Developing tools to account for population dynamics to improve the use of no-take marine reserves for fishery management

Victoria Quennessen and J. Wilson White

Department of Fisheries and Wildlife, Oregon State University

http://blogs.oregonstate.edu/whitelab/

victoria.quennessen@oregonstate.edu

@frenchita_

PISCO Celebrating 20 years of ocean study

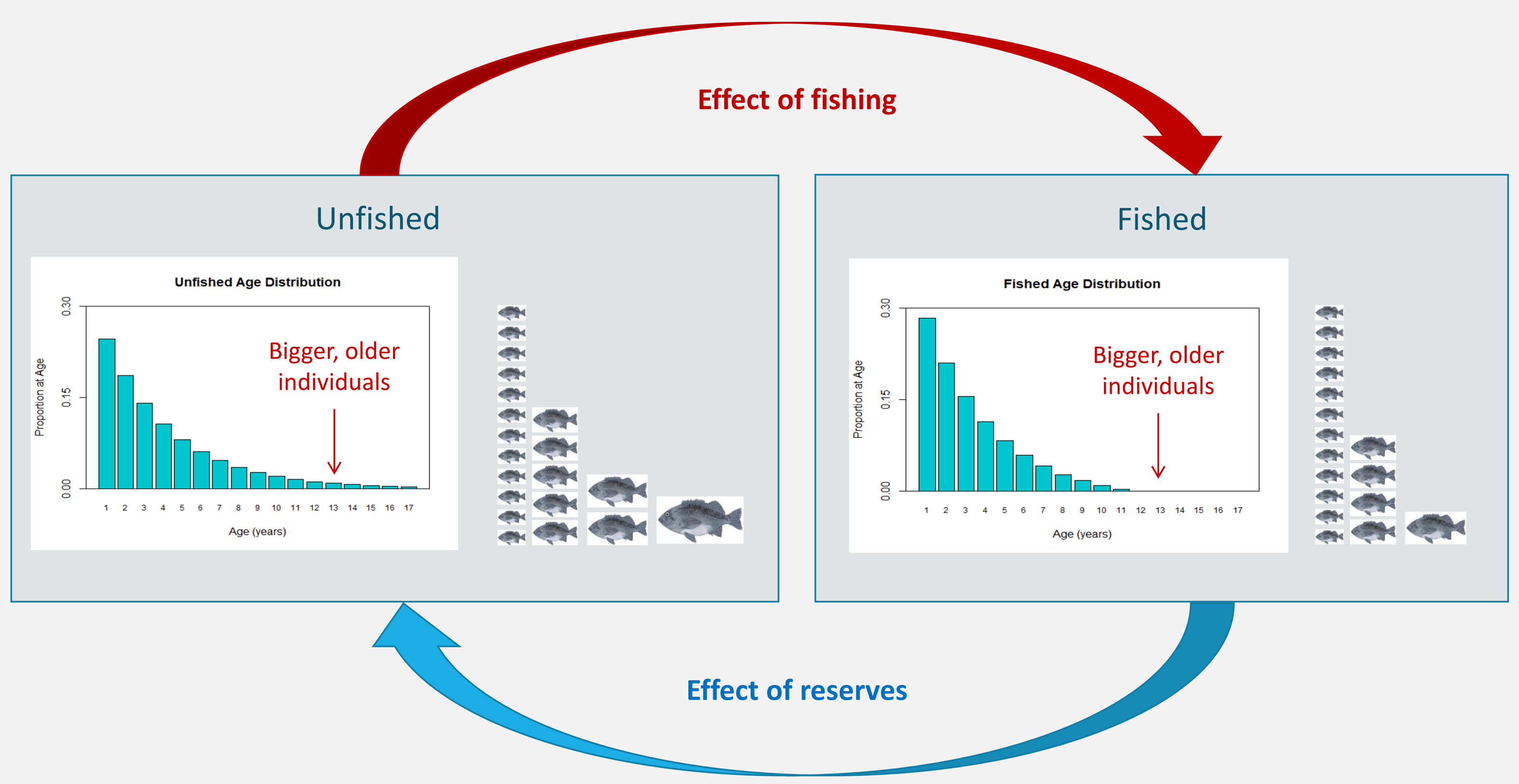
Oregon State University Coastal Oregon Marine Experiment Station

Abstract

- Stock assessments are a key tool for fishery management – they estimate how depleted a stock is, and how much we can safely catch
- Estimating depletion depends on knowing how big the stock was before fishing started, but this is not usually known
- Populations inside marine reserves that are not fished may act as reference populations
- These populations experience time lags – there is a transient period as the population goes from the fished state to an unfished state
- We are exploring how accounting for these time lags can improve the use of reserves as reference points for assessment and management

Reserves change the age structure of fished populations over short-term timescales

Reserves can reverse the effects of fishing on a fish population's age structure



It takes time for reserves to fill the population back in all the way

- During the transition from a fished to an unfished age structure, the stock has **transient dynamics** (these dynamics are different from **equilibrium dynamics**, the dynamics unfished stocks have)
- The transition is a result of time lags that depend on the biology of the fish, such as:
  - Natural mortality: species with a lower natural mortality take longer to finish transitioning [2]
  - Growth rate: species with a lower growth rate take longer to finish transitioning

Black Rockfish (*Sebastes melanops*)

Lingcod (*Ophiodon elongatus*)

Cabezon (*Scorpaenichthys marmoratus*)

Copper Rockfish (*Sebastes caurinus*)

A new control rule could help manage fisheries around reserves

A control rule dictates how high fishing effort can be based on some biological reference point

- The current west coast groundfish fishery has a 40:10 control rule
- This control rule depends on how big a stock is compared to how big it would be if it was not fished (the unfished biomass)

Density ratio: $\dfrac{\text{\# fish / area outside reserve}}{\text{\# fish / area inside reserve}}$

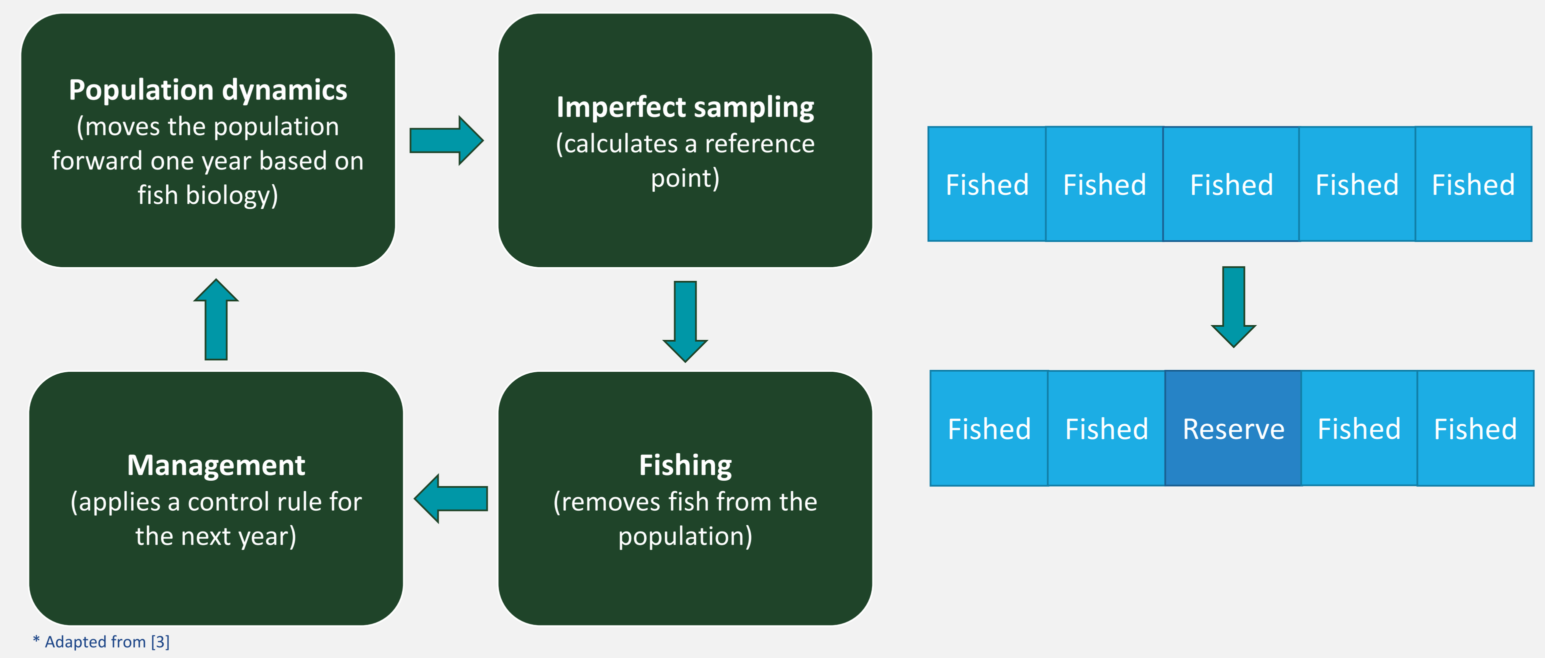
- Benefit: it can be calculated based on only a few years of sampling data, so it can be used for data-poor fisheries
- The density ratio can be calculated at local scales

Research Questions

1. How can we best use information from inside reserves to help manage fisheries after reserve implementation?
2. How does the inclusion of transient dynamics influence the short-term effect of control rules on yield and biomass?
3. What happens when we don't have an accurate estimate of natural mortality?

Methods – computational model

The computational simulates the assessment and management of a fished population



* Adapted from [3]

- Used life history characteristics from Black Rockfish (*Sebastes melanops)*
- Started the population with the unfished age structure
- Model ran with only population dynamics and fishing for 50
- At year 50, a reserve is implemented in Area 3, and fishing stops there
- Fishing effort is re-distributed between the other areas based on fish biomass

Comparing static and transient control rules

CR	1	2	3	4	5	6
Type	Static	Static	Static	Transient	Transient	Transient
M	Low	Correct	High	Low	Correct	High

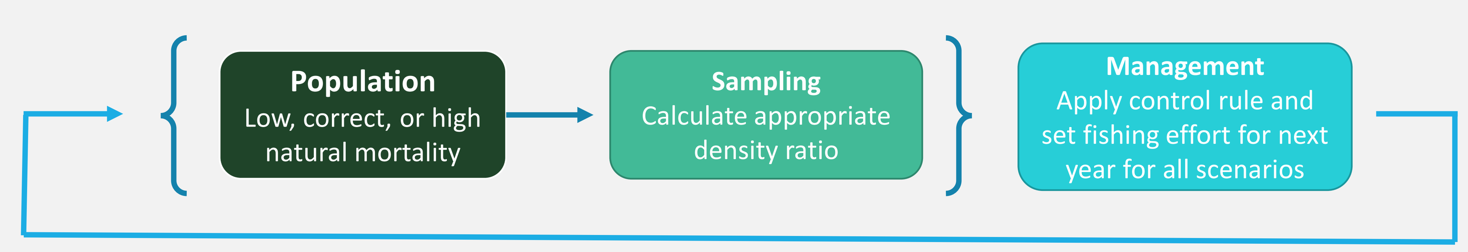
* Static control rules adapted from [3]

Eq. 1: $$Target\ DR = 1 - (1 - Final\ DR) * e^{-Mt}$$

* Adapted from [2]

- The **static** control rules use the same density ratio over time because it assumes the reserve works right away
- The **transient** control rules use a shifting target density ratio over time (Eq. 1), where **t** is the number of years after reserve implementation to account for the time lag

What happens if don't know the correct natural mortality? For each of 3 scenarios:



Acknowledgements

Thanks to support from lab mates Dr. Christian Commander, Montana McLeod, Jennifer Fisher, and Laura Storch; PISCO, the partnership for Interdisciplinary Studies of Coastal Oceans, funded primarily by the David and Lucile Packard Foundation; Dr. Elizabeth Babcock; and friends and family.

Funding: Oregon State University, The Oregon Lottery Scholarship, and the James Sedell Graduate Scholarship

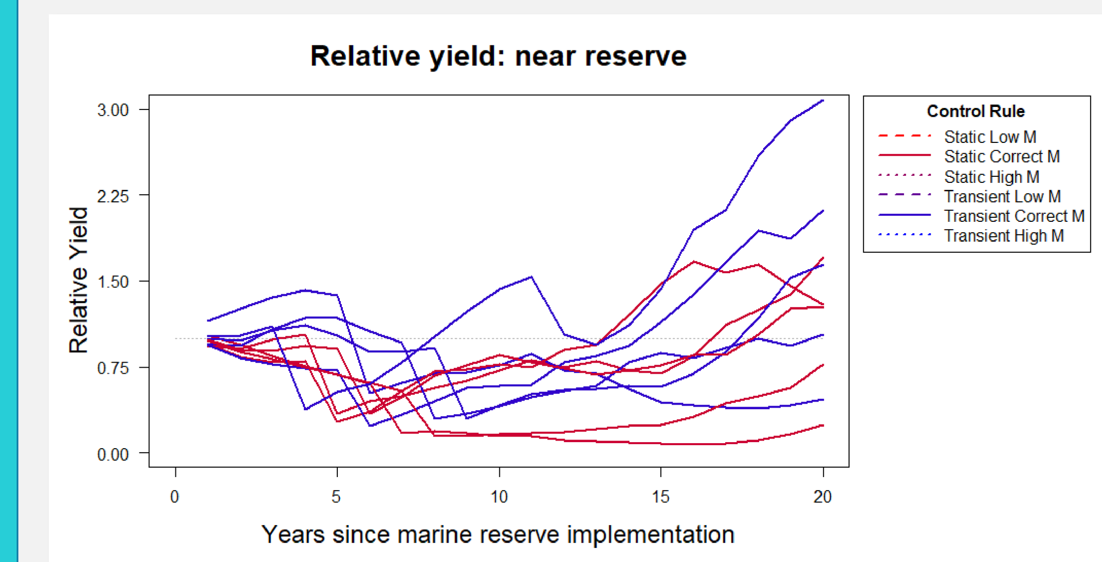
References

1. J. Lubchenco, K. Grorud-Colvert, *Science*. **350**, 382–383 (2015).
2. J. W. White *et al.*, *Conservation Letters*. **6**, 180–191 (2013).
3. E. A. Babcock, A. D. MacCall, Canadian Journal of Fisheries and Aquatic Sciences. 68, 343–359 (2011).
4. K. A. Kaplan *et al.*, *Ecol Appl*. **29** (2019), doi:10.1002/eap.1949.
5. K. J. Nickols *et al.*, *J Appl Ecol*. **56**, 2376–2385 (2019).

For more information about the White Lab, scan this QR code!

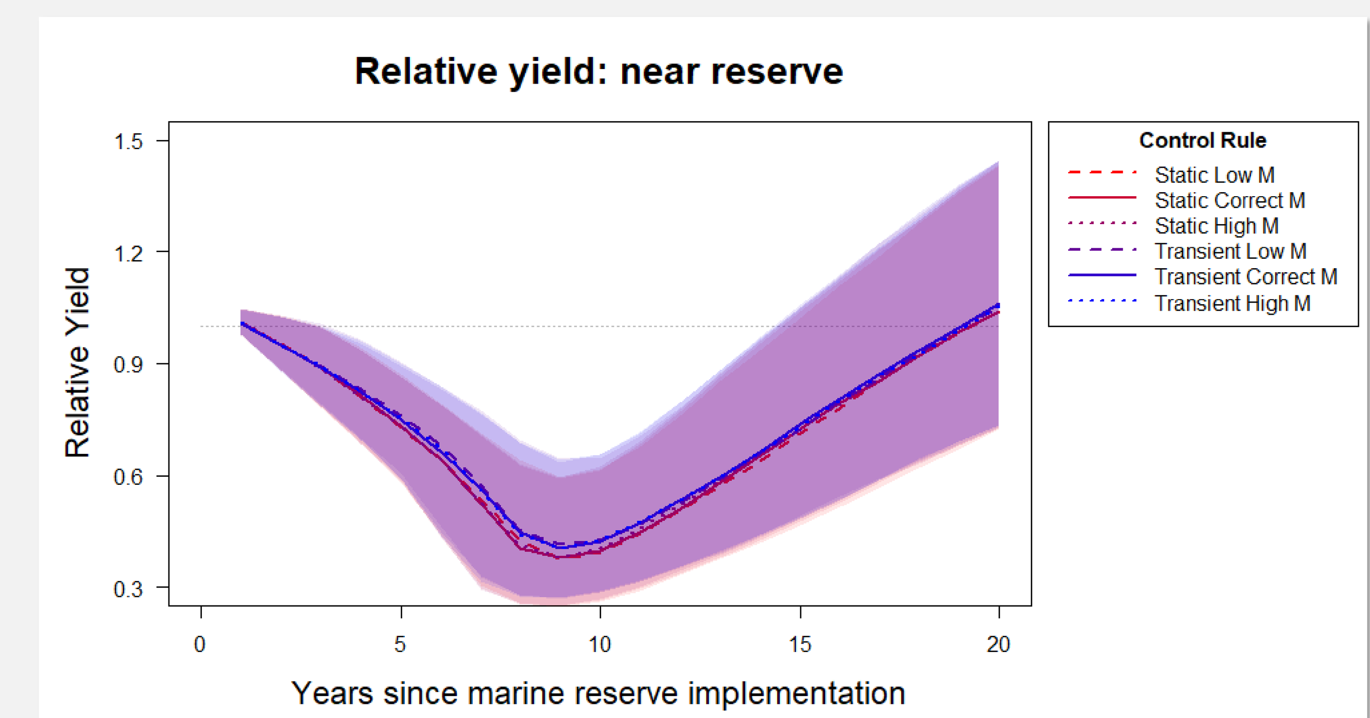
Results

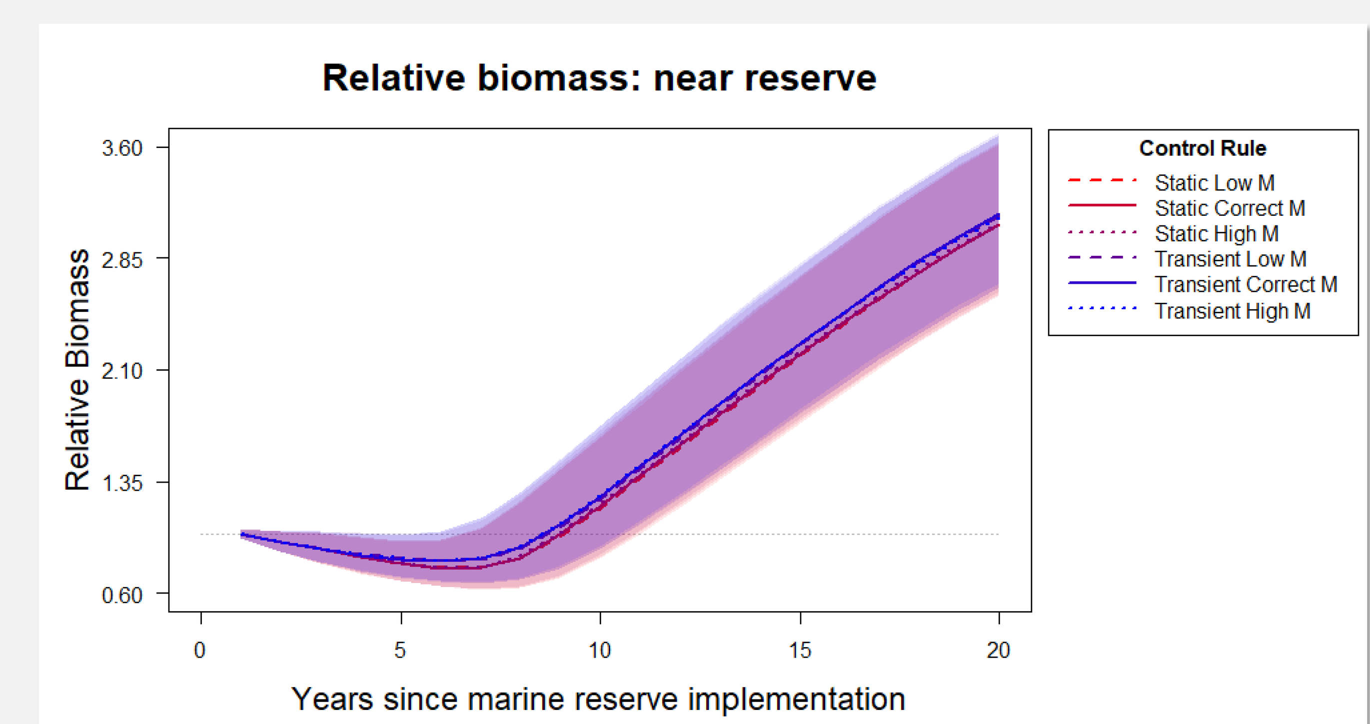
Transient control rules sometimes perform better than static control rules for yield



- Plot shows results from 5 simulations where the control rules estimated the correct natural mortality (M)
- Yield is plotted relative to values at the time the marine reserve was implemented
- Conclusions: transient control rules show that on average, higher yields over time than static control rules – does this trend hold up when we run many more simulations?

Transient control rules perform better on average, but variability can mask the effect





- Plots show results from 10,000 simulations
- Yield and biomass are plotted relative to values at the time the marine reserve was implemented
- **Lines** are average values (medians) and **shaded areas** show interquartile ranges (50% of the values)
- **Conclusions**: there are consistent differences in yield and biomass between transient and static control rules on average, and across all estimates of natural mortality (M), but variability from random recruitment will mask those effects in individual simulations

Next steps

- Explore the effectiveness of different control rules that incorporate different target density ratios, sample different ages of fish, sample fish from different areas, or sample for longer amounts of time.
- Explore effect of control rules on different species: cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), and copper rockfish (*Sebastes caurinus*).
- Incorporate data from Oregon and California marine reserves to adjust the model.