Operationalizing the impact on stock assessments of size-selective fishing's effect on body size

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What is the Effect of Size Selectivity in Fisheries? "Rosa Lee Phenomenon"

- Fish that survive the fishery are, on average, smaller than projected from growth of fish that entered the fishery.
- Detected by back-calculating size-at-age from annual rings in fish scales.
- Why? Faster-growing fish are more exposed to size-selective fisheries, and at an earlier age.
- Know as the Rosa Lee Phenomenon
  - Lee (1912). "An investigation into the methods of growth determination in fishes by means of scales".

Rosa Mabel Lee (1884-1976) was a British statistician, the first woman scientist to be employed by the Marine Biological Association and the first woman to work as a government fishery scientist in the United Kingdom. (Wikipedia, 2023)

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Rosa Lee Phenomenon has been studied for decades

- For 50 years, the quantitative effect of size-selectivity on population dynamics has been demonstrated.
- Conclude: Ignoring this phenomenon creates bias in estimated population parameters and MSY estimates

Ricker. 1969. Effects of size-selective mortality and sampling bias on estimates of growth, mortality, production, and yield

Goodyear. 1984. Analysis of potential yield per recruits for striped bass….. [platoons]

Parma and Deriso. 1990. Dynamics of age and size composition in a population subject to size-selective mortality: effects of phenotypic variability in growth.

McGarvey et al. 2007. Modeling fish numbers dynamically by age and length: partitioning cohorts into 'slices'.

Taylor and Methot. 2013. Hiding or dead? A computationally efficient model of selective fisheries mortality

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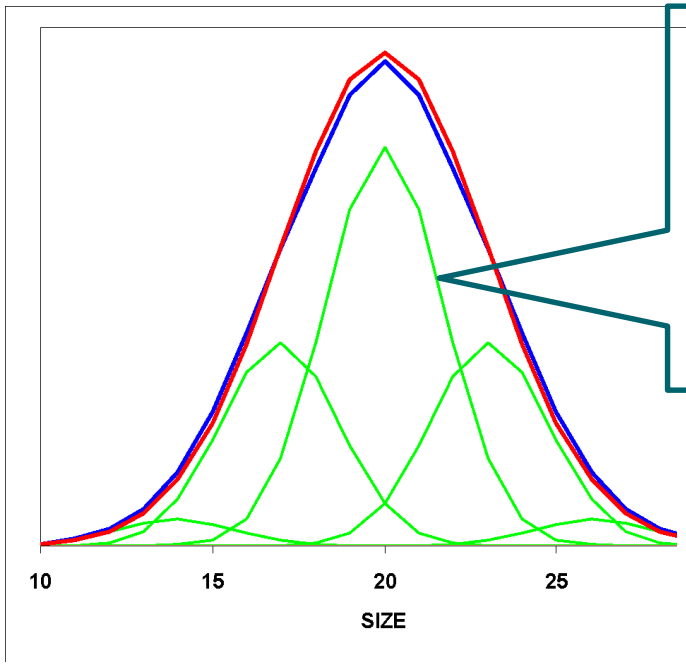
Rosa Lee Phenomenon is not Routinely Implemented

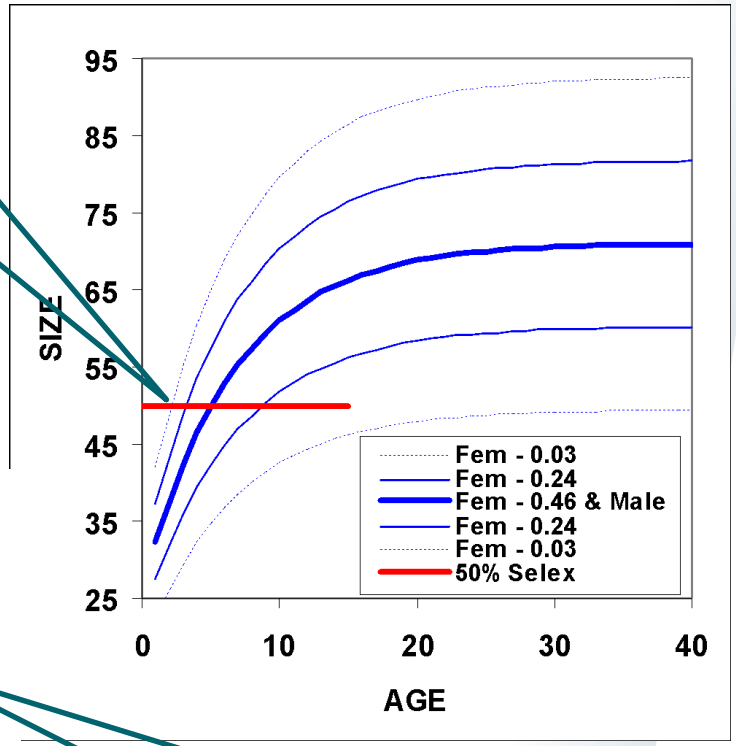
- Kraak et al. 2019. The Rosa Lee phenomenon and its consequences for fisheries advice on changes in fishing mortality or gear selectivity.
- "Surprisingly, the effect that the Rosa Lee phenomenon may have in … stock projections and simulations … has not received much attention." [in routine assessments]
- Current stock assessment models either:
  - Treat body size as empirically measured, but not dynamically modeled
  - Or, model body growth as time-invariant or environmentally driven, but not in response to pressure of size-selectivity.
- Here we advocate for routine adoption of the platoon approach in Stock Synthesis for dynamically modelling changes in size-at-age.

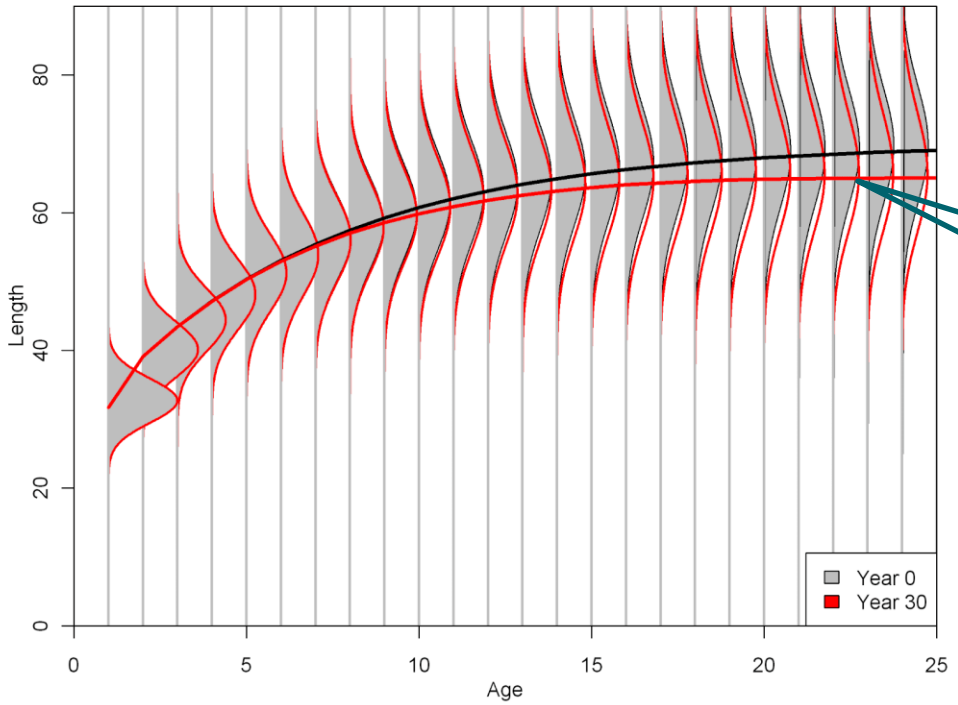
Platoons in Stock Synthesis**



Total recruitment divided into 5 platoons (green) to better approximate reality than a single platoon

Size-selectivity has differential impact on platoons





Result is a dynamic, reversible effect of fishing on size-at-age in population

QUESTION: How much separation/overlap between platoons? Ratio of within platoon length std.dev. to between platoon std.dev.

** https://github.com/nmfs-stock-synthesis

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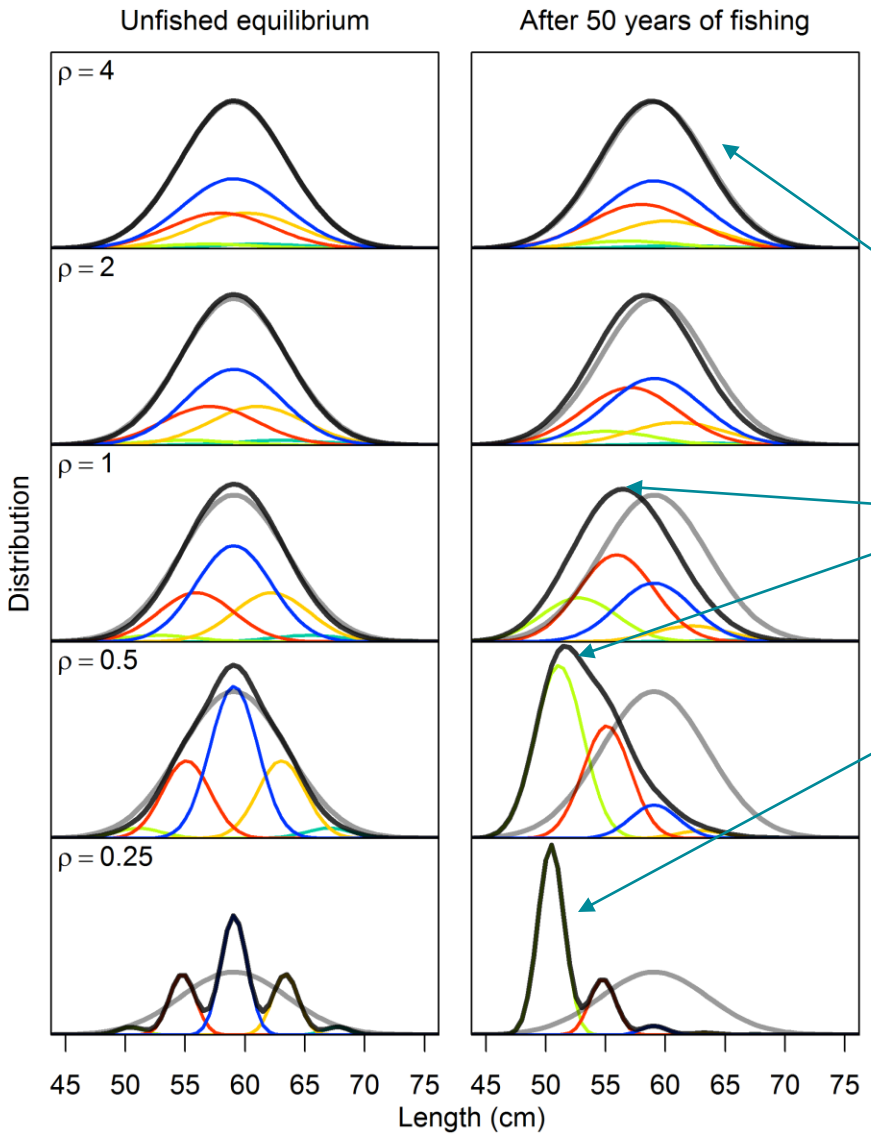
Range for the Platoon Ratio



- Ratio (ρ) of 4 produces near complete overlap, so nil effect
- The lower the ratio, the stronger the shift in mean size-at-age
- Ratios below 0.5 produce unrealistic distributions
- 0.75 seems a good start – Can it be estimated?

Black line is sum of 5 platoons

Grey line is without platoons

From Taylor and Methot, 2013

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Estimation Experiment

- Four scenarios used, with 100 replicates each

	flat-series	1-Way
10% CV growth	3A	4A
20% CV growth	3B	4B

- Simulate data using an IBM, similar to the Kraak study, with random, correlated draws of L_∞ and K for each simulated fish
- Use Stock Synthesis with either 5 platoons or 1 platoon to estimate growth, selectivity, platoon ratio, annual recruitment and F parameters*
- Project long-term mean catch (MSY) when fishing at rate that gives SPR40%**

* Same simulated data used in a just submitted paper comparing the platoon method to the slice method
** F that reduces spawning biomass to 40% of what it would have been if unfished

Result – Platoon Ratio Parameter

- In release 3.30.22 of Stock Synthesis, the platoon ratio became an estimable parameter rather than an assigned constant.
- This ratio is an approximation for the tendency for fish to follow a consistent growth path rather than randomly change their rank order of size-at-age within a cohort.
- Estimates shown below varied across the scenarios due to the degree to which the scenarios provide information on the Rosa Lee effect

	3A	3B	4A	4B
mean ratio	1.75	0.91	0.91	0.61

Table showing estimated ratio related to overlap between platoons.

Result – Growth Parameters

- With 10% CV in simulated growth parameters (3A, 4A), the 5 platoon and 1 platoon estimation methods produced accurate mean estimates from 100 replicates.
- With 20% CV in growth, the Rosa Lee effect is stronger. With no time series contrast (3B), the 1 platoon approach underestimates L_∞ by over 30%. It overestimates K (not shown) to match the age-at-length data.
- One-way trip scenario has data from earliest years - before mean size is reduced
- Low time series contrast after high historical F levels are common real world assessment situations.

		no contrast		one-way trip	
	TRUE L∞	3A	3B	4A	4B
5 platoons	1000	968	937	1012	1012
1 platoon	1000	947	670	1014	1012

Result – MSY Proxy

- Tabled values are long-term catch at $F_{SPR40\%}$. This catch level is a proxy for MSY.
- Stock Synthesis carries the platoon approach through the calculation of equilibrium benchmarks and through the forecast of future conditions
- Same low contrast scenario that underestimated L_∞ also underestimates MSY.

	no contrast		one-way trip	
	3A	3B	4A	4B
5 platoons	8250	7595	8256	8371
1 platoon	8039	5983	8280	8573

Platoons: More Facts & Notes

- Size-at-age of each platoon is time-invariant, although time-varying is possible.
- The proportion of fish among the platoons changes over time as platoons with higher selectivity experience more mortality.
- Numbers from the age-length matrices from all platoons are summed in order to produce expected values for the data, in which platoons are indistinguishable.
- Model runs slower with more platoons because each platoon is getting independent calculations, so 5 platoons is a pragmatic compromise.
- Proportion (%) in each platoon set at birth in Synthesis. Conceivable to make the % dependent on % in the spawning biomass to make the % heritable

Conclusions

- SS3 uses platoons to mimic the effect of size selectivity on the distribution of size-at-age for the surviving fish.
- With this capability, SS3 can recreate population's L_∞ value even though contemporary data have been affected by the Rosa Lee phenomenon.
- Without the use of platoons, SS3 (and simpler models) can estimate contemporary size-at-age, but cannot estimate the degree to which size-at-age (and resultant MSY) will dynamically shift, up or down, in response to changes in fishing mortality rate.
- It is time to routinely incorporate this improved approximation to real fish growth in real world assessments.
- Expect to see higher L_∞ estimates and/or less dome-shaped selectivity as Rosa Lee becomes part of the assessment paradigm.
- Just flip the switch in SS3 from 1 to 5 platoons, the rest is automatic