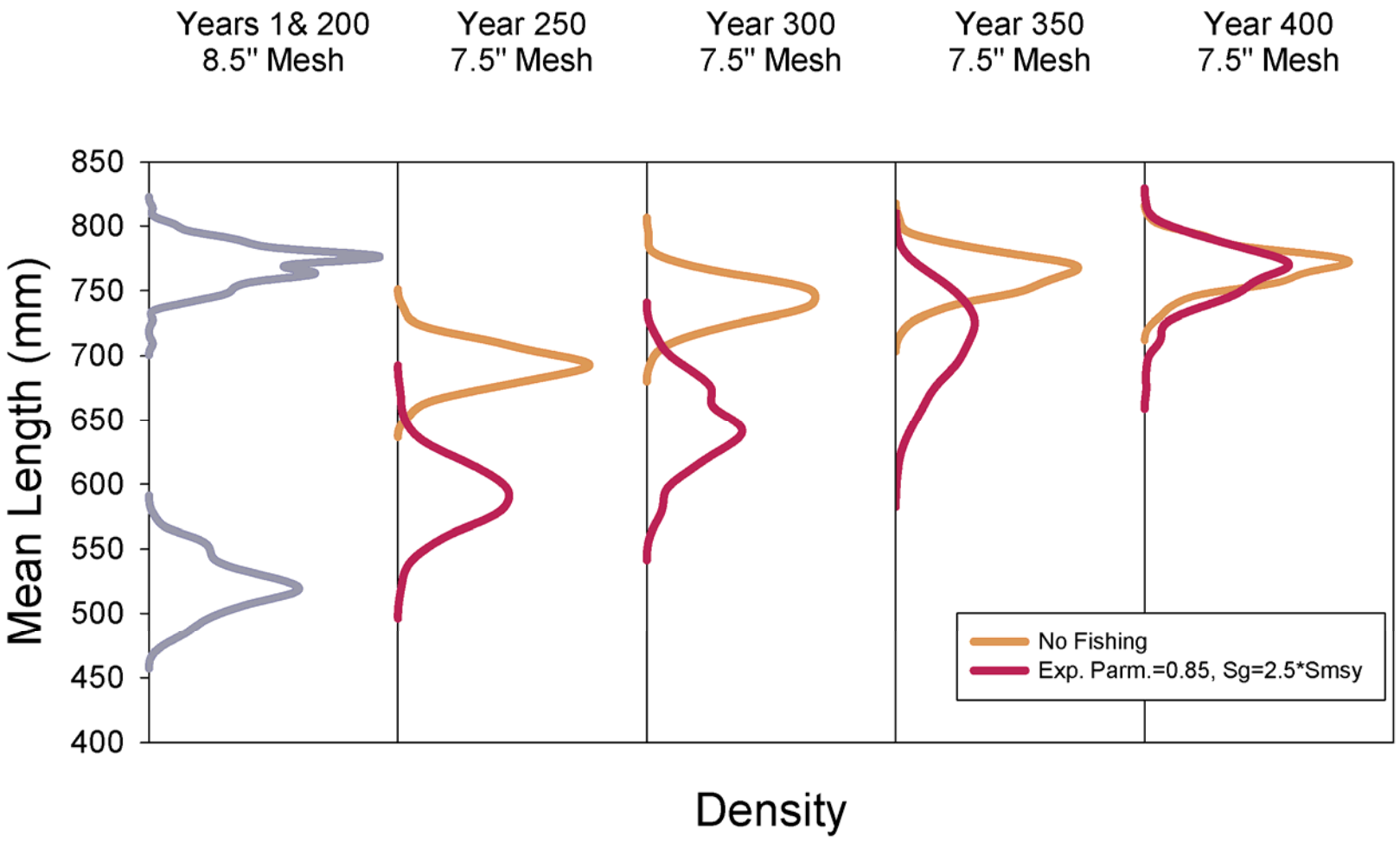
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



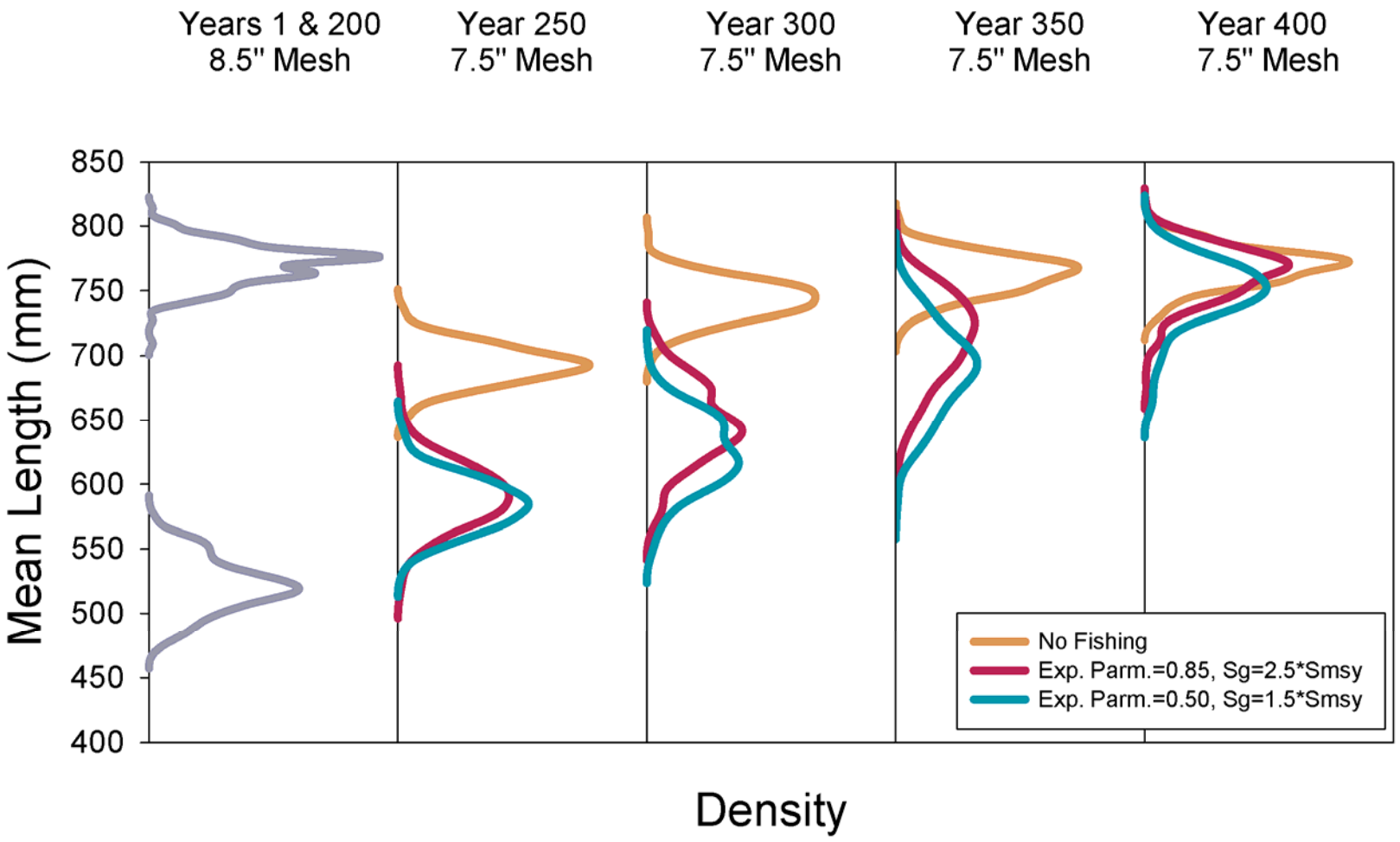
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



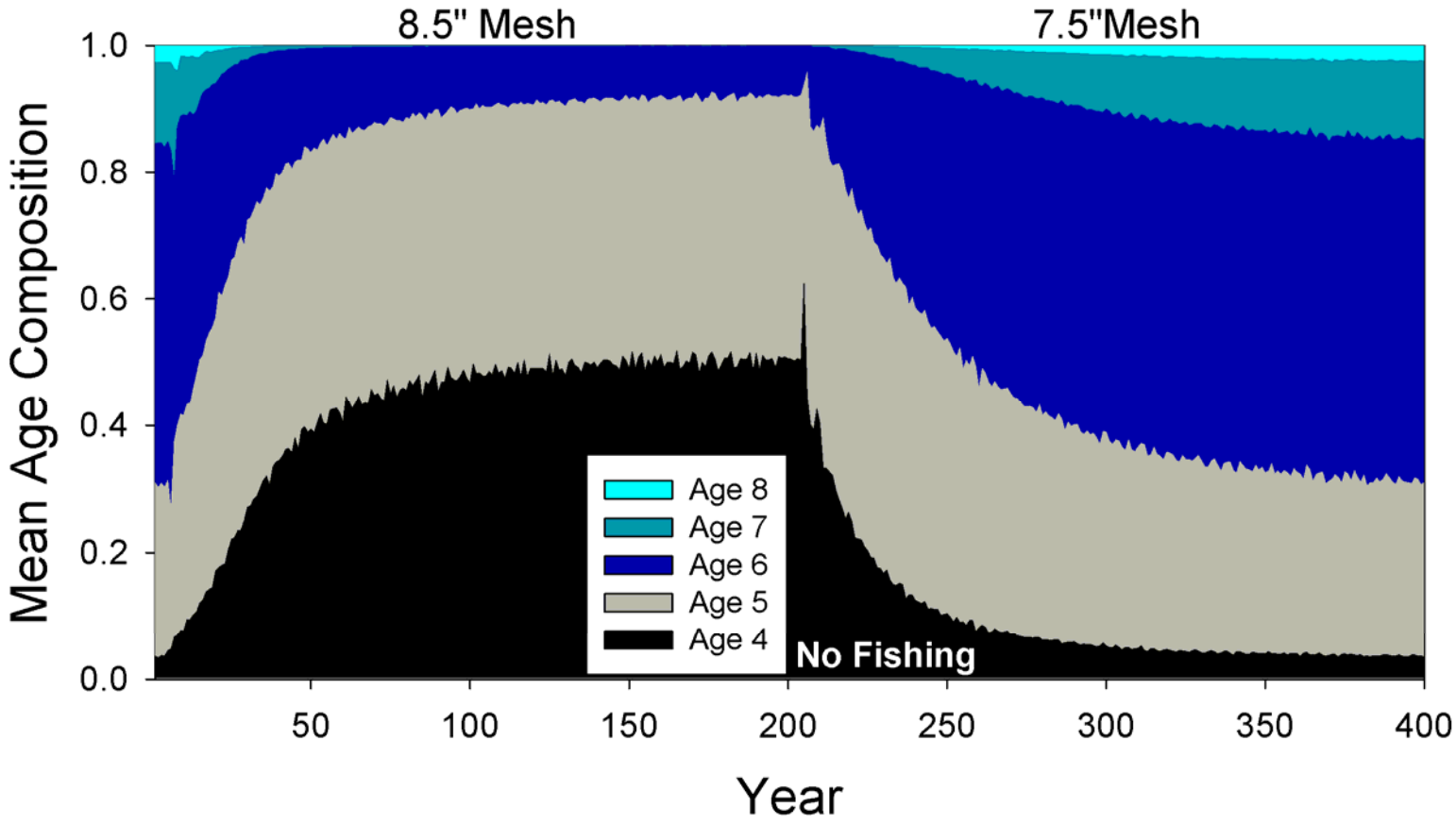
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



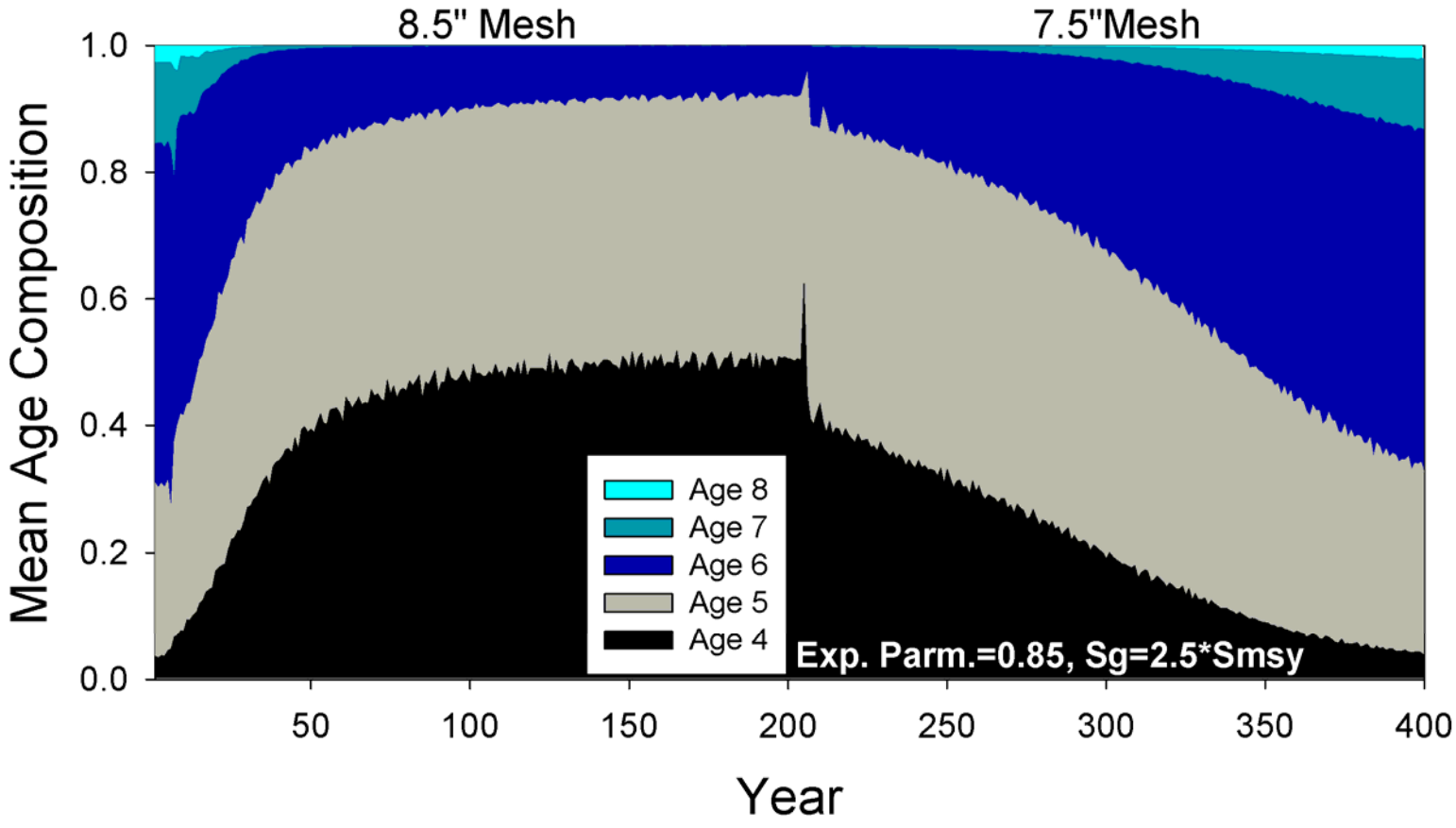
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



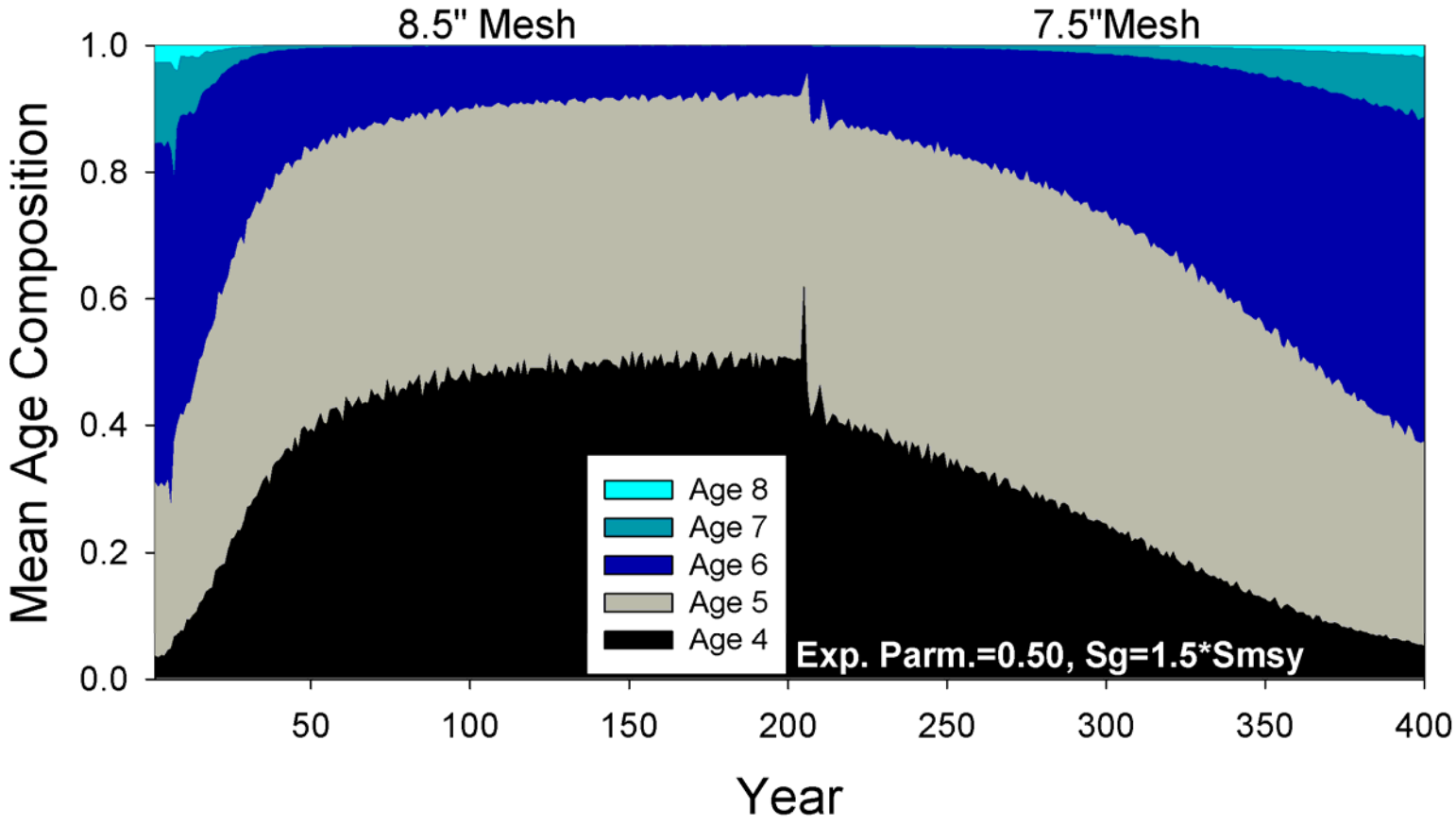
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



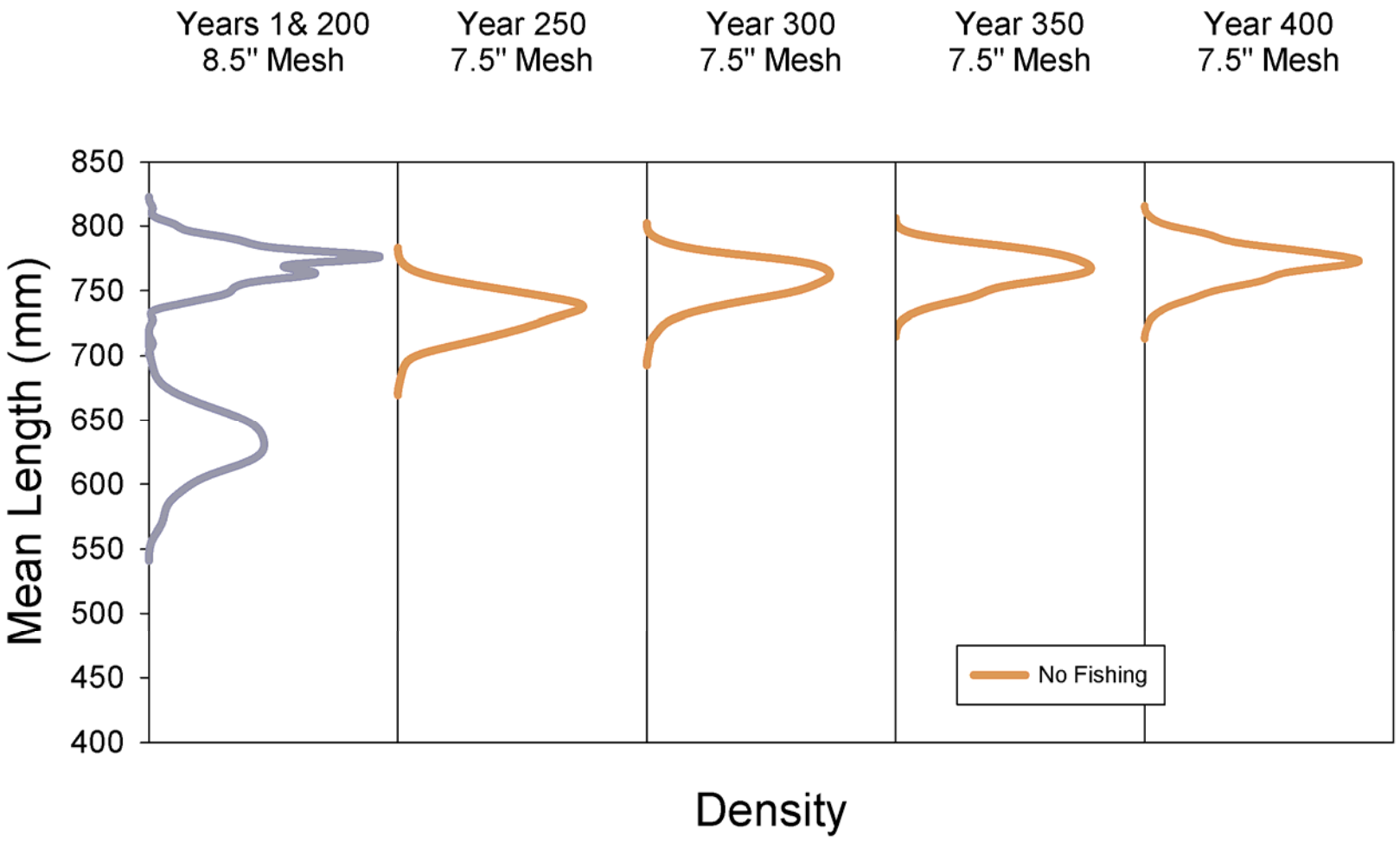
Alternative Fishing Simulations

- Simulation 21 – high exploitation, low escapement goal



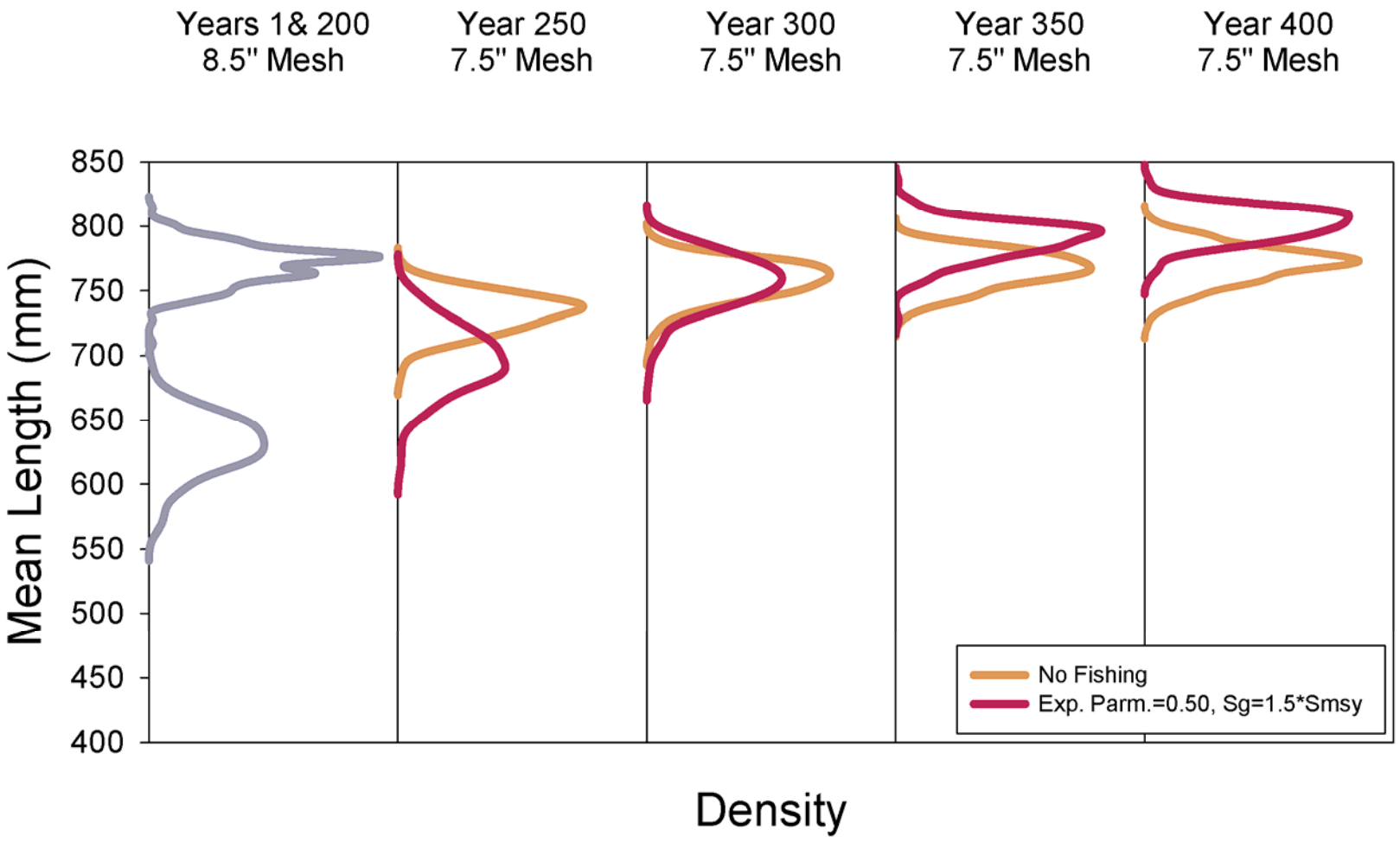
Alternative Fishing Simulations

- Simulation 26 – low exploitation, high escapement goal



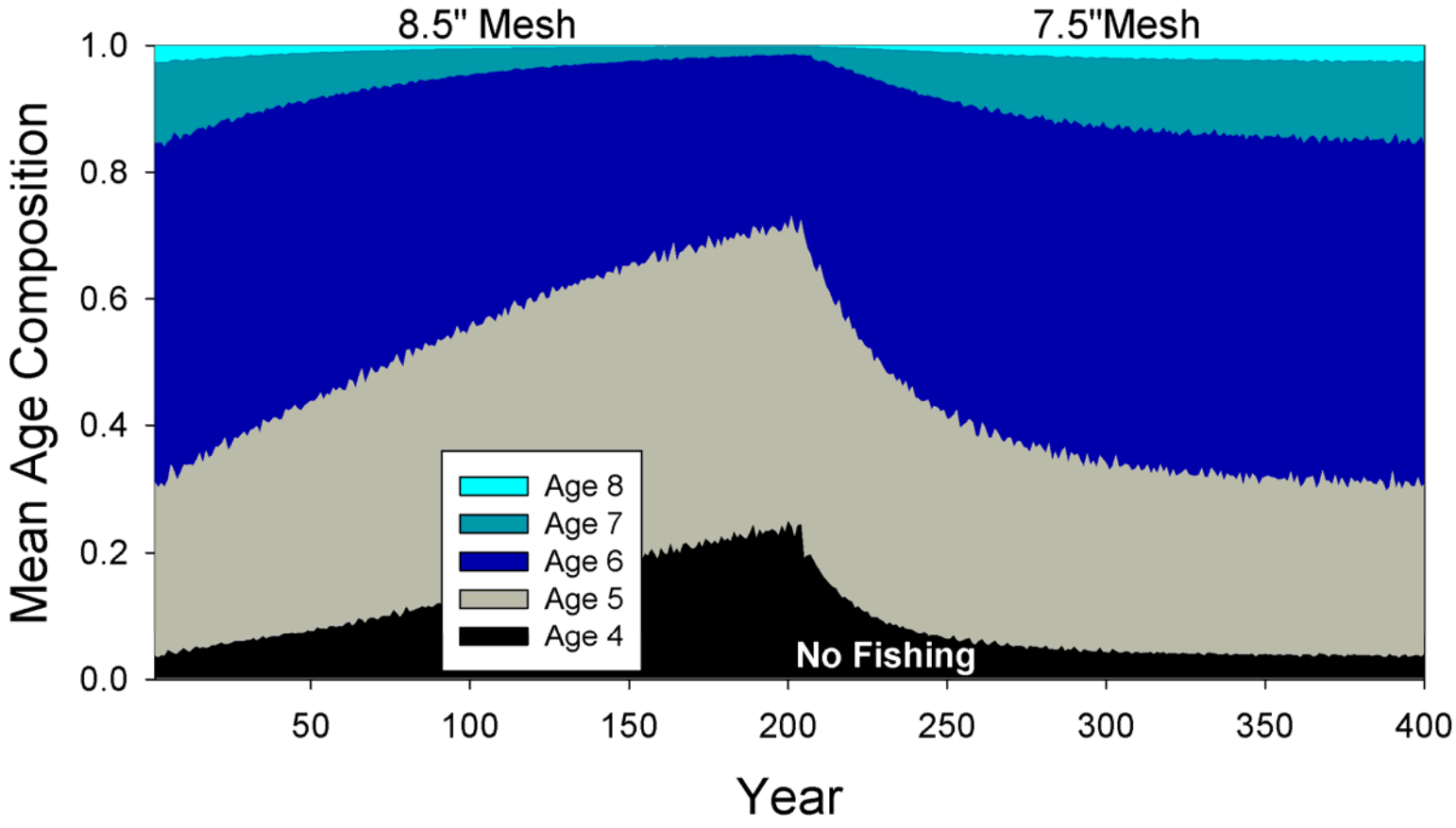
Alternative Fishing Simulations

- Simulation 26 – low exploitation, high escapement goal



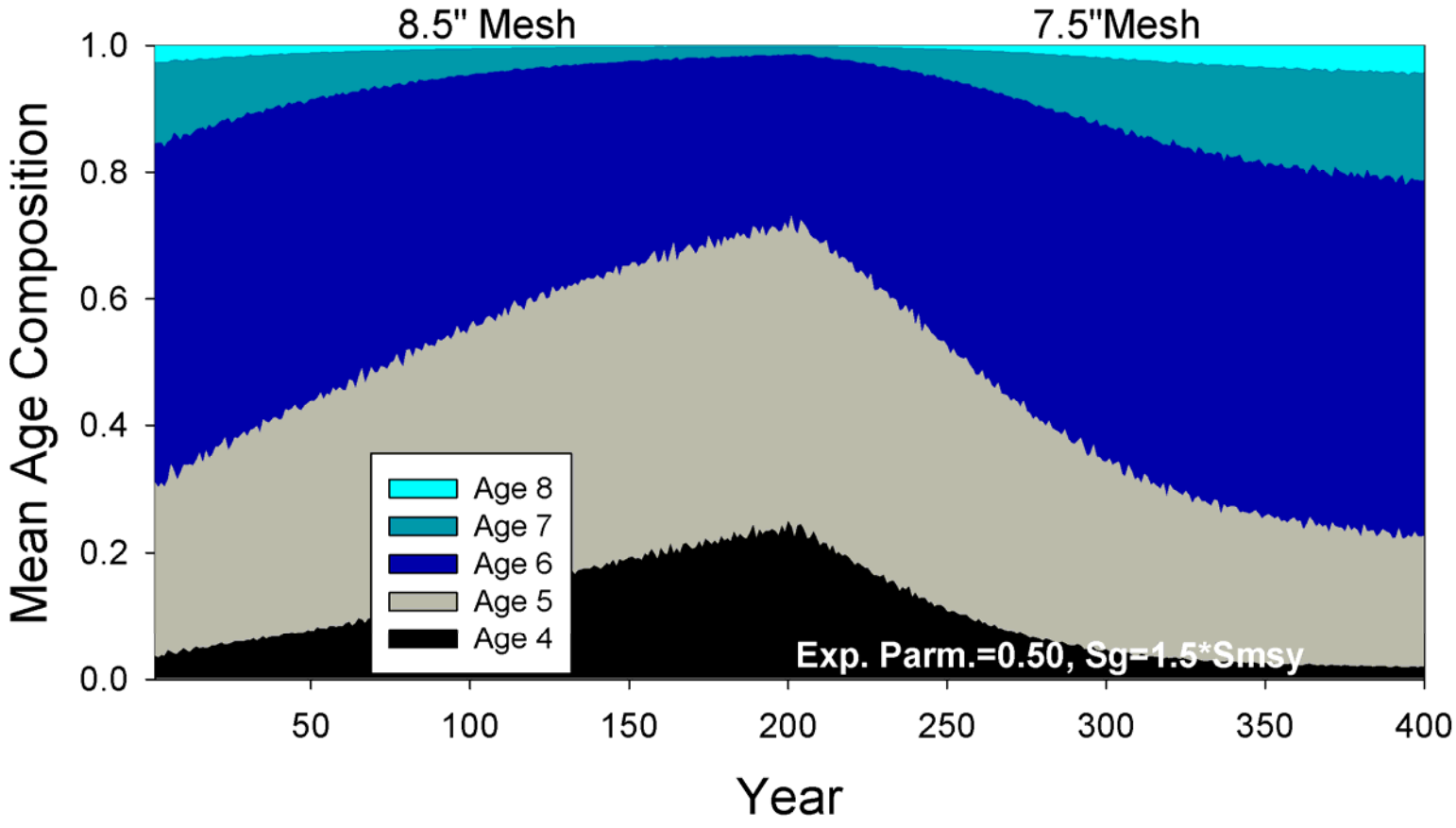
Alternative Fishing Simulations

- Simulation 26 – low exploitation, high escapement goal



Alternative Fishing Simulations

- Simulation 26 – low exploitation, high escapement goal



Summary of Results

- Mean length, age, and fecundity declined in all harvest scenarios.
- Declines affected most strongly by escapement level and the exploitation parameter.
- Increasing escapement goals, reducing harvest on smaller runs, and reducing mesh size were most effective when **jointly implemented**.
- Once the population stabilized at reduced levels, severe fishery restrictions were required to reverse prior declines.

Conclusions & Recommendations

- Prolonged selection for large fish seems likely to reduce spawner size and age, and population productivity.
  - Magnitude of reductions difficult to predict.
- Maintaining large escapements provides resiliency.
- Avoid directional selection for large individuals.
- Individual-based models have potential.
  - Model structure needs additional development.
- USFWS Fisheries Technical Report 100 available at: http://alaska.fws.gov/fisheries/biometrics/reports.htm

Acknowledgments

- Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYKSSI Project #607)
- Karen Gillis, AYKSSI & BSFA
- Danielle Evenson, Gene Sandone, Larry Dubois, and Toshihide Hamazaki, ADF&G
- Dave Hankin, Humboldt State Univ.
- Brian Riddell, David Patterson, and Michael Bradford, Canada DFO
- Lyman McDonald, WEST, Inc.
- Rod Simmons, Russ Holder, and Jeff Olsen, USFWS

Larry DuBois, ADF&G